ADB | Japan Fund for Poverty Reduction

July 2013

TA-8128 BAN (PPTA): Preparing Coastal Towns Infrastructure Improvement Project

DRAFT FINAL REPORT
VOLUME 5: ANNEX – INFRASTRUCTURE, WATER RESOURCES

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Cover Photographs

Latrine, Amtali Pourashava	Damaged outfall flapgate, Galachipa Pourashava
Possible site for boat landing station, Pirojpur Pourashava	Water supply pond, and pond sand filter unit, Mathbaria Pourashava

This report consists of six volumes:

Volume 1	Main Report
Volume 2	Appendices
Volume 3	Project Administration Manual
Volume 4	Annex: Climate Change Assessment and Adaptation Strategy
Volume 5	**Annex: Infrastructure, Water Resources**
Volume 6	Annex: Financial and Economic Analyses

PREPARING COASTAL TOWNS INFRASTRUCTURE IMPROVEMENT PROJECT
PPTA - TA-8128 BAN

DRAFT FINAL REPORT

VOLUME 5: INFRASTRUCTURE, WATER RESOURCES

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GLOSSARY OF BANGLADESHI TERMS

crore	10 million (= 100 lakh)
ghat	boat landing station
hartal	nationwide strike/demonstration called by opposition parties
khal	drainage ditch/canal
khas, khash	belongs to government (e.g. land)
katcha	poor quality, poorly built
lakh, lac	100,000
madrasha	Islamic college
mahalla	community area
mouza	government-recogized land area
parashad	authority (pourashava)
pourashava	municipality
pucca	good quality, well built, solid
thana	police station
upazila	subdistrict

ACRONYMS

ABD	Asian Development Bank
ADP	annual development plan
ADSL	Associates for Development Services
AIFC	average incremental financial cost
AP	affected person (resettlement)
BBS	Bangladesh Bureau of Statistics
BC	bitumous carpeting
BCCRF	Bangladesh Climate Change Resilience Fund
BDT	Bangladesh Taka
bgl	below ground level
BLS	boat landing station
BMD	Bangladesh Meteorological Department
BMDF	Bangladesh Municipal Development Fund
BMGF	Bill and Melinda Gates Foundation
BRAC	Bangladesh Rural Advancement Committee
BRM	Bangladesh Resident Mission (ADB)
BT	bitumen topped (road)
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAG	Comptroller and Auditor General
CAGR	compounded annual growth rate
CARE	An NGO
CBO	community-based organization
CC	city corporation; cement concrete; climate change
CCA	climate change adaptation
CCF	Climate Change Fund
CCR	climate change resilience
CCRIP	Climate Change Resilient Infrastructure Project
CDIA	Cities Development Initiative for Asia
CDMP	Comprehensive Disaster Management Programme
CDTA	capacity development technical assistance
CEIP	Coastal Embankment Improvement Program
CEP	Coastal Embankment Project
CLTS	Community-Led Total Sanitation
CQS	Consultants' Qualification Selection
CTIIP	Coastal Towns Infrastructure Improvement Project
CUIDG	

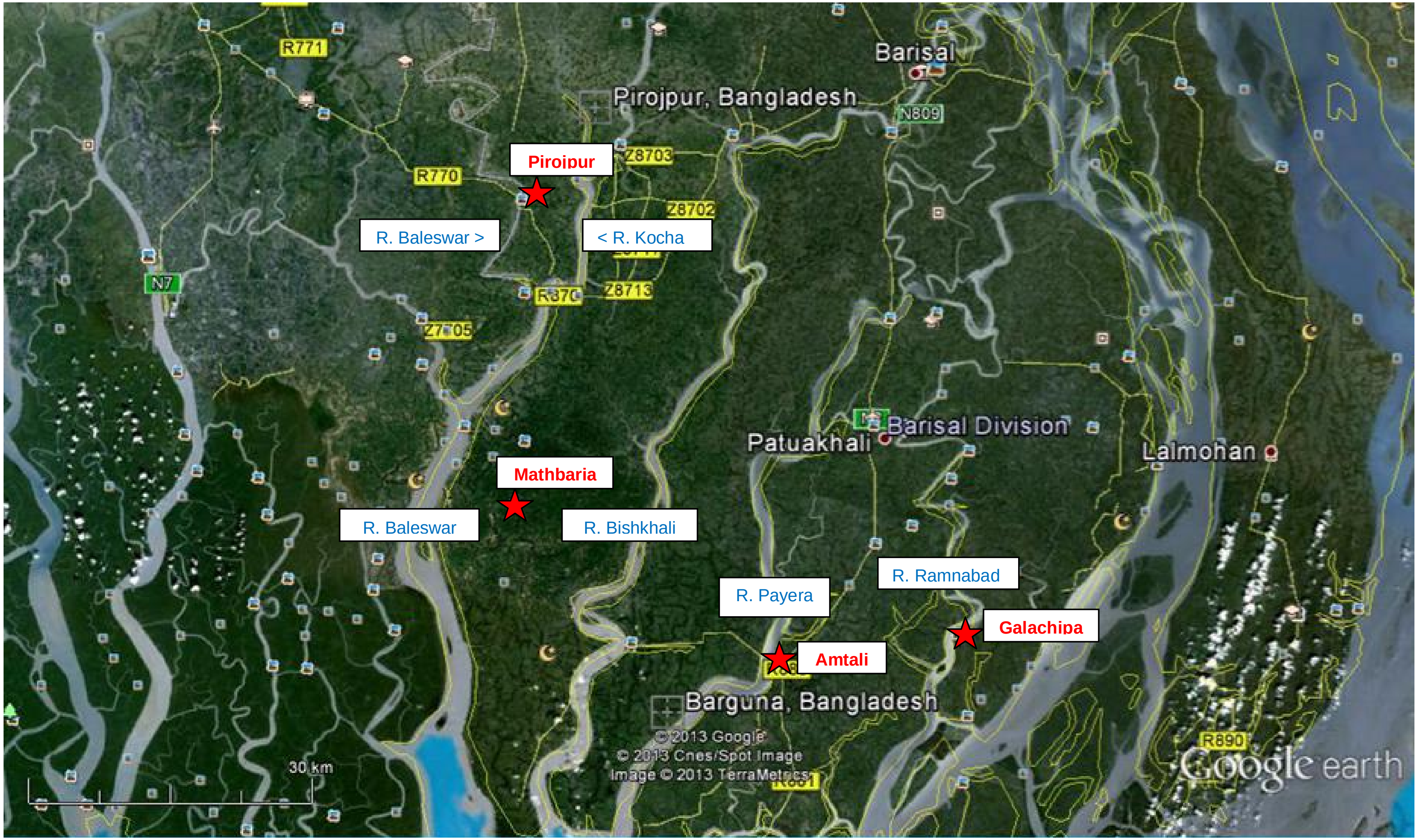
DANIDA	Danish International Development Agency
DED	detailed engineering design
DEM	digital elevation models
DEWATS	decentralized wastewater treatment system
DFID	Department for International Development (UK)
DFR	draft final report
DM	disaster management
DMC	developing member country
DMF	design and monitoring framework
DP	development partner
DPHE	Department of Public Health Engineering
DPP	development project proforma
DRM	disaster risk management
DRR	disaster risk reduction
DSCR	debt service coverage ratio
DSK	Dushthya Shasthya Kendra (an NGO)
DSP	deep set pump (in tubewell)
DTIDP	District Towns Infrastructure Development Project
DWASA	Dhaka Water Supply and Sanitation Authority
EA	executing agency
EARF	environmental assessment review framework
EIA	environmental impact analysis
EIRR	economic internal rate of return
EMP	environmental management plan
EOCC	economic opportunity cost of capital
EU	European Union
FAPAD	Foreign Aided Project Audit Directorate
FGD	focus group discussion
FMAQ	financial management assessment questionnaire
forex	foreign exchange
FS	feasibility study
FY	fiscal year (1 July – 30 June)
GBM	Ganges-Brahmaputra-Meghna river basin
GCM	General Circulation Model
GHG	greenhouse gas
GHK	GHK Consulting Limited (ICF GHK)
GIS	geographic information system
GIZ	German Society for International Cooperation
GOB	Government of Bangladesh
HBB	herring bone bond (road)
HH	household
IA	implementing agency
ICB	international competitive bidding
IEC	information-education-communication
IEE	initial environmental examination
IIED	International Institute of Economic Development
IOL	inventory of losses
IPCC	International Panel on Climate Change
IPPF	indigenous peoples planning framework
IT	information technology
IUCN	International Union for Conservation of Nature
IWA	International Water Association
JFPR	Japan Fund for Poverty Reduction

JICA	Japan International Cooperation Agency
KfW	German development funding agency
KPI	key performance indicators
LARP	land acquisition and resettlement plan
LBDT	lakh Bangladesh taka (BDT100,000)
LDRRF	local disaster risk reduction fund
LGD	Local Government Division
LGED	Local Government Engineering Department
LGI	local government institution
LOI	letter of intent
LS	lump sum
l/s, lps	liters per second
MAR	managed aquifer recharge
MBDT	million Bangldesh taka
MCA	multi-criteria analysis
MDG	Millennium Development Goals
M&E	monitoring and evaluation
MFF	Multitranche Financing Facility (ADB)
MHRW	Ministry of Housing and Public Works
MIDP	municipal infrastructure development plan
MIS	management information system
MLD	million liters per day
MLGRDC	Ministry of Local Government, Rural Development, and Cooperatives
MODMR	Ministry of Disaster Management and Relief
MOE	Ministry of Education
MOF	Ministry of Finance
MOU	memorandum of understanding
MSP	Municipal Services Project
MTBF	Medium Term Budget Framework
NAPA	National Adaptation Program of Action
NCB	national competitive bidding
NGO	non-government organization
NIRAPAD	Network for Information, Response and Preparedness Activities on Disaster
NPDM	National Plan for Disaster Management
NPV	net present value
NRW	non-revenue water
OCR	Ordinary Capital Resources (ADB)
ODA	official development assistance
OHT	overhead tank
OJT	on-the-job training
O&M	operation and maintenance
PAM	project administration manual (ADB)
PD	project director
PDA	project design advance
PDP	pourashava development plan
PIU	project implementation unit
PMO	project management office
PMU	project management unit
PPCR	Pilot Program for Climate Resilience
PPMS	project performance management system
PPP	public-private partnership
PPTA	project preparatory technical assistance
PRA	participatory rural appraisal

PSF	pond sand filter
PSU	pourashava sanitation unit
PWD	Public Works Department (datum)
QC	quality control
QCBS	Quality- and Cost-Based Selection
QM	quality management
RAJUK	Rajdhani Unnayan Katripakkha
RCC	reinforced cement concrete
RF	resettlement framework
ROW	right of way
R&R	resettlement and rehabilitation
RRP	report and recommendation of the president (ADB)
RSC	rural sanitation center
SCF	Strategic Climate Fund (ADB)
SDP	sector development plan
SEWTPS	socioeconomic and willingness-to-pay survey
SFYP	(Bangladesh) Sixth Five-Year Plan
SIDA	Swedish International Development Agency
SLR	sea level rise
SPA	social poverty assessment
SPCR	Strategic Program for Climate Resilience (GOB, 2010)
SPEC	Special Project Evaluation Committee
SPS	Safeguard Policy Statement (ADB)
SST	sea surface temperature
STWSSSP	Secondary Towns Water Supply and Sanitation Sector Project
SWM	solid waste management
SWOT	strength-weakness-opportunities-threat (analysis)
SWTP	surface water treatment plant
TA	technical assistance
TNA	training needs assessment
TOR	terms of reference
TOT	training-of-trainers
TRM	tidal river management
UDD	Urban Development Directorate, Ministry of Housing and Public Works
UFW	unaccounted-for water
UGIAP	urban governance improvement action plan
UGIIP	Urban Governance Infrastructure Improvement Project
ULB	urban local body
UNDP	United Nations Development Programme
UNFRA	United Nations Food Relief Agency
UN-HABITAT	United Nations agency for human settlements
UNICEF	United Nations Children’s Fund
UP	union parashad
UPPRP	Urban Partnerships for Poverty Reduction Project
USAID	United States Agency for International Development
UTIDP	Upazila Towns Infrastructure Development Project
V	variation (contract)
VRC	vulnerability reduction credit (climate change adaptation)
WACC	weighted average cost of capital
WAPDA	Water and Power Development Authority
WARPO	Water Resources Planning Organization
WASH	water, sanitation and hygiene
watsan	water and sanitation

WB	World Bank
WFPF	Water Financing Partnership Facility (Netherlands Trust Fund)
WHO	World Health Organization
WQ	water quality
WRM	water resources management
WS	water supply
WSP	water service provider
WSP-EAP	Water and Sanitation Program – East Asia Pacific
WSS	water supply and sanitation
WSUP	Water and Sanitation for Urban Poor
WTP	willingness-to-pay
WWTP	wastewater treatment plant

LOCATION MAP



★ **Study town**

ANNEX A: MUNICIPAL INFRASTRUCTURE DATA

Attachment 1: Sub-projects with relevant information, stage I (4-Pourashava).

Attachment 2: Unit cost of items /works for Road [same for 4-Pourashava].

Attachment 3: Location maps shown sub-projects, stage I (4-Pourashava).

Attachment 4: Typical drawing /cross-section [same for 4-Pourashava].

Attachment 5: Sub-projects (probable) for stage II (4-Pourashava).

ATTACHMENT 1: SUB-PROJECTS WITH RELEVANT INFORMATION, STAGE I (4-POURASHAVA)

Town: Amtali Pourashava

***Road:** Priority list - Amtali Pourashava.*

Sl. No.	*Names of roads, Ward No.*	*Length m*	*Score obtained*	*Stage*	*Tentative Cost BDT Lakh*
1	Sabujbag Selim's house to R&H road via TNT & College Mosque. Ward # 5,6.	1000	*36*	I	124
2	From R&H BC road near AK Schhol to Bandh Ghat Chowrasta via Al Helal Mor. Ward No -02,04,06 .	1500	*35*	I	333
3	Wapda road to Kamal Sangbadik house via Mostofa Commissioner) and Firoj. Ward # 08.	1100	*32*	I	149
4	Road from Pourashava near Jogen Singh kouse to Bandth of Ward # 1,4.	250	*32*	I	54
5	Zilla Parishad road to Ferry Ghat road via TNT Office.Ward No-05,06.	600	*32*	I	102
6	Zilla Parishad Road to Muktizodda School via Mofij Talukder House. Ward # 06,05.	430	*32*	I	80
7	Mazar road to ATO Kashem Mia house via Lekerparpar. Ward # 3	1000	*32*	I	122
8	Road from Sluice-gate to Locha Bottola. Ward No-8,9.	2500	*32*	I	202
	Total =	**8,380**			**11,66**
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads : Inventory of major works necessary to be executed – Amtali Pourashava.

Sl. No.	Road Name	Existing Feature.	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
1	Sabujbag Selim's house to R&H road via TNT & College Mosque. Ward # 5,6.	W= 3m, BC,CC,	1000	3.7	1.0	0.30	450	100	3	400	BC road.
2	From R&H BC road near AK Schhol to Bandh Ghat Chowrasta via Al Helal Mor. Ward No -02,04,06 .	W=5.00 BC road.	1500	8.0	1.0	0.00	750	250	4	500	BC with WBM and Widening.
3	Wapda road to Kamal Sangbadik house house via Mostofa Commissioner) and Firoj. Ward # 08.	W= 2.0m, CC.	1100	3.0	1.0	0.30	500	200	5	400	RCC road

Roads : Inventory of major works necessary to be executed – Amtali Pourashava.

4	Road from Pourashava near Jogen Singh kouse to Bandth of Ward # 1&4.	W= 3.6m, Earthen.	250	3.7	1.0	0.45	250	100	2	0	RCC road
5	Zilla Parishad road to Ferry Ghat road via TNT Office.Ward No-05 & 06.	W= 2.5m, CC.	600	3.0	1.0	0.30	600	60	3	250	RCC road
6	Zilla Parishad Road to Muktizodda School via Mofij Talukder House. Ward # 06,05.	W= 3m, CC,	430	3.7	1.0	0.30	200	150	3	200	RCC road
7	Mazar road to ATO Kashem Mia house via Leker Par. Ward # 3	W= 2m. CC road.	1000	3.0	1.0	0.30	300	200	2	200	RCC road
8	Road from Sluice gate to Locha Bottola. Ward No-8,9.	W=4m BC road	2500	4.0	1.0	0.00	0	0	5	800	BC with WBM only.
		Total =	**8380**				**3050**	**1060**	**27**	**2750**	

Note : L=length, W =width, S /FP =Shoulder /Footpath, SD =side drain, SP =side protection, TP =tree plantation. BC =Bituminous Carpeting,

Cyclone Shelter : Priority list – Amtali Pourashava.

Sl. No.	**Name, Location, Ward No.**	**Land Ownership**	**Present Condition**	**Score**	**Stage**	***Tentative Cost BDT Lakh***
1	Amtali Bandar Hosainia Fajil Madrasa in Ward # 4.	Madrasa Authority.	Damaged tin-shade.	45	I	250
2	Achal Int. Ideal Reg. Primary School. Ward # 1.	School Authority.	Open land.	45	I	250
3	Basuki Non-Govt. Primary School in Ward # 8.	School Authority.	Open land.	45	I	250
					Total =	**750**

Solid Waste Management - Amtali Pourashava.

Equipment, Name	**Quantity (No.)**	**Stage**	**Unit rate BDT Lakh**	***Tentative Cost BDT Lakh***
i) Ricksha –Van.	5	I	0.25	1.25
ii) Push Cart /hand trolley.	10	I	0.10	1.00
			Total =	**2.25**

Town: Galachipa Pourashava

Road: *Priority list - Galachipa Pourashava.*

Sl. No.	*Name of road, Ward No.*	*Length m*	*Score obtained*	*Stage*	*Tentative Cost BDT Lakh*
1	College road, Ward # 8 to 9.	1640	*36*	I	280
2	Wapda road (damaged parts), ward # 1,2,3, 4.	1500	*35*	I	167
3	Banani road with connecting Khalifa road. Ward # 9.	1210	*35*	I	225
4	Santi Bagh road, Ward #3	610	*32*	I	86
5	Sadar road, Ward # 4 to 7.	840	*32*	I	145
6	Feeder road, Ward # 7.	695	*29*	I	96
7	Samudabad road, Ward # 6 to 8.	500	*29*	I	58
	Total =	**6995**			**1057**
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads : Inventory of major works necessary to be executed –Galachipa Pourashava.

Sl. No.	**Road Name**	**Existing Feature.**	**L (m)**	**W (m)**	**S /FP (m)**	**Rise (m)**	**SD (m)**	**SP (m)**	**Culvert #**	**TP #**	**Type**
1	College road, Ward # 8 to 9.	Type =BC, W=4.8m.	1640	5.00	1640	0.30	1640	200	5	800	BC road, FP.
2	Wapda road (damaged parts), ward # 1,2,3, 4.	Type =BC, W =4.5m	1500	5.00	1000	0.0	1000	200	4	400	BC with WBM, V-drain.
3	Banani road with connecting Khalifa road. Ward # 9.	W =2.5m, HBB/BFS.	1210	4.00	0	0.0	1210	200	6	600	BC road
4	Santi Bagh road, Ward #3	Type =BSF, W =3m	610	4.00	0	0.0	0	150	3	200	RCC road, FP
5	Sadar road, Ward # 4 to 7.	Type =B/,CC. W =4m	840	4.00	840	0.30	840	0	4	0	RCC road..
6	Feeder road, Ward # 7.	W =3.2m. RCC	695	4.00	0	0.3	0	150	3	0	RCC road.
7	Samudabad road, Ward # 6 to 8.	Type =BC, W=3m.	500	4.50	500	0.3	0	100	4	200	BC road
		Total =	**6995**				**4690**	**1000**	**29**	**2200**	

Cyclone Shelter: Priority list – Galachipa Pourashava.

Sl. No.	Name, Location, Ward No.	Land Ownership	Present Condition	Score	Stage	*Tentative Cost BDT Lakh*
1	Back side of 40-Barak Abasan in Ward # 1.	Govt. Abansn.	Open land.	45	I	250
2	Galachipa Degree College compound. Ward # 9.	College Authority.	Damaged tin-shade.	45	I	250
3	Beside Sarshina Khanka and Hafezia Madrasa in Ward # 3.	Madrasa Authority.	Open land.	45	I	250
					Total =	**750**

Solid Waste Management - Galachipa Pourashava.

Equipment, Name	Quantity (No.)	Stage	Unit rate BDT Lakh	*Tentative Cost BDT Lakh*
i) Ricksha –Van.	5	I	0.25	1.25
ii) Push Cart /hand trolley.	10	I	0.10	1.00
			Total =	**2.25**

Town: Mathbaria Pourashava.

Road: *Priority list – Mathbaria Pourashava.*

Sl. No.	*Name of Road, Ward No.*	*Length m*	*Score obtained*	*Stage*	*Tentative BDT Cost (Lakh)*
1	Land Office to Mollik Bari house Via Sadar road, Length 3500m. Ward # 2 & 4.	3500	*42*	I	510
2	R&H road to Bairatala Khal via Vatenary hospital. Ward # 5.	600	*42*	I	93
3	Mathbaria Masua road to Matbaria Tuskhali khal via Women's college. Length 800. Ward # 2.	800	*39*	I	125
4	R&H road to Govt. College vai New Market. Ward # 7.	1200	*39*	I	200
5	Bairatala to Mistri bari via (Shafa road) end of Pourashava. Ward # 5.	1900	*38*	I	255
	Total =	**8000**			**1183**
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads : Inventory of major works necessary to be executed –Mathbaria Pourashava.

Sl. No.	**Road Name**	**Existing Feature**	**L (m)**	**W (m)**	**S /FP (m)**	**Rise (m)**	**SD (m)**	**SP (m)**	**Culvert #**	**TP #**	**Type**
1	Land Office to Mollik Bari house Via Sadar road, Ward # 2 & 4.	Type =CC, BC. WBM. W=3.65 t0 5m	3500	5.50	0	0.45	3500	0	4	700	BC road.
2	R&H road to Bairatala Khal via Vatenary hospital. Ward # 5.	Type =CC/BSF. W=2.25m. Poor condition.	600	3.00	0	0.45	600	0	3	0	BC road.
3	Mathbaria Masua road to Matbaria Tuskhali khal via Women's college. Ward # 2.	Type=WBM. W=3m. Poor condition.	800	3.70	0	0.45	1400	0	2	200	BC road.
4	R&H road to Govt. College vai New Market. Ward # 7.	Type =BC. W=3m. Poor condition.	1200	4.25	0	0.30	2400	0	2	0	BC road.
5	Bairatala to Mistri bari via (Shafa road) end of Pourashava. Ward # 5.	Type=BC. W=3m. Poor condition.	1900	4.50	0	0.00	1900	100	2	600	BC road.
		Total =	**8000**				**9800**	**100**	**13**	**1500**	

Bridge: One - Mathbaria Pourashava.

Sl. No.	Name, Location, Ward No.	Required Length (m)	Present Condition	Score	Stage	Tentative Cost BDT Lakh)
1	Bridge over Masua Khal near Govt. Hospital. Connected RH and WAPDA roads. Ward # 2&3	42	Wooden bridge used as temporarily.	35	I	**252**

Cyclone Shelter: One – Mathbaria Pourashava.

Sl. No.	Name, Location, Ward No.	Land Ownership	Present Condition	Score	Stage	Tentative Cost Lakh)
1	Mahiuddin Ahamed Girls' Degree College compound, Ward # 2.	College Authority.	Open place.	45	I	**250**

Solid Waste Management - Mathbaria Pourashava.

Equipment, Name	Quantity (No.)	Stage	Unit rate BDT Lakh	*Tentative Cost BDT Lakh*
i) Ricksha –Van.	5	I	0.25	1.25
ii) Push Cart /hand trolley.	10	I	0.10	1.00
			Total =	**2.25**

Town: Pirojpur Pourashava.

Road: *Priority list – Pirojpur Pourashava.*

Sl. No.	*Name of Road with Ward No.*	*Length (m)*	*Score obtained*	*Stage*	*Tentative Cost BDT Lakh*
1	Masimpur main road from R&H road Sargicare (in front) towards Yasin Khal Pul towards west side Jubo Unnayan to bypass road. Length 2100m. Ward #8.	*2100*	*37*	**I**	156
2	Balaka Club to Sargicare hospital via Modho Pirojpur Govt. P /School (Masid bari road). Ward #7	*1500*	*30*	**I**	142
3	South Sikarpur Muslimpara road. Length 1500m. Ward #4.	*1500*	*29*	**I**	245
4	Narkahli road from, Baro Khalisha khali road to Jalil Sk house via Narkhali Govt. Primary School. Length 3000m. Ward # 3.	*3000*	*27*	**I**	260
5	Sadhona Bridge to Shaik Bari Mosque via Basontopul. Ward No.5.	*1000*	*27*	**I**	118
6	Vijora road, from R&H road (near Vijora Govt. Primary School) to Mathkhola via Modho Namajpur Govt.P/School. Ward # 6.	*4000*	*27*	**I**	355
7	Masimpur Varani khal road from Baro Pul to Molla Bari Pul at east side. Ward #8.	*2000*	*25*	**I**	133
8	Baneshwar pur - Kumirmara road,from Baneshwarpur Govt. P/School to RHD road via Kumirmara Govt. P/School. Length 1800m. Ward #9.	*1800*	*25*	**I**	175
9	Apar circular Branch road, Moddo road from Shahid Bidhan road to bypass road, Ward No.5	*1100*	*24*	**I**	185
10	Muktarkati road from Pirojpur -Nazirpur road to Nima bridge via water supply road. Ward #1, 4.	*4200*	*22*	**I**	394
11	Jhatokati road Sahebpara road to Sunil Dakua's house. (Left side canal). Ward # 2.	*1200*	*22*	**I**	98
12	Pirojpur -Nazirpur R&H road to Police line via Kanak Thakur's house. Ward # 2.	*2000*	*22*	**I**	195
13	Narkahli Mallik bari to Molla bari and Kalam Sk house. Length 2000m. Ward # 3.	*2000*	*22*	**I**	197
14	West Sikarpur road from Palpara –Razarhat road near Amjed Bekari to Jaydebi tala with Maddo Sikarpur road in front of Uttarpara Govt. Primary School. Length 2700m. Ward #4.	*2700*	*22*	**I**	317
15	Ranipur Branch road from Ranipur BC Road Pourashava last to Bekutia-RHD road via Sorab Hossain master's house. Length 900m. Ward #9.	*900*	*22*	**I**	97
16	Brammonkati road, from Pirojpur –Nazirpur BC road to Mozahar Mia's house via Misu Councilor's house. Length 700m. Ward # 1.	*700*	*19*	**I**	74
17	Vijora road, from R&H road (near Boropul) to Vijora Krinhnachura via Skdar bari. Ward # 6.	*2500*	*19*	**I**	244
	Total (I) =	**34,200**			**33,85**
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads: Inventory of major works necessary to be executed –Pirojpur Pourashava.

Sl. No.	Road Name	Existing Feature	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
1	Masimpur main road from R&H road Sargicare (in front) towards Yasin Khal Pul towards west side Jubo Unnayan to bypass road. Ward #8.	Type =BC, W=2.50 to 3.00m. Poor condition.	2100	3.00	0	0.45	0	600	3	500	BC road
2	Balaka Club to Sargicare hospital via Modho Pirojpur Govt. primary School (Majid bari road). Ward #7.	Type =BC,.W=3.00 to 3.50m. Poor condition.	1500	3.70	0	0.3	300	200	1	0	BC road.
3	South Sikarpur Muslimpara road. Ward # 4.	Type =CC/BFS, W=2.00 to 2.44m.	1500	3.70	0	0.30	1000	0	2	0	RCC road.
4	Narkahli road from, Baro Khalisha khali road to Jalil Sk house via Narkhali Govt. Primary School. Ward # 3.	Type =BFS, Earthen. W=2.44 to 3.00m	3000	3.00	0	0.30	0	200	3	100	RCC road.
5	Sadhona Bridge to Shaik Bari Mosque via Basonto pul. Ward No.05.	Type =BC, W=3.00 to 3.50m.	1000	3.70	0	0.45	600	0	0		BC road.
6	Vijora road, from R&H road (near Vijora Govt. Primary School) to Mathkhola via Modho Namajpur Govt.P/School. Ward # 6.	Type =BFS, W=2.44 to 3.00m. Poor condition.	4000	3.00	0	0.30	0	400	4	800	RCC road.
7	Masimpur Varani khal road from Baro Pul to Molla Bari Pul at east side. Ward #8.	Type =BC,.W=3.00 to 3.50m.	2000	3.00	0	0.3	0	400	0	400	BC road.
8	Baneshwarpur - Kumirmara road,from Baneshwarpur Govt. P/School to RHD road via Kumirmara Govt. P/School. Ward #9.	Type =BFS,.W=2.50 to 3.00m. Poor condition.	1800	3.00	0	0.3	0	400	4	400	RCC road.
9	Apar circular Branch road, Moddo road from Shahid Bidhan road to bypass road, Ward No.05	Type =BC, W=3.00 to 3.50m. Poor condition.	1100	3.70	0	0.30	1500	0	0	0	BC road.
10	Muktarkati from Pirojpur Nazirpur BC road to Nimabridge via water supply road. Ward 1, 4.	Type =BFS, W=3.00 to 3.50m.	4200	3.00	0	0.30	0	400	3	800	RCC road.
11	Jhatokati road Sahebpara road to Sunil	Type =BC,.W=3.00	1200	3.70	0	0.30	0	300	2	0	BC road.

Sl. No.	Road Name	Existing Feature	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
	Dakua's house. (Left side canal). Ward # 2.	to 3.50m									
12	Pirojpur -Nazirpur R&H road to Police line via Kanak Thakur's house. Ward # 2.	Type =BFS ,W=2.44 to 3.00m.	2000	3.70	0	0.60	0	300	3	400	RCC road.
13	Narkahli Mallik bari to Molla bari and Kalam Sk house. Ward # 3.	Type=BFS,Earthen. W=2.5 to 3m	2000	3.00	0	0.30	0	300	4	100	RCC road.
14	West Sikarpur road from Palpara –Razarhat road near Amjed Bekari to Jaydebi tala with Maddo Sikarpur road in front of Uttarpara Govt. Primary School. Ward #4.	Type =BC. W=3.00 to 3.7m. Poor condition.	2700	3.70	0	0.00	1200	200	4	0	BC road.
15	Ranipur Branch road from Ranipur BC Road Pourashava last to Bekutia-RHD road via Sorab Hossain master's house. Ward #9.	Type =BFS,.W=2.50 to 3.00m. Poor condition.	900	3.00	0	0.3	0	200	3	200	RCC road.
16	Brammonkati road, from Pirojpur –Nazirpur BC road to Mozahar Mia's house via Misu Councilor's house. Length 700m. Ward # 1.	Type =B.FS, W=3.00 to 3.50m. Poor condition.	700	3.00	0	0.30	0	0	0	200	RCC road.
17	Vijora road, from R&H road (near Boropul) to Vijora Krinhnachura via Skdar bari. Ward # 6.	Type =BFS, W=2.44 to 3.00m	2500	3.00	0	0.30	0	400	3	400	RCC road.
		Total (I) =	**34200**				**4600**	**4300**	**39**	**4300**	

Note : L=length, W =width, S /FP =Shoulder /Footpath, SD =side drain, SP =side protection, TP =tree plantation. BC =Bituminous Carpeting,

Bridges: Priority list –Pirojpur Pourashava

Sl. #	Name, Location,	Required Length (m)	Present Condition	Ward #	Score	Stage	Tentative Cost Lakh)
1	Bridge on proposed road near Kuddus Mia's house. **Road :** Vijora road, from R&H road (near Vijora Govt. primary School) to Mathkhola. Ward # 6.	10	Iron sleeper bridge. Damaged and risky.	6	32	**I**	50
2	Bridge on proposed road near Feroj Howladar's house. **Road :** Vijora road, from R&H road (near Vijora Govt. primary School) to Mathkhola. Ward # 6.	10	Iron sleeper bridge. Damaged and risky.	6	32	**I**	50
3	Bridge on P/road near Shakil Khan's house. **Road :** Masimpur main road from R&H road Sargicare (in front) towards Yasin Khal Pul towards west side Jubo Unnayan to bypass road. Ward #8.	8	Iron sleeper bridge. Damaged and risky.	8	32	**I**	40
4	Bridge on P/road near X-Councilor Shajahan Sk's house. **Road :** Masimpur Varani khal road from Baro Pul to Molla Bari Pul at east side. Ward #8.	10	Iron sleeper bridge. Damaged and risky.	8	32	**I**	50
						Total =	**190**

Cyclone Shelter: Priority list –Pirojpur Pourashava.

Sl. No.	Name, Location, Ward No.	Land Ownership	Present Condition	Score	Stage	Tentative Cost Lakh)
1	Adrashapara Secondary School. Ward # 5.	School Authority.	Tin-shade with land.	50	I	250
2	Khamkata Govt. Primary School. Ward # 8.	School Authority.	Open land	50	I	250
3	Moidho Namajpur Govt. Primary School. Ward # 6.	School Authority.	Open land	50	I	250
4	Moidho Dumuritala Govt. Primary School. Ward # 9.	School Authority.	Tin-shade with land.	50	I	250
					Total =	**10,00**

Solid Waste Management - Pirojpur Pourashava.

Equipment, Name	Quantity (No.)	Stage	Unit rate BDT Lakh	*Tentative Cost BDT Lakh*
i) Ricksha –Van.	6	I	0.25	1.50
ii) Push Cart /hand trolley.	15	I	0.10	1.50
			Total =	**3.00**

ATTACHMENT 2: UNIT COST OF ITEMS /WORKS FOR ROADS [SAME FOR 4-POURASHAVAS].

Road : Unit Cost considered for Estimation (followed LGED Schedule of Rates, 2012 –July).

BC Road : Unit Cost of Items/Works

Sl.	Item (short name)	L (m)	W (m)	T (m)	Quantity	Unit	Rate BDT	Cost (A)	Cost (B)	Remarks
1	Box cutting	1000	3.7		3700	m2	39	144300	144300	
2	Bed preparation	1000	3.7		3700	m2	10	37000	37000	
3	ISG	1000	3.7	0.25	925	m3	560	518000	518000	
4	Sub-base (SA)	1000	3.7	0.15	555	m3	2553	1416915	1416915	
5	Brick on end edging (125m)	1000			2000	m	143	286000	286000	
6	WBM	1000	3.7	0.15	555	m3	4327	2401485	2401485	
7	Prime Coat	1000	3.7		3700	m2	112	414400	414400	
8	Shoulders (LS)	1000	1.2		1200	m2	344	55880	412800	normal /hard
9.1	BC 25mm with Seal coat 7mm	1000	3.7		3700	m2	586	2168200	0	
9.2	BC 40mm with Seal coat 12mm	1000	3.7		3700	m2	878	0	3248600	
10.1	Turf for side protection	1000	3.0		3000	m2	14	0	42000	
10.2	Grass/shurb for E/W protection	1000	1.5		1500	m2	35	0	52500	
	Total cost for fixed items				**3700**	**m2**	BDT	7442180	8974000	1531820
	Unit cost for fixed items				1	m2	BDT	2011.40	2425.41	414.01
	Unit cost for fixed items				1	m2	BDT Lakh	**0.02011**	**0.02425**	**0.00414**
	Other items as necessary :									
11.1	Rise of road level with E/W					m2/m	BDT Lakh		**0.0031**	
11.2	Tree Plantation with CT 1-year				400 #	Km	BDT Lakh		**0.6**	Calculated
12.1	Taking out, existing sand					m2	BDT Lakh		**0.000188**	
12.2	Existing HBB, Picking up					m2	BDT Lakh		**0.000380**	
12.3	Dismantling, Sub-B, Base-C					m2	BDT Lakh		**0.000635**	
13	RCD /Culvert (8mX1.5mX1m)					No.	BDT Lakh		**2.6**	Calculated
14.1	Drain (1.5m X1m), RCC					m	BDT Lakh		**0.0738**	Calculated
14.2	Drain (1.5m X1m), Brick					m	BDT Lakh		**0.0622**	Calculated

BC Road : Unit Cost of Items/Works

Sl.	Item (short name)	L (m)	W (m)	T (m)	Quantity	Unit	Rate BDT	Cost (A)	Cost (B)	Remarks
14.3	Drain cover slab					m	BDT Lakh		**0.0310**	Calculated
14.4	V-drain with road.					m	BDT Lakh		**0.0050**	Calculated
15.1	Side protection by Brick Wall					m	BDT Lakh		**0.0482**	Calculated
15.2	Side protection by RCC Wall,					m	BDT Lakh		**0.0744**	Calculated
15.3	Side protection by RCC Palisading					m	BDT Lakh		**0.0475**	
16	Overlaying (WBM) with BC.					m2	BDT Lakh		**0.0188**	Calculated
17	Widening of BC pavement					m2	BDT Lakh		**0.0262**	Calculated

RCC Road : Unit Cost for Items/Works

Sl.	Item (short name)	L (m)	W (m)	T (m)	Qnty.	Unit	Rate BDT	Cost (A)	Cost (B)	Remarks
1	Box cuting	1000	3.7		3700	m2	53	196100	196100	
2	Bed preparation	1000	3.7		3700	m2	10	37000	37000	
3	ISG	1000	3.7	0.25	925	m3	560	518000	518000	
4	Sub-base	1000	3.7	0.10	370	m3	2553	944610	944610	
5	B/wall beside pavement	2000				m		0	2297433	Calculated
6	Shoulders/side by E/W	1000	1.0	0.1	100	m3	311	31100	31100	
7	Polythen below RCC pavement	1000	3.7		3700	m2	16	59200	59200	
8.1	RCC Pavement (150mm), stone	1000	3.7	0.15	555	m3	8513	4724715	4724715	
8.2	RCC Pavement (125mm), stone	1000	3.7	0.13	463	m3	0	0	0	
9	MS Rod				18500	Kg	96	1766400	1766400	
10	Turf for E/W protection	1000	3.0		3000	LS	14	0	42000	Ref. CRIIP
11	Grass/shurb for E/W protection	1000	1.5		1500	LS	35	0	52500	Ref. CRIIP
	Total cost for fixed items					**3700**	BDT	8277125	10669058	2391933
	Unit cost for fixed items					m2	BDT	2237.061	2883.529	646.468
	Unit cost for fixed items					m2	BDT Lakh	**0.02237**	**0.02884**	0.00646
If	RCC Pavement (125mm), stone					m2	BDT Lakh		**0.02666**	
	Other items as necessary :									

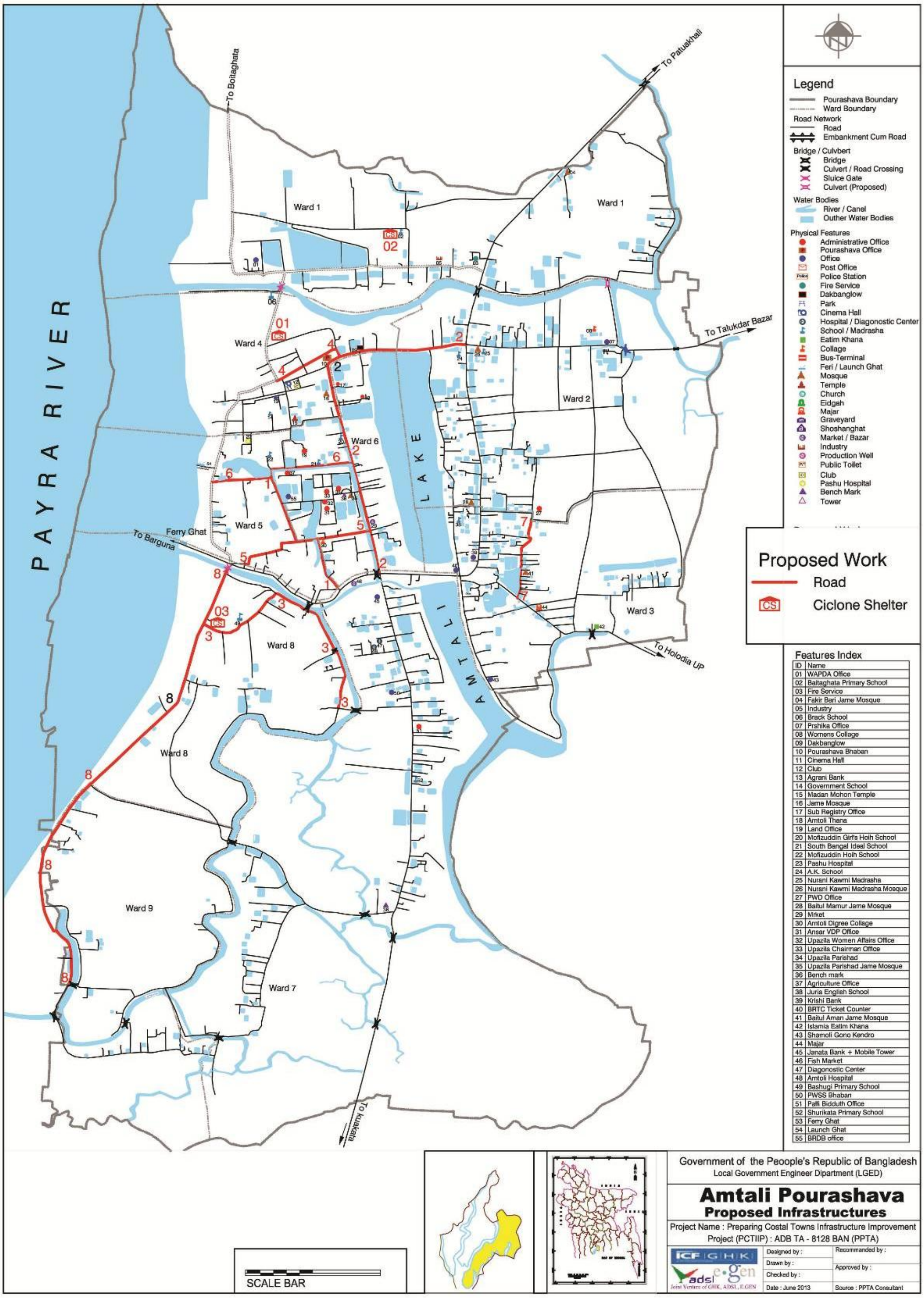
BC Road : Unit Cost of Items/Works

Sl.	Item (short name)	L (m)	W (m)	T (m)	Quantity	Unit	Rate BDT	Cost (A)	Cost (B)	Remarks
11.1	Rise of road level with E/W					m2/m	BDT Lakh		**0.0031**	
11.2	Tree Plantation with CT 1-year				400 #	Km	BDT Lakh		**0.6**	Calculated
12.1	Taking out, existing sand					m2	BDT Lakh		**0.000188**	
12.2	Existing HBB, Picking up					m2	BDT Lakh		**0.000380**	
12.3	Dismantling, Sub-B, Base-C					m2	BDT Lakh		**0.000635**	
13	RCC Culvert/RCD (8mX1.5mX1m)					No.	BDT Lakh		**2.6**	Calculated
14.1	Drain (1.5m X1m), RCC					m	BDT Lakh		**0.0738**	Calculated
14.2	Drain (1.5m X1m), Brick					m	BDT Lakh		**0.0622**	Calculated
14.3	Drain cover slab					m	BDT Lakh		**0.0310**	Calculated
14.4	V-drain with road.					m	BDT Lakh		**0.0050**	Calculated
15.1	Side protection by Brick Wall					m	BDT Lakh		**0.0482**	Calculated
15.2	Side protection by RCC Wall,					m	BDT Lakh		**0.0744**	Calculated
15.3	Side protection by RCC Palisading					m	BDT Lakh		**0.0475**	

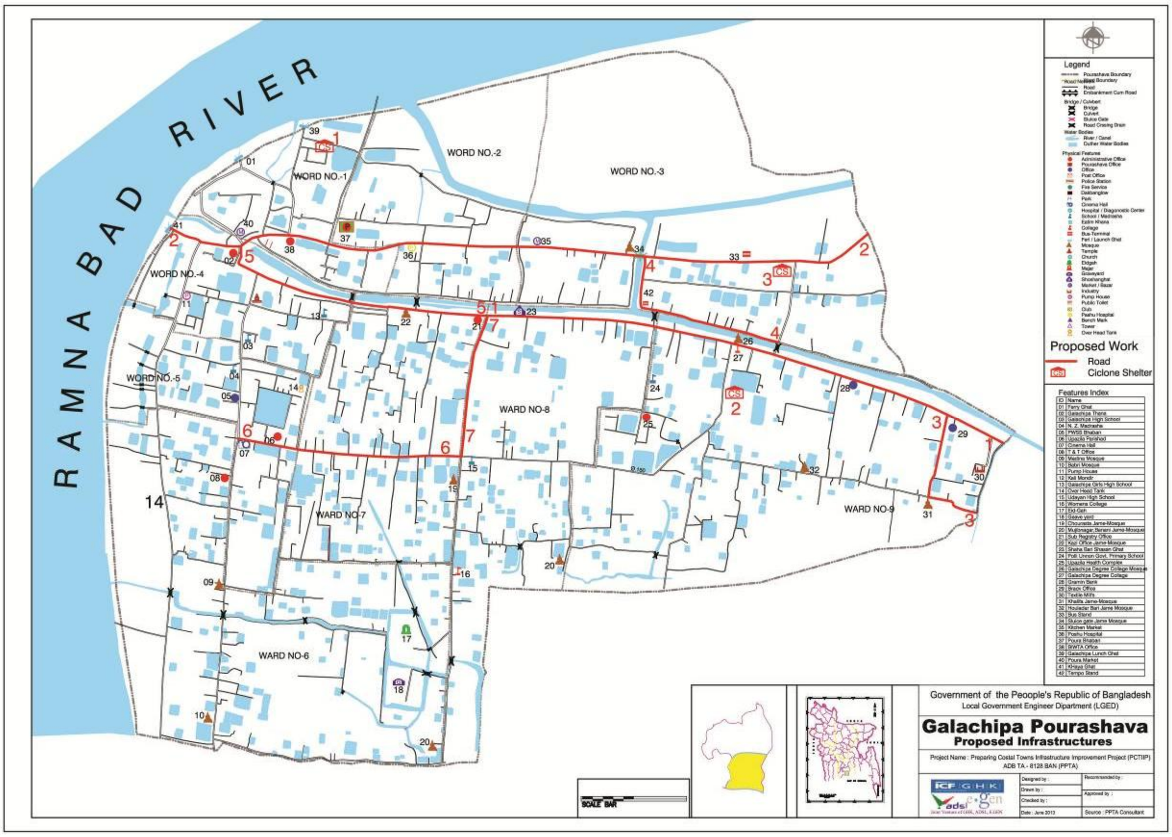
Note : Cost (A) = Cost without CCR, Cost (B) = Cost with CCR, CCR =Climate Change Resilience.

ATTACHMENT 3: LOCATION MAPS SHOWN SUB-PROJECTS, STAGE I (4-POURASHAVA)

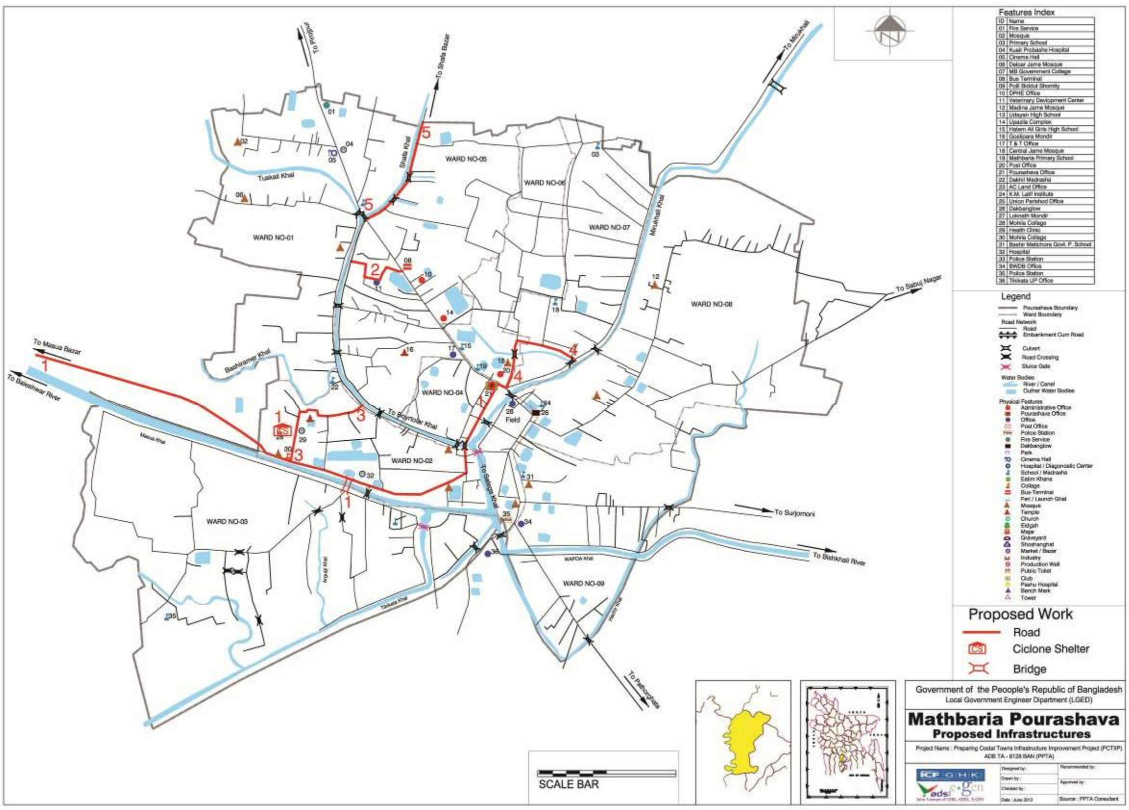
Town: Amtali Pourashava



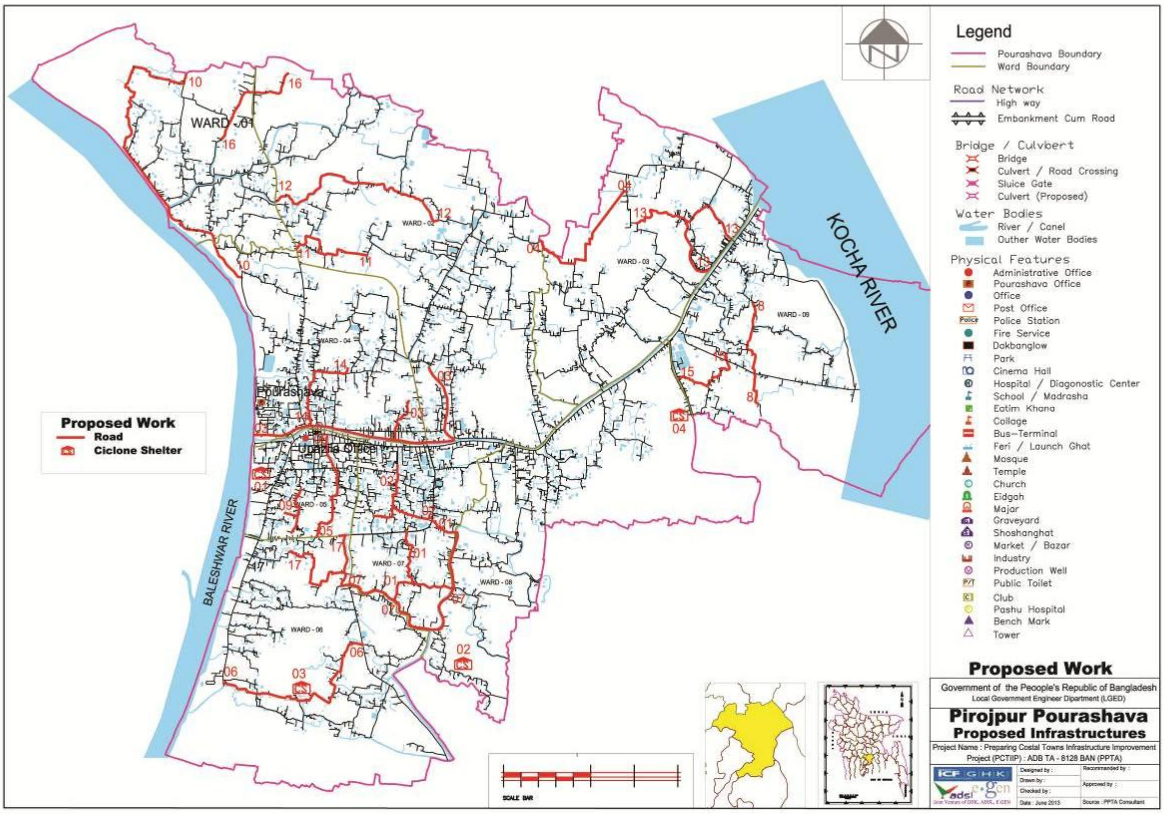
Town: Galachipa Pourashava



Town: Mathbaria Pourashava

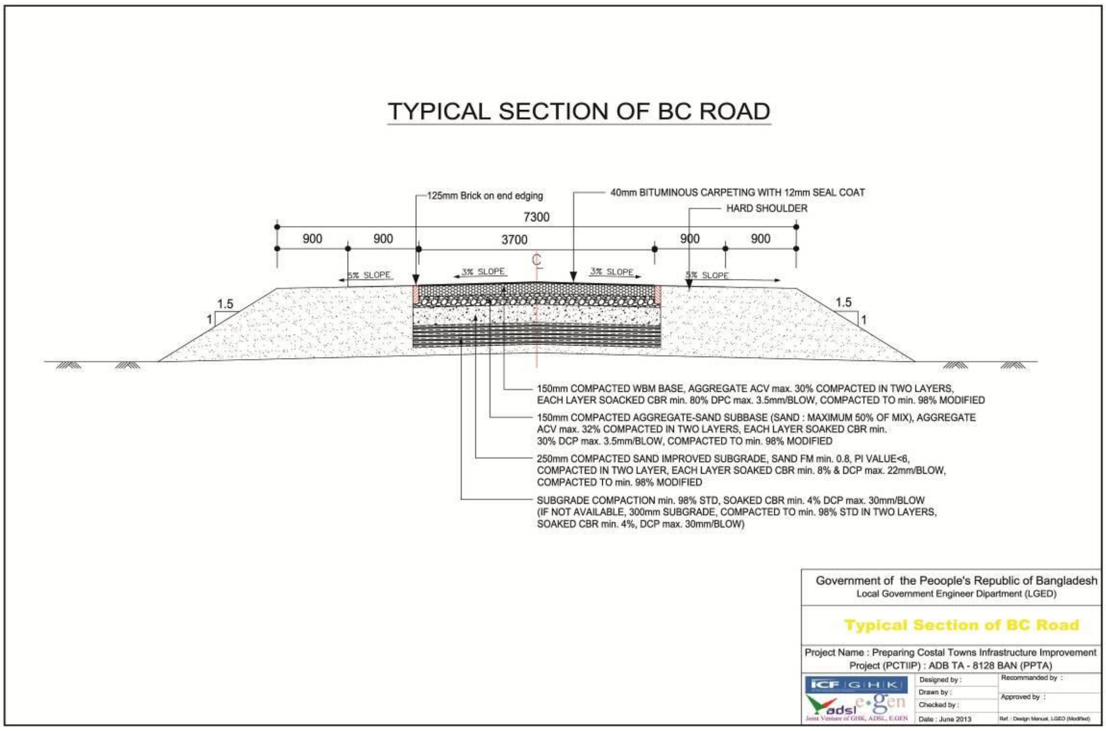


Town: Pirojpur Pourashava

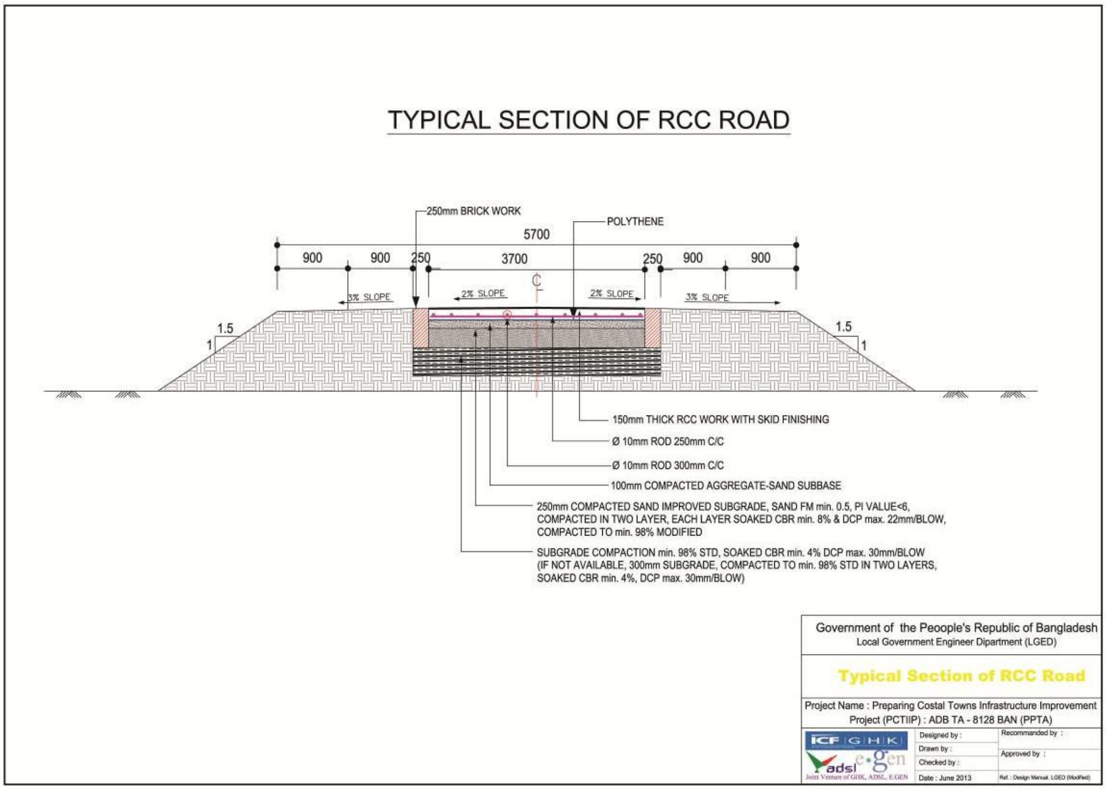


ATTACHMENT 4: TYPICAL DRAWING /CROSS-SECTION [SAME FOR 4-POURASHAVA]

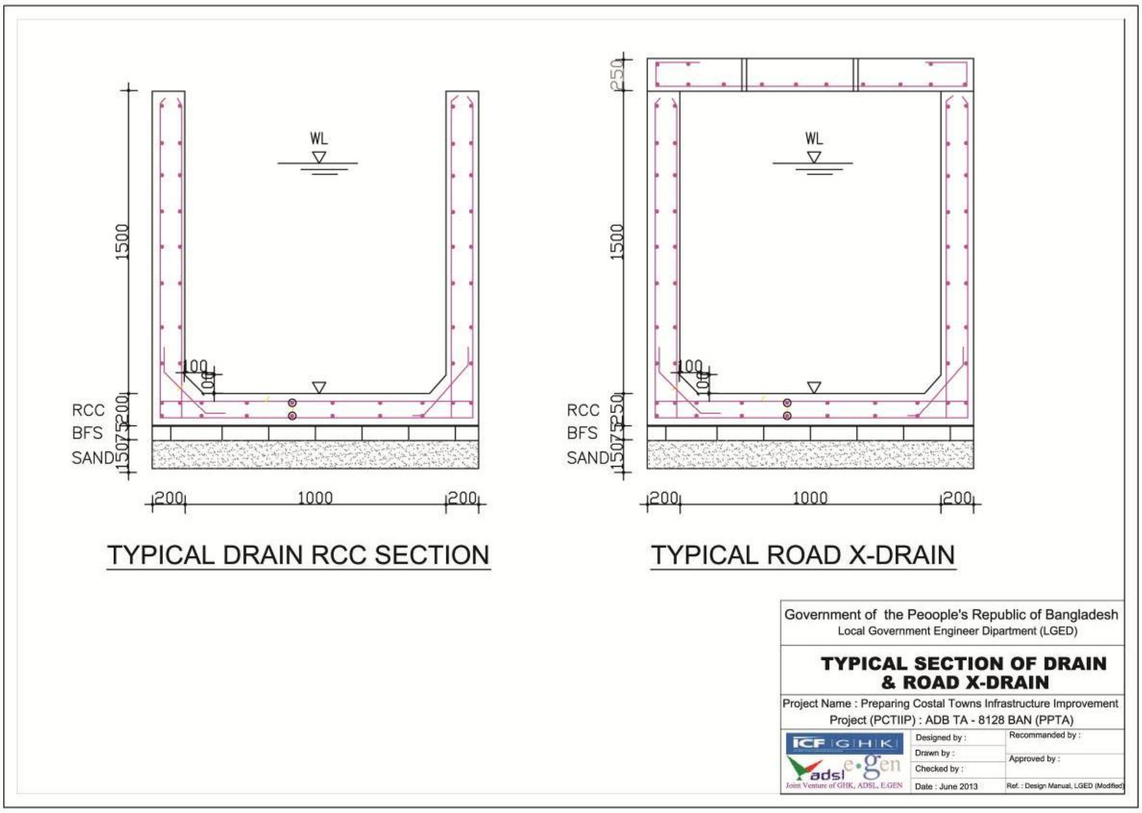
Typical Section of Bitumous Carperting (BC) Road



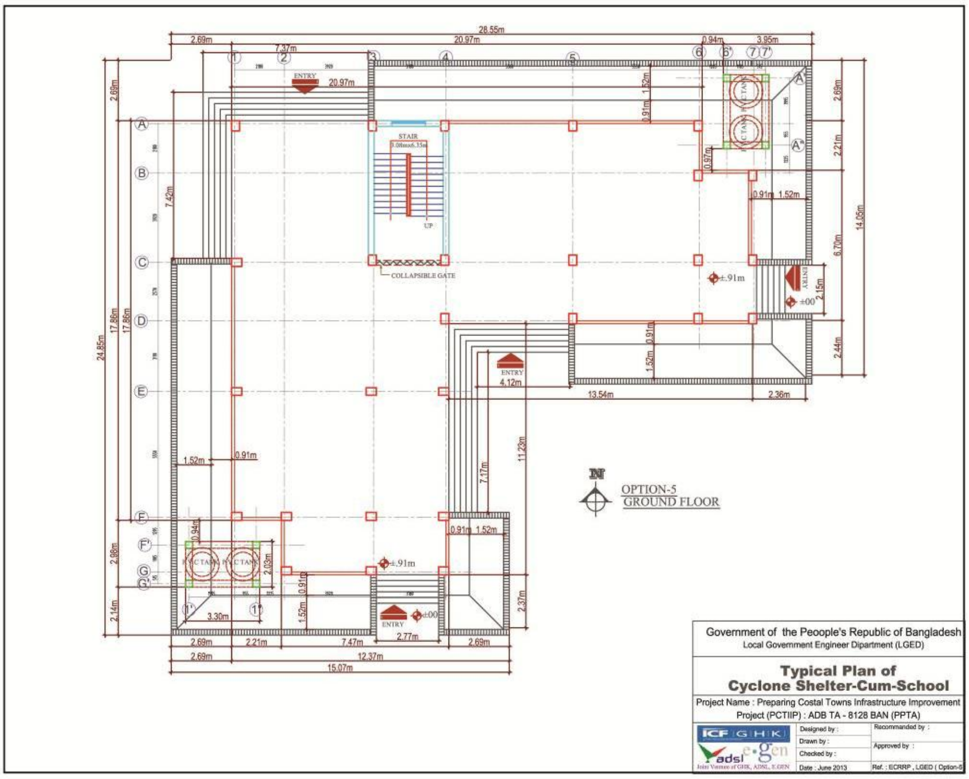
Typical Section of RCC Road



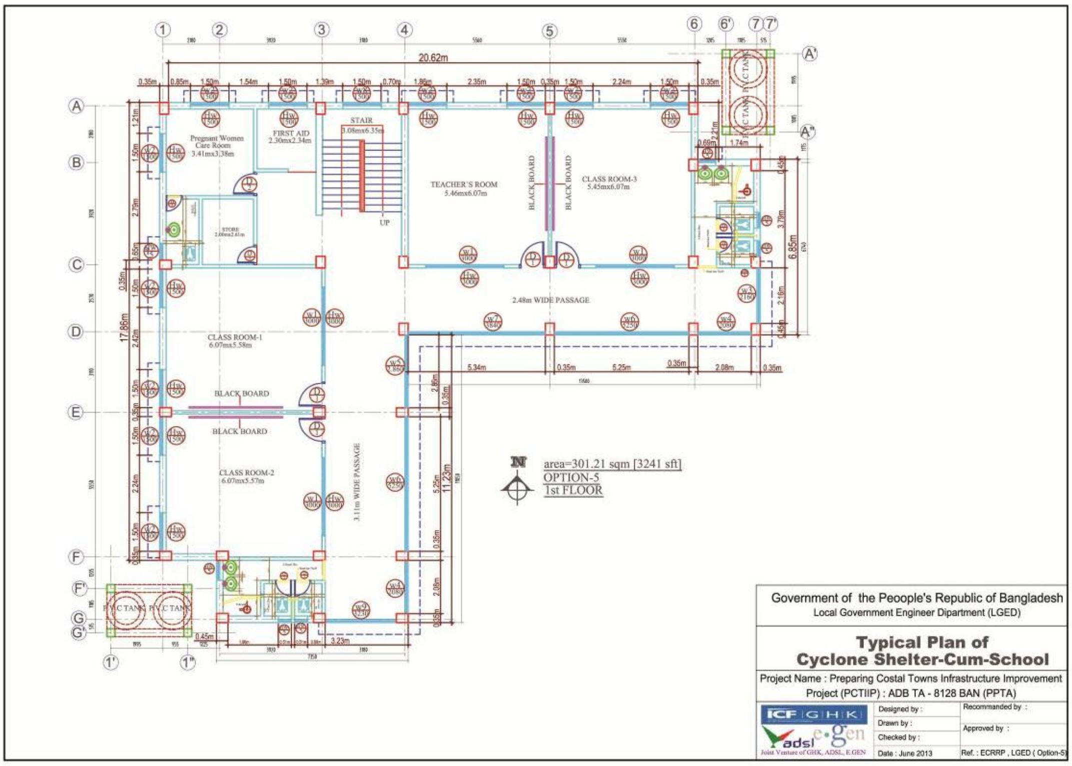
Typical Section of Reinforced Cement Concrete (RCC) Drain



Cyclone Shelter: Ground Floor Plan



Cyclone Shelter: First Floor Plan



ATTACHMENT 5: SUB-PROJECTS (PROBABLE) FOR STAGE II (4-POURASHAVA)

The following list of sub-projects identified and selected during PPTA. Sub-projects can be selected during stage II from this list as suitable.

Town: Amtali Pourashava

Road: *Priority list for stage II - Amtali Pourashava.*

Sl. No.	*Names of roads, Ward No.*	*Length m*	*Score obtained*	*Stage*	*Tentative Cost BDT Lakh*
1	Surikata R&H road to Locha Battala (Ch 900m to 2610m). Ward # 09	1710	*32*	II	107
2	Road from Kamal Sangbadik house (beside Basuki Khal) to Unus Gazi's house.Ward No-08.	1000	*28*	II	244
3	Wapda road to Piku Mirdha house via houses of Lal Gazi and Kalu khan. Ward # 8,9.	1100	*27*	II	138
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads: Inventory of major works necessary to be executed – Amtali Pourashava.

Sl. No.	Road Name	Existing Feature.	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
1	Surikata R&H road to Locha Battala (Ch 900m to 2610m). Ward # 09	W= 3m. BC&HBB.	1710	3.7	1.0	0.30	750	400	6	600	BC road.
2	Road from Kamal Sangbadik house (by the side of Basuki Khal) to Unus Gazi's house.Ward No-08.	Plane Land	1000	3.7	1.0	1.00	0	0	6	400	BC road.
3	Wapda road to Piku Mirdha house via Lal Gazi and Kalu khan houses. Ward # 8,9.	W= 3.6m, CC(50m), Earthen.	1100	3.7	1.0	0.45	50	100	3	400	RCC road
	Note : L=length, W =width, S /FP =Shoulder /Footpath, SD =side drain, SP =side protection, TP =tree plantation. BC =Bituminous Carpeting,										

Bridge: *Priority list for stage II - Amtali Pourashava.*

Sl. No.	Name, Location,	Required Length (m)	Present Condition	Ward #	Score	Stage	***Tentative Cost BDT Lakh***
1	Middle Amtali Bridge. Ward No. 08.	25	Iron Sleeper Bridge.	8	37	II	125
2	Near Ismail Hawlader Bari, Ward No. 07, 08	20	Bamboo bridge (sako)	7, 8	32	II	100
3	Near Eid Ghah.Ward No. 01, 04.	20	Bamboo bridge (sako)	1, 4	32	II	100

Boat Landing Station: Priority list for stage II, Amtali Pourashava..

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Required Size (L x W)	Score	Stage	***Tentative Cost BDT Lakh***
1	Near Amal Pal Saw mill. Bank of Piara river. Ward No-04.	Govt. khas land	Damaged infrastructure. To be used for material, people.	L=30m, W=4.5m	35	II	20
2	Kat Bazar. Bank of Piara river. Ward No-04.	Govt. khas land	Damaged infrastructure. To be used for food, other material.	L=20m, W=4.5m.	35	II	20
3	Near Sluice Canal. Ward No-08.	Govt. khas land	Without infrastructure. To be used for cattle, material, people.	L=10m, W=4.5m.	35	II	10
4	Beside Ferry Gaht. Ward # 5.	Govt. khas land	Without infrastructure. To be used for light goods, people.	L=10m, W=4.5m.	30	II	10
5	Near Bandh Ghat. Ward No-07.	Govt. khas land	Without infrastructure. To be used for light goods, people.	L=10m, W=4.5m.	30	II	10
6	Near AK School. Ward No-02	Govt. khas land	Without infrastructure. To be used for people mainly.	L=10m, W=4.5m.	25	II	10

Market: One for stage II, Amtali Pourashava..

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Stage	***Tentative Cost BDT Lakh***
1	Poura Market, South Side of Sadar Road. Ward No-04. Proposed for 1-S building with foundation of 4S. Effective floor area =2500sft.	Pourashava.	Tin-shade. Usage as store as present.	II	110

Solid Waste Management: For stage II, Amtali Pourashava.

Facilities : Required	**Stage**	***Tentative Cost BDT Lakh***
i) Construction of Transfer Station: 2 (two) in Ward no. 4 and 7. Location yet to be identified.	II	10
ii) Improvement of new landfill, Ward 1 : [Beside WAPDA Embankment road. Opposite to WAPDA Office compound]	II	40
	Total	**50**

Town: Galachipa Pourashava

Road: *Priority list for stage II - Galachipa Pourashava.*

Sl. No.	*Names of roads, Ward No.*	*Length m*	*Score obtained*	*Stage*	*Tentative Cost BDT Lakh*
1	Mujib Nagar road, Ward # 8, 9.	1092	***32***	II	208
2	Sher-e-Bangla road, Ward # 8.	800	***32***	II	116
3	TNT road, Ward # 5, 6.	933	***28***	II	200
4	Wajed road, Ward # 2,3.	820	***28***	II	178
5	Kutial Para,Kalabaghan Road , Ward # 2,3	1500	***28***	II	205
6	Hospital road, Ward #9	573	***28***	II	136
7	Sagardi road, Ward # 4 to 6.	1538	***27***	II	218
8	High School road, Ward # 4 to 6.	515	***27***	II	123
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads: Inventory of major works necessary to be executed –Galachipa Pourashava.

Sl. No.	**Road Name**	**Existing Feature.**	**L (m)**	**W (m)**	**S /FP (m)**	**Rise (m)**	**SD (m)**	**SP (m)**	**Culvert #**	**TP #**	**Type**
1	Mujib Nagar road, Ward # 8, 9.	HBB/BFS, W=3m.	1092	4.00	1092	0.3	0	100	5	400	BC road, FP
2	Sher-e-Bangla road, Ward # 8.	Type =HBB, W=3m.	800	5.00	1600	0.3	0	150	4	300	BC road.
3	TNT road, Ward # 5, 6.	Type =CC, W=3m.	933	4.50	1866	0.3	933	250	4	400	RCC road.
4	Wajed road, Ward # 2,3.	CC/BFS/Earth, W=3m.	820	4.50	0	0.3	820	400	4	400	RCC road.
5	Kutial Para,Kalabaghan Road , Ward # 2,3	Earthen, W=2m.	1500	4.50	0	0.60	0	500	5	600	BC road
6	Hospital road, Ward #9	Type =CC, W=2.5m.	573	4.50	0	0.0	573	200	3	200	RCC road.
7	Sagardi road, Ward # 4 to 6.	HBB/BFS/Earthen, W=3m.	1538	5.00	3076	0.0	3076	200	5	800	BC road, V-drain.
8	High School road, Ward # 4 to 6.	Type =BC/CC, W=4.5m.	515	5.50	1030	0.3	515	200	3	200	RCC road.
Note : L=length, W =width, S /FP =Shoulder /Footpath, SD =side drain, SP =side protection, TP =tree plantation. BC =Bituminous Carpeting,											

Bridge: *Priority list for stage II -Galachipa Pourashava.*

Sl. No.	Name, Location,	Required Length (m)	Present Condition	Ward #	Score	Stage	*Tentative Cost BDT Lakh*
1	Bridge over Ulania – Galachipa Canal. Beside Santibag road. Ward # 3, # 8.	15	Damaged foot-bridge.	3,8	42	II	75
2	Proposed Bridge over Galachipa Poura internal Canal, near Hafez Pol. Beside Sadar road. Connection Ward # 1, # 7.	15	Damaged foot-bridge.	1,7	42	II	75
3	Proposed Bridge over Galachipa Poura internal Canal, near Kazi Mosque. Beside Sadar road. Connection of Ward # 2, # 7.	15	Damaged foot-bridge.	2,7	42	II	75
4	Beside Mohiuddin Police's house. Wards # 4 & 5.	10	Iron sleeper bridge.	4,5	32	II	75
5	Arambag. Beside Minhaz Peada's house. Ward #6.	15	Iron sleeper bridge.	6	32	II	75
6	Helipad to Islam Bag road. Ward #6.	15	Iron sleeper bridge.	6	32	II	75
7	Food Godown to Kalabagan. Beside Faruk's house. Ward # 2.	15	Wooden bridge.	2	27	II	75
8	Sahi Mosque to Kalabagan. Beside Faruk's house. Connection of Ward # 2 &3.	15	Wooden bridge.	2,3	27	II	75

Boat Landing Station*: Priority list for stage II - Galachipa Pourashava.*

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Required Size (L x W)	Score	Stage	*Tentative Cost BDT Lakh*
1	Arat Potty bank of Ramnabad river. Ward # 4.	Govt. khas land	No infrastructure. Used for passengers and goods. Need yard development (80mX30m).	30m X 4.5m.	35	II	25
2	Near Arat Potty bank of Ramnabad river. Ward # 4.	Govt. khas land	No infrastructure Used for construction materials –sand/brick etc. and stationery items.	30m X 4.5m.	35	II	20
3	Location between Ferry Ghat and Launch Ghat, bank of Ramnabad river. Ward # 1.	Govt. khas land	No infrastructure. Used for Cargo landing, Need approach road.	30m X 4.5m.	35	II	25

Bus Terminal: For stage II, Galachipa.

Name, proposed works	**Stage**	***Tentative Cost BDT Lakh***
Improvement of Shantibag Bus terminal. Ward No.3. [Land development done by Pourashava). **Proposed works :** Required. HBB in terminal yard, Ticket Counter construction, Boundary protection work etc.	II	80

Market: One for stage II, Galachipa Pourashava..

Sl. #	**Name, Location, Ward #**	**Land Ownership**	**Present Condition.**	**Stage**	***Tentative Cost BDT Lakh***
1	Super Market Complex at Pouro Mancho Chattar, Ward # 4. Proposed for 1-S building with foundation of 4S. Effective floor area =3000sft.	Pourashava.	Tin-shade with open land space.	II	130

Solid Waste Management: For stage II, Galachipa Pourashava.

Facilities : Required	**Stage**	***Tentative Cost BDT Lakh***
i) Construction of Transfer Station : 2 (two) in (a) East side of Ferry-ghat in Ward No. 1 and (b) Location yet to be identified.	II	10
ii) Improvement of new landfill, Ward 3 : [Beside RHD road]	II	40
	Total	**50**

Town: Mathbaria Pourashava

Road: *Priority list for stage II, Mathbaria Pourashava.*

Sl. No.	***Name of Road, Ward No.***	***Length m***	***Score obtained***	***Stage***	***Tentative BDT Cost (Lakh)***
1	WAPDA Road to Betmor Khal Via Islam Bag. Ward # 3.	1000	*37*	II	121
2	R&H road to Bairatala Khal via Mizan Councilor and Shafa BC Road to Rupnogor. Ward # 5.	1000	*35*	II	134
3	Upazila Parishad to Mirukhali road via Udayan H/School. Ward # 6,7.	1000	*35*	II	150
4	Bankpara to Boyratala bridge road. Ward # 4,5.	1250	*33*	II	165
5	Mathbaria Tushkhali BC road to Baraitala Khal (Arambag Rd). Ward # 5.	600	*32*	II	98
6	Shafa Bairatala BC road to Moti Kazi's house. Ward # 5&6.	800	*32*	II	119
7	Mathbaria Safa Road to Uddaon Rej. School Via Mokter Bari &Sara Bari Ward #5.	2500	*32*	II	403
8	WAPDA BC road to WAPDA Moque via houses of Whabia Madrasa Jahangir Mater house to Katchira Khal. Ward # 3.	650	*32*	II	60
9	Udayan Primary School to Bijoy Krishna Howladar. Ward # 7.	600	*32*	II	57
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads: Inventory of major works necessary to be executed –Mathbaria Pourashava.

Sl. No.	**Road Name**	**Existing Feature**	**L (m)**	**W (m)**	**S /FP (m)**	**Rise (m)**	**SD (m)**	**SP (m)**	**Culvert #**	**TP #**	**Type**
1	WAPDA Road to Betmor Khal Via Islam Bag. Ward # 3.	Type=CC/Earthen. W=2m. Poor condition.	1000	3.00	0	0.45	1000	0	2	100	BC road.
2	R&H road to Bairatala Khal via Mizan Councilor.Shafa BC Road to Rupnogor Area Ward # 5.	Type =BSF/Earthen.Soling W=2m. Poor condition.	1000	3.70	0	0.45	900	50	2	50	BC road.
3	Upazila Parishad to Mirukhali road via Udayan H/School. Ward # 6,7.	Type =RCC/BC. W=2.5m. Poor condition.	1000	3.70	0	0.45	2000	0	2	200	BC road.
4	Bankpara to Boyratala bridge road. Ward # 4,5.	Type =Earthen. W=2.5m. Poor condition.	1250	3.70	0	0.45	800	200	4	400	BC road.

Roads: Inventory of major works necessary to be executed –Mathbaria Pourashava.

Sl. No.	Road Name	Existing Feature	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
5	Mathbaria Tushkhali BC road to Baraitala Khal (Arambag Rd). Ward # 5.	Type=CC. W=2.44m. Poor condition.	600	3.00	0	0.45	1200	0	2	0	BC road.
6	Shafa Bairatala BC road to Moti Kazi's house. Ward # 5&6.	Type=BC/CC. W=2.5m. Poor condition.	800	3.60	0	0.30	800	150	2	100	BC road.
7	Mathbaria Safa Road to Uddaon Rej. School Via Mokter Bari &Sara Bari Ward #5.	Type=Earth&Soling W=2.44m. Poor condition.	2500	3.70	0	0.60	4000	200	5	800	BC road.
8	WAPDA BC road to WAPDA Moque via houses of Whabia Madrasa Jahangir Mater house to Katchira Khal. Ward # 3.	Type=Earthen. W=1.82m. Poor condition.	650	3.00	0	0.60	0	100	2	70	BC road.
9	Udayan Primary School to Bijoy Krishna Howladar. Ward # 7.	Type =CC/BSF/Earthen. W=2m. Poor condition.	600	3.00	0	0.60	600	150	3	100	BC road.

Bridge: Priority list for stage II, Mathbaria Pourashava..

Sl. No.	Name, Location,	Required Length (m)	Present Condition	Ward #	Score	Stage	Tentative Cost BDT Lakh)
1	Bridge over WAPDA Khal near Pathorghata Bus stand. Ward # 9.	18	Old steel bridge.	9	42	II	90
2	Bridge over Masua Khal near Cattle Market & Rice Mill Chatal. Ward # 2&3.	42	Bamboo bridge.	2, 3	**35**	II	252
3	Bridge over Mirukhali Khal near Dipchar area. Ward # 7.	18	Bamboo bridge.	7	31	II	90
4	Bridge over Dauatala Canal Hachir Khal. Ward # 9.	30	Bamboo bridge.	9	31	II	180

Culvert over Canal: Priority list for stage II, Mathbaria Pourashava

Sl. No.	Name, Location,	Required Length (m)	Ward #	Present Condition	Scored (weight)	Stage	Tentative cost BDT Lakh
1	Near Fish Market. Canal : Mathbaria -Mirukhali Khal.	*12m x 5m x 5m*	*4.8*	*Iron with RCC Slab bridge. Damaged and risky.*	37	II	40
2	Bayratala, in front of Hafizia Madrasha. Canal : Madthbaria -Sata Khal.	*12m x 5m x 5m*	*1,5*	*Iron with RCC Slab bridge. Damaged and risky.*	37	II	40
3	*Backside Hari Mandir.* Canal : Mathbaria -Mirukhali Khal.	*12m x 5m x 4m*	*4*	*Iron with sleeper bridge. Damaged and risky.*	32	II	35
4	*In front of Halim Huzur* Canal : Madthbaria -Sata Khal.	*12m x 5m x 4m*	*1,5*	*Iron with sleeper bridge. Damaged and risky.*	32	II	35
5	Goali para, beside of Faruk Mia's house Canal : Madthbaria -Tushkhali Khal	*12m x 5m x 4m*	*1,5*	*Iron with sleeper bridge. Damaged and risky.*	32	II	35
6	Beside Mirukhali Rikshaw stand Canal : Mathbaria –Mirukhali Khal.	*12m x 5m x 4m*	*7,8*	*Iron with sleeper bridge. Damaged and risky.*	32	II	35
7	Piajhata, Capor Patty Canal : Madthbaria -Tushkkali Khal	*12m x 5m x 4m*	*2,4*	*Iron with sleeper bridge. Damaged and risky.*	32	II	35
8	TNT road, beside Bishnu Professor. Canal : Madthbaria -Tushkkali Khal	*12m x 5m x 4m*	*2,5*	*Iron with sleeper bridge. Damaged and risky.*	32	II	35
9	Andar manik, In front of Bada Ojha Canal : Mathbaria –Mirukhali connected Khal.	*12m x 5m x 4m*	*8*	*Bamboo made skako (bridge).*	27	II	35
10	Mathbaria bazar, Backside Samir Kumar Das. Canal : Mathbaria –Mirukhali Khal.	*12m x 5m x 4m*	*4*	*Bamboo made skako (bridge).*	27	II	35

Boat Landing Station: Priority list for stage II, Mathbaria Pourashava..

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Required Size (L x W)	Score	Stage	Tentative Cost Lakh
1	Near Food Godown beside Masua Khal. Ward # 2.	Govt. Khas land	No infrastructure. Used own wooden sleeper.	L=10m, W=4.5m	35	II	10
2	Nabi Nagar beside Masua Khal. Ward # 3.	Govt. Khas land	No infrastructure. Used own wooden sleeper.	L=10m, W=4.5m	35	II	10
3	Near Chatal besides Masua Khal. Ward # 3.	Govt. Khas land	No infrastructure. Used own wooden sleeper.	L=10m, W=4.5m	35	II	10
4	Tikakata beside UP, Ward #9.	Govt. Khas land	No infrastructure.	L=10m, W=4.5m	35	II	10
						Total =	**50**

Bus Terminal: For stage II, Mathbaria.

Name, proposed works	Stage	*Tentative Cost BDT Lakh*
Improvement of existing Bus terminal of Mathbaria. Ward No.1. **Proposed works :** Required. HBB in terminal yard, Ticket Counter construction, Boundary protection work etc.	II	**80**

Cyclone Shelter: Priority list for stage II, Mathbaria Pourashava.

Sl. No.	Name, Location, Ward No.	Land Ownership	Present Condition	Score	Stage	Tentative Cost Lakh)
1	Halim Ali High School compound, Ward # 6.	School Authority.	Old damaged building with open land.	45	**I**	250
2	Udayan High School compound, Ward # 7.	Madrasha Authority.	Old damaged tin-shade.	45	**I**	250

Market: One for stage II, Mathbaria Pourashava..

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Stage	***Tentative Cost BDT Lakh***
1	Fish Market in Ward #4. Proposed for 1-S building with foundation of 4S.	Pourashava. Effective floor area =4000sft.	Tin-shade.	II	110

Solid Waste Management: For stage II, Mathbaria Pourashava.

Facilities : Required	Stage	***Tentative Cost BDT Lakh***
i) Construction of Transfer Station : 2 (two) in Ward No. 4 and 7. Location yet to be identified.	II	10
ii) Improvement of new landfill, beyond Pourashava. Beside Baleshawar river, 8Km far from Pourashava	II	40
	Total	**50**

Town: Pirojpur Pourashava

Road: *Priority list for stage II, Pirojpur Pourashava.*

Sl. No.	*Name of Road with Ward No.*	*Length (m)*	*Score obtained*	*Stage*	*Tentative Cost BDT Lakh*
1	Upazila bridge to Hularhat road beside canal. Length 4300m. Ward # 3, 4.	*4300*	*36*	II	477
2	Palpara –Razarhat road from east Sikarpur Alam Khan's house to Baleshawar river. Ward #4.	*1800*	*36*	II	110
3	Horerhowla bridge to Manik master house via X-Councilor Rushtam Ali Sk bari. Ward # 6.	*2500*	*32*	II	244
4	Lakkha kati main road, Sadon Master to Hularhat R&H. Length 1500m. Ward # 3.	*1500*	*28*	II	174
5	Narilpara road, from Kacha bazar bridge to Eidgh. Length 550m. Ward #7.	*550*	*28*	II	67
6	South-east corner puratan Khamkata to Munshi bari connecting road. Ward #8.	*1300*	*28*	II	130
7	North Krisna Nagar Judge Court to Fultala Malik house via Talukdar house and Fulltala Tayub house's pul to Zahangir's shop at south. Length 2000m. Ward #8.	*2000*	*28*	II	187
Note : Cost includes road with necessary works related to road like drain, culvert, side protection work etc. covering climate change resilient issues.					

Roads: Inventory of major works necessary to be executed – Pirojpur Pourashava.

Sl. No.	Road Name	Existing Feature	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
1	Upazila bridge to Hularhat road beside canal. Ward # 3,2,4.	Type =BFS/Earthen. W=2.5m. Poor condition.	4300	3.00	0	0.90	0	1500	12	800	RCC road.
2	Palpara–Razarhat road from east Sikarpur Alam Khan's house to Baleshawar river. Ward #4.	Type =BC,.W=2.50 to 3.00m. Poor condition.	1800	3.00	0	0	0	0	3	0	BC road.
3	Horerhowla bridge to Manik master house via X-Councilor Rushtam Ali Sk bari. Ward # 6.	Type =BFS. W=2.5m. Poor condition.	2500	3.00	0	0.60	0	400	3	500	RCC road.
4	Lakkha kati main road, Sadon Master to Hularhat R&H. Ward # 3.	Type =Earthen. W=2.5 to 3m. Poor condition.	1500	3.50	0	0.3	300	300	2	400	RCC road.
5	Narilpara road, from Kacha bazar bridge to Eidgh. Length 550m. Ward #7.	Type =CC,.W=3.00 to 3.75m. Poor condition.	550	4.00	0	0.3	500	0	0	0	RCC road.

Sl. No.	Road Name	Existing Feature	L (m)	W (m)	S /FP (m)	Rise (m)	SD (m)	SP (m)	Culvert #	TP #	Type
6	South-east corner puratan Khamkata to Munshi bari connecting road. Ward #8.	Type =BFS, Earthen. W=3m. Poor condition.	1300	3.00	0	0.30	0	200	3	100	RCC road.
7	North Krisna Nagar Judge Court to Fultala Malik house via Talukdar house and Fulltala Tayub house's pul to Zahangir's shop at south. Ward #8.	Type =BFS, W=3 to 3.5m. Poor condition.	2000	3.00	0	0.45	200	0	0	400	RCC road.
Note : L=length, W =width, S /FP =Shoulder /Footpath, SD =side drain, SP =side protection, TP =tree plantation. BC =Bituminous Carpeting,											

Bridge: Priority list for stage II, Pirojpur Pourashava.

Sl. No.	Name, Location,	Required Length (m)	Present Condition	Ward #	Score	Stage	Tentative Cost Lakh)
1	*Bridge over Damudar canal, Loakati near hularhat baza. Ward # 3,9 connection.*	35	RCC bridge, Damaged and risky.	3,9	42	II	210
2	Bridge beside proposed road at Brammoakhati Nasaria Dakhil Madrasha. **Road :** Brammonkati road, from Pirojpur –Nazirpur BC road to Mozahar Mia's house via Misu Councilor's house. Ward # 1.	25	Iron sleeper bridge. Damaged and risky.	1	28	II	125
3	Bridge over Fultala khal near Mollabari at end of P/road, **Road :** Masimpur Varani khal road from Baro Pul to Molla Bari Pul at east side. Ward #8.	25	Iron sleeper bridge. Damaged and risky.	8	26	II	125
4	*Bridge over Damodar canal, Old Hospital, Ward # 4,7 connection.*	35	Bamboo sako (bridge).	4,7	23	II	210
5	*Bridge over Damudar canal, Narkhali, in front of REB,* Ward # 3,9 connection.	35	Bamboo sako (bridge).	3.9	23	II	210
6	Bridge on proposed road near Kuddus Mia's house. **Road :** Vijora road, from R&H road (near Vijora Govt. Primary School) to Mathkhola. Ward # 6,8 connection.	25	Bamboo sako (bridge).	6,8	23	II	125

Boat Landing Station: Priority list for stage II, Pirojpur Pourashava.

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Required Size (L x W)	Score	Stage	Tentative Cost Lakh)
1	Baleshwar Kheya Ghat. River : Baleshwar. Ward #5	Govt. Khas land	No suitable (damaged) infrastructure is available.	L=10m, W=4.5m.	35	II	10
2	Mahishpura Kheya Ghat. River : Baleshwar. Ward #5	Govt. Khas land	No suitable infrastructure is available.	L=10m, W=4.5m.	35	II	10
3	Razarhat Kheya Ghat. River : Baleshwar. Ward #4.	Govt. Khas land	No infrastructure is available.	L=10m, W=4.5m.	35	II	10
4	Hularhat Kheya Ghat. River : Baleshwar. Ward #9.	Govt. Khas land	Damage of existing infrastructure.	L=10m, W=4.5m.	35	II	10
5	Beside Bekutia Ferry Ghat. Ward #9.	Govt. Khas land	No infrastructure is available.	L=10m, W=4.5m.	30	II	10

Market: One for stage II, Pirojpur Pourashava..

Sl. No.	Name, Location, Ward #	Land Ownership	Present Condition.	Stage	***Tentative Cost BDT Lakh***
1	Multi-purpose Super Market. **Ward #5.** Proposed for 1-S building with foundation of 4S.	Pourashava. Effective floor area =6000sft.	Fish, Meat, Kitchen market. Tin-shade.	II	250

Solid Waste Management: For stage II, Pirojpur Pourashava.

Facilities : Required	**Stage**	***Tentative Cost BDT Lakh***
i) Construction of Transfer Station : 2 (two) in Ward No. 4 and 7.	II	10
ii) Improvement of existing landfill, Ward 1 :	II	40
	Total	**50**

ANNEX B: DRAINAGE AND FLOOD CONTROL DATA

1. **Rainfall Hyetographs**
2. **Flooding and Drainage Congestion Analysis**
3. **Hydraulic Design Criteria**
4. **Proposed Interventions for Drainage Works**
5. **Maps showing Locations of Proposed Drainage Works**

1. DESIGN HYETOGRAPHS FOR 2 HOUR DESIGN STORM FOR VARIOUS RETURN PERIODS

Table 1: Khepupara

Duration (min)	Rainfall (mm)													
	without climate change						2026-2035, with climate change				2046-2055, with climate change			
	2-year	5-year	10-year	25-year	50-year	100-year	2-year	5-year	10-year	25-year	2-year	5-year	10-year	25-year
0-10	2.40	3.24	3.80	4.49	5.00	5.51	3.02	4.07	4.77	5.64	3.06	4.13	4.83	5.72
10-20	2.72	3.69	4.33	5.13	5.72	6.31	3.41	4.63	5.44	6.44	3.46	4.70	5.51	6.53
20-30	3.17	4.34	5.11	6.08	6.79	7.50	3.99	5.45	6.42	7.63	4.04	5.53	6.51	7.74
30-40	3.93	5.43	6.42	7.67	8.59	9.51	4.94	6.82	8.07	9.63	5.01	6.92	8.18	9.76
40-50	5.55	7.80	9.28	11.16	12.55	13.93	6.97	9.79	11.66	14.02	7.07	9.92	11.82	14.21
50-60	22.29	34.32	42.61	53.31	61.36	69.43	28.00	43.11	53.52	66.96	28.37	43.69	54.24	67.86
60-70	7.55	10.76	12.89	15.59	17.60	19.59	9.48	13.51	16.20	19.59	9.61	13.70	16.41	19.85
70-80	4.55	6.34	7.51	9.00	10.10	11.19	5.72	7.96	9.44	11.30	5.80	8.07	9.56	11.45
80-90	3.50	4.81	5.67	6.75	7.56	8.35	4.39	6.04	7.12	8.48	4.45	6.12	7.22	8.60
90-100	2.92	3.98	4.68	5.55	6.20	6.84	3.67	5.00	5.87	6.97	3.72	5.07	5.95	7.07
100-110	2.55	3.45	4.04	4.78	5.33	5.88	3.20	4.33	5.07	6.01	3.24	4.39	5.14	6.09
110-120	2.28	3.07	3.59	4.24	4.72	5.20	2.86	3.86	4.51	5.33	2.90	3.91	4.57	5.40
total (mm)	**63.4**	**91.2**	**109.9**	**133.8**	**151.5**	**169.2**	**79.7**	**114.6**	**138.1**	**168.0**	**80.7**	**116.2**	**139.9**	**170.3**

Table 2: Barisal

Duration (min)	Rainfall (mm)													
	without climate change						2026-2035, with climate change				2046-2055, with climate change			
	2-year	5-year	10-year	25-year	50-year	100-year	2-year	5-year	10-year	25-year	2-year	5-year	10-year	25-year
0-10	1.73	2.32	2.71	3.21	3.57	3.93	2.17	2.91	3.41	4.03	2.2	2.95	3.45	4.08
10-20	1.95	2.61	3.05	3.60	4.01	4.42	2.45	3.28	3.83	4.53	2.49	3.33	3.88	4.59
20-30	2.28	3.04	3.55	4.18	4.65	5.12	2.86	3.82	4.45	5.25	2.9	3.87	4.51	5.32
30-40	2.82	3.74	4.36	5.13	5.70	6.27	3.54	4.7	5.47	6.44	3.59	4.77	5.55	6.53
40-50	3.97	5.23	6.07	7.13	7.92	8.70	4.98	6.57	7.63	8.96	5.05	6.66	7.73	9.08
50-60	15.69	19.93	22.77	26.38	29.07	31.74	19.7	25.03	28.6	33.14	19.97	25.37	28.99	33.58
60-70	5.38	7.05	8.16	9.57	10.61	11.64	6.76	8.86	10.25	12.02	6.85	8.98	10.39	12.18
70-80	3.26	4.32	5.02	5.90	6.56	7.21	4.09	5.42	6.3	7.41	4.15	5.5	6.39	7.52
80-90	2.51	3.34	3.89	4.59	5.10	5.62	3.15	4.2	4.89	5.76	3.19	4.25	4.96	5.84
90-100	2.10	2.81	3.27	3.86	4.30	4.73	2.64	3.52	4.11	4.85	2.67	3.57	4.17	4.92
100-110	1.83	2.46	2.87	3.39	3.77	4.16	2.3	3.08	3.6	4.26	2.33	3.13	3.65	4.31
110-120	1.64	2.20	2.58	3.05	3.40	3.74	2.06	2.77	3.24	3.83	2.09	2.81	3.28	3.88
total (mm)	**45.2**	**59.1**	**68.3**	**80.0**	**88.7**	**97.3**	**56.7**	**74.2**	**85.8**	**100.5**	**57.5**	**75.2**	**87.0**	**101.8**

Source: CDTA Final Report, Annex II.

2. FLOODING AND DRAINAGE CONGESTION ANALYSIS

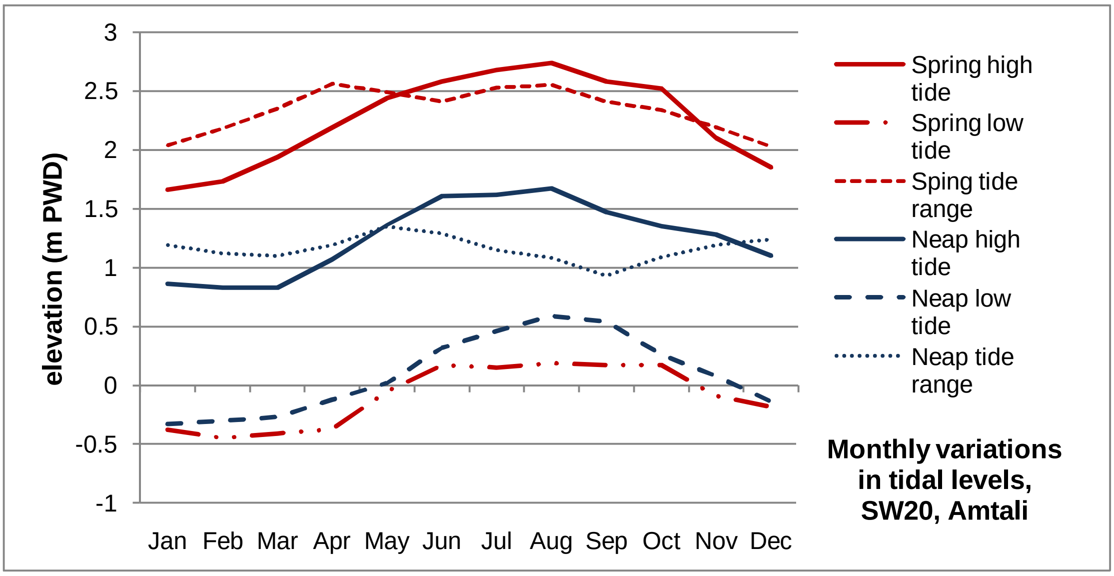
Amtali - Tides, drainage congestion and inundation assessment, 2012 & 2050

Table 1.1: Average high tides, low tides and ranges, SW 20, Amtali

Month	SpringTide			NeapTide		
	HighTide	LowTide	Range	HighTide	LowTide	Range
Jan	1.66	-0.38	2.04	0.86	-0.33	1.19
Feb	1.73	-0.45	2.18	0.83	-0.3	1.12
Mar	1.94	-0.41	2.35	0.83	-0.27	1.10
Apr	2.19	-0.37	2.56	1.07	-0.12	1.19
May	2.44	-0.05	2.49	1.36	0.02	1.35
Jun	2.58	0.17	2.41	1.61	0.32	1.29
Jul	2.68	0.15	2.53	1.62	0.46	1.15
Aug	2.74	0.19	2.55	1.67	0.59	1.08
Sep	2.58	0.17	2.41	1.47	0.54	0.93
Oct	2.52	0.17	2.34	1.35	0.26	1.09
Nov	2.10	-0.09	2.19	1.28	0.08	1.19
Dec	1.85	-0.18	2.03	1.1	-0.14	1.24

source: BWDB

Fig 1.1: Monthly variations in average tidal levels, SW20, Amtali



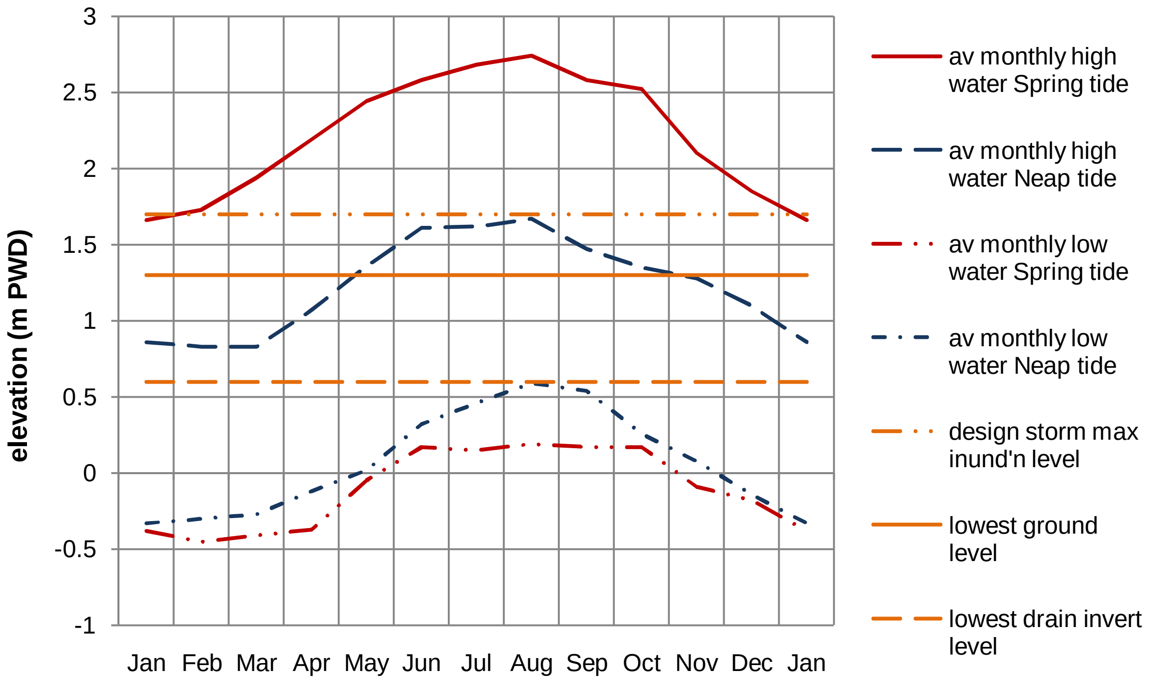
The CDTA reported average peak and minimum water levels near Amtali and the estimated 1:100 year peak water level, excluding sea level rise, as shown in Table x.2. Using these data and the 1:10 year design storm (Annex xx) the drainage congestion and likely flood inundation were plotted. The results are shown in the figures and tables that follow.

Table 1.2: Annual maximum and minimum water levels, Buriswar River, near Amtali

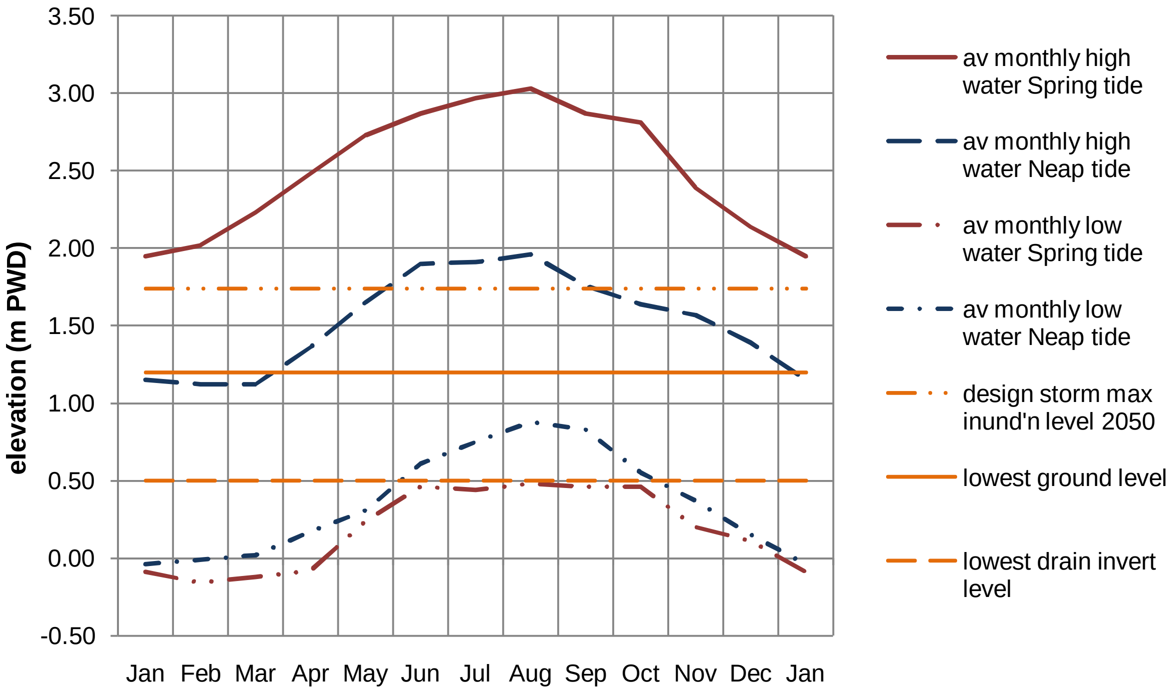
River	Buriswar	
Years of records	1982-2002	
water level	Hightide	Low tide
Average level	2.94	-0.67
Maximum level	3.52	0.50
Minimum level	2.50	-0.96
1:100 yr maximum level (excl SLR)	3.65	-

Source: CDTA Final Report Annex IV
All levels m PWD

Fig 1.2: Drainage congestion, Amtali, 2012 & 2050:
Tide, inundation and ground level charts



Monthly average tidal levels (SW183) & inundation, ground and drain invert levels Amtali 2012



Monthly average tidal levels (SW183) & inundation, ground and drain invert levels Amtali 2050

Fig 1.3: Amtali main catchments

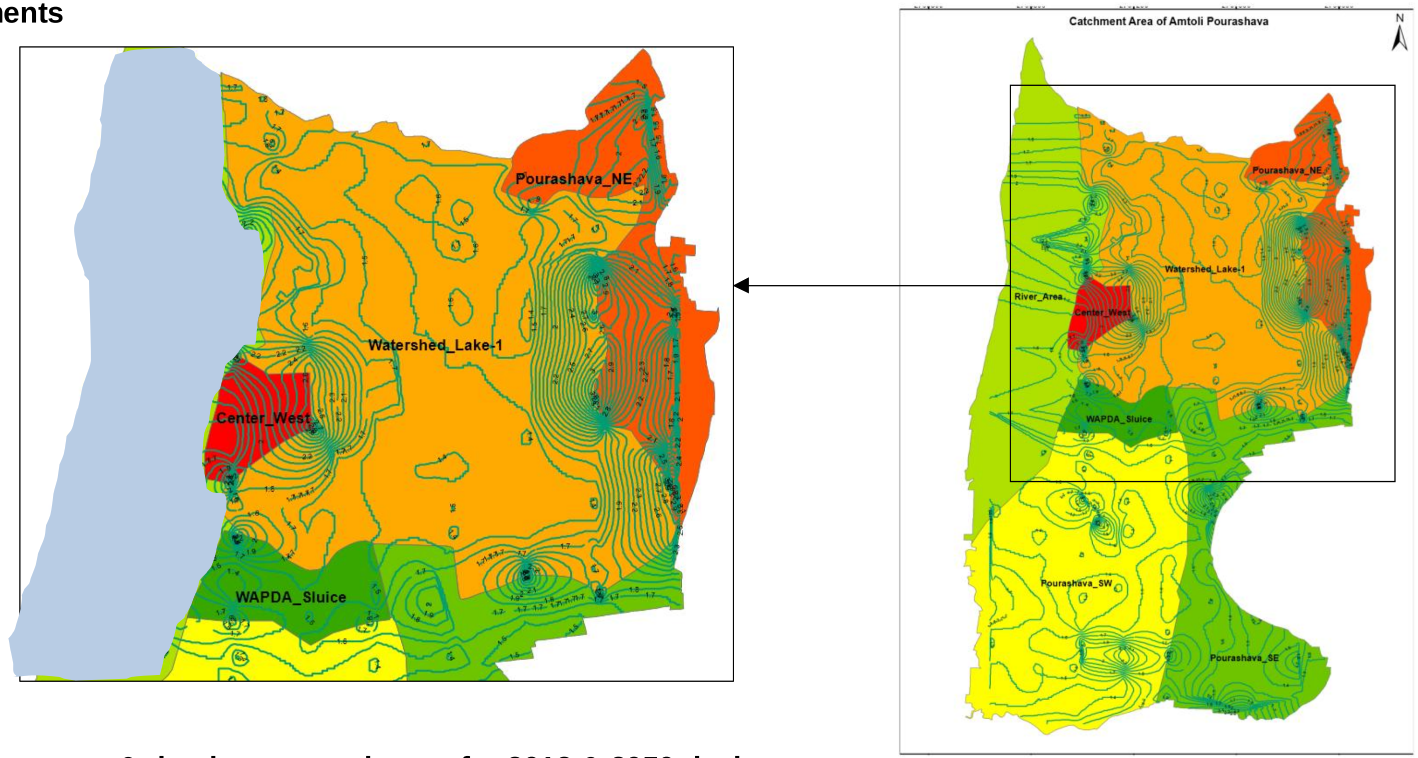


Table 1.3: Amtali - Inundation areas & depths per catchment for 2012 & 2050 design storms

Catchment			**2012 elevations (m PWD), inundated areas (ha) & depths (m)**						**2050 elevations (m PWD), inundated areas (ha) & depths (m)**						
name	**area**	**max inund'n**	**lowest grd lvl**	**total inund'n vol**	**total inund'n area**	**< 0.25**	**0.25-0.75**	**>0.75**	**max inund'n**	**lowest grd lvl**	**total inund'n vol**	**total inund'n area**	**< 0.25**	**0.25-0.75m**	**>0.75m**
Center_West & Lake	268.6														
(without lake as detention device)		1.70	1.3	295,266	168.16	130.68	37.48	0.00	1.74	1.2	375,871	179.75	108.06	71.69	0.0
(with lake as detention device)		*1.64*	*1.3*		*147.99*	*145.53*	*2.46*	*0.00*	*1.69*	*1.2*		*167.05*	*164.59*	*2.46*	0.0
WAPDA_Sluice	22.8	1.68	1.3	25,161	18.96	17.19	1.78	0.00	1.72	1.2	32,030	20.34	17.76	2.58	0.0
Pourashava_SE	124.5	1.61		136,899	78.58	57.55	21.04	0.00	1.66		174,271	84.90	55.22	29.68	0.0
Pourashava_SW	232.8	1.55		157,940	141.87	140.59	1.29	0.00	1.58		201,056	159.68	158.39	1.29	0.0
Total	648.7			615,266	407.58	346.01	61.58	0.0			783,288	444.66	339.43	105.23	0.0

Fig 1.4: 1:10 year design storm inundation due to drainage congestion in Amtali, 2012 (a) & 2050 (b) with no management of water level in Amtali Lake for runoff detention

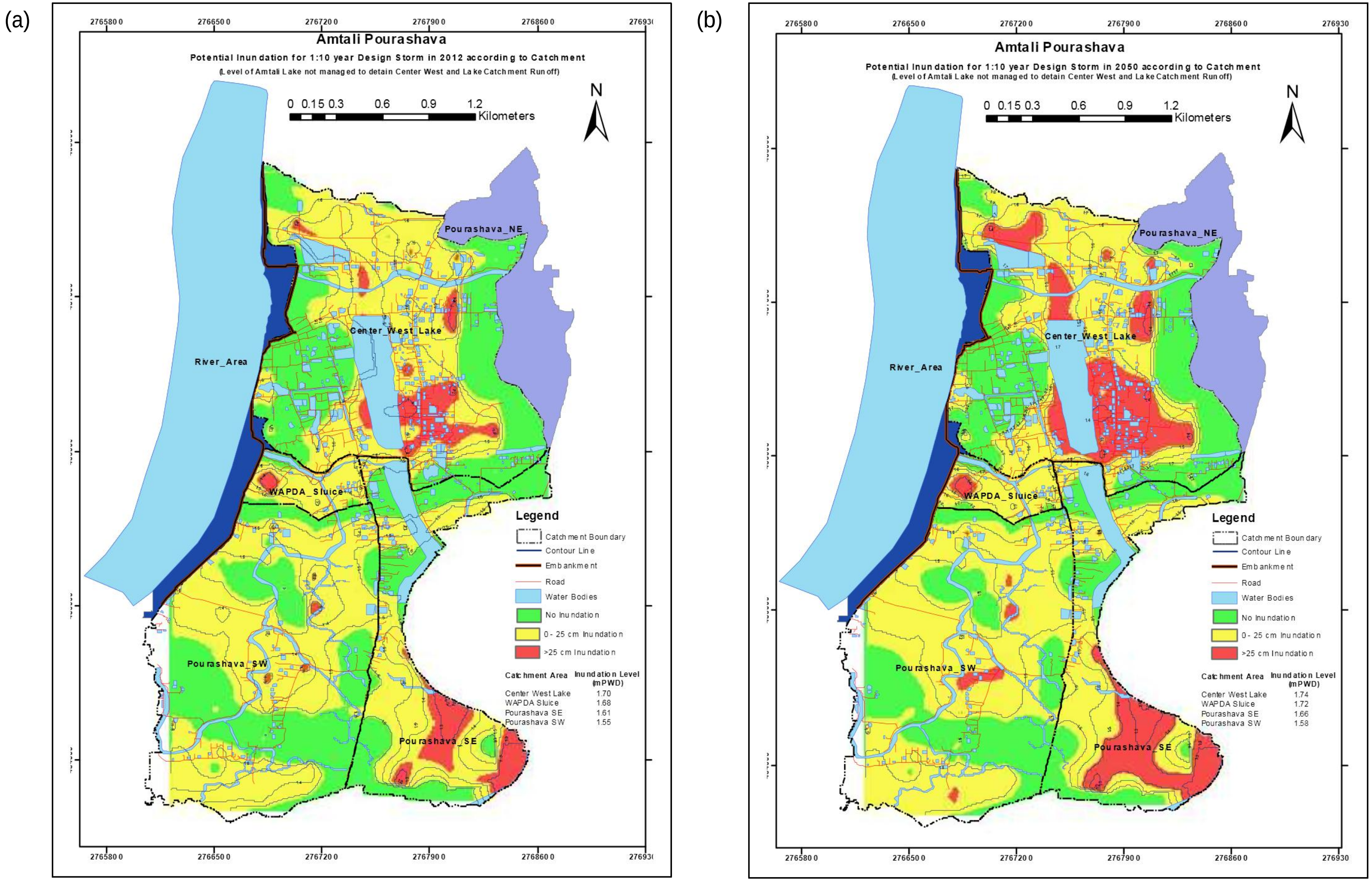
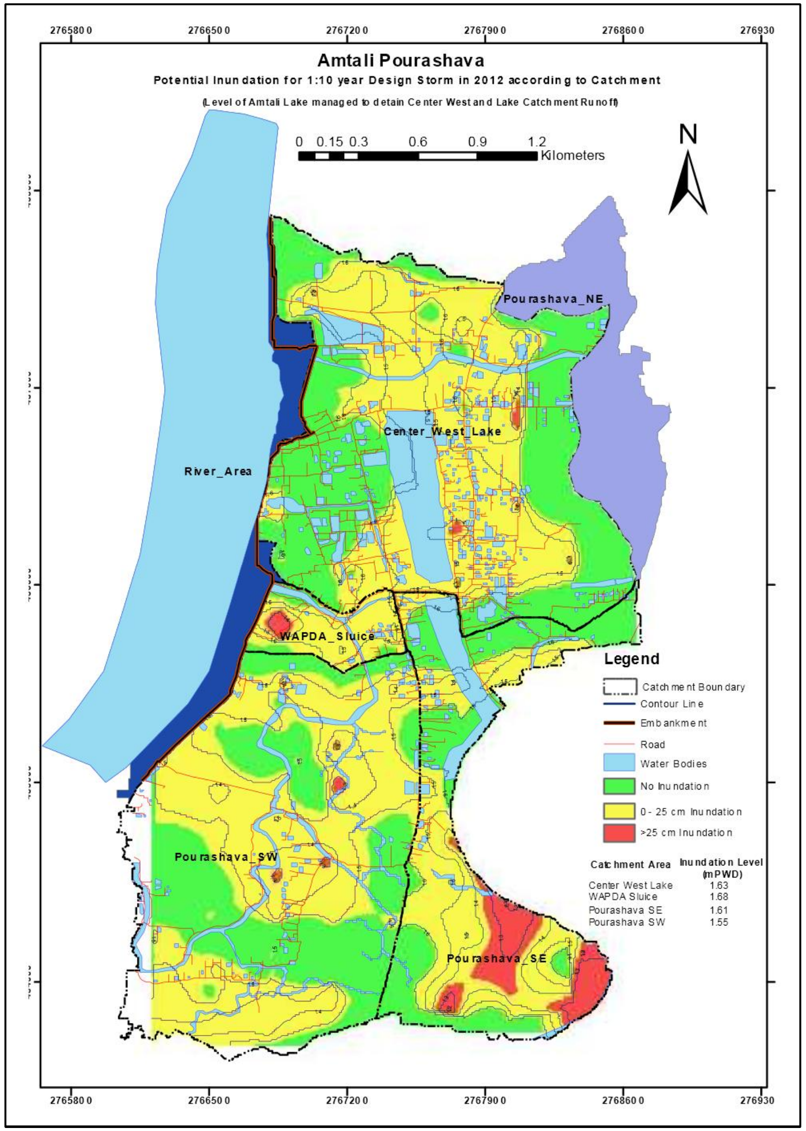


Fig 1.5: 1:10 year design storm inundation due to drainage congestion in Amtali, 2012 (a) & 2050 (b) with management of water level in Amtali Lake for runoff detention

(a)



(b)

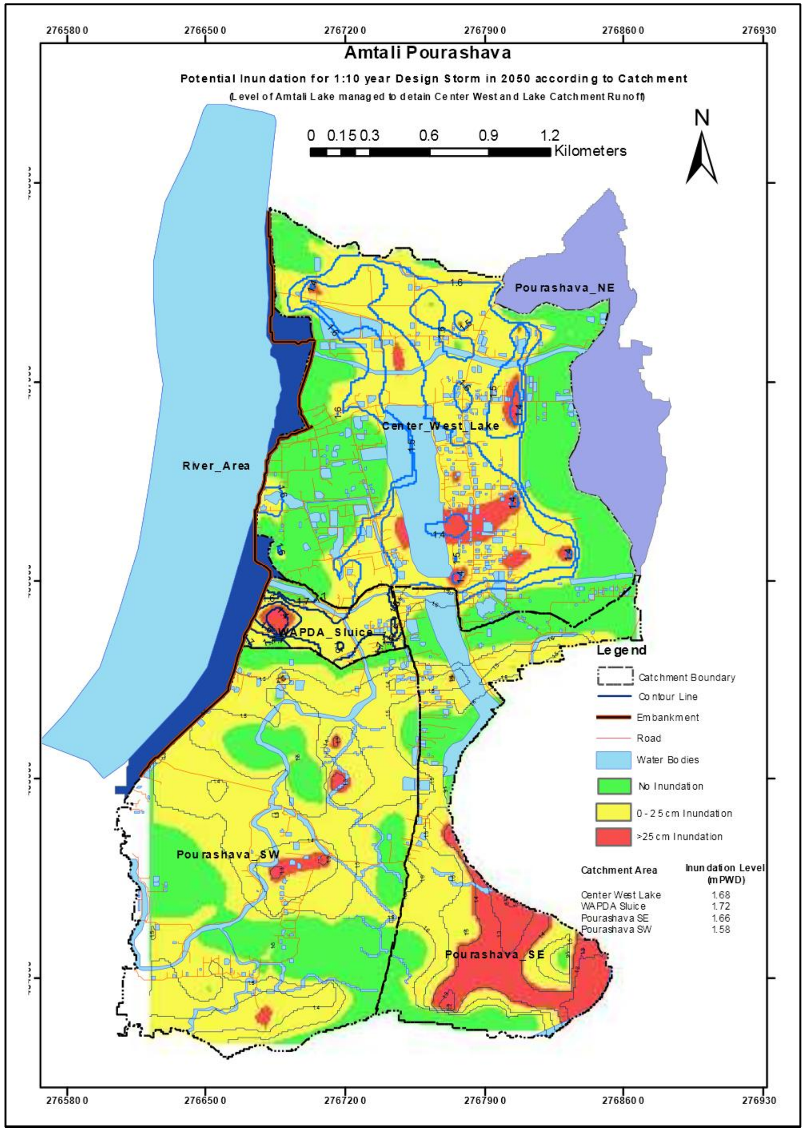


Table 1.4: Summary of monthly drainage congestion for average tidal levels, Amtali Pourashava, 2012 & 2050

2012	Spring tides												Neap tides											
	maximum inundation				lowest ground level				lowest drain invert				maximum inundation				lowest ground level				lowest drain invert			
level (m PWD)	1.70				1.30				0.60				1.70				1.30				0.60			
Average high water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	early-Jan – late-Jan				never				never				all year				Nov - early-May				never			
	0.5				0				0				12				6.2				0			
Average low water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	all year				all year				all year				all year				all year				all year			
	12				12				12				12				12				12			
Congestion (hrs)/ tide cycle (12.4 hrs) wrt min grd lvl	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	3.4	3.6	4.3	5.0	5.9	6.5	6.6	6.7	6.5	6.4	5.1	4.3	0	0	0	0	1.7	4.0	4.4	4.9	3.5	1.7	0	0
drain invert inundation (m)																								

2050	Spring tides												Neap tides											
	maximum inundation				lowest ground level				lowest drain invert				maximum inundation				lowest ground level				lowest drain invert			
level (m PWD)	1.74				1.20				0.50				1.74				1.20				0.50			
Average high water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	never				never				never				mid-Sep – late-May				early-Jan – late-Mar				never			
	0				0				0				8.2				2.5				0			
Average low water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	all year				all year				all year				all year				all year				late-Oct – early Jun			
	12				12				12				12				12							
Congestion (hrs)/ tide cycle (12.4 hrs) wrt min grd lvl	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	5.1	5.2	5.7	6.2	7.1	7.8	7.8	8.0	7.8	7.7	6.5	5.9	0	0	0	3.0	4.9	6.5	7.1	7.0	5.4	4.7	3.2	0
drain invert inundation (m)																		0.11	0.25	0.38	0.33	0.05		

Source: PPTA Consultant, based on BWDB data

Light and dark shaded cells indicate average minimum low water level is above drain invert level for part or all of month respectively

Table 1.5: Details of monthly drainage congestion, Amtali – 2012 & 2050: Center & West catchment, based on 1:10 year design storm

2012	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.66	2.04	1.30	0.36	3.42	27.6%	0.86	1.19	1.30	0.00	0.00	0.0%
Feb	1.73	2.18	1.30	0.43	3.63	29.3%	0.83	1.12	1.30	0.00	0.00	0.0%
Mar	1.93	*2.35*	1.30	0.63	4.28	34.5%	0.83	1.10	1.30	0.00	0.00	0.0%
Apr	2.19	2.56	1.30	0.89	4.98	40.1%	1.07	1.19	1.30	0.00	0.00	0.0%
May	2.44	2.49	1.30	1.14	5.87	47.3%	1.36	1.35	1.30	0.06	1.68	13.5%
Jun	2.58	2.41	1.30	1.28	6.45	52.0%	1.61	1.29	1.30	0.31	4.04	32.6%
Jul	2.68	2.53	1.30	1.38	6.56	52.9%	1.62	1.15	1.30	0.32	4.39	35.4%
Aug	2.74	2.55	1.30	1.44	6.71	54.1%	1.67	1.08	1.30	0.37	4.94	39.8%
Sep	2.58	2.41	1.30	1.28	6.45	52.0%	1.47	0.93	1.30	0.17	3.49	28.1%
Oct	2.52	2.34	1.30	1.22	6.37	51.4%	1.35	1.09	1.30	0.05	1.70	13.7%
Nov	2.10	2.19	1.30	0.80	5.12	41.3%	1.28	1.19	1.30	0.00	0.00	0.0%
Dec	1.85	2.03	1.30	0.55	4.32	34.9%	1.10	1.24	1.30	0.00	0.00	0.0%

2050	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.95	2.04	1.20	0.75	5.14	41.5%	1.15	1.19	1.20	0.00	0.00	0.0%
Feb	2.02	2.18	1.20	0.82	5.21	42.0%	1.12	1.12	1.20	0.00	0.00	0.0%
Mar	2.23	2.35	1.20	1.03	5.71	46.1%	1.12	1.10	1.20	0.00	0.00	0.0%
Apr	2.48	2.56	1.20	1.28	6.20	50.0%	1.36	1.19	1.20	0.16	2.96	23.9%
May	2.73	2.49	1.20	1.53	7.11	57.4%	1.65	1.35	1.20	0.45	4.86	39.2%
Jun	2.87	2.41	1.20	1.67	7.76	62.6%	1.90	1.29	1.20	0.70	6.54	52.7%
Jul	2.97	2.53	1.20	1.77	7.82	63.1%	1.91	1.15	1.20	0.71	7.14	57.5%
Aug	3.03	2.55	1.20	1.83	7.98	64.3%	1.96	1.08	1.20	0.76	7.86	63.4%
Sep	2.87	2.41	1.20	1.67	7.76	62.6%	1.76	0.93	1.20	0.56	7.01	56.5%
Oct	2.81	2.34	1.20	1.61	7.72	62.3%	1.64	1.09	1.20	0.44	5.43	43.8%
Nov	2.39	2.19	1.20	1.19	6.54	52.8%	1.57	1.19	1.20	0.37	4.67	37.7%
Dec	2.14	2.03	1.20	0.94	5.91	47.6%	1.39	1.24	1.20	0.19	3.17	25.6%

Galachipa - Tides, drainage congestion and inundation assessment, 2012 & 2050

Table 2.1 Average high tides, low tides and ranges, SW183 Kaitpara – u/s of Galachipa

Month	Spring Tide			Neap Tide		
	HighTide	LowTide	Range	HighTide	LowTide	Range
Jan	1.54	0.13	1.41	0.9	0.04	0.86
Feb	1.64	0.07	1.57	0.82	-0.04	0.86
Mar	1.82	0.06	1.76	0.87	0.11	0.77
Apr	2.01	0.17	1.84	0.9	0.2	0.7
May	2.29	0.76	1.53	1.29	0.42	0.88
Jun	2.42	1.24	1.18	1.58	0.77	0.81
Jul	2.51	1.32	1.19	1.84	1.24	0.6
Aug	2.58	1.51	1.07	1.81	1.36	0.45
Sep	2.46	1.38	1.07	1.73	1.16	0.57
Oct	2.31	1.19	1.12	1.52	0.83	0.7
Nov	2.01	0.81	1.2	1.44	0.48	0.96
Dec	1.68	0.44	1.24	1.15	0.22	0.92

source: BWDB

Fig 2.1: Monthly variations in average tidal levels, SW183, nr Galachipa

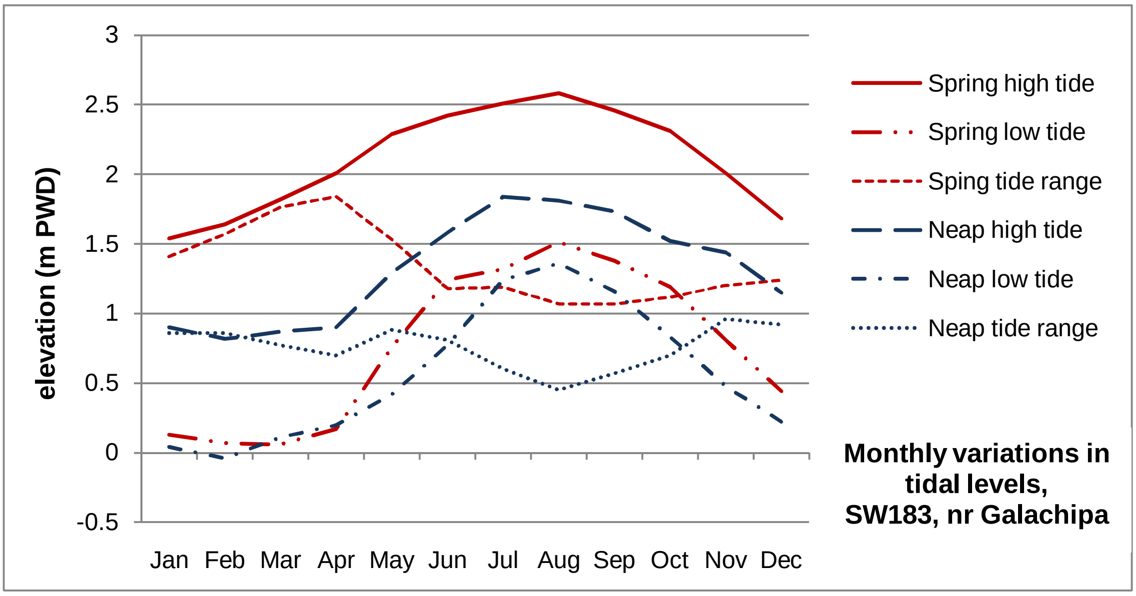
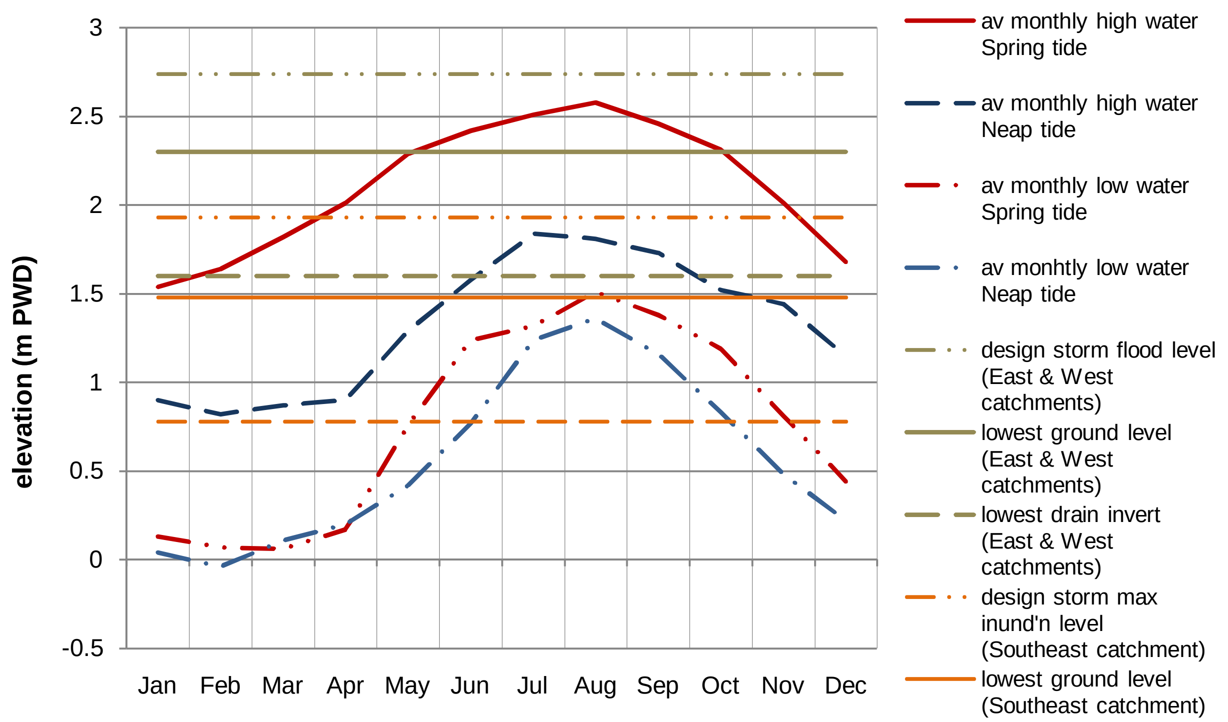


Table 2.2: Annual maximum and minimum river levels in Galachipa

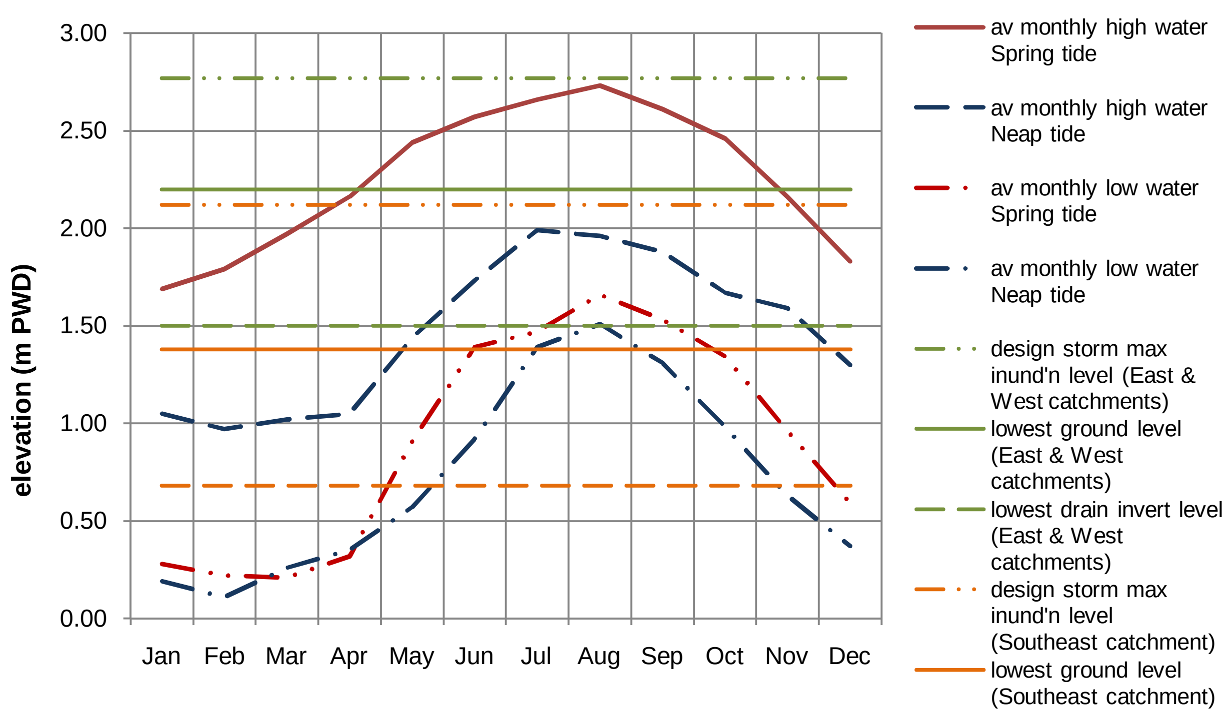
River	Lohalia	
Years of records	1968-1988	
water level	**Flood tide**	**Ebb tide**
Average level	2.96	-0.56
Maximum level	3.58	-0.12
Minimum level	2.48	-1.95
1:100 yr maximum level (excl SLR)	3.85	-

Source: CDTA Final Report Annex IV
All levels m PWD

Fig 2.2: Drainage congestion, Galachipa, 2012 & 2050: Tide, inundation and ground level charts



Monthly average tidal levels (SW183) & inundation, ground and drain invert levels Galachipa 2012



Predicted monthly average tidal levels & inundation, ground and drain invert levels Galachipa 2050

Fig 2.3: Galachipa main catchments

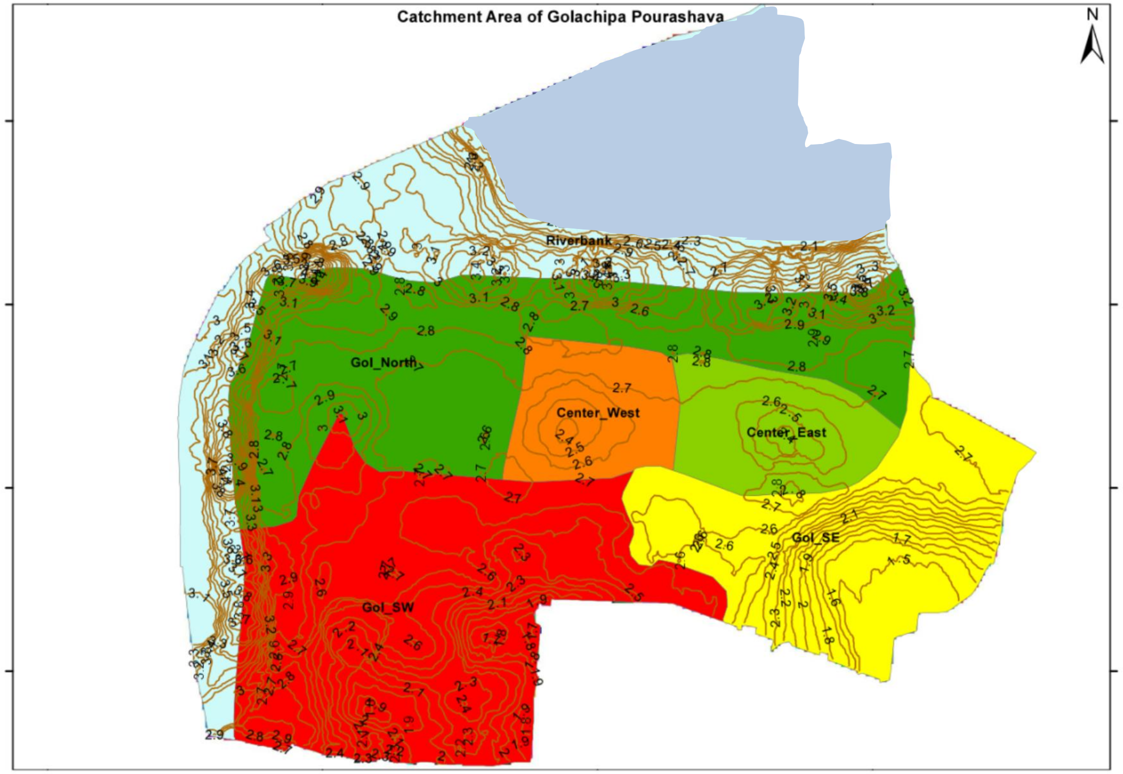
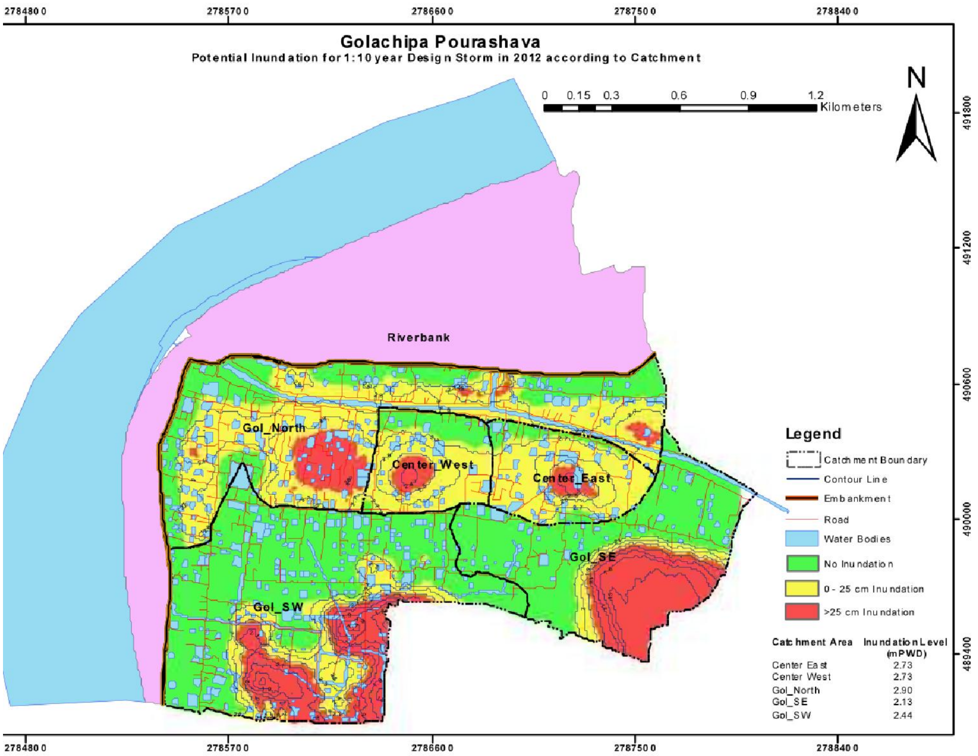


Table 2.3: Galachipa - Inundation areas & depths per catchment for 2012 & 2050 design storms

Catchment		2012 elevations (m PWD), inundated areas (ha) & depths (m)							2050 elevations (m PWD), inundated areas (ha) & depths (m)						
name	area	max inund'n	lowest grd lvl	total inund'n vol	total inund'n area	< 0.25	0.25-0.75	>0.75	max inund'n	lowest grd lvl	total inund'n vol	total inund'n area	< 0.25m	0.25-0.75m	>0.75m
Center East	25.6	2.74	2.3	28,147	22.2	19.85	2.35	0.00	2.77	2.2	35,831	24.0	20.62	3.36	0.00
Center West	22.7	2.74	2.3	25,002	17.9	15.43	2.50	0.00	2.77	2.2	31,827	20.2	16.40	3.79	0.00
Gol_North	93.3	2.91	2.4	102,610	64.8	53.00	11.84	0.00	2.95	2.3	130,621	68.2	47.61	20.57	0.00
Gol_SE	63.6	1.93	1.5	69,880	20.4	5.51	14.89	0.00	2.12	1.4	88,957	24.6	5.12	19.24	0.00
Gol_SW	104.9	2.45	1.6	115,284	39.7	18.95	20.61	0.18	2.52	1.5	146,756	47.1	22.01	24.00	1.11
Total	310.1			340,923	165.1	112.75	52.19	0.18			433,992		111.76	70.96	1.11

Figure 2.4: 1:10 year design storm inundation due to drainage congestion in Galachipa, 2012 (a) & 2050 (b)

(a)



(b)

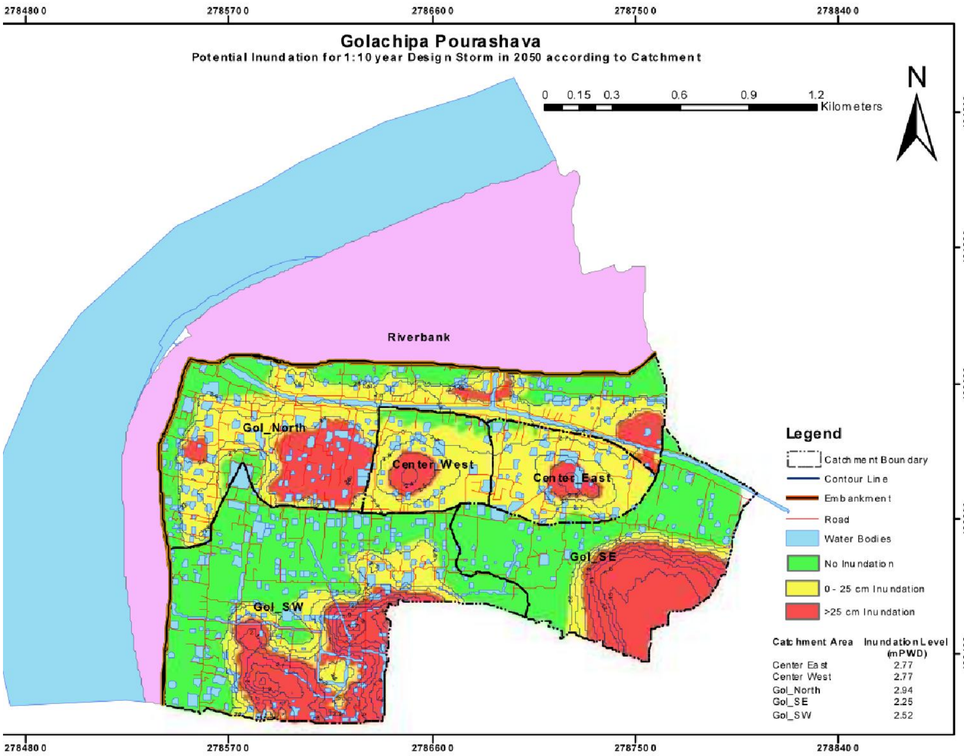

Golachipa Pourashava
Potential Inundation for 1:10 year Design Storm in 2050 according to Catchment
0 0.15 0.3 0.6 0.9 1.2 Kilometers
N
Riverbank
Gol_North
Center_West
Center_East
Gol_SE
Gol_SW
Legend
Catchment Boundary
Contour Line
Embankment
Road
Water Bodies
No Inundation
0 - 25 cm Inundation
>25 cm Inundation
Catchment Area Inundation Level (mPWD)
Center East 2.77
Center West 2.77
Gol_North 2.94
Gol_SE 2.25
Gol_SW 2.52
2784800 2785700 2786600 2787500 2788400
491800 491200 490600 490000 489400

Table 2.4: Summary of monthly drainage congestion for average tidal levels, Galachipa Pourashava, 2012 & 2050

2012	Spring tides												Neap tides											
	maximum inundation				lowest ground level				lowest drain invert				maximum inundation				lowest ground level				lowest drain invert			
level (m PWD)	1.93				1.48				0.78				1.93				1.48				0.78			
Average high water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	5				0				0				12				7.4				0			
	late-Nov – early Apr				never				never				always				late-Oct – late-Jun				never			
Average low water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	12				11.5				6				12				12				8			
	always				late-Aug – early-Aug				mid-Nov - mid-May				always				always				mid-Oct – mid-Jun			
Congestion (hrs)/ tide cycle (12.4 hrs) wrt min grd lvl	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	2.5	3.2	4.0	4.8	6.9	9.4	10.3	12.4	11.6	8.9	6.3	3.9						3.9	8.1	10.0	6.8	3.4	1.6	
drain invert inundation (m)					0	0.46	0.54	0.73	0.6	0.41	0.03							0	0.46	0.58	0.38	0		

2050	Spring tides												Neap tides											
	maximum inundation				lowest ground level				lowest drain invert				maximum inundation				lowest ground level				lowest drain invert			
level (m PWD)	2.12				1.38				0.68				2.12				1.38				0.68			
Average high water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	4.5				0				0				12				7.4				0			
	late-Nov – early-Apr				never				never				always				late-Oct – early-Jun				never			
Average low water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	12				8				5				12				9.2				6.2			
	always				mid-Oct – mid-Jun				early-Dec - early-May				always				early-Sep – mid-Jul				mid-Nov – late-May			
Congestion (hrs)/ tide cycle (12.4 hrs) wrt min grd lvl	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	5.2	5.4	4.8	6.5	9.1	12.4	12.4	12.4	12.4	12.4	9.1	6.5	0	0	0	0	4.7	7.9	12.4	12.4	12.4	8.1	5.8	3.2
drain invert inundation (m)					0.23	0.71	0.79	0.98	0.85	0.66	0.28	0					0	0.24	0.71	0.82	0.63	0.30	0	

Source: PPTA Consultant, based on BWDB data

Light and dark shaded cells indicate average minimum low water level is above drain invert level for part or all of month respectively

Table 2.5: Details of monthly drainage congestion, Galachipa – 2012: East & West catchments, based on 1:10 year design storm

2012	**spring tides**						**neap tides**					
Month	**high wtr level (m PWD)**	**range (m)**	**grd level (m PWD)**	**congest'n (m)**	**t_c (hr)**	**% (tidal cycle)**	**high wtr level (m PWD)**	**range (m)**	**grd level (m PWD)**	**congest'n (m)**	**t_c (hr)**	**% (tidal cycle)**
Jan	1.54	1.41	2.30	0.00	0.00	0.0%	0.90	0.86	2.30	0.00	0.00	0.0%
Feb	1.64	1.57	2.30	0.00	0.00	0.0%	0.82	0.86	2.30	0.00	0.00	0.0%
Mar	1.82	1.76	2.30	0.00	0.00	0.0%	0.87	0.77	2.30	0.00	0.00	0.0%
Apr	2.01	1.84	2.30	0.00	0.00	0.0%	0.90	0.70	2.30	0.00	0.00	0.0%
May	2.29	1.53	2.30	0.00	0.00	0.0%	1.29	0.88	2.30	0.00	0.00	0.0%
Jun	2.42	1.18	2.30	0.12	2.56	20.7%	1.58	0.81	2.30	0.00	0.00	0.0%
Jul	2.51	1.19	2.30	0.21	3.42	27.6%	1.84	0.60	2.30	0.00	0.00	0.0%
Aug	2.58	1.07	2.30	0.28	4.24	34.2%	1.81	0.45	2.30	0.00	0.00	0.0%
Sep	2.46	1.07	2.30	0.16	3.13	25.3%	1.73	0.57	2.30	0.00	0.00	0.0%
Oct	2.31	1.12	2.30	0.01	0.75	6.0%	1.52	0.70	2.30	0.00	0.00	0.0%
Nov	2.01	1.2	2.30	0.00	0.00	0.0%	1.44	0.96	2.30	0.00	0.00	0.0%
Dec	1.68	1.24	2.30	0.00	0.00	0.0%	1.15	0.92	2.30	0.00	0.00	0.0%

2050	**spring tides**						**neap tides**					
month	**high wtr level (m PWD)**	**range (m)**	**grd level (m PWD)**	**congest'n (m)**	**t_c (hr)**	**% (tidal cycle)**	**high wtr level (m PWD)**	**range (m)**	**grd level (m PWD)**	**congest'n (m)**	**t_c (hr)**	**% (tidal cycle)**
Jan	1.83	1.41	2.20	0.00	0.00	0.0%	1.19	0.86	2.20	0.00	0.00	0.0%
Feb	1.93	1.57	2.20	0.00	0.00	0.0%	1.11	0.86	2.20	0.00	0.00	0.0%
Mar	2.11	1.76	2.20	0.00	0.00	0.0%	1.16	0.77	2.20	0.00	0.00	0.0%
Apr	2.30	1.84	2.20	0.10	1.86	15.0%	1.19	0.7	2.20	0.00	0.00	0.0%
May	2.58	1.53	2.20	0.38	4.12	33.2%	1.58	0.88	2.20	0.00	0.00	0.0%
Jun	2.71	1.18	2.20	0.51	5.66	45.7%	1.87	0.81	2.20	0.00	0.00	0.0%
Jul	2.80	1.19	2.20	0.60	6.23	50.3%	2.13	0.6	2.20	0.00	0.00	0.0%
Aug	2.87	1.07	2.20	0.67	7.21	58.1%	2.10	0.45	2.20	0.00	0.00	0.0%
Sep	2.75	1.07	2.20	0.55	6.31	50.9%	2.02	0.57	2.20	0.00	0.00	0.0%
Oct	2.60	1.12	2.20	0.40	5.06	40.8%	1.81	0.7	2.20	0.00	0.00	0.0%
Nov	2.30	1.2	2.20	0.10	2.31	18.6%	1.73	0.96	2.20	0.00	0.00	0.0%
Dec	1.97	1.24	2.20	0.00	0.00	0.0%	1.44	0.92	2.20	0.00	0.00	0.0%

Table 2.6: Details of monthly drainage congestion, Galachipa – 2012: Southeast catchment, based on 1:10 year design storm

2012	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.54	1.41	1.40	0.14	2.53	20.4%	0.9	0.86	1.40	0.00	0.00	0.0%
Feb	1.64	1.57	1.40	0.24	3.17	25.6%	0.82	0.86	1.40	0.00	0.00	0.0%
Mar	1.82	1.76	1.40	0.42	4.03	32.5%	0.87	0.77	1.40	0.00	0.00	0.0%
Apr	2.01	1.84	1.40	0.61	4.84	39.1%	0.9	0.7	1.40	0.00	0.00	0.0%
May	2.29	1.53	1.40	0.89	6.85	55.2%	1.29	0.88	1.40	0.00	0.00	0.0%
Jun	2.42	1.18	1.40	1.02	9.42	76.0%	1.58	0.81	1.40	0.18	3.88	31.3%
Jul	2.51	1.19	1.40	1.11	10.33	83.3%	1.84	0.6	1.40	0.44	8.12	65.5%
Aug	2.58	1.07	1.40	1.18	12.40	100.0%	1.81	0.45	1.40	0.41	10.01	80.7%
Sep	2.46	1.07	1.40	1.06	11.64	93.8%	1.73	0.57	1.40	0.33	6.83	55.0%
Oct	2.31	1.12	1.40	0.91	8.86	71.5%	1.52	0.7	1.40	0.12	3.37	27.2%
Nov	2.01	1.2	1.40	0.61	6.27	50.5%	1.44	0.96	1.40	0.04	1.62	13.1%
Dec	1.68	1.24	1.40	0.28	3.91	31.5%	1.15	0.92	1.40	0.00	0.00	0.0%

2050	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.83	1.41	1.30	0.53	5.21	42.0%	1.19	0.86	1.30	0.00	0.00	0.0%
Feb	1.93	1.57	1.30	0.63	5.42	43.7%	1.11	0.86	1.30	0.00	0.00	0.0%
Mar	2.11	1.76	1.30	0.81	5.89	47.5%	1.16	0.77	1.30	0.00	0.00	0.0%
Apr	2.30	1.84	1.30	1.00	6.54	52.8%	1.19	0.7	1.30	0.00	0.00	0.0%
May	2.58	1.53	1.30	1.28	9.12	73.5%	1.58	0.88	1.30	0.28	4.73	38.2%
Jun	2.71	1.18	1.30	1.41	12.40	100.0%	1.87	0.81	1.30	0.57	7.86	63.4%
Jul	2.80	1.19	1.30	1.50	12.40	100.0%	2.13	0.6	1.30	0.83	12.40	100.0%
Aug	2.87	1.07	1.30	1.57	12.40	100.0%	2.10	0.45	1.30	0.80	12.40	100.0%
Sep	2.75	1.07	1.30	1.45	12.40	100.0%	2.02	0.57	1.30	0.72	12.40	100.0%
Oct	2.60	1.12	1.30	1.30	12.40	100.0%	1.81	0.7	1.30	0.51	8.07	65.1%
Nov	2.30	1.2	1.30	1.00	9.08	73.2%	1.73	0.96	1.30	0.43	5.79	46.7%
Dec	1.97	1.24	1.30	0.67	6.52	52.6%	1.44	0.92	1.30	0.14	3.16	25.5%

Pirojpur - Tides, drainage congestion and inundation assessment, 2012 & 2050

Table 3.1: Average high tides, low tides and ranges, SW107 Gorai-Modhumati, Pirojpur

Month	Spring tides			Neap tides		
	HighTide	LowTide	Range	HighTide	LowTide	Range
Jan	1.52	-0.11	1.63	0.89	-0.19	1.08
Feb	1.56	-0.18	1.75	0.84	-0.20	1.04
Mar	1.79	-0.18	1.97	0.84	-0.22	1.06
Apr	1.95	-0.08	2.03	1.01	-0.07	1.08
May	2.10	0.27	1.83	1.18	0.12	1.06
Jun	2.18	0.49	1.69	1.46	0.45	1.02
Jul	2.23	0.61	1.62	1.59	0.65	0.94
Aug	2.32	0.85	1.47	1.60	0.83	0.78
Sep	2.27	0.79	1.48	1.55	0.75	0.80
Oct	2.19	0.65	1.54	1.35	0.39	0.96
Nov	1.93	0.35	1.58	1.25	0.16	1.09
Dec	1.66	0.09	1.57	1.06	-0.06	1.12

source: BWDB

Fig 3.1: Monthly variations in average tidal levels, SW107, nr Pirojpur

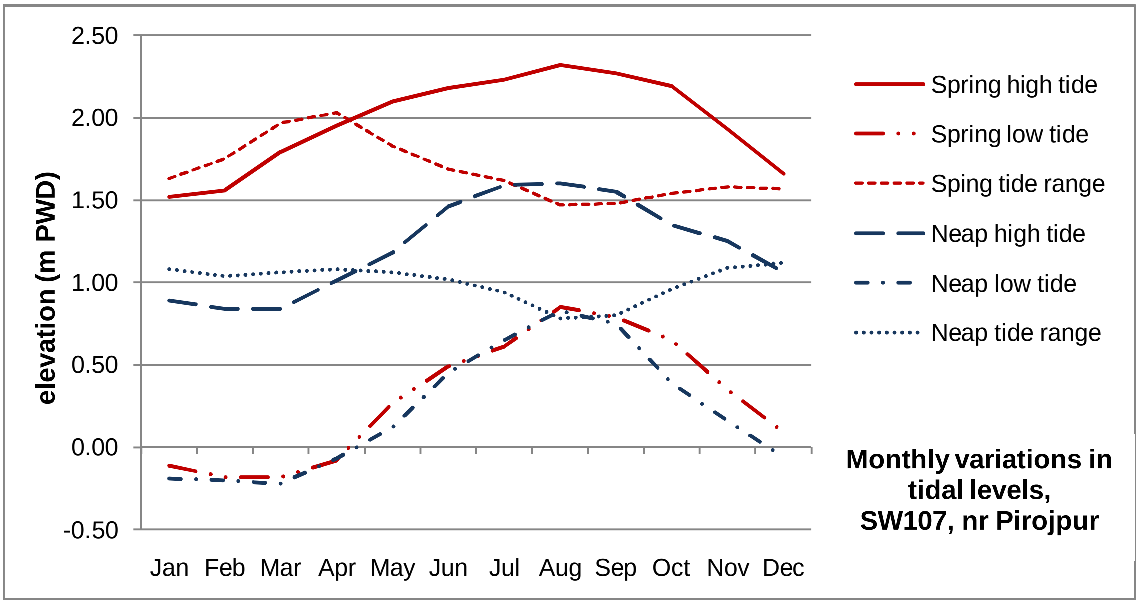
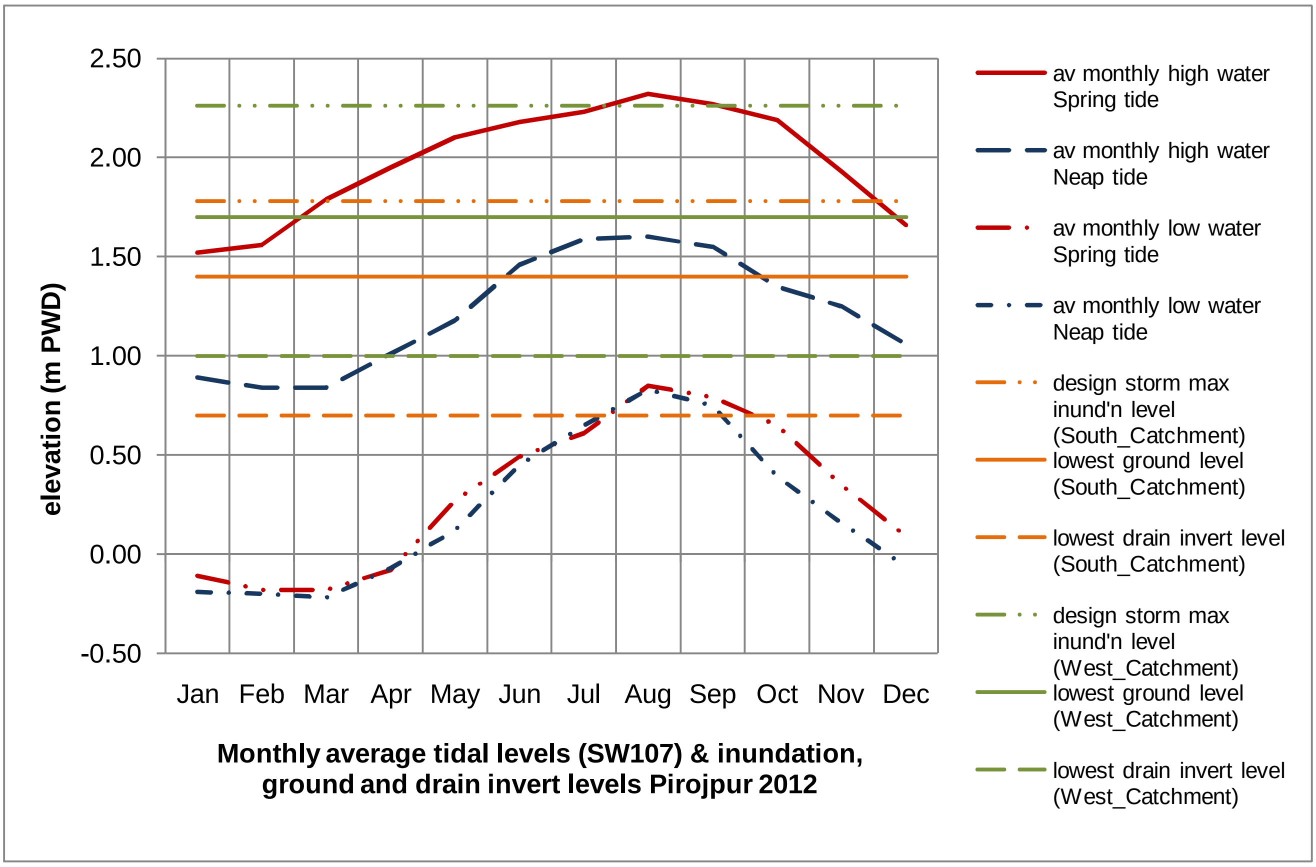


Table 3.2: Annual maximum and minimum river levels in Projpur

River	Baleshwar		Kocha	
Years of records	1982-2002		1982-2002	
water level	**High tide**	**Low tide**	**High tide**	**Low tide**
Average level	2.55	-0.41	2.59	-0.42
Maximum level	3.48	-0.10	2.70	-0.13
Minimum level	2.29	-0.72	2.48	-0.61
1:100 yr max level (excl SLR)	4.01	-	2.77	-

Source: CDTA Final Report Annex IV
All levels m PWD

Fig 3.2: Drainage congestion, Pirojpur, 2012 & 2050: Tide, inundation and ground level charts



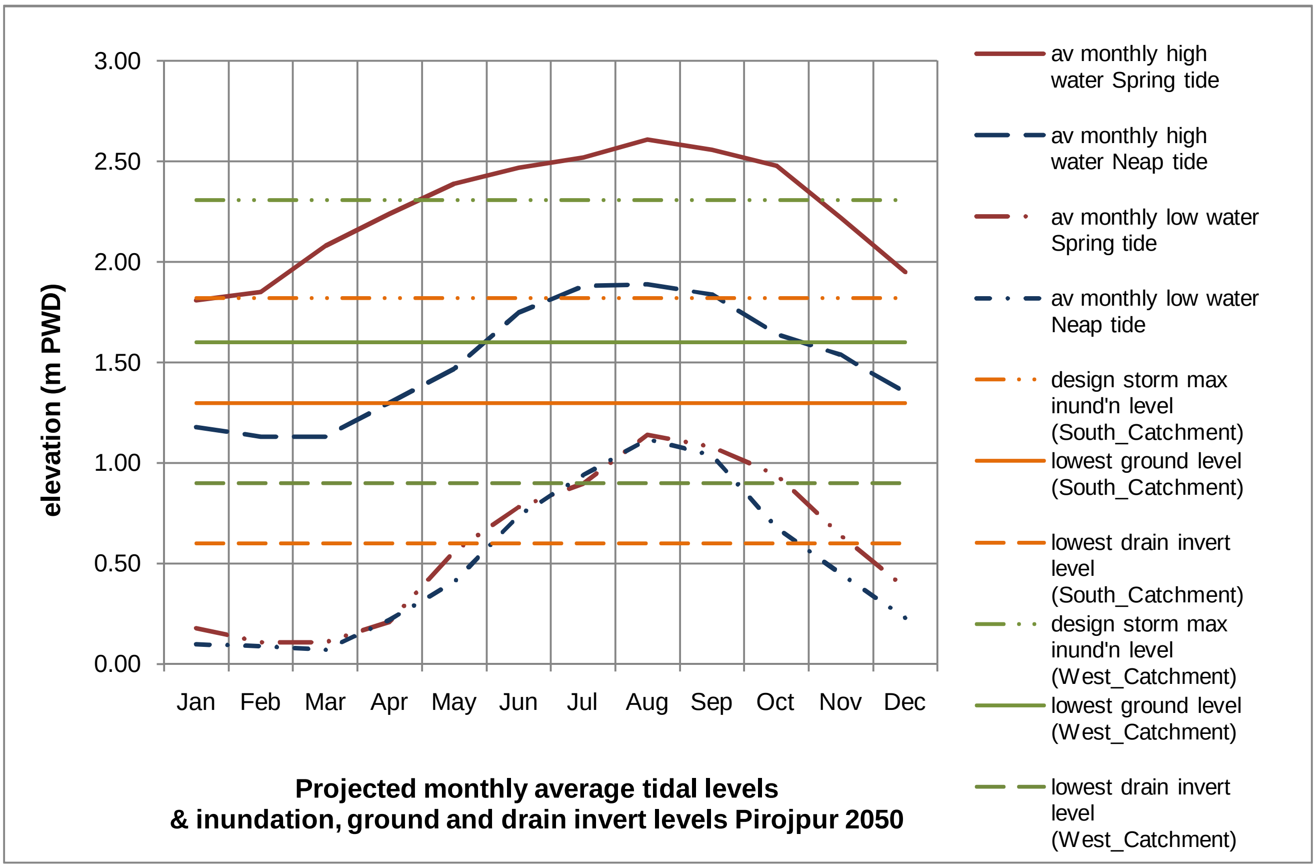


Fig 3.3: Pirojpur main catchments

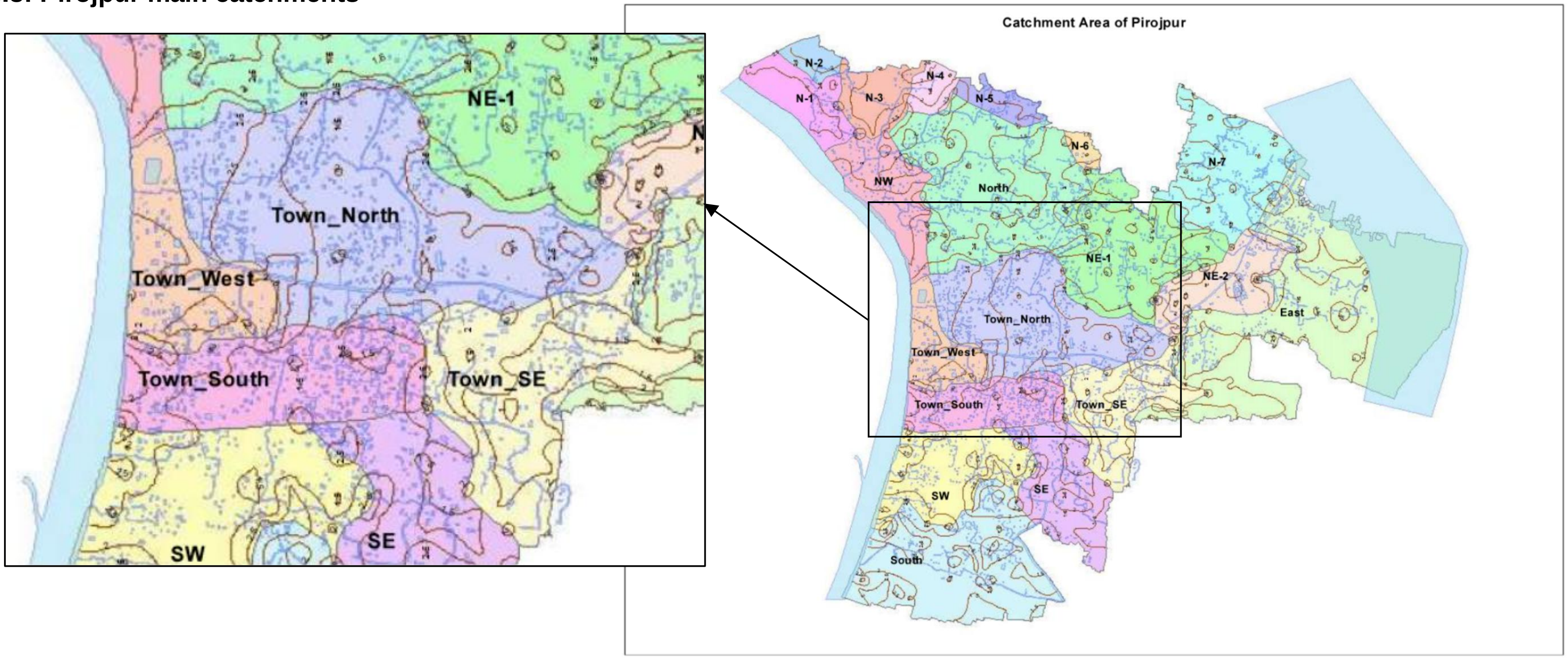
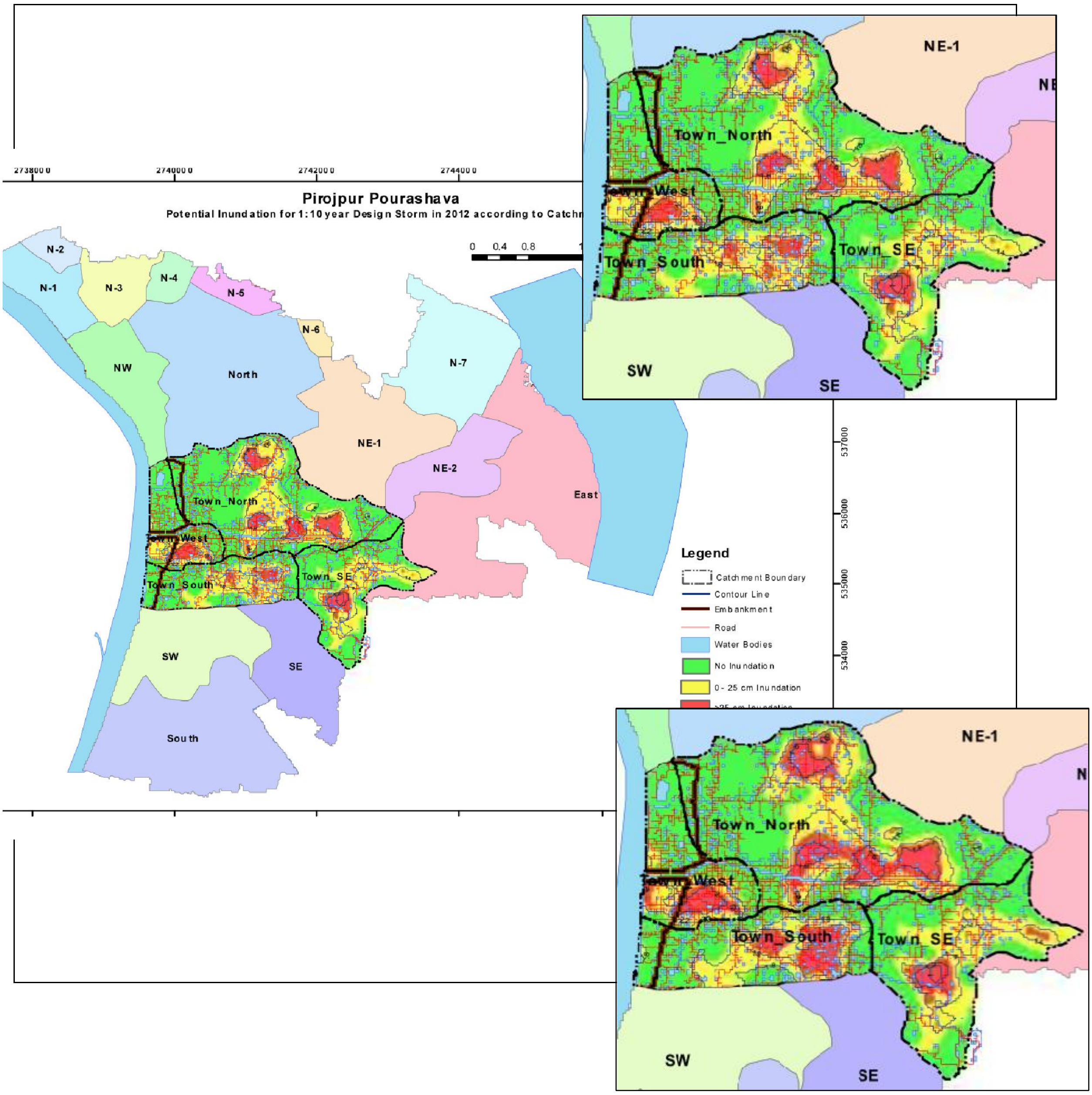


Table 3.3: Pirojpur - Inundation areas & depths per catchment for 2012 & 2050 design storms

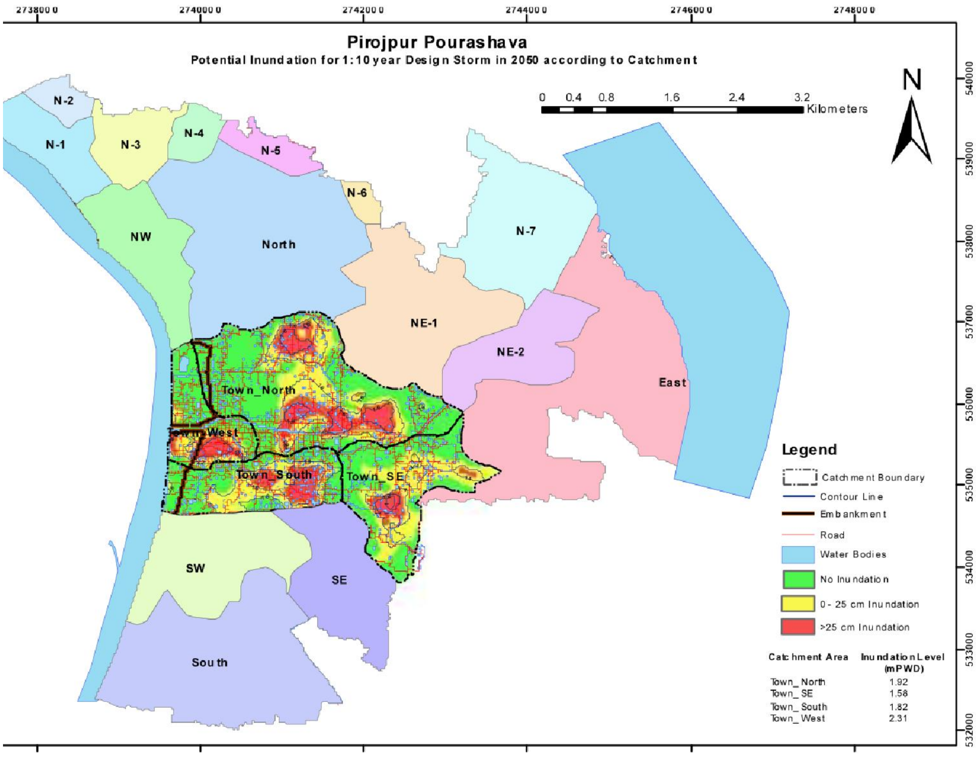
Catchment		2012 elevations (m PWD), inundated areas (ha) & depths (m)							2050 elevations (m PWD), inundated areas (ha) & depths (m)						
name	area	max inund'n	lowest grd lvl	total inund'n vol	total inund'n area	< 0.25	0.25-0.75	>0.75	max inund'n	lowest grd lvl	total inund'n vol	total inund'n area	< 0.25m	0.25-0.75m	>0.75m
Town_North	338.0	1.87	1.3	230,833	128.93	93.61	35.32	0.00	1.92	1.2	293,864	148.03	93.16	54.87	0.00
Town_SE	176.8	1.55	0.8	120,748	77.08	66.67	10.41	0.00	1.59	0.7	153,720	87.94	73.54	14.16	0.24
Town_South	140.8	1.78	1.4	96,163	61.07	51.01	10.07	0.00	1.82	1.3	122,421	69.40	45.44	23.96	0.00
Town_West	93.3	2.26	1.7	63,743	33.64	24.68	8.96	0.00	2.31	1.6	81,149	38.36	23.69	14.67	0.00
Total	748.9			511,487	300.72	235.97	64.75	0.00			651,154	343.73	235.84	107.66	0.24

Figure 3.4: 1:10 year design storm inundation due to drainage congestion in Pirojpur, 2012 (a) & 2050 (b)

(a)



(b)



Pirojpur Pourashava
Potential Inundation for 1:10 year Design Storm in 2050 according to Catchment
0 0.4 0.8 1.6 2.4 3.2 Kilometers
N
N-1
N-2
N-3
N-4
N-5
N-6
N-7
NW
North
NE-1
NE-2
East
Town_North
Town_West
Town_South
Town_SE
SW
SE
South
Legend
Catchment Boundary
Contour Line
Embankment
Road
Water Bodies
No Inundation
0 - 25 cm Inundation
>25 cm Inundation
Catchment Area
Inundation Level (mPWD)
Town_North 1.92
Town_SE 1.58
Town_South 1.82
Town_West 2.31

Table 3.4: Summary of monthly drainage congestion for average tidal levels, Pirojpur Pourashava, 2012 & 2050

2012	Spring tides												Neap tides											
	max inundation				lowest ground level				lowest drain invert				max inundation				lowest ground level				lowest drain invert			
level (m PWD)	1.78				1.40				0.70				1.78				1.40				0.70			
Average high water level is below: maximum inundation, lowest ground and lowest drain invert level:																								
months	3				0				0				12				7.5				0			
	early-Dec - early-Mar				never				never				all year				early-Oct - mid-Jun				never			
Average low water level is below maximum inundation, lowest ground and lowest drain invert level level:																								
months	12				12				9.2				12				12				9.6			
	all year				all year				early-Oct- late-Jul				all year				all year				late-Sep - mid-Jul			
Congestion (hrs)/ tide cycle (12.4 hrs) wrt min grd lvl	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	3.0	3.1	3.9	4.8	5.7	6.4	6.8	7.8	7.5	6.8	5.4	3.9	0	0	0	0	0	3.2	4.7	5.3	4.7	1.8	0	0
av drain invert inundation (m)							0	0.15	0.05	0									0	0.13	0.05			

2050	Spring tides												Neap tides											
	max inundation				lowest ground level				lowest drain invert				max inundation				lowest ground level				lowest drain invert			
level (m PWD)	1.82				1.30				0.60				1.82				1.30				0.60			
Average high water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	1				0				0				7				3.7				0			
	late-Dec – late-Jan				never				never				late-Oct – late-May				late Dec - mid Apr				never			
Average low water level is below maximum inundation, lowest ground and lowest drain invert level:																								
months	12				12				6				12				12				7.2			
	all year				all year				mid-Nov – mid-May				all year				all year				late-Oct –May			
Congestion (hrs)/ tide cycle (12.4 hrs) wrt min grd lvl	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	5.2	5.2	4.3	6.3	7.4	8.3	8.9	10.8	10.1	9.1	7.4	6.0	0	0	0	2.4	4.2	6.5	8.0	9.7	8.7	5.9	4.7	3.00
av drain invert inundation (m)					0	0.18	0.3	0.54	0.48	0.34	0.4							0.14	0.34	0.52	0.44	0.08		

Source: PPTA Consultant, based on BWDB data

Light and dark shaded cells indicate average minimum low water level is above drain invert level for part or all of month respectively

Table 3.5: Details of monthly drainage congestion, Pirojpur – 2012 & 2050: South catchment, based on 1:10 year design storm

2012	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.52	1.63	1.30	0.22	2.97	23.9%	0.89	1.08	1.30	0.00	0.00	0.0%
Feb	1.56	1.75	1.30	0.26	3.12	25.2%	0.84	1.04	1.30	0.00	0.00	0.0%
Mar	1.79	1.97	1.30	0.49	3.86	31.1%	0.84	1.06	1.30	0.00	0.00	0.0%
Apr	1.95	2.03	1.30	0.65	4.75	38.3%	1.01	1.08	1.30	0.00	0.00	0.0%
May	2.10	1.83	1.30	0.80	5.70	46.0%	1.18	1.06	1.30	0.00	0.00	0.0%
Jun	2.18	1.69	1.30	0.88	6.36	51.3%	1.46	1.02	1.30	0.16	3.21	25.9%
Jul	2.23	1.62	1.30	0.93	6.79	54.7%	1.59	0.94	1.30	0.29	4.65	37.5%
Aug	2.32	1.47	1.30	1.02	7.77	62.7%	1.60	0.78	1.30	0.30	5.28	42.6%
Sep	2.27	1.48	1.30	0.97	7.45	60.1%	1.55	0.80	1.30	0.25	4.68	37.8%
Oct	2.19	1.54	1.30	0.89	6.82	55.0%	1.35	0.96	1.30	0.05	1.82	14.7%
Nov	1.93	1.58	1.30	0.63	5.40	43.5%	1.25	1.09	1.30	0.00	0.00	0.0%
Dec	1.66	1.57	1.30	0.36	3.94	31.8%	1.06	1.12	1.30	0.00	0.00	0.0%

2050	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.81	1.63	1.20	0.61	5.20	41.9%	1.18	1.08	1.20	0.00	0.00	0.0%
Feb	1.85	1.75	1.20	0.65	5.17	41.7%	1.13	1.04	1.20	0.00	0.00	0.0%
Mar	2.08	1.97	1.20	0.88	4.33	34.9%	1.13	1.06	1.20	0.00	0.00	0.0%
Apr	2.24	2.03	1.20	1.04	6.30	50.8%	1.30	1.08	1.20	0.10	2.44	19.7%
May	2.39	1.83	1.20	1.19	7.40	59.7%	1.47	1.06	1.20	0.27	4.18	33.7%
Jun	2.47	1.69	1.20	1.27	8.28	66.8%	1.75	1.02	1.20	0.55	6.51	52.5%
Jul	2.52	1.62	1.20	1.32	8.89	71.7%	1.88	0.94	1.20	0.68	8.03	64.7%
Aug	2.61	1.47	1.20	1.41	10.79	87.0%	1.89	0.78	1.20	0.69	9.66	77.9%
Sep	2.56	1.48	1.20	1.36	10.12	81.6%	1.84	0.8	1.20	0.64	8.74	70.5%
Oct	2.48	1.54	1.20	1.28	9.06	73.0%	1.64	0.96	1.20	0.44	5.87	47.3%
Nov	2.22	1.58	1.20	1.02	7.37	59.4%	1.54	1.09	1.20	0.34	4.68	37.7%
Dec	1.95	1.57	1.20	0.75	6.02	48.6%	1.35	1.12	1.20	0.15	2.96	23.9%

Table 3.6: Details of monthly drainage congestion, Pirojpur – 2012 & 2050: West catchment, based on 1:10 year design storm

2012	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.52	1.63	1.60	0.00	0.00	0.0%	0.89	1.08	1.60	0.00	0.00	0.0%
Feb	1.56	1.75	1.60	0.00	0.00	0.0%	0.84	1.04	1.60	0.00	0.00	0.0%
Mar	1.79	1.97	1.60	0.19	2.09	16.9%	0.84	1.06	1.60	0.00	0.00	0.0%
Apr	1.95	2.03	1.60	0.35	3.38	27.3%	1.01	1.08	1.60	0.00	0.00	0.0%
May	2.10	1.83	1.60	0.50	4.34	35.0%	1.18	1.06	1.60	0.00	0.00	0.0%
Jun	2.18	1.69	1.60	0.58	4.94	39.8%	1.46	1.02	1.60	0.00	0.00	0.0%
Jul	2.23	1.62	1.60	0.63	5.32	42.9%	1.59	0.94	1.60	0.00	0.00	0.0%
Aug	2.32	1.47	1.60	0.72	6.12	49.4%	1.60	0.78	1.60	0.00	0.00	0.0%
Sep	2.27	1.48	1.60	0.67	5.83	47.0%	1.55	0.80	1.60	0.00	0.00	0.0%
Oct	2.19	1.54	1.60	0.59	5.27	42.5%	1.35	0.96	1.60	0.00	0.00	0.0%
Nov	1.93	1.58	1.60	0.33	3.75	30.2%	1.25	1.09	1.60	0.00	0.00	0.0%
Dec	1.66	1.57	1.60	0.06	1.55	12.5%	1.06	1.12	1.60	0.00	0.00	0.0%

2050	spring tides						neap tides					
month	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)	high wtr level (m PWD)	range (m)	grd level (m PWD)	congest'n (m)	t_c (hr)	% (tidal cycle)
Jan	1.81	1.63	1.50	0.31	3.56	28.7%	1.18	1.08	1.50	0.00	0.00	0.0%
Feb	1.85	1.75	1.50	0.35	3.66	29.5%	1.13	1.04	1.50	0.00	0.00	0.0%
Mar	2.08	1.97	1.50	0.58	2.78	22.5%	1.13	1.06	1.50	0.00	0.00	0.0%
Apr	2.24	2.03	1.50	0.74	5.12	41.3%	1.30	1.08	1.50	0.00	0.00	0.0%
May	2.39	1.83	1.50	0.89	6.09	49.1%	1.47	1.06	1.50	0.00	0.00	0.0%
Jun	2.47	1.69	1.50	0.97	6.79	54.7%	1.75	1.02	1.50	0.25	4.09	33.0%
Jul	2.52	1.62	1.50	1.02	7.24	58.3%	1.88	0.94	1.50	0.38	5.44	43.9%
Aug	2.61	147	1.50	1.11	8.31	67.0%	1.89	0.78	1.50	0.39	6.20	50.0%
Sep	2.56	1.48	1.50	1.06	7.97	64.2%	1.84	0.8	1.50	0.34	5.61	45.2%
Oct	2.48	1.54	1.50	0.98	7.29	58.8%	1.64	0.96	1.50	0.14	3.09	24.9%
Nov	2.22	1.58	1.50	0.72	5.85	47.2%	1.54	1.09	1.50	0.04	1.52	12.3%
Dec	1.95	1.57	1.50	0.45	4.46	36.0%	1.35	1.12	1.50	0.00	0.00	0.0%

3. HYDRAULIC DESIGN CRITERIA

a) Manning's roughness coefficient (LGED Urban Drainage Manual)

Surface material	Manning Coefficient (n)
concrete	0.014
rendered brick	0.014
plain brick with cement mortar	0.016
earth	0.025
grass	0.030

Structural design criteria:

a) Concrete compressive strength: (F_c):

unreinforced cement concrete	14 N/mm^2
cement concrete block	14 N/mm^2
reinforced cement concrete	21 N/mm^2

b) Yield strength of reinforcing bars: (F_y)

Mild steel	250 N/mm^2
High tensile steel	415 N/mm^2

4. PROPOSED INTERVENTIONS FOR DRAINAGE WORKS (PRIORITY LIST STAGE-I)

L = length
dia. = diameter
PD = Primary drain
FCD = Flood control and drainage
PPD = Proposed primary drain
PSG = Proposed sluice gate
RCC = Reinforced cement concrete
Rd = Road
SD = Secondary drain
SG = Sluice gate
SL = Serial number
Str = Structure
WAPDA = Water and Power Development Authority
W = Ward number
Type of Drain:
Type 1 = Section is 600 mm x 750 mm
Type 11 = Section is 750 mm x 900 mm
Type 111 = Section is 900 mm x 1,200 mm

ID = Identification
m = meter
mm = millimeter
R&H = Roads and Highway Department
RCC = Reinforced cement concrete
Rd = Road
SL = Serial number
STD = Street drain
T&T = Telephone & Telegraph
W# = Ward number)

AMTALI POURASHAVA - DRAINAGE

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section (m x m)	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
02	NPD01	W2				2.13 x 1.83	RCC box culvert with gate on lakeside & weir to regulate water	152.44	The drain will connect Amtali Lake to the sluice intake channel crossing the Zilla Parishad Rd & proposed Eidgah (large open field for Eid prayers)	Km	58	8.85	7.08	0.2	0.4
03	PD01	W7	From R&H culvert to canal junction along Ferry ghat Rd L=950'	T=9.15m B=3.05m D=1.52m	Channel filled up with trash & debris	T=9.15m B=2.44m D=2.13m	Earthen channel Re-excavation	289.63		Km	4	1.16	0.928	1	2
05	NSD02	W6				T=3.05m B=1.52m D=1.52m	Earthen cc block lined canal	121.95	Ward#6, connecting Lake to SND01/W6 to evacuate Lake water	Km	25	3.05	2.44	1	2
06	NSD01	W6				1.52 m X 2.13m	RCC box culvert	12.20	Ward#6, Zilla Parrshad Rd crossing to college boundary, New Drain	Km	58	0.71	0.568	0.2	0.4
07	SD06	W6	Side of Nazrul Rd, Ward #6 L=259.15m	9.15m wide earthen channel	North side canal bank erosion damage adjacent road	CC block lined channel	256.15 m	256.15	The channel to connect the proposed sluice gate NSG03/W5	Km	25	6.47	5.176	0.25	0.50

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section (m x m)	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
08	NSD07	W6/W5				RCC box culvert, 2.74 m x 2.74 m	12.20m	12.20	Connect the SD06/W6 to the proposed sluice gate & adjacent to the existing road crossing culvert	Km	58	0.71	0.568	0.2	0.4
09	PD08	W5	Ward 5 at the intake of PSG03/W5 201.22m X 48.78m	201.22m X 48.78 m X 1.21 m deep, earthen channel	Used as collection of wastewater from nearby settlements	201.22m x 48.8m x 1.83m	Earthen channel	201.22	The pond to be re-excavated by 0.61m @ ponding area @ intake of PSG03/W5	Km	4	0.81	0.648	1	2
10	SD09	W6	Along west side of Zilla Parisad Rd, L =457.32m	T = 18.29m, B=9.15m, D=1.22m, deep, earthen channel	Used as drainage channel	T=18.29m , B=9.15m D=1.83m	do	457.32	Re-excavate of bed by 2'	Km	4	1.83	1.56	0.2	0.4
11	SD10	W4	Old mango market, W4, L=121.95m	Katcha drain flat section	Water congestion due to wastewater overflowing Katcha drain	W=0.46m, D=0.915m	RCC drain	122	Connect the existing brick drain to outfall canal	Km	15	1.83	1.56	0.2	0.4
12	SD11	W4/W1	Rashid Sakar House to Shahnaj House W4, L=72.22m	Flat section Katcha drain	Wastewater overflow causes water congestion	W=0.76m D=1.37m	RCC drain	213.42	Connect the existing RCC 2'6" x 4'6" drain from Rashid Sarkar House to Kalibari Sluice Gate	Km	15	3.2	2.72	0.2	0.4
13	NSD13	W2	AKS School Chowrasta to Khontakata ,	Irregular flat section, earthen canal	Due to flat & shallow depth, flow discontinuity	T=3.05m B=1.52m H=1.52m	Lined earthen channel	152.44	Connect SD12/W2 to the Amtoli Lake	Km	7	1.05	0.84	1	2

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section (m x m)	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
			L=152.44m												
14	SD14	W2	AKS School Chowrasta to Khontakata, L=198.17 m	Irregular flat earthen channel	Due to flat & shallow depth, discontinuity of flow	T=3.05m B=1.52m H=1.52m	Earthen channel re-excavation	198.17	Connect the existing borrow pits to work as channel	Km	4	0.80	0.64	1	2
15	NSD15	W2/W 3	Khontakata			1.52m X 1.83m	RCC box culvert	9.15	Facilitating drainage flow through roadside drain in government land at Khontakata	Km	58	0.53	0.424	0.2	0.4
16	SD16	W3	Khontakata Mazar Rd., L=18.29m	RCC pipe culvert	Inadequate section causing congestion upstream	1.52m X 1.83m	RCC box culvert	21.34	Connect two water bodies on both sides of road	Km	58	1.24	0.992	0.2	0.4
17	SD17	W3	Khontekata Lake/ Jhiler Par, L=76.22m	0.915m x1.22m earthen drain	Water congestion due to encroachment into drain	1.22m x 1.52m	RCC rectangular open channel	76.22	Connect the existing water body to the road culvert SD18/W3	Km	15	1.14	0.912	0.2	0.4
18	SD18	W3	Khontakata Rd., L=6.1m	5.49m dia. RCC pipe culvert	Inadequate section to drain out water from large catchment	1.52m X 1.52m	RCC box culvert	18.29	Outfall to Amtali Khal	Km	58	1.20	0.96	0.2	0.4
19	SD19	W2	East Kalibari, L=27.44m	1.83m X1.22m earthen channel	The channel is filled up with trash and debris by local people	T=3.05m B=1.52m D=1.22m	Re-excavation of earthen channel	27.44	Connect between two separated channels for flow continuity	Km	4	0.11	0.088	1	2

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section (m x m)	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
20	NSD20	W2	Bokulgacha Mohila College Rd. to Kalibari Khal	Flat sloped land	No defined drain exists in the area	T=1.83m B=0.92m D=0.92m	New lined earthen channel	182.93	Connect main road to khal outfall	Km	25	4.57	3.656	1	2
21	SD21	W7	Nutan Bazar Chowrasta, L=24.39m	1.53m x 1.53m gated RCC culvert of Roads &Highway	Gate on riverside damaged; culvert filled up by garbage			24.39	Clean box culvert & rehabilitation of gate needed	Km		0.62	0.496	0.2	0.4
22	SD22		North side of Dhiren Tahshilder House.From zilla porished Rd. to Amtoli lake L=121.95m	Earthen Channel				121.95	Earthen lined channel connecting with Amtoli Lake	Km	25	3.05	2.44	1	2
23	SD23	W2				1.22m x1.22m RCC	Box culvert carring main road to NSD 20	12.2	Connecting NSD 20 to open land south side through crossing the 0main road	Km	58	0.707	0.56	0.2	0.4
Sub Total												43.63	35.26		
Purchase of drainage maintenance equipments												0.8	0.4	3	5
Total for Amtali												44.44	35.66		

GALACHIPA POURASHAVA – DRAINAGE

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
01	PD04	W1,2,3,4,7,8	Thana Morh to Textile School, L=2484.8 m	T=18.3m B=6.1m, D=1.52m, earthen canal	Silted up, encroached by settlements	T=18.3m, B=4.57m, D=4.57m	Earthen canal with CC block	2484.8	Re-excavation With CC block lining	Km	25	62.13	49.70	1	2
02	NPD02	W8,7,6	Sub-Registrar Office to Kabikha Rd. drain			B=1.52m, D=1.83m.	RCC open U-drain	1367		Km	30	41	34.85	0.2	0.4
03	NPD03	W8	Registrar Office Morh (roundabout)			1.52 m x 1.83 m	RCC box culvert	40	Connect NP02 to Galachipa Khal	Km	30	1.2	0.96	0.2	0.4
04	NPD04	W5,6,7	Sohrab Mia House to Cinema Hall Morh, L=351 m	No drain		1.52 m x 1.83 m	RCC open U-drain	351		Km	30	10.5	8.93	0.2	0.4
05	NPD05	W5,6	Cinema Hall Morh to Asad Manjil Lane, L=524 m	Do		1.52 m x 1.83 m	RCC U-drain covered with slab	523		Km	30	15.69	13.57	0.2	0.4
06	NSD01	W4,7,9	Thana Morh to Textile School, L=2484 m	Do		0.915m x 1.22 m	RCC U-drain covered by slab0	2283		Km	20	45.66	38.81	0.2	0.4

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
07	NSD14	W8,9	Dr. Alamin house to Jasim house canal			0.915m x 1.22 m	RCC U-drain covered	293		Km	25	7.32	6.22	0.2	0.4
08	NSD15	W3	Delwar matbar hose to canal via chunnu molla house			0.915m x 1.22 m	RCC U-drain covered	168		Km	25	4.2	3.57	0.2	0.4
09	NPD01	W4,5,6	Thana Complex to Puran Piadabari			B=2.44m, D=1.52m	RCC open U-drain	1460	Connect the existing & proposed sluice gates on country side	Km	30	43.78	37.21	0.2	0.4
10	NSD03	W5	Muktijhoddha Parshad Morh to WAPEDA Drain, L=250 m	Do		0.915m x 1.22 m	Do	250		Km	20	5.6	4.76	0.2	0.4
11	NSD04	W5,6	Mustafa Enterprise Morh to WAPDA Main Drain, L=274.4 m	Do		0.915m x 1.22 m	Do	274		Km	20	5.5	4.68	0.2	0.4
12	NSD10	W7	Samir Pal hause to Sohrab Mia canal	Do		0.915 m x1.83m	Do	366		Km	20	7.3	6.21	0.2	0.4

SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length (m)	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
13	NSD13	W2	Veterinarian Hospital to Galachipa canal via football ground, L=183m	No drain	Water congestion	0.915m x 1.52 m	RCC covered U-drain	183		Km	20	3.66	3.11	0.2	0.4
18	PD02	W6	Arambag & heliport Khal L=305m	T=12.2m B=6.1m D=1.52m	Earthen canal Silted up	T=12.2m B=6.1m D=2.13m	Earthen Canal	305	Earthen Canal re-excavation	Km	4	1.22	0.976	1	2
											Sub Total	254.76	214.56		
19											Purchase of drainage maintenance equipment	4	2.40	3	5
											Total for Galachipa	258.76	216.96		

PIROJPUR POURASHAVA – DRAINAGE

SL No	Drain / Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
01	PD 01	W4,5,7, 2,3,8,9	Damudar khal,From Bowlesher river,L= 4.00 km (Up to Borokhalishakhali Bridge)	T-17.71 m B- 6.5 m D-1.7 m Earthen Canal	Bed Silted up: Settlement of bank	T- 20.00m B - 7.50m D- 3.5 m	Earthen Canal	3800. m	Re-excavation of Canal	Km	4	15.2	12.16	1	2
							CC block lined channel	200m		Km	25	5	4	0.25	0.5
02	SD 02	W5,6,7, 8	2(a) Pirojpur parerhat varani khal,fromDamuder khal to parerhat khal nearBarapul, L=2.6km	T- 7.00m B –2.00m C -1.25 m Earthen Canel	Do	T- 8.00m, B-3.50m, D-1.75m	Earthen Canal	2470 m	Do	Km	4	9.88	7.904	1	2
							CC block lined channel	130		Km	25	3.25	2.6	0.25	0.5
			2(b) Malaria pule to Primary School (Mashid bari)	T -5.00m, B-2.00m, D-1.25m	Do	T-5.00m B-2.00m	Earthen Canal	450m	Do	Km	4	1.8	1.44	1	2
							CC block lined channel	50m		Km	25	1.25	1	0.25	0.5
03	SD 03	W4	Pal para khal,from Damuder khal to Mr.Kabil house,L-1.50 km	T-4.25m B-1.5m D-1.00m Earthen Canel	Do	T-1.25m, D-1.50m	R.C.C Covered U Channel	1500m	Adjacent road to be Widened	Km	25	37.5	31.88	0.2	0.4
04	PD 02	W5	Chan Mari khal, from Bowlesher River to Sarder bari field, L-1580.00m	T -4.55m B-2.00m D-1.30m Earthen Canel	Do	04	Earthen Canal	1422m	Do	Km	4	5.69	4.55	1	2
							CC block lined channel	158		Km	25	3.95	3.16	0.25	0.5
05	SD 04	W7	Gazi bari khal from Damuder khal(near barring gate) to S.K. Jalil mia`s house,L-	T-4.80m B-2.00m D-1.20m	Do	B=4.0m D=1.5m	R.C.C Covered U Channel	1736m	Re-Excavation of Canal	Km	23	40.0	34	0.2	0.4

SL No	Drain / Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
			1736m	Earthen Canel											
06	SD 06	W5	Modda Rasta Kacha drain from Chan mari khal to Maddo rasta via Mr.Farruk sarder house,L- km	B-2.00m D-1.5m	Do	B-2.00m D-1.5m	R.C.C. Open Channel	500m	Do	Km	30	15	12.75	0.2	0.4
07	SD 07	W5	Primary Education Office Drain from Existing R.c.c.drain to Mr.Delower house,L- km	B-1.5m D-1.25m	Do	B-1.5m D-1.25m	R.C.C. Open Channel	250 m	Do	Km	30	7.5	6.38	0.2	0.4
08	SD 08	W4	West Sikarpur kacha drain from Chilla khal to cfitala near Mr.Abu mia house,via babo Dulal Ghoos,	B-2.00m D-1.50m	Do	B-2.00m D-1.50m	R.C.C. Open Channel	600m	Do	Km	30	18	15.3	0.2	0.4
09	SD 09	W7	Damuder khal to Mr.Haque Mias house, side of S.P house,	B-2.00m D-1.50m	Do	B-2.00m D-1.50m	R.C.C. Open Channel	500m	Do	Km	30	15	12.75	0.2	0.4
10	SD 10	W7	Pirojpur – Paraerhat Varani khal to Maddo Mushid house north side of Bypass	B-1.50m D-2.50m	Do	T-6.00m B-1.75m D-1.50m	R.C.C Covered U Channel	1736m	Re-Excavation of Canal	Km	30	4.8	4.08	0.2	0.4
11	SD 11	W5	Adorshapara drain from Bolesher river to east side of sultan mia`s house,	New	Do	B-2.00m D-1.5m	R.C.C. Open Channel	500m	Do	Km	30	15	12.75	0.2	0.4
12	PD 12	W7	Murshid bari khal from pirojpur –parerhat varani khal to Mr.Alom house,	New	Do	B-1.50m D-2.00m	R.C.C. Open Channel	500m	Do	Km	30	15	12.75	0.2	0.4
13	SD 13		Khumuria Asrom bari road side drain to Balasher river,	New	Do	B- 2.00m D-1.50m	R.C.C. Open Channel	600m	Do	Km	30	18	15.3	0.2	0.4
14	SD 04	W4	14(a) Sikarpur khal from Damuder khal to water	T-5.68m B-2.00m	Do	T-6.50m B-3.00m	Earthen Canal	900m	Do	Km	4	3.6	2.88	1	2

SL No	Drain / Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
			supply Compound ,L-1.00 Km	D-1.25m Earthen canel			CC block lined channel	100m		Km	25	2.5	2	0.25	0.5
		W4	14(b)Sikder bari to Sheikh bari ,L – 2.50 km	T-5.00m B-2.00m D-1.25m	Do	T-5.00m B-2.00m D-1.25m	Earthen Canal	440 m	Do	Km	4	1.76	1.408	1	2
							CC block lined channel	60m		Km	25	1.5	1.2	0.25	0.5
		W4	14(c) Sikder bari Culvart to Huque driver house,	Do	Do	T-6.50m B-3.00m	Earthen Canal	450m	Do	Km	4	1.8	1.44	1	2
							R.C.C. Open Channel	600m		Km	25	1.25	1	0.25	0.5
15	SD 05	W8	Fire service khal(Machempur Kisnagur) from Damuder khal to Stadium compound L- 1522 m	B-2.00m D-1.50m Earthen khal	Do	T-5.00m B-2.00m D-1.25m	Earthen Canal	1369.8m	Do	Km	4	5.48	4.381	1	2
							CC block lined channel	152.2m		Km	25	3.8	3.04	0.25	0.5
16	SD 06	W2,4	Side of Primary Teacher's Training Institute khal,from Damuder khal to Police line, L-1736m	T-10.10m B-3.00m D-1.30m Earthen Canel	Do	T-6.00m B-1.75m	Earthen Canal	1.35 km	Do	Km	4	6.25	5	1	2
							CC block lined channel	0.15		Km	25	4.34	3.47	0.25	0.5
17	SD 07	W8,9	Dhup pasa khal,fromDamuder khal to Krisna Nagur Feild, L-1275m	T-9.23m B-3.5m D-1.5m Earthen Canel	Do	D-1.50m T-9.23m	Earthen Canal	2700m	Do	Km	4	5.4	4.32	1	2
							CC block lined channel	300m		Km	25	3.75	3	0.25	0.5
18	SD 08	W4	HBN Bricks to East side of Mr. Muklasur Rahman house,via Madu Mia`s Mill	T-4.80m B-2.00m D-1.20m	Do		Earthen Canal	1562.4m	Re Excavation of Canel	Km	4	10.8	8.64	1	2
							CC block	173.6m		Km	25	7.5	6	0.25	0.5

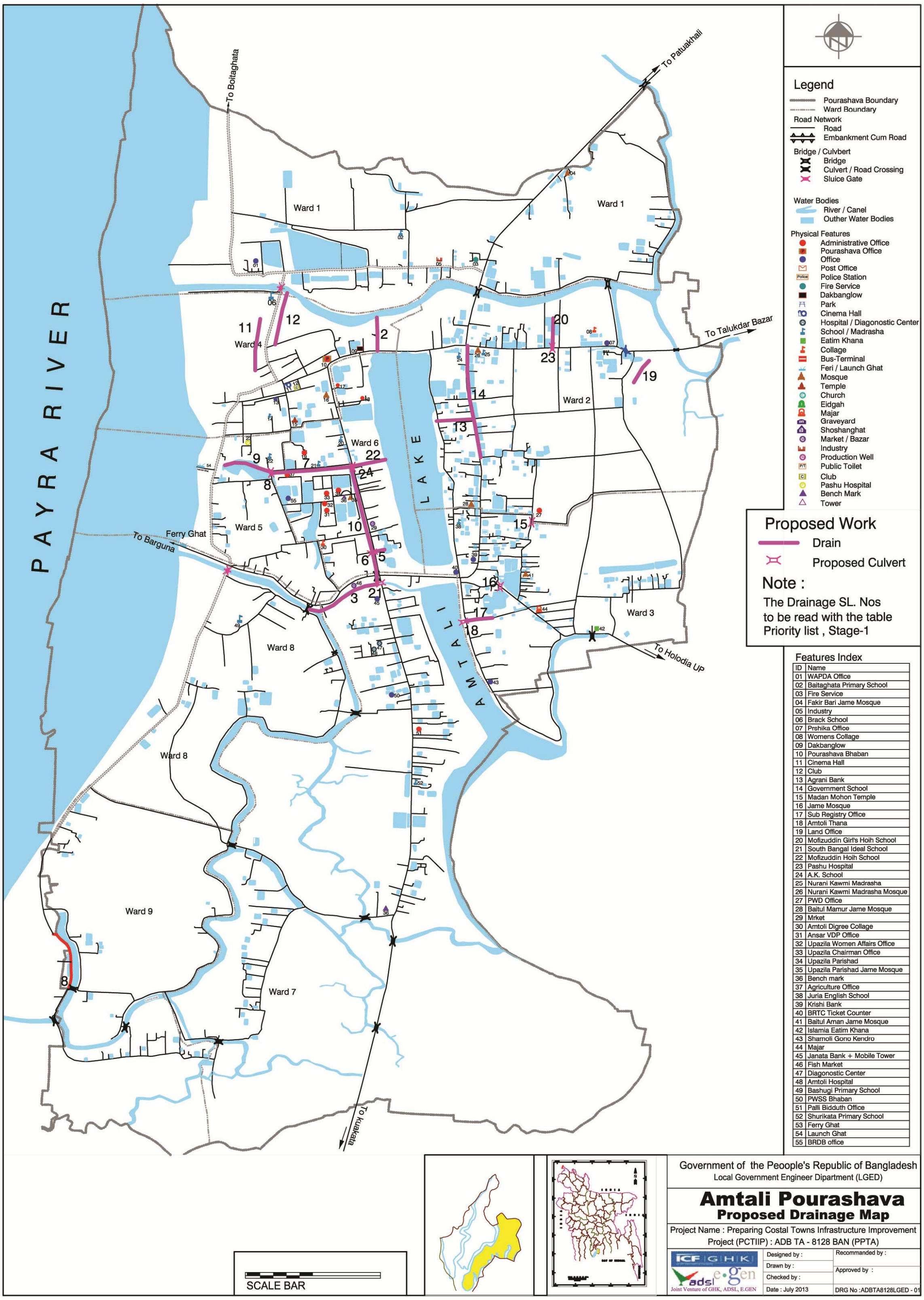
SL No	Drain / Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.) With CCR	Capital Cost (Million tk.) Without CCR	O & M cost (Million tk.) From year 3 to 10 (% of capital cost)	O & M cost (Million tk.) From year 11&beyond (% of capital cost)
			khal,L-3km	Earthen Canel			lined channel								
												291.69	242.53		
									Maintenance equipment			6.0	3.6	3	5
									Total for Pirojpur			297.69	246.13		

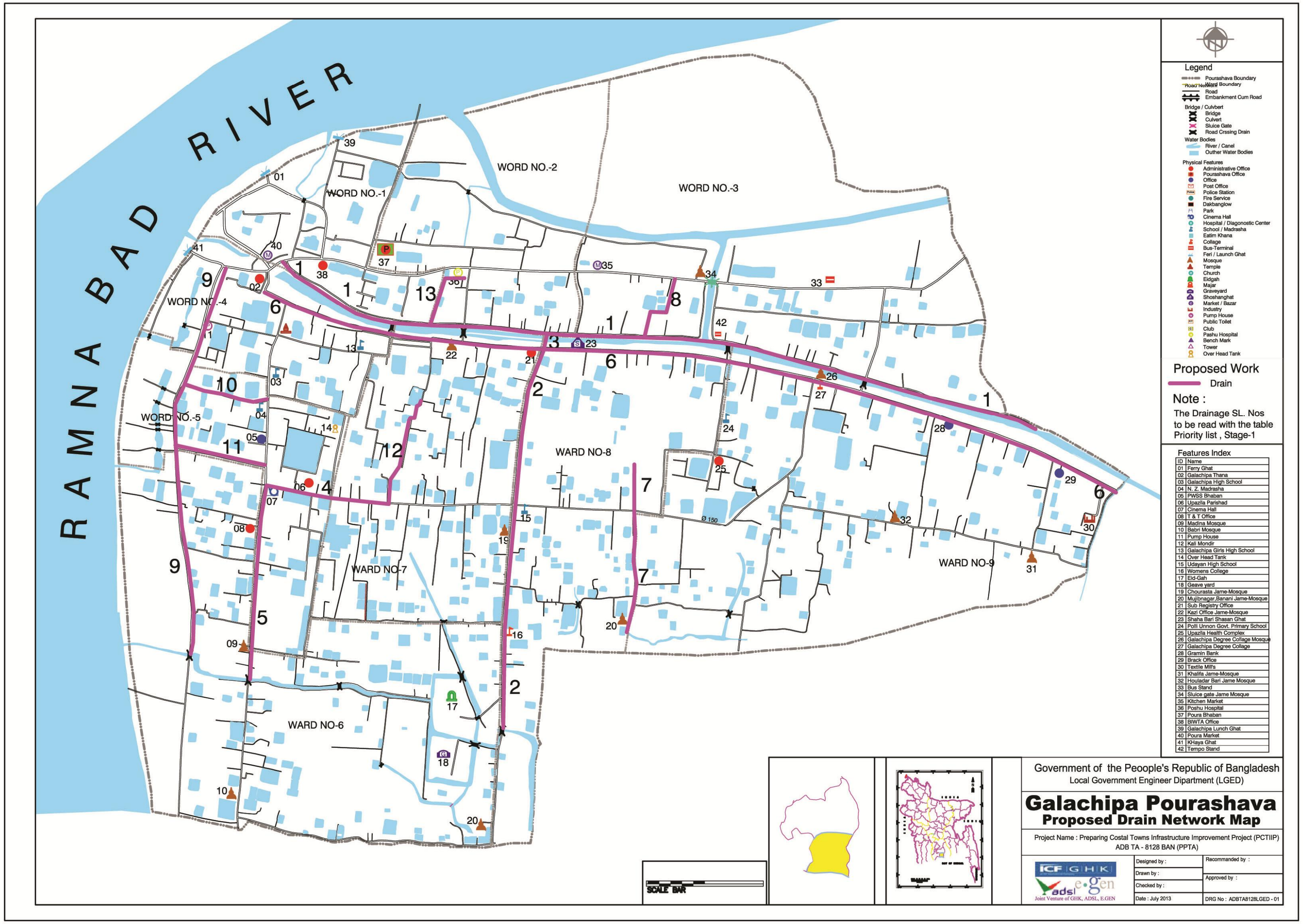
MATHBARIA POURASHAVA – DRAINAGE

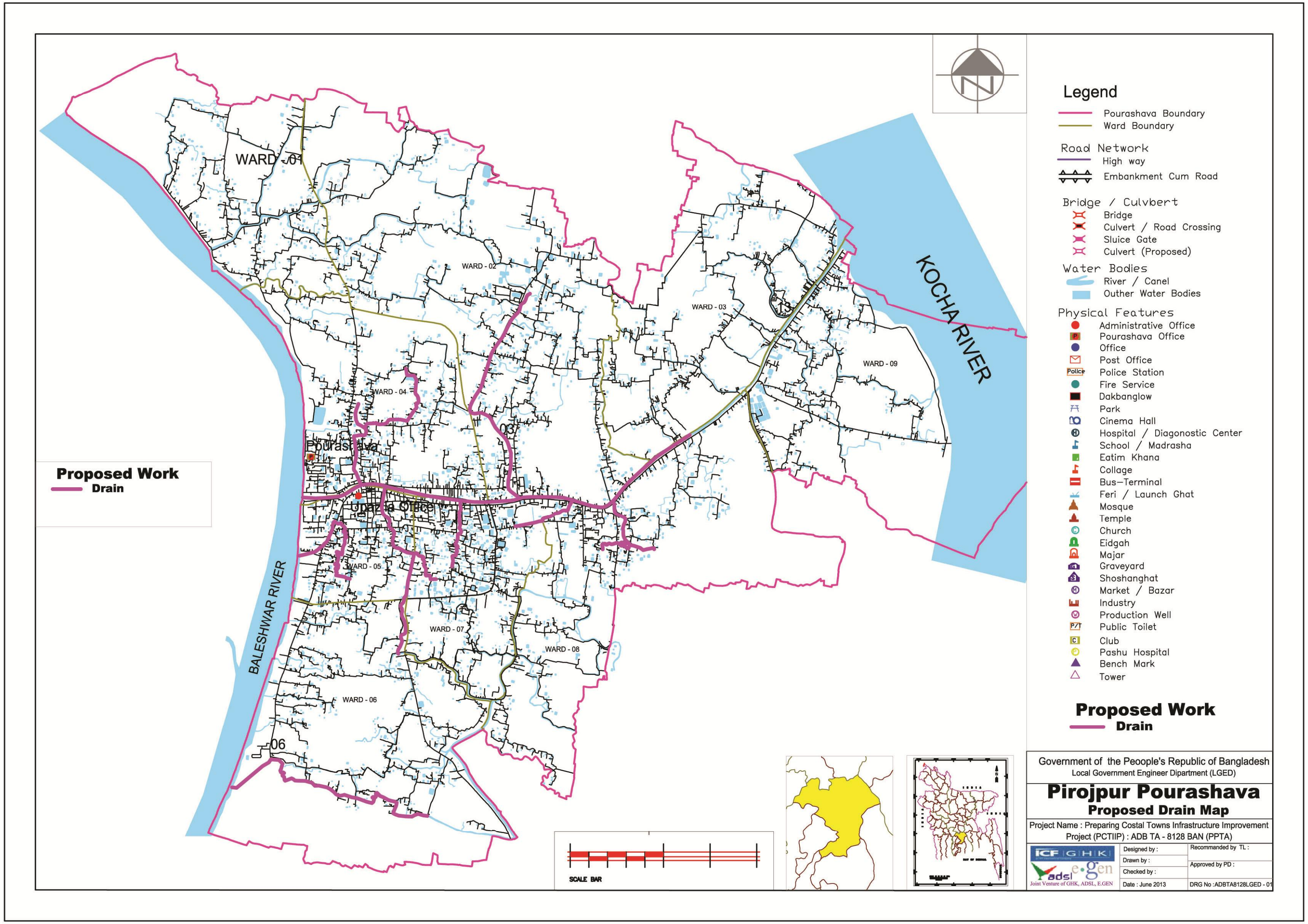
SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
04	SD01	W1, 2	Mominia Madrasha to Skider Bari, L =1,050 m	T =6.71m B =2.44m, D =1.52m, Earthen	Silted up; garbage dumping; canal encroachment by settlements	T=7.31m, B=1.22m, D =2.13m	CC block lined channel	1,050 m	Basi Rum Canal to be re-excavated	Km	25	26.25	21	0.25	0.50
01	SD02	W7,6, 5	Graveyard culvert to Ismail House, L = 750 m	T = 3.354m, B =1.22m, D =0.915m, Earthen canal	Do	W =2.14m D =1.53m	R.C.C. covered drain	750 m	Central Mosjid Canal	Km	40	30	25.5	0.2	0.4
07	SD03	W5	A. Halim Jalim Jamadder House to Pourashava End, L = 900 m	T = 3.66m, B =1.22m, D =0.915m, Earthen canal	Do	W =2.14m D =1.53m	Do	900 m	Discharges in to Shafa Khal	Km	40	36	30.6	0.2	0.4
03	SC02	W4,2, 5,1	Dakkhin Bondor Sluice to Baheratola, L = 1,700 m	T=17.68m, B =6.40m, D =2.44m. Earthen canal	Do	T = 18.29m, B = 9.15m D =3.05m	Earthen canal	1,600 m	Boyratala Khal; to be re-excavated	Km	4	6.4	5.12	1	2
							CC block lined channel	100 m		Km	25	2.5	2	0.25	0.50
05	SC03	W1	Baharatala to Pourashava End, L = 1,700 m	T =12.20m, B =3.96m, D =1.52m. Earthen canal	Do	T=12.20m B =6.10m, D =2.13m	Earthen canal	1,525 m	Tushkhali Khal, needs to be re-excavated	Km	4	6.1	4.88	1	2
							CC block lined channel	175 m		Km	25	4.38	3.504	0.25	0.50
06	SC04	W5,1	Baharatala to Jomadder Bari,	T = 15.24m, B =6.10m,	Do	T=15.24m B =9.15m	Earthen	2,050 m	Shafa Khal; needs re-	Km	4	8.2	6.56	0	1

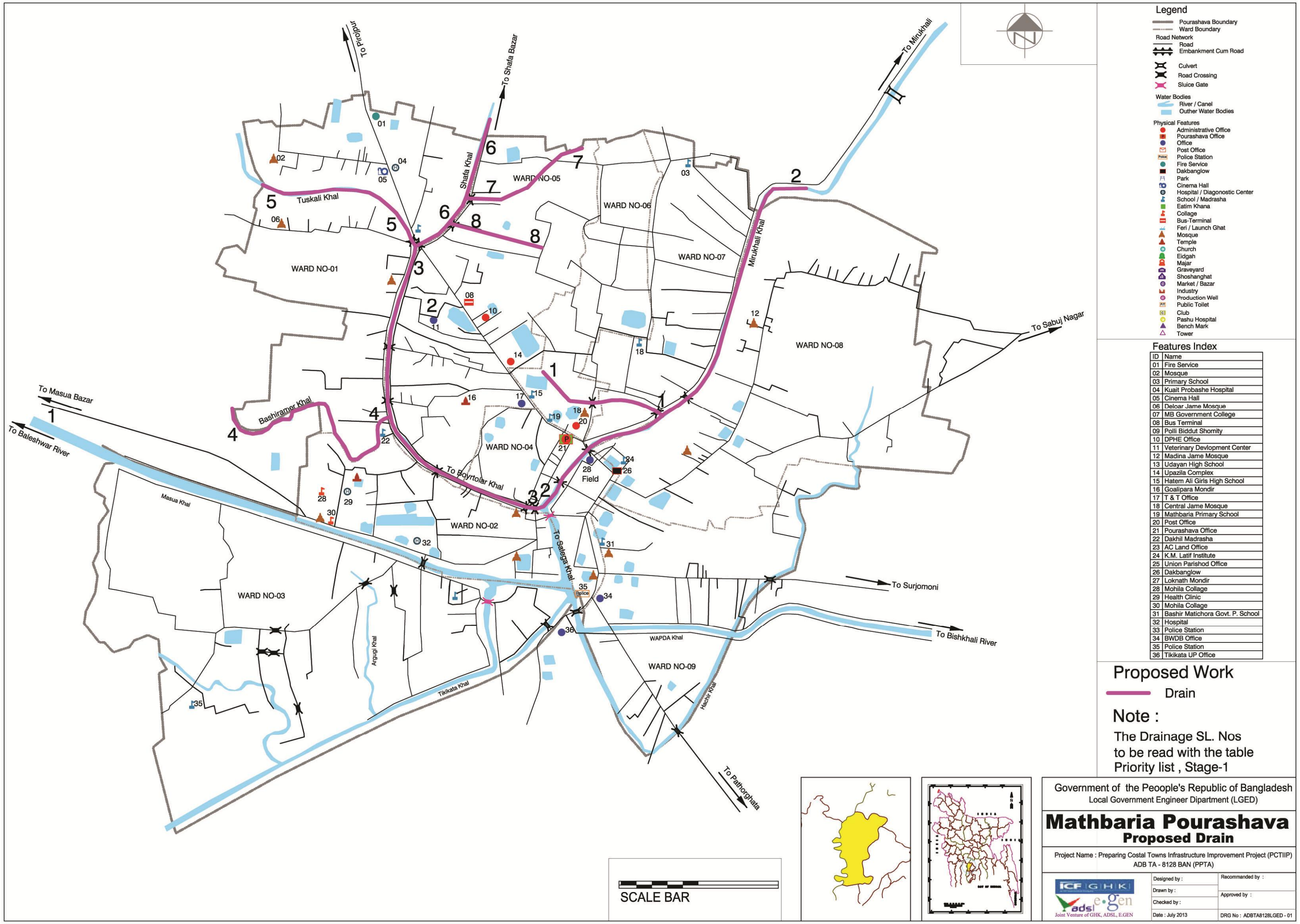
SL No	Drain/ Str.ID No.	Ward No.	Existing Condition			Proposed Intervention				Rough Estimated Cost (Million tk.)					
			Location & Length	Section & Str. Type	Existing Condition	Section	Proposed Str. Type	Length	Scope of works / Remarks	Unit	Unit Cost (Million tk.)	Capital Cost (Million tk.)		O & M cost (Million tk.)	
												With CCR	Without CCR	From year 3 to 10 (% of capital cost)	From year 11&beyond (% of capital cost)
			L = 2,200 m	D =1.52m. Earthen canal		D =2.13m	canal		excavated						
							CC block lined channel	150m		Km	25	3.75	3	0	0.25
02	PC02	W2,4, 7,8	Dakkhim Bondor Sluice to Gopal Bori House, L = 2,500 m	T =16.77, B =15.49m, D =2.44m, Earthen canal	do	T=16.77m B =7.62m D =3.05m	Earthen canal	2,300 m	Mirukhali Khal; to be re-excavated	Km	4	9.2	7.36	0	1
							CC block lined channel	200m		Km	25	5.0	4	0	0.25
Sub Total												137.78	113.52		
Purchase of drainage maintenance equipments												2.62	1.5	3	5
Total for Mathbaria												140.40	115.02		

5. MAPS SHOWING LOCATIONS OF PROPOSED DRAINAGE WORKS


PAYRA RIVER
To Boitaghata
To Patuakhali
To Talukdar Bazar
To Barguna
Ferry Ghat
To Holodia UP
To Kuakata
LAKE
AMTALI
Ward 1
Ward 1
Ward 2
Ward 3
Ward 4
Ward 5
Ward 6
Ward 7
Ward 8
Ward 8
Ward 9
Legend
Pourashava Boundary
Ward Boundary
Road Network
Road
Embankment Cum Road
Bridge / Culvbert
Bridge
Culvert / Road Crossing
Sluice Gate
Water Bodies
River / Canel
Outher Water Bodies
Physical Features
Administrative Office
Pourashava Office
Office
Post Office
Police Station
Fire Service
Dakbanglow
Park
Cinema Hall
Hospital / Diagonostic Center
School / Madrasha
Eatim Khana
Collage
Bus-Terminal
Feri / Launch Ghat
Mosque
Temple
Church
Eidgah
Majar
Graveyard
Shoshanghat
Market / Bazar
Industry
Production Well
Public Toilet
Club
Pashu Hospital
Bench Mark
Tower
Proposed Work
Drain
Proposed Culvert
Note :
The Drainage SL. Nos to be read with the table Priority list , Stage-1
Features Index
ID Name
01 WAPDA Office
02 Baitaghata Primary School
03 Fire Service
04 Fakir Bari Jame Mosque
05 Industry
06 Brack School
07 Prshika Office
08 Womens Collage
09 Dakbanglow
10 Pourashava Bhaban
11 Cinema Hall
12 Club
13 Agrani Bank
14 Government School
15 Madan Mohon Temple
16 Jame Mosque
17 Sub Registry Office
18 Amtoli Thana
19 Land Office
20 Mofizuddin Girl's Hoih School
21 South Bangal Ideal School
22 Mofizuddin Hoih School
23 Pashu Hospital
24 A.K. School
25 Nurani Kawmi Madrasha
26 Nurani Kawmi Madrasha Mosque
27 PWD Office
28 Baitul Mamur Jame Mosque
29 Mrket
30 Amtoli Digree Collage
31 Ansar VDP Office
32 Upazila Women Affairs Office
33 Upazila Chairman Office
34 Upazila Parishad
35 Upazila Parishad Jame Mosque
36 Bench mark
37 Agriculture Office
38 Juria English School
39 Krishi Bank
40 BRTC Ticket Counter
41 Baitul Aman Jame Mosque
42 Islamia Eatim Khana
43 Shamoli Gono Kendro
44 Majar
45 Janata Bank + Mobile Tower
46 Fish Market
47 Diagonostic Center
48 Amtoli Hospital
49 Bashugi Primary School
50 PWSS Bhaban
51 Palli Bidduth Office
52 Shurikata Primary School
53 Ferry Ghat
54 Launch Ghat
55 BRDB office
SCALE BAR
Government of the Peoople's Republic of Bangladesh
Local Government Engineer Dipartment (LGED)
Amtali Pourashava
Proposed Drainage Map
Project Name : Preparing Costal Towns Infrastructure Improvement Project (PCTIIP) : ADB TA - 8128 BAN (PPTA)
Joint Venture of GHK, ADSL, E.GEN
Designed by :
Drawn by :
Checked by :
Date : July 2013
Recommanded by :
Approved by :
DRG No :ADBTA8128LGED - 01


RAMNABAD RIVER
WORD NO.-1
WORD NO.-2
WORD NO.-3
WORD NO.-4
WORD NO.-5
WARD NO-6
WARD NO-7
WARD NO-8
WARD NO-9
Legend
Proposed Work
Drain
Note :
The Drainage SL. Nos to be read with the table Priority list , Stage-1
Features Index
ID Name
01 Ferry Ghat
02 Galachipa Thana
03 Galachipa High School
04 N. Z. Madrasha
05 PWSS Bhaban
06 Upazila Parishad
07 Cinema Hall
08 T & T Office
09 Madina Mosque
10 Babri Mosque
11 Pump House
12 Kali Mondir
13 Galachipa Girls High School
14 Over Head Tank
15 Udayan High School
16 Womens College
17 Eid-Gah
18 Geave yard
19 Chourasta Jame-Mosque
20 Mujibnagar,Banani Jame-Mosque
21 Sub Registry Office
22 Kazi Office Jame-Mosque
23 Shaha Bari Shasan Ghat
24 Polli Unnon Govt. Primary School
25 Upazila Health Complex
26 Galachipa Degree Collage Mosque
27 Galachipa Degree Collage
28 Gramin Bank
29 Brack Office
30 Textile Mill's
31 Khalifa Jame-Mosque
32 Houladar Bari Jame Mosque
33 Bus Stand
34 Sluice gate Jame Mosque
35 Kitchen Market
36 Poshu Hospital
37 Poura Bhaban
38 BIWTA Office
39 Galachipa Lunch Ghat
40 Poura Market
41 KHaya Ghat
42 Tempo Stand
Government of the Peoople's Republic of Bangladesh
Local Government Engineer Dipartment (LGED)
Galachipa Pourashava
Proposed Drain Network Map
Project Name : Preparing Costal Towns Infrastructure Improvement Project (PCTIIP)
ADB TA - 8128 BAN (PPTA)
Joint Venture of GHK, ADSL, E.GEN
Designed by :
Drawn by :
Checked by :
Date : July 2013
Recommanded by :
Approved by :
DRG No : ADBTA8128LGED - 01


Legend
Pourashava Boundary
Ward Boundary
Road Network
High way
Embankment Cum Road
Bridge / Culvbert
Bridge
Culvert / Road Crossing
Sluice Gate
Culvert (Proposed)
Water Bodies
River / Canel
Outher Water Bodies
Physical Features
Administrative Office
Pourashava Office
Office
Post Office
Police Station
Fire Service
Dakbanglow
Park
Cinema Hall
Hospital / Diagonostic Center
School / Madrasha
Eatim Khana
Collage
Bus-Terminal
Feri / Launch Ghat
Mosque
Temple
Church
Eidgah
Majar
Graveyard
Shoshanghat
Market / Bazar
Industry
Production Well
Public Toilet
Club
Pashu Hospital
Bench Mark
Tower
Proposed Work
Drain
KOCHA RIVER
BALESHWAR RIVER
WARD - 01
WARD - 02
WARD - 03
WARD - 04
WARD - 05
WARD - 06
WARD - 07
WARD - 08
WARD - 09
Pourashava
Upazila Office
SCALE BAR
Government of the Peoople's Republic of Bangladesh
Local Government Engineer Dipartment (LGED)
Pirojpur Pourashava
Proposed Drain Map
Project Name : Preparing Costal Towns Infrastructure Improvement Project (PCTIIP) : ADB TA - 8128 BAN (PPTA)
Designed by :
Recommanded by TL :
Drawn by :
Approved by PD :
Checked by :
Date : June 2013
DRG No :ADBTA8128LGED - 01
Joint Venture of GHK, ADSL, E.GEN


To Pirojpur
To Shafa Bazar
To Mirukhali
To Sabuj Nagar
To Masua Bazar
To Baleshwar River
To Surjomoni
To Bishkhali River
To Pathorghata
WARD NO-01
WARD NO-02
WARD NO-03
WARD NO-04
WARD NO-05
WARD NO-06
WARD NO-07
WARD NO-08
WARD NO-09
Tuskali Khal
Shafa Khal
Mirukhali Khal
Bashiramer Khal
To Boyrtolar Khal
To Saleqa Khal
Masua Khal
Arguqi Khal
Tikikata Khal
WAPDA Khal
Hachir Khal
Field
SCALE BAR
Legend
Pourashava Boundary
Ward Boundary
Road Network
Road
Embankment Cum Road
Culvert
Road Crossing
Sluice Gate
Water Bodies
River / Canel
Outher Water Bodies
Physical Features
Administrative Office
Pourashava Office
Office
Post Office
Police Station
Fire Service
Dakbanglow
Park
Cinema Hall
Hospital / Diagonostic Center
School / Madrasha
Eatim Khana
Collage
Bus-Terminal
Feri / Launch Ghat
Mosque
Temple
Church
Eidgah
Majar
Graveyard
Shoshanghat
Market / Bazar
Industry
Production Well
Public Toilet
Club
Pashu Hospital
Bench Mark
Tower
Features Index
ID | Name
01 | Fire Service
02 | Mosque
03 | Primary School
04 | Kuait Probashe Hospital
05 | Cinema Hall
06 | Deloar Jame Mosque
07 | MB Government College
08 | Bus Terminal
09 | Polli Biddut Shomity
10 | DPHE Office
11 | Veterinary Devlopment Center
12 | Madina Jame Mosque
13 | Udayan High School
14 | Upazila Complex
15 | Hatem Ali Girls High School
16 | Goalipara Mondir
17 | T & T Office
18 | Central Jame Mosque
19 | Mathbaria Primary School
20 | Post Office
21 | Pourashava Office
22 | Dakhil Madrasha
23 | AC Land Office
24 | K.M. Latif Institute
25 | Union Parishod Office
26 | Dakbanglow
27 | Loknath Mondir
28 | Mohila Collage
29 | Health Clinic
30 | Mohila Collage
31 | Bashir Matichora Govt. P. School
32 | Hospital
33 | Police Station
34 | BWDB Office
35 | Police Station
36 | Tikikata UP Office
Proposed Work
Drain
Note :
The Drainage SL. Nos
to be read with the table
Priority list , Stage-1
Government of the Peoople's Republic of Bangladesh
Local Government Engineer Dipartment (LGED)
Mathbaria Pourashava
Proposed Drain
Project Name : Preparing Costal Towns Infrastructure Improvement Project (PCTIIP)
ADB TA - 8128 BAN (PPTA)
Joint Venture of GHK, ADSL, E.GEN
Designed by :
Drawn by :
Checked by :
Date : July 2013
Recommanded by :
Approved by :
DRG No : ADBTA8128LGED - 01

ANNEX C: WATER SUPPLY DRAWINGS

Amtali

01 Physical Features Map (A3)
02 Existing Water Supply System Map (A4)
03 Proposed Water Supply (Integrated) (A3)
04 Proposed Water Supply (Zone Wise) (A3)
05 Site Plan – Zone 2 (A4)

Galachipa

01 Physical Features Map (A3)
02 Existing Water Supply System Map (A4)
03 Proposed Water Supply (Integrated) (A3)
04 Proposed Water Supply (Zone Wise) (A3)
05 Tubewell Site Plan (A4)

Mathbaria

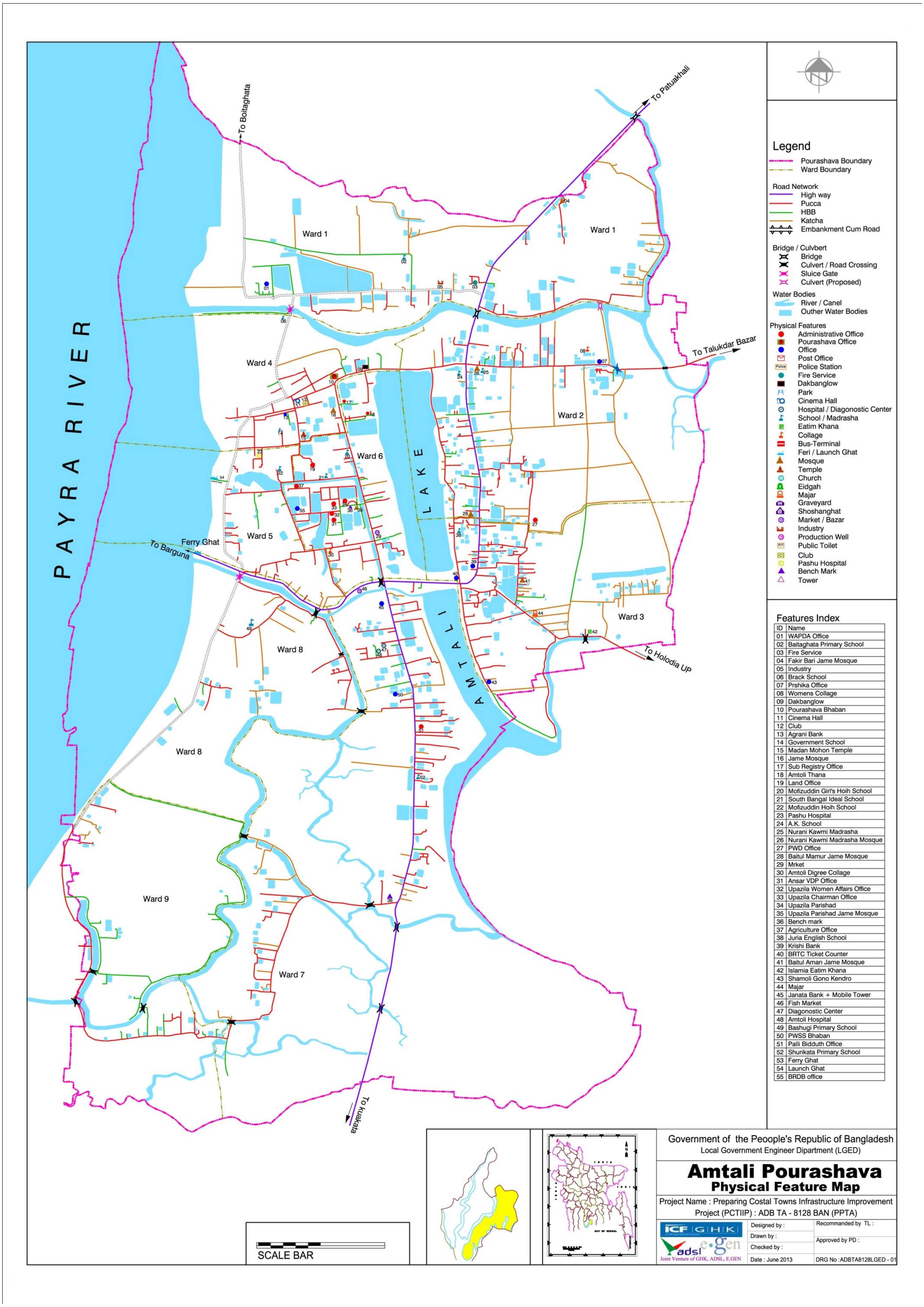
01 Physical Features Map (A3)
02 Proposed Water Supply (Integrated) (A3)
03 Surface Water Treatment Plant – Site Plan (A4)
04 Overhead Tank – Site Plan (A4)

Common Drawing

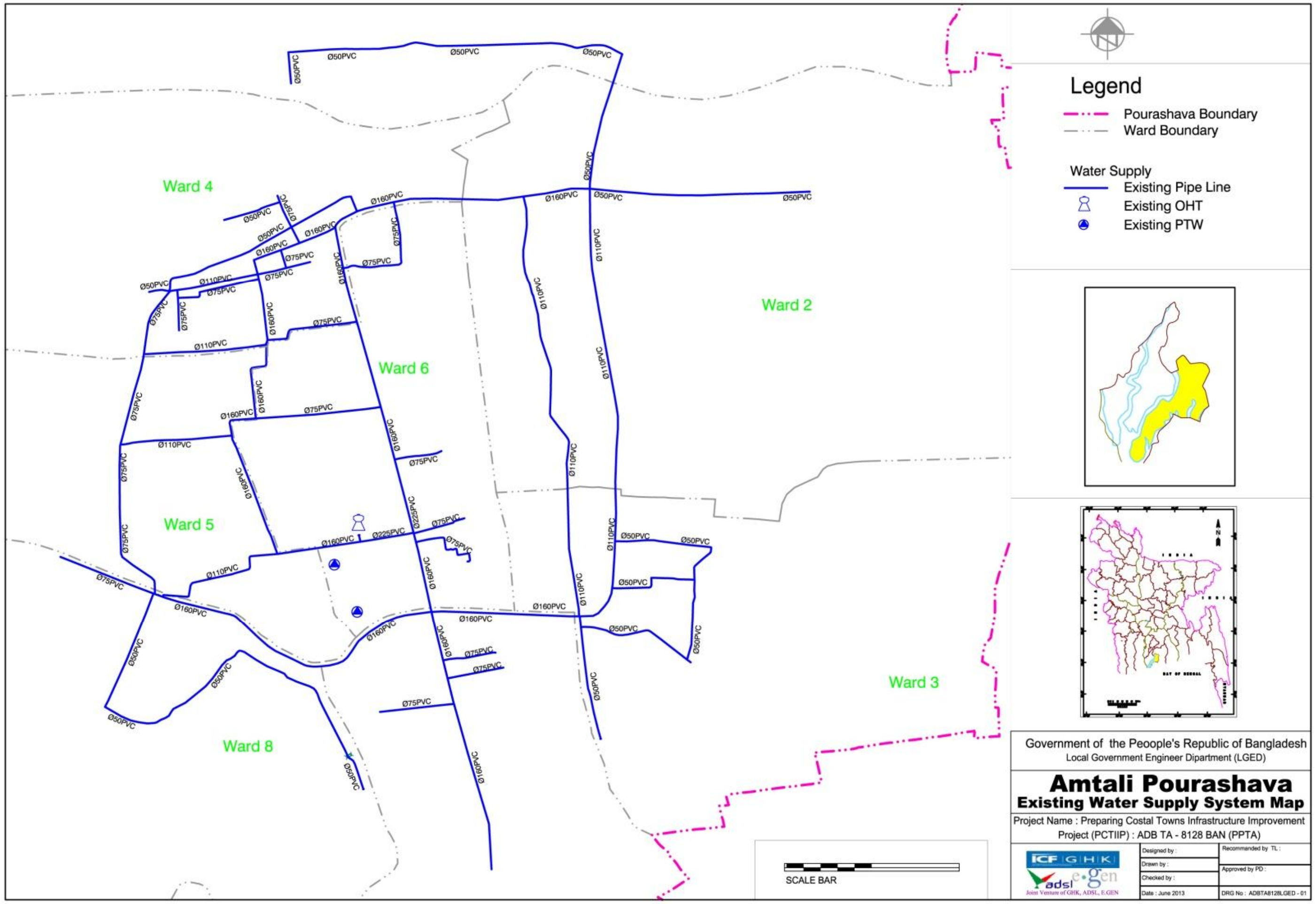
01 ProductionTubewell Design (A4)

Water Supply Drawings - Amtali

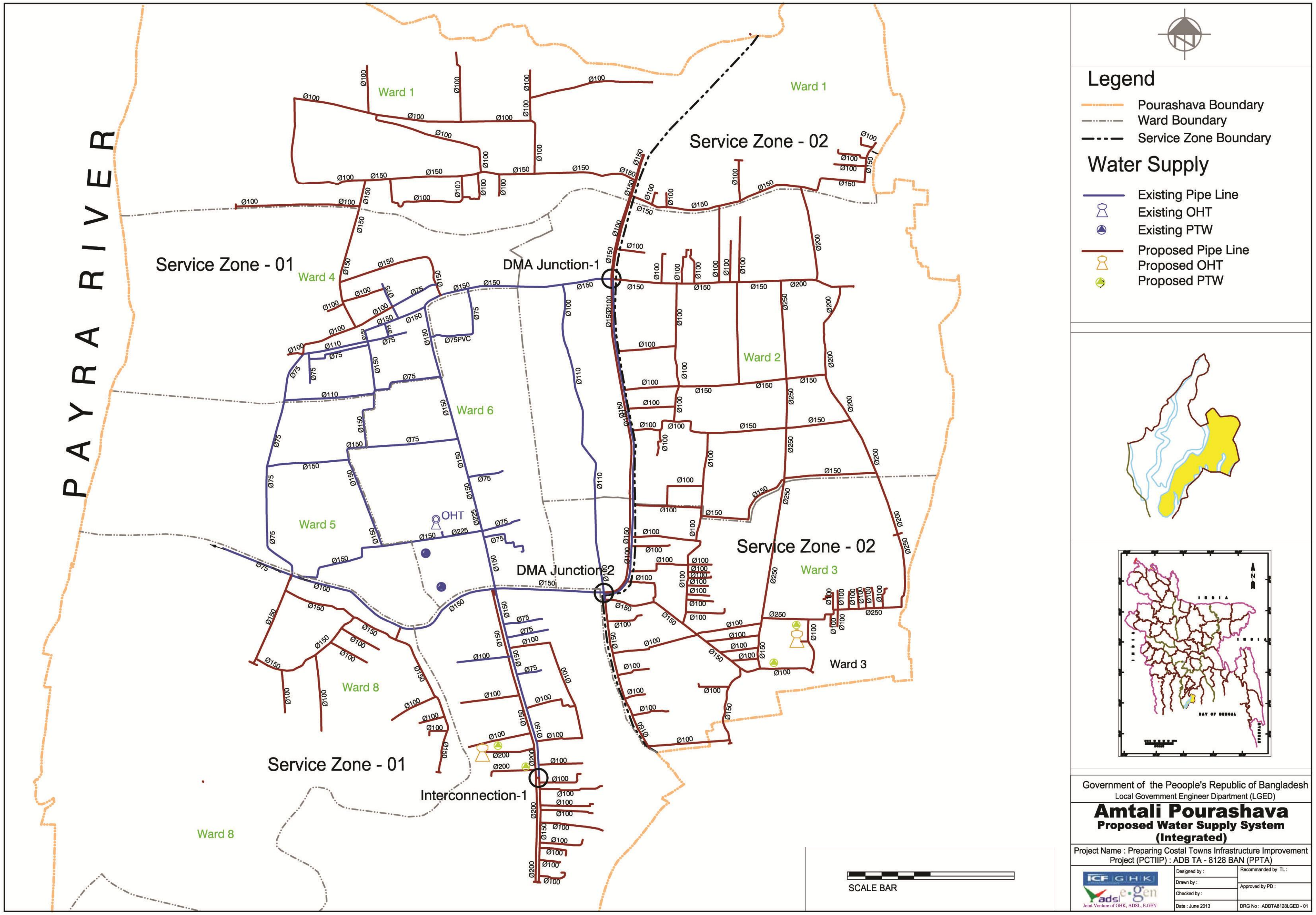
01 Physical Features Map (A3) - Amtali



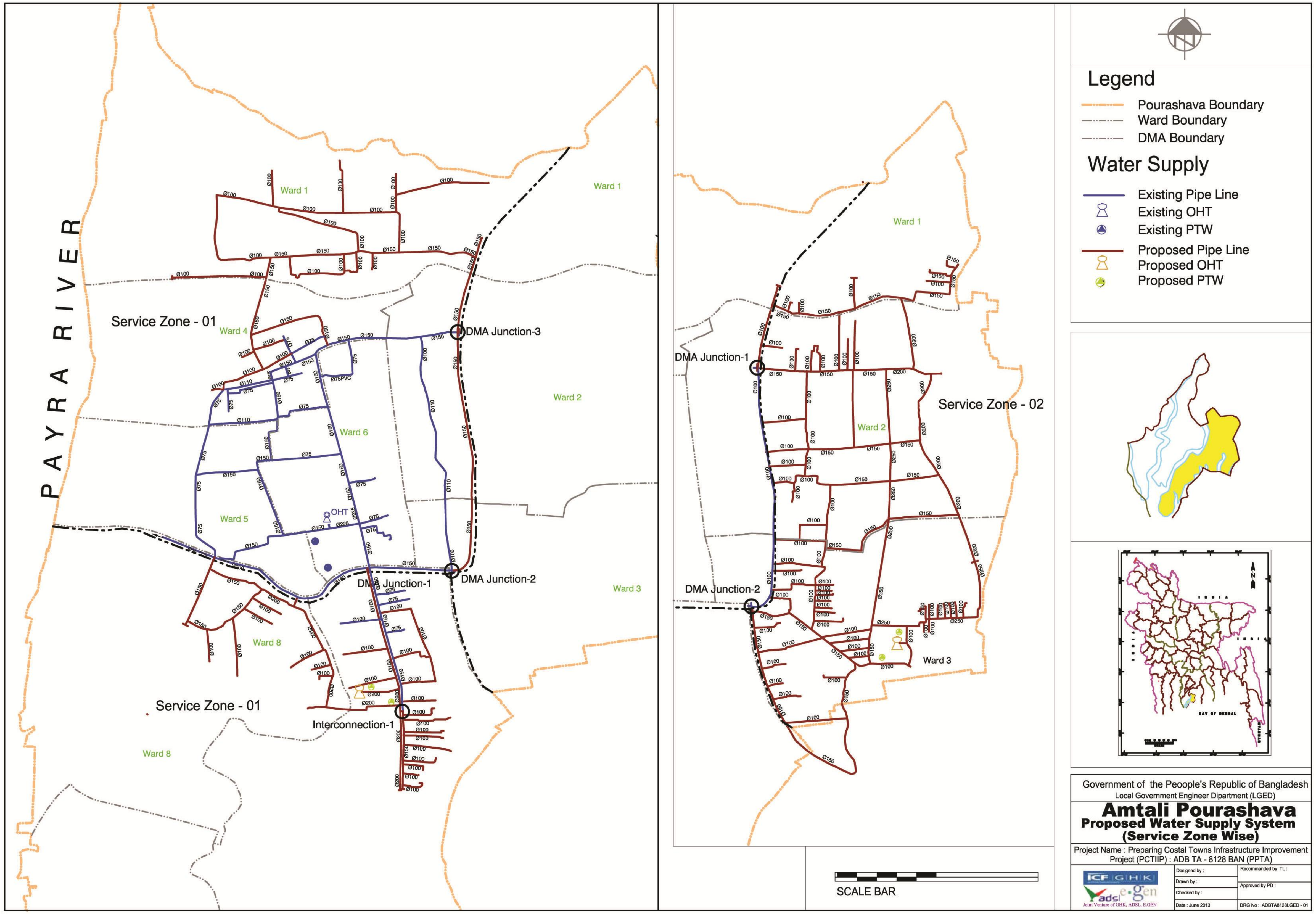
02 Existing Water Supply System Map (A4) – Amtali



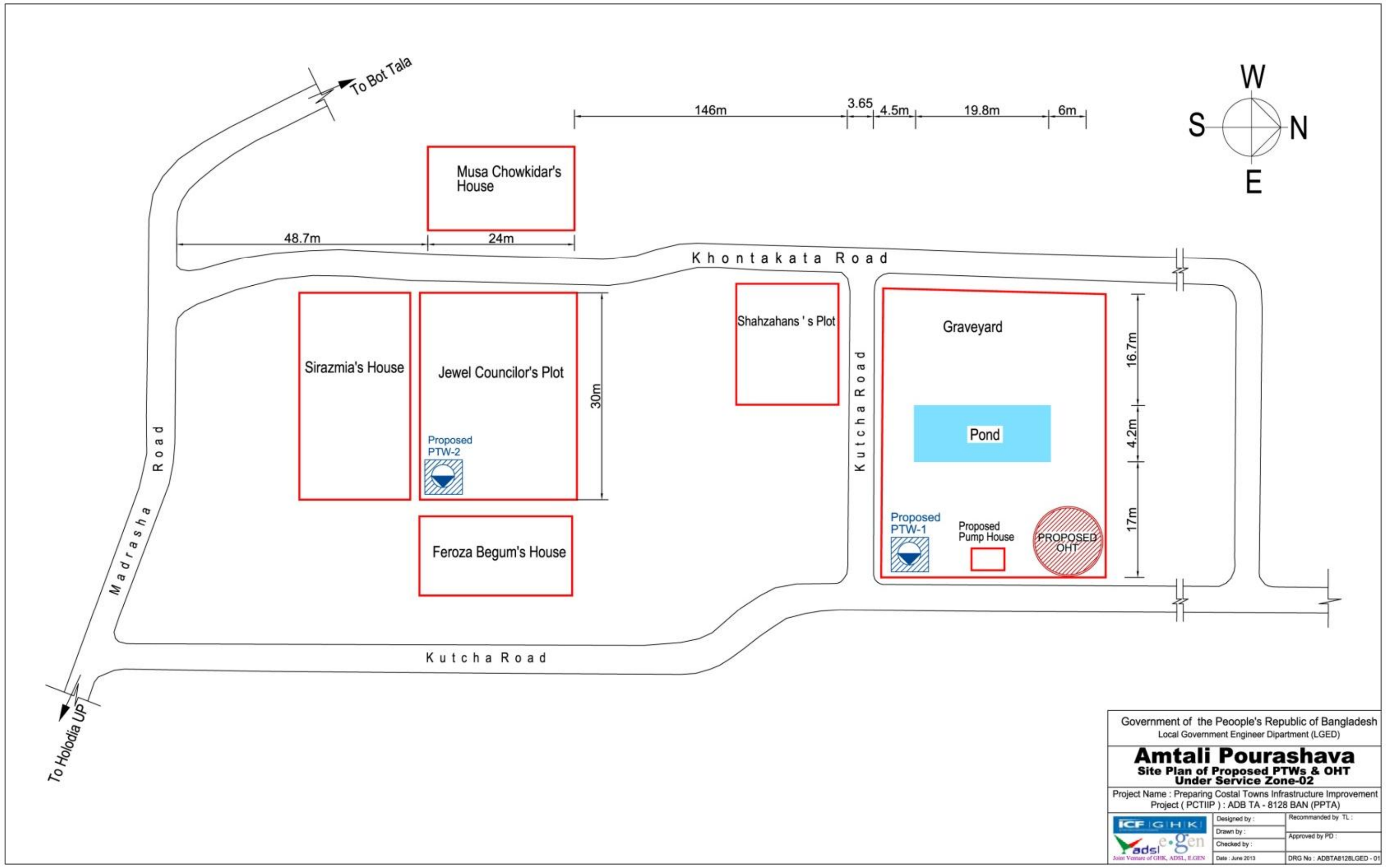
03 Proposed Water Supply (Integrated) (A3) – Amtali



04 Proposed Water Supply (Zone Wise) (A3) – Amtali

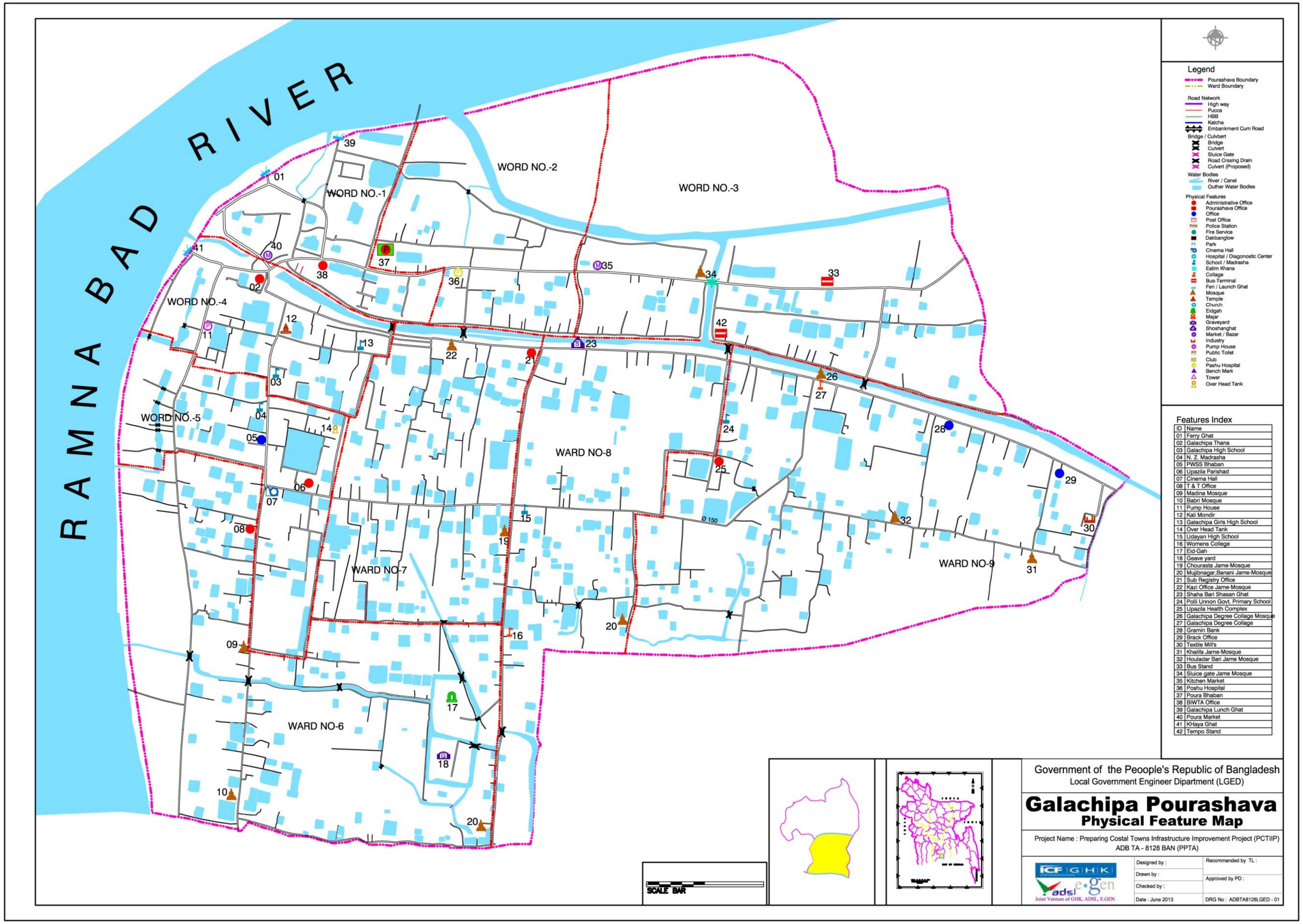


05 Site Plan – Zone 2 (A4) – Amtali

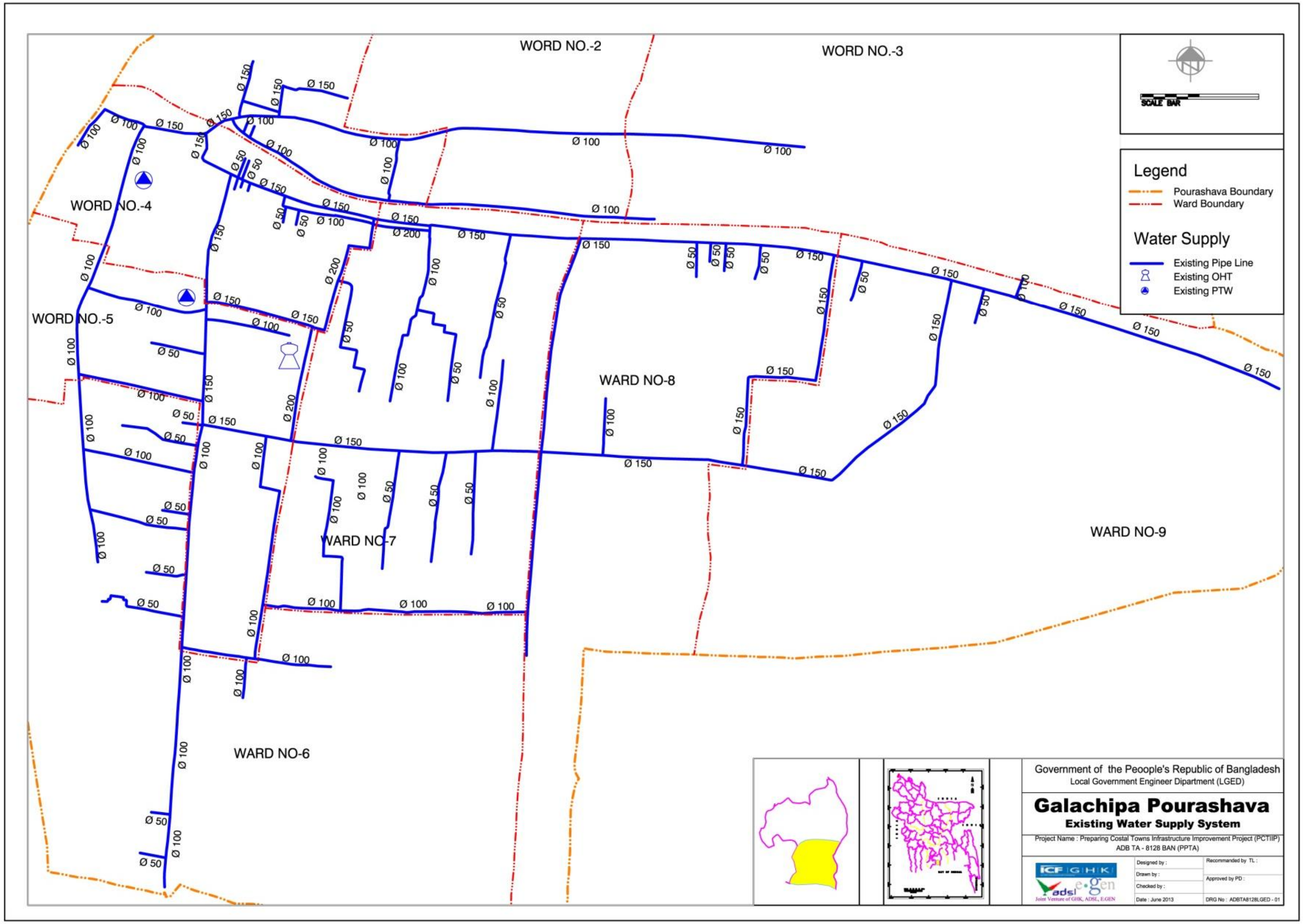


Water Supply Drawings - Galachipa

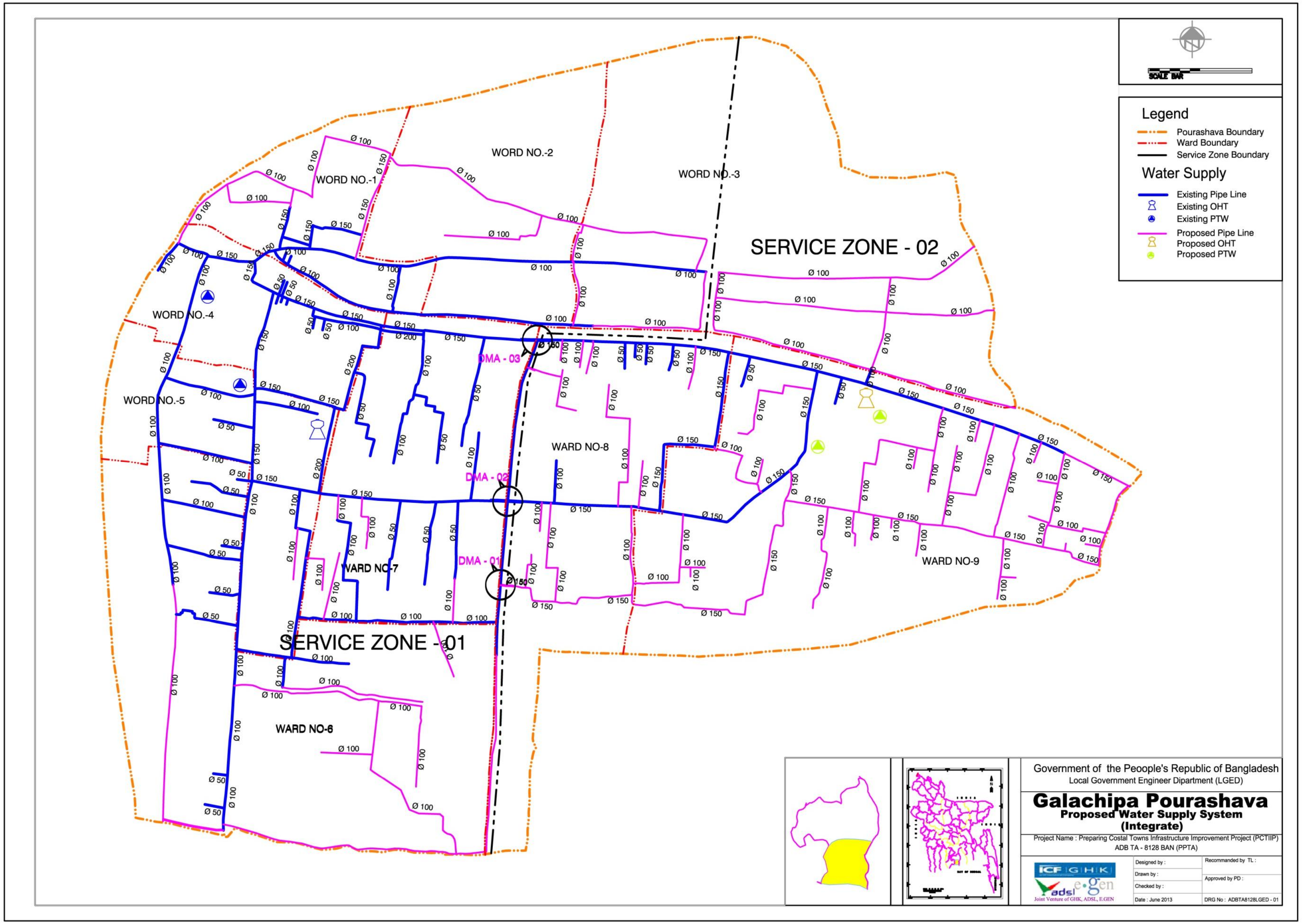
01 Physical Features Map (A3) - Galachipa



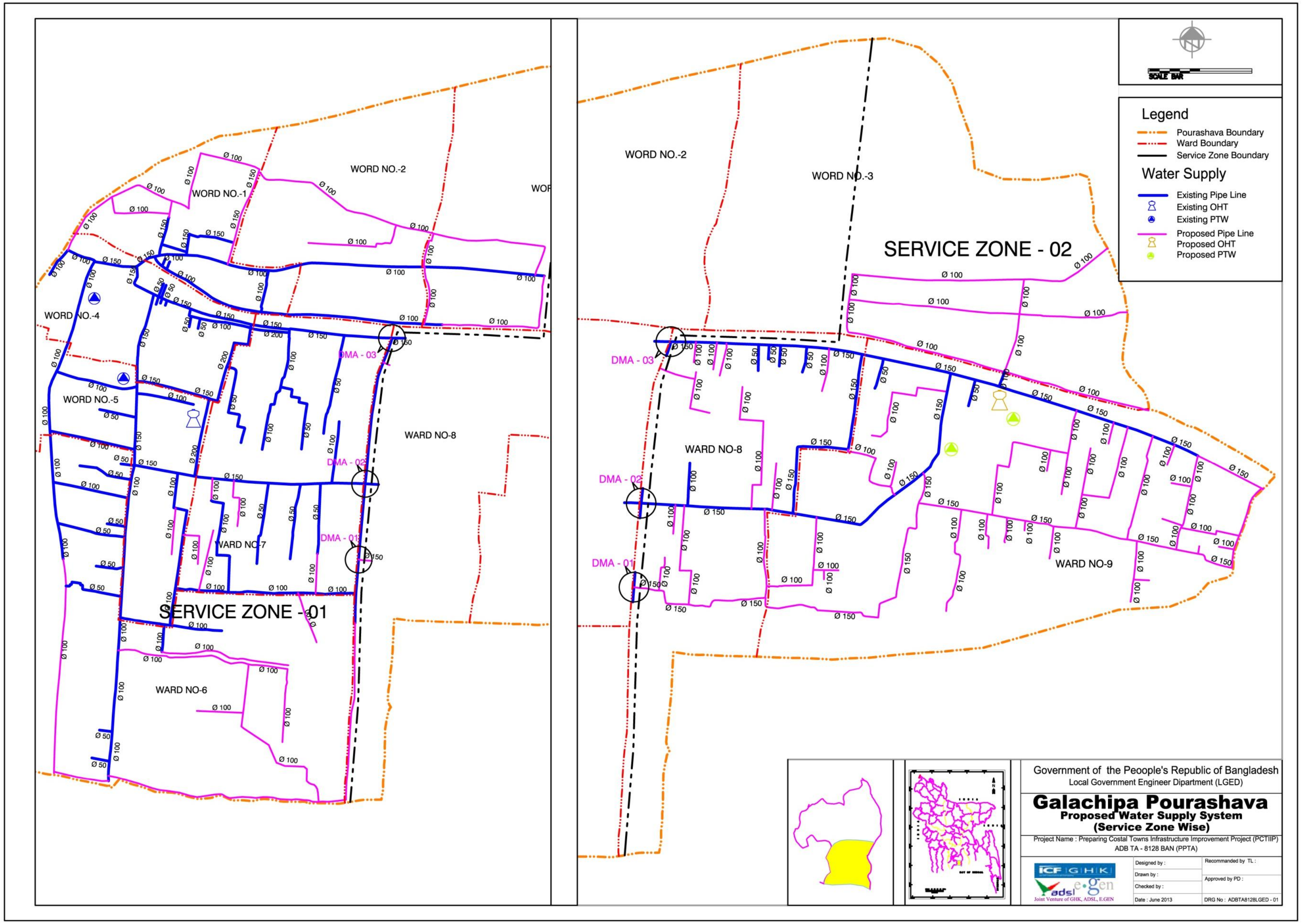
02 Existing Water Supply System Map (A4) – Galachipa



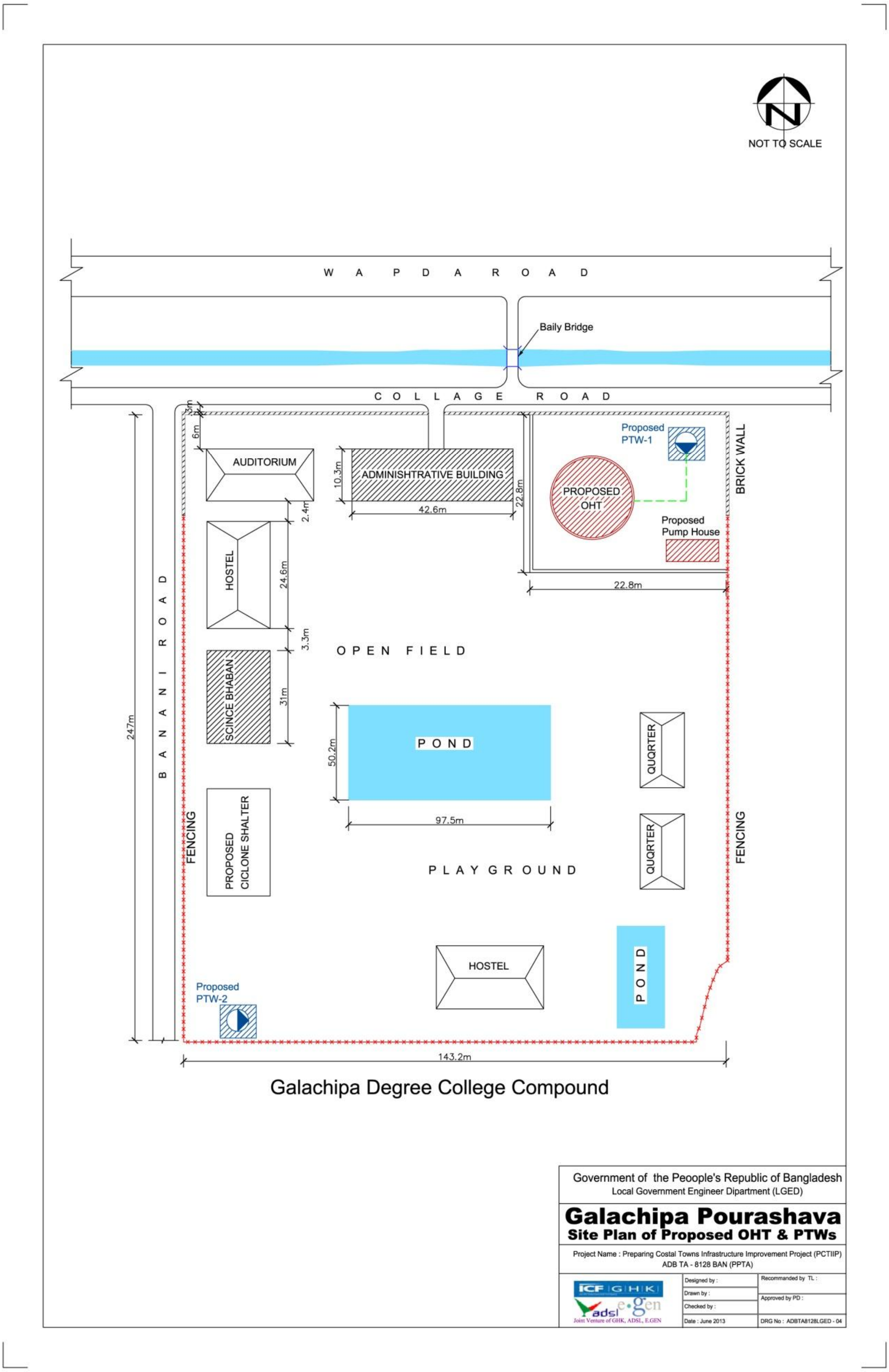
03 Proposed Water Supply (Integrated) (A3) – Galachipa



04 Proposed Water Supply (Zone Wise) (A3) – Galachipa

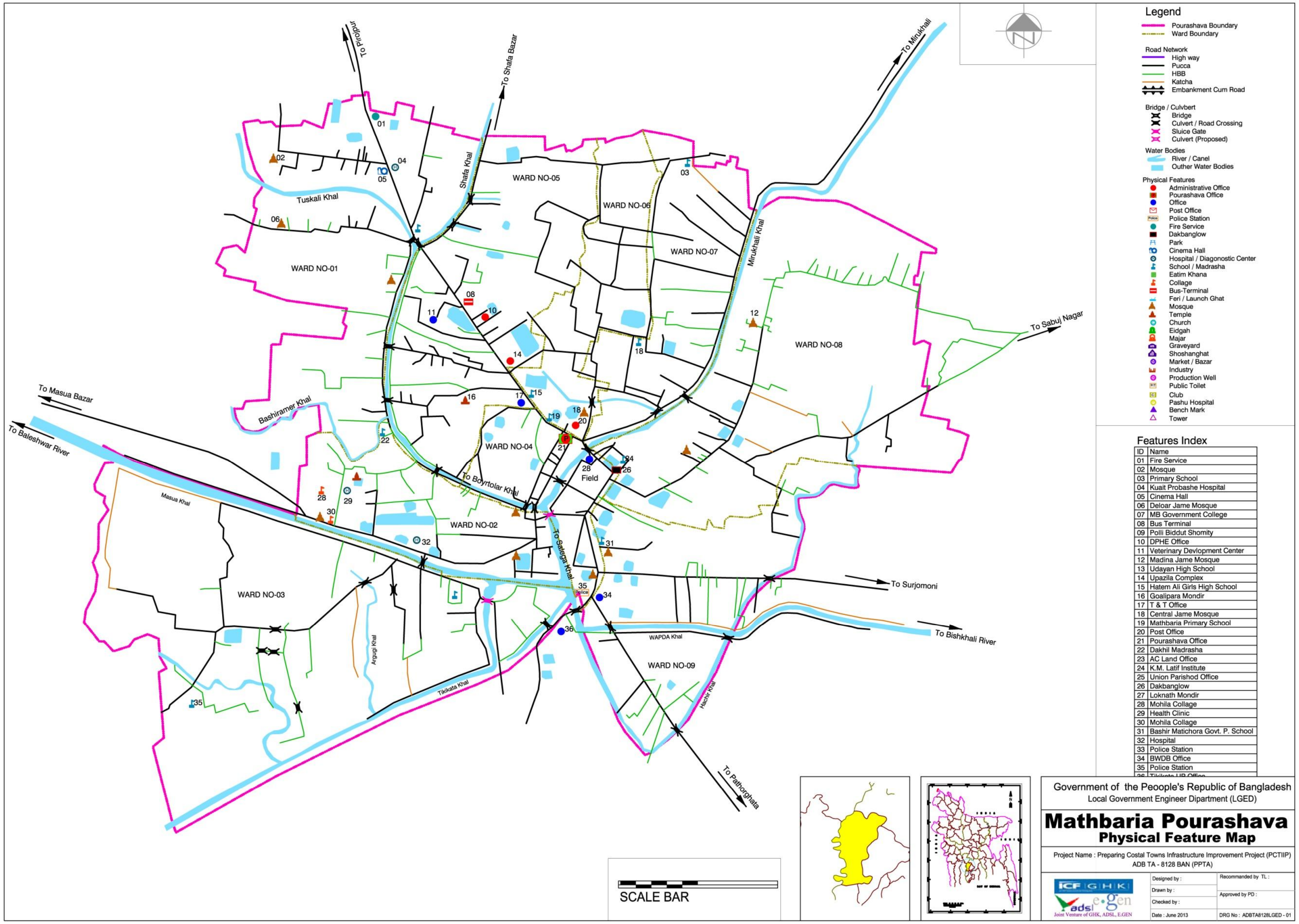


05 Tubewell Site Plan (A4) - Galachipa

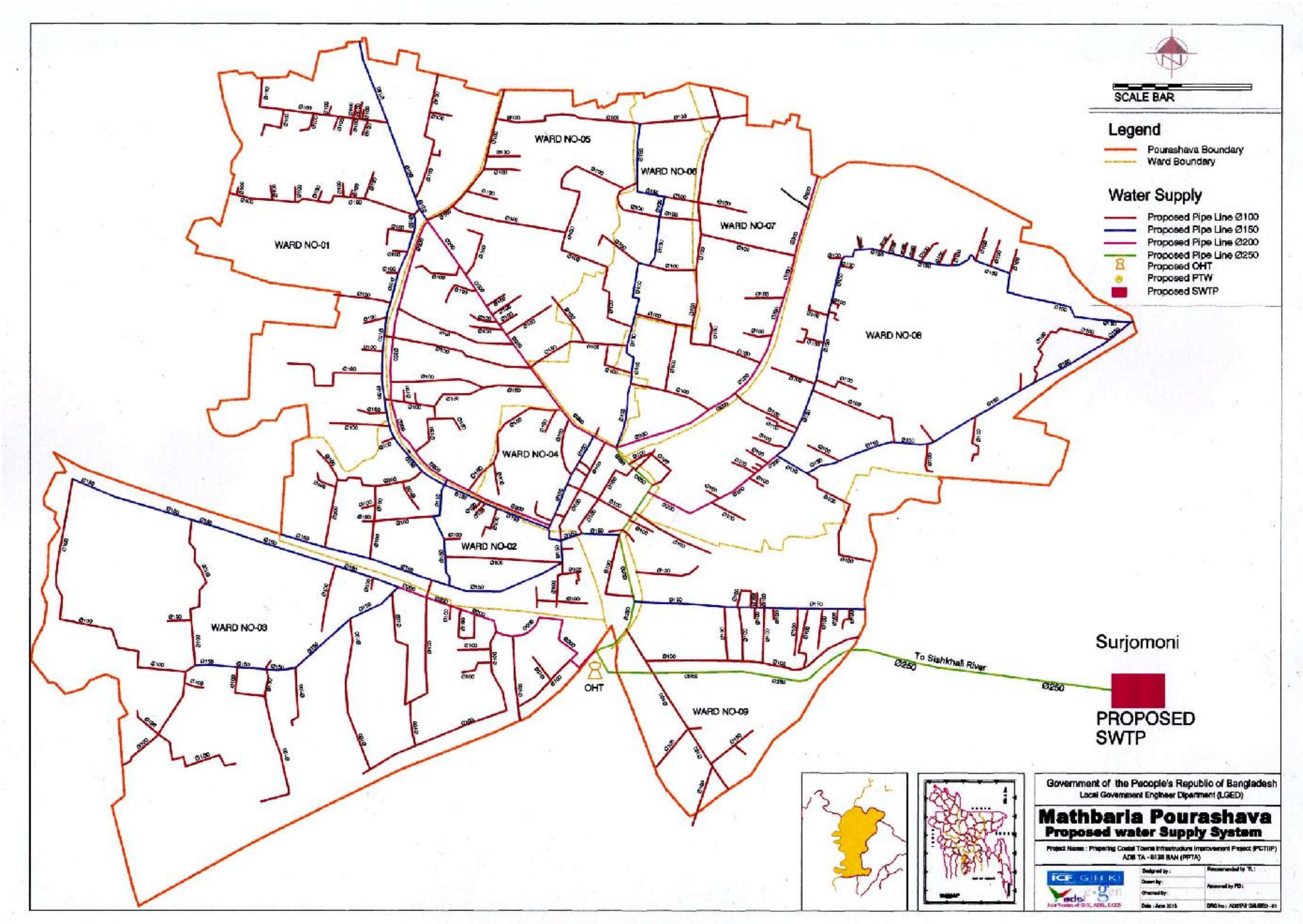


Water Supply Drawings – Mathbaria

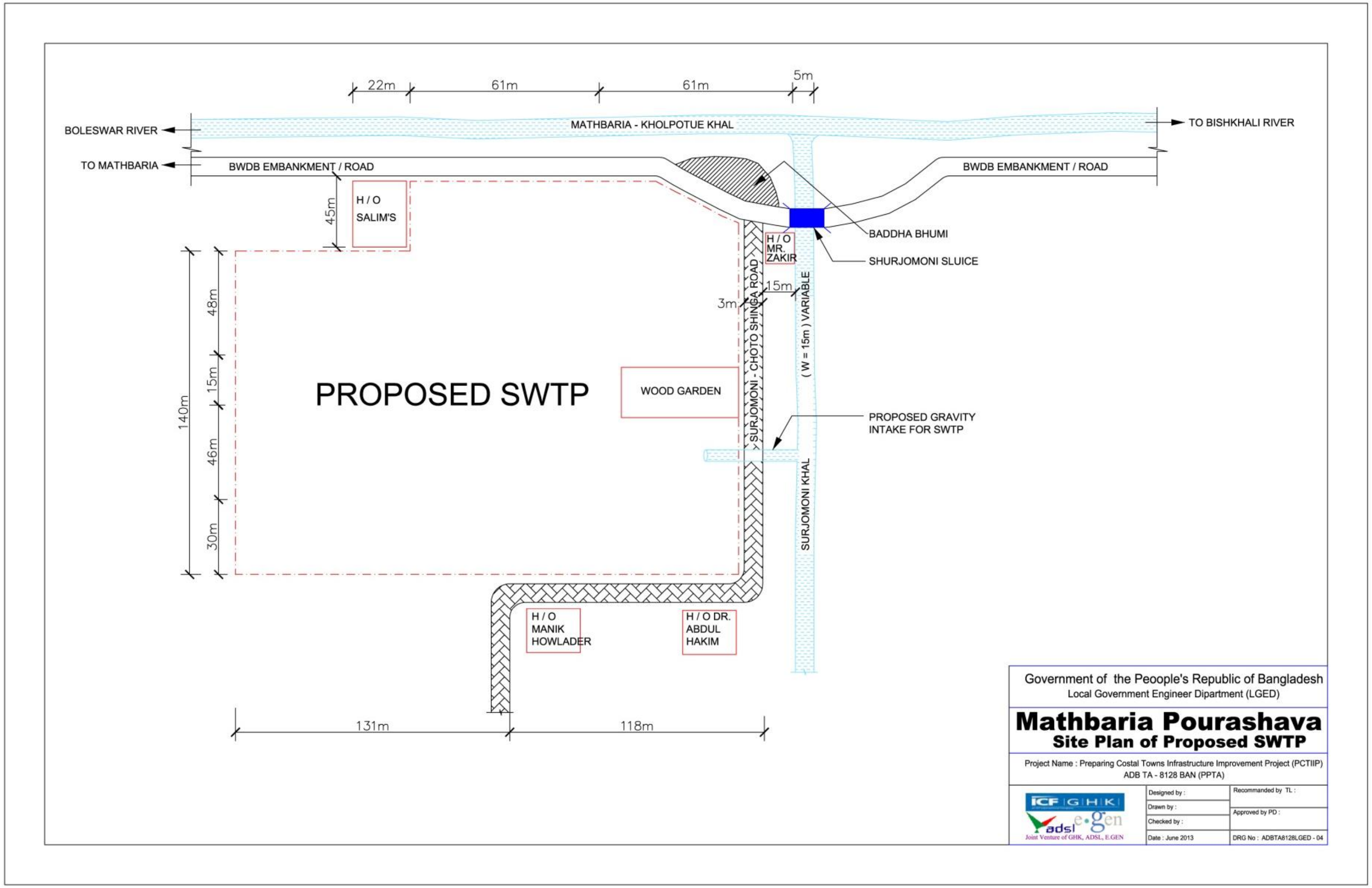
01 Physical Features Map (A3) - Mathbaria



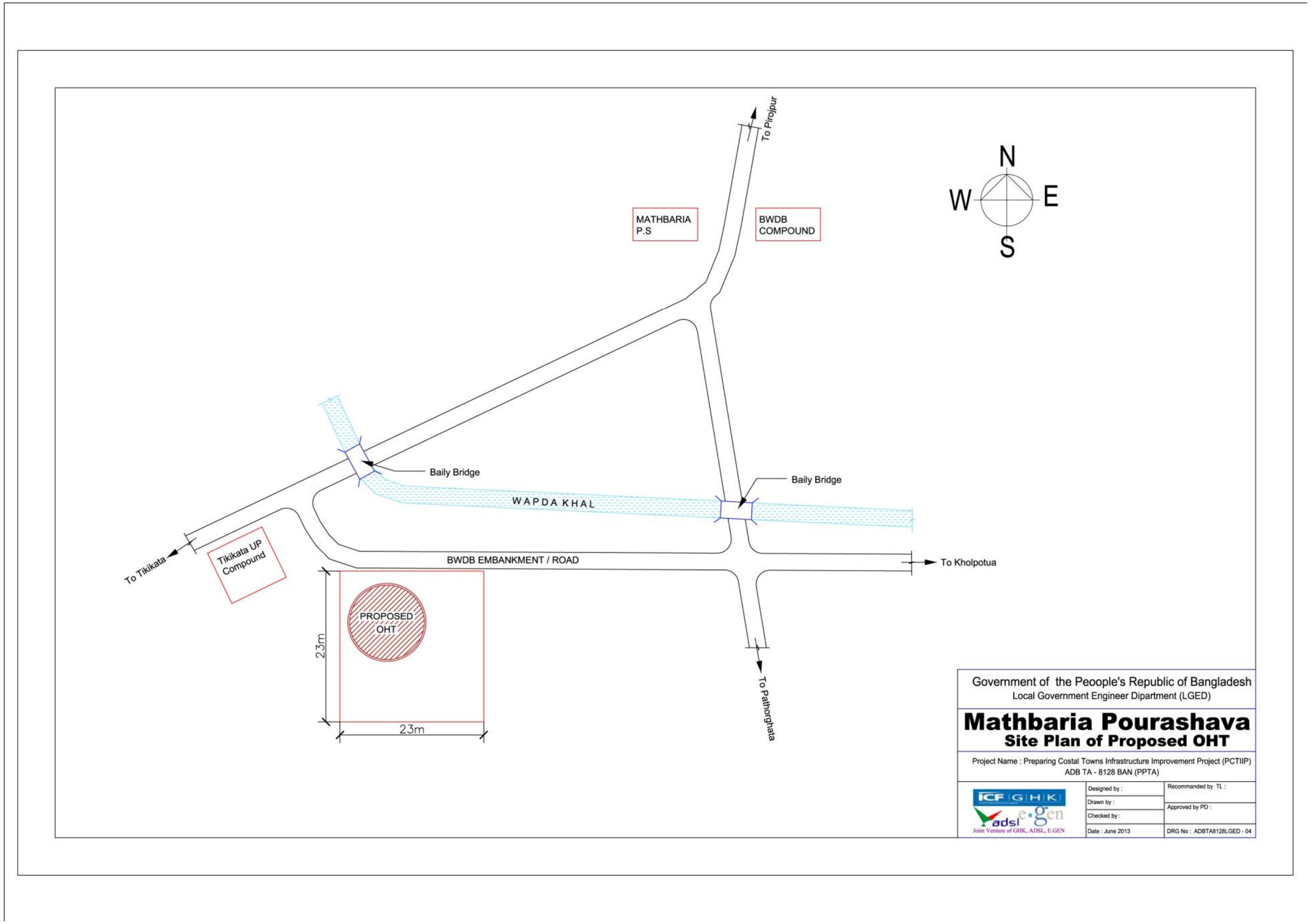
02 Proposed Water Supply (Integrated) (A3) – Mathbaria



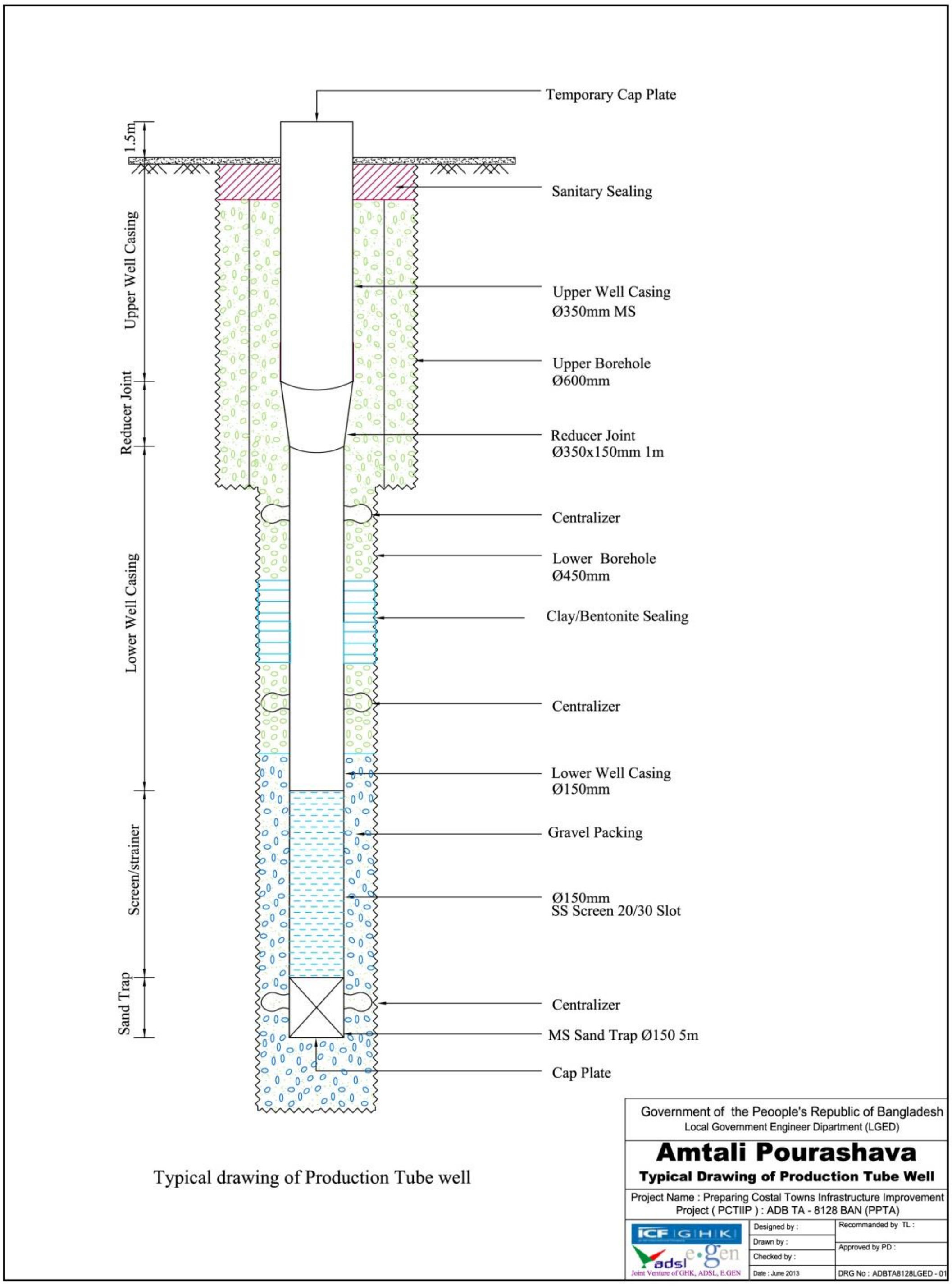
03 Surface Water Treatment Plant – Site Plan (A4) – Mathbaria



04 Overhead Tank – Site Plan (A4) – Mathbaria



01 ProductionTubewell Design (A4)



ANNEX D: WATER QUALITY LABORATORY EQUIPMENT

Requirement of Equipment, Spare Parts and Chemicals for Four Costal Zonal Laboratories (Khulna, Barishal, Noakhali and Gopalgonj)

SL No.	Name of Item	Quantity of each lab	Total	Rate (BDT)	Total Amount (BDT)
Equipment					
	Lemenea Air Flow	1	4	700,000	2,800,000
	BOD Tra (Including Incubator)	1	4	400,000	1,600,000
	P^H Meter bench top	2	8	200,000	1,600,000
	P^H Meter	2	8	50,000	400,000
	Magnetic stirrer with hot plate	1	4	150,000	600,000
	Turbidity Meter	1	4	150,000	600,000
	Refrigerator	1	4	150,000	600,000
	ION Meter with seven elctrods	1	4	600,000	2,400,000
	GPS Machine	1	4	50,000	200,000
	Projector Set	1	4	75,000	300,000
	Fax	1	4	30,000	120,000
	Laptop	1	4	75,000	300,000
	Photocopier Machine	1	4	350,000	1,400,000
	Computer (Brand)	2	8	120,000	960,000
	UPS 10 KVA 2 Hour Backup	1	4	500,000	2,000,000
	Fire Extinguisher	3	12	20,000	240,000
	Analytical Balance	2	8	200,000	1,600,000
	Rough Balance	2	8	75,000	1,200,000
	Multimeter	2	8	300,000	2,400,000
	Auto Clave	1	4	300,000	1,200,000
	Scanner	1	4	25,000	100,000
Spare Parts					0
	HCL (Arsenic)	2	8	90,000	720,000
	HCL (Magnasim)	2	8	90,000	720,000
	HCL (Iron)	2	8	90,000	720,000
	Quartz Cell	4	16	75,000	1,200,000
	VGA Tube set	2	8	20,000	160,000
	VGA Set for AS machine	1	4	700,000	2,800,000
Others					0
	Millpore Filter Paper for FC Test	10 Packet	40	10,000	400,000
	Standard Solution for AS	3	12	10,000	120,000
	Standard Solution for IRON	3	12	10,000	120,000
	Standard Solution for Manganese	3	12	10,000	120,000
	Standard Solution for K	3	12	10,000	120,000
	Total in BDT				**29,820,000**
	Total in USD @ BDT78/$				**382,308**

Source: DPHE.

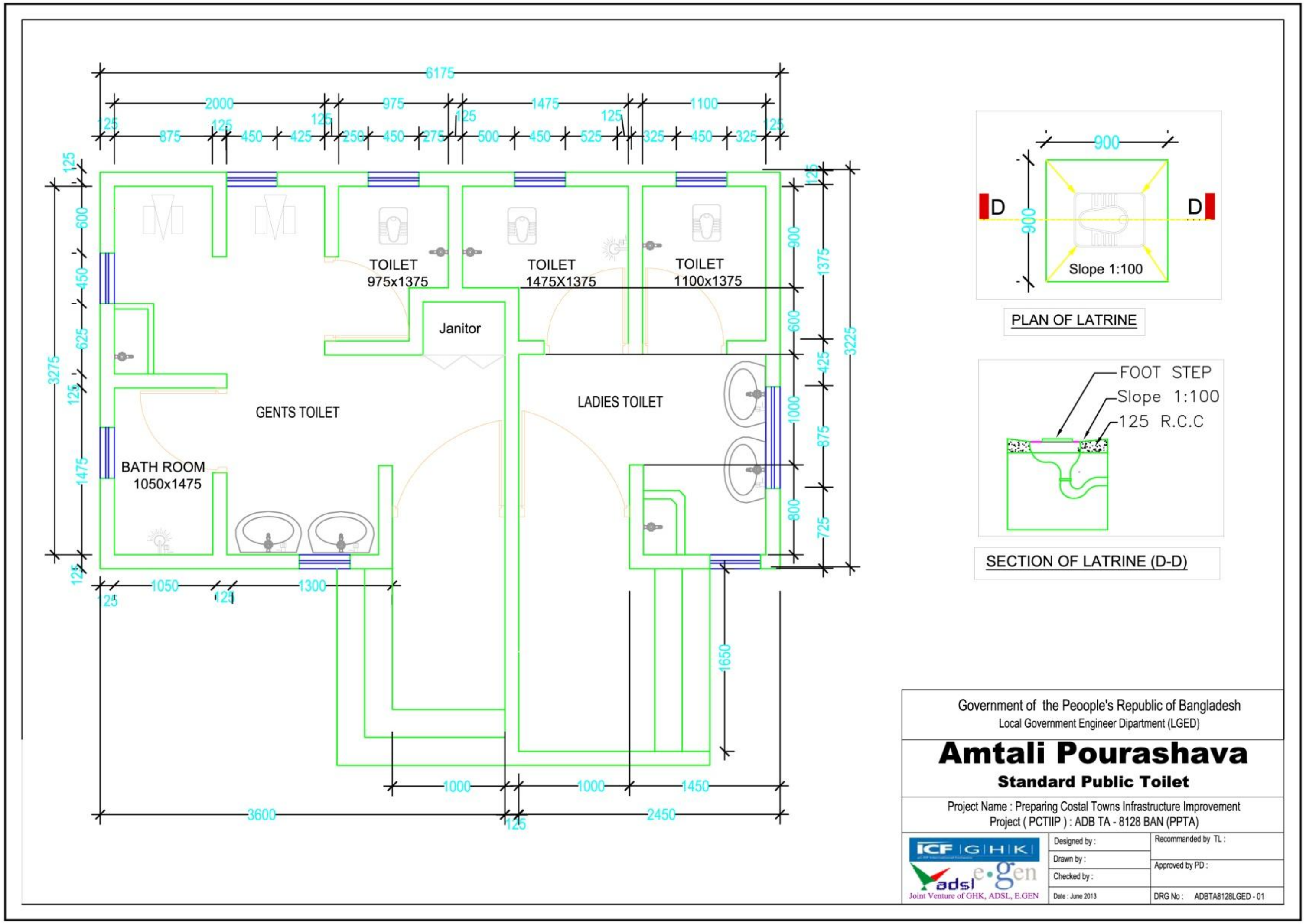
ANNEX E: SANITATION

Drawings (common to all pourshavas):

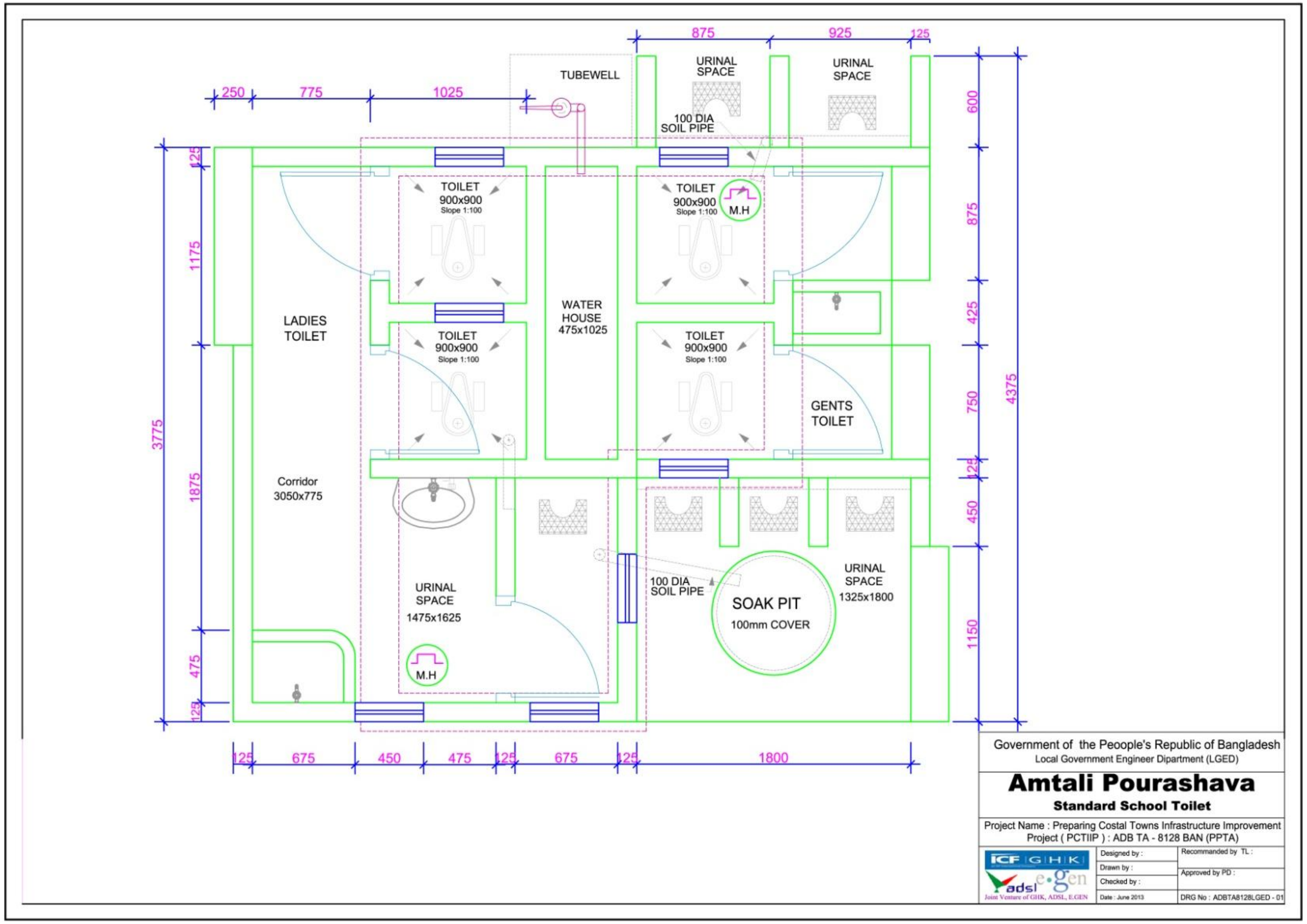
08 Public Toilet
09 School Toilet
10 Community Toilet

Interim Report – Sanitation Technologies
July 2013
Submitted to The Bill and Melinda Gates Foundation

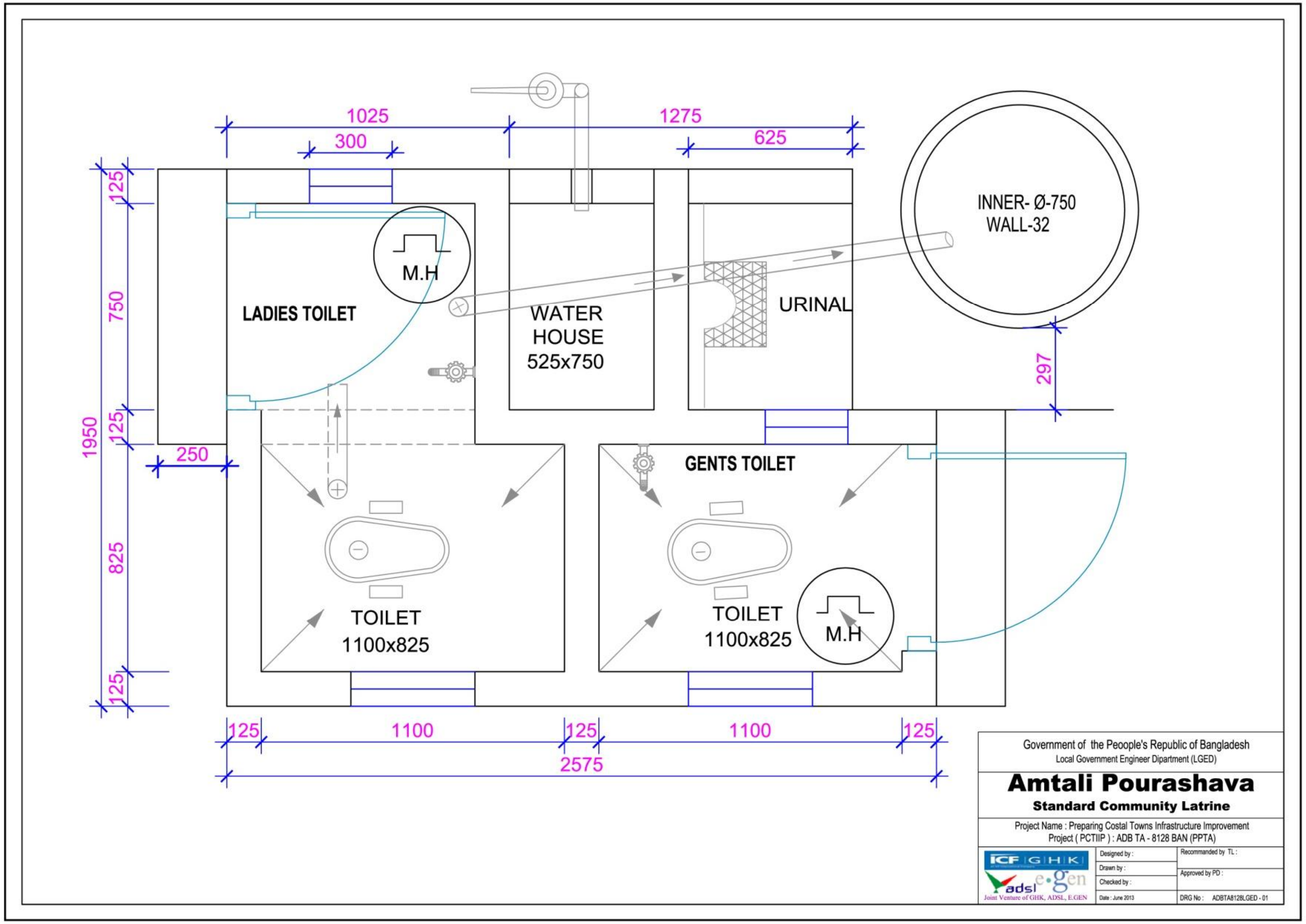
08 Public Toilet



09 School Toilet



10 Community Toilet



INTERIM REPORT – SANITATION TECHNOLOGIES

July 2013

Submitted to The Bill and Melinda Gates Foundation

Contract no. 23596

Support in Sanitation Planning for ADB-PPTA (TA-8128 BAN) in Preparing Coastal Town Infrastructure Improvement Project

Bangladesh

Interim Report – Sanitation technologies
July,2013

Towns visited:
Pirojpur
Mathbaria
Amtali
Galachipa

Submitted to:

The Bill and Melinda Gates Foundation

GLOSSARY OF TERMS

POURASHAVA – MUNICIPALITY
KHAL – CANAL

ACRONYMS

ABR	-	Anaerobic Baffled Reactor
ADB	-	Asian Development Bank
AF	-	Anaerobic Filter
BDT	-	Bangladeshi Taka
BGD	-	Biogas digester
BOD	-	Biological Oxygen Demand
CDTA	-	Capacity Development Technical Assistance
COD	-	Chemical Oxygen Demand
Cu.m		Cubic metre
DEWATS	-	Decentralized Wastewater Treatment System
DPHE	-	Department of Public Health and Engineering
GWL	-	Ground Water Level
HH	-	Household
HPGF	-	Horizontal Planted Gravel Filter
HRT	-	Hydraulic Retention Time
LGED	-	Local Government Engineering Department
LPCD	-	Litres per capita per day
PCTIIP	-	Preparation of Coastal Towns Infrastructure Improvement Project
PPTA	-	Project Preparatory Technical Assistance
SoR	-	Schedule of Rates
Sq.m		square metre
ST	-	Settler
TN	-	Total Nitrogen
TOR	-	Terms of Reference
TSS	-	Total Suspended Solids
USD	-	United States Dollar
WSP	-	Waste Stabilisation Pond

In this document 1USD = 70 BDT

Contents

EXECUTIVE SUMMARY

The Asian Development Bank (ADB) under the proposed Coastal Towns Infrastructure Improvement Project (CTIIP) is assisting the Government of Bangladesh through Project Preparatory Technical Assistance (PPTA) for four towns in coastal areas of Bangladesh i.e. Pirojpur, Mathbaria, Amtali and Galachipa focussing on building climate resilient infrastructure and natural disaster preparedness in the towns.

The Bill and Melinda Gates Foundation's Global Development Program has collaborated with ADB to promote sustainable on-site and decentralized sanitation options under CTIIP. The Foundation has engaged Mr. Rajesh Pai, decentralised sanitation expert, to explore possibilities of introducing decentralised sanitation alternatives in coastal areas of Bangladesh. Based on a detailed sanitation situation assessment in the selected coastal towns appropriate decentralised wastewater collection, conveyance, treatment and disposal solutions that are more adaptive to climate changes have been proposed.

The PPTA towns are only using basic sanitation systems like single pit, twin pit and septic tanks for wastewater collection. The systems are vulnerable to climatic conditions in coastal areas. Unscientific fecal sludge/septage disposal poses a potential health threat due to contamination of surface/ground water sources and immediate environments. Considering the local site conditions in PPTA towns, socio-economic profile, capacities of pourashava to implement sanitation interventions, awareness and cultural acceptability to different sanitation technologies, detailed selection criterion have been developed. This forms the basis of selection of various technologies most appropriate in coastal areas of Bangladesh. Various sanitation technologies across on-site and off-site (decentralised) applications and fecal sludge/septage treatment systems are identified that can be applied in coastal areas. The recommendations include improving sanitation systems in practice and provision of new technologies for wastewater management.

The treatment technologies are described in detail in terms of its design, areas of application, O&M requirements, climate adaptation measures for efficient functioning of treatment systems, capital costs and it's, pros and cons. Various combinations of treatment modules are proposed that are applicable for diverse land uses in PPTA towns.

It is proposed to prepare comprehensive sanitation plan for each PPTA town to address sanitation issues in stress areas. An overall approach and methodology to prepare the same has been presented along with the financials.

The broad cost estimates for provision of sanitary infrastructure in public domain (public/community toilets, public buildings, institutions like schools, hospitals etc.) and preparing a detailed sanitation plan for all the PPTA towns combined is approx. 2,921,000 USD.

1. INTRODUCTION

Bangladesh is home to 150 million people (BBS 2011), with 38 .1 million residing in the low-lying coastal delta of which 8.6 million reside in urban areas. These regions are highly vulnerable to severe weather events like flooding, tropical cyclones and storm/tidal surges. These calamities damage the building structures, infrastructure facilities like water supply systems, sanitation facilities, roads and boat-docking stations. Climate change impact is expected to result in an average sea level rise of about 0.45m by 2050—this could make 10-15% of the country extremely vulnerable to floods, and dislocate around 35 million people from coastal towns and rural areas (ADB 2013). Sea level rise will affect the surface and ground water resources adversely. Floods and water logging will affect the sanitation and health situation of the region.

The Asian Development Bank (ADB) is assisting the Government of Bangladesh in building climate resilient infrastructure in the coastal towns of the country and helping the local governments in development and operation of basic needs infrastructure services. The proposed ADB-assisted project is known as the Coastal Towns Infrastructure Improvement Project (CTIIP). The key themes of the project are: Climate change resilience and natural disaster preparedness, in poor and vulnerable coastal towns of Bangladesh (ADB 2013). The project scope includes implementation of improved infrastructure for delivering basic needs services in priority coastal towns of Bangladesh. The infrastructure design should be able to mitigate effects from natural disasters and climate change.

The project interventions envisages the following outcomes (ADB 2013):

i. Improved municipal infrastructure with climate-resilient designs, particularly for water supply, sanitation and drainage;

ii. Strengthened local governance and capacity for sustainable service delivery and urban planning;

iii. Awareness raising and behavioural change in climate change adaptation and disaster preparedness, water conservation and hygiene activities; and

iv. Project management and administrative support. The project design will incorporate the role of women in water supply and sanitation, and target the poor.

With limited resources and time frame of PPTA, the towns as selected under the CDTA-7890 (Pirojpur, Amtali and Galachipa) have been considered. The fourth town i.e. Mathbaria has been selected as it falls in the same region (Barisal division) for ease in implementation of the PPTA.

The Bill and Melinda Gates Foundation's Global Development Program is working with partners in developing countries on improving people's health and creating opportunities to alleviate themselves from poverty and hunger. The newest program area under Global Development Program is Water, Sanitation and Hygiene, which focuses on sanitation solutions that works for the poor. The Foundation and ADB has collaborated with each other to promote sustainable on-site and decentralized sanitation options particularly in the poor regions of Asia to improve and safeguard public health. The purpose of collaboration is to create platforms for implementation of innovative technologies developed as part of foundation's R&D investments in improved emptying and treatment technologies and support from ADB for up scaling of successful approaches throughout the Asia region. In this context, the CTIIP has been selected as one of the project to team up for introducing innovative decentralized sanitation technologies in the selected towns.

The Foundation has engaged Mr. Rajesh Pai, Director (Planning and Infrastructure), CDD Society, Bangalore, India to explore possibilities of introducing decentralised sanitation alternatives in coastal areas of Bangladesh. Mr. Pai has more than 13 years of experience in designing and implementing decentralized sanitation projects (mainly with respect to toilet provision and decentralized wastewater treatment) in Asian, South East Asian and African Countries. Team involving Mr. Rahul Sachdeva (Environmental Planner) and Ms. Namrata Ginoya (Climate Change Professional) assists him. The key objective of the consultancy assignment is to support the PPTA in preparation of detailed investment plan for better sanitation facilities with focus on decentralized and on-site sanitation options in coastal areas of Bangladesh.

1.1 Scope of Work

Under the CTIIP, four towns (hereafter referred to as PPTA towns) have been selected for further studies and implementation. Each town has a sanitation component. The scope of work for the consultant is as follows: (i.) Plan for better sanitation facilities with focus on decentralized and on-site sanitation options for the selected towns, (ii.) Advise on the investment plan for the same.

1.2 Objectives

The objectives of the project are as follows:

i. Appraise the current sanitation status of the towns
ii. Advise on appropriate and affordable on-site sanitation facilities
iii. Check possibilities of introducing decentralized sanitation facilities
iv. Advise on costs of relevant components
v. Advise on best practices for financing
vi. Advise on developing public promotion campaigns for sanitation
vii. Advise on preparation of overall sanitation strategy for the coastal region

1.3 Deliverables

Interim report with following information:

i. Information on design of existing sanitation facilities with success and failures
ii. Appraisal report on the current status of sanitation in coastal belt
iii. Recommendation of appropriate technical solution for appropriate and affordable on-site and decentralized sanitation facilities
iv. Estimated cost for relevant components

Final report with:

i. Finalized information submitted in the interim report
ii. Strategies on public promotion campaigns for sanitation
iii. Strategies on best practices for financing decentralized and on-site sanitation facilities
iv. Advise on preparation of overall sanitation strategy for the coastal region

<u>Contents of this report:</u>

The situation analysis of sanitation sector in each of the PPTA towns has been conducted and the findings are presented in interim report. However, this report specifically focuses on technical solutions recommended for PPTA towns, application of selected technologies in various landuse and related cost estimates

2. SANITATION TECHNOLOGY CHOICE

After detailed analysis of the sanitation issues from technical, institutional, financial and socio-economic perspectives, this section will focus on technical options for improvements in sanitation sector.

2.1 Understanding sanitation technologies

The sanitation systems have to be selected to address the complete chain of waste management including collection, conveyance, treatment and safe disposal/reuse of sewage (black water), sullage (grey water) and fecal sludge/septage. The systems can be either off-site or on-site.

2.1.1 Off-site systems

Off-site sanitation system includes collection and conveyance of sewage and sullage to another location away from point of generation for treatment, disposal or possible reuse. It can be classified into two main categories: decentralised and centralised. Decentralised system includes collection and treatment of wastewater from small clusters whereas; systems serving several clusters at city level are termed as centralized systems.
Centralised systems require huge amount of water for smooth conveyance. Enormous investments are needed for laying of extensive sewer network, installation of treatment plant and its maintenance. The treatment systems are large in size, energy intensive, requires skilled labour for operations and maintenance.

2.1.2 On-site systems

On-site sanitation systems aim to contain human excreta at the point of generation. It can be classified into two main categories: wet systems, which require water for flushing and are connected to a leach pit or septic tank. On the other hand, dry systems do not require any water for flushing. The systems are designed to separate feces and urine and reuse of treated excreta.
The wet systems involve collection of waste in a pit or tank for further treatment and disposal in a pre-defined place. It is a preferred option where water availability or use is limited or in towns which do not have a sewer network or where a sewer network is not feasible. Waste from pits and tanks is collected and transported to a treatment facility for scientific treatment and disposal.
On site sanitation, systems are less capital intensive and do not require highly skilled labour. These systems are easy to maintain and do not require energy for operations.

2.1.3 Fecal sludge and septage management

Fecal sludge is the semi-solid settled contents of pit latrines while septage is the partially digested solid matter in the septic tank. The pits/tanks require regular desludging. The sludge and septage is either removed manually or pumped out mechanically. The sludge is then transported to a designated facility for further treatment and disposal.

2.2 Sanitation Technology Options

In order to address the sanitation needs in the PPTA towns specific sanitation technologies have been identified for on-site, off-site (decentralised) sanitation and fecal sludge treatment based on the parameters mention below and consultations with the pourashavas.

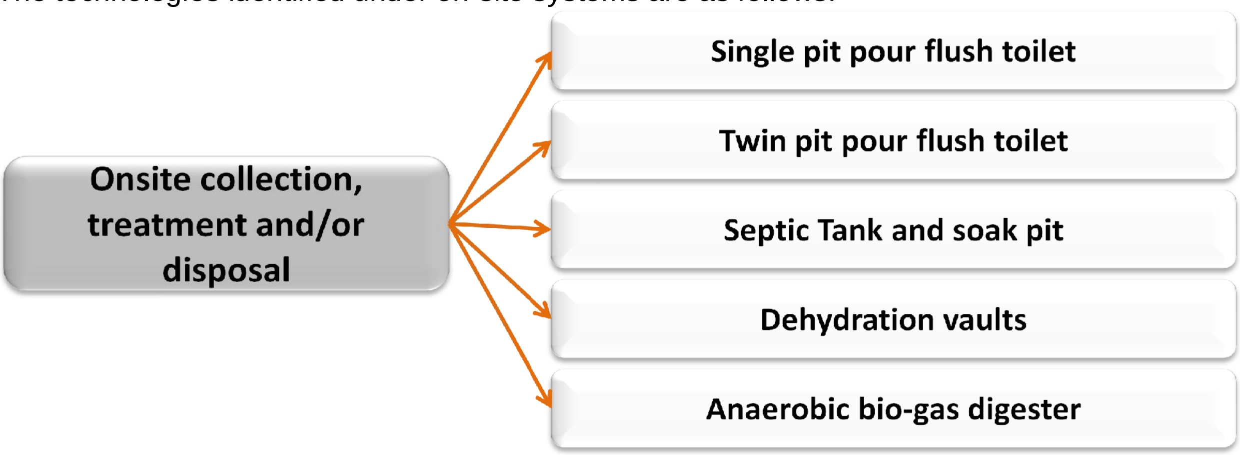
- The socio economic profile of the town
- Pourashavas operating budget, exposure to and acceptability of various sanitation technologies
- Awareness and cultural acceptability of the community about different sanitation technologies
- Environmental pollution
- Local site conditions of PPTA towns

As the Pourashavas and the residents of the towns are only exposed to basic systems like single pit, twin pit and septic tanks; sophisticated systems requiring large capital investment, high maintenance cost, skilled manpower for operations and high-energy use have not been selected.

Climate adaptation measures have been suggested for the identified technologies mainly to address the increased adverse impacts of cyclones, floods and sea level rise. The implementation of these suggested measures will help sanitary infrastructure to be more resilient to the climatic changes in PPTA towns. The measures will address the issues associated with heavy rains and strong winds during cyclones, seasonal floods and high ground water table.

2.2.1 Technologies for on-site collection, treatment and/or disposal:

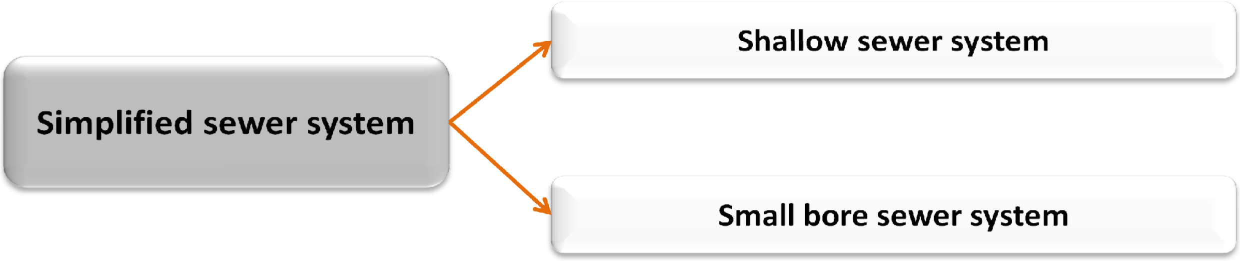
The technologies identified under on-site systems are as follows:



2.2.2 Technologies for decentralised treatment system:

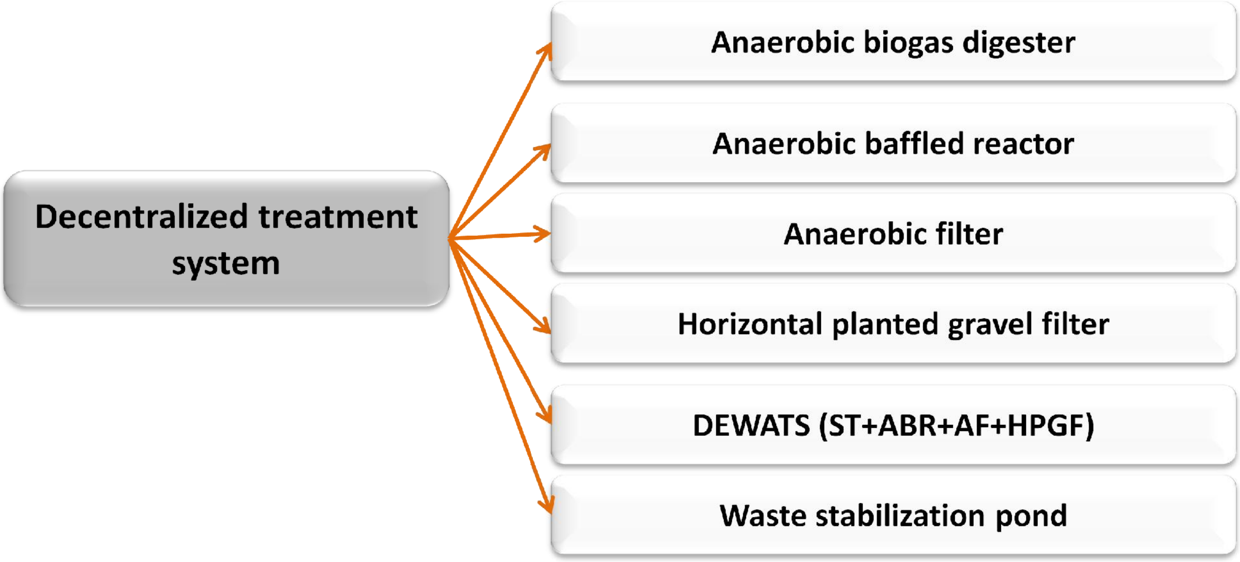
Conveyance systems for decentralised sanitation system

To overcome the drawbacks of conventional systems like cost of laying of extensive sewer lines, work involved in installation and maintenance issues, alternative approaches are identified, which make the ease of installation and maintenance higher. This is referred to as simplified sewer system (SSS). Two approaches are identified under SSS described as follows:



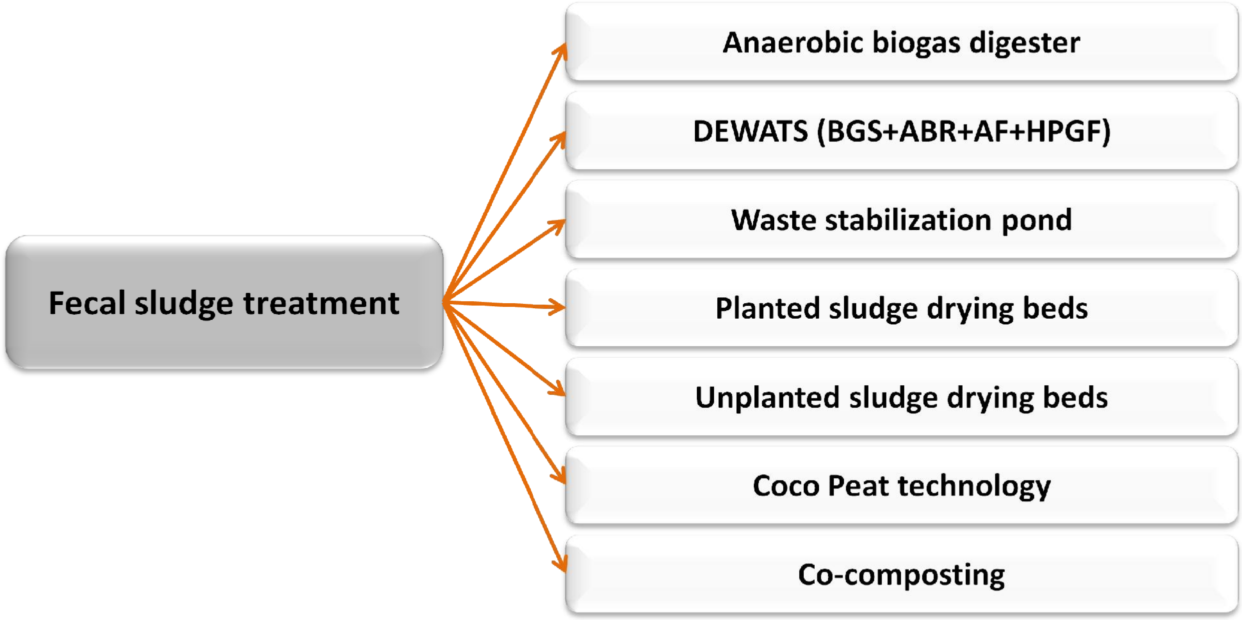
Treatment technologies

The technologies identified under decentralised treatment systems are as follows:



2.2.3 Fecal sludge treatment technologies:

The technologies identified for fecal sludge treatment are as follows:



2.3 Detailed review and description of identified technologies

This section provides detailed description of the sanitation technologies identified in section 2.2.

As Single pit system and conventional septic tanks are extensively used and procedures related to design and implementation is in place, the same has not been considered under this section. However, improved version of the same is discussed below:

2.3.1 Improved Twin pit system

The twin pit system is an improved version of a single pit system wherein two pits are provided to hold fecal matter. This provides a long holding period for digestion of fecal matter since pits are used alternatively. These systems retain the simplicity of construction and maintenance and fulfil the low cost requirements of single pit systems in PPTA towns.

Design description: The number of rings to be provided for each pit is arrived based on the number of users and desludging period. For a household with 5 persons, it is suggested to have 10 rings (5 rings for each pit) with a diameter of 75cm and depth of 30 cm for each ring.

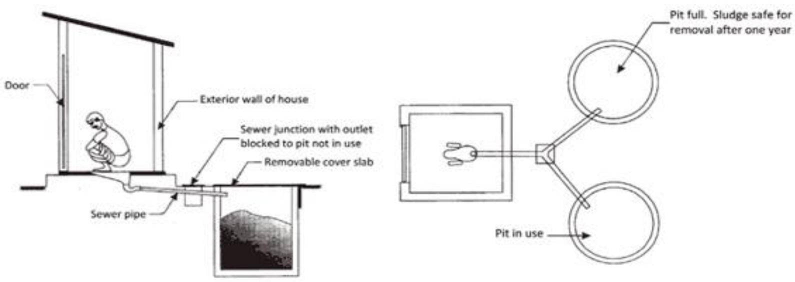


Figure 0.1 – Twin pit system (EAWAG & WSCC 2008)

The pits can be below the superstructure or offset to the user interface for ease in maintenance. In case of offset structure, the pits needs to be connected to the toilet by an inspection chamber with 'Y' junction that can allow flow of black water in either of the pit. At a time only one pit has to be connected to the toilet. When the pit is full, the connection is blocked and black water is allowed in to the second pit. It is recommended that grey water should not be discharged in the pits to avoid frequent desludging and maintain the required moisture level of the fecal matter. The contents of the first pit are emptied when the second pit is almost full. The dehydrated feces from the first pit are safe to handle. To stop the water from infiltrating, the pit should be covered with a water-tight concrete top slab.

Application: Suitable for semi-urban and urban areas. In low- to medium-density areas, particularly peri-urban areas, where there is space on or immediately outside the plot to install the pits and where the digested sludge can be applied to local fields and/or gardens as a fertilizer and soil conditioner. It can be used where, water supply is less and soil percolation capacity is good.

Climate adaptation measures:

- The toilet superstructure should be well designed to withstand cyclonic winds by using structurally stable materials.
- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The toilet pan must be installed 15-30cm above the locally accepted flood level to prevent flood water accessing fecal chambers and allowing the waste to mix with flood water.
- To stop the floodwater from infiltrating the pit, it should be installed 15-30cm above the locally accepted flood level or covered with a water-tight concrete top slab.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the pit during the flooding situation by enhancing the structural strength
- In order to increase the performance of the pits some of the proposed design modifications like
    - Rings should be constructed water-tight (bottom and sides) and the outlet of the pit should be atleast 10 cm above the maximum ground water table (GWT during monsoon season – 3 feet, summer season – 5 feet)
    - If the rings are constructed water-tight, there is a risk of ring structure getting uplifted due to ground water pressure. To counter this risk, the weight of the rings should be increased. In addition, desludging should be avoided during the rainy season (if possible) or the pit should not be emptied completely.
- If the pits are not constructed water-tight, in order to avoid infiltration of ground water into the pit, the base of the pit should be above the maximum GWT of rainy season. Increase in diameter of the rings can be considered to increase the desludging period in case the depth of the pit is less.

Operation and maintenance: The pits must be used alternately and the diversion chamber must be accessible so that flow can be diverted between chambers. Wastewater should never be diverted back to the first chamber before digested sludge has been removed from it. The seal on ‘Y’ junction should be checked regularly to prevent infiltration of water. To avoid the clogging in the pipes as well as ‘Y’ junction a minimum of 1.5 to 2 L of water should be used for each flush.

If the pits are directly below the superstructure then adequate access to each pit should be ensured for regular maintenance.

Supplementary infrastructure and treatment requisite: If digestion of fecal matter cannot be ensured due to high moisture content then it has to be transported for further treatment in sludge drying beds (or can be used in co-composting). prior to reuse or disposal. Collection methods need to be hygienic, preventing contact between workers and feces.

Estimated Cost: The cost estimated for construction/installation of twin pit system is 50 to 75 USD for single household with 5 persons. The cost includes 10 rings (5 rings for each pit) and toilet slab. However, the cost does not include superstructure.

Pros and cons

+ Flies and mosquitoes are considerably reduced from the existing systems
+ Can be built and repaired with locally available material
+ Easy to desludge and maintain
+ Sludge from twin pit can be reused
+ Low capital and operating costs
+ Pathogen reduction in case of full digestion
- High space requirement in comparison to single pit system
- If water for flushing is low, toilet/pipe can get clogged
- Further treatment of sludge is required if it is not fully digested
- Ground water contamination risk

2.3.2 Improved Septic tank with soak pit

Septic tank is an underground watertight structure for containment and treatment of domestic wastewater. It is a rectangular structure normally constructed using masonry and concrete as shown in Figure 2.2. Tanks are also available in ferro-cement and fibre glass materials. This is an improved treatment system compared to pit systems and mostly recommended where there is no sewerage network.

In recent years, improved septic tank designs have been developed to enhance the removal efficiency of unsettleable and dissolved solids, a major drawback of conventional septic tank.

Design and description: The basic principle of such a system is to increase contact between entering wastewater and active biomass in the accumulated sludge. This can be achieved by constructing additional compartments (2-3) with vertical baffle system in to the conventional septic tank to force the wastewater to flow through the accumulated biomass as it passes from the inlet to outlet. Wastewater flowing from bottom to top passes through the settled sludge and enables contact between incoming wastewater and bio mass. The treatment efficiency of this system is 20-30% higher than the conventional septic tank in terms of BOD and TSS removal.

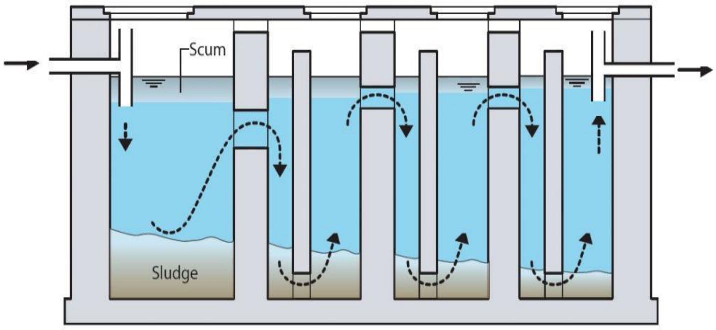


Figure 0.2 – Improved septic tank

The first chamber is made twice the size of other chambers as the maximum solids are deposited here. In order to ensure anaerobic condition within the system, a minimum depth of 1.8 to 2 m is maintained. The retention time is designed for a minimum of 24-48 hrs. A vent pipe is provided over the tank slab so that gases produced in the degradation process can escape in the atmosphere. The system is designed for a minimum desludging period of 2-3 years. The location of the tank should ensure proper access for desludging.

Figure 0.3 – Improved septic tank for public toilet, Tamil Nadu, India

The effluent from the improved septic tank flows out into the soak pit for further treatment. Soak pits can be circular or like a trench in shape. In case of high ground water level, a collection device is provided along with the percolation system. This is mainly to prevent back flow of water from soak pit to septic tank. The soak pit is a covered, porous walled pit that allows water to slowly redistribute and infiltrate it in surrounding soil for absorption. However, its capacity must correspond to the output of the septic tank and the required dimensions are dependent on the percolation rate.

If the percolation rate is too high, the wastewater might drain into the nearby watercourses before any effective treatment can take place. If it is too low, the pit/trenches might soon clog up and wastewater will backflow into the preceding treatment module or overflows. A site percolation test must be done to determine the soil permeability. The depth of the soak pit can range from 1.5m to 4m depending on ground water level. The bottom of the soak pit has to be 1.5m above ground level. Well-sized soak pits can operate for 3-5 years without any maintenance requirements. The soak pit should be located away from the ground water sources.

Approximate area required for a improved septic tank with soak pit for a household size of 5 persons is 5 to 10 sq.m

Application: It can be used as an on-site wastewater treatment system for households, clusters, schools and other institutional building. It should not be considered as a complete treatment system. The sludge and effluent require further treatment before discharge.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the top slab of the tank should be 15-30cm above the locally accepted high flood level or the top slab should be constructed water-tight.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength

Figure 0.4 – Water tight improved septic tank

- Adequate freeboard volume should be provided to allow the usage of septic tank for the flooding period (when the outlet is closed).
- Non-return valve can be provided at the outlet of the tanks to avoid the backflow of water during the flooding period.
- As the tanks are water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure. In addition, desludging should be avoided during the rainy season (if possible) or the tank should not be emptied completely

Operation and maintenance: The inlet, outlet and tank condition has to be monitored regularly. The scum generated from the system should be removed regularly. Desludging needs to be carried out as per the design period (2-3 years). The sludge has to be removed manually or by pumping. Some amount of activated sludge should be left in the baffle compartments to ensure continuity of treatment process.
If the soak pit is provided with a filter media, then once in 3-5 years it needs to be removed and cleaned or replaced. If not provided with filter media, then desludging of accumulated biomass needs to be ensured.

Supplementary infrastructure and treatment requisite: If discharge of effluent is not possible through soak pit, then further treatment needs to be ensured. The sludge accumulated in the septic tank needs to be desludged through appropriate mechanical means and transported to designated sludge treatment facility.

Estimated Cost: The cost of improved septic tank with soak pit ranges from 750 to 1250 USD for a household size of 5 persons.

Pros and cons:

\+ Higher organic load reduction as compared to conventional septic tank
\+ Moderate capital and low maintenance cost
\+ High acceptance among users
\+ No electrical energy required
\+ Long service life
\- Secondary treatment for sludge required
\- Low pathogen reduction
\- More space required compared to conventional septic tank

2.3.3 Biogas digester (fixed dome)

The biogas digester is a watertight underground tank working on the principle of anaerobic treatment. The technology is mainly used for digestion of organic matter present in wastewater, sludge and other biodegradable waste (See Figure 2.5). Digested slurry and biogas is generated during the treatment process. Slurry can be used as soil conditioner and biogas supplements energy needs for cooking.

Design and description: The principles of biogas digester design are the same as normal septic tank. In biogas digester, some of the design parameters are changed to suit treatment requirements, mainly hydraulic retention time and shape of digester construction. If the biogas digester is used as, a standalone system hydraulic retention time (HRT) of 15 to 25 days is recommended, however, if the digester is used in combination with other treatment module (e.g. in DEWATS), 12 to 24 hrs of HRT is recommended.

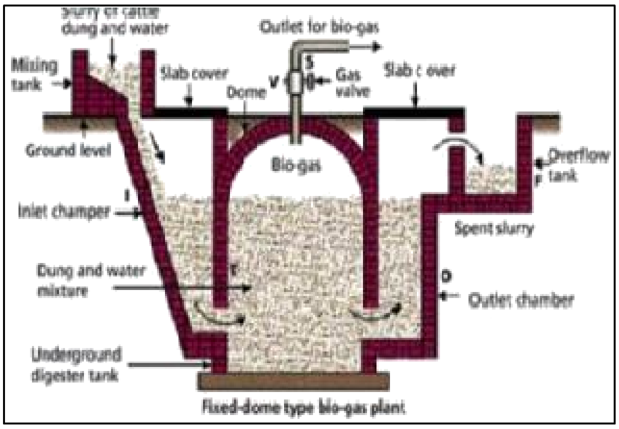


Figure 0.5 – Fixed dome biogas digester

While determining dimensions of the digester apart from the sludge, water and scum volume, biogas storage volume is also provided. An efficiently designed and operated biogas digester can deliver better treatment efficiency than a similarly designed septic tank. Higher retention time ensures higher removal of BOD than normal septic tank. BOD removal of 40-60% while removal of suspended solids 50-70% can be ensured.

Figure 0.6 – Biogas digester

The diameter of the biogas digester should be chosen based on the storage volume required for sludge, gas, wastewater quantity and scum formation. When bricks are used as a construction material the maximum diameter of the dome should be limited to 5m. However, with concrete it can be more than 5m. The normal diameter chosen for household biogas digester is 2-3m.

Application: Suitable at household level and cluster level. They can be used along with animal waste and other bio-degradable waste. They can be built in dense, semi-dense and low density areas. Users require to be educated about the technology.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The digester should be constructed water-tight (Bottom and sides).

- To stop the floodwater from entering the digester, the top slab of the tank should be 15-30cm above the locally accepted high flood level or the top slab should be constructed water-tight.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the digester during the flooding situation by enhancing the structural strength
- Adequate freeboard volume should be provided to allow the usage of digester for the flooding period (when the outlet is closed).
- Non-return valve can be provided at the outlet of the digester to avoid the backflow of water during the flooding period.
- As the digester is water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure. In addition, desludging should be avoided during the rainy season (if possible) or the tank should not be emptied completely

Operation and maintenance: Desludging of settled solids needs to be carried out once in 2-3 years. The reactors should also regularly be checked for scum formation. Gas tightness of the BGD and the gas pipes needs to be checked regularly. In order to ensure effective use of biogas the supply pipes and gas usage equipment (e.g. stove burner, lamps etc.) should be cleaned regularly. Skilled labour is not required but the households should be trained to understand the system.

Supplementary infrastructure and treatment requisite: The sludge accumulated in the digester needs to be desludged through appropriate mechanical means and transported to designated sludge treatment facility. The effluent from the biogas digester needs further treatment before disposal.

Estimated Cost: The cost of biogas digester ranges from 500 to 1000 USD for a household size of 5 persons. If the digester is used in combination with other treatment modules the cost ranges from 350 to 500 USD per cu.m for a treatment capacity of 10 cu.m

Pros and cons:

+ Can be built with local materials
+ Renewable energy and fertilizer production
+ No electrical energy requirements
+ Treatment of human waste, animal waste and solid waste
+ Moderate capital cost and low operating and maintenance cost
+ Long service life
+ Reduces use of wood burning for cooking fuel
- Expert design required along with skilled labour for construction
- Slurry and sludge requires further treatment
- Long start-up time

2.3.4 Shallow sewer system

Figure 0.7 Shallow sewer system at Tsunami affected colony, Tamil

Shallow sewer system is an off-site sanitation technology used to convey all the wastewater from the household environment at a shallow depth for offsite and onsite treatment and safe disposal. *Condominial sewerage* is the application of simplified sewerage coupled with consultations and ongoing interactions between users and planning and implementation agencies. Shallow sewerage is also conducive to local community participation. This is because sewer pipes need to cross private property boundaries, hence the need for the community to agree to the arrangement.

Design and description: Shallow sewers are usually laid in the front or back yards of the house plots or under the pavement (sidewalk). Sidewalk branches are usually preferred in regular urbanized areas while the front and back yard branches are particularly suited to neighborhoods with challenging topography or urbanization patterns. However, in some cases neither of these options is feasible.

A shallow sewer system is designed based on the same hydraulic theory as a conventional sewerage. Its design assumptions are, however, less conservative. Smaller diameter pipes are used when the per capita consumption is known to be less. The minimum depth of cover for laying pipes can be as low as 0.2 m if the expected traffic volume is low. Manholes can be replaced by inspection cleanouts because of the shallow pipes. The flow in the shallow sewer system is always open channel flow, which means that there is always some free space above the flow of wastewater in the sewer. The sewer gradient applied is generally in the range of 1:100 to 1:200 (1% to 0.5%) and the minimum diameter of 100 mm and maximum up to 200 mm is the accepted norm.

Application: The shallow sewer system is mainly used for conveyance of large volumes of wastewater from different sources to cluster level decentralised wastewater treatment. Mainly applicable in large housing colonies, institutions like hospitals, schools and colleges etc.

Climate adaptation:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- To avoid the flood water entering the sewer system the manhole cover chambers top slab should be constructed at least 15 – 30 cm above the locally accepted flood level
- The manhole registers and sewer pipe network should be constructed water-tight
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the manhole chambers and sewer pipe network during the flooding situation by enhancing the structural strength

Operation and maintenance: Homeowners and households should be responsible to maintain the interceptor tanks, the grease trap and the sewers. Alternatively, a private contractor or user's committee can be hired to assume responsibility for the maintenance. Blockages can usually be removed by opening the sewer and forcing a length of rigid wire through the sewer. Inspection chambers must be cleared periodically to prevent grit overflowing into the system.

Estimated Cost: The cost ranges from 35 – 55 USD per running meter length

Pros and Cons:

+ Low in investment and maintenance costs as compared to conventional sewer network (30-50%)
+ Can be built with locally available materials and repaired locally
+ Easy to maintain
+ Incremental expansion of network possible as per the requirement
- Requires expert design and construction supervision
- Shallow sewer system is suitable where adequate ground slopes are available
- As sewers are to be laid at flat gradients, solids are likely to get deposited unless flushed at peak flow conditions, failing which these sewers may clog and require frequent cleaning
- Frequent repairs and removal of blockages
- Households may be reluctant to allow sewers to be routed through their properties

2.3.5 Small Bore Sewer System

The small-bore sewer system is designed to collect and transport only the liquid portion of the domestic wastewater for off-site or on-site treatment and safe disposal. The solids are separated from the wastewater in septic tanks or interceptor tanks installed upstream of every connection (at household level) to the small-bore sewers. Since the small-bore sewers collects only settled wastewater, it needs reduced water requirements (for transportation) and reduced flow velocities.

Design and description: The effluent from the interceptor tank/septic tank is discharged into the small-bore sewer system, where flow occurs by gravity utilizing the head resulting from the difference in elevation between its upstream and downstream ends. The wastewater flows, which reach the small-bore sewers are attenuated markedly in the interceptor tank from the rate at which they are discharged by the user.
Unlike conventional gravity sewers, which are designed for open channel flow, the small-bore sewer may be installed with sections depressed below the hydraulic grade line. The minimum pipe diameter used in the small-bore sewer system is 100mm. Selection of the minimal permissible size of the sewer should primarily be based on investment and maintenance considerations. Maintenance of strict sewer gradients to ensure minimum self-cleansing velocities may not be necessary. Minimum velocities in the range of 0.3 to 0.6 m/sec may be used.

Application: The small-bore sewer systems are applicable where households have septic tanks for retention of solids in existing and newly developing areas.

Climate adaptation:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- To avoid the flood water entering the sewer system the manhole cover chambers top slab should be constructed at least 15 – 30 cm above the locally accepted flood level
- The manhole registers and sewer pipe network should be constructed water-tight

- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the manhole chambers and sewer pipe network during the flooding situation by enhancing the structural strength

Operation and maintenance: Regular desludging of the septic/interceptor tank must be regularly done to insure optimal performance of the Solids-Free Sewer network. If the pre-treatment is efficient, the risk of clogging in the pipes is low, but some maintenance will be required periodically. Flushing of sewers should be done once a year as part of the regular maintenance regardless of their performance

Estimated Cost: The cost ranges from 35 – 55 USD per running meter length

Pros and Cons:

+ Reduced water requirements for transportation, as it requires less water flow
+ Reduced excavation and construction material costs
+ Reduced complexity in maintenance
- Regular cleaning and desludging of interceptor tanks
- Well planned maintenance system is required
- Experience with the system is limited and mixed
- Solids entering sewer system due to illegal connection

2.3.6 Dehydration vaults

It is a dry on-site system used to collect, store and dehydrate feces. The vaults are built watertight and urine/anal cleansing water is diverted away from the vaults as shown in Figure 2.8.

Design and description: One person requires approx. 100L of storage space for disposal of feces. The size of the vaults should be based on the household size, sufficient area for uneven distribution of feces (to prevent piling up of feces within the tank) and number of visitors. Six months drying time is required for one vault. Two vaults can be constructed for alternate use. When the first vault is full, it is closed and second vault is opened for use. The vaults should be water-tight. Urine can be collected in another container and reused in garden. Anal cleansing water can be discharged with further treatment. A vent is required on the slab to control flies and odour. 3 to 5 sq.m of area is required for the vaults.

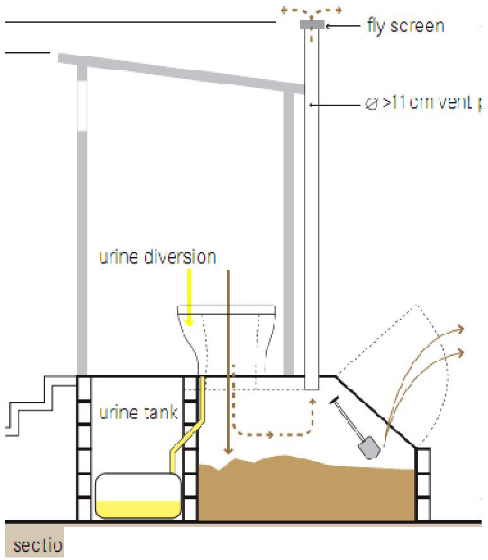


Figure 0.8 – Dehydration vaults (EAWAG & WSCC 2008)

Application: As it can be installed indoor, it can be used in low-lying, flood prone areas and on the banks of khals. It is a treatment technology applicable at household level. The users may require counselling regarding proper usage and benefits of this technology.

Climate adaptation measures:

- This technology is appropriate in areas with high ground water table and flood prone regions

Operation and maintenance: To dehydrate the feces, ash, soil or lime should be used to cover the feces after every use. If urine or water gets inside the vault, then extra lime or ash should be spread for extra drying. The feces mound up after some time, thus it should be evenly spread out in the vault. If water is used for anal cleansing, it should be diverted appropriately. If dehydrated feces are used as fertilizer then, then it should be applied atleast one month prior to harvest.

Supplementary infrastructure and treatment requisite: Vault emptying equipments are required. Space for application or disposal of dehydrated feces and urine needs to be identified. If the dehydration process is incomplete and vaults are filled then the partially digested fecal sludge needs to be desludged and transported for further treatment.

Estimated Cost: The cost of dehydration vault ranges from 75 to 110 USD for a household size of 5 persons excluding superstructure.

Pros and cons:

- \+ Can be constructed with local materials
- \+ Long service life
- \+ Suitable in flood prone areas
- \+ Easy emptying of vaults, easy to manage dried feces
- \+ No flies and mosquito problems if constructed properly
- \+ Low capital costs, no or low maintenance costs
- \+ Low space requirements
- \+ No energy requirement
- \- Low acceptance
- \- Users need education for its usage
- \- High operating and maintenance requirements
- \- Constant source of ash, lime or soil required
- \- Appropriate discharge point for feces and urine is required
- \- Manual emptying of vaults

2.3.7 Anaerobic Baffled Reactor (ABR)

The anaerobic baffled reactor is an underground or closed watertight tank with chambers in series as shown in Figure 2.9.

Design and description: In the ABR, each chamber is designed to take care of required organic and hydraulic loadings. The length and width (area) required for each chamber is derived from the peak hour flow and defined velocity of wastewater within the chamber.

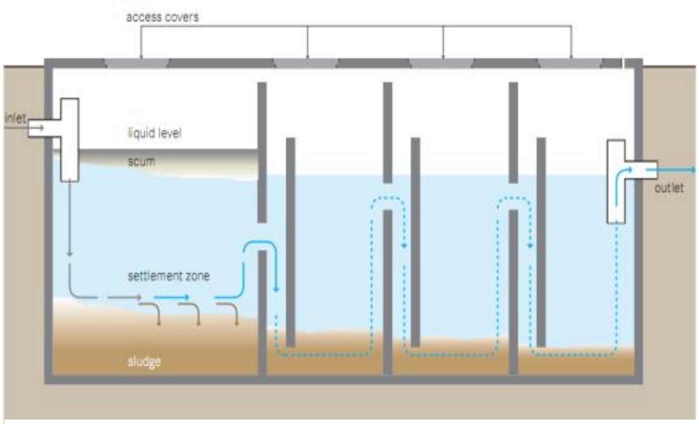


Figure 0.9 – Anaerobic baffled reactor (EAWAG & WSCC 2008)

The baffle walls or pipes ensure direction of wastewater flow within the tank. through the activated sludge accumulated at the bottom of each chamber. An equal distribution of fresh wastewater and a close contact between the fresh influent and old active sludge are important process features.

The baffle reactor is one of the most efficient anaerobic treatment modules. Efficiency increases with higher organic load. Treatment performance is in the range of 65-90% COD removal, 70-95% BOD removal and TSS in the range of 80-90%. The treatment efficiency in the baffled reactor increases with increase in number of chambers and availability of active bacterial mass. If the ABR is used as a standalone system, HRT of 48-72 hrs is recommended, however, if used in combination with other treatment module (e.g. in DEWATS), HRT of 12 to 24 hrs is recommended.

Figure 0.10 – Anaerobic baffled reactor, housing colony, Maharashtra, India

Application: It is suitable for treating large volumes of wastewater from different sources like housing clusters, institutions, hotels etc. The ABR can be used as a standalone or in combination with other treatment modules (eg. in DEWATS).

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the top slab of the tank should be 15-30cm above the locally accepted high flood level or the top slab should be constructed water-tight.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength
- Adequate freeboard volume should be provided to allow the usage of tank for the flooding period (when the outlet is closed).
- Non-return valve can be provided at the outlet of the tank to avoid the backflow of water during the flooding period.
- As the tank is water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure. In addition, desludging should be avoided during the rainy season (if possible) or the tank should be emptied chamber-wise or should not be emptied completely.

Operation and maintenance: The ABR tank should be checked for scum formation and sludge accumulation. It is essential to ensure the water tightness of the structure to achieve effective treatment. The tank should be desludged once in 2-3 years.

Supplementary infrastructure and treatment requisite: A settler can be provided before ABR to contain the settleable organic and inorganic solids for enhanced treatment. The effluent from ABR needs to be subjected to tertiary treatment for higher treatment efficiency and re-use. The excess activated sludge in any of the chambers needs to be transferred to other chambers having less sludge. The sludge removed can be treated in a sludge drying bed.

Estimated Cost: The ABR if used in combination with other treatment modules, the cost ranges from 425 to 650 USD per cu.m for a treatment capacity of 10 cu.m

Pros and cons:

- + If constructed properly, it can be resilient to high ground water table and flooding conditions
- + Can be built from local materials
- + High organic load reduction
- + Long service life
- + No electrical energy required
- + Moderate capital, low operating and maintenance cost (low sludge generation)
- - Requires skilled designers and labourers
- - Effluent requires tertiary treatment
- - Less pathogen reduction

2.3.8 Anaerobic Filter (AF)

Anaerobic filters are also known as fixed bed or fixed film reactors. Anaerobic filter tanks are underground or closed watertight tanks with chamber in series with a fixed filter media as shown in Figure 2.11.

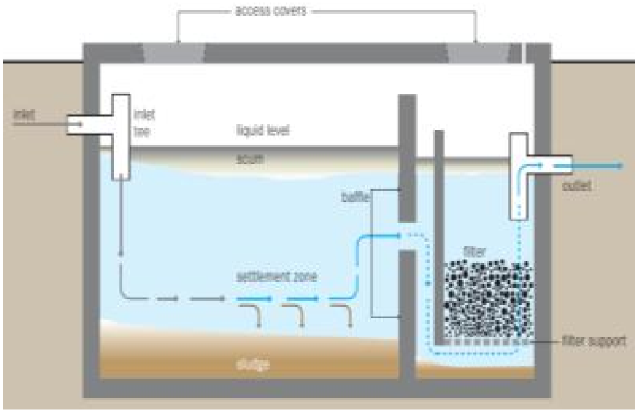


Figure 0.10 – Anaerobic Filter (EAWAG & WSCC 2008)

Figure 0.12 – Anaerobic filter at Tsunami rehabilitation housing colony, Tamil Nadu, India

Design and description: They are generally used as a secondary treatment module for pre-treated wastewater. AF includes the treatment of non-settleable and dissolved solids besides treatment through sedimentation and sludge digestion. Filter material such as gravel, rocks, cinder or specially formed plastic pieces provide additional surface area for bacteria to grow. The pre-settled wastewater is made to pass through active bacteria mass growing on the filter media. The larger the surface area of the filter media, the higher the treatment efficiency.

An important design criterion is equal distribution of wastewater upon the filter area. The baffle walls or pipes ensure the direction of wastewater flow within the tank; it forces the wastewater to flow through the filter media in each chamber.

Each of the chambers is designed to take care of the required hydraulic and organic loading. Through intensive contact between wastewater and bacterial biomass, organic matter is digested with short retention times. The HRT of the tank will be 12-36 hrs.

Anaerobic filters are suitable for domestic wastewater with low content of suspended solids. In any case pre-treatment is necessary to prevent clogging. Suspended solids and BOD removal of 85-90% can be achieved.

Application: This technology can be used at household level or cluster level. AF is also used as secondary treatment module in DEWATS, which enhances the overall wastewater treatment efficiency.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the top slab of the tank should be 15-30cm above the locally accepted high flood level or the top slab should be constructed water-tight.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength
- Adequate freeboard volume should be provided to allow the usage of tank for the flooding period (when the outlet is closed).
- Non-return valve can be provided at the outlet of the tank to avoid the backflow of water during the flooding period.
- As the tank is water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure. In addition, desludging should be avoided during the rainy season (if possible) or the tank should be emptied chamber-wise or should not be emptied completely.

Operation and maintenance: The filter media needs to be cleaned by back washing or flushing or may have to be washed and placed back periodically (filter media cleaning every 3-5 years, desludging of tanks every 2-3 years). The baffle pipes needs to be checked for clogging and cleaned regularly. De-sludging needs to be done periodically, when sludge accumulates in the AF chambers. Protective gear has to be used and appropriate safety precautions have to be taken while desludging and cleaning filter material.

Supplementary infrastructure and treatment requisite: If AF is used as a standalone system, then pre-treatment of wastewater in septic tank or ABR is necessary and further treatment of effluent is required for safe disposal or reuse.

Estimated Cost: If AF is used in combination with other treatment modules (eg. in DEWATS), the cost ranges from 350-500 USD per cu.m for a treatment capacity of 10 cu.m.

Pros and cons:

+ Resistant to hydraulic shocks
+ No electrical energy required
+ High BOD and TSS reduction
+ Can be built with local materials
+ Moderate capital and maintenance costs
+ Long service life

+ Less frequency of sludge removal
- Influent requires primary treatment and effluent requires further tertiary treatment
- Less pathogen reduction
- Requires skilled designers and labourers
- Blockages in filter material possible
- Filter material cleaning is tedious process

2.3.9 Horizontal planted gravel filter

Horizontal planted gravel filter bed is a shallow over-ground open watertight tank filled with graded filter material. HPGF are also known as sub-surface wetland system or root zone treatment system as shown in Figure 2.13. HPGF are simple and low maintenance treatment system provided they are well designed and constructed.

Design description: HPGF are suitable for pre-treated domestic wastewater with BOD content less than 100mg/l. Wastewater must be pre-treated especially with respect to suspended solids. The treatment process consists of physical processes of filtration, biological treatment and the intake of oxygen. Generally, the nutrients are removed through adsorption by the plant roots. Pathogens are removed and eliminated through natural die off, UV exposure and adherence. The BOD and COD are reduced through biological aerobic and anaerobic decomposition in the respective layers of filters.

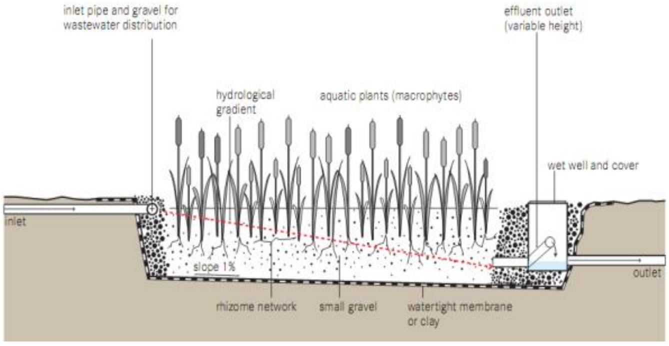


Figure 0.12 – Horizontal planted gravel filter

Figure 0.13 – HPGF at IIYW Institute, Lonara

River pebbles or construction gravel are often used as filter material and planted with vegetation like Canna Indica, Colacasia, Reed Juncas and Pappyrus. A good distribution system at the inlet is required to ensure equal distribution of influent across the entire width, which is essential for efficient performance. The filter body is permanently soaked with water and operates partly aerobic in the top layer, partly anoxic in the middle layer and partly anaerobic in the bottom layer. The oxygen required for aerobic degradation is supplied directly from the atmosphere by diffusion or oxygen released from the vegetation roots.

The removal efficiency is based on surface area and cross-sectional area available for the flow. The quality of treatment in well-operated HPGF is in the range of 50-60% BOD removal. The enrichment of dissolved oxygen occurs largely in this treatment module.

Application: Appropriate at household level and cluster level. Pre-treated wastewater from ABRs, AFs, septic tanks can be further treated. It requires community involvement for proper functioning if applied at cluster level. It is a good option where land is cheap and available.
Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the side walls of the tank should be 30-60cm above the locally accepted high flood level.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength
- Non-return valve can be provided at the outlet of the tank to avoid the backflow of water during the flooding period.
- As the tank is water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure. In addition, removal of filter material for cleaning should be avoided during the rainy season (if possible) or the filter material should be removed for cleaning compartment-wise.

Operation and maintenance: The flow of wastewater though the treatment unit should always be sub-surface or else algal formation may occur on the surface, which may lead to filter clogging. Filter bed needs regular visual checking for clogging. The filter material needs to be cleaned or replaced periodically (every 3-5 years). Trimming of vegetation and cleaning of dead leaf litter is required regularly.

Supplementary infrastructure and treatment requisite: In order to avoid clogging of filter media, pre-treatment system should be provided before HPGF.

Estimated Cost: If HPGF is used in combination with other treatment modules (eg. in DEWATS), the cost ranges from 250-350 USD per cu.m for a treatment capacity of 10 cu.m

Pros and cons:

+ Good reduction in BOD, TSS and pathogens
+ Low operation and maintenance requirements
+ No electrical energy required
+ No issue of mosquito breeding and odour
+ Treatment unit can be nicely integrated with landscape
- Moderate capital cost
- Pre-treatment is required to prevent clogging
- Requires expert design and supervision
- Requires ample space for installation

2.3.10 DEWATS

A combination of primary, secondary and tertiary treatment modules like Septic Tank, Biogas digester, Anaerobic Baffled Reactor, Anaerobic Filter and Horizontal Planted Gravel Filter (See Figure 2.15) can provide comprehensive wastewater treatment with organic load reduction up-to 95%. This combination of mentioned treatment modules is termed as DEWATS and follows the principles of simple technical approach to wastewater treatment with minimal maintenance and environment friendly.

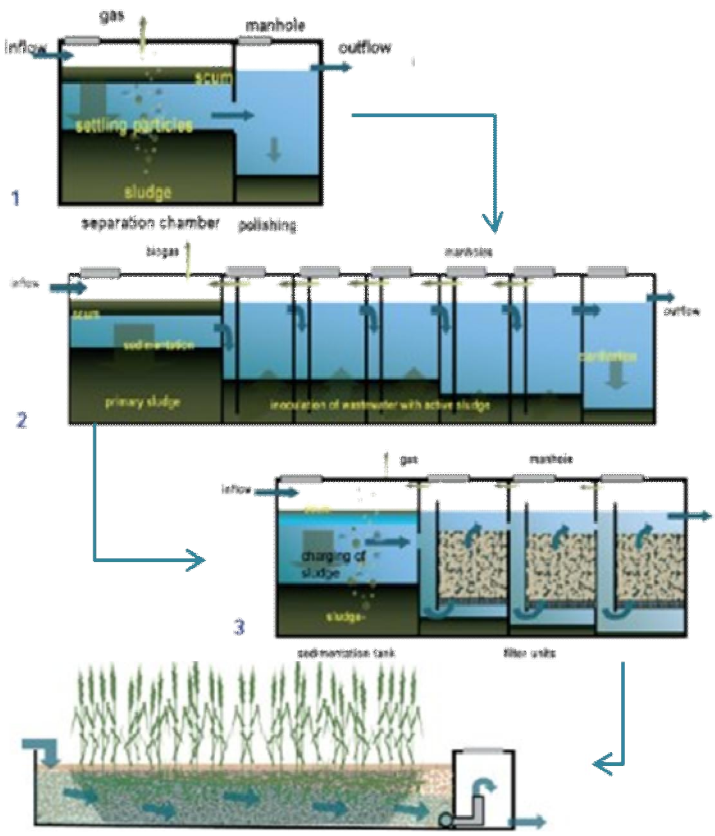


Figure 0.14 - DEWATS (BORDA 2010)

Overall, the modules combination selection should comply with the basic principles of reliability, longevity, tolerance towards inflow fluctuation, desired effluent standards and most importantly of minimal maintenance

Design description: The design description of each of these modules has been explained in the previous paragraphs. The combination of the DEWATS modules follows gravity flow and therefore does not require any mechanical equipment. As it is a natural biological treatment process, no chemicals are used for treatment.

Figure 0.15 – DEWATS for school, Bangalore, India

The various modules described above can be applied in different possible combinations depending on the wastewater characteristics, usage pattern, climatic conditions, topography, desired effluent quality, and other local factors like land availability. Some of the most commonly adopted and practiced combinations are described below:

- → Combination 1: Primary treatment module (septic tanks or settler or bio-gas digester) with part of secondary treatment modules (anaerobic baffle reactor)
- → Combination 2: Primary treatment module (septic tanks or settler or bio-gas digester) + Secondary treatment modules (anaerobic baffle reactor and/or anaerobic filter)

- → Combination 3: (septic tanks or settler or bio-gas digester) + Secondary treatment modules (anaerobic baffle reactor and/or anaerobic filter) + Tertiary treatment modules (horizontal planted gravel filter)
- → Polishing pond is added as a post treatment module to Combination 3.

Application: Appropriate for domestic wastewater from cluster level households, institutions, public/community toilets, Septage treatment etc.

Climate adaptation measures:
As the treatment modules provided under DEWATS are discussed above, refer to sections 2.3.4, 2.3.5, 2.3.7, 2.3.8 and 2.3.9 for climate adaptation measures.

Operation and maintenance: The O&M requirements for each treatment module is described in previous sections.

Estimated Cost: The cost ranges from 550-1000 USD per cu.m for a treatment capacity of 10 cu.m

Pros and cons:

+ If constructed properly, it can be resilient to high ground water table and flooding conditions
+ Maintenance is simple and does not require extensive technical support.
+ It eliminates the use of electrical and mechanical equipments.
+ It can be integrated with the landscaping. Can be built from local materials
+ Reuse of the treated wastewater for the gardening and irrigation purposes
+ High organic load reduction
+ Long service life
- The treatment is less efficient with the weak wastewater.
- The tertiary treatment system requires larger space
- Technical knowledge and care is required during the construction.
- Capital cost and the area required is more for the total infrastructure.

2.3.11 Cocopeat technology

The Cocopeat treatment technology is a secondary treatment process for pre-settled wastewater. It is an open shallow watertight tank with layered cocopeat as a filter media, which acts as a bio-filter as shown in Figure 2.17. The treated wastewater is then discharged or can be reused.

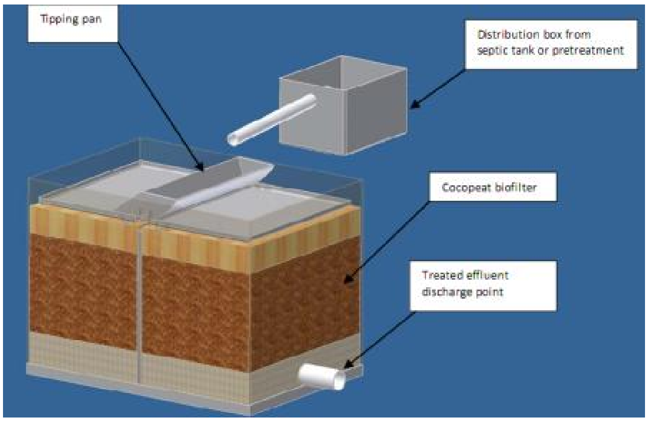


Figure 0.16 – Cocopeat filter (Robbins and Richkus 2012)

Design and description: The effluent from the septic tank/settler is evenly distributed onto the filter media through a specified number of orifices and applied in doses that are controlled by a simple analogue timer. As the wastewater percolates through the coconut-based medium, the downward flow into the pore spaces in the media draws in air, thus creating an aerobic environment within the filter. Microorganisms and fungi that reside within the filter consume the organic matter giving out effluent that can be re-used for irrigation, street cleaning and toilet flushing. The system also reduces considerably the pathogen content in the treated effluent.

Cocopeat bio-filter technology can be modular in design. Dimensions of one plastic bio-filter units can be 2.2 meters long by 1.1 meters wide and 1.2 meters in height. Hydraulic loading for one unit is from 350 to 500 litres of wastewater per day. To save on space, the modules can be stacked on top of each other (Watsan 2012). If sloping land is available, septic tank can be constructed on a higher level than coco-peat filter. If the septic tanks and coco-peat filter are on same level then regular pumping of effluent from septic tank to bio-filter is required.

Application: This technology can be installed in semi-dense and peri-urban areas, at household level, commercial establishments, schools and other institutional buildings. For hotels and restaurants grease trap has to be provided as first treatment module. In case of high effluent volumes to be treated, more number of coco-peat modules can be added in series. For low-lying flood prone areas both, septic tank and coco-peat filter should be built above ground level. The outlet of the coco-peat module should be above the high flood level.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the side walls of the tank should be atleast 15-60cm above the locally accepted high flood level.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength
- If the tank is constructed underground and water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure.

Operation and maintenance: If septic tank and coco-peat filter are on the same level then daily pumping of effluent from septic tank to inlet of coco-peat is required to ensure uniform distribution of effluent over the filter media. The filter media has to be replaced every 2-3 years. The coco-peat is very cheap and readily available in Bangladesh. After the filter media's lifespan of about 2-3 years, the spent filtering media can be composted and utilised to condition soil due to its high organic content.

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upplementary infrastructure and treatment requisite: To avoid clogging of coco-peat, periodic desludging of the primary treatment module like septic tank/settler is required.

Estimated Cost: Information is not available

Pros and cons:

+ Suited for different wastewater streams like households, institutions and small clusters in different physical environments
+ Easy to construct, operate and maintain
+ Low or no electrical energy required
+ Effluent discharge can be reused or safely disposed in drains
+ Can be used where flow of wastewater is variable
+ Suitable in coconut producing regions
- Implementation of treatment module is mainly dependent on coco-peat availability
- The cost of filter material is the major factor affecting the cost of maintenance.

2.3.12 Unplanted drying beds

The unplanted drying beds are shallow watertight open tanks as shown in Figure 2.18. Septage/sludge from treatment modules is spread evenly on the drying beds and allowed to dry.

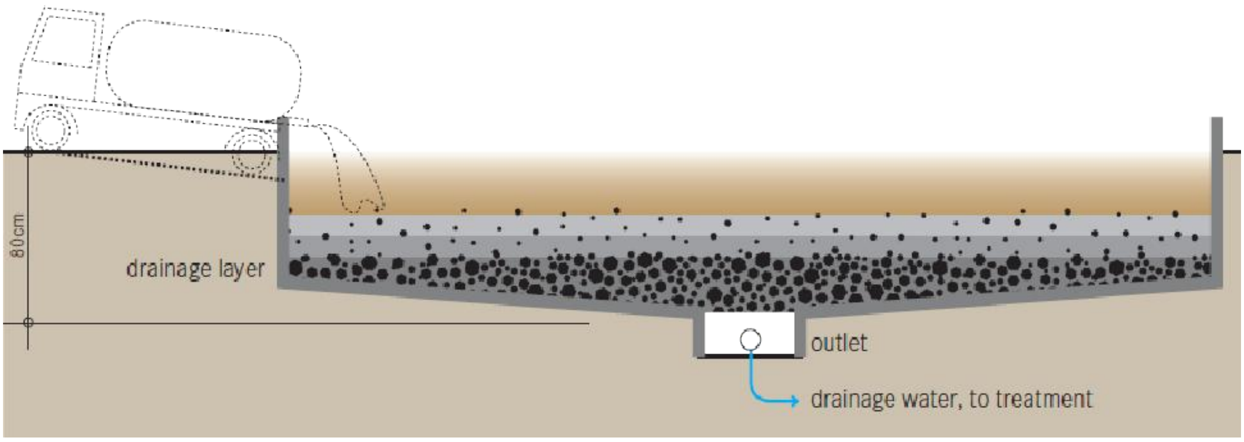


Figure 0.17 – Unplanted dryings beds (EAWAG & WSCC 2008)

Design and description: Sand and gravel filters are used for dewatering the sludge. Generally, the coarse gravel layer of grain diameter: 15 to 50 mm is within 20 to 30 cm of height. A gravel layer of 10 to 15 cm height with grain diameter of 7 to 15 mm follows this layer. The sludge is applied in layers every 10-15 days. The thickness of bed layers should not be more than 30 cm. 50 to 80% of the sludge volume is reduced depending on the climatic conditions. Drain pipes below the filter material carry the leachate to assigned discharge location. When the sludge is dried, it should be removed and can be used for land application. A covering roof may be required in high rainfall regions.

Application: Can be applied for small and medium towns. It is best suited for peri-urban and rural areas with land available away from the settlements for construction of drying beds. Land requirements are 0.05 m^2 per capita for a 10 day cycle

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the side walls of the tank should be atleast 30-60cm above the locally accepted high flood level.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength
- Non-return valve can be provided at the outlet of the tank to avoid the backflow of water during the flooding period.
- If the tank is constructed underground and water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure.
- In order to maintain the required moisture level in the sludge, it is recommended that the unit should be covered for protection against rainfall.

Operation and maintenance: Proper access should be provided for trucks to dispose sludge in the beds and transfer the dried sludge. The dried sludge from the beds should be removed every 10-15 days. The level of sand used as filter media should be maintained for the designed thickness.

Supplementary infrastructure and treatment requisite: The leachate collected from the beds needs further treatment.

Estimated Cost: The cost ranges from 50-75 USD per sq.m.

Pros and cons:

+ Can be build with local materials
+ Low construction and maintenance costs
+ No electrical energy required
+ High pathogen removal
+ High reduction in sludge volume
- Large land area required
- Further treatment of leachate required
- Bad odour, flies and mosquitoes may create nuisance

2.3.13 Planted drying beds

Planted drying beds are provided with plants as a media to support sludge drying through transpiration as shown in Figure – 2.19.

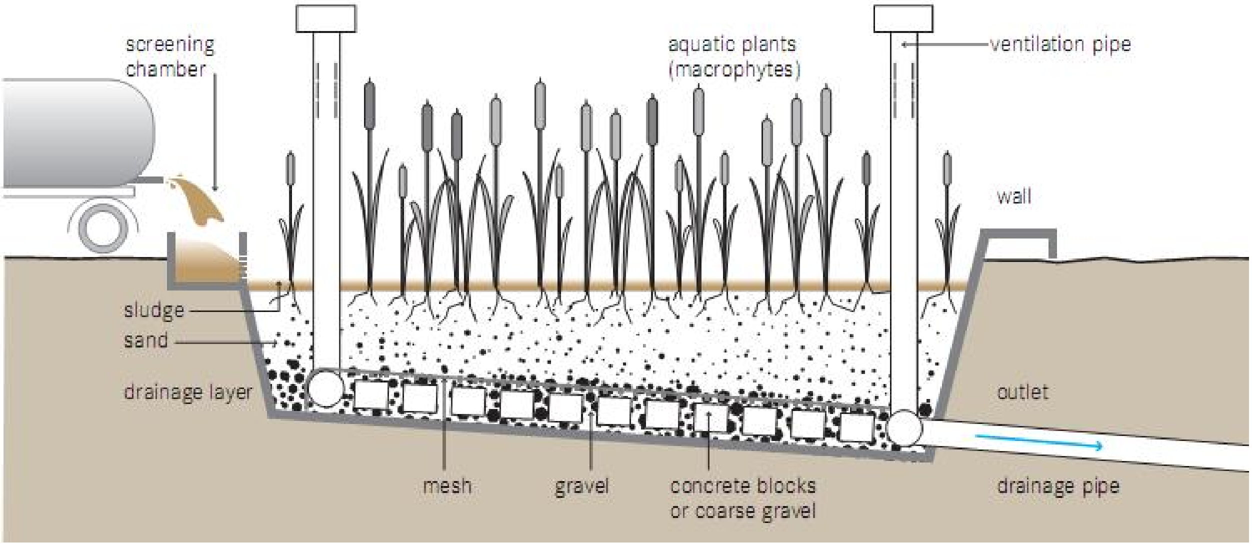


Figure 0.19 – Planted drying beds (EAWAG & WSCC 2008)

Design and description: In unplanted beds, there are three layers of filter material ranging from coarse grain gravel to fine grain sand. Each layer is 25-30 cm thick. The plants in the bed allow for higher transpiration. The sludge to be treated should be applied every 3-7 days. The thickness of the sludge layer should range between 75-100mm. Sludge needs to be removed after 2-3 years and can be used for land application. A covering roof may be required in high rainfall regions

Application: Can be applied for small and medium towns. It is best suited for peri-urban and rural areas with land available away from the settlements for construction of drying beds.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- The tank should be constructed water-tight (Bottom and sides).
- To stop the floodwater from entering the tank, the side walls of the tank should be atleast 30-60cm above the locally accepted high flood level.
- Additional care should be taken during the design and construction phase to avoid damage to the exposed part of the tank during the flooding situation by enhancing the structural strength
- Non-return valve can be provided at the outlet of the tank to avoid the backflow of water during the flooding period.
- If the tank is constructed underground and water-tight, to avoid the risk of tank structure getting uplifted due to ground water pressure, the tank should be designed to counter the water pressure.
- In order to maintain the required moisture level in the sludge, it is recommended that the unit should be covered for protection against rainfall.

Operation and maintenance: Proper access should be provided for trucks to dispose sludge in the beds and transfer the dried sludge. Planted drying beds require less maintenance compared to unplanted drying beds as dried sludge has to be removed after 2-3 years only.

Supplementary infrastructure and treatment requisite: The leachate collected from the beds needs further treatment.

Estimated Cost: The cost ranges from 50-75 USD per sq.m.

Pros and cons:

+ Can be built with locally available material
+ Dried sludge can be directly used as soil conditioner
+ Easy to operate and maintain
+ Low construction and maintenance cost
+ High pathogen removal
+ Can be used for high sludge loads
+ No electrical energy requirements
- Large land area requirements
- Leachate requires further treatment
- Bad odour, flies and mosquitoes may create nuisance

2.3.14 Waste stabilization ponds (WSP)

WSPs are large man made water bodies where wastewater is treated by solar energy, wind, micro organisms and algae in anaerobic, anaerobic and facultative ponds. These ponds can be used individually or in series.

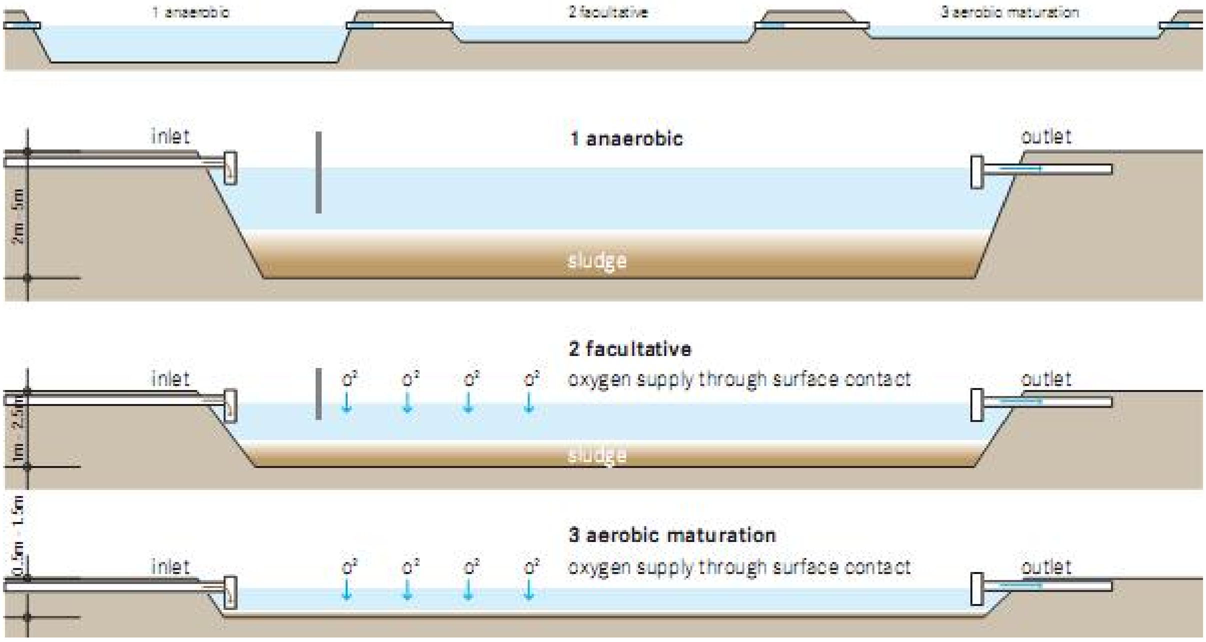


Figure 0.20 – Waste stabilization pond (EAWAG & WSCC 2008)

Design and description: The effluent is transferred from anaerobic pond to facultative to aerobic pond. Solids and BOD (up to 60%) are reduced in anaerobic pond. These ponds are 2-5m in depth and require a retention time of 1-7 days. The facultative ponds are 1-2.5m in depth where solids accumulate at the bottom and are digested. BOD reductions of 75% are achieved with retention time of 5 to 30 days. A number of aerobic ponds can be added to achieve highly polished effluent. The depth of aerobic ponds is 0.5 to 1.5m at to ensure sunlight penetration till the bottom. Pathogen removal up to 90% can be achieved. Wing mixing and algae provide oxygen in the pond. If aquaculture is practised in these ponds then high efficiency of nitrogen and phosphorus removal can be achieved. To prevent leaching, the ponds should have a liner. The liner can be clay, asphalt, compacted earth, or another impervious material. The ponds should protected by bunds in low-lying and flood prone regions.

Application: Suitable for semi-urban and rural areas where large land mass is available. Can be applied in areas where there is a demand for treated water for reuse in agriculture and/or aquaculture. They offer a robust treatment process that can deal with a wide variety of wastewaters of varying types and concentrations. For higher organic load, high surface area is required.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- To avoid the floodwater from entering the ponds it is recommended to provide a structurally stable earthen bund around the pond atleast 30-60cm above high flood level.

Operation and maintenance: Scum formation has to be prevented, thus excess solids and garbage entering the ponds has to be removed. The fencing has to be well-kept. The liner of the ponds has to be repaired time to time.

Supplementary infrastructure and treatment requisite: If septage and fecal sludge has to be treated, the transportation infrastructure should be in place.

Estimated Cost: Estimated Cost: The cost ranges from 50-100 USD per cu.m of wastewater for a treatment capacity of 1000cu.m

Pros and cons:

+ High strength wastewater treatment system for high quality effluent. High reduction in pathogens.
+ Can be built and repaired with local materials
+ No electrical energy requirement
+ Low construction and operating costs
+ Reuse of effluent in agriculture and aquaculture a major benefit
- Requires expert design and supervision
- If land cost is high then the capital investment will increase drastically
- Requires large land mass away from settlements but near enough for low transportation costs
- Scientific methods of desludging and disposal of sludge have to be followed
- If the effluent is not to be reused then appropriate discharge methods have to be followed.
- Poor design can result in bad odour.

2.3.15 Co-composting

Composting is the process of stabilization of organic material by aerobic thermophillic degradation. The composting process converts the organic material to a stable product by biological degradation process. The decomposition process of the organic material in the septage heats the compost (through thermophillic decomposition) to temperatures in the range of 50 to 70 degrees Centigrade (°C) destroying harmful pathogens. The resulting humus-like material is suitable as a soil conditioner and source of nitrogen and phosphorus.

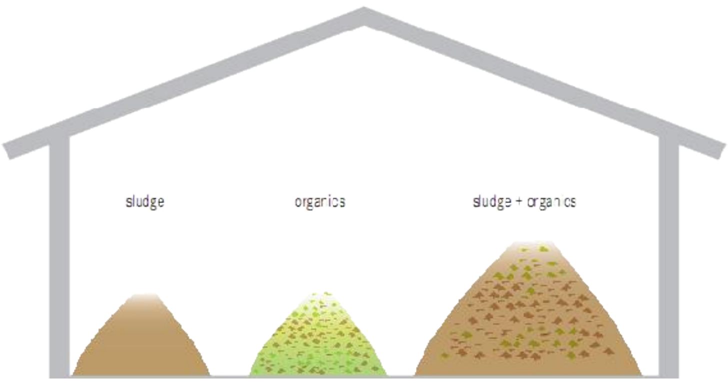


Figure 0.21 – Co-composting (EAWAG & WSCC 2008)

The process of composting of two input organic material – septage and organic municipal waste is known as co-composting. The organic municipal waste acts as the bulking agent. The organic fraction of municipal solid waste includes food wastes, paper, yard-wastes (e.g. leaves, branches, shrubbery, etc. cut or removed during landscaping). The municipal solid waste serves as the bulking agent.

Design and description: Co-composting can be done in open or under a roof and in a container. The material is mixed and piled for decomposing. Open windrow composting is the most common method. The mixture of septage or wastewater solids and bulking agent is pushed into long parallel rows called “windrows”, about 1 to 2 meters high and about 2 to 4.5 meters at the base. The cross-section is either trapezoidal or triangular. These piles required regular mixing to provide oxygen. Several times a week the mixture is turned over. Although specialized equipment has been developed for windrow composting, it is possible to use a front-end loader to move, push, stack, and turn the mixture. Factors affecting the composting process include moisture content (40% to 60%); oxygen (5% to 15%); temperature (must reach 55 to 65 oC); pH (6 to 9); and carbon-to-nitrogen ratio (30 to 1).

The facility should be covered in high rainfall areas and be built on a higher ground in flood prone areas. Container mixing requires mechanical energy. The sludge to solid waste ratio should be properly monitored. For dewatered sludge, ratio of 1:2 to 1:3 of dewatered sludge to solid waste should be maintained. For liquid sludge, ratio of 1:5 to 1:10 of sludge to solid waste should be maintained. The finished product can be directly applied in fields as soil conditioner.

Application: Suitable for small communities and at a city level. Sorted bio-degradable solid waste is a major requirement. Waste from unplanted drying beds and WSPs can be utilised. Land area of about 800 m^2 for a 3 ton per day plant is required. There should be a demand for use of the finished product.

Climate adaptation measures:

- The maximum depth, duration and frequency of flooding must be established to determine the most feasible design to install in these areas
- In order to maintain the required moisture level in the sludge, it is recommended that the unit should be covered for protection against rainfall.
- The plinth of the co-composting yard should be constructed atleast 30-60cm above the high flood level.
- The superstructure of the yard should be designed and implemented to sustain the cyclonic winds

Operation and maintenance: The mixture has to be regularly and properly mixed to achieve aeration of the degrading organic matter. Regular watering of the piles is also required. Every day operation and maintenance of the facility is required. Labour and management staff is required for the facility. Protective gear should be worn while mixing the piles.

Supplementary infrastructure and treatment requisite: Transportation facilities for sludge and solid waste are required. Drying beds for dewatering septage is essential along with treatment of the leachate. A market place for selling the finished product is also essential.

Estimated Cost: Cost not available

Pros and cons:

+ Easy to construct and maintain
+ Reuse of product
+ Reduces the load on solid waste management
+ Reduces methane emission
+ Reduces land required for landfill
+ Income generation, job creation
+ No electrical energy required
+ No issue with flies, mosquitoes and odour
- Large area requirements
- Demand for organic fertilizer
- Labour intensive operations and maintenance
- Long storage time

2.4 Decision making matrix for technology selection

2.4.1 Criteria for selection of appropriate technology

Sanitation technologies for individual houses, communities or towns should be selected based on local conditions and user requirements. The criteria for selection of appropriate technology is as follows (criteria adapted from WSP 2008):

Figure 0.22 – Selection criteria for appropriate sanitation technology choice

i. **Cultural acceptability:** A technology, which is not accepted by users, does not fare well in long term. Thus, cultural notions have to be taken into consideration before proposing a technology. For example, in case of Bangladesh, cleansing with water is preferred over use of paper.

ii. **Affordability:** High capital and operation cost is generally a major deterrent for a technology to be adopted. In case of on-site technologies, user affordability has to be ascertained while in case of off-site technologies, financial capacity of the authorities has to be considered.

iii. **Operation and maintenance requirements:** System requiring extensive O&M is not easily accepted by users and government authorities, which are already scampering for funds and skilled labour. However, no technology is entirely maintenance free. Technology requiring less O&M requires less investment in terms of capacity building as well as recurring costs.

iv. **Land availability:** The selection of a technology is mainly dependent on availability of land. In peripheral settlements where space is often available, decentralised sanitation facilities can be implemented. However in dense areas, considering the space constraints, on-site systems or connection to sewer network may be feasible.

v. **Treatment efficiency:** The selected technology should have high treatment efficiency to impact environment positively. For example, single pit latrines have negligible treatment efficiency, thus fecal sludge requires further treatment.

vi. **Energy requirements:** Most of the wastewater treatment projects fail due to unavailability of continuous electricity. In order to ensure sustenance it is necessary that technology should be selected which is less energy intensive or do not require energy for its operations.

vii. **Health Impact:** Current sanitation practices in the PPTA towns may adversely impact the environment and health of the residents. The proposed technologies should improve the environmental condition and minimise the health risk.

viii. **Reuse opportunity:** Reuse of the treated waste should be considered to reduce environmental pollution and sustain the technology. Reuse of treated waste and wastewater, as fertilizer has proven beneficial for the functioning of the system in many regions. Reuse generates revenue in certain cases, which helps in financially sustaining the system.

ix. **Adequacy of water:** Per capita water availability is one of the key criteria for selection of technology. For example if, per capita availability of water is less than 40 lpcd then, off-site technologies are not feasible.

x. **Ground water table:** High ground water table affects the construction as well as day-to-day working of the sanitation system. If the ground water table is high, the technologies should be selected which can work in such conditions or technologies have to be adapted to the situation.

xi. **Type and permeability of soil:** If systems require supernatant water, grey water or sullage to be disposed in soak pit or to be leached in surrounding soil then the permeability of the soil should be high.

xii. **Climatic conditions:** While considering sanitation technologies, the climate of the region should be taken into account. Temperature, rainfall pattern, frequency and intensity of floods and cyclonic storms should be taken into consideration.

xiii. **Compliance:** The technology has to comply to building bylaws, environmental laws and social norms.

The decision-making matrix has been prepared by evaluating the identified technologies against the 'selection criteria' as discussed above. The matrix ascertains the favourability of a technology in comparison to other identified technologies. Red colour symbolizes low favourability, yellow moderate favourability and green high favourability.

2.4.2 Selection of on-site treatment technologies

Table 0.1 – Decision making matrix for on-site collection, treatment and/or disposal

	Legend	Single Pit (without water seal)	Single pit with pour flush	Twin pits with pour flush	Dehydration vaults	Septic tank	Improved septic tank
Cultural acceptability	Red: Low acceptability Yellow: Medium acceptability Green: High acceptability	Green	Green	Green	Red	Green	Yellow
Health Impact	Red: Poor impact Yellow: Good impact Green: Very good impact	Red	Yellow	Yellow	Yellow	Green	Green
Environmental Impact	Red: Poor impact Yellow: Good impact Green: Very good impact	Red	Red	Yellow	Yellow	Green	Green
Capital cost*	Red: High cost Yellow: Medium cost Green: Low cost	Green	Green	Yellow	Yellow	Red	Red
Land requirement	Red: High requirement Yellow: Medium requirement Green: Low requirement	Green	Green	Green	Green	Yellow	Red

	Legend	Single Pit (without water seal)	Single pit with pour flush	Twin pits with pour flush	Dehydration vaults	Septic tank	Improved septic tank
O&M requirements**	[Red] High requirement [Yellow] Medium requirement [Green] Low requirement	[Red]	[Red]	[Yellow]	[Yellow]	[Green]	[Green]
Ease of construction	[Red] Difficult [Yellow] Moderately difficult [Green] Easy	[Green]	[Green]	[Green]	[Green]	[Green]	[Green]
High ground water table	[Red] Not favoured [Green] Favoured	[Red]	[Red]	[Red]	[Green]	[Green]	[Green]
Treatment efficiency	[Red] Low [Yellow] Medium [Green] High	[Red]	[Red]	[Yellow]	[Green]	[Yellow]	[Green]
Reuse opportunity	[Red] Low [Yellow] Medium [Green] High	[Red]	[Red]	[Yellow]	[Green]	[Red]	[Yellow]

*Capital cost does not include land cost
**O&M requirements include ease of maintenance, frequency and cost

Amongst the evaluated technologies, as shown in Table 0.1, twin pits with pour flush and conventional/improved septic tank are the most favourable means for collection and treatment of wastewater. Single pits are not favourable as they impact the environment, health adversely. In addition, they are highly vulnerable to local flooding conditions. The dehydration vaults are also favourable but cultural acceptability could be a hindrance.

Combination of technological options

The grey and black water streams from different sources can be collected, conveyed, treated and disposed off by adopting various possible combinations as mentioned in Figure 0.23.

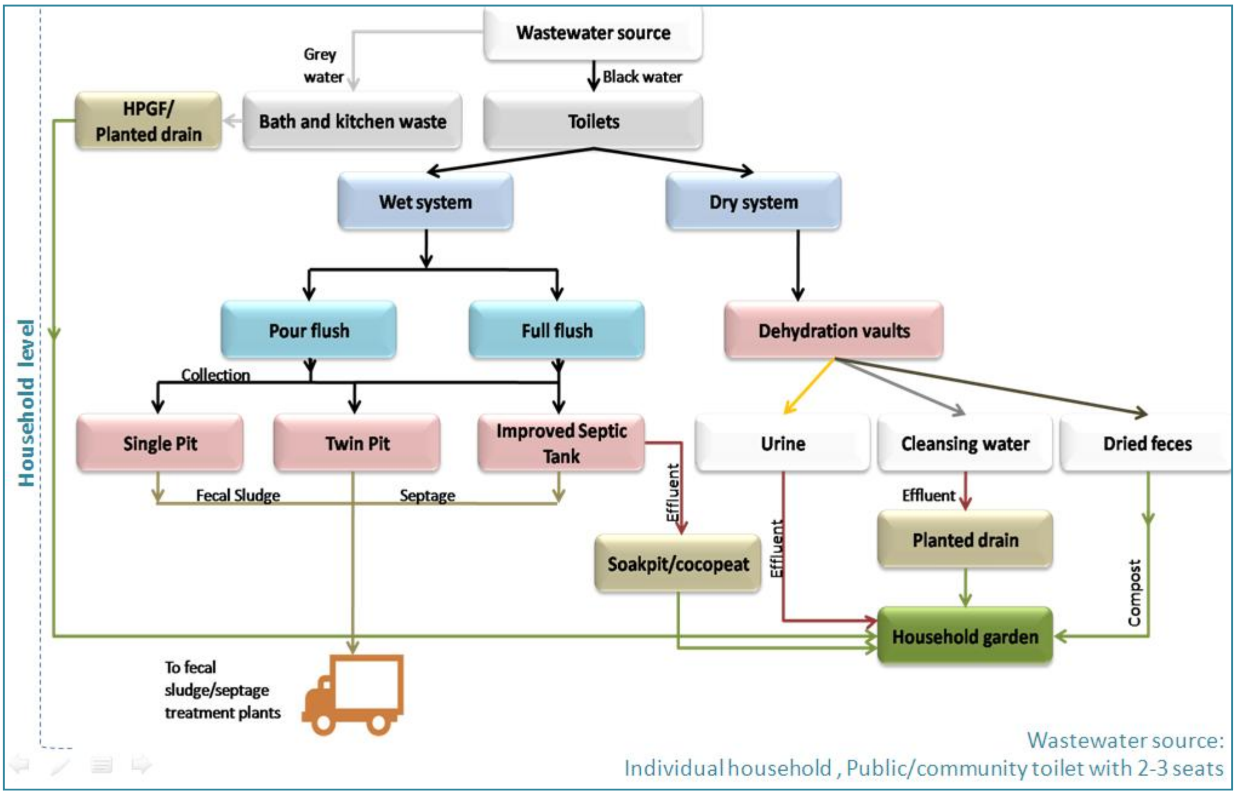


Figure 0.23 – Flow of wastewater in on-site collection, treatment and/or disposal systems

The fecal sludge /septage from the on-site systems like single pit, twin pit and septic tanks needs further treatment before disposal. Effluent from the septic tank needs to be disposed in the soak pit or further treated before disposal. The application of the various combinations are discussed in Table 0.2. The technology options for fecal sludge treatment are discussed below in section 2.4.3.

Table 0.2 – Application of various on-site sanitation combinations

Areas of application	User interface	Collection/ treatment	Disposal/reuse options	Remarks
• **Households** • **Small schools**	Flush toilets	Twin pit	a.)Sludge - Desludging and transportation to treatment facility	
• **Households (2-5)with shared treatment system** • **Public toilet,** • **Community toilets**	Flush toilets	Improved septic tank with soak pit	a.)Effluent –Soak pit b.)Sludge – Desludging and transportation to treatment facility	
• **Households**	Flush toilets	Biogas digester	a.)Effluent –Soak pit b.)Sludge – Desludging and transportation to treatment facility c.)Biogas - cooking	
• **Households**	Dry toilet	Dehydration vault	a.)Land application of dried feces or removal and transportation for safe disposal	Urine and anal cleansing water needs to be safely disposed Dehydration vaults can be used especially in households on the banks of khals

2.4.3 Fecal Sludge Treatment

Table 0.3 - Decision making matrix for fecal sludge treatment

	Legend	Biogas digester	Planted/unplanted drying beds	WSP	Co-composting
Land requirements	High requirement Medium requirement Low requirement				
Capital cost*	High cost Medium cost Low cost				
O&M cost	High cost Medium cost Low cost				
Ease of construction	Difficult Moderately difficult Easy				
Ease of maintenance	Difficult Moderately difficult Easy				

Energy required for daily operations	High Medium Low				
Treatment efficiency	Low Medium High				
Reuse opportunity	Low Medium High				
Environmental Impact	Poor impact Good impact Very good impact				
Public Nuisance	High Medium Low				
Resilience to flood	Not resilient Resilient Highly resilient				

Note:
* Capital cost does not include land cost

From Table 0.3 it can be ascertained that for fecal sludge treatment, biogas digester is highly favourable due to its low space requirements and cost, high treatment efficiency, and reuse opportunities. Waste stabilization ponds and drying beds are also applicable, however the major issue with them is the large land requirement and they are less resilient to floods.

Combination of technological options

The various combinations of technology for sludge/septage treatment are mentioned in Figure 0.24.

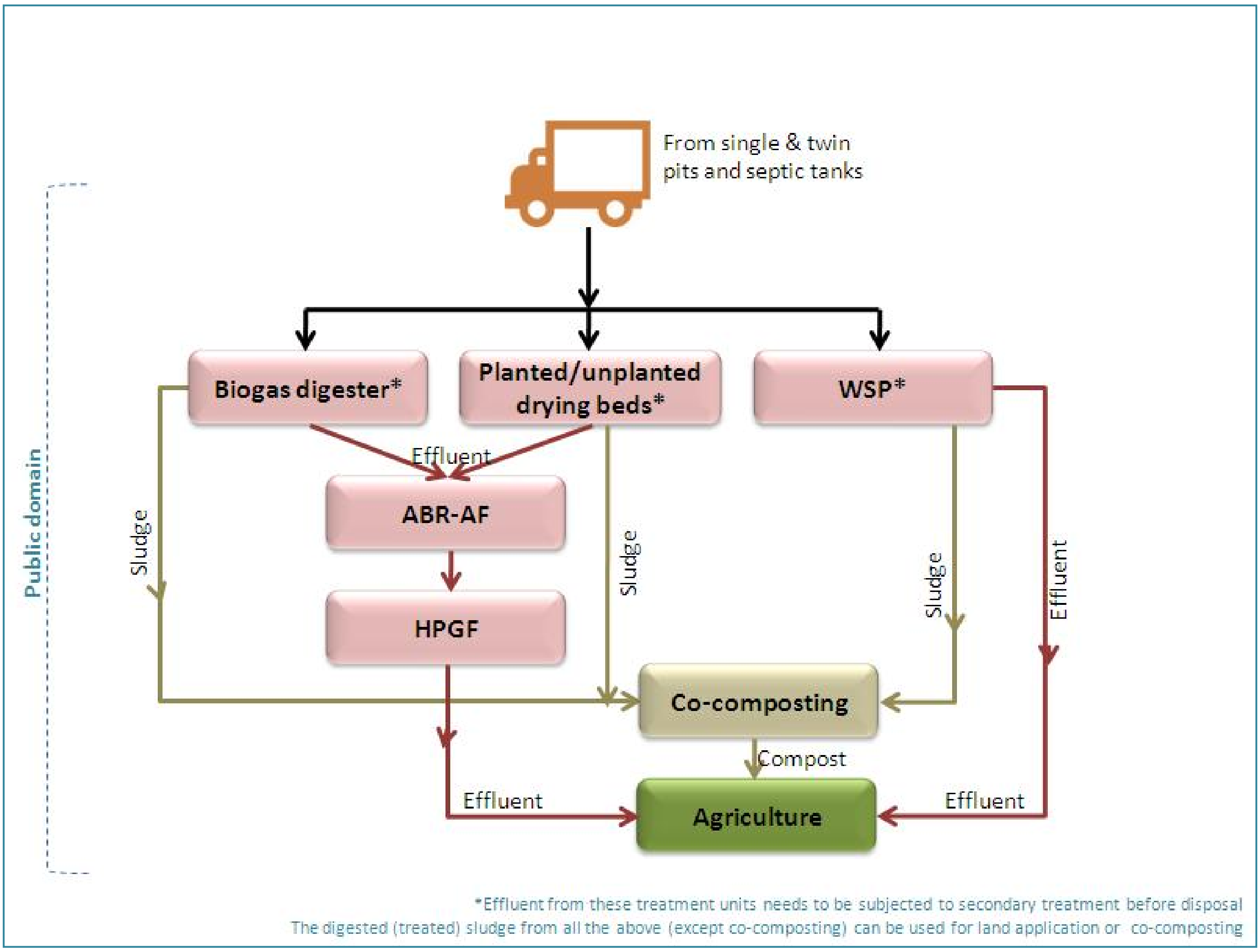


Figure 0.24 – Flow of fecal sludge through treatment systems

From the on-site collection systems the sludge and septage has to be treated further. The Pourashavas have to provide the desludging, transportation and treatment facilities for the same. The flow of sludge and effluent in the system has been shown in Figure 0.24. The sludge from the pits and tanks can be treated in biogas digester, WSP or drying beds. The effluent generated from biogas digester and drying beds can be further treated using various combination of technologies. The treated sludge can be applied in agricultural fields after co-composting along with the treated effluent. Application of various combinations are as mentioned in Table 0.4 - Application of various fecal sludge treatment combinations

Application of various combinations:

Table 0.4 - Application of various fecal sludge treatment combinations

Areas of application	Sludge treatment	Effluent (leachate) treatment		Disposal/reuse options	Remark
		Secondary treatment	Tertiary treatment		
• **Town-wide sludge/septage**	Biogas digester	ABR+AF	HPGF	a.)Digested sludge – land application b.)Effluent – Land application	Digested sludge from the treatment units can be used in co-composting unit with other bio-degradable waste
	Unplanted/planted drying beds	ABR+AF	HPGF	a.)Digested sludge – land application b.)Effluent – Land application	
	WSP			a.)Digested sludge – land application b.)Effluent – Land application	

2.4.4 Decentralised Wastewater Treatment

Table 0.5 – Decision making matrix for off-site decentralized wastewater treatment

	Legend	BGD	ABR with ST**	AF with ST**	HPGF with ST***	DEWATS	WSP	Cocopeat with IST
Land requirements	High requirement Medium requirement Low requirement	Green	Yellow	Yellow	Red	Red	Red	Yellow
Capital cost*	High cost Medium cost Low cost	Green	Yellow	Yellow	Yellow	Red	Yellow	Green
O&M cost	High cost Medium cost Low cost	Green	Green	Green	Green	Green	Green	Green
Ease of construction	Difficult Moderately difficult Easy	Red	Yellow	Yellow	Yellow	Yellow	Green	Green
Ease of maintenance	Difficult Moderately difficult Easy	Yellow	Yellow	Yellow	Green	Yellow	Green	Yellow

	Legend	BGD	ABR with ST**	AF with ST**	HPGF with ST***	DEWATS	WSP	Cocopeat with IST
Energy required for daily operations	High Medium Low							
Treatment efficiency	Low Medium High							
Reuse opportunity	Low Medium High							
Compliance	Not compliant Compliant Highly compliant							
Environmental Impact	Poor impact Good impact Very good impact							
Public Nuisance	High Medium Low							

Resilience to flood	Low Medium High							
*Capital cost does not include land cost								

According to Table 0.5, cocopeat technology with improved septic tank is favourable due to low capital and life cycle cost, ease of maintenance, proven to be good for low volume wastewater quantity, good treatment efficiency and reuse opportunity. However, combination of treatment modules like BGS, ST, ABR, AF and HPGF (e.g. in DEWATS) is suitable for treatment of wastewater (low and high volume of wastewater quantity) at cluster level due to its high treatment efficiency, low maintenance and opportunities for re-use of its treatment byproducts like biogas, treated wastewater and digested sludge as compost.

Combination of technological options

The various combinations of technology for decentralised wastewater treatment are mentioned in Figure 0.25. The wastewater can be conveyed from toilets to treatment units like ABR-AF, HPGF, cocopeat and WSP through shallow sewer system and/or small-bore system. The treated effluent can be used for land application in agricultural fields. The digested sludge from the treatment units can be co-composted with municipal organic solid waste, which can further be used a fertilizer.

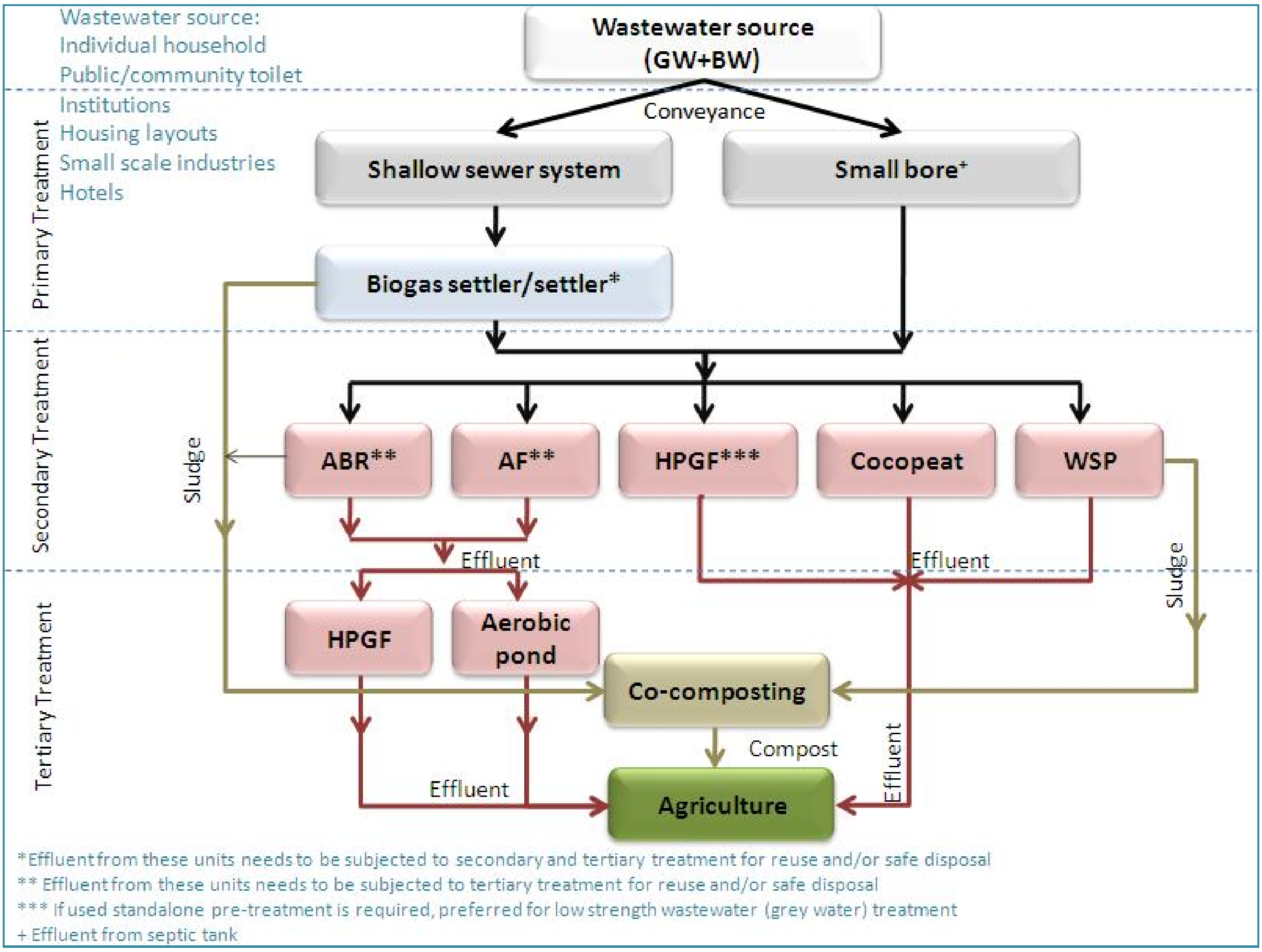


Figure 0.25 – Flow of wastewater in off-site decentralized wastewater treatment systems

The application of various combinations are as mention in Table 0.6

Application of various combinations:

Table 0.6 - Application of various decentralized treatment combinations

Areas of application	User interface	Conveyance	Primary treatment	Secondary treatment	Tertiary treatment	Disposal/reuse options	Remark
• **Housing cluster** • **Public toilets** • **Community toilets,** • **Hospitals,** • **Schools**	Toilet, bathroom, laundry, kitchen	Shallow/small bore sewer system	Settler	ABR+AF	HPGF	a.)Sludge/effluent - Land application	Small bore is adapted where septic tank is available
• **Community toilets** • **Hospitals,** • **Schools** • **Hotels**	Toilet, bathroom, kitchen, laundry	Shallow sewer system	Biogas settler	ABR+AF	HPGF	a.)Biogas - cooking b.)Sludge/effluent - land application	Wastewater with high organic load
• **Guest house,** • **Small hotels,** • **Small housing clusters,** • **Office buildings**	Toilet, bathroom, laundry, kitchen	Shallow sewer system	Improved septic tank		Cocopeat	a.)Sludge – further treatment b.)Effluent – Land application	
• **Housing cluster**	Toilet, bathroom, laundry, kitchen	Shallow/small bore sewer system	Waste stabilization pond			a.)Sludge/effluent - Land application	For housing clusters in the peripheral areas

2.5 Application of sanitation technologies in PPTA towns

Based on the technological options recommended as per the decision-making matrix and its possible combinations, the most applicable technology options and its application in PPTA towns is discussed in detail below.

In order to demonstrate the application of the suitable technologies and its combination it is proposed to classify the areas of application into two categories (a) public domain and (b) private domain. The same has been demonstrated through a pilot project for various sectors under each category as mentioned below.

The pilots have been selected based on the site visits, situation analysis and interventions identified by the project team for sanitation improvement in the PPTA towns. A pilot in a particular town can be replicated for similar conditions in other PPTA towns.

2.5.1 Application of technology in public domain

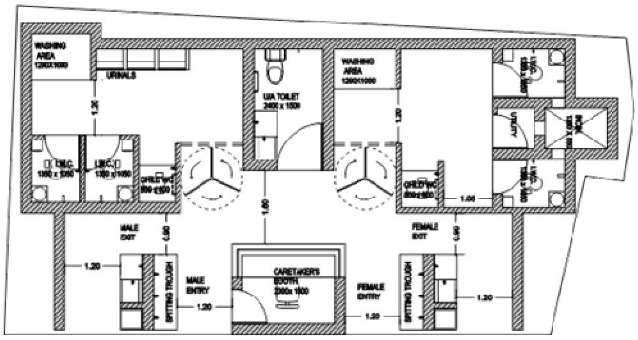
The public domain consists of following areas/sectors/landuse:

- Public toilet - Bus stand, Market areas
- Community toilet – Urban poor areas
- Public Institutions – Offices, Hospitals, Educational institutions (School, Hostels, Colleges)
- Cyclone shelters
- Townwide septage management

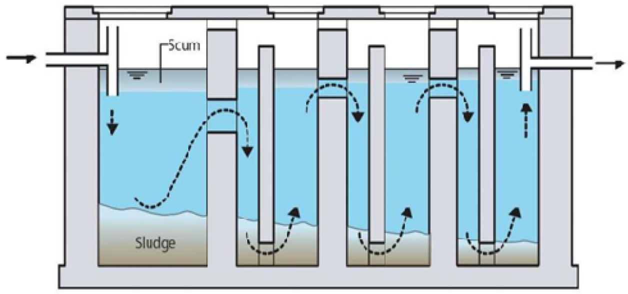
Public Toilets – Market place, Pirojpur

Design parameters

- No. of users/day – 100-125
- No. of toilet seats – 2 for men, 2 for women
- No. of urinals – 3
- Wastewater quantity – 5 cu.m per day



Source: Project samman, Anagram Architects (2010)



Source: SWSM(2010), improved septic tanks, www.swsm.com

Area required

Toilet super structure = 50 - 75 sq.m
Treatment system = 10 -15 sq.m

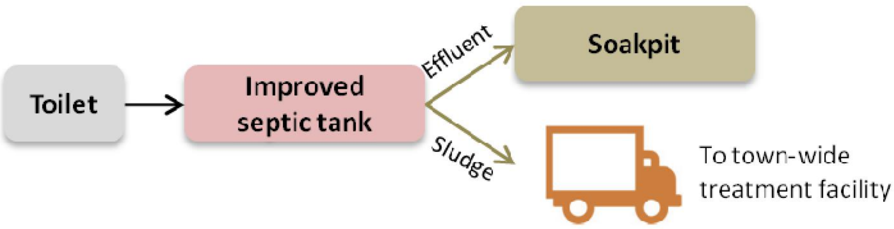
Estimated Capital Cost

Toilet complex = 12000- 15000 USD
Treatment system = 1500 - 2000 USD

Estimated O&M Cost

For treatment system = 75 – 125 USD once in two to three years

Wastewater treatment



The wastewater from the toilet complex will be conveyed to an improved septic tank (IST). The settled sludge at the IST bottom needs to be collected and transported to town-wide septage treatment facility for further treatment whereas, the effluent can be discharged in a soak pit .

O&M

- Desludging as per design period (once in 2-3 years)
- Monitor inlet and out let condition
- The filter media in soak pit requires cleaning or replacing every 3-5 years

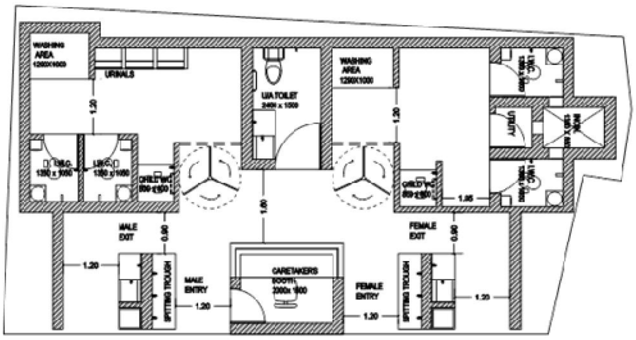
Climate change adaptation

- Tank should be constructed water-tight
- Top slab of the tank should be constructed 15-30 cm above high flood level
- Provide a non-return valve at the outlet
- Avoid complete desludging of tank during rainy season
- Provide adequate freeboard volume to allow usage of tank during flooding situation

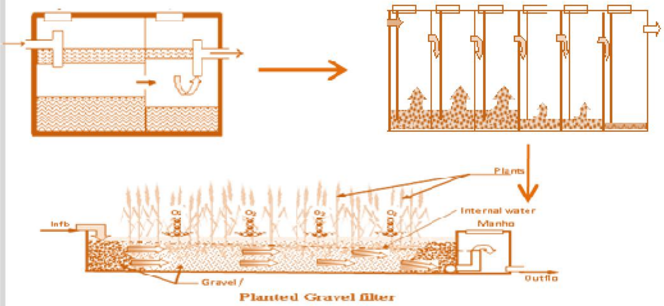
Public Toilets – Ferry Ghat, Amtali

Design parameters

- No. of users/day – 150-200 users
- No. of toilet seats – 2 for men, 2 for women
- No. of urinals – 3
- Wastewater quantity – 10 cu.mper day



Source: Project samman, Anagram Architects (2010)



Source: CDD Society (2011), DEWATS: An overview

Area required

Toilet super structure = 55 - 75 sq.m
Treatment system = 70 - 100 sq.m

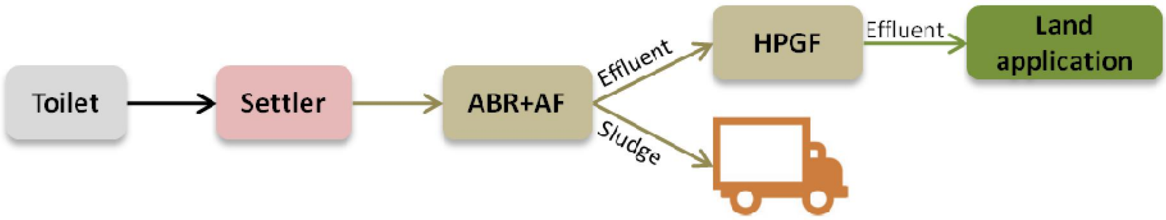
Estimated Capital Cost

Toilet complex = 12000 - 15000 USD
Treatment system = 5500 - 10000 USD

Estimated O&M Cost

For treatment system = 100 – 150 USD per annum

Wastewater treatment



The wastewater from the toilet complex is collected in the settler. The wastewater from the settler is further conveyed to the Anaerobic baffle reactor (ABR) integrated with Anaerobic filter (AF) and Horizontal Planted Gravel Filter (HPGF) for secondary and tertiary treatment. The treated effluent from HPGF can be collected for reuse requirements like agriculture and gardening purpose or it can be discharged in to the nearby natural drain for safe disposal. The sludge from the primary and secondary treatment modules is transported for further treatment .

O&M

- Desludging of primary and secondary treatment module as per design period of 2-3 years
- Clean the filter media in AF or replace it every 3-5 years
- Filter media in HPGF needs cleaning or replacement in 3-5 years

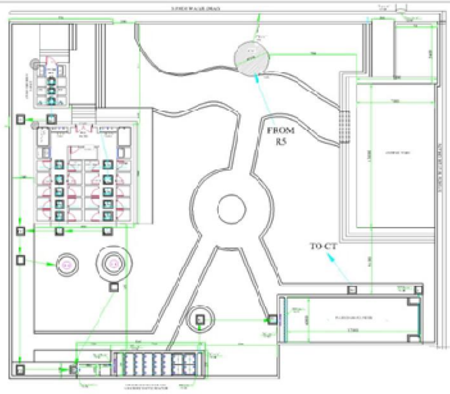
Climate change adaptation

- Tanks should be constructed water-tight
- Top slab of the tank should be constructed 15-30 cm above high flood level
- Provide a non-return valve at the outlet
- Avoid complete desludging of tanks and removal of filter material during rainy season
- Provide adequate freeboard volume to allow usage of tank during flooding situation

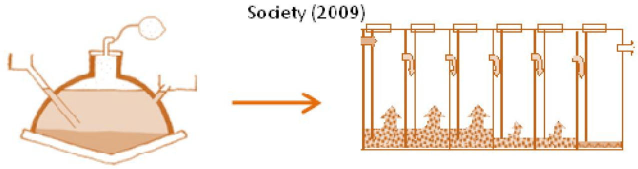
Community Toilets – Kathpotti slum, Near Pourashava office, Galachipa

Design parameters

- No. of users – 500-600
- No. of toilet seats – 4 for men, 4 for women
- No. of urinals – 2
- Bathing units – 1 for men, 1 for women
- Wastewater quantity – 10 cu.m per day



Source: CBS project at Rajendranagar, Kolhapur,India, CDD Society (2009)



Source: CDD Society (2011), DEWATS: An overview

Area required

Toilet super structure = 200 - 250 sq.m
Treatment system = 70 - 100 sq.m

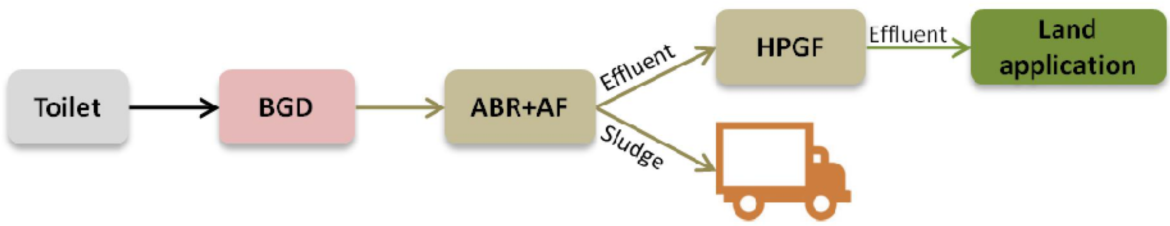
Estimated Capital Cost

Toilet complex = 18000 - 20000 USD
Treatment system = 6500 - 11000USD

Estimated O&M Cost

For treatment system = 100 – 150 USD per annum

Wastewater treatment



The wastewater from the toilet complex is collected in the Biogas digester (BGD). The wastewater from the BGD is further conveyed to the Anaerobic baffle reactor (ABR) integrated with Anaerobic filter (AF) and Horizontal Planted Gravel Filter (HPGF) for secondary and tertiary treatment. The treated effluent from HPGF can be collected for reuse requirements like agriculture and gardening purpose or it can be discharged in to the nearby natural drain for safe disposal. The sludge from the primary and secondary treatment modules is transported for further treatment. The biogas generated can be used for cooking purposes.

O&M

- Desludging of primary and secondary treatment module as per design period of 2-3 years
- Clean the filter media in AF or replace it every 3-5 years
- Filter media in HPGF needs cleaning or replacement in 3-5 years

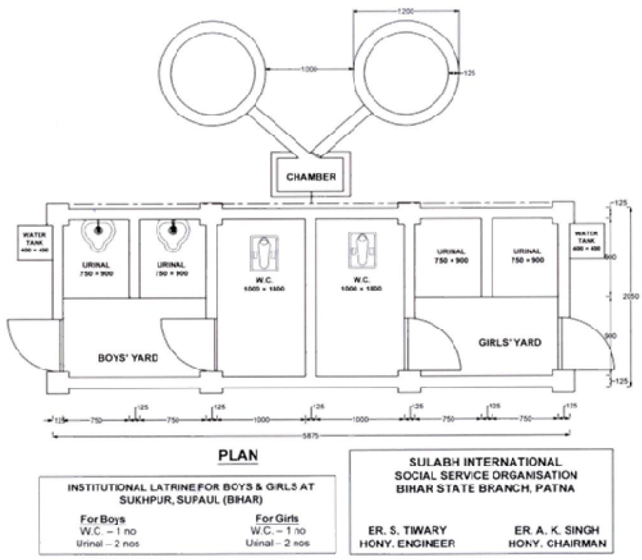
Climate change adaptation

- Tanks should be constructed water-tight
- Top slab of the tank should be constructed 15-30 cm above high flood level
- Provide a non-return valve at the outlet
- Avoid complete desludging of tanks and removal of filter material during rainy season
- Provide adequate freeboard volume to allow usage of tank during flooding situation

Public Institutions – Municipal primary school, Galachipa

Design parameters

- No. of users – 100 - 150 users
- No. of toilet seats – 1 for men, 1 for women
- No. of urinals – 2 for men, 2 for women
- Wastewater quantity – 1-2 cu.m perday



Area required

Toilet super structure = 12 - 15 sq.m
Treatment system = 10 – 12 sq.m

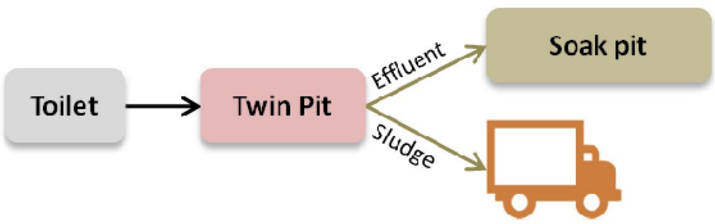
Estimated Capital Cost

Toilet complex = 2500 - 5000 USD
Treatment system = 100-150 USD

Estimated O&M Cost

For treatment system = 50 – 75 USD once in one to two years

Wastewater treatment



The wastewater from the toilet complex will be conveyed to one pit through a 'Y' junction chamber. After one pit is full the wastewater will be diverted to another pit. When the second pit is almost full, the first pit can be desludged. The effluent seeps in the surrounding soil through the seep holes provided in the pit lining.

O&M

- Use one pit at a time
- Check the seal of 'Y' junction regularly
- Use of 1.5 to 2L of water use should be ensured
- Desludging period of the pit is 6 months to 12 months

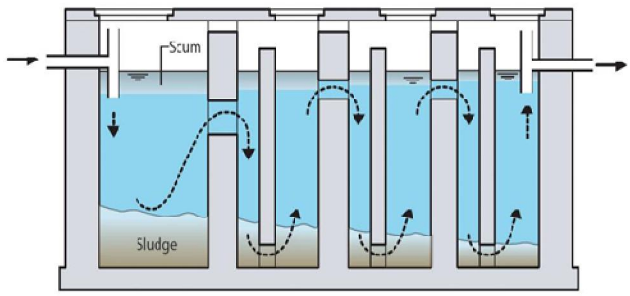
Climate change adaptation

- The toilet pan must be installed 15-30cm above the locally accepted flood level
- Rings should be constructed water-tight on the top and sides till outlet level
- The outlet of the pit should be atleast 10 cm above the maximum ground water table
- If the rings are water tight, then the pit should not be completely desludged to avoid uplifting of ring tank

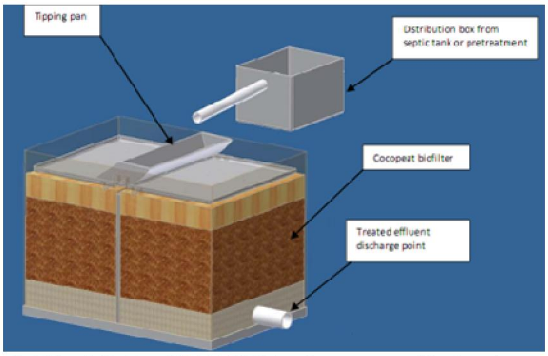
Public Institutions – Pourashava building, Mathbaria

Design parameters

- No. of users including the visitors – 400-500
- Wastewater quantity – 5 cu.m per day



Source: SWSM (2010), improved septic tanks, www.swsm.com



Source: Robbins D, Richkus J (2011) Utilizing Cocopeat as a Medium for Wastewater Treatment Biofiltration for Residential, Institutional Applications

Area required

Treatment system = 20 - 30sq.m

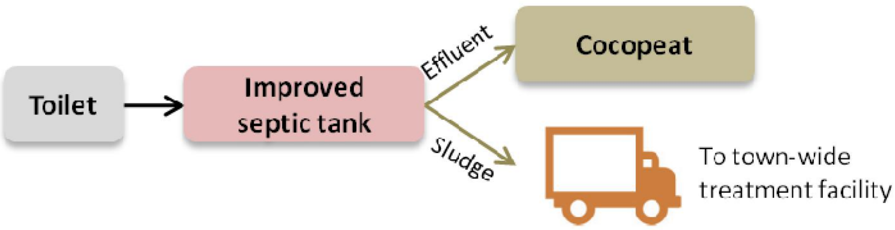
Estimated Capital Cost

Treatment system = 2000 - 3000 USD

Estimated O&M Cost

For treatment system = 100 – 150 USD once in two to three years

Wastewater treatment



The wastewater from the different source of Porashava building will be conveyed to an improved septic tank. The settled sludge at the bottom needs to be collected and transported to town-wide septage treatment facility for further treatment whereas, the effluent can be treated in cocopeat for land application.

O&M

- Desludging as per design period (once in 3-5 years)
- Monitor inlet and out let condition
- Cocopeat filter requires replacement every2-3 years

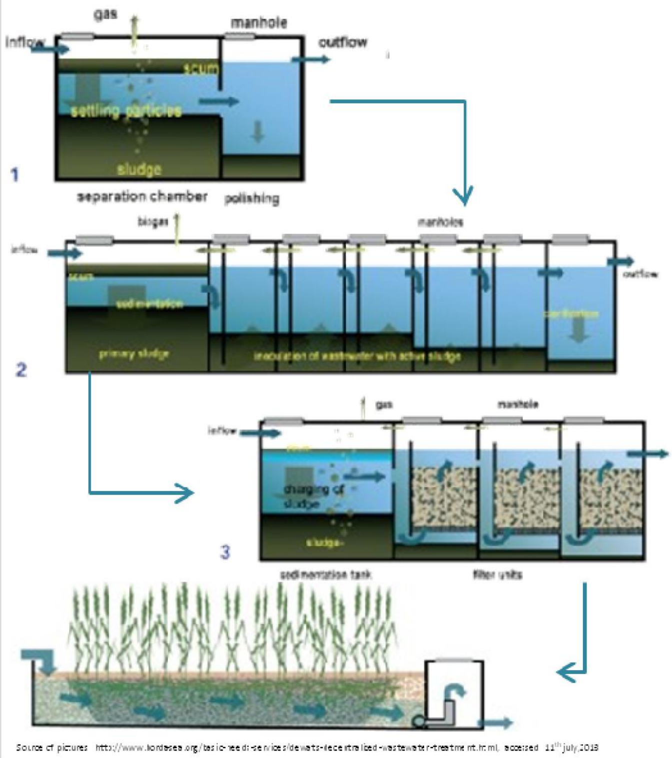
Climate change adaptation

- Tank should be constructed water-tight
- Top slab of the tank should be constructed 15-30 cm above high flood level
- Avoid complete desludging of tank during rainy season
- Provide adequate freeboard volume to allow usage of tank during flooding situation

Public Institutions – Hospital building, Galachipa

Design parameters

•No. of beds = 100
•Water consumption per bed = 400 Litres
•Wastewater quantity = 40 cu.m per day



Area required

Treatment system = 250 - 300 sq.m

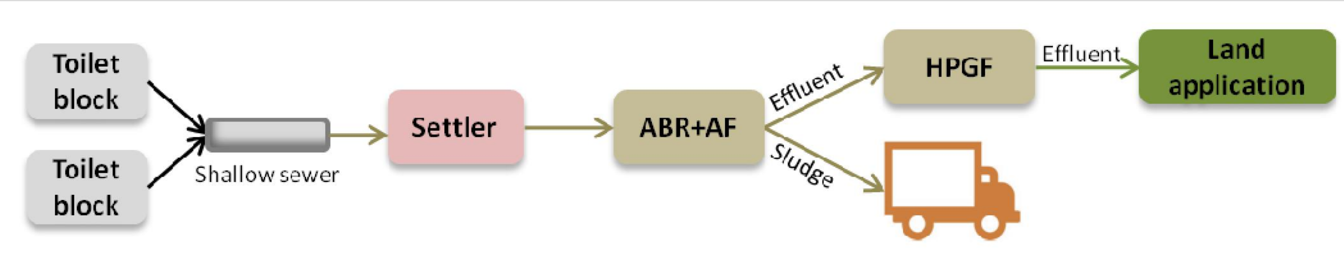
Estimated Capital Cost

Treatment system = 22,000 – 40,000USD
Cost for Shallow sewer system – 8000 – 10000 USD

Estimated O&M Cost

For treatment system = 250 – 300 USD per annum

Wastewater treatment



The wastewater from the different source of Hospital will be conveyed to a settler through shallow sewer system. The wastewater from the settler is further conveyed to the Anaerobic baffle reactor (ABR) integrated with Anaerobic filter (AF) and Horizontal Planted Gravel Filter (HPGF) for secondary and tertiary treatment. The treated effluent from HPGF can be collected for reuse requirements like agriculture and gardening purpose or it can be discharges in to the nearby natural drain for safe disposal. The sludge from the primary and secondary treatment modules is transported for further treatment .

O&M

•Desludging of primary and secondary treatment module as per design period of 2-3 years
•Clean the filter media in AF or replace it every 3-5 years
•Filter media in HPGF needs cleaning or replacement in 3-5 years

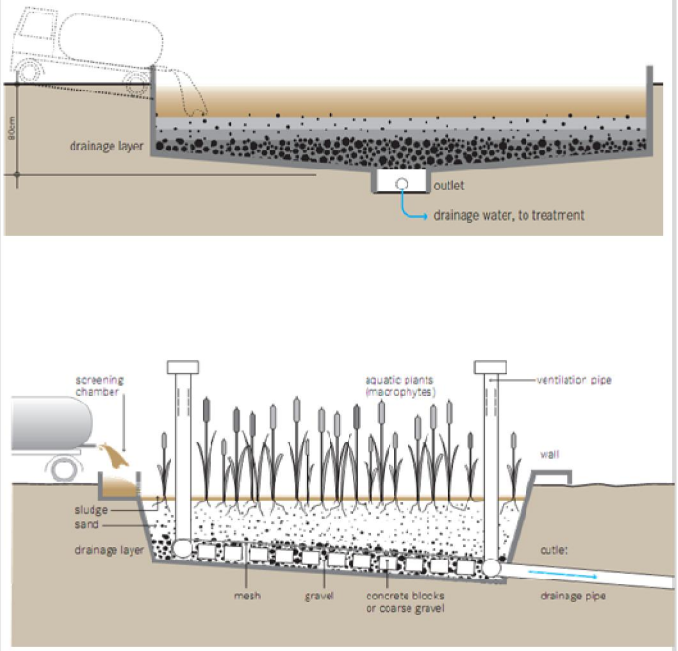
Climate change adaptation

•Tanks should be constructed water-tight
•Top slab of the tanks should be constructed 15-30 cm above high flood level
•Provide a non-return valve at the outlet
•Avoid complete desludging of tanks and removal of filter material in HPGF during rainy season
•Provide adequate freeboard volume to allow usage of tank during flooding situation

Townwide Septage Management – Pirojpur town

Design parameters

•Septage treatment capacity = 50 cu.m per day



Source: Compendium of sanitation systems and technologies, Eawag aquatic research, 2008

Area required

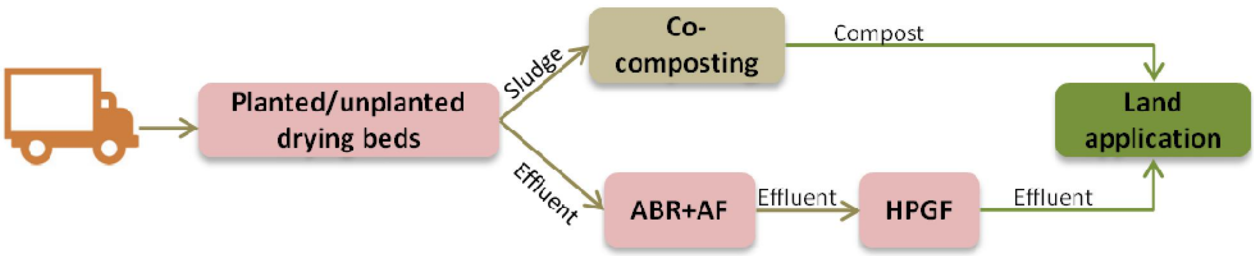
Treatment system = 1000 - 1250 Sq.m

Estimated Capital Cost

Treatment system = 80000 -110000 USD

Estimated O&M Cost

Wastewater treatment



The sludge collected from on-site systems is spread on drying beds. Unplanted drying beds collects percolated leachate from sludge, and allows drying of sludge by evaporation. The volume of the sludge is decreased for further treatment. Planted drying beds are similar to unplanted drying beds. Here the beds are planted for increased transpiration. The dried sludge is taken to co-composting unit for compost preparation which can be used as fertilizer. The effluent if passed through ABR, AF and HPGF for further treatment. The treated effluent can be used for irrigation.

O&M

•Provision of proper access for trucks
•In unplanted beds – sludge to be removed every 10-15 days, sand to be added when required
•In planted drying beds – sludge removal 2-3 years, remove unwanted plants regularly

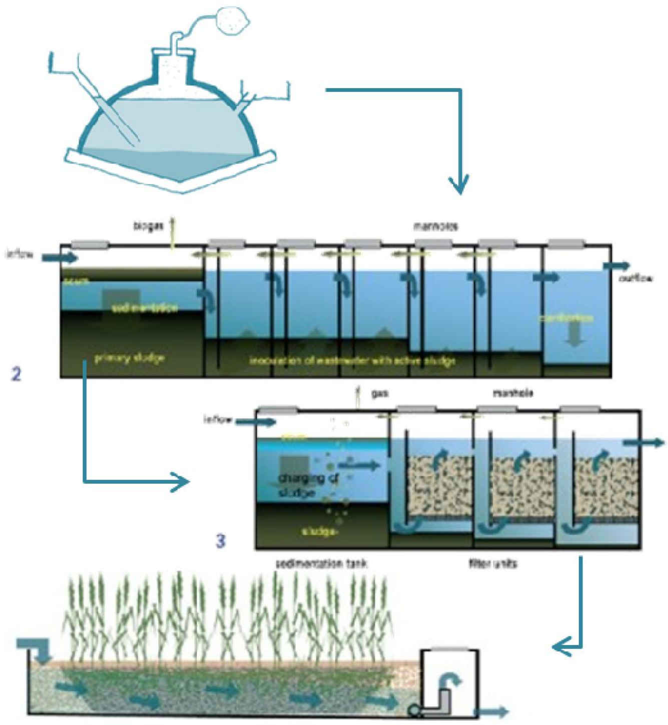
Climate change adaptation

•Tanks should be constructed water-tight
•Side walls of the tank should be atleast 30-60 cm above high flood level
•The unit should be covered to protect against rainfall
•Provide a non-return valve at the outlet
•The tanks should be designed to counter ground water pressure

Townwide Septage Management – Amtali, Galachipa or Mathbaria town

Design parameters

•Septage treatment capacity = 20 cu.m per day



Source of pictures: http://www.borda-sea.org/basic-needs-services/dewats-decentralized-wastewater-treatment.html accessed 11th july,2013

Area required

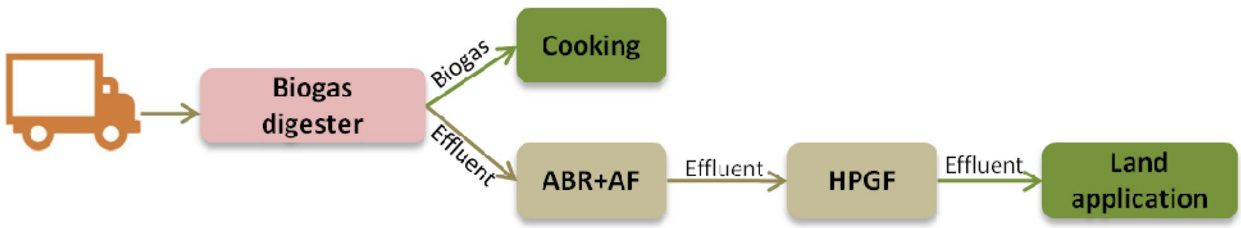
Treatment system = 500 - 750 sq.m

Estimated Capital Cost

Treatment system = 40,000 – 50,000 USD

Estimated O&M Cost

Wastewater treatment



The sludge collected from on-site systems is fed to a biogas digester. The effluent of BGD is further conveyed to the Anaerobic baffle reactor (ABR) integrated with Anaerobic filter (AF) and Horizontal Planted Gravel Filter (HPGF) for secondary and tertiary treatment. The treated effluent from HPGF can be collected for reuse requirements like agriculture and gardening purpose or it can be discharges in to the nearby natural drain for safe disposal. The biogas generated can be used for cooking purposes. The digested sludge from BGD can be used for co-composting or land application

O&M

- Desludging of BGD as per design period
- Desludging of secondary modules once in 2-3 years
- Clean the filter media in AF or replace it every 3-5 years
- Filter media in HPGF needs cleaning or replacement in 3-5 years

Climate change adaptation

- Tanks and digester should be constructed water-tight
- Top slab of the tanks should be constructed 15-30 cm above high flood level
- Provide a non-return valve at the outlet
- Avoid complete desludging of tanks and removal of filter material during rainy season in HPGF
- Provide adequate freeboard volume to allow usage of tank during flooding situation

2.5.2 Application of technology in private domain

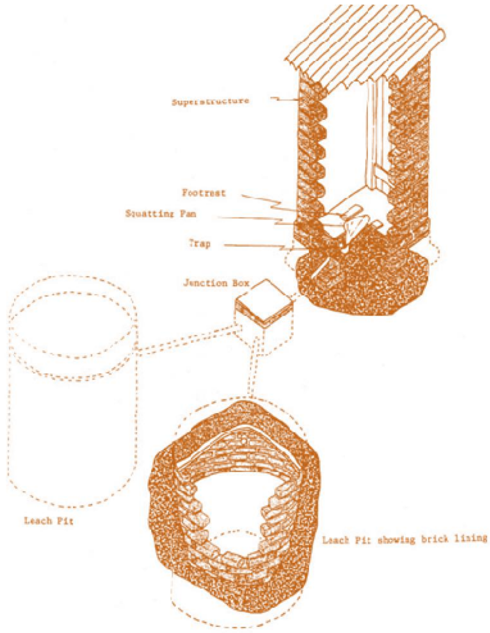
The private domain consists of following areas/sectors/landuse:

- Individual households
- Individual households on the bank of the river streams
- Housing clusters – township, colonies
- Private Institutions – offices, hospitals, education (school, hostels, colleges)
- Hotels and guest house

Individual Household

Design parameters

•No. of users – 5 users
•Wastewater quantity – 0.5 – 1.0 cu.m per day



Source: MARA, D.D. (1985): The Design of Pour-Flush Latrines. United Nations Development Programme (UNDP) and World Bank.

Area required

Treatment system = 7 – 10 sq.m

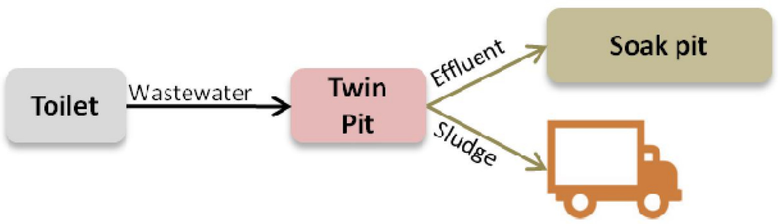
Estimated Capital Cost

Treatment system = 50 -75 USD

Estimated O&M Cost

Treatment system = 50 – 75 USD once in one to two years

Wastewater treatment



The wastewater from the toilet will be conveyed to one pit through a 'Y' junction chamber. After one pit is full the wastewater will be diverted to another pit. When the second pit is almost full, the first pit can be desludged. The effluent seeps in the surrounding soil through the seep holes provided in the pit lining

O&M

•Use one pit at a time
•Check the seal of 'Y' junction regularly
•Use of 1.5 to 2L of water use should be ensured
•Desludge the pit every 6 months

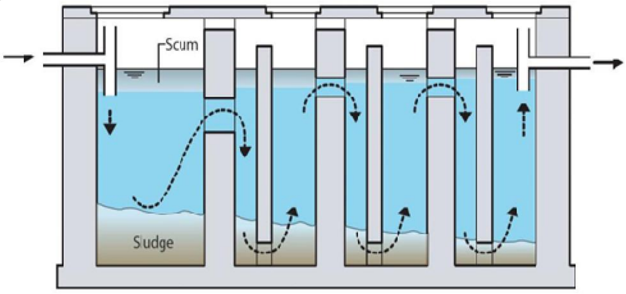
Climate change adaptation

•The toilet pan must be installed 15-30cm above the locally accepted flood level
•Rings should be constructed water-tight on the top and sides till outlet level
•The outlet of the pit should be atleast 10 cm above the maximum ground water table
•If the rings are water tight, then the pit should not be completely desludged to avoid uplifting of ring tank

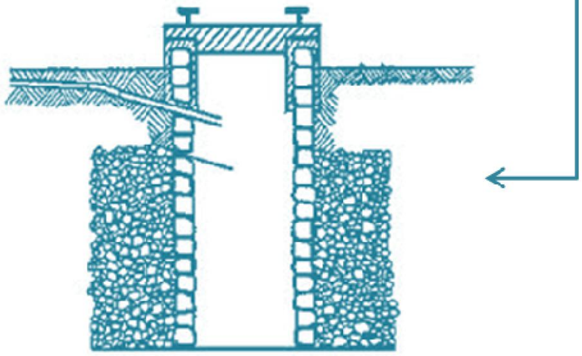
Individual Household

Design parameters

- Household size – 5 members
- Wastewater quantity – 0.5 – 1.0 cum per day



Source: SWSM (2010), improved septic tanks, www.swsm.com



Area required

Treatment system = 5 - 7 sq.m

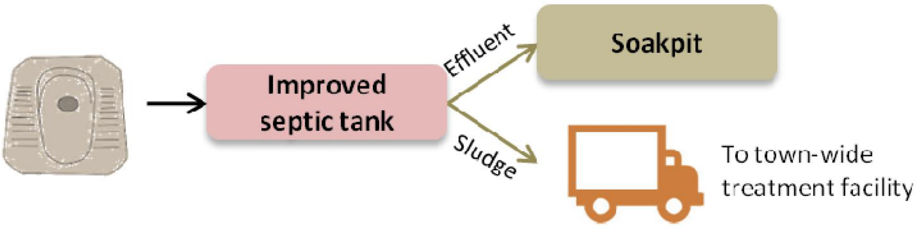
Estimated Capital Cost

Treatment system 750-1100 USD

Estimated O&M Cost

For treatment system = 75 – 125 USD once in two to three years

Wastewater treatment



The wastewater from the toilet complex will be conveyed to an improved septic tank. The settled sludge at the bottom needs to be collected and transported to town-wide septage treatment facility for further treatment whereas, the effluent can be discharged in a soakpit.

O&M

- Desludging as per design period (once in 2-3 years)
- Monitor inlet and out let condition
- The filter media in soak pit requires cleaning or replacing every 3-5 years
- Cocopeat filter requires replacement every2-3 years

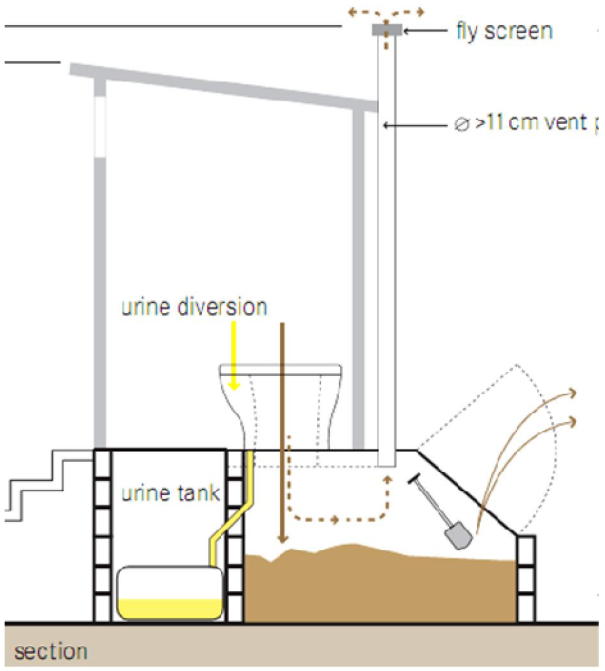
Climate change adaptation

- Tank should be constructed water-tight
- Top slab of the tank should be constructed 15-30 cm above high flood level
- Provide a non-return valve at the outlet
- Avoid complete desludging of tank during rainy season
- Provide adequate freeboard volume to allow usage of tank during flooding situation

Individual Household

Design parameters

•Household size – 5 persons



Source: Compendium of sanitation systems and technologies, Eawag aquatic research, 2008

Area required

Treatment system = 5 - 7 sq.m

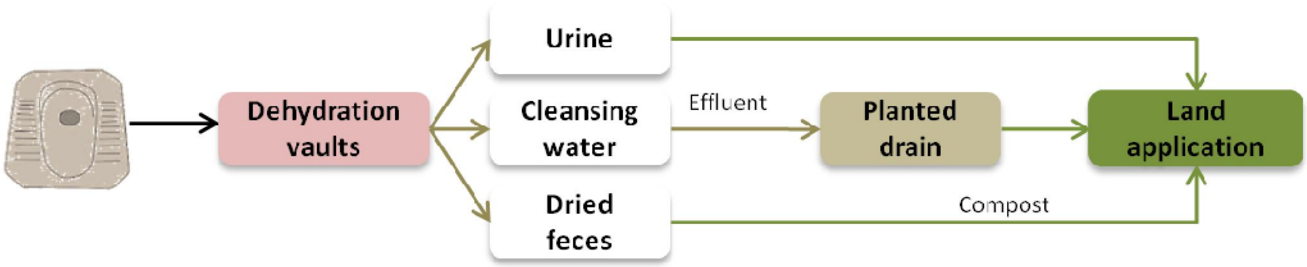
Estimated Capital Cost

Treatment system = 75 – 110 USD

Estimated O&M Cost

Treatment system = 40 - 50 USD per annum

Wastewater treatment



It is a dry on-site system used to collect, store and dehydrate feces. The vaults are built watertight. The feces are stored in the vaults and urine/anal cleansing water is diverted away from the vaults. The dried feces can be removed after six months and used in kitchen gardens/agricultural fields. The anal cleansing can be passed through planted drain and used for gardening purposes or discharged safely.

O&M

•To dehydrate the feces, ash, soil or lime should be used to cover the feces after every use
•If urine or water gets inside the vault, then extra lime or ash should be spread for extra drying.
•If water is used for anal cleansing, it should be diverted appropriately

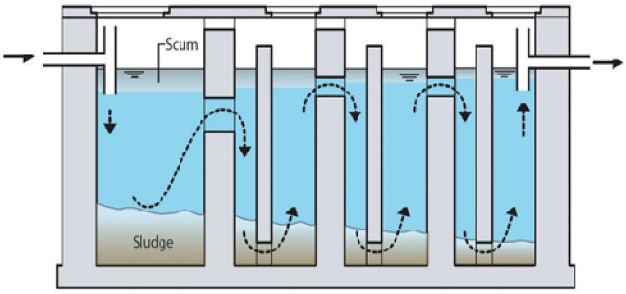
Climate change adaptation

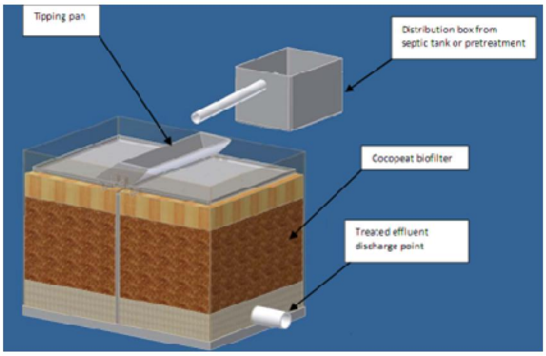
•This technology is appropriate in areas with high ground water table and flood prone regions

Housing Clusters

Design parameters

•No. of Houses – 10-20
•Household size - 5
•Wastewater quantity – 10 cu.m per day





Area required

Treatment system = 40 - 50 sq.m

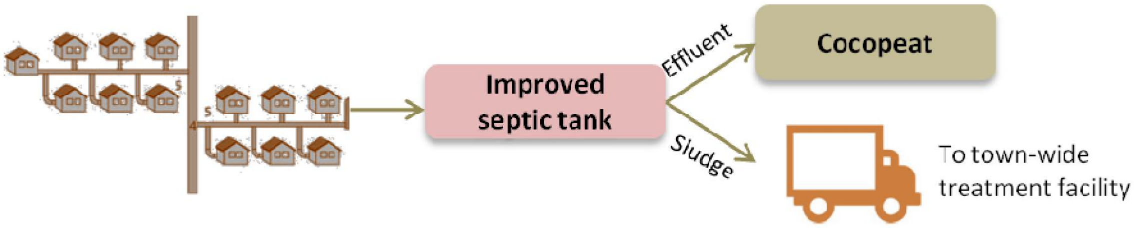
Estimated Capital Cost

Treatment system = 3500 - 5000 USD

Estimated O&M Cost

For treatment system = 200 – 250 USD per annum

Wastewater treatment



The wastewater from the different source of Porashava building will be conveyed to an improved septic tank. The settled sludge at the bottom needs to be collected and transported to town-wide septage treatment facility for further treatment whereas, the effluent can be treated in cocopeat for land application.

O&M

•Desludging as per design period
•Monitor inlet and out let condition
•Cocopeat filter requires replacement every 2-3 years
•The sewer system should be checked for leakages regularly

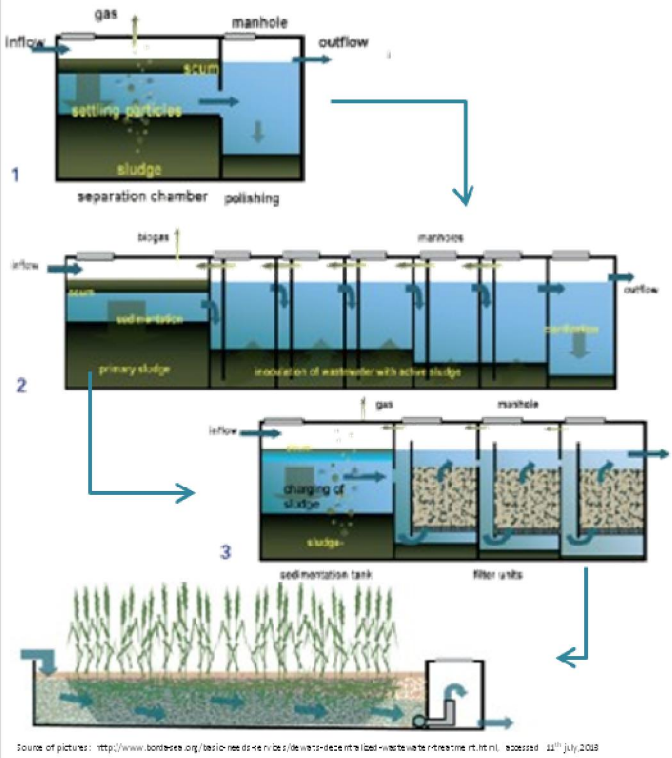
Climate change adaptation

•Tanks should be constructed water-tight
•Top slab of the tank should be constructed 15-30 cm above high flood level
•Provide a non-return valve at the outlet
•Avoid complete desludging of tank during rainy season
•Provide adequate freeboard volume to allow usage of tank during flooding situation

Housing Clusters

Design parameters

- No. of Houses – 50
- Household size - 5
- Wastewater quantity – 20 cu.m per day



Area required

Treatment system = 100 – 150 sq.m

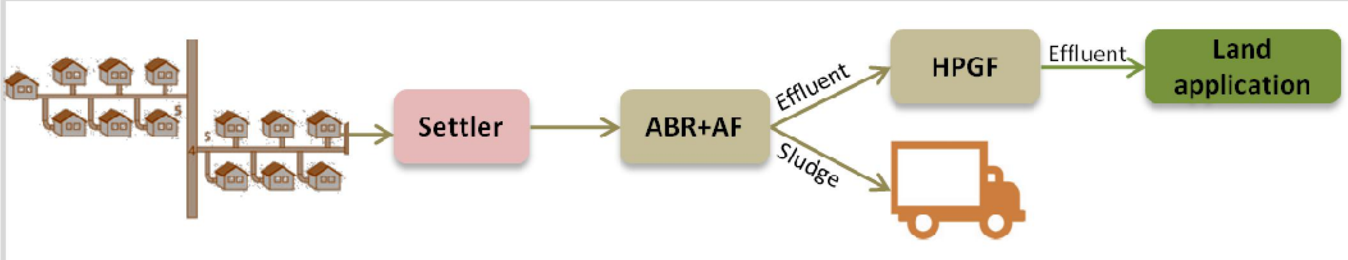
Estimated Capital Cost

Treatment system = 15000 -17000 USD
Cost of shallow sewer system – 11000 – 14500 USD

Estimated O&M Cost

Treatment system = 200 – 250 USD per annum

Wastewater treatment



The wastewater from the different source of households will be conveyed to a settler through shallow sewer system. The wastewater from the settler is further conveyed to the Anaerobic baffle reactor (ABR) integrated with Anaerobic filter (AF) and Horizontal Planted Gravel Filter (HPGF) for secondary and tertiary treatment. The treated effluent from HPGF can be collected for reuse requirements like agriculture and gardening purpose or it can be discharges in to the nearby natural drain for safe disposal. The sludge from the primary and secondary treatment modules is transported for further treatment

O&M

- Desludging of primary and secondary treatment module as per design period of 2-3 years
- Clean the filter media in AF or replace it every 3-5 years
- Filter media in HPGF needs cleaning or replacement in 3-5 years

Climate change adaptation

- Tanks should be constructed water-tight
- Top slab of the tanks should be constructed 15-30 cm above high flood level
- Provide a non-return valve at the outlet
- Avoid complete desludging of tanks and removal of filter material in HPGF during rainy season
- Provide adequate freeboard volume to allow usage of tank during flooding situation

2.6 Town Level cost estimation for Sanitation Infrastructure in Public Domain in PPTA towns

The town level cost requirements are estimated based on

a) Cost for each of the pilot intervention for sanitation improvement in different sectors
b) Sanitation demand identified for each sector within PPTA town based on the interim report and initial demand assessment through site visits
c) Cost for preparation of town-wide sanitation plan for all the four PPTA towns

However, the actual demand for sanitary infrastructure, related services and its cost needs to be arrived through detailed ***Town-wide Sanitation Planning*** for each of the PPTA towns.

Total estimated cost for planning and implementation of identified sanitation intervention:

Table 0.7 – Cost Abstract for all the PPTA Towns

Sl. No	Cost Head	Total investment required (in USD)
A	Sanitation infrastructure proposed for each town	
	Pirojpur Town	981750
	Mathbaria Town	583750
	Amtali Town	442750
	Galachipa Town	692750
	Sub Total	**2,701,000**
B	Cost for preparation of detailed Town-wide sanitation plan	220,000
	Grand Total	**2,921,000**

The total estimated cost for proposed sanitation infrastructure for each town has been tabulated below. The following parameters have been considered for arriving at the total cost:

a) Basis for arriving at number of units under each type
   1. The number of public toilets required for each town have been arrived based on the interim report and after discussion with Pourashava officials.
   2. For each designated slum pocket one community toilet complex with 8 toilet seats and 2 bathing units is proposed. However, in some slums more than one may be required.
   3. Two office building are considered for each town – Pourashava office and DPHE office
b) Basis for arriving at unit cost for each type
   1. The unit cost for different types have been arrived based on pilot application in the PPTA towns as mention in section 2.5

Pirojpur

Table 0.10 – Cost estimation for Pirojpur

Sr. No	Type	Treatment technology options	Cost per Unit in USD	No. of units required	Total cost in USD
1	Public Toilet *	Improved septic tank with soak pit	17000	5	85000
2	Community toilet**	BGD+ABR+AF+HPGF (DEWATS)	31000	20	620000
3	Public office buildings	Improved septic tank with cocopeat	3000	2	6000
4	Government hospitals	Shallow sewer system with DEWATS	50000	1	50000
5	Small government schools	Twin pit system	150	5	750
6	Government schools/colleges	Shallow sewer system with DEWATS	10000	3	30000
7	Cyclone shelters	Improved septic tank with soak pit	5000	2	10000
8	Town-wide septage treatment***	Drying beds	110000	1	110000
9	Pump mounted desludging vehicle		35000	2	70000
Total Cost					**981750**

Note:
*The cost includes superstructure and treatment system
**The cost includes superstructure and treatment system. One unit is considered for each slum
*** Refer section 2.6.1.5 for calculation of treatment capacity and no. of vehicle required for transportation

Mathbaria

Table 0.81 – Cost estimation for Mathbaria

Sr. No	Type	Treatment technology options	Cost per Unit in USD	No. of units required	Total cost in USD
1	Public Toilet *	Improved septic tank with soak pit	17000	6	102000
2	Community toilet**	BGD+ABR+AF+HPGF (DEWATS)	31000	10	310000
3	Public office buildings	Improved septic tank with cocopeat	3000	2	6000
4	Government hospitals	Shallow sewer system with DEWATS	50000	1	50000
5	Small government schools	Twin pit system	150	5	750
6	Government	Shallow sewer system	10000	2	20000

	schools/colleges	with DEWATS			
7	Cyclone shelters	Improved septic tank with soak pit	5000	2	10000
8	Town-wide septage treatment***	BGD+ABR+AF+HPGF (DEWATS)	50000	1	50000
9	Pump mounted desludging vehicle		35000	1	35000
Total cost					**5837500**

Note:
*The cost includes superstructure and treatment system
**The cost includes superstructure and treatment system. One unit is considered for each slum
*** Refer section 2.6.1.5 for calculation of treatment capacity and no. of vehicle required for transportation

Amtali

Table 0.92 – Cost estimation for Amtali

Sr. No	Type	Treatment technology options	Cost per Unit in USD	No. of units required	Total cost in USD
1	Public Toilet *	Improved septic tank with soak pit	17000	5	85000
2	Community toilet**	BGD+ABR+AF+HPGF (DEWATS)	31000	6	186000
3	Public office buildings	Improved septic tank with cocopeat	3000	2	6000
4	Government hospitals	Shallow sewer system with DEWATS	50000	1	50000
5	Small government schools	Twin pit system	150	5	750
6	Government schools/colleges	Shallow sewer system with DEWATS	10000	2	20000
7	Cyclone shelters	Improved septic tank with soak pit	5000	2	10000
8	Town-wide septage treatment***	BGD+ABR+AF+HPGF (DEWATS)	50000	1	50000
9	Pump mounted desludging vehicle		35000	1	35000
Total cost					**447750**

Note:
*The cost includes superstructure and treatment system
**The cost includes superstructure and treatment system. One unit is considered for each slum
*** Refer section 2.6.1.5 for calculation of treatment capacity and no. of vehicle required for transportation

Galachipa

Table 0.103 – Cost estimation for Galachipa

Sr. No	Type	Treatment technology options	Cost per Unit in USD	No. of units required	Total cost in USD
1	Public Toilet*	Improved septic tank with soak pit	17000	10	170000
2	Community toilet**	BGD+ABR+AF+HPGF (DEWATS)	31000	11	341000
3	Public office buildings	Improved septic tank with cocopeat	3000	2	6000
4	Government hospitals	Shallow sewer system with DEWATS	50000	1	50000
5	Small government schools	Twin pit system	150	5	750
6	Government schools/colleges	Shallow sewer system with DEWATS	10000	3	30000
7	Cyclone shelters	Improved septic tank with soak pit	5000	2	10000
8	Town-wide septage treatment***	BGD+ABR+AF+HPGF (DEWATS)	50000	1	50000
9	Pump mounted desludging vehicle		35000	1	35000
	Total Cost				**692750**

Note:
*The cost includes superstructure and treatment system
**The cost includes superstructure and treatment system. One unit is considered for each slum
*** Refer section 2.6.1.5 for calculation of treatment capacity and no. of vehicle required for transportation

Estimation of sludge treatment capacity required:

For each town fecal sludge and septage treatment facility is required. In order to determine the capacity of sludge treatment required for each of the town, the following methodology was adopted. The Table 0.11 below gives the estimation of treatment capacity required for every town.

Table 0.114 – Estimation of sludge treatment capacity required for PPTA towns

Description	Pirojpur	Mathbaria	Amtali	Galachipa
No. of households	13646	4330	4067	4967
Households with pit latrine (70% of total households)	9552	3031	2846	3476
Households with septic tank (30% of total households)	4093	1299	1220	1490
Approx. volume of sludge collected in single pit systems	7164	2273	2135	2607
Approx. volume of septage collected in septic tanks	4093	1299	1220	1490
Number of households desludging pit every year	19104	6062	5693	6953
Number of households desludging tank every year	818	259	244	298
Volume of sludge generated by pits every year (cu.m)	14328	4546	4270	5215
Volume of sludge generated by Tanks every year (cu.m)	818	259	244	298
Total sludge to be desludged every year (cu.m)	15147	4806	4514	5513
Total sludge to be desludged every day (cu.m)	41.5	13.2	12.4	15.1
Number of vehicles required (5 volume cu.m each, with 4 trips every day)	**2**	**1**	**1**	**1**
Thus, the estimated treatment capacity required (cu.m/day) Rounded Volume	**50**	**20**	**20**	**20**

Note:

1. The percentage of households using soak pits and septic tanks are arrived based on the consultations with the Pourashava officials
2. The fecal sludge and septage volume per household is arrived based on normal practice of designing the system in the project towns
3. Considerations for sludge volume calculations:
    a. Pit volume: Pit size with a diameter of 0.76m and height of 0.304m and minimum of 5 rings is considered. Thus the average volume of 0.75 cu.m needs to be desludge every six months
    b. Septic tank volume: The tank dimensions with Length = 1.8m, width = 0.75m and depth = 1.5m is considered. Thus, tank volume capacity id 2 cu.m. However, a average volume of 1cu.m needs to be desludged every 5 years.
4. The sludge generated from public places is not considered for the calculations
5. Total sludge to be desludged every day (cu.m) is calculated based on 365 days

6. The methodology adopted for arriving at the treatment capacity required is very basic and the volume estimated is indicative. Detailed study needs to be conducted to arrive at the actual valume required.

The overall approach and methodology for preparation of Sanitation Plan for each of the PPTA towns described in detail in the next chapter.

2.7 Sanitation Planning in PPTA towns

A lot of efforts are being channelized in the sanitation sector in Bangladesh through various programs. However, the sanitation interventions to be implemented are not derived based on systematic assessment of sanitation situation in the towns. The recommendations made by the local bodies relies to a great extent on their day to day working experiences in delivery of sanitation services, however the absence of a town wide sanitation strategy/plan often results in critical areas being neglected where measures are needed on priority basis.

Based on the field visits conducted to the PPTA towns, some observations regarding the status of sanitation services and its access to communities and, working knowledge and framework of pourashava are mentioned as follows:

- Absence of country level sanitation strategy for coastal towns
- Pourashavas limited exposure to on-site and off-site sanitation systems which can be applied to coastal areas in Bangladesh
- The provision of sanitation services follows more of a piece meal approach
- In absence of a systematic sanitation data compilation and analysis system at town level, the pourashava does not have in-depth understanding of the sanitation issues in their jurisdiction areas
- The sanitation staff in pourashavas are not exposed to sanitation planning practices

2.7.1 Approach and methodology

The approach for addressing the gap in sanitation infrastructure and services is taking coastal towns towards 'Total Sanitation' through a 'Systems' driven approach. This can be achieved through City Sanitation Planning (CSP) process, which systematically looks into service delivery levels in the towns, identify critical/stress areas for sanitation provision, community engagement in grass root sanitation planning and awareness generation as well as framework for monitoring and evaluation of sanitation services in the urban area.

The overall goal is to achieve 100% sanitation in the PPTA towns wherein every citizen has access to a toilet facility and all the fecal sludge/Septage/solid waste is collected, treated and disposed off safely. Every aspect of the process and infrastructure provision must integrate community participation and must be inclusive. In addition, water and wastewater management must be carried out in an environmentally sustainable manner, recycling and reusing the byproducts as far as possible.
The Sanitation Plan preparation process for a PPTA town would consist of following main activities:

1. Formation of sanitation task force
2. Sanitation Awareness Campaign
3. Sanitation Plan
4. Capacity building of urban local bodies in sanitation service delivery

2.7.2 The city sanitation task force (CTF)

The city sanitation task force is the institutional structure that will hold the vision of "Total Sanitation" for the PPTA towns. With this context it shall ensure the successful implementation of the 100% sanitation campaign as well as oversee the plan and project formulation, implementation and operations.

The representation of all sections of the society in the task force is pivotal to understand the status of sanitation and associated issues at micro level. Stakeholder mapping is one of the key activity for formation of sanitation task force. The task force should consist of local decision makers, civil societies, educational institutes, market association, trade union, pourashava staff, urban poor etc.

2.7.3 The 100% sanitation campaign

The sanitation improvements in urban context cannot be achieved by provision of sanitary infrastructure alone. The communities/end users and their behavioral aspects also have an implication on creating sanitation success stories. Since the lack of sanitation facilities/services impacts different sectors of society in various ways, one of the important activities for sanitation campaign at city level is to map the sanitation issues prevailing in the city and target groups that need to be imparted sanitation related awareness. The task force in consultation can identify the target groups. A broad division of potential target groups for awareness building can include children and young adults through educational institutions, slum dwellers, general citizens etc.

As part of the overall sanitation plan, a short term, medium term and long-term plan should be created. Various means of communication contextual to Bangladesh conditions like television advertisements, school competitions, street plays and debates, etc should be explored.

2.7.4 The city sanitation plan

The City Sanitation Plan is the strategy document, which includes technical aspects to address the sanitation gaps in the towns, project proposals and block cost estimates. The plan preparation includes following key activities:

Sanitation Mapping
This includes preparation of base map of a town on GIS platform. The existing maps are used and up-dated using various sources of information like satellite images, field surveys and consultations with the local bodies.

Assessing Demand Supply Gap in sanitation provision
The data on various sectors like water supply, sewerage system, solid waste management, public sanitation and storm water management is collected and mounted as layers of information on GIS platform. Available secondary data shall be collected mentioned as follows:

- Demographics – current and projected population
- Water supply – source, quantity and quality of water supplied, areas facing scarcity of water
- Sanitation – public toilets/community toilets (location, number of toilet seats, user charges etc.)
- Wastewater management – fecal sludge/Septage management
- Solid waste management – waste generation, collection, treatment and disposal
- Assessment of pourashava budget
- Pourashava - institutional and legal framework

Based on the information mentioned above, detailed demand supply gap in provision of sanitary services with a pourashava will be determined. The extent of gap in service delivery is indication of a particular area under sanitation stress. This helps in prioritizing the sanitation interventions during implementation phase.

Assessing technology options

The section of correct technology choice is one of the key challenges for reaching 100 % sanitation access. The technology options are broadly classified into on-site sanitation and off-site sanitation systems. The characteristics of each type of system and their application in Bangladesh context shall be captured. The application of appropriate technologies to address stress areas under sanitation shall be explored. The technologies as presented above shall be used as reference for decision making.
It is important that a holistic technical approach, which incorporates centralized and decentralized systems are chosen. A mix of options (including conventional and non conventional solutions) needs to be chosen to address the sanitation issues as a whole at a city wide level. The planning approach has to define the project-specific social, cultural, economic, health and environmental priorities which will influence technology selection and the system design. Technologies that promote recycle and reuse of treated wastewater should be preferred.

Strategies and Project Formulation

Strategies and solutions for addressing sanitation needs in all the un-served areas in the city shall be provided. In addition, a strategy to address the sanitation needs of future population growth shall also be formulated through project solutions as well as recommendations to policy initiatives.

The strategies shall focus on strengthening existing systems and proposing new systems relevant to the local conditions in Bangladesh. Special emphasis shall be given to address issues pertaining to livelihood linkages of the urban poor with sanitation sector, user charges etc to develop strategies that are financially self sustaining.

Costing and Implementation Strategy

Block cost estimates will be developed along with a phasing plan. This shall be consistent with the goals to achieve 100% sanitation. Cost estimation shall also include O & M costs as well as replacement costs.

Community participation in operations and maintenance as well as vendor development requirements shall be explored.

Recommendations to the Legislative Framework

Recommendations shall be given to the development control regulations, building bye-laws and other legislation to facilitate achievement of 100% sanitation.

2.7.5 Capacity building

The capacity of the local body needs to be enhanced for implementing the sanitation improvement interventions. The extent of capacity building requirements can be assessed by benchmarking of existing human resource, infrastructure, hardware and software to achieve 100% sanitation. Based on the benchmarking the training needs shall be identified where in house capacities required to be built. A plan for training requirements needs to be formulated based on the needs assessment

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ANNEX F: WATER RESOURCES

1. **Water Quality Standards**
2. **Hydrological and Hydrogeological Study: Coastal Town Amtali**
3. **Hydrological and Hydrogeological Study: Coastal Town Galachipa**
4. **Hydrological and Hydrogeological Study: Coastal Town Pirojpur**
5. **Hydrological and Hydrogeological Study: Coastal Town Mathbaria**
6. **Groundwater Resource Assessment for Coastal Areas of Bangladesh**

1. WATER QUALITY STANDARDS

Schedule – 3
Water Quality Standards
[vide Rule 12]

A. Inland Surface Water Quality Standard

Best Practice Based Coliform	pH	BOD mg/l	Dissolved Oxygen (DO), mg/l	Total Bacteria Coliform quantity/ml
(a) Potable Water Source Supply After bacteria freeing only	6.5-8.5	2 or less	6 or above	50 or less
(b) Water used for recreation purpose	6.5-8.5	3 or less	5 or above	200 or less
(c) Potable Water Source Supply after conventional processing	6.5-8.5	3 or less	6 or above	5000 or less
(d) Water used for pisciculture	6.5-8.5	6 or less	5 or above	5000 or less
(e) Industrial use water including	6.5-8.5	10 or less	5 or above	
(f) Water used for Irrigation	6.5-8.5	10 or less	5 or above	1000 or less

Note 1) Maximum amount of ammonia presence in water are 1..2 mg/l (as nitrogen molecule) which is used for pisciculture.
2) For Water Used for Irrigation, Electrical Conductivity – 2250 micromhos/cm (at 25^{0}C), Sodium less than 26 mg/l, Boron less than 2mg/l*

REFERENCE:
GUIDE TO ENVIRONMENTAL
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RULES 1997 –Bangladesh Hand written by Joe a Philippine Expert to STIFPP-II project.

B. Potable Water quality Standard

Sl. No.	Parameter	Unit	Standard Limit
1.	Aluminium	mg/l	0.2
2.	Ammonia (NH3)	“	0.5
3.	Arsenic	“	0.05
4.	Barium	“	0.01
5.	Benzene	“	0.01
6.	BOD5 200C	“	0.2
7.	Boron	“	1.0
8.	Cadmimum	“	0.005
9.	Calcium	“	75
10.	Chloride	“	150-600**
11.	Chlorinated alkanes	“	
	Carbon tetrachloride	“	0.01
	1,1 Dichloroethelene	“	0.001
1,2	“	“	0.03
	Tetrachloroethelyne	“	0.03
	Trichloroethelyne	“	0.09
12.	Chlorinated phenols	“	
	Pentachlorophenol	“	0.03
	2,4,6 Trichlorophenol	“	0.03
13.	Chlorine Residula	“	0.2
14.	Choloroform	“	0.09
15.	Chromium (hexavalent)	“	
16.	Chromium (total)	“	
17.	COD	“	
18.	Coliform(fecal)	n/100 ml	0
19.	Coliform(total)	“	0
20.	Color	Huyghens unit	15
21.	Copper	mg/l	1
22.	Cynide	“	0.1
23.	Detergents	“	0.2
24.	DO	“	6

** In coastal area - 1000

B. Potable Water Quality Standard (continued)

Sl. No.	Parameter	Unit	Standard Limit
25.	Fluoride	mg/l	1
26.	Alkalinity as CaC3	“	200-500
27.	Iron	“	0.3
28.	Nitrogen (total)	“	1
29.	Lead	“	0.05
30.	Magnesium	“	30-35
31.	Manganese	“	0.1
32.	Mercury	“	0.001
33.	Nickel	“	0.1
34.	Nitrate	“	10
35.	Nitrite	“	<1
36.	Odor	“	Odorless
37.	Oil&Grease	“	0.01
38.	pH	*[1]	6.6-8.5
39.	Phenolic Compounds	mg/l	0.002
40.	Phosphate	“	6
41.	Phosphorous	“	0
42.	Potassium	“	12
43.	RadioActiveMaterialsTotal α Radiation	Bq/l	0.01
44.	RadioActiveMaterialsTotal β Radiation	“	0.1
45.	Selenium	mg/l	0.01
46.	Silver	“	0.02
47.	Sodium	“	200
48.	Suspended Solid Particles	“	10
49.	Sulphide	“	0
50.	Sulphate	“	400
51.	Total Dissolved Solids	“	1000
52.	Temperature	0C	20-30
53.	Tin	mg/l	2
54.	Turbidity	JTU	10
55.	Zinc “	mg/l	5

[1] -ive of logarithm of H ion Concentration

Schedule – 10
Waste Discharge Quality Standards for Industrial Units and Projects
[Vide Rule 13]

Quality Standard at Discharge Point

Sl No.	Parameter	Unit	Inland Surface Water	Public Sewer at secondary Treatment Plant	Irrigated Land	
1.	Ammoniacal Nitrogen (N molecule)		mg/l	50	75	75
2.	Ammonia (free ammonia)	“	5	5	15	
3.	Arsenic(As)	“	0.2	.05	0.2	
4.	BOD5 200C	“	50	250	100	
5.	Boron	“	2	2	2	
6.	Cadmium(Cd)	“	0.05	0.5	0.5	
7.	Chloride	“	600	600	600	

2. HYDROLOGICAL AND HYDROGEOLOGICAL STUDY COASTAL TOWN AMTALI

04 July, 2013

Table of Contents

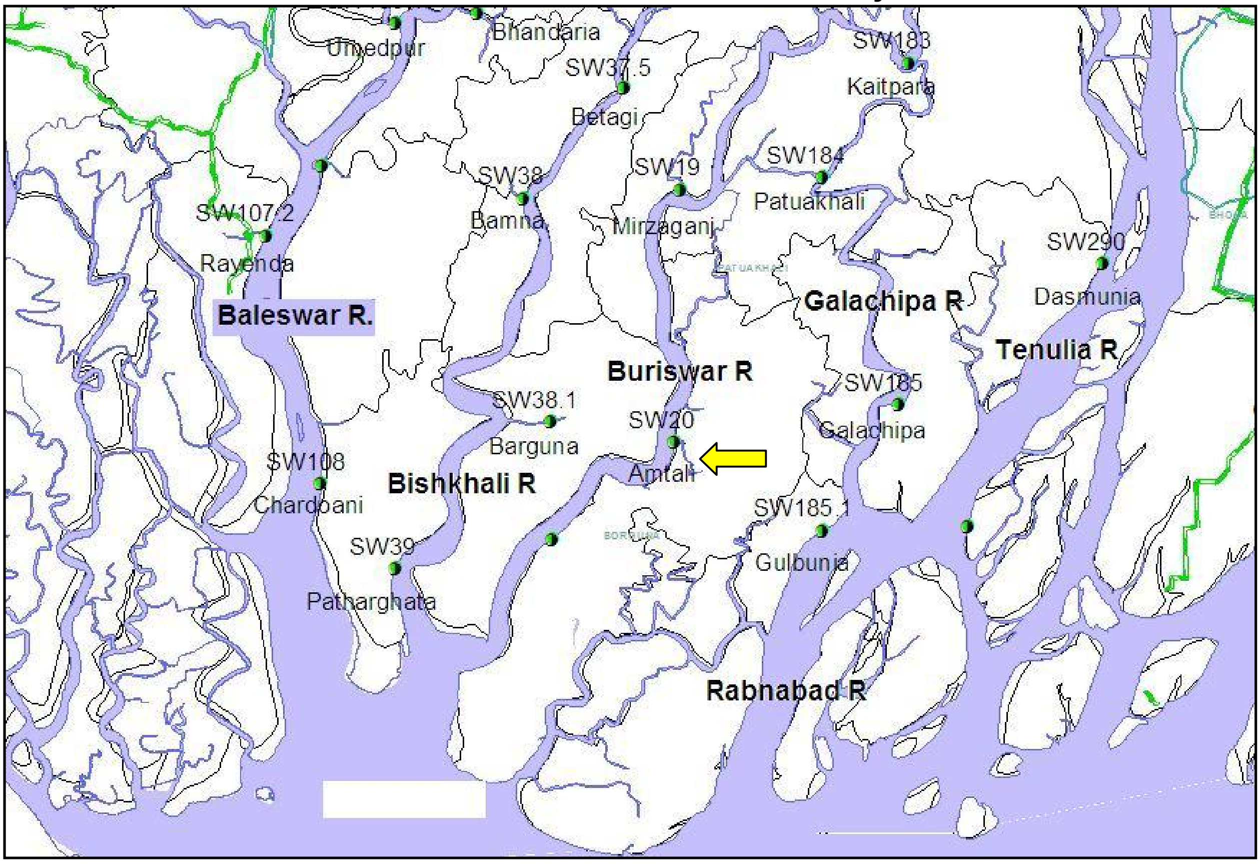
Draft
Hydrology and Hydrogeology at Amtali

1. Background Information

1.1 Location of Coastal Town Amtali

The coastal town Amtali[2] is a Upazila town under Barguma district. Amtali pourashova is on the left bank of Buriswar river. The town is located within polder P43/1 approximately at Latitude 22^0 08' 15".71 N and Longitude 90^0 13' 44".94 E and is about 38.93 km upstream of sea face along Buriswar river.

Exhibit 1: Location of Amtali Town and river system around



In respect of topography, Amati is a flat basin land and is defined by: land level - LL_Low: 1.3 m-PWD, LL_Avg: 1.5 and LL_High: 2.8 m_PWD

2

PolderID	Pourashova	Low	Average	High
P43/1	Amtali	1.3	1.5	2.8
P55/2	Galachipa	1.4	2.5	2.8
P39/1B_D	Mothbaria	0.2	2.2	4.5
P38	Pirojpur	1.4	2.1	2.9

Note: From Paul Dean Flood Control and Drainage Engineer

Other important rivers in the area are Rupsa-Passur to the west a highly saline river that connects Gorai-Modhumati through Halifax-cut at Bardia, Atharobanka and Ghasiakhali (not shown in map above), Bishkhali, Buriswar and Lohalia/Galachipa to the east. The last three rivers together forms a fresh water corridor of Padma-Meghna spill channels – Arial Khan river system (Annex A).

1.2 Availability of Hydrological stations in the area

The following hydrological stations are available in Amtali UZ and around that affect the hydrological environment of the area.

Table 1a: List of Hydrological stations

District	Upazila	RiverName	StationID	TypeCode	Seaface km	Lat	Long
Barisal	Barisal Sadar	Buriswar	SW18	TDWL,SA	130.75	22.70	90.38
Barisal	Bakerganj	Buriswar	SW18.1	TDWL	97.88	22.54	90.34
Patuakhali	Mirzaganj	Buriswar	SW19	TDWL,SA	63.63	22.35	90.23
Barguna	Amtali	Buriswar	SW20	TDWL,SA	38.93	22.14	90.23

Note Type Code: TDWL- Tidal WL & SA- Sea Salinity

Table 1b: List of Climatological stations

District	Upazila	StationID	DataCode	StationName	Lat	Long
Patuakhali	Galachipa	CL262	RF	Galachipa	22.13	90.44
Pirojpur	Mathbaria	CL265	RF	Mathbaria	22.32	89.93
Patuakhali	Patuakhali Sadar	CL266	RF, EV	Patuakhali	22.34	90.35

Note Type Code: RF- Daily rainfall & EV- Daily Pan Evaporation

There is no rainfall station at Amtali. Amtali town is located in between Galachipa and Barguna. So rainfall at Amtali will be estimated from rainfall data from Galachipa and Barguna.

1.3 Availability of Groundwater monitoring stations in the area

There are two GW Water table monitoring wells in Amtali upazilla and particulars of these wells are furnished table below:

Table 1.D: List of GW Water Table monitoring wells in Amtali UZ

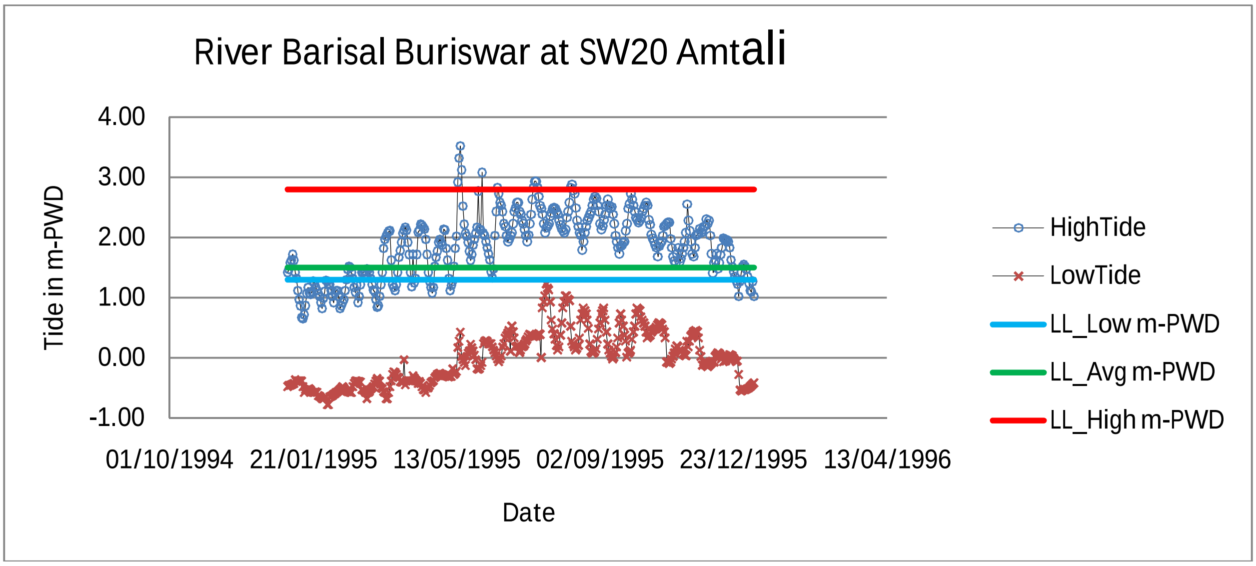
District	Upazila	WellID	Parapet Height(m)	RL (m-PWD) parapet	GL m-PWD	Depth (m)	Well Dia(m)	Lat	Long
Barguna	Amtali	GT0409001	0.46	2.29	1.83	23.47		22.20	90.29
Barguna	Amtali	GT0409002	0.46	2.70	2.24	32.32	0.04	22.13	90.27

BWDB Groundwater Hydrology has no groundwater quality monitoring wells in or near Amtali. But the existing production Deep Tube wells at Amtali show acceptable water quality of groundwater.

2. Tide at Amtali

As already stated the Coastal Town Amtali is located on the left bank of the river Buriswar a distributaries of the Arial Khan river and BWDB operates a manual tide recording station at SW20 Amtali. Tide in Bangladesh coast is semidiurnal i.e. there are two high and two low tides in about 24^h 48^m. BWDB hydrology records only day time 3 hourly level from 6 am to 6 pm and in addition, time and heights of high and low tide. Thus BWDB tide record shows only one high and one low tide each day.

Figure 1: Tide Hydrograph SW20 Amtali 2001 and Town Land level



The tide hydrograph shows that low tide is well below low land level and as such there should not be problem of drainage if drainage structures are operated properly. Medium high land will be inundated during high tide but can be protected by appropriate operation of drainage structures. Even the rainfall can also be drained between inter-tidal periods.

Table 2: Summary of high tide, low tide and range (SW20 Amtali)

	SpringTide				NeapTide		
Month	HighTide	LowTide	Range		HighTide	LowTide	Range
Jan	1.66	-0.38	2.04		0.86	-0.33	1.19
Feb	1.73	-0.45	2.18		0.83	-0.30	1.12
Mar	2.56	-0.41	2.97		0.83	-0.27	1.10
Apr	2.19	-0.37	2.56		1.07	-0.12	1.19
May	2.44	-0.05	2.49		1.36	0.02	1.35
Jun	2.58	0.17	2.41		1.61	0.32	1.29
Jul	2.68	0.15	2.53		1.62	0.46	1.15
Aug	2.74	0.19	2.55		1.67	0.59	1.08
Sep	2.58	0.17	2.41		1.47	0.54	0.93
Oct	2.52	0.17	2.34		1.35	0.26	1.09
Nov	2.10	-0.09	2.19		1.28	0.08	1.19
Dec	1.85	-0.18	2.03		1.10	-0.14	1.24

The Table 2 above shows that average highest high tide 2.74 m-PWD occur during spring tide in August with a range of 2.55 m while average lowest high tide 0.83 m-PWD occur during neap tide of Feb & March with a range of 1.12 m and 1.10 m-PWD. Average Highest low tide 1.67 m-PWD occur during neap tide of August which is also the month with highest high tide and is therefore is a constraint for drainage. Flood level frequency analysis shows the following flood level for different return period.

Table 4: Flood level frequency at SW20 Amtali

Rp in yrs	Flood level
100	3.76
50	3.59
25	3.42
20	3.36
10	3.19
5	3.01
2.33	2.79

Figure 2: Time trend of tide at SW20 Amtali on Buriswar

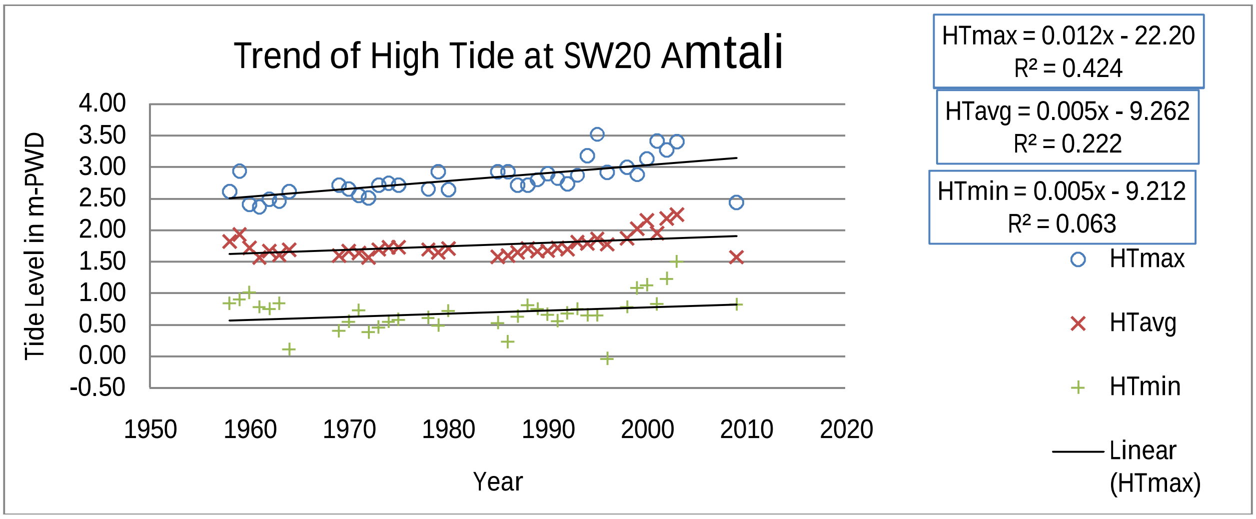


Table 5: Summary of trend of Tide at SW20 Amtali

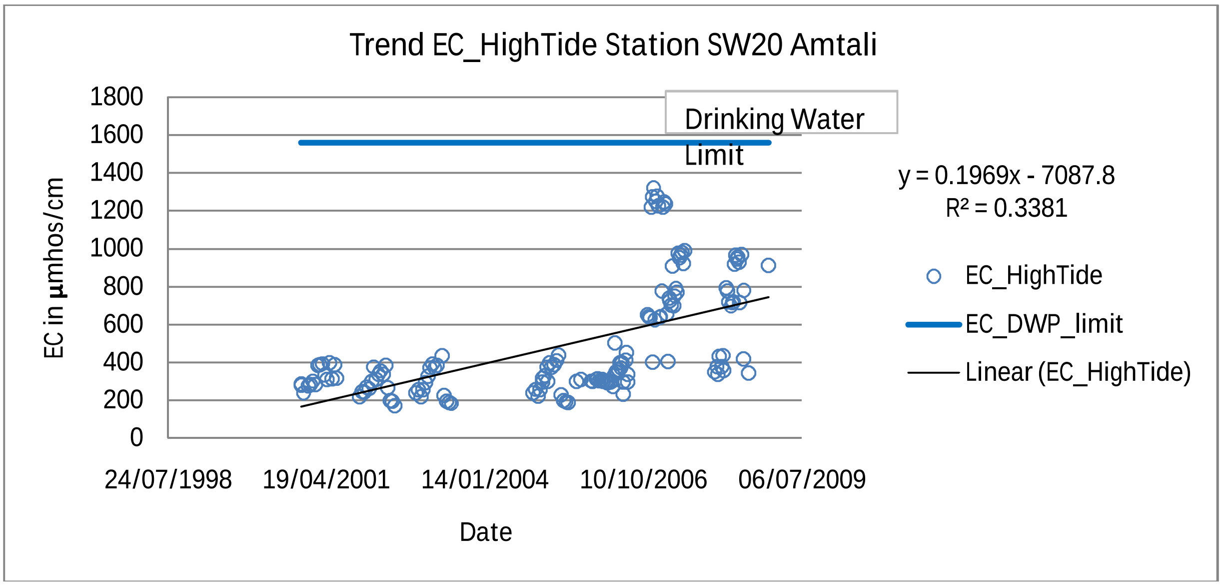
Tide	Rate of rise mm/year	R^2
Annual highest high tide AHTide	12	.424
Annual average tide AATide	5	.222
Annual lowest tide AL Tide	5	0.063

At this station there seems to be rising trend of tide. Over a 50 year time horizon, expected rise in Annual highest high tide is 12x50=600 mm=.6 m. With appropriate planned maintenance of Polder dike, raising the embankment by .6 m over the 50 year period should not be difficult.
Over a 50 year time horizon, expected rise in Annual lowest tide is 5x50=250 mm=.25 m. This will not create any problem for the drainage of polders.

3. Sea Salinity

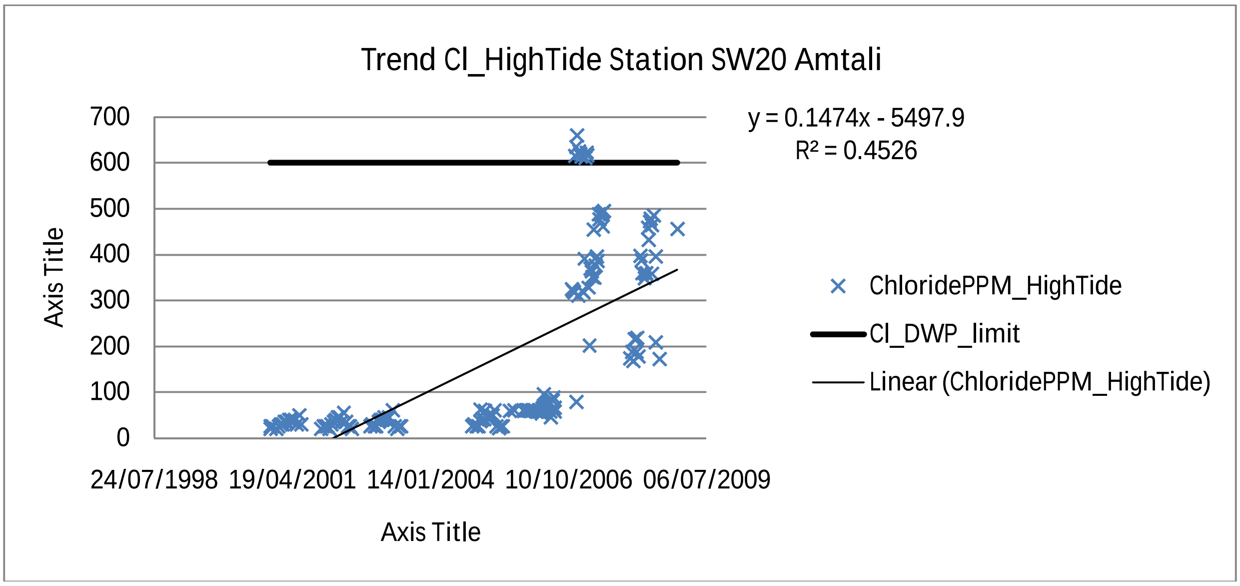
Salinity measurements consist of measurement of Electrical Conductivity (EC) - a measure of TDS in terms of μhos/cm and Chloride in mg/l. Measurements is made at high and low tide only during dry season. Permissible limit of EC and Cl in drinking water are 1560 μhos/cm and 600 mg/l. Time trend of EC and Cl at SW20 Amtali is given below:

Figure 3: Trend of high and low tide EC



Most of the times EC (estimate of salinity) is well below drinking water permissible limit. High water salinity is however in increasing trend and a closure watch has to be maintained .

Figure 4: Trend of high and low tide Chloride in ppm



Only in a few cases, chloride is slightly above drinking water permissible limit. However a closure watch has to be maintained on the future trend of chloride.

4. Rainfall

There is no rainfall station at Amtali but will be estimated from Barguna and Galachipa. The nearest evaporation station is at Patuakhali and data from this station has been used for Amtali. In Bangladesh seasons are normally defined as:

1. Pre-monsoon - Mar, Apr, May
2. Monsoon - Jun, Jul, Aug, Sep
3. Post-monsoon – Oct, Nov
4. Winter – Dec, Jan, Feb

Exhibit 2: Location of Rainfall and Evaporation stations

Table 6: Seasonal Rainfall and Pan Evaporation at Amtali (taking evaporation at Pirojpur as estimate of evaporation at Amtali CT)

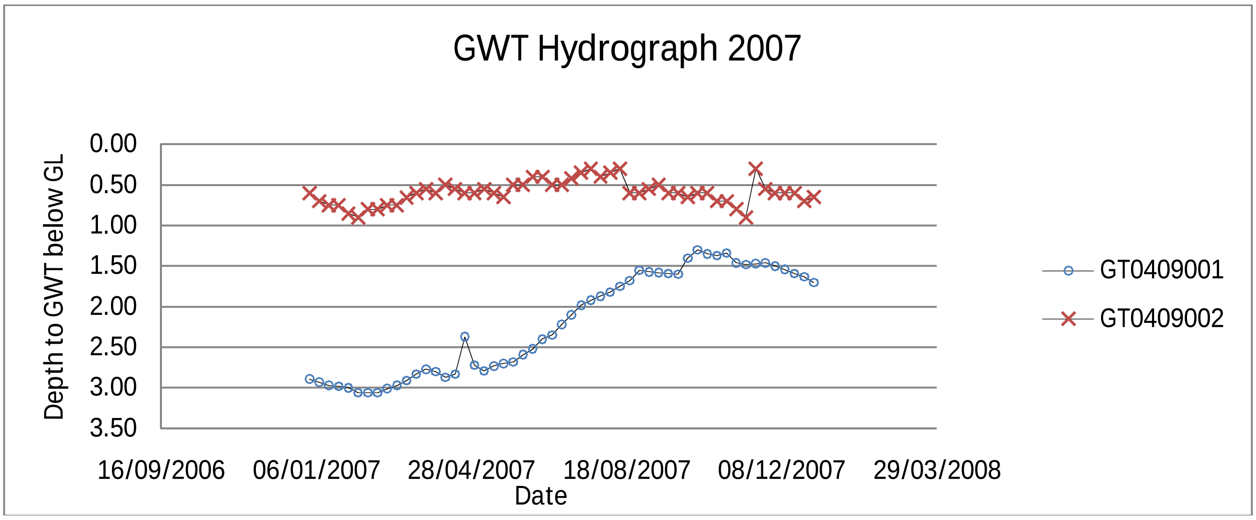
Variable	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
RF	413	1988	283	43	2726
EV	268	261	130	150	807
ΔRF	145	1727	153	-107	1919

Amtali town is located in a high rainfall zone of Bangladesh. Annual average rainfall at Amtali is 2726 mm against Bangladesh Annual average of about 2362 mm. Monsoon rainfall at Amtali is 1988 mm against Bangladesh monsoon rainfall of about 1656 mm. Thus in the polder area there is a huge scope of groundwater recharge and surface runoff draining out through drainage structures.

5. Groundwater

Two Groundwater level monitoring wells (GT0409001 & GT0409002) located in Amtali UZ with the available particulars are presented in **Table 1.D**:
This is a typical GW table hydrograph for the 2 wells:

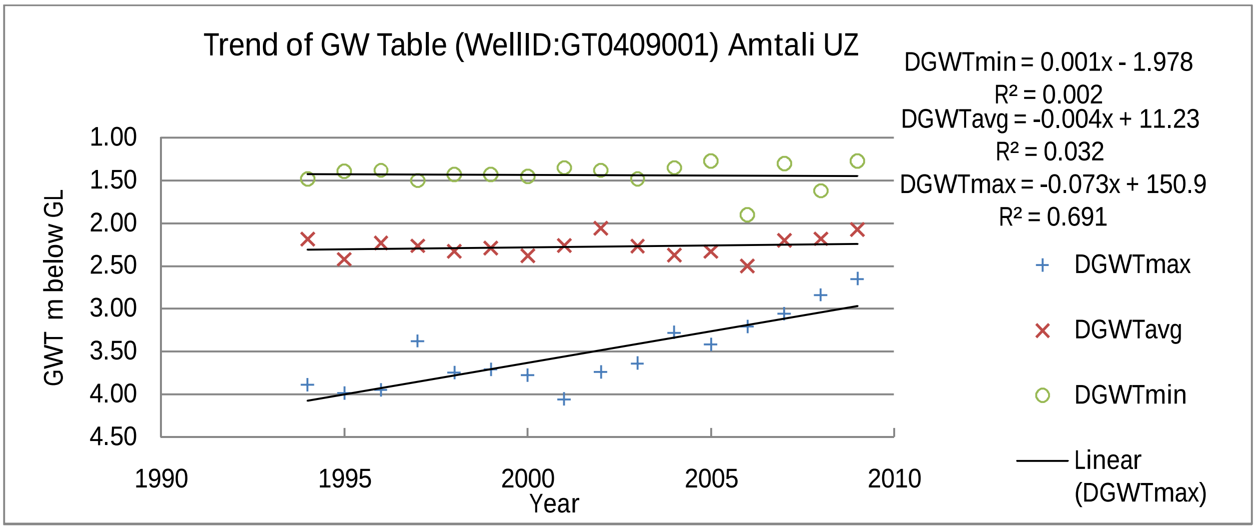
Figure 5: GW Table Hydrograph



At least for the year 2007 GWT fluctuation was almost nil for the Well: GT0409002 in comparison to well GT0409001 while the latter behaved normally. Annual gross recharge of about 1.50 m is acceptable.

Because of doubtful data – trend of wellID:GT0409002 studied but not quoted here. The following are the trend of GWT in the wellID:GT0409001.

Figure 5: GW Table Trend

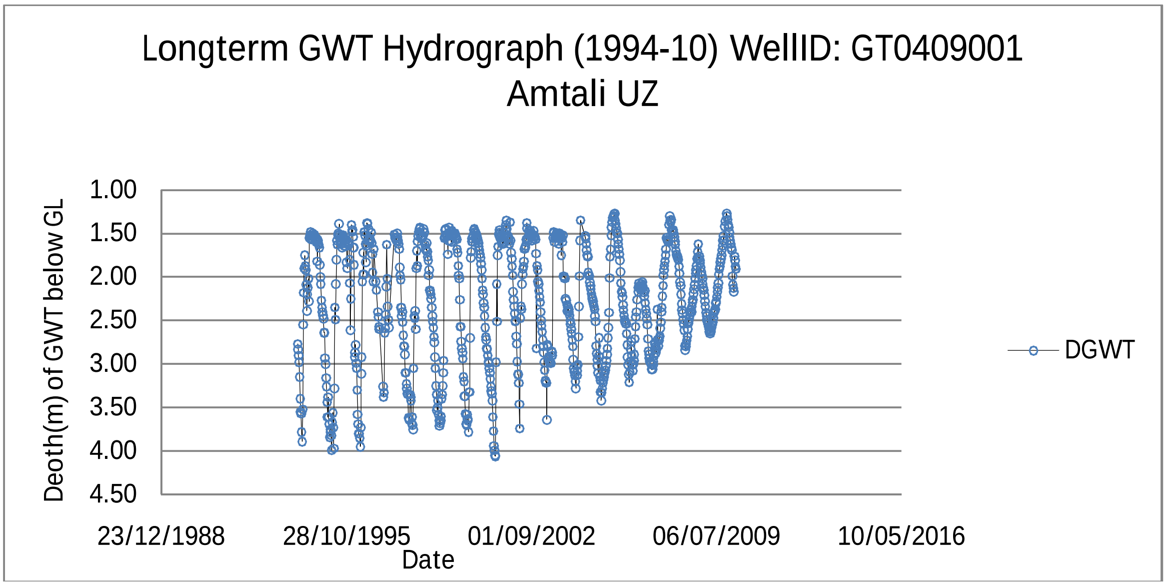


Annual DGWTmin and DDGWTavg does not show any trend and are steady over the period of record. But DGWTmax is showing a rising trend which means fall of water table at the end of dry season is progressibly reduced. It needs investigation if this is due to malfunction of the well or underground waterlogging.

Table 7: Trend of Depth to GWT - (WellID:GT0409001)

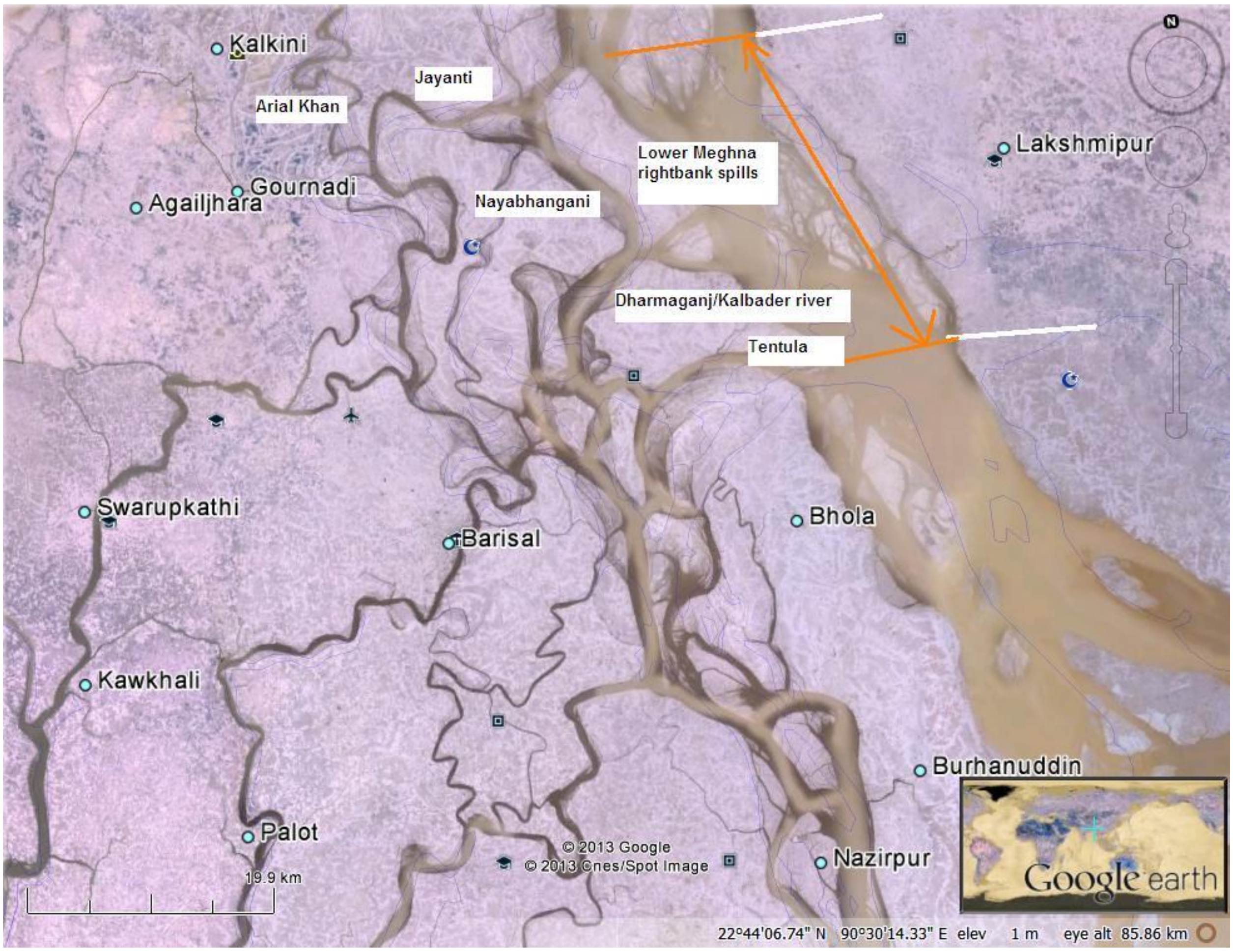
Depth to GWT	Rate of rise mm/year	R^2
DGWTmin	1	0.002
DGWTavg	4	0.032
DGWTmax	73	0.691

Figure 6: GW Table Hydrograph (1994-2010)



The long term trend of annual lowest groundwater table started rising from the year 2001.

Annex A: Fresh water corridor of Padm-Meghna spill channels – Arial Khan river system



3. HYDROLOGICAL AND HYDROGEOLOGICAL STUDY COASTAL TOWN GALACHIPA

04 July, 2013

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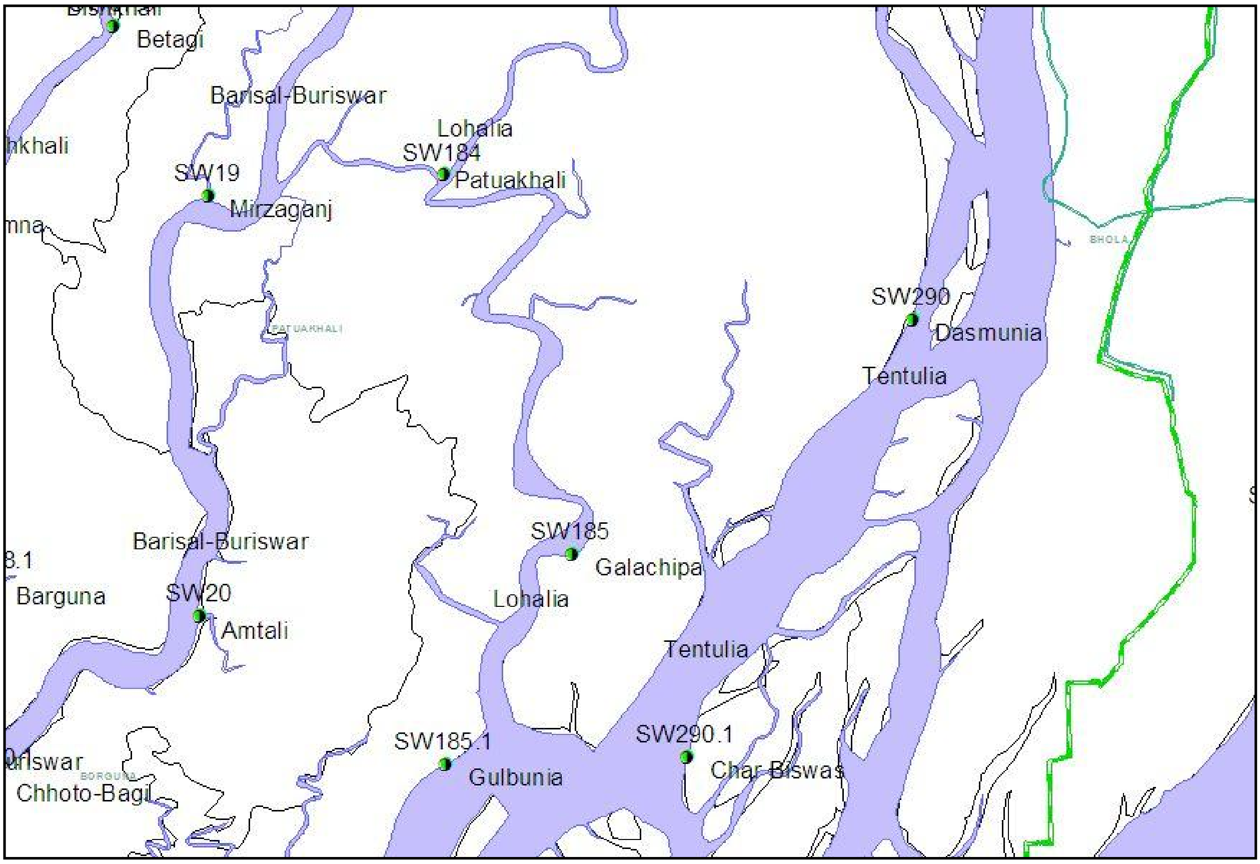
Draft
Hydrology and Hydrogeology at Galachipa

1. Background Information

1.1 Location of Galachipa

The coastal town Galachipa[3] is a Upazila town under Patuakhali district. The town is located within polder P-50 & P-51 approximately at Latitude 22.14 N and Longitude 90.23 E and is about 43 km upstream of sea face along Rabnabad-Lohalia/Galachipa river. The river is of course tidal here.

Exhibit 1: Location of Galachipa Town and river system around



Galachipa town is on the left bank of Lohalia/Galachipa river a tributary of Tentulia-Rabnabad river. The district head quarter Patuakhali is on the same river Lohalia/Galachipa some 33.49 km upstream. Other important rivers in the area are

3

PolderID	Pourashova	Low	Average	High
P43/1	Amtali	1.3	1.5	2.8
P55/2	Galachipa	1.4	2.5	2.8
P39/1B_D	Mothbaria	0.2	2.2	4.5
P38	Pirojpur	1.4	2.1	2.9

Note: From Paul Dean Flood Control and Drainage Engineer

Barisal-Buriswar to the west and Tentula to the east. The location may be called fresh water corridor of Padm-Meghna spill channels – Arial Khan river system (Annex A).

Table 1:Pourashova information

District	Pourashavas	Area (km^2)	Population	Main Drinking Water Source
Patuakhali	Galachipa	4.50	21,386	Groundwater

1.2 Availability of Hydrological stations in the area

The following hydro-geological stations are available in Galachipa UZ and around that affect the hydrological environment of the area.

Table 1a: List of Hydrological stations

District	Upazila	RiverName	StationID	Station	TypeCode	Dist km
Barisal	Bakerganj	Lohalia/Galachipa	SW183	Kaitpara	TDWL,SA	96
Patuakhali	Galachipa	Lohalia/Galachipa	SW185	Galachipa	SA	43
Patuakhali	Galachipa	Lohalia/Galachipa	SW185.1	Gulbania	SA	27
Barguna	Amtali	Buriswar	SW20	Amtali	TDWL,SA	39

Note:Dist. Km is the distance from sea face. Type Code: TDWL- Tidal WL & SA- Sea Salinity

In Lohalia-Galachipa river, the tide station at SW185 Galachipa and SW185.1 Gulbania are not in operation. The station SW183 Kaitpara is some 53 km upstream of Galachipa. On the other hand the station SW20 Amtali on the Buriswar river is of similar distance (Table 1a: 43km/39km) from sea face. So tide for Amtali will be quoted for Galachipa also.

Table 1b: List of Climatological stations

District	Upazila	StationID	DataCode	StationName	Lat	Long
Patuakhali	Galachipa	CL262	RF	Galachipa	22.13	90.44
Patuakhali	Patuakhali Sadar	CL266	RF, EV	Patuakhali	22.34	90.35

Note Type Code: RF- Daily rainfall & EV- Daily Pan Evaporation

There is no evaporation station at Galachipa – evaporation of the nearest station at Patuakhali will be quoted.

1.3 Availability of Groundwater monitoring stations in the area

There is one GW Water table monitoring well in Galachipa and particulars of this well is furnished in the table below:

Table 1.D: List of GW Water Table monitoring wells in Galachipa UZ

District	Upazila	WellID	Parapet Height(m)	RL (m-PWD) parapet	GL m-PWD	Depth (m)	Lat	Long
Patuakhali	Galachipa	GT7857001	0.56	2.39	1.83	17.17	22.19	90.44

BWDB Groundwater Hydrology has no groundwater quality monitoring well in or near Galachipa. One GW Water Quality monitoring well exists at Patuakhali and the particulars of the well is given below:

Table 1.E: List of GW Water Quality monitoring wells in Galachipa UZ

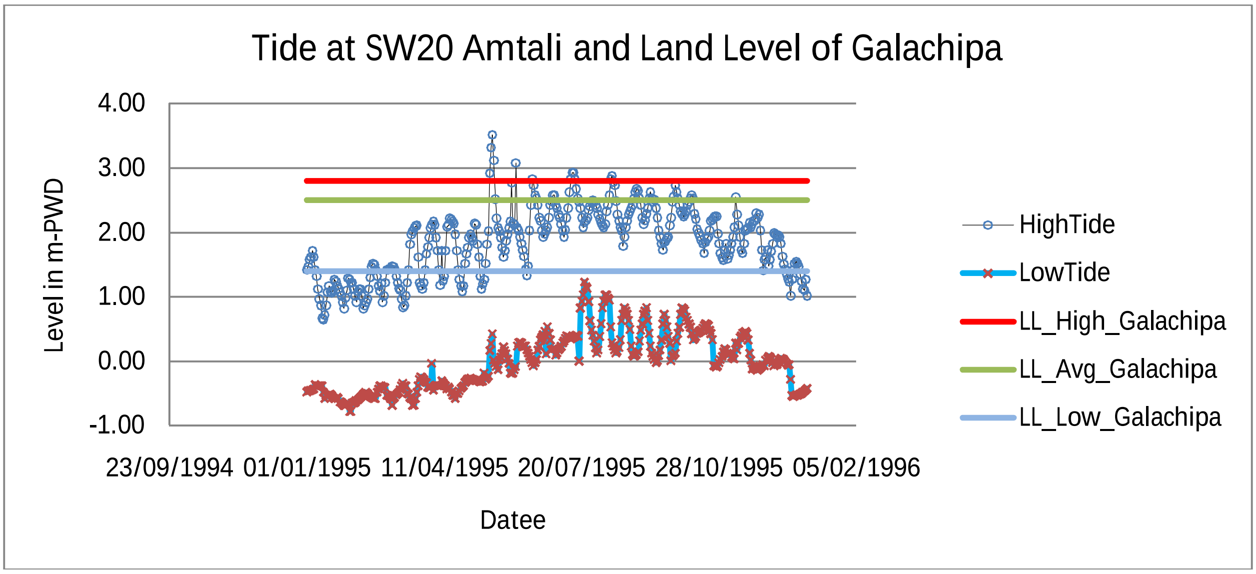
District	Upazila	WellID	Parapet Height(m)	RL (m-PWD) parapet	GL m-PWD	Depth (m)	Lat	Long
Patuakhali	Patuakhali	GQ7895077	0.56	3.30	2.74	194.81	22.38	90.28

2. Tide at Galachipa

As already stated the Coastal Town Galachipa is located on the left bank of the river Lohalia/Galachipa a tributary of the Tentulia river and BWDB operates a manual tide recording station at SW183 Kaitpara at Bakerganj UZ. The tide station is some 53 km u/s of Galachipa (96 km u/s of sea face). Unfortunately no other station is available downstream of SW183 kaitpara neither in Galachipa river nor in Tentulia river.
In Lohalia-Galachipa river, the tide station at SW185 Galachipa and SW185.1 Gulbania are not in operation. The station SW183 Kaitpara is some 53 km upstream of Galachipa. On the other hand the station SW20 Amtali on the Buriswar river is of similar distance (Table 1a: 43km/39km) from sea face. So tide for Amtali will be quoted for Galachipa also.

Tide in Bangladesh coast is semidiurnal i.e. there are two high and two low tides in about 24^{h} 48^{m}. BWDB tide records therefore have only one high and one low tide.

Figure 1: Tide Hydrograph SW20 Amtali 1995 and Land level of Galachipa



The tide hydrograph shown above are really the envelope curve of high and low tide that also shows the effect of spring tide (during full and new moon) and neap tide (during quarter of the moon phase).Low tide is always well below low land level at Galachipa. As such no drainage obstruction due to tide in the river is foreseen. During the monsoon spring tide rises over average land level but could be easily controlled by operating gates of drainage structures.

Table 3: Summary of high tide, low tide and range at SW20 Amtali

	SpringTide				NeapTide		
Month	HighTide	LowTide	Range		HighTide	LowTide	Range
Jan	1.66	-0.38	2.04		0.86	-0.33	1.19
Feb	1.73	-0.45	2.18		0.83	-0.30	1.12
Mar	2.56	-0.41	2.97		0.83	-0.27	1.10
Apr	2.19	-0.37	2.56		1.07	-0.12	1.19
May	2.44	-0.05	2.49		1.36	0.02	1.35
Jun	2.58	0.17	2.41		1.61	0.32	1.29
Jul	2.68	0.15	2.53		1.62	0.46	1.15
Aug	2.74	0.19	2.55		1.67	0.59	1.08
Sep	2.58	0.17	2.41		1.47	0.54	0.93
Oct	2.52	0.17	2.34		1.35	0.26	1.09
Nov	2.10	-0.09	2.19		1.28	0.08	1.19
Dec	1.85	-0.18	2.03		1.10	-0.14	1.24

The table shows that highest high tide 2.74 m-PWD occur during spring tide in August with a range of 2.55 m-PWD while lowest high tide 0.83 m-PWD occur during neap tide of March with a range of 1.10 m. Highest low tide occur during neap tide of August which is also the month with highest high tide and is therefore is a constraint for drainage. (See also rainfall). Flood level frequency analysis shows the following flood level for different return period.

Figure 2: Trend of Annual High Tide at SW20 Amtali

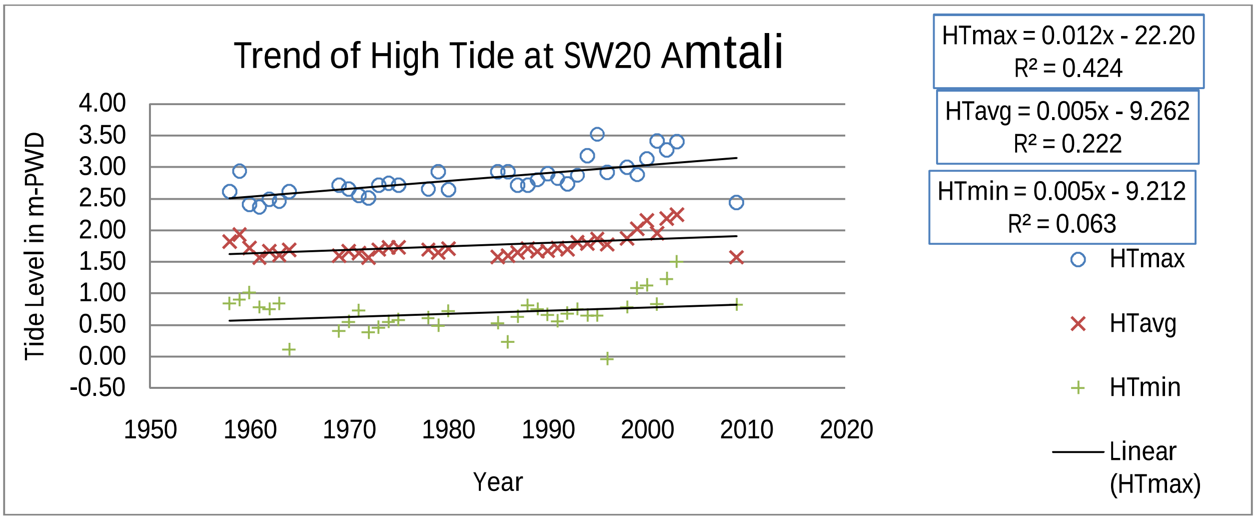


Table 4: Summary of trend of High Tide at SW20 Amtali

Tide	Rate of rise mm/year	R^2
Annual highest high tide HTmax	12	0.424
Annual highest high tide HTavg	5	0.222
Annual highest high tide Htmin	5	0.063

This confirms SLR in the Bay of Bengal. Comparatively higher land level in Galachipa has the advantage of fighting the scourge of rising sea level better than other towns in the area.

Table 5: Flood level prediction at SW20 Amtali

Rp in yrs	Flood level
100	3.76
50	3.59
25	3.42
20	3.36
2.33	2.79

3. Rainfall

Rainfall station CL262 Galachipa is located within Galachipa town. There is no evaporation station at Galachipa – evaporation of the nearest station at Patuakhali will be quoted.

Table 5 below shows the seasonal rainfall at Galachipa. In Bangladesh seasons are normally defined as:

1. Pre-monsoon - Mar, Apr, May
2. Monsoon - Jun, Jul, Aug, Sep
3. Post-monsoon – Oct, Nov
4. Winter – Dec, Jan, Feb

Exhibit 2: Location of Rainfall and Evaporation stations

Table 5: Seasonal rainfall (mm) -Galachipa

Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
422	1979	288	150	2737

Table 6 below shows seasonal evaporation at Patuakhali:

Table 6: Seasonal evaporation (mm) at Patuakhali

Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
268	261	130	150	808

Table 7 below shows a simple balance of seasonal rainfall and evaporation.

Table 7: Seasonal Rainfall and Pan Evaporation Amtali CT

Variable	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
RF	422	1979	288	150	2737
EV	268	261	130	150	808
ΔRF	154	1718	158	0	1929

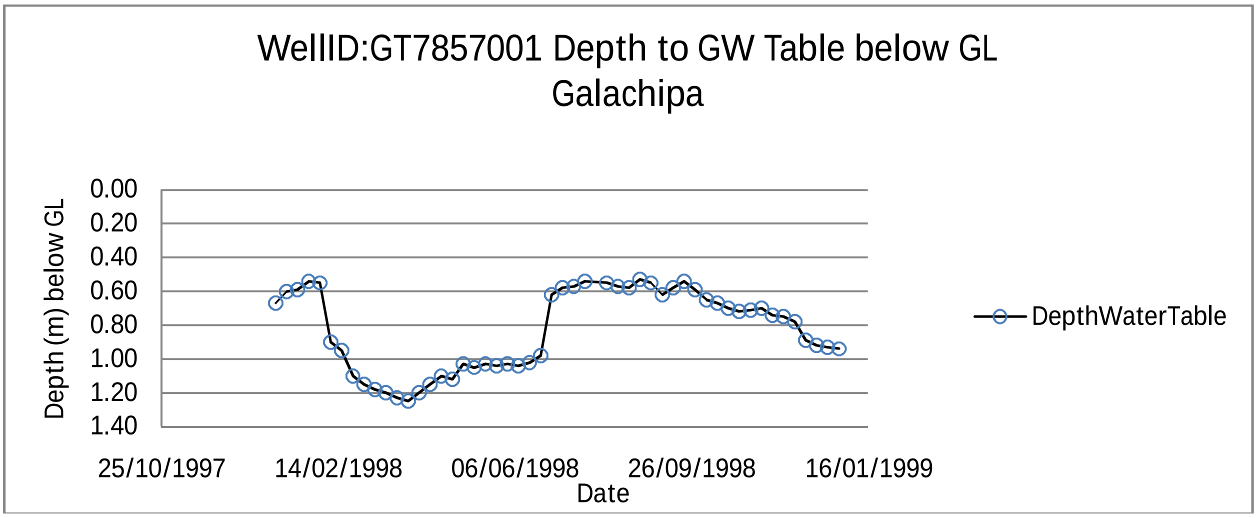
Galachipa town is located in a high rainfall zone of Bangladesh. Annual average rainfall at Galachipa is 2737 mm against Bangladesh Annual average of about 2362 mm. Monsoon rainfall at Galachipa is 1979 mm against Bangladesh monsoon rainfall of about 1656 mm.

Thus in the polder area there is a huge scope of groundwater recharge and surface runoff draining out through drainage structures.

5. Groundwater

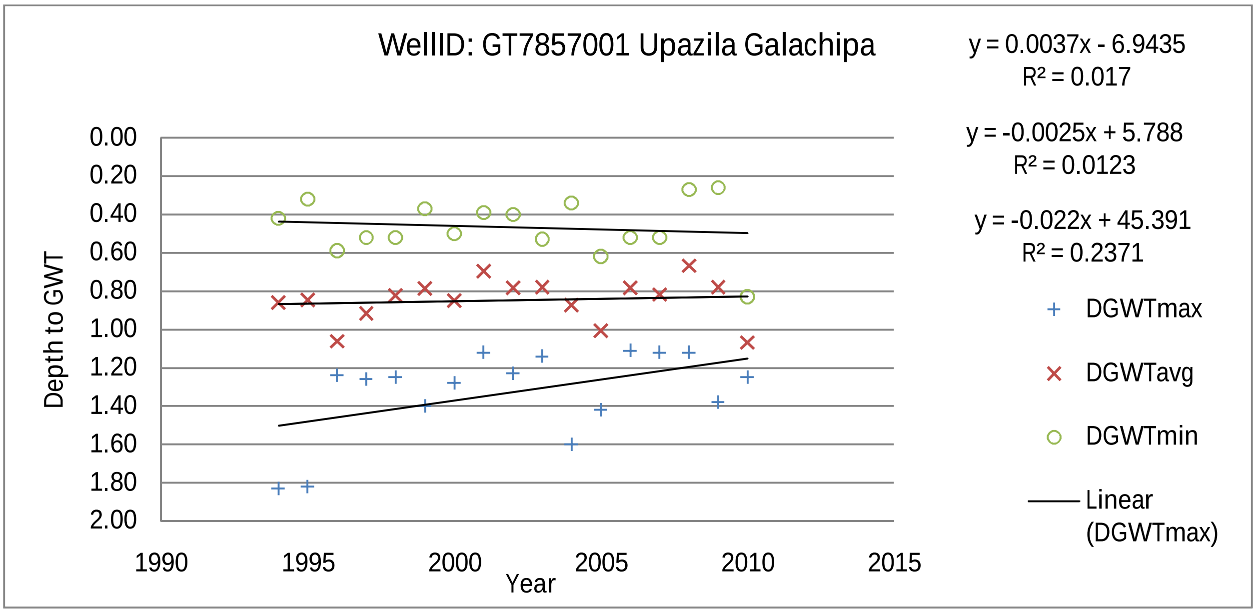
One groundwater level monitoring well is located in Galachipa UZ with the following particulars shown in Table 1D. Figure 3 below shows a sample GW level Hydrograph.

Figure 3: GW Table Hydrograph (1998)



The following are the trends of GWT in the two wells.

Figure 2: Trend of GWT Galachipa - Annual means and xtremes



DGWTmax has a rising trend showing that groundwater table is rising @ 22 mm/yr but the value of R^2 is too low to justify this rise. On the other hand DGWTavg and DGTmin does not show any trend. DGWTmin is the groundwater level at the end of rainy season has no rising trend which means that at the end of each rainy season the aquifer is fully recharged.

6. Sea Salinity

Figure 3: Monthly Salinity (EC) distribution at Galachipa

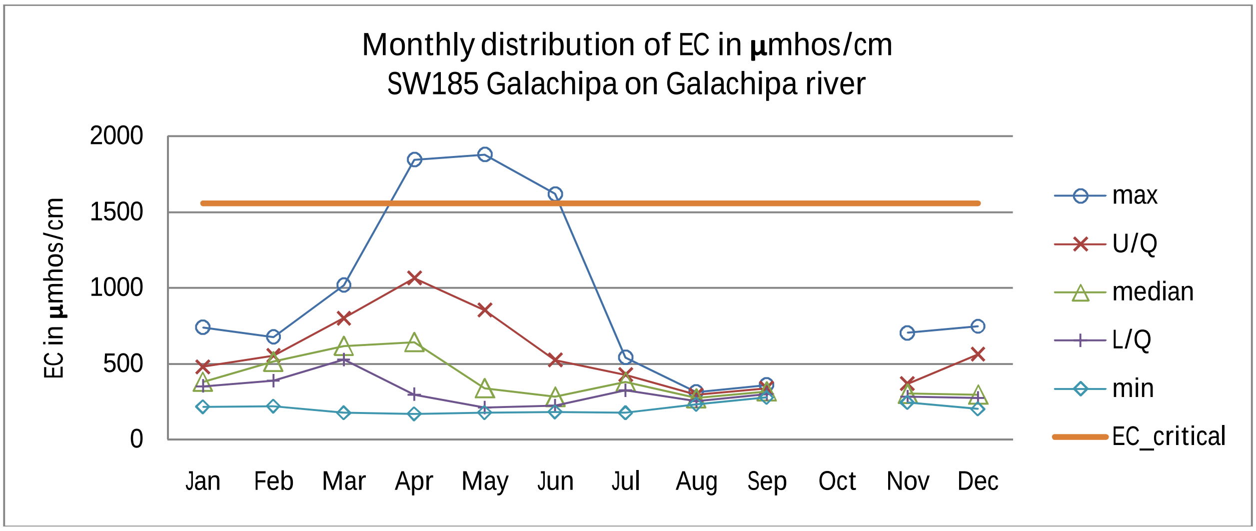


Figure 3 above show monthly distribution of salinity. Even during months of high salinity there are mostly low salinity.

Figure 4: Monthly Chloride distribution at Galachipa

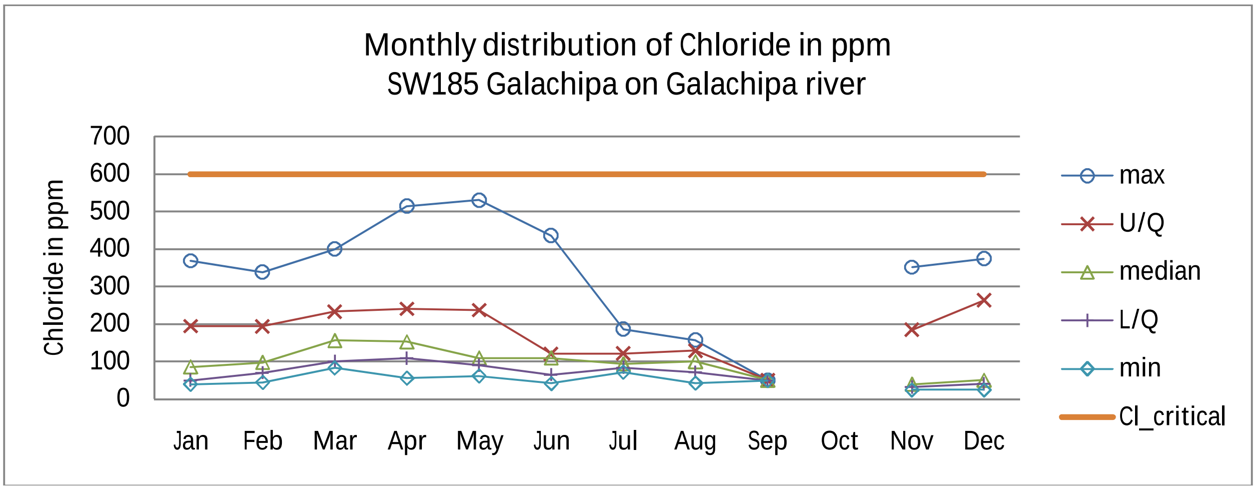
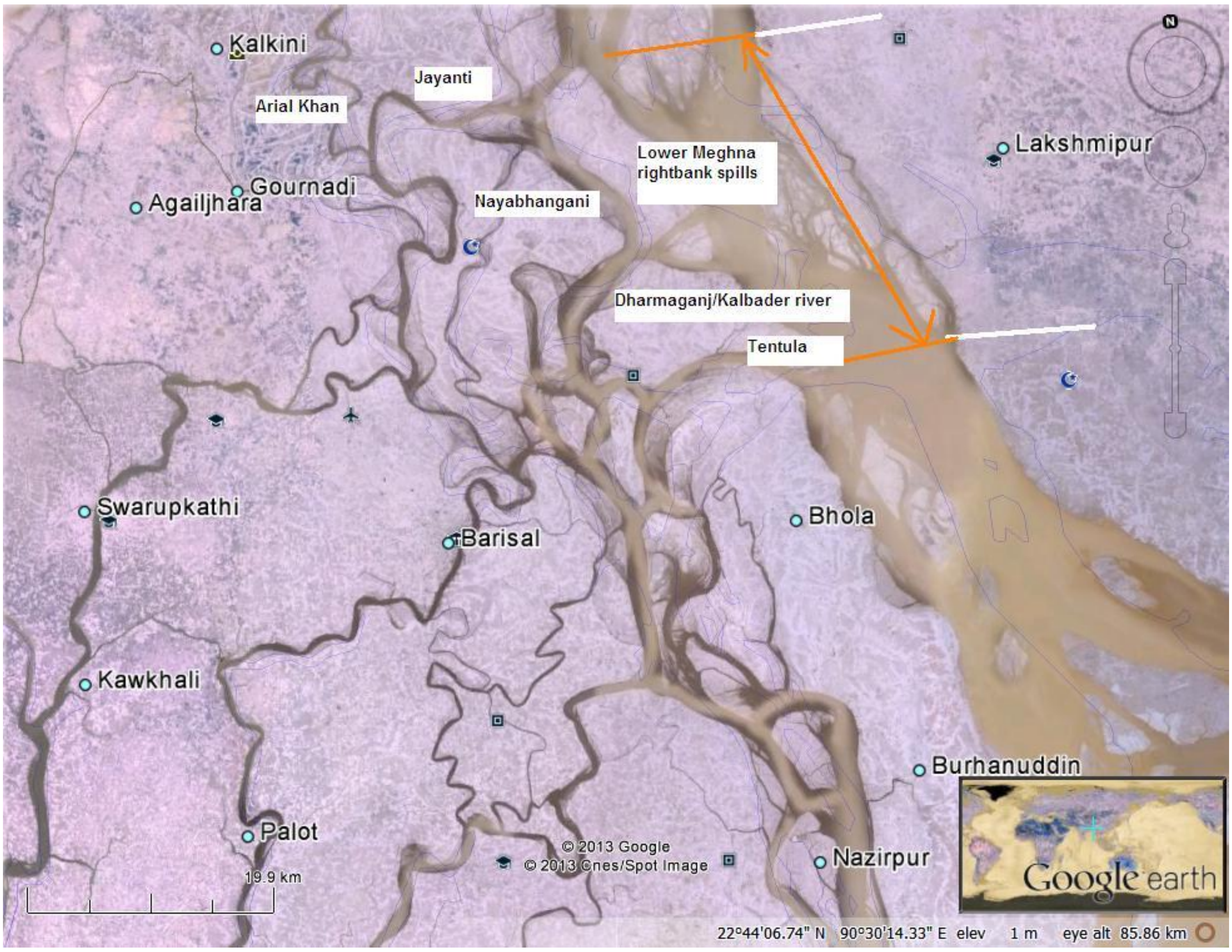


Figure 4 above show monthly distribution of chloride is within drinking water permissible limit all the year round.

Annex A: Fresh water corridor of Padm-Meghna spill channels – Arial Khan river system



4. HYDROLOGICAL AND HYDROGEOLOGICAL STUDY COASTAL TOWN PIROJPUR

04 July, 2013

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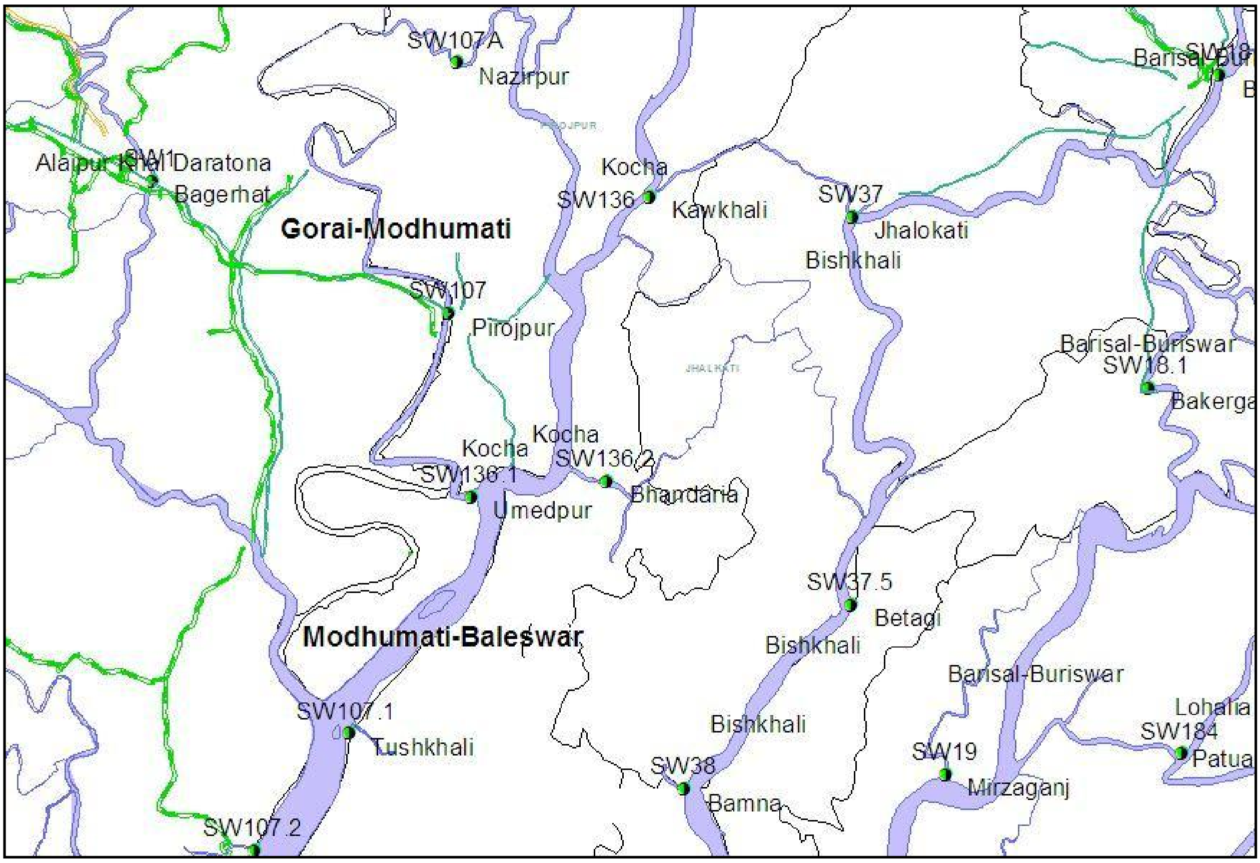
Draft
Hydrology and Hydrogeology at Pirojpur

1. Background Information

1.1 Location of Pirojpur

The coastal town Pirojpur[4] is a District town under Barisal Division. The town is located within polder P38 on the right bank of the river Baleswar approximately at Latitude 22 30' 00" N and Longitude 89 52' 00" E and is about 84 km upstream of sea face along Baleswar river.

Exhibit 1: Location of Pirojpur Town and river system around



About 6 km east of Perojpur town flows the Kotcha river the combined flow of Kaliganga and Swarupkati river that carries greater amount of freshwater from the Arial Khan.

4

PolderID	Pourashova	Low	Average	High
P43/1	Amtali	1.3	1.5	2.8
P55/2	Galachipa	1.4	2.5	2.8
P39/1B_D	Mothbaria	0.2	2.2	4.5
P38	Pirojpur	1.4	2.1	2.9

Note: From Paul Dean Flood Control and Drainage Engineer

Pirojpur pourashova is located inside BWDB Polder 38 and is a flat area. Other important rivers in the area are Rupsha-Passur to the west a highly saline river that connects Gorai-Modhumati through Halifax-cut at Bardia, Atharobanka and Ghasiakhali (not shown in map above), Bishkhali, Buriswar and Lohalia/Tentulia to the east. The last three rivers together forms a fresh water corridor of Padm-Meghna spill channels – Arial Khan river system (Annex A).

The course of the Gorai-Modhumati-Baleswar separates the highly saline zone to the west and the freshwater corridor to the east.

1.2 Availability of Hydrological stations in the area

The following hydro-geological stations are available in Pirojpur district.

Table 1a: List of Hydrological stations

District	Upazila	River	StationID	StationName	TypeCode
Pirojpur	Nazirpur	Gorai-Modhumati	SW107A	Nazirpur	TDWL
Pirojpur	Pirojpur Sadar	Gorai-Modhumati	SW107	Pirojpur	TDWL, SA
Pirojpur	Pirojpur Sadar	Kocha	SW136.1	Umedpur	TDWL,SA
Pirojpur	Bhandaria	Kocha	SW136.2	Bhandaria	TDWL
Pirojpur	Swarupkati	Swarupkati	SW253	Swarupkati	TDWL,SA

Note Type Code: TDWL- Tidal WL & SA- Sea Salinity

Table 1b: List of Climatological stations

District	Upazila	StationID	StationName	TypeCode
Pirojpur	Mathbaria	CL265	Mathbaria	RF
Pirojpur	Bhandaria	CL259	Bhandaria	RF
Pirojpur	Pirojpur Sadar	CL267	Pirojpur	EV
Pirojpur	Pirojpur Sadar	CL267	Pirojpur	RF
Pirojpur	Nazirpiur	CL271	Nazirpur	RF

Note Type Code: RF- Daily rainfall & EV- Daily Pan Evaporation

1.3 Availability of Groundwater stations

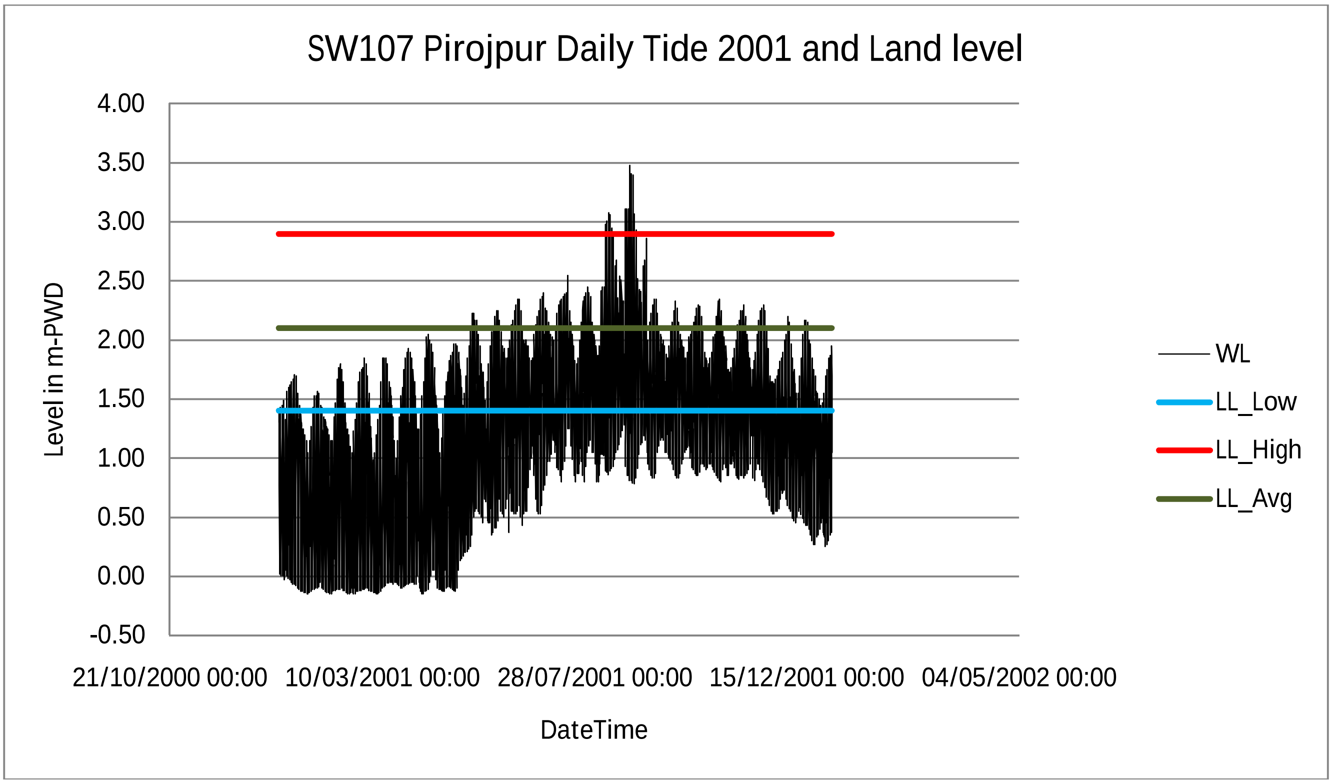
Table 1C: List of Groundwater table monitoring stations

District	Upazila	WellID	OldID	WellType	RL parapet	Parapet Height(m)	GL m-PWD	Depth
Pirojpur	Nazirpiur	GT7976009	BA005	Piezometer	2.03	0.41	1.62	20.73
Pirojpur	Pirojpur Sadar	GT7980010	BA015	Piezometer	1.98	0.43	1.55	33.38
Pirojpur	Nesarabad(Swarupkati)	GT7987011	BA016	Piezometer	2.11	0.58	1.53	39.02

2. Tide at Pirojpur

As already stated the Coastal Town Pirojpur is located on the left bank of the river Gorao-Modhumati a distributaries of the Ganga-Padma river and BWDB operates a manual tide recording station at SW107 Pirojpur. The tide station is some 84 km u/s of sea face. The next d/s station is SW107.2 Rayenda is 39 km d/s and 45 km u/s from sea face. Tide in Bangladesh coast is semidiurnal i.e. there are two high and two low tides in about 24^h 48^m. BWDB hydrology records only day time 3 hourly level from 6 am to 6 pm and in addition time and heights of high and low tide. Thus BWDB tide record shows only one high and one low tide each day.

Figure 1: Tide Hydrograph SW107 Pirojpur 2001 and Town Land level



The tide hydrograph shows the effect of spring tide (during full and new moon) and neap tide (during quarter of the moon phase). Low tide is well below low land level and as such the City may be drained quite easily.

Table 2: Summary of high tide, low tide and range

	SpringTide				NeapTide		
Month	HighTide	LowTide	Range		HighTide	LowTide	Range
Jan	1.60	-0.05	1.65		0.98	-0.14	1.13
Feb	1.66	-0.12	1.78		0.93	-0.15	1.08
Mar	1.89	-0.12	2.01		0.95	-0.13	1.08
Apr	2.08	0.04	2.04		1.13	-0.03	1.15
May	2.19	0.40	1.79		1.35	0.23	1.12
Jun	2.33	0.59	1.73		1.61	0.51	1.10
Jul	2.37	0.74	1.63		1.78	0.73	1.06
Aug	2.48	1.01	1.47		1.77	0.92	0.85

Sep	2.42	0.91	1.50		1.68	0.81	0.87
Oct	2.30	0.70	1.60		1.50	0.45	1.05
Nov	2.06	0.46	1.61		1.38	0.26	1.12
Dec	1.82	0.20	1.62		1.18	0.07	1.11

The Table 2 above shows that average highest high tide 2.48 m-PWD occur during spring tide in August with a range of 2.55 m-PWD while average lowest high tide .93 m-PWD occur during neap tide of Feb with a range of 1.08 m. Average Highest low tide occur during neap tide of July which is also the month with highest high tide and is therefore is a constraint for drainage. Flood level frequency analysis shows the following flood level for different return period.

Table 4: Flood level prediction at SW107 Pirojpur

Rp in yrs	Flood level
100	3.69
50	3.49
25	3.27
20	3.21
10	2.99
5	2.76
2.33	2.49

Figure 2: Trend of Annual Extreme and Average Tide

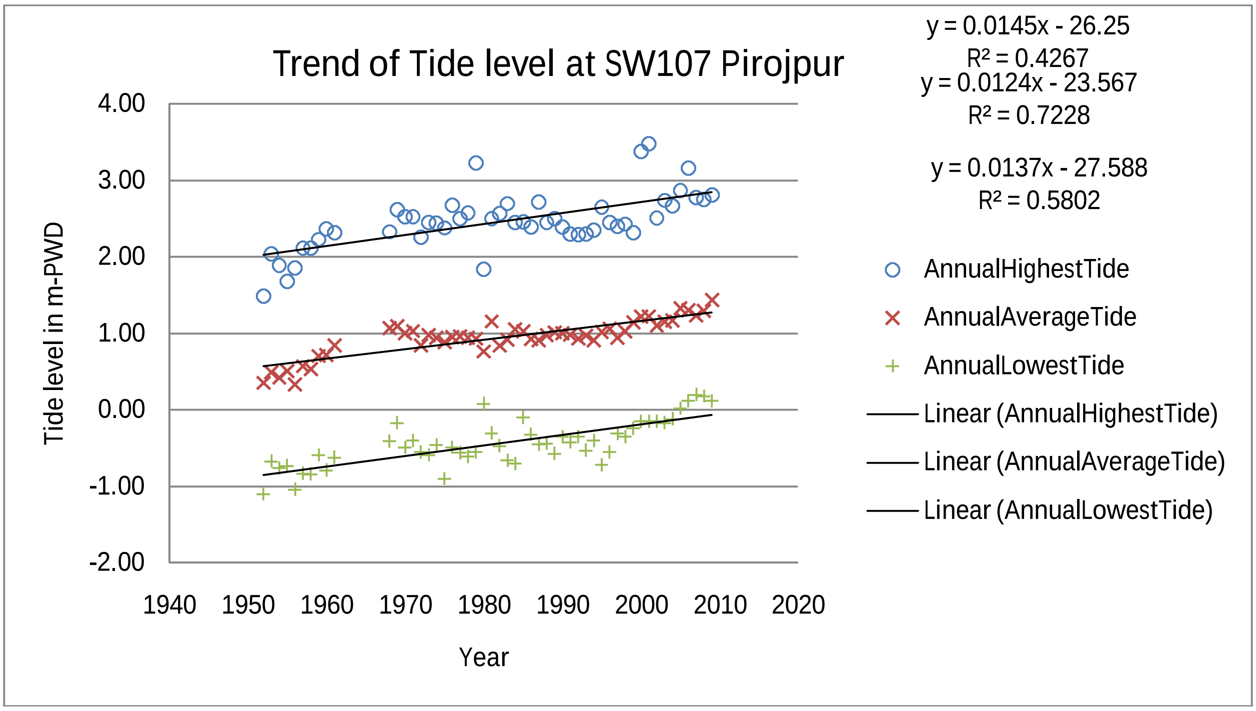


Table 5: Summary of trend of Annual average and Xtreme Tide at SW107 Pirojpur

Tide	Rate of rise mm/year	R^2
Annual highest high tide HTmax	14	0.426
Annual average tide HTavg	12	0.722
Annual highest high tide Htmin	13	0.580

3. Sea Salinity

Salinity measurements consist of measurement of Electrical Conductivity (EC) - a measure of TDS in terms of μhos/cm and Chloride in mg/l. Measurements are made at high and low tide only during dryseason. Permissible limit of EC and Cl in drinking water are 1560 μhos/cm and 600 mg/l. Time trend of EC and Cl at Pirojpur are given below:

Figure 3: Trend of Electrical Conductivity at Pirojpur

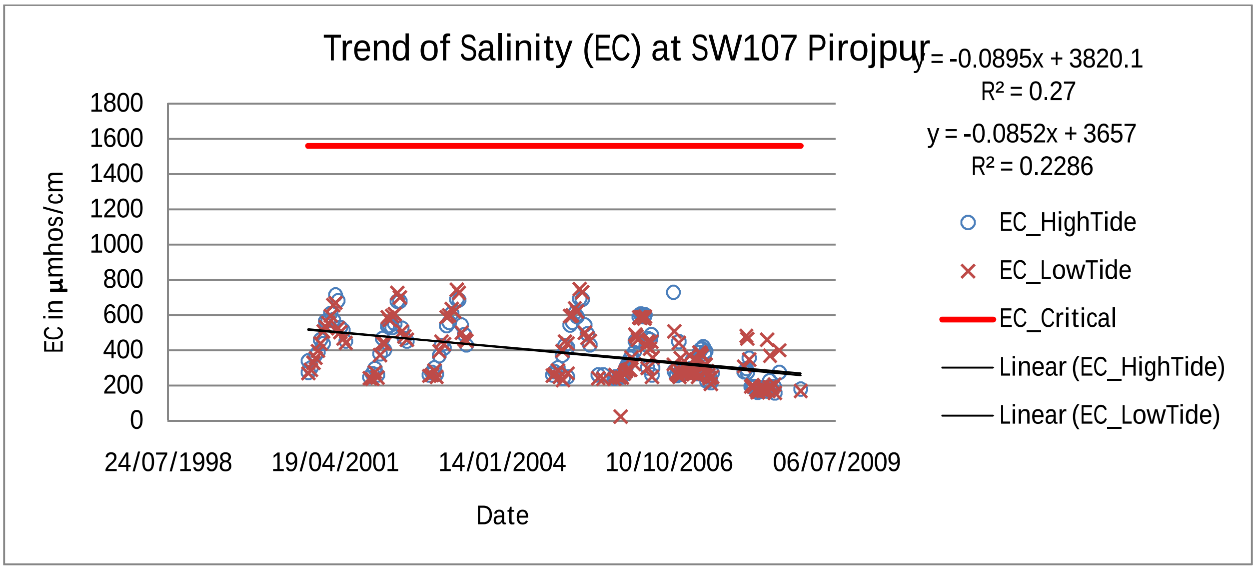
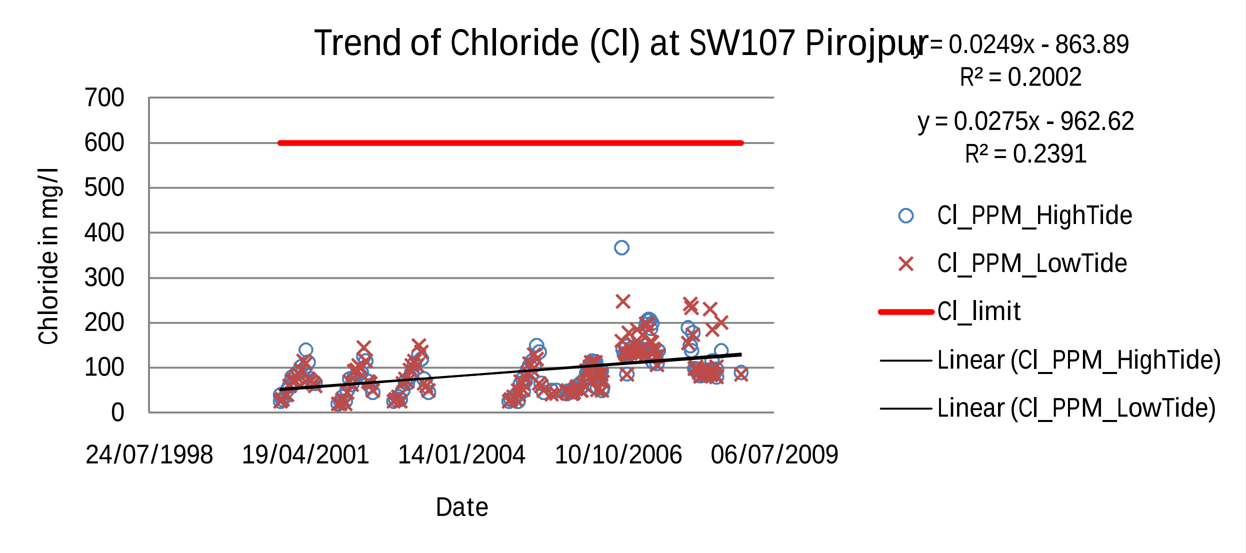


Figure 4: Trend of Chloride at Pirojpur



Both the graphical presentations show that salinity and chloride concentrations in the river water are well below the permissible limit of drinking water.

4. Rainfall

Table 1b shows the four rainfall stations in Pirojpur district of which one station along with a Pan Evaporation station is in Pirojpur town. In Bangladesh seasons round the year are normally defined as:

1. Pre-monsoon - Mar, Apr, May (MAM)
2. Monsoon - Jun, Jul, Aug, Sep (JJAS)
3. Post-monsoon – Oct, Nov (ON)
4. Winter – Dec, Jan, Feb (DJF)

Table below shows seasonal rainfall and evaporation in mm (1975-2005)

Table 6: Seasonal Rainfall and Pan Evaporation Pirojpur CT

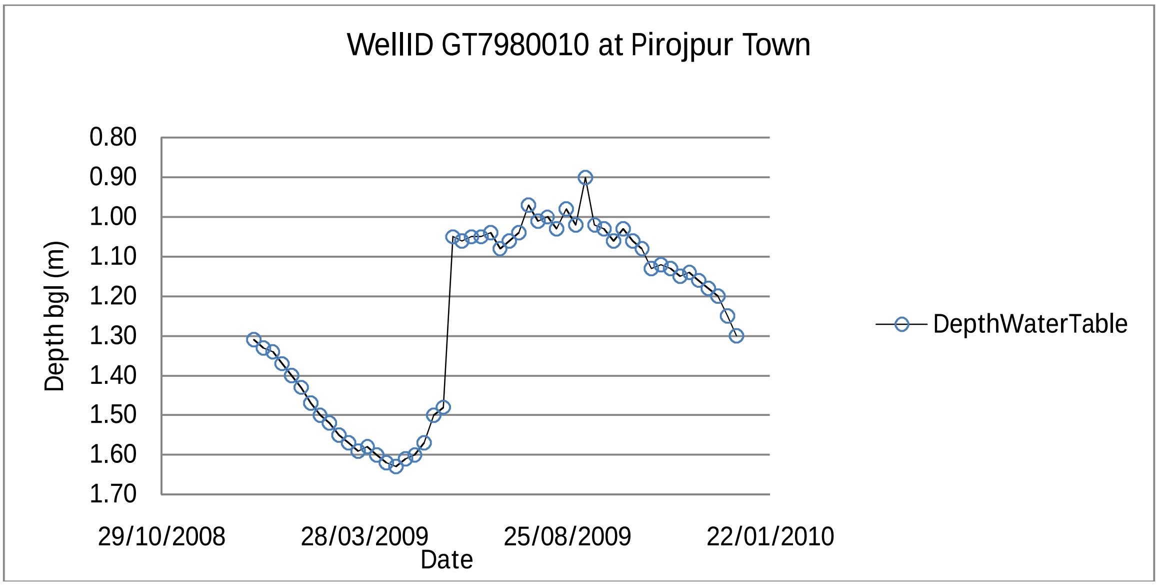
Variable	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
RF	373	1653	205	51	2283
EV	563	402	313	362	1640
∆RF	-190	1251	-108	-311	643

Pirojpur town is located beyond the coastal high rainfall zone of Bangladesh. Annual average rainfall at Pirojpur 2283 mm against Bangladesh Annual average of about 2362 mm. Monsoon rainfall at Pirojpur is 1653 mm against Bangladesh monsoon rainfall of about 1656 mm. During the monsoon there is a high balance of rainfall against evaporation thus in the polder area there is a huge scope of groundwater recharge. Sufficient provision is also required for surface runoff draining out through drainage structures.

5. Groundwater

There is one groundwater level monitoring well (WellID:GT7980010) in Pirojpur Town – particulars of the well is given in Table 1C. Figure 3 below shows the year round variation of Ground Water Table.

Figure 3: Groundwater Table Hydrograph at Pirojpur - 2009



The following are the trends of GWT in the wells.

Figure 4: Trend of depth to GWT - Annual means and xtremes

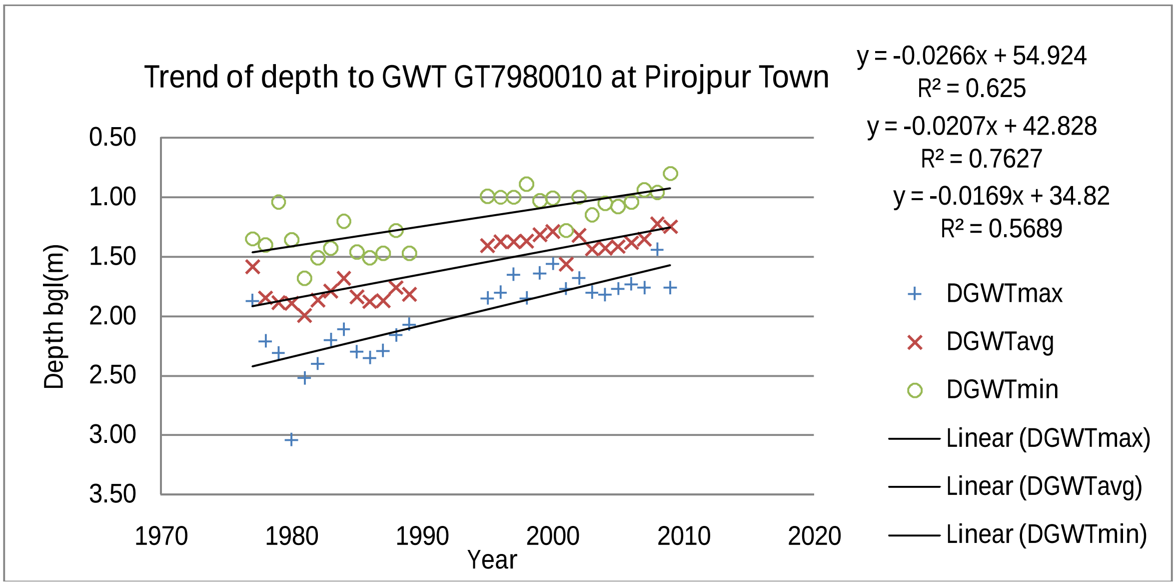
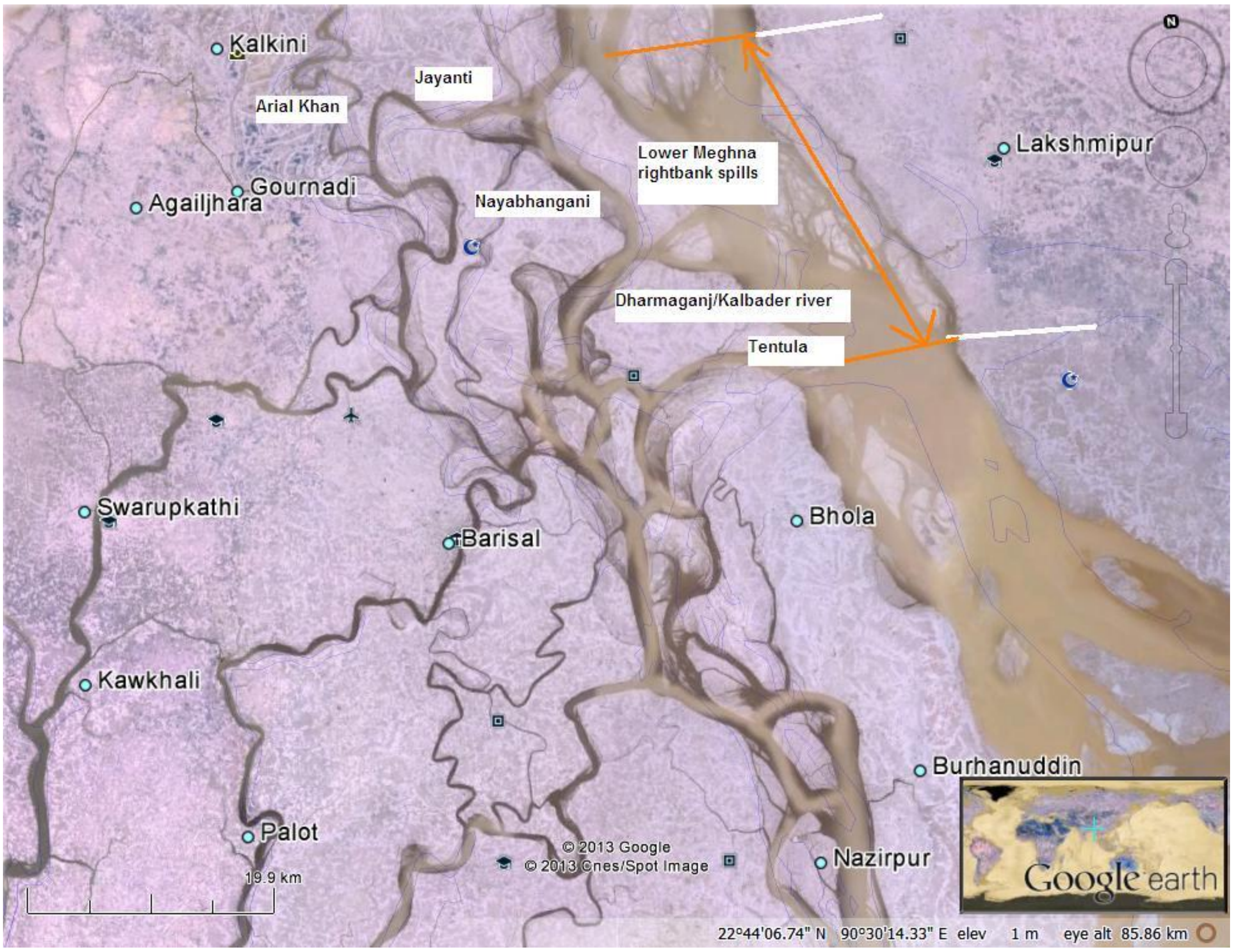


Table 7: Summary of trend of GW Table - Pirojpur

Tide	Rate of rise mm/year	R^2
Annual max depth to GWT	26	0.625
Annual avg depth to GWT	20	0.762
Annual min depth to GWT	16	0.568

Here in this case all the three GWT indicators show that these are rising showing a possibility of water logging and necessity of drainage improvement is foreseen.

Annex A: Fresh water corridor of Padm-Meghna spill channels – Arial Khan river system



5. HYDROLOGICAL AND HYDROGEOLOGICAL STUDY COASTAL TOWN MATHBARIA

04 July, 2013

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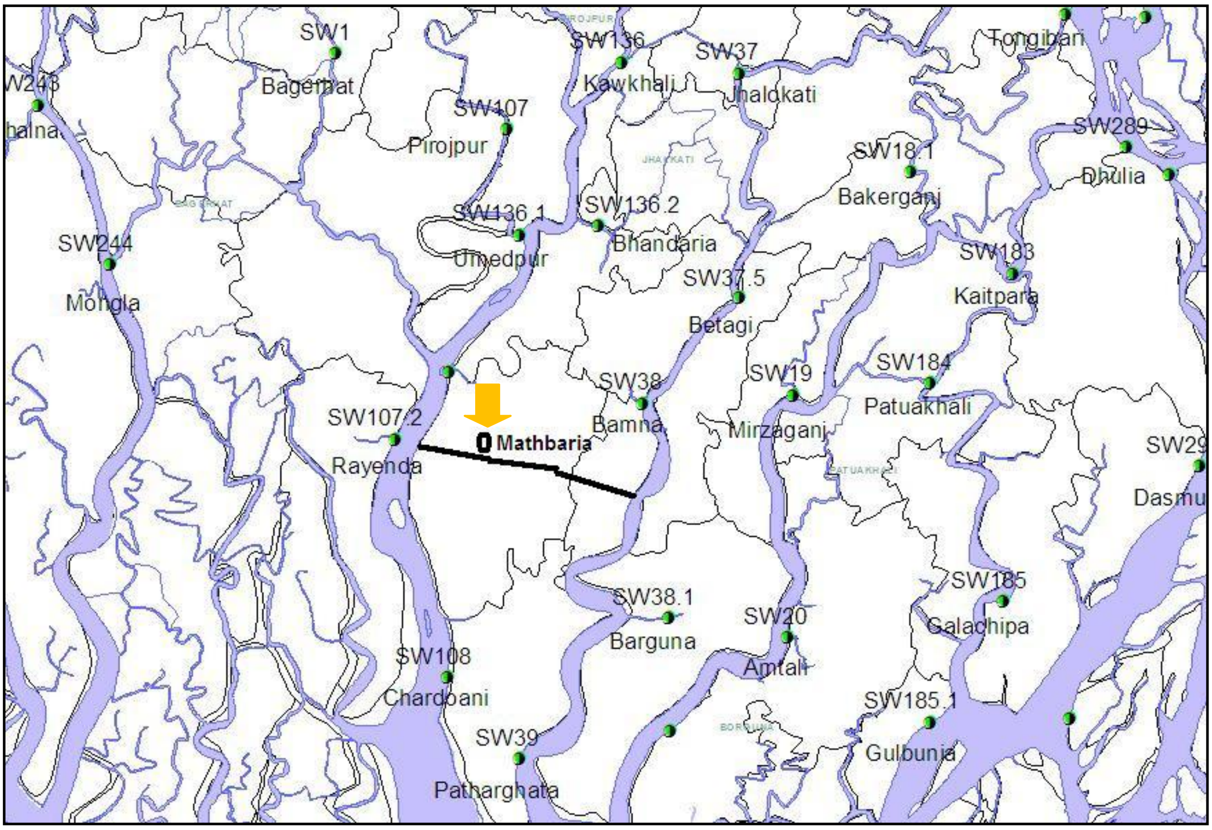
Draft
Hydrology and Hydrogeology at Mathbaria

1. Background Information

1.1 Location of Mathbaria

The coastal town Mathbaria[5] is a Upazila town under Pirojpur district. The town is located within polder P39/1B_D approximately at Latitude 22.2883 N and Longitude 89.9589 E and is about 45 km upstream of sea face along Baleswar river.

Exhibit 1: Location of Mathbaria Town and river system around



In respect of topography of Mathbaria (unconfirmed values given by Paul FC&Drainage Engineer) as no topo maps were available are: land level - LL_Low: 0.4 m-PWD, LL_Avg: 2.2 and LL_High: 4.5 m_PWD. Mathbaria pourashova is about 9 km east – away from Baleswar

5

PolderID	Pourashova	Low	Average	High
P43/1	Amtali	1.3	1.5	2.8
P55/2	Galachipa	1.4	2.5	2.8
P39/1B_D	Mothbaria	0.2	2.2	4.5
P38	Pirojpur	1.4	2.1	2.9

Note: From Paul Dean Flood Control and Drainage Engineer

river left bank and about 12 km west from Bishkhali river right bank.(Exhibit 1). Other important rivers in the area are Rupsha-Passur to the west a highly saline river that connects Gorai-Modhumati through Halifax-cut at Bardia, Atharobanka and Ghasiakhali (not shown in map above), Bishkhali, Buriswar and Lohalia/Tentulia to the east. The last three rivers together form a fresh water corridor of Padma-Meghna spill channels – Arial Khan river system (Annex A).

The course of the Gorai-Modhumati-Baleswar separates the highly saline zone to the west and the freshwater corridor to the east. While Baleswar river near Mathbaria is highly saline the Bishkhali about 12 km west has the freshwater flow and the two rivers are connected by Masua khal.

2. Availability of Hydro-geological stations in the area

The following hydrological stations are available in Mathbaria UZ and around that affect the hydrological environment of the area.

Table 1a: List of Hydrological stations

District	Upazila	River	StationID	StationName	TypeCode
Pirojpur	Nazirpur	Gorai-Modhumati	SW107A	Nazirpur	TDWL
Pirojpur	Pirojpur Sadar	Gorai-Modhumati	SW107	Pirojpur	TDWL, SA
Bagerhat	Sarankhola	Gorai-Modhumati	SW107.2	Rayenda	TDWL, SA
Barguna	Patharghat	Gorai-Modhumati	SW108	Chardoani	SA
Barguna	Bamna	Bishkhali	SW38	Bamna	TDWL,SA
Barguna	Barguna	Bishkhali	SW38.1	Barguna	TDWL
Pirojpur	Swarupkati	Swarupkati	SW253	Swarupkati	TDWL,SA

Note Type Code: TDWL- Tidal WL & SA- Sea Salinity

Table 1b: List of Climatological stations

District	Upazila	StationID	StationName	TypeCode
Pirojpur	Mathbaria	CL265	Mathbaria	RF
Pirojpur	Pirojpur Sadar	CL267	Pirojpur	EV
Pirojpur	Pirojpur Sadar	CL267	Pirojpur	RF

Note Type Code: RF- Daily rainfall & EV- Daily Pan Evaporation

Groundwater data availability

There are four GW Water table monitoring well in Mathbaria upazilla and particulars of these wells are furnished table below:

Table 1.D: BWDB Hydrology GW Water Table Monitoring wells

WellID	OldID	UpazilaCode	SinkDate	Parapet Height(m)	RLparapet m-PWD	GL m-PWD	Depth m	WellDia (m)	Lat	Long
GT7958005	BA025	7958	24-May-79	0.58	3.00	2.42	80.98		22.3700	89.9500
GT7958006	BA026	7958	14-May-79	0.66	3.04	2.38	52.44		22.3600	89.9600
GT7958007	BA027	7958	24-May-79	0.58	3.00	2.42	60.98		22.3700	89.9800
GT7958008	BA031	7958	15-Dec-77	0.58	2.11	1.53	25.84	0.04	22.3000	89.9700

Groundwater quality in Mathbaria area does not seem to be suitable for drinking purpose. BWDB Groundwater Hydrology has groundwater quality record for the following three wells:

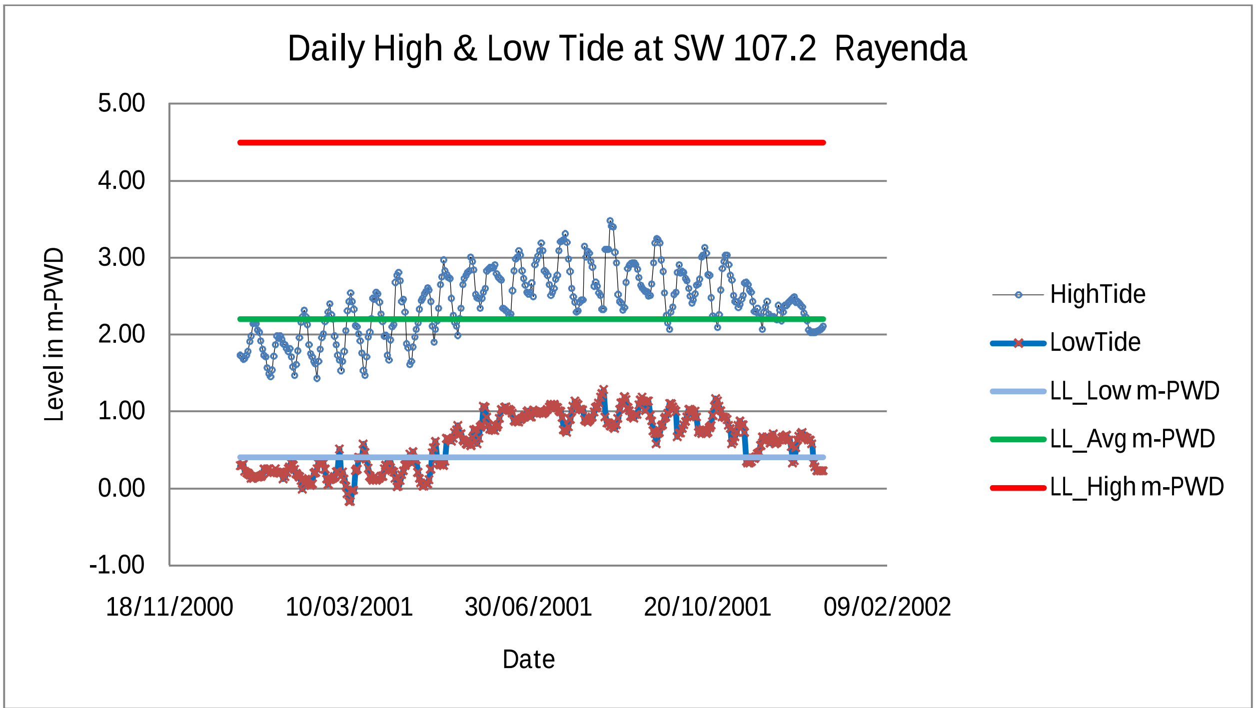
Table 1.E: BWDB Hydrology GW quality wells

Well Info			
WellID	GQ7958108	GQ7958109	GQ7958110
OldID	BAWQ025(CMD)	BAWQ026(CMD)	BAWQ027(CS)
UpazilaCode	7958	7958	7958
Site	Abdul Ghani Talikder House	Abdul Gani Talikder's House	Abdul Ghani Talikder's House
WellType	Drinking Well	Drinking Well	Drinking Well
SinkDate	01-Jan-01	01-Jan-01	01-Jan-01
ParapetHeight(m)			
Rlparapet m-PWD	3.01	3.01	3.01
Depth (m)	280.48	152.44	60.97
WellDia(m)			
Lat	22.37167	22.37167	
Long	89.94	89.94	

3. Tide at Mathbaria

As already stated the Coastal Town Mathbaria is located on the left bank of the river Gorai-Modhumati-Baleswar a distributaries of the Ganga-Padma river and BWDB operates a manual tide recording station at SW107.2 Rayenda on the right bank of the river(Bagerhat – Sarankhola). The tide station Rayenda is some 45 km u/s of sea face. The next d/s station is SW108 Chardoani is 24 km d/s and 21 km u/s from sea face. Tide in Bangladesh coast is semidiurnal i.e. there are two high and two low tides in about 24^{h} 48^{m}. BWDB hydrology records only day time 3 hourly level from 6 am to 6 pm and in addition time and heights of high and low tide. Thus BWDB tide record shows only one high and one low tide each day.

Figure 1: Tide Hydrograph SW107.2 Rayenda 2001 and Town Land level



The tide hydrograph shows that during the monsoon low land will remain inundated. Medium high land will be inundated during high tide but can be protected by appropriate operation of drainage structures. Even the rainfall can also be drained between inter-tidal periods.

Table 2: Summary of high tide, low tide and range (SW107.2 Rayenda)

	Spring Tide				Neap Tide		
Month	HighTide	LowTide	Range		HighTide	LowTide	Range
Jan	2.02	0.12	1.90		1.33	0.18	1.15
Feb	2.11	-0.04	2.15		1.34	0.15	1.18
Mar	2.33	-0.04	2.38		1.35	0.19	1.17
Apr	2.51	0.08	2.43		1.57	0.33	1.24
May	2.77	0.24	2.53		1.79	0.47	1.31
Jun	2.84	0.52	2.32		1.96	0.62	1.34
Jul	3.01	0.67	2.33		2.15	0.90	1.25
Aug	3.13	0.75	2.38		2.16	0.96	1.20
Sep	3.04	0.81	2.23		2.03	0.90	1.13
Oct	2.89	0.61	2.28		1.88	0.79	1.09
Nov	2.66	0.42	2.24		1.72	0.52	1.20
Dec	2.24	0.20	2.04		1.59	0.36	1.22

The Table 2 above shows that average highest high tide 3.13 m-PWD occur during spring tide in August with a range of 2.38 m while average lowest high tide 1.33 m-PWD occur during neap tide of Jan with a range of 1.15 m. Average Highest low tide 2.16 m-PWD occur during neap tide of August which is also the month with highest high tide and is therefore is a constraint for drainage. Flood level frequency analysis shows the following flood level for different return period.

Table 4: Flood level prediction at SW107.2 Rayenda

Rp in yrs	Flood level
100	3.69
50	3.49
25	3.27
20	3.21
10	2.99
5	2.76
2.33	2.49

Figure 2: Time trend of tide at SW107.2 Rayenda on Baleswar

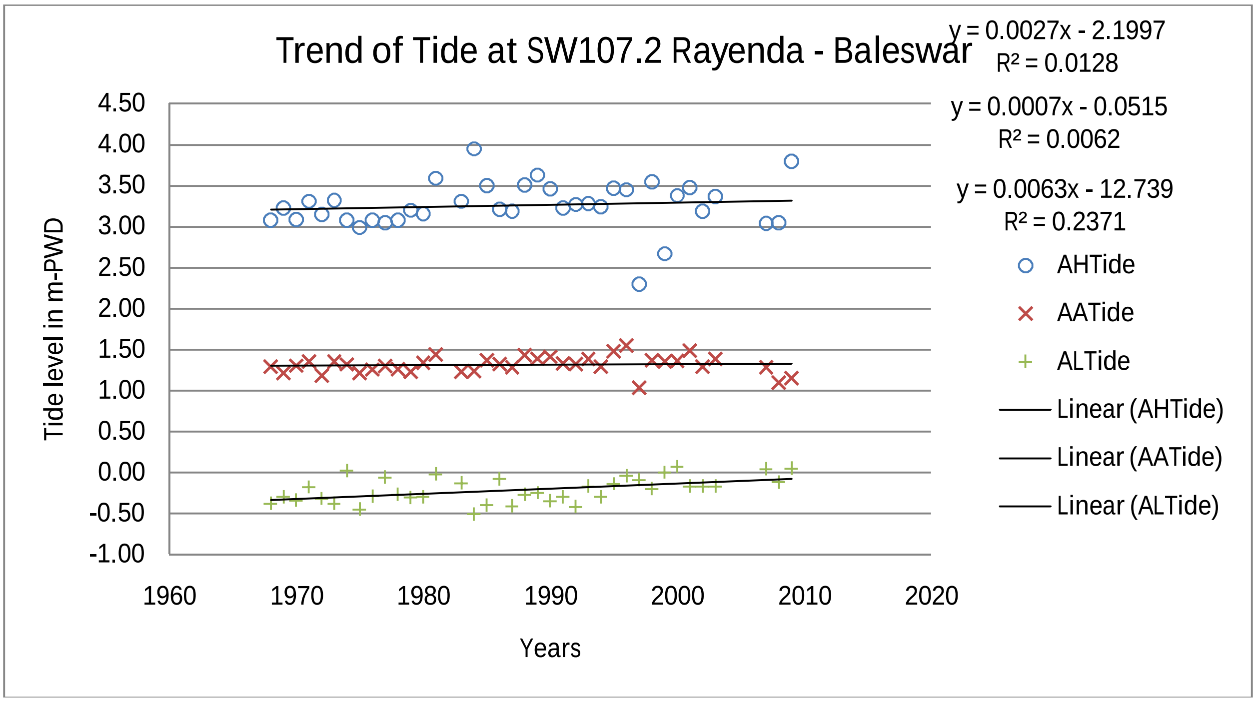


Table 5: Summary of trend of High Tide at SW107.2 Rayenda

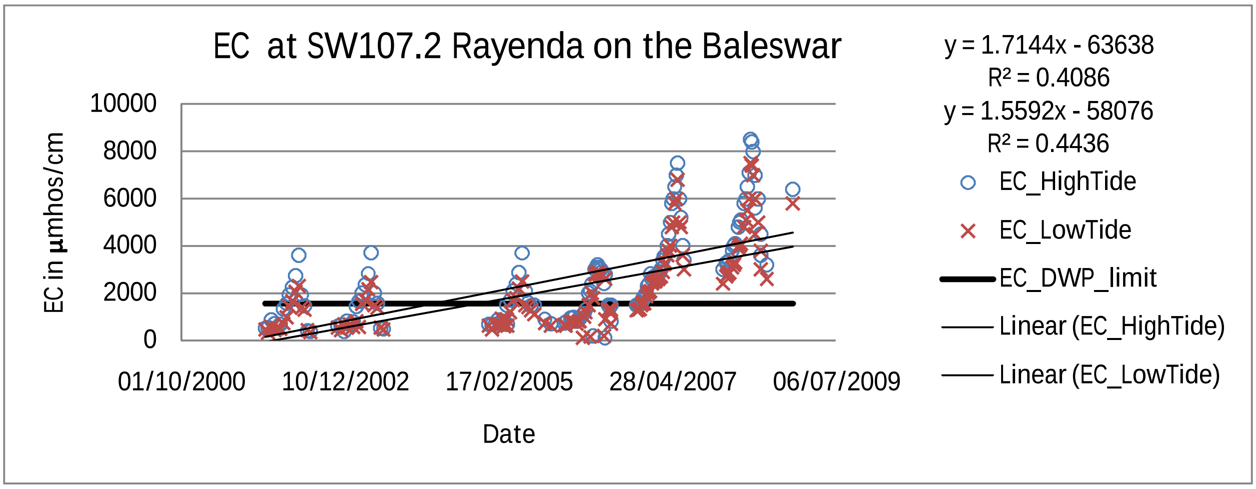
Tide	Rate of rise mm/year	R^2
Annual highest high tide AHTide	2	0.012
Annual average tide AATide	0	?
Annual lowest tide AL Tide	6	0.237

At this station there seems no significant time trend in tide.

4. Sea Salinity

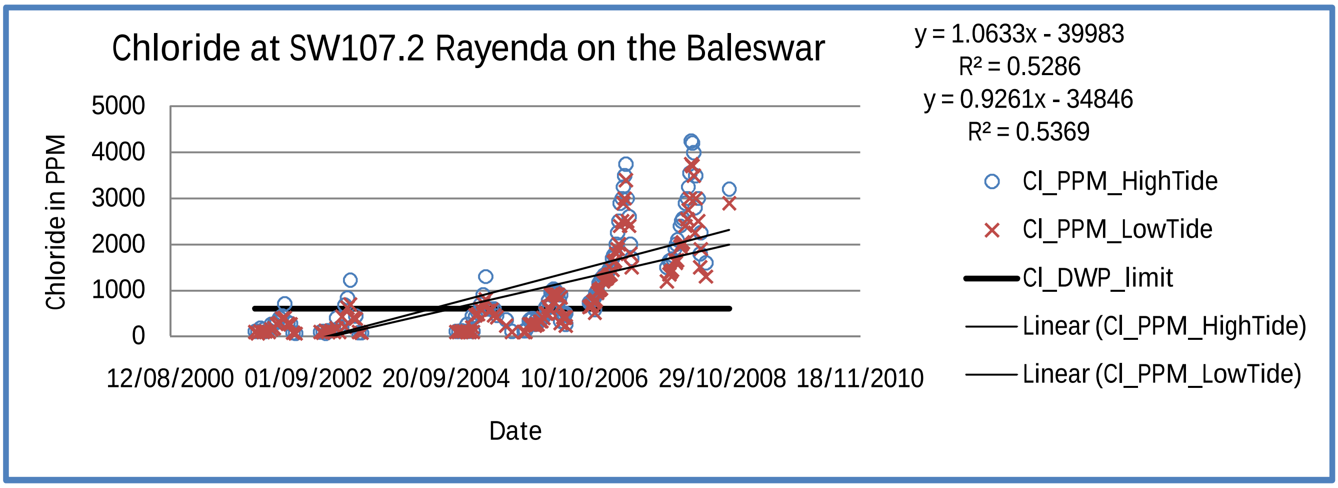
Salinity measurements consist of measurement of Electrical Conductivity (EC) - a measure of TDS in terms of μhos/cm and Chloride in mg/l. Measurements are made at high and low tide only during dry season. Permissible limit of EC and Cl in drinking water are 1560 μhos/cm and 600 mg/l. Time trend of EC and Cl at SW1072 Rayenda (estimate for Mathbaria) are given below:

Figure 3: Trend of high and low tide EC



Most of the times EC (estimate of salinity) is above drinking water permissible limit. Both high water low water salinity is in increasing trend. High water salinity is increasing @1.714 EC in μmhos/cm and low water salinity is increasing @1.559 EC in μmhos/cm

Figure 4: Trend of high and low tide Chloride in ppm



Most of the times Chloride is above drinking water permissible limit. Both high water low water Chloride is in increasing trend. High water chloride is increasing @1.063 mg/l and Low water chloride is increasing @ 0.926 mg/l.

Rainfall

There is a rainfall station at Mathbaria while the nearest evaporation statio is at Pirojpur. In Bangladesh seasons are normally defined as:

1. Pre-monsoon - Mar, Apr, May

2. Monsoon - Jun, Jul, Aug, Sep
3. Post-monsoon – Oct, Nov
4. Winter – Dec, Jan, Feb

Exhibit 2: Location of Rainfall and Evaporation stations

Table 6: Seasonal Rainfall and Pan Evaporation at Mathbaria (taking evaporation at Pirojpur as estimate of evaporation at Mathbaria CT

Variable	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
RF	432	2079	208	38	2758
EV	268	261	130	150	808
∆RF	164	1818	78	-112	1950

Mathbaria town is located in a high rainfall zone of Bangladesh. Annual average rainfall at Mathbaria is 2758 mm against Bangladesh Annual average of about 2362 mm. Monsoon rainfall at Mathbaria is 2079 mm against Bangladesh monsoon rainfall of about 1656 mm. Thus in the polder area there is a huge scope of groundwater recharge and surface runoff draining out through drainage structures.

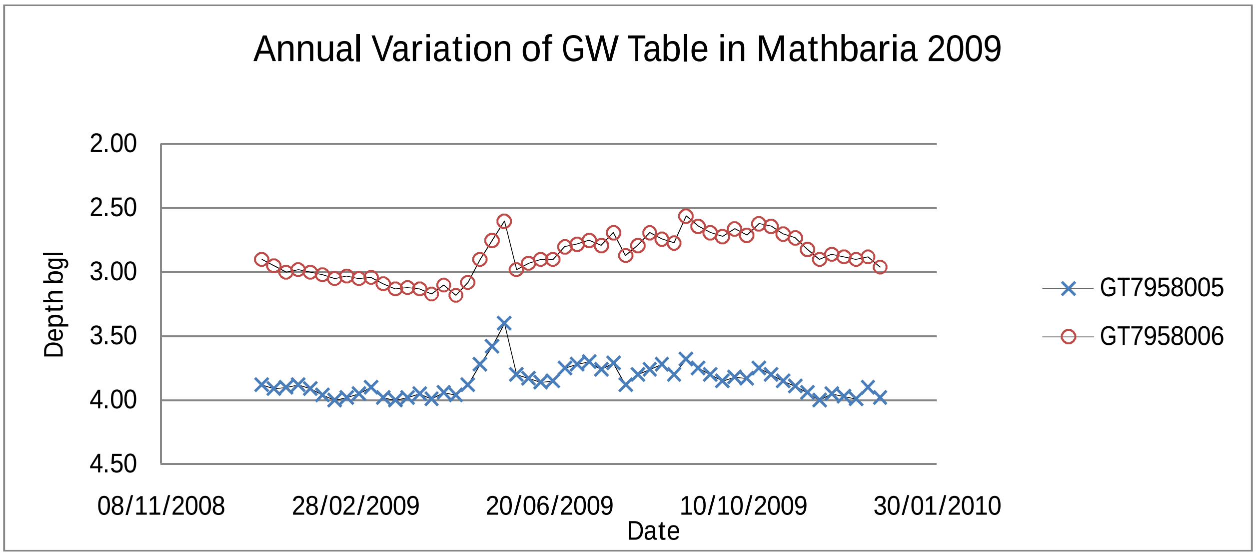
5. Groundwater

Four Groundwater level monitoring wells located in Mathbaria UZ with the available particulars are presented in **Table 1.D**:

Measuring point to depth to GWT is top of parapet of well. GL=RLparapet-parapetHeight i.e. GL of the well with WellID GT7958005 is 2.42 m-PWD and well with WellID GT7958006 is 2.38 m-PWD.

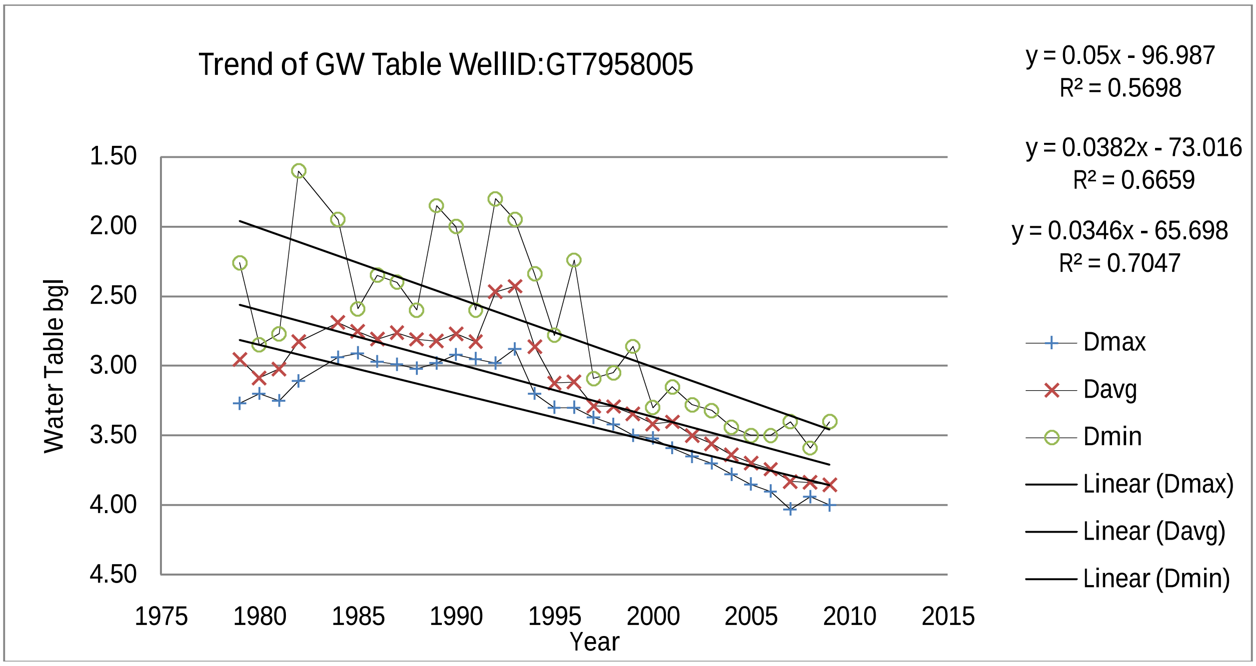
The is a typical GW table hydrograph for the 2 wells:

Figure 5: GW Table Hydrograph



The following are the trends of GWT in the two wells.

Figure 5: GW Table Hydrograph



Annual Dmax, Davg and Dmin all have a falling trend showing that groundwater table is falling quite rapidly.

Table 7: Trend of Depth to GWT - (WellID:GT7958005)

Depth to GWT	Rate of fall mm/year	R^2
Annual Dmax	50	0.568
Annual Davg	38	0.665
Annual Dmin	34	0.704

Table 1D show that the monitoring wells have depths in the range 50-80 m. Falling trend of groundwater table is therefore indication of the upper aquifer. So if drainage management within the polder is improved so as to increase infiltration – there could be a scope of improving the water quality of the upper aquifer also.

Water Supply in Mathbaria Paurashova area

Ground Water, River Water and Rainfall harvesting are the three sources of water supply in Coastal Towns in Bangladesh. Of course if suitable water in quality and quantity is available then Groundwater is the best alternative of water supply.

Table 1: Rainfall at Mathbaria

Monthly rainfall mm at Mothbaria (Estimate)

Month	RF mm	EV mm	RF-EV mm
Jan	7.6	108.2	-100.6
Feb	22.0	126.3	-104.3
Mar	52.2	188.7	-136.5
Apr	104.6	202.2	-97.6
May	275.4	172	103.4
Jun	533.7	136.3	397.4
Jul	632.9	64.8	568.1
Aug	523.3	90.2	433.1
Sep	388.8	110.9	277.9
Oct	171.6	161.9	9.7
Nov	36.7	150.6	-113.9
Dec	8.6	127.7	-119.1
Annual	2757.4	1639.8	1117.6

Table 2: Seasonal rainfall

Season	RF mm	% Annual
Winter DJF	38	1
Pre-monsoon MAM	432	16
Monsoon JJAS	2079	75
Post-monsoon ON	208	8
Annual	2757	100

There a good number of medium to large size ponds in the Pauroshova area. These ponds may be surveyed and Pauroshova may take initiative to undertake a survey of the present condition of the ponds and ownership and may develop program for proper O&M and its larger use as a source of drinking water and it may be a complementary source of water.

2. Groundwater Quality

Groundwater quality in Mathbaria area does not seem to be suitable for drinking purpose. BWDB Groundwater Hydrology has groundwater quality record for the following three wells:

Table 3: BWDB Hydrology GW quality wells

Well Info			
WellID	GQ7958108	GQ7958109	GQ7958110
OldID	BAWQ025(CMD)	BAWQ026(CMD)	BAWQ027(CS)
UpazilaCode	7958	7958	7958
Site	Abdul Ghani Talikder House	Abdul Gani Talikder's House	Abdul Ghani Talikder's House
WellType	Drinking Well	Drinking Well	Drinking Well
SinkDate	01-Jan-01	01-Jan-01	01-Jan-01
ParapetHeight(m)			
Rlparapet m-PWD	3.01	3.01	3.01
Depth (m)	280.48	152.44	60.97
WellDia(m)			
Lat	22.37167	22.37167	
Long	89.94	89.94	

Table 4 below shows statistics of TDS and Chlorides for the three wells. The result shows none of these wells are suitable for development of drinking water.

Table 4: Statistics of TDS and Chlorides in the three wells in Mothbaria

Parameters	WellID: GQ7958108		WellID: GQ7958109		WellID: GQ7958110	
	TDS mg/l	Chloride mg/l	TDS mg/l	Chloride mg/l	TDS mg/l	Chloride mg/l
Max	13020	10000	14000	11400	15226	9350
Upper Quartile	13000	9500	14000	8513	11360	1455
Median	12010	7875	12220	8500	2320	242
Lower Quartile	7500	4288	12150	4298	944	200
Min	1370	71	1431	32	650	13

Drinking Water Limit: TDS – 1000 mg/l and Chloride – 600 mg/l
Table 5/a, 5/b and 5/c shows the details of the water quality of these wells.

GW quality data are shown in the following tables:

Table 5/a: WellID: GQ7958108 Mathbaria UZ

DateTime	Temperature	pH	TDS	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3	Fe	Mn	B	Silica	As	Fluoride	Iodide	CO_2
25/12/1994		10.47	12010	23.6	9.03	3413	18.5	5250	180	338	1	9.2	1	0	5	5.6		0.49		
08/11/1997		7.70	1370	110.4	21.97	910		1400		389	21		1.7	0.2		13.6				32
27/07/1998		8.08		34.96	1.83	49.7	33.2	71.4		165	0.88				2	0.19	6		5.84	
11/12/1998		9.65		252	9.00	6175	18.5	9500	150	884	1.02	10		0.2	1	5.7		0.33		310
12/03/2000		9.60		254	9.00	6175	18.6	9500	152	890	1.02	10		0.2	1	5.8		0.33		320
04/01/2001	27.0	9.60	13000	254	9.00	6175	18360	9500	152	890	1.02	10	0.1	0.2	1	5.8		0.33		320
27/12/2004	27.2	9.60	13020	255	9.00	6175	18.6	10000	152	895	1.02	10	0.1	0.2	1	5.8		0.33		320
18/02/2010	30.7	9.20	7500	200	10.96	4063	14	6250	150	709	2	8.75	0.1	0.2	0	6		0.25		310.3

Table 5/b: WellID: GQ7958109 Mathbaria UZ

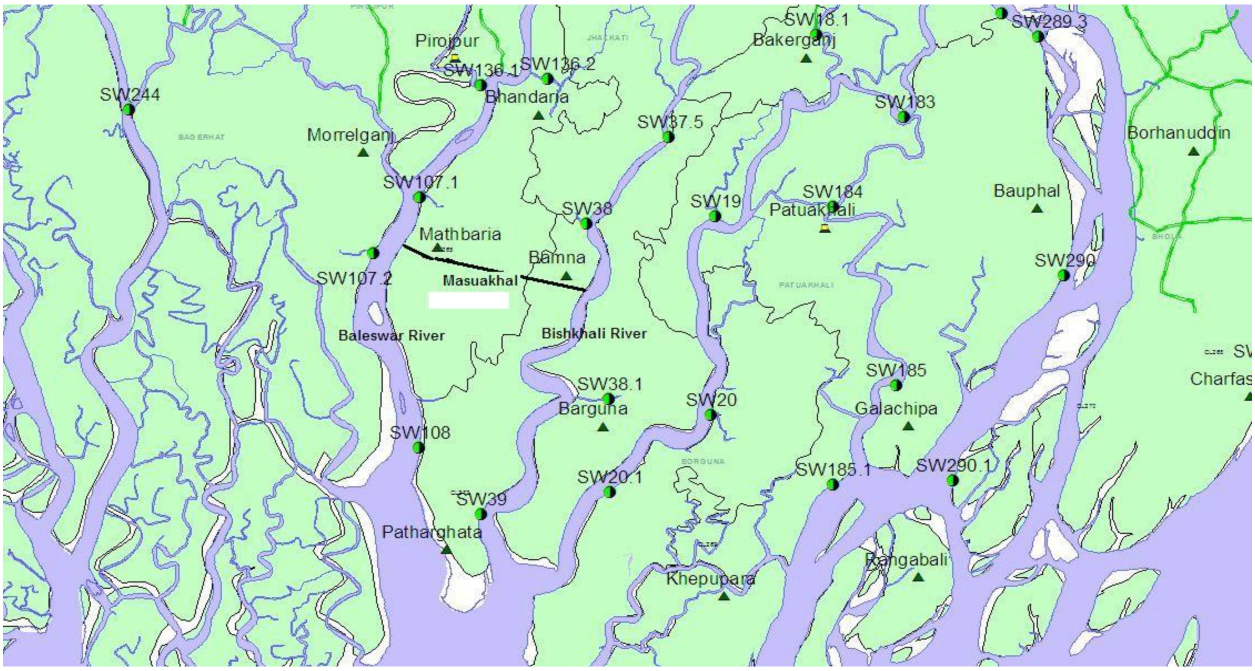
DateTime	T^oC	pH	TDS	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3	Fe	Mn	B	Silica	As	Fluoride	Iodide	CO_2
25/12/1994		9.2	12220	140.4	49.81	7410	32.5	11400	39	98	1	1.8	1.4	0.3	0	2.3		1.77		0
08/11/1997		8.0	1431	537.2	239.04	2080		32		158			1.8	0.1	1	4.3				17
27/07/1998		8.8		104.6	282.86	54.5	126	91.4	0	96.1	0.3	0.5	0.1	0	1	0.08	1	-0.01	2.72	
11/12/1998		9.0		92.0	50	5525	32	8500		624	1	1.9	0	0.1		2.3		0.36		226
12/03/2000		9.0		92.0	50	5525	32	8500		625	1	1.8	0	0.1		2.5		0.36		220
04/01/2001	27.0	9.1	14000	92.0	50	5525	32	8500	0	625	1	1.8	0.4	0.1	0	2.5		0.36		220
27/12/2004	27.2	9.1	14000	95.0	52	5530	32	8550	0	620	1	1.8	0.4	0.1	0	2.5		0.36		320
18/02/2010	30.2	8.9	12150	105.2	16.32	3705	15	5700	1500	452	1	2.75	0.1	0.1	0	3.25		0.35		240

Table 5/c: WellID: GQ7958110 Mathbaria UZ

DateTime	Temperature	pH	TDS	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3	Fe	Mn	B	Silica	As	Fluoride	Iodide	CO_2
01/07/1979		10	13574	210	262.9	4364		7801		135			2.4	0.1						4
01/07/1980		10	15226	50	292.8	5515		9350	54				0.7		15	2.3				
01/03/1981		8.5	2150	40	37.8	768		925		695		0.1	4.9			32.5				6
01/07/1981		8.5	2355	46	45.1	831		1050		702			4.4			32.7				15
01/03/1985		6.8	11120	98.8	127.38	4050		6759		35.9			4.7							149.2
01/03/1986			2284	34.5	19.74	853		894.6	105.8				4.7		1	22				
01/03/1993		7.94	3160	57.6	86.4	12.9		1860		534	41	1.5	0.8	0.1		1.44				38
08/11/1997		7.92	12080	36.4	14.4	8.45		13		108	1	8.8	0.1	0.1		1.2				109
11/12/1998		7.48		59.6	18.9	130	12	200		255	27	0.3	0	0.3		42		2.2		152
12/03/2000		7.5			19	130	12	200		255	27	0.3	0	0.3		44		2.2		150
25/12/1994		7.72	1040	54.8	18.8	83.4	11	137.5		508	28	0.3	0.8	0	2	41.9				56
27/07/1998		8.19		17.28	17.92	317	6.77	242		569	12.42	0.8	0.4	0.1	0	19.7	15	0.17	0.061	
04/01/2001	27.1	7.6	650	60	19	130	12	200		255	27	0.31		0.3		44		2.2		150
27/12/2004	27.2	7.6	655	62	19.5	132	12	220		260	27	0.31		0.3		44		2.2		150
18/02/2010	32.2	7.45	650	65.2	11.45	114	7.5	175		238	25	0.75	0.8	0.2		42		0.27		164

Decreasing trend of TDS and Chloride after 1997 is to be investigated. In this high rainfall zone, if embankment and regulators are operated properly and saline water from the river are not allowed into the polder, it is expected that groundwater salinity will gradually be leached out. But shrimp farming which needs allowing saline water inside the polder is a contradiction to this.

Exhibit 1: Existing Masua khal interconnecting Baleswar and Bishkhali rivers (22 km)



In Exhibit 1 – location of Baleswar and Bishkhali river along with Mothbaria and Bamna coastal town has been shown.

An approximate line drawn from Baleswar river to Bishkhali river shows the course of Masuakhal. The map also shows the river stations SW108 Chardoani, SW107.2 Rayenda and SW107.1 Tushkhali (presetly out of operation) and SW107 Patuakhali along Baleswar river where tide level and river salinity data are available. The river stations SW39 Patharghata, SW38.1 Barguna, SW38 Bamna along Bishkhali river have records of tide and salinity.

Figure 1: Salinity (EC) at SW107.2 Rayenda near offtake of Masuakhal.

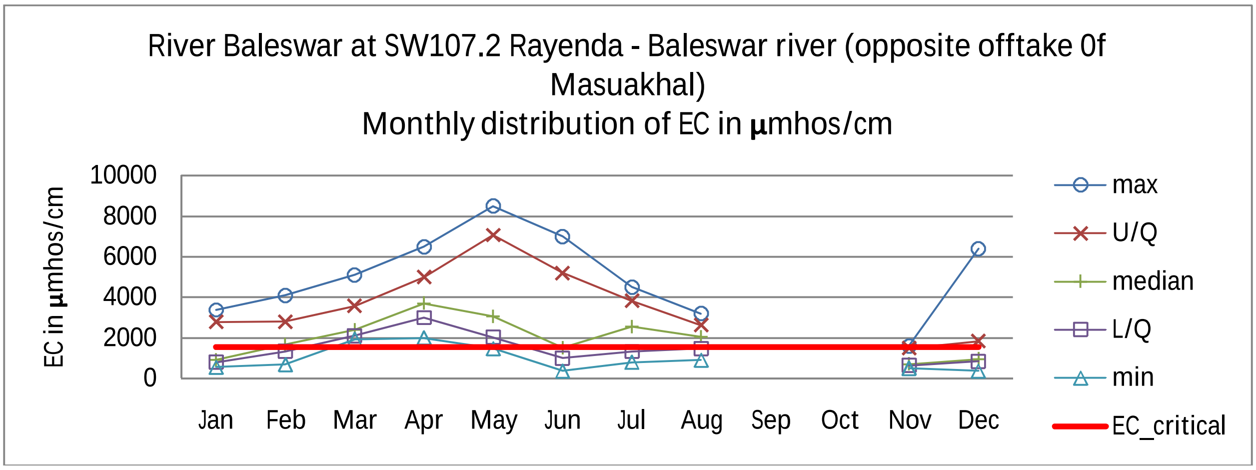
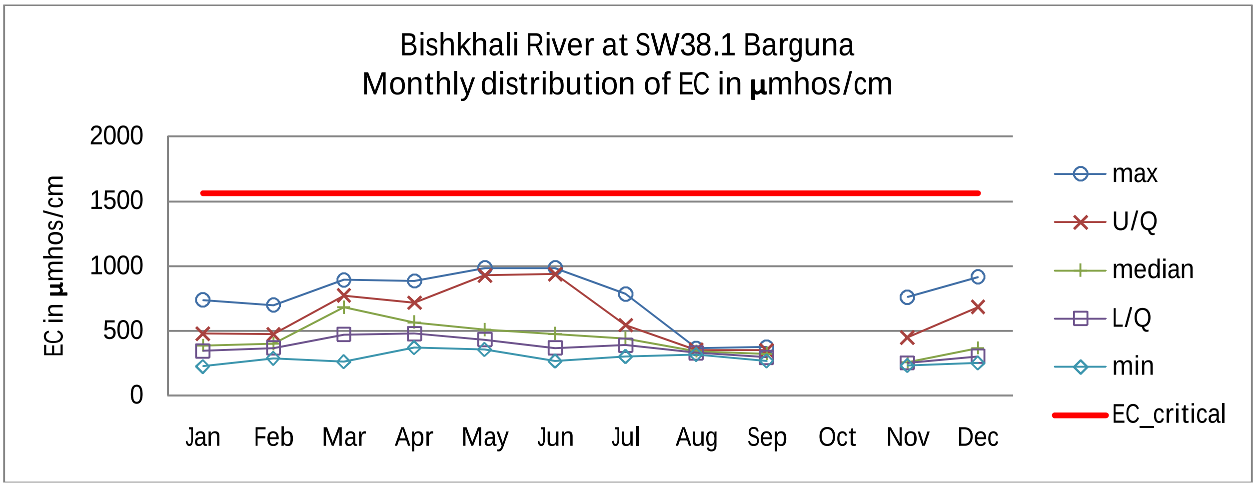


Figure 2: Salinity (EC) at SW38.1 Barguna 16 km downstream of outfall of Masuakhal.



It will be noticed that EC in the Baleswar river near offtake of Masuakhal is much above drinking water limit (red line: 1560 µmhos/c) almost throughout the year. In Bishkhali river however EC is well below drinking water limit throughout the year. Since the outfall of Masuakhal is about 16 km upstream EC values are likely to be further less than shown in Figure 2.

Figure 3: Salinity (Chloride) at SW107.2 Rayenda near offtake of Masuakhal.

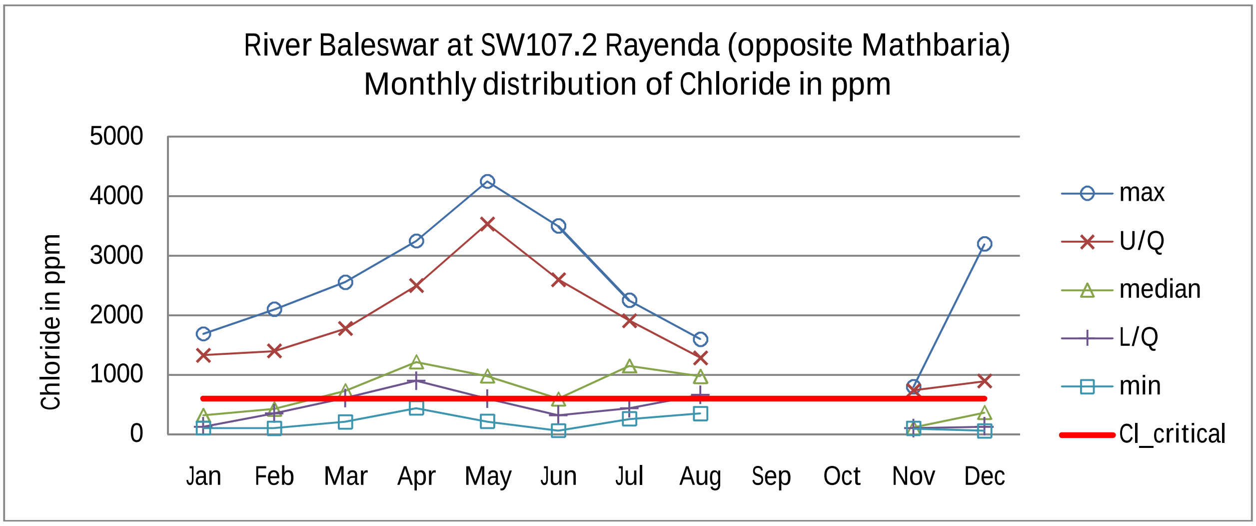
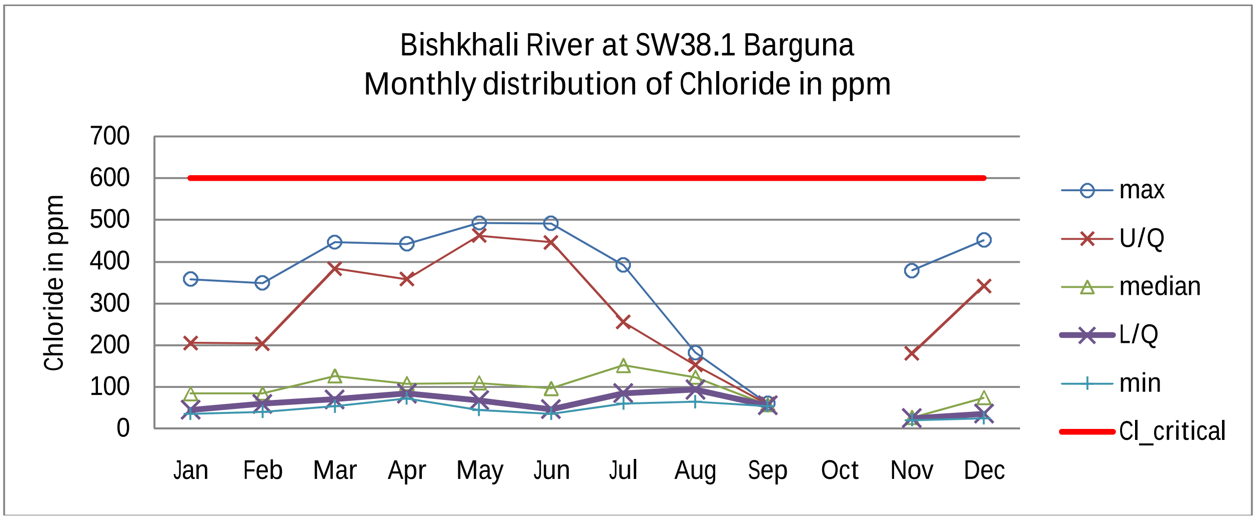
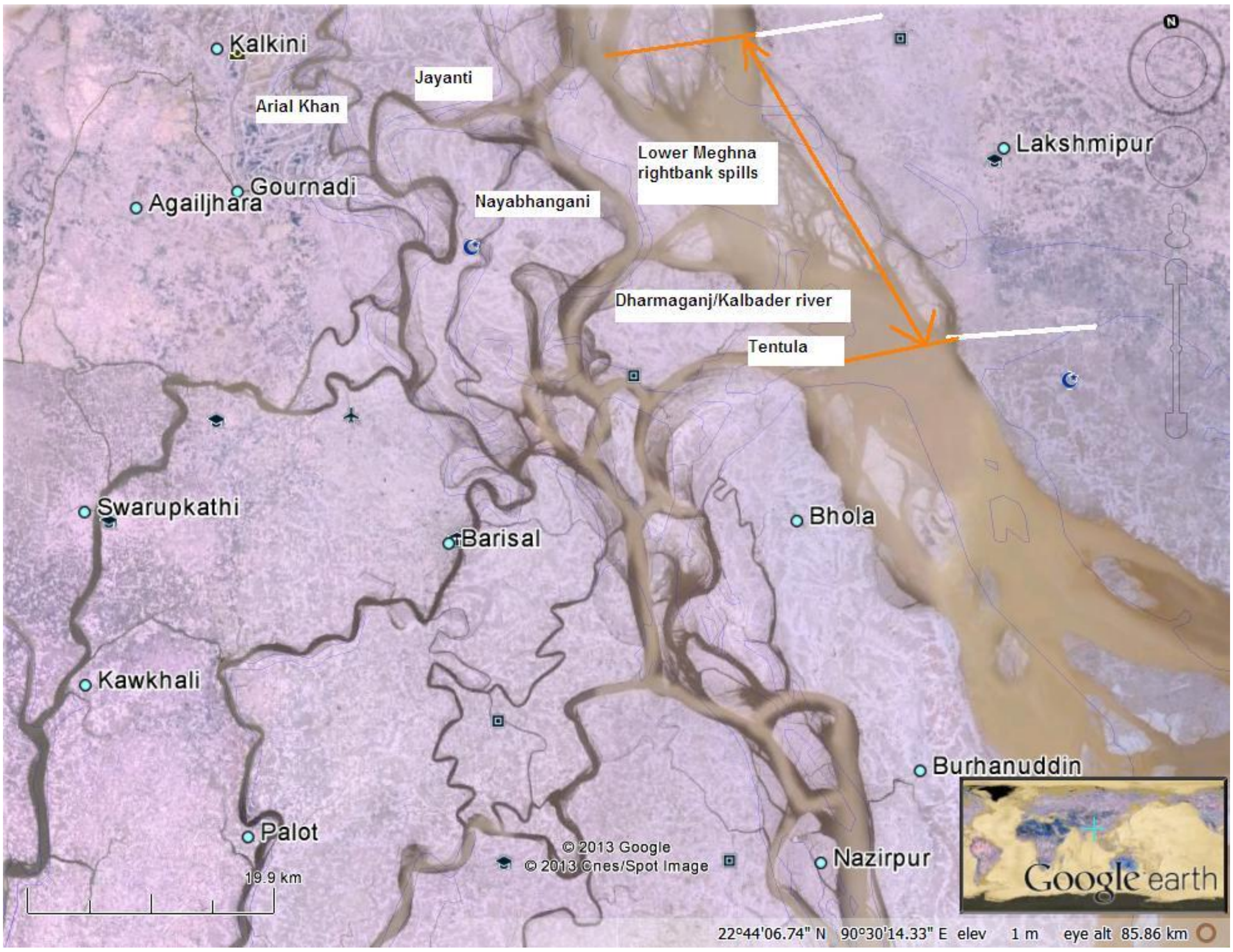


Figure 4: Salinity (Chloride) at SW38.1 Barguna 16 km downstream of outfall of Masuakhal.



From Baleswar river to Mothbaria town the Masuakhal is about 9 km and from Mothbaria town to Bishkhali river the khal is 12 km. Both EC and Chloride values in Baleswar river is above permissible limit of drinking water whereas in Bishakhali river it is within permissible limit round the year. So it seems Baleswar river seem to be a better source rather only river water source for the water supply of Mothbaria town (possibly including Bamna UZ town).

Annex A: Fresh water corridor of Padm-Meghna spill channels – Arial Khan river system



6. GROUNDWATER RESOURCE ASSESSMENT FOR COASTAL AREAS OF BANGLADESH

Note: The format from the original document has been slightly adjusted to fit with the main style of this volume.

Preparing the Coastal Towns Infrastructure Improvement Project

Groundwater Resource Assessment for Coastal Areas of Bangladesh

ADB – TA-8128 BAN (PPTA)

J F Punthakey and M A Matin

Photo Reference

- Deep hand tube well LGED Patuakhali (top left cover page)
- Amtali town, ponds (top right cover page)

Project Contact

Contact Person	Dr. Jay F. Punthakey	
Position	Director Groundwater & Environment	
Firm	Ecoseal Developments Pty Ltd	
Address	PO Box 496 Roseville NSW 2069, Australia	
Phone	+612 9880 8900	
Mobile	+614 1017 2300	
Fax	+612 9924 3580	
Email	eco@ecoseal.com	
Doc No.	Ecoseal CR: 2013-126	Date: 11 Jul 2013

ADB Contact

Submitted to:	Asian Development Bank
Project:	Preparing the Coastal Towns Infrastructure Improvement Project - Groundwater Resource Assessment for Coastal Areas of Bangladesh
Project Contact	Ron Slangen
Position	Urban Economist
Address	PO Box 789 Manila 0980, Philippines
Phone	+632 632 6270
Mobile	
Fax	+632 632
Email	rslangen@adb.org
Project Ref.	TA-8128 BAN (PPTA)

Acknowledgements

This Report is based on (a) site visit to Dhaka and coastal towns from 4 to 14 February 2013, and from 9 to 23 June and 28-30 June and (b) information provided by staff from the Asian Development Bank (ADB) and several Government of Bangladesh agencies, NGO's and development agencies.

The report draws extensively from studies of the groundwater resources of selected coastal towns in Bangladesh, and discussions with Ron Slangen, Project Director PPTA-8128, Abul Bashar PD for PPTA-8128 and the PPTA consultant team led by Roger Jackson and Zahangir Alam. We are grateful for the background briefing, extensive discussions and guidance provided by Ron Slangen of the ADB.

We acknowledge the assistance of S Tapu for GIS assistance and Toma Saha for assistance with data entry and analysis.

We are particularly grateful to the DPHE engineers that have shared groundwater data for the Barisal Division, and convey are thanks to the focal point of contact for DPHE Mr Bhuiyan, and A.K Ibrahim and Saifur Rahman for sharing knowledge and information with us.

Our sincere thanks for the assistance with obtaining data provided by Peter Ravenscroft (UNICEF), Zia u Haq (NGOF), Alok Majumder (Dutch Wash Allaiance), Abdus Salam (SLOPB, and (JICA). NGO's such as NGOF, SLOPB and others are playing a key role in providing communities with access to groundwater from deep tube wells.

Abbreviations

ADB	Asian Development Bank
APSU	Arsenic Policy Support Unit
bgl	below ground level
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CDTA	Capacity Development Technical Assistance
DPHE	Department of Public Health and Engineering
EC	Electrical conductivity (µS/cm)
GBM	Ganges, Brahmaputra and Meghna
GOB	Government of Bangladesh
IUCN	International Union for Conservation of Nature
IWM	Institute of Water Modelling
MAR	Managed Aquifer Recharge
MASL	Metres Above Sea Level
MSL	Mean Sea Level
NGOF	
PPTA	Project/Program Preparatory Technical Assistance
PTW	Public Tube Wells
SLOPB	

Table of Contents

TA-8128 BAN (PPTA):

Preparing the Coastal Towns Infrastructure Improvement Project

Groundwater Resource Assessment for Coastal Areas of Bangladesh

1. Introduction

1. The low-lying coastal region of Bangladesh supports the livelihoods of over 38.5 million people. Communities in coastal towns are particularly vulnerable to climate related events and increased salinity of rivers as sea levels rise. Much of the area is subjected to annual cyclones that result in flooding. Moreover storm surges, erosion, waterlogging, salinity and an increasing population make the coastal zone and its inhabitants particularly vulnerable.

2. The coastal areas also offer opportunities for reducing poverty and contributing towards the development goals of the Government of Bangladesh (GOB). The coastal zone has significant agricultural production (rice and other crops) and natural resources including fisheries, shrimp farms and related infrastructure to support these industries. In the western part of the coastal zone lies the Sunderbans – an extensive area of mangrove forests and wildlife that provide essential ecosystem support services.

3. The projected impacts of climate change will increase the vulnerability of the coastal zone, causing people to migrate inland due to the loss of coastal land to sea level rise. Fig 1.1 shows the extent of salinity intrusion for the baseline and for sea level rise of 0.32 m and 0.88 m. For instance a 0.88 m sea level rise is projected to impact coastal areas as far as Patuakhali and Bhola.

4. Sea-level rise may also alter the salinity of groundwater and surface water resources, increasing soil salinity in farm land. Saline intrusion along the main river channels is at its maximum in the dry season when flows are low and at a minimum during the monsoon season.

5. Cyclones and associated storm surges are also predicted to increase in severity and frequency in the coastal zone of Bangladesh which would have a significant impact on water supplies, coastal lands and its inhabitants with increased severity of impacts on the poor.

6. The Coastal Towns Infrastructure Improvement Project will provide climate-resilient municipal infrastructure in coastal towns of Bangladesh with key investments in water supply, sanitation, drainage, urban roads and bridges, solid waste management, slum improvements, and transport facilities.

7. The GOB has determined that the most damaging effects of climate change are flooding, salinity intrusion and drought. The challenges induced by climate change include scarcity of freshwater; drainage congestion; riverbank erosion; and wider salinity in surface water, groundwater, and soil. Salinity intrusion into water

supplies is a major concern in coastal areas as climate change impacts are likely to put water sources at greater risk.

8. Recent studies have shown that in coastal areas, surface water sources are at risk from the projected impacts of climate change. It is not clear how climate change will impact deep groundwater resources that currently supply many coastal communities with safe potable water. The water from deep aquifers is arsenic-safe, making this a valuable resource for coastal communities, and providing water security particularly in the dry season. Furthermore, deep aquifers are not affected by increased salinity as is the case with surface water sources in coastal regions which experience saline intrusion along the main river channels during low flow conditions.

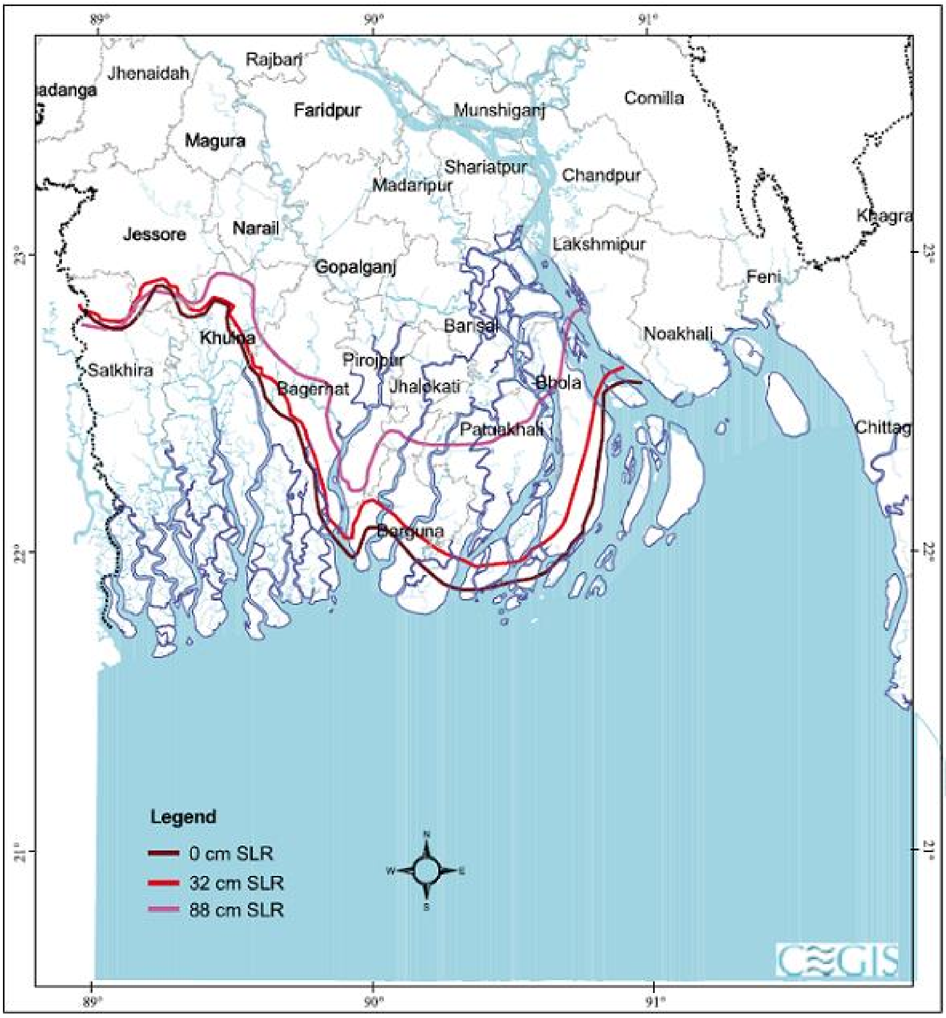


Fig 1.1 Likely salinity ingress in Southern Bangladesh due to different SLR.
Source: CEGIS Dhaka.

2. Objectives of the Groundwater Study for Coastal Towns

9. The overall objective of the Groundwater Study is to advise ADB and GOB on sustainable sources of groundwater to be developed under the planned project considering water quality (salinity) under various climate scenarios and projected increases in population. The specific objectives include:

i. To assess the groundwater resource potential of future abstraction of groundwater in the vicinity of project towns with attention to salinity by mapping the groundwater potential and salinity for Barisal Division.

ii. To undertake the development of a coupled flow and transport cross-section model of the deep groundwater system through Amtali to estimate the relative impact of increased groundwater demand, salinity intrusion, and impact of sea level rise on fresh groundwater in deep aquifers. To assess the overall sustainability of the system to meet the projected demand till 2040.

iii. To prepare a framework to monitor and manage groundwater resources in coastal areas so that the future risks of groundwater extraction from deep aquifers can be assessed.

3. Groundwater Resources for Coastal Towns

10. In coastal towns in Barisal Division groundwater plays a significant role in supplying potable water for coastal communities and several thousand individual households have deep hand tube wells or access to deep hand tube wells for potable water needs.

11. Groundwater levels of the shallow aquifers are in close proximity to the surface and fluctuate with annual recharge and discharge conditions. Water level rises during the monsoon and decline during the dry season and in some areas are influenced by groundwater pumping. Since the realisation of arsenic in the shallow groundwater in Bangladesh in the early 1990s, there has been increased development of the deep aquifer for water supply and irrigation which generally has very low levels of arsenic (<0.01 mg/l) which is below the Bangladesh standard of 0.05 mg/l.

12. The shallow aquifer is separated from a deeper freshwater aquifer by a clay layer which is regionally extensive but varies considerably in thickness. Generally the shallow aquifer lies within 150 m from the surface. Little is known about the water level response of the deep aquifers in the coastal area in the CTIIP area of interest. Limited data show that the deeper aquifer water levels also fluctuate annually similar to the shallow groundwater.

13. Morton and Khan (1979) describe the deep aquifer from Barisal and Patuakhali districts which occurs at depths ranging from 238 to 328 m with an average thickness of 32m consisting of several hydraulically interconnected stratigraphic horizons. They also report that the deep aquifer is overlain and protected from vertical intrusion of saline water by a 65 to 165 m thick clay layer. More recent drilling has shown that the deep aquifer in the coastal zone south of Pirojpur extends to a depth of 380 m. However, it should be noted that it is unlikely that the bores have drilled down to the base of the deep aquifer as the driller stops when a good source of freshwater has been reached.

14. In recent years there have been several bores drilled into the deep aquifer. Of these the work by Danida and the Department of Public Health and Engineering (DPHE) which is most relevant to this study covers 9 Pourashavas in 5 districts in the coastal zone Patuakhali, Barguna, Noakhali, Lakshmipur, and Feni. The study included geophysical surveys, drilling, installation of tubewells and water quality analyses. The exploration program located deep groundwater resources below sequences of aquifer layers containing saline or brackish water. Freshwater was found to occur in a single thick aquifer or a sequence of sand lenses separated by clay and silt layers. This study and especially the borelogs and water quality analyses collected in this study is a valuable resource in understanding the groundwater resources in the deep aquifer in the coastal areas. Future studies should make the necessary formal agreements to get access to the data from these studies.

15. A hydrostratigraphic model of the Barisal-Patuakhali region is shown in Figure 3.1. It shows that the region is characterized by the occurrence of distinct deep and shallow aquifers separated by a thick aquitard. The aquitard occurs all over the region at around 150 m and has a thickness of 10 to 50 m over most of the region, with some areas where the thickness is more than 50 m.

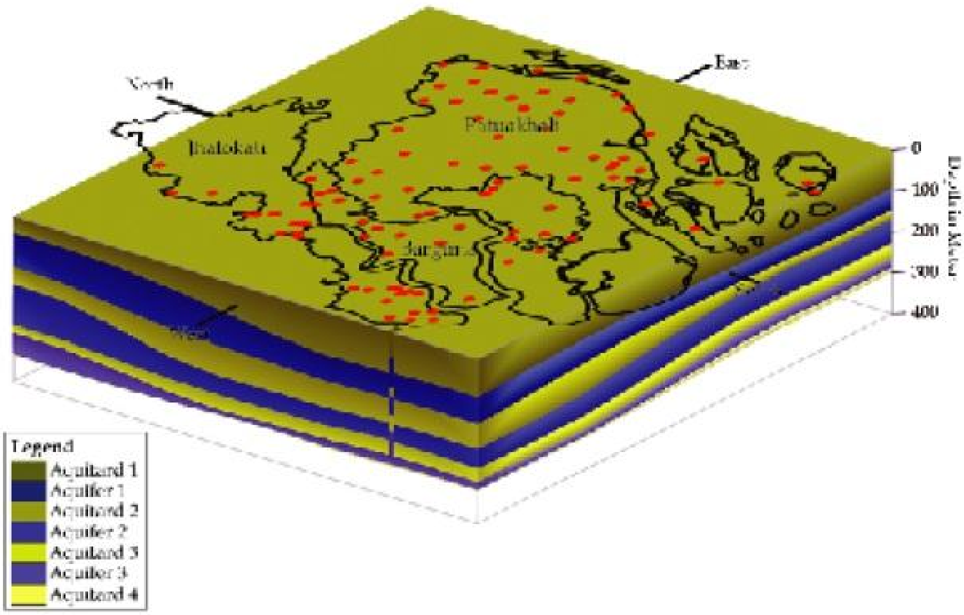


Fig 3.1 Hydrostratigraphic model of the Barisal-Pautakhali region.
Source: JICA.

16. An on-going study that may be useful for the PDA and future projects in coastal areas is the Establishment of Monitoring Network and Mathematical Model Study to Assess Salinity Intrusion in Groundwater in the Coastal Area of Bangladesh due to Climate Change. The Bangladesh Water Development Board (BWDB) has commissioned the Institute of Water Modelling (IWM) to undertake this study. This study does not cover all of the areas covered by the four Capacity Development Technical Assistance (CDTA) towns, however, the model covers two small regions: (1) an area stretching from south of Patuakhali to Galachipa which may provide some useful information on groundwater extraction in the area and a sustainable yield from the modelled zone; and (2) the area west of Amtali. Additionally a program of groundwater and salinity monitoring has also been undertaken which would provide useful data for future studies.

17. There are several other studies and data sources such as the data on 100 deep bore logs held by BWDB which would also provide useful information for assessing groundwater resources.

18. Basic information for the three coastal towns covered in the Project/Program Preparatory Technical Assistance (PPTA) is listed below in Table 3.1. Of these Amtali and Galchipa are dependent on groundwater for potable supplies.

Table 3.1 Basic Information of the Three Project Townships (Pourashavas)[1]

District	Pourashavas	Area (km^2)	Population	Main Drinking Water Source
Barguna[1]	Amtali	8.92	17,311	Groundwater
Patuakhali[1]	Galachipa	3.39	21,200	Groundwater
Pirojpur[1]	Pirojpur	29.50	60,056	River
Patuakhali[2]	Patuakhali	26.00	80,000	Groundwater
Pirojpur[2]	Mathbharia	15.92	16,573	River

[1] *Source: CDTA-7890 Draft Final Report.*
[2] *Source:* http://www.patpou.net/; http://www.citypopulation.de/Bangladesh-Mun.html, http://www.lged.gov.bd/DistrictHome.aspx?districtID=3

3.1 Benefits of the Groundwater Study for Coastal Towns

19. Understanding the impact of increased groundwater withdrawals as the population increases and the impact of sea level rise will allow for improved understanding of the sustainability of the system. The key outcome indicator for incorporating climate-resilient designs is compliance with government and/or WHO salinity standards for drinking water.

20. Water level and water quality monitoring of a consistent set of deep tubewells is recommended. The framework to monitor and manage groundwater resources will provide the basis for improving groundwater management and for assessing future risks of increased abstraction. A second key outcome will be improved capacity to monitor groundwater resources, and will build capacity for improved groundwater governance at the Pourashava level. Monitoring will also provide information on a key indicator that drinking water standards are complied with.

21. Observation and monitoring and careful use of this information to guide management of deep fresh groundwater aquifers in the coastal zone is essential and recommended to be undertaken at the Pourashava level. This in turn will require capacity building and training in groundwater monitoring and assessment at the Pourashava level.

22. Water supply to coastal towns is mainly from groundwater sources drawn from deep and shallow tube wells. To meet increasing demand, local government bodies plan to build or expand water supply facilities. Thus, water supply facilities should include strengthened resilience to climate change. New water supply wells should be located where there is the likelihood of obtaining safe potable supplies and the design should give consideration to flooding so that the well head is above the expected flood levels to ensure that access to potable water during flooding is maintained.

4. Seawater Intrusion and Upconing

23. During recent decades there has been worldwide increase in urbanisation. Many major population centres are situated on or near a coast, and increasingly rely on coastal aquifers for water supply. Saline water has been reported to be the most common pollutant in fresh groundwater. Todd (1980) indicated that as little as 2 percent seawater in freshwater can render the water unpotable. The problem of saline intrusion and upconing requires the careful and specific management of coastal aquifers to ensure their long term viability and sustainability.

24. Saline intrusion occurs when modern seawater displaces, or mixes with, freshwater within an aquifer in response to a change in the hydrogeological environment. Saline water may be derived from many sources:

- seawater intrusion into an aquifer;
- upconing of ancient seawater (connate water);
- water concentrated by evaporation; or
- in situ mineralisation.

25. In coastal aquifers excess pumping may reduce groundwater seaward gradients, which reduces outflow of freshwater towards the sea and which may result in denser saline water displacing the fresh water within the aquifer. The increased use of groundwater from coastal aquifers along the eastern seaboard of Australia has increased the potential for saline intrusion by modern sea water encroaching into the aquifer along the coast and by localised upconing due to over-abstraction. Improved monitoring and management of coastal aquifers in Australia is being undertaken in order to minimise adverse impacts.

4.1 Causes and control of seawater intrusion

26. In coastal aquifer there is an interface between freshwater which has a relative density of 1 and seawater which has a relative density of 1.025. This difference in density results in the seawater lying beneath the freshwater on the landward side of the coastline. In practice the fresh and saline waters are miscible which results in a mixing zone, however, the thickness of this zone depends on hydrodynamics of the aquifer. The shape of the interface will generally be similar to that shown in Figure 4.1 with a steep slope in the shallowest part of the aquifer grading to a gentler slope at depth. This change of slope may create a "toe" of salt water extending into the aquifer beneath the salt water. As discussed below, the interface is likely to be more or less diffuse depending on prevailing conditions. The position, shape and sharpness of the interface depend on the degree of balance between the head conditions in the aquifer and the sea level and the flow conditions that prevail. The extent of the toe into the aquifer beneath the fresh water will depend in part on the depth to the base of the aquifer. In a very shallow aquifer there may be essentially no toe, and the steep part of the interface will extend to the base of the aquifer.

27. Groundwater discharge to the sea from the aquifer occurs adjacent to the salt water interface, on the landward side, as the groundwater head in the aquifer overcomes the salt water head of the sea and moves fresh water up to the surface along the interface. This phenomenon is clearly visible along the beaches of the study area, at low tide, when drainage of water from the aquifer discharges in a linear zone along the higher side of the beach.

28. The balance that sustains the position and shape of the salt water interface can be upset by a change of conditions in the aquifer, such as by pumping. If pumping lowers the head in the aquifer, the seaward gradient will be lowered, there will be a reduction in fresh water flow towards the sea, and there will be a tendency for the interface to move in a landward direction. In other words, there will be seawater intrusion into the aquifer.

29. If the aquifer is sufficiently deep to allow a toe of salt water to extend into it, reduced heads in the aquifer consequent upon pumping may induce a landward shift of the toe, and continued pumping may induce upconing of salt water from it into the productive part of the aquifer.

30. Seawater intrusion is caused primarily by the reduction of head in the dunal aquifer, and the subsequent reduction of fresh water discharge to the sea as a result of groundwater abstraction. This discharge of freshwater is derived from one of three sources: drainage from the water table; release from elastic storage; and drainage at the seawater/freshwater interface (Essaid, 1986). Reduction in freshwater discharge to the coastal boundary will result in the salt water wedge moving inland as flushing with fresh water decreases, and the thickness of the wedge increases. If a reasonable quantity of fresh water flow is maintained at the coast, a new equilibrium eventually develops.

31. Groundwater abstraction above a freshwater/saltwater interface causes upconing. Depending on aquifer characteristics, well penetration, and pumping rate, a stable situation may be attained, where salt water does not reach the well. However, when this critical state is exceeded, salt water enters the well, mixes with the fresh water, and the quality of the discharge decreases.

32. Abstraction is not the only control on the position of the saline water/fresh water interface. A number of other factors can affect its position including:

- seasonal changes in natural groundwater flow;
- tidal effects;
- barometric pressure;
- dispersion; and
- climate change – global warming and associated sea level rise.

33. Some of these have short term implications (tidal effects and barometric pressure) some are periodic (seasonal changes in groundwater flow) and others are long term (climate change and artificial influences).

34. Climate change resulting in a rise in global mean sea levels is likely to threaten vulnerable coastal aquifers. The impacts of sea level rise will be felt first in low lying coastal areas and deltaic zones where land elevations are within a few metres above or below sea level. The impacts will include increased saltwater intrusion into coastal aquifers, and a further shift inland of the mixing zone between freshwater and seawater. This could also threaten many groundwater wells in coastal regions resulting in higher risk of upconing of saline groundwater resulting in decreased water quality from these wells.

35. Control of saline intrusion requires understanding of the hydraulic conditions within the aquifer; it also requires knowledge of the source of the saline water. It is therefore necessary to identify the extent of the problem, and to assess the behaviour of the saline water body under various conditions of recharge and discharge, so that efficient water resources management can be implemented.

36. The optimum solution to the problem of saline intrusion is prevention, with aquifer management being such that the encroachment of sea water is prevented or controlled to an acceptable degree.

37. The problems of saline intrusion cannot be ignored. The implications in terms of public water supply include the possible reduction of groundwater abstraction, abandonment of fresh water sources and possible need for desalination in order to provide potable water.

38. The location of the sea water/freshwater interface is important to groundwater management in coastal regions. The exact locations of the freshwater/saline water interface and the transitional zone are difficult to determine, either theoretically or by field-testing. There are many approaches to delineating the depth to, and extent of, a saline water body. Water salinity has been defined by Hem (1970) in terms of the Total Dissolved Solids (TDS) content. His classification is shown in Table 4.1.

Table 4.1 Degree of salinity after Hem (1970)

Description	**TDS (mg/l)**
Fresh	< 1000
Slightly saline	1000 - 3000
Moderately saline	3000 - 10000
Very saline	10000 - 35000
Brine	> 35000

39. When water bodies with differing salinities are in contact, molecular diffusion causes mixing across the line of contact. The effects of diffusion are exacerbated when groundwater and seawater are in motion, and the intergranular structure of the formation causes dispersion and the development of a transition zone due to groundwater and saline water movement. External influences such as tides, recharge events and pumping will cause movement of the interface and encourage mixing, thus increasing the interface thickness. Thus the processes of diffusion and dispersion result in a transition zone where the salinity gradually changes from completely fresh to fully saline, the thickness of the zone depending on these two components.

4.2 Modelling seawater intrusion

40. Modelling can provide a useful tool to predict the likely extent of saline intrusion. A wide spectrum of models has been developed over recent years. Saline intrusion problems are intrinsically complex due to the number of interacting phenomena. It is therefore difficult to acquire the detailed understanding needed to effectively manage such situations. Several quite common real-world occurrences do not lend themselves to conventional analytical techniques. Numerical models are therefore valuable tools for quantifying the hydraulic parameters and testing conceptual models of the aquifer system.

41. As with most modelling exercises, saline intrusion models incorporate some simplifying assumptions and approximations. These may affect the accuracy of the results but such simplifications are often necessary because of limitations in the available field data for the system. To be useful, the numerical model must be based on an adequate conceptual model that incorporates all the mechanisms relevant to the situation under study.

42. The dominant mechanism of saline intrusion is mass transport: the salt in solution is carried with the water by advection. In addition to the normal flow equations, saline intrusion models usually take account of the effects of density variations within the groundwater due to the mass of salt in solution. These introduce vertical flow to the system and lead to stratification in the eventual salinity distribution. This is important because a number of common conceptual models assume groundwater flow is entirely horizontal. The transport is often regarded as conservative though at a higher level of sophistication solute production or decay and chemical evolution can be included. The principle distinction between classes of saline intrusion model lies in their treatment of the interface between the separate bodies of water within the aquifer. As described earlier, saline and fresh water are miscible, and mixing occurs at the interface due to molecular diffusion and mechanical dispersion. The parameters that control diffusion and dispersion are difficult to quantify directly and in any case the width of the transition zone is often small compared to the dimensions of the saline water body. Consequently many models have included a sharp interface approximation, with the advance of one water body completely displacing the other body by piston flow.

43. The vertical flow components mentioned above mean that saline intrusion problems are fully three-dimensional. However, some line of symmetry can often be deduced (eg. perpendicular to a straight coastline) so that vertical strip, 2D models can provide a useful insight to the situation while minimising the computational complexity. Horizontal 2D models imply a vertical interface which can be misleading: wells that appear safely on the fresh side of the interface might be at risk of degradation by upconing at the toe of the intruding wedge.

4.3 Seawater intrusion impacts on coastal aquifers

44. The general pattern of fresh ground-water flow in coastal aquifers is from areas where ground-water levels (hydraulic heads) are high towards coastal discharge areas where ground-water levels are, by definition, at the lowest elevation in the groundwater system. Fresh ground water comes in contact with saline ground water at the seaward margins of coastal aquifers. The seaward limit of freshwater in a particular aquifer is controlled by groundwater head in the aquifer (which controls the amount of freshwater flowing through the aquifer), the thickness and hydraulic properties of the aquifer and adjacent confining units, the relative densities of saltwater and freshwater, and by other less obvious variables. Because of its lower density, freshwater tends to remain above the saline (saltwater) zones of the aquifer, although in multilayered aquifer systems, seaward-flowing freshwater can discharge upward through confining units into overlying saltwater. Seawater has a total dissolved-solids concentration of about 35,000 mg/L, of which dissolved chloride is the largest component (about 19,000 mg/L) and its density is about 1,025 kg/m^3.

45. The freshwater and saltwater zones within coastal aquifers are separated by a transition zone (also referred to as the zone of dispersion) within which there is mixing between freshwater and saltwater (Figure 4.1). The transition zone can be identified by measurements of either the total dissolved-solids concentration, the electrical conductivity (EC) or the chloride concentration of ground water sampled at observation wells. Although there are no standard practices for defining the transition zone, a change of concentration of total dissolved solids from about 1,000 to about 35,000 mg/L, or a change in electrical conductivity (EC) from 1500 to 55000 µS/cm, or a change in chloride concentration from about 250 to 19,000 mg/L are common indicators of the zone.

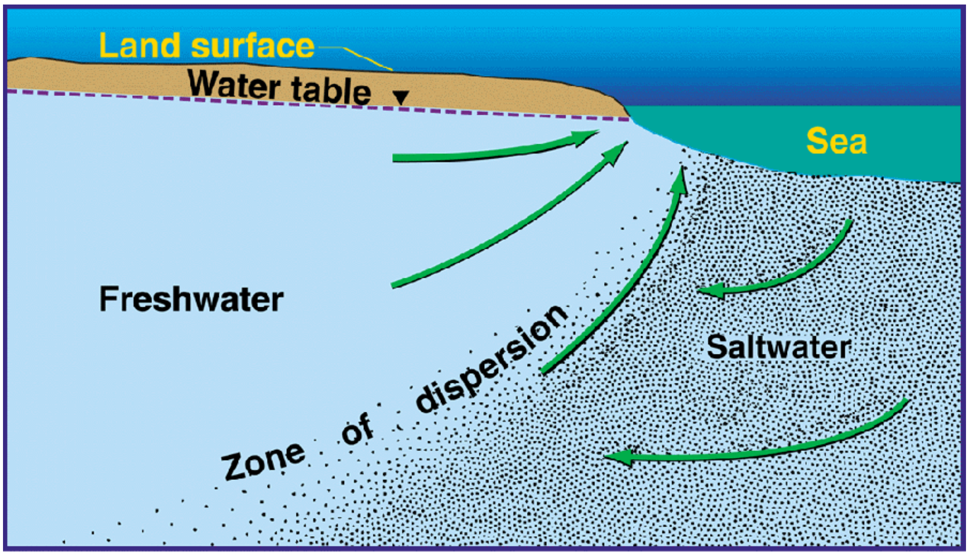


Fig 4.1 Freshwater and saltwater zones within coastal aquifers separated by a transition zone. *Source: water.usgs.gov.*

46. Within the transition zone, freshwater flowing to the ocean mixes with saltwater by the processes of dispersion and molecular diffusion. Mixing by dispersion is caused by spatial variations (heterogeneities) in the geologic structure and the hydraulic properties of an aquifer and by dynamic forces that operate over a range of time scales, including daily fluctuations in tide stages, seasonal and annual variations in ground-water recharge rates, and long-term changes in sea-level position. These dynamic forces cause the freshwater and saltwater zones to move seaward at times and landward at times. Because of the mixing of freshwater and saltwater within the transition zone, a circulation of saltwater is established in which some of the saltwater is entrained within the overlying freshwater and returned to the sea, which in turn causes additional saltwater to move landward toward the transition zone.

5. Groundwater Resource Potential of Deep Aquifers for Barisal Division

5.1 Groundwater resource potential

47. The map in Fig 5.1 shows the groundwater resource potential for the upper deep aquifer. This is the upper deep aquifer defined approximately from 150 to 320 m. A total of 203 borelogs were evaluated to determine the thickness of this aquifer. In several borelogs this aquifer is layered comprising of a sequence of sand layers with inter-bedded clay and silty clay layers. The hydraulic conductivity of the sand layers was estimated at 5 m/d and for the clay layers at 0.2 m/d. The estimation of transmissivity was calculated based on the thickness for various layers comprising the upper deep aquifer.

48. Fig 5.1 shows the higher potential for groundwater in areas of high transmissivity shown in blue and dark blue shades. The areas with high probability of encountering groundwater cover the area south of Barguna and extend up towards Betagi. Other areas with reasonable groundwater potential extend from southwest of Dashmina towards Bauphal and east of Bakergang. There are also isolated pockets which show good groundwater potential near Amtali, and southwest and northwest of Patuakhali. Suprisingly there is also an isolated pocket of high groundwater potential north of Mathbharia in the Daudkhali and Dhanisafa Unions.

49. The areas surrounding Amtali and Galachipa show moderate potential, however, this is due to very few bores in the Galachipa area available for this analysis. We know from the two bores operating in Galachipa town that there is reasonably good potential from the lower deep aquifer. The map shown in Fig 5.1 reflects the groundwater potential in the upper deep aquifer.

50. Areas of lower groundwater potential are shown in pink and yellow shades. These areas extend from Patharghata in a north-northwest direction to Mathbharia, Pirojpur, Nazipur and west of Nazirpur. There are also pockets of low groundwater potential around Barisal Sadar, Mehendiganj, Lalmohan and southeast of Amtali as shown by bores 16 and 17 in Fig 5.1).

51. Mapping based on lithology has some limitations that need to be considered while interpreting this map. The major limitations are that although the map gives an indication of groundwater potential it does not account for water quality. Thus the results should be interpreted in conjunction with the chloride map presented in Fig 5.3. A second limitation is that results will be more reliable in areas where there is a higher density of bores. Thus areas around Pirojpur Sadar have very few bores thus results there should be interpreted with caution. It is however clear that the upper deep aquifer is not uniform and has thick sequence of clays in some areas which result in reduced groundwater potential.

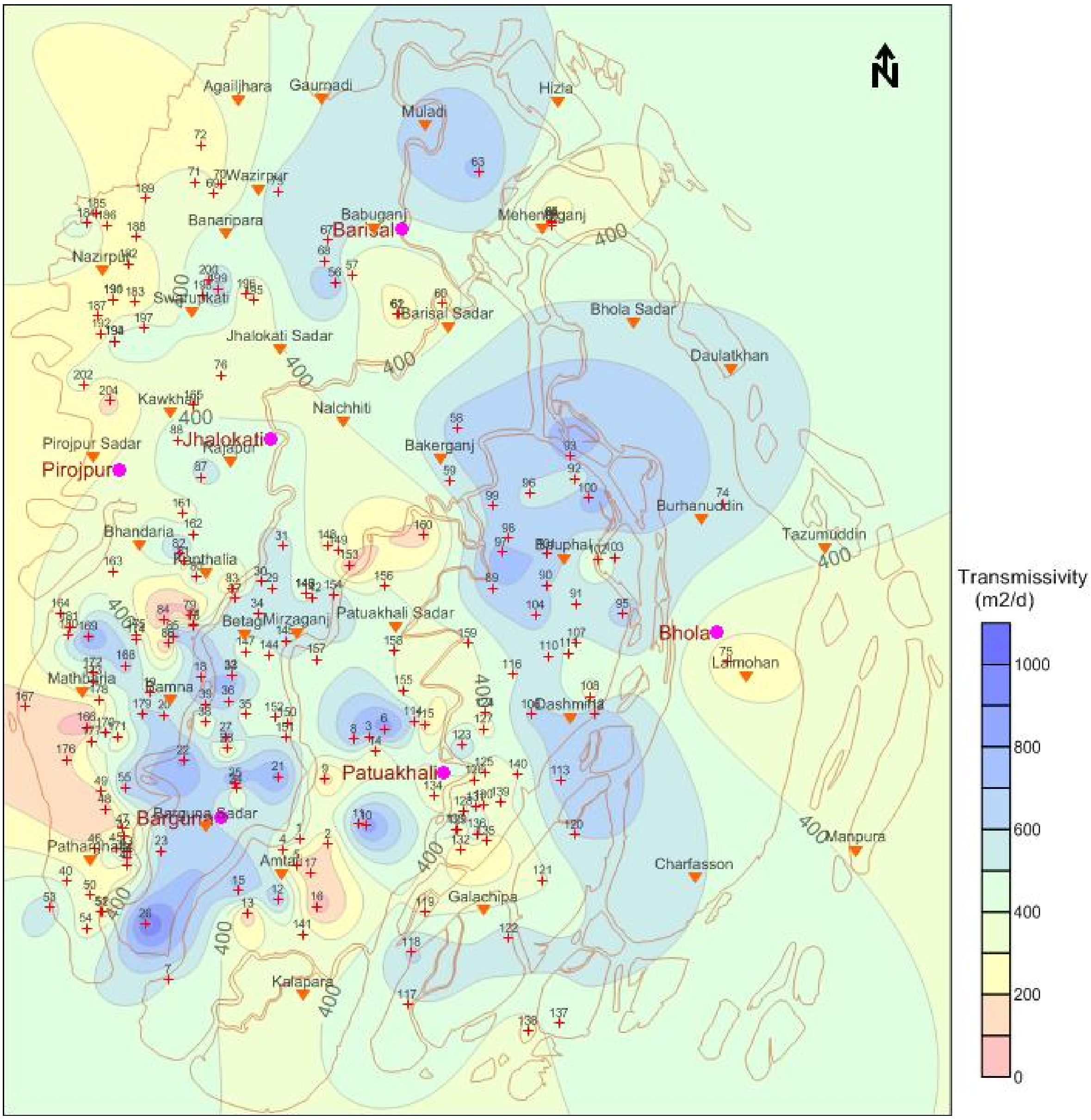


Fig 5.1 Groundwater resource potential of the upper deep aquifer, transmissivity (m^2/d).

52. It should be noted that the map in Fig 5.1 focuses on the upper deep aquifer. There is also a lower deep aquifer in the coastal zone which extends approximately from 320 m to 390 m as evidenced by the deep bores at Amtali and Galachpa used for public water supply. Unfortunately there is not enough lithological information for this aquifer. Of the 203 bore logs in Barisal Division (DPHE-JICA 2010), less than 30 bores have lithological information of the lower deep aquifer, thus a map of the lower deep aquifer would have low reliability. In addition to this most of the 30 bores do not fully penetrate the lower deep aquifer as such the calculation of groundwater resource potential is more than likely underestimated using this approach. Nevertheless Fig 5.2 shows the areas of low and high groundwater resource potential from the lower deep aquifer.

53. Fig 5.2 shows specific locations where deep bores have penetrated the lower deep aquifer. Despite the fact that most of these bores have only partially penetrated the deep aquifer the areas of known high resource potential are shown by blue circles. These are typically aquifers with transmissivities greater than 300 m^2/d. some of

these may well have higher transmissivities as the aquifer may be much deeper than penetrated by the bore.

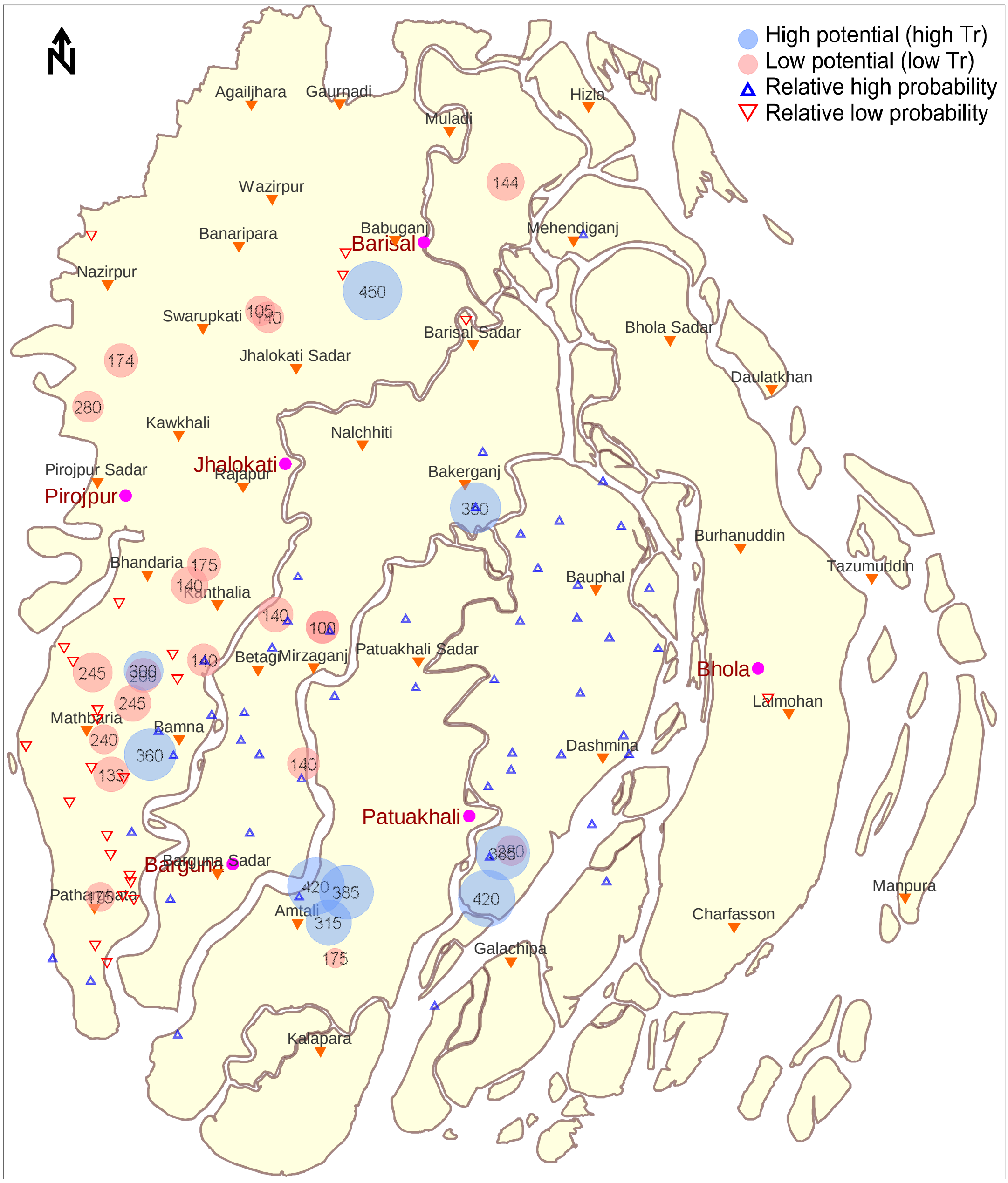


Fig 5.2 Groundwater resource potential of the lower deep aquifer, transmissivity (m^2/d).

54. The areas with good groundwater resource potential for the lower deep aquifer are around Amtali, Galachipa, Bakerganj, northwest of Barisal Sadar, south west of Banma which is just southeast of Mathbharia.

55. The areas where the deep aquifer shows lower groundwater potential are areas north and south of Mathbharia, between Bhandaria and Mirzaganj and other isolated pockets. We emphasise that the lower resource potential of the deep aquifer is limited by the depth of penetration which results in a reduced aquifer thickness and consequently a lower transmissivity. We would recommend a deep drilling program to at least 390 m bgl similar to the Amtali bores in order to

determine the resource potential of the lower deep aquifer, particularly in the vicinity of Mathbharia where there is an acute need for water supply.

56. Fig 5.2 also shows a qualitative assessment of relative high and low probability of encountering high yielding wells. The qualitative assessment is made by identifying those bores where sand layers have been encountered in the bottom of the hole typically at depths greater than 280 m. The relative low probability locations have been identified where deep bores have encountered thick clay sequences at depths greater than 300 m. Although a subjective assessment it is nevertheless useful in identifying possible locations where the aquifer yield is high, and conversely where the aquifer yield is likely to be low, and interestingly are similar to the upper deep aquifer.

57. It would also be noteworthy to check the salinity levels in the existing nearby wells before commencing drilling. Simply put the aquifer yields may be good but if the salinity is over 1000 mg/l it is not useable for potable supplies.

58. Although these maps cannot definitively point to a location of good groundwater potential it nevertheless gives a good visual representation where there would be increased probability of finding high yielding aquifers. Another good use of these maps may be to guide drilling programs in so far as to identify areas to avoid drilling. These are typically characterised by low transmissivity and low probability of finding suitable high yielding aquifers.

5.2 Depth to groundwater for Barisal Division

59. Depth to groundwater maps were constructed from data supplied by DPHE for 196 deep tube wells and are shown in Figs 5.3, 5.4 and 5.5 for 1990, 2000 and 2012 respectively. The main limitations of this data set is that bore coordinates have not been recorded. The approximate locations of the wells were identified from the Union and Mouza in which the wells are listed. A second limitation is the lack of any data on surveyed levels. It would be useful for each bore to be surveyed so that an accurate groundwater level can be determined.

60. The map in Fig 5.3 shows depth to groundwater was close to the surface in 1990 in the southern coastal districts south of Mirzagang, Dashmina and Burhanuddin. The map also shows distinct zones with depth to groundwater increasing in a northerly direction with the greatest depths in Barisal District.

61. The depth to groundwater map for 2000 in Fig 5.4 shows an increase in depth to groundwater and reflects increased groundwater usage over the 10-year period from 1990 to 2000. There is a 1 m increase in depths to groundwater for the areas around Bhola and Lalmohan and similarly for Barisal District. The depth to groundwater is greatest around Barisal in a northerly direction.

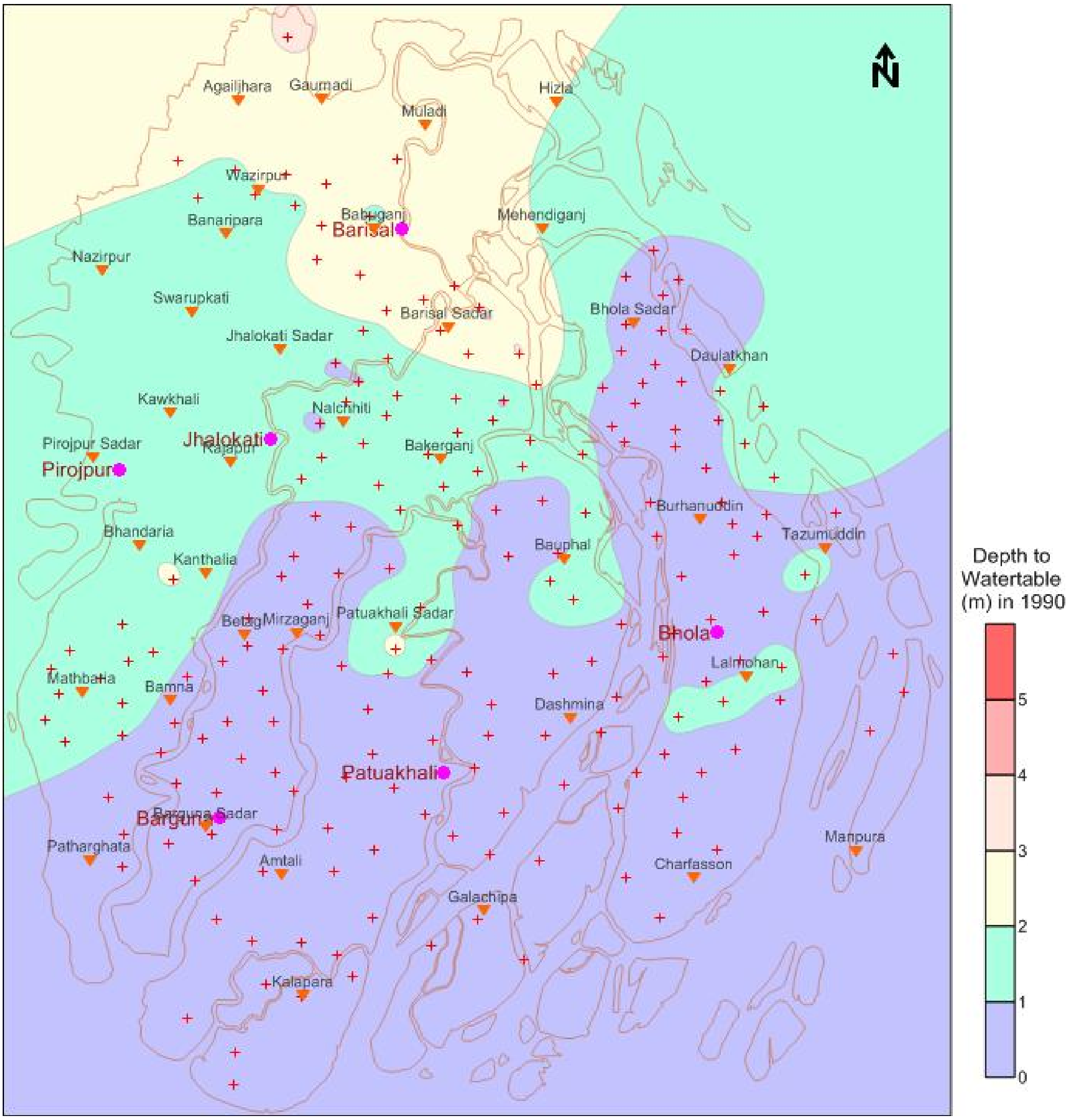


Fig 5.3 Depth to groundwater (m) for 196 deep tube wells (> 150 m) in 1990.

62. The depth to groundwater is also higher around Pirojpur and Mathbharia in 2000 which does not seem consistent with current groundwater usage which is lower in this area. A possible explanation is the time of the year when the survey was carried out. If for instance the survey was carried out pre-monsoon instead of post-monsoon season, then the depth to groundwater would be higher. However, the date of the survey is not recorded in the database, the only information available is the year. A systematic framework for monitoring and recording groundwater data would be most beneficial for water supply projects in the coastal zone and also for other areas in the country.

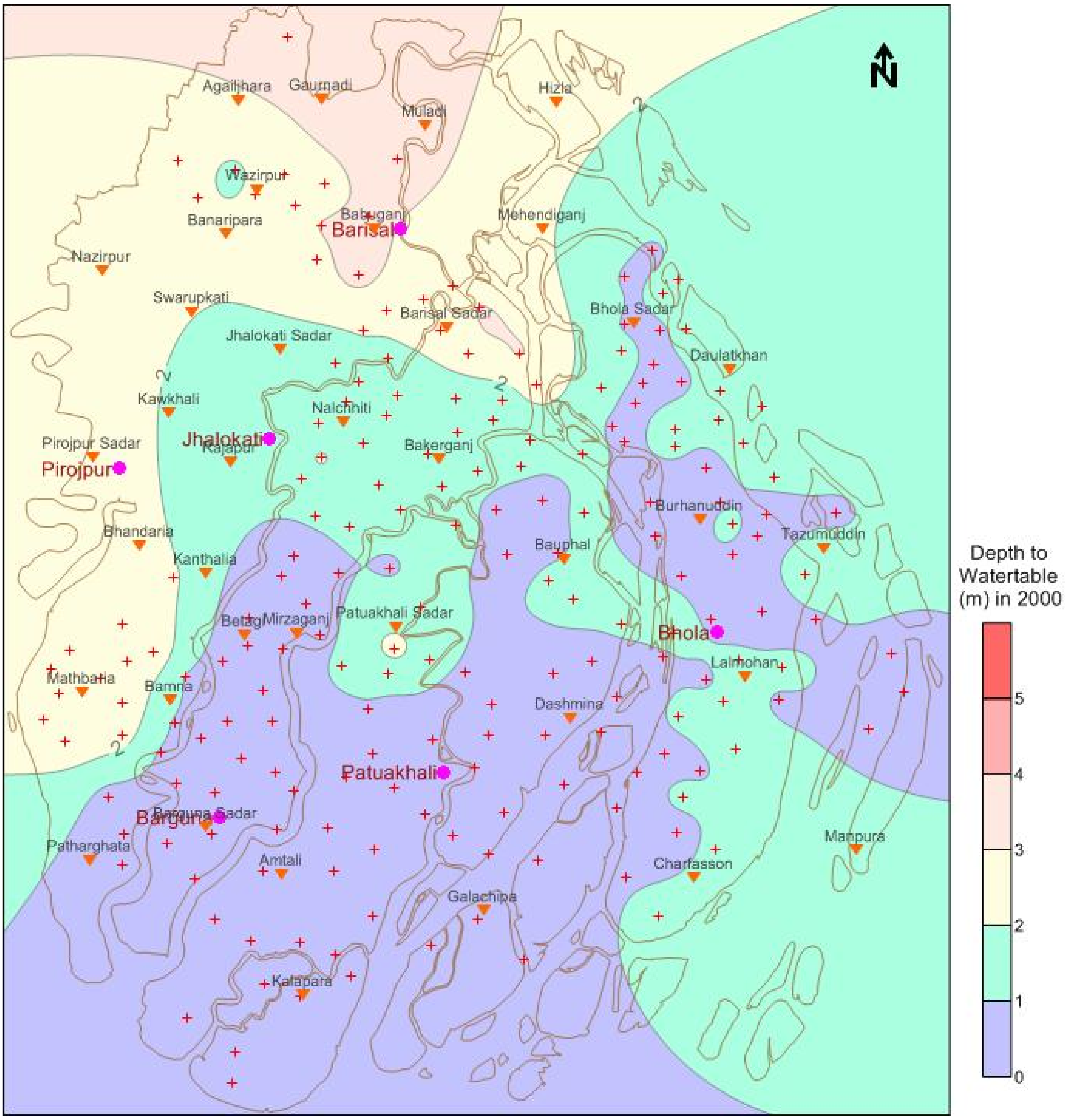


Fig 5.4 Depth to groundwater (m) for 196 deep tube wells (> 150 m) in 2000.

63. The depth to groundwater map for 2012 gives a most useful picture of the current situation. The main aspects are the Barisal Sardar area shows increased depth to groundwater. The areas covered by lower groundwater levels stretches from Barguna towards Barisal Sadar and across to Bhola Sadar and then down toward Burhanuddin. The depth to groundwater is deepest at Burhanuddin as shown by the red zone there. The depth of over 12 m in this area needs to be rechecked as previous readings for this bore from 1986 to 2009 is in the 1.5 to 2.5 m range. Thus it seems unusual for the bore to record a reading of 12.5 m. Notwithstanding this reading the increased depth to groundwater from Barguna to Barisal and then to Bhola is a reflection of increased number of wells tapping the groundwater from the upper deep aquifer. If, as the data suggests, these trends are pointing to increased groundwater usage from the upper deep aquifer, then it would be reasonable to make the case for a monitoring framework for water levels and water quality in the

Barisal Division. Building knowledge and capacity to monitor groundwater resources and to improve the management of resources at the local level is required. This does not mean that groundwater use needs to be restricted. Rather, we advocate building awareness for water conservation and managed aquifer recharge schemes in the coastal areas which would benefit coastal communities.

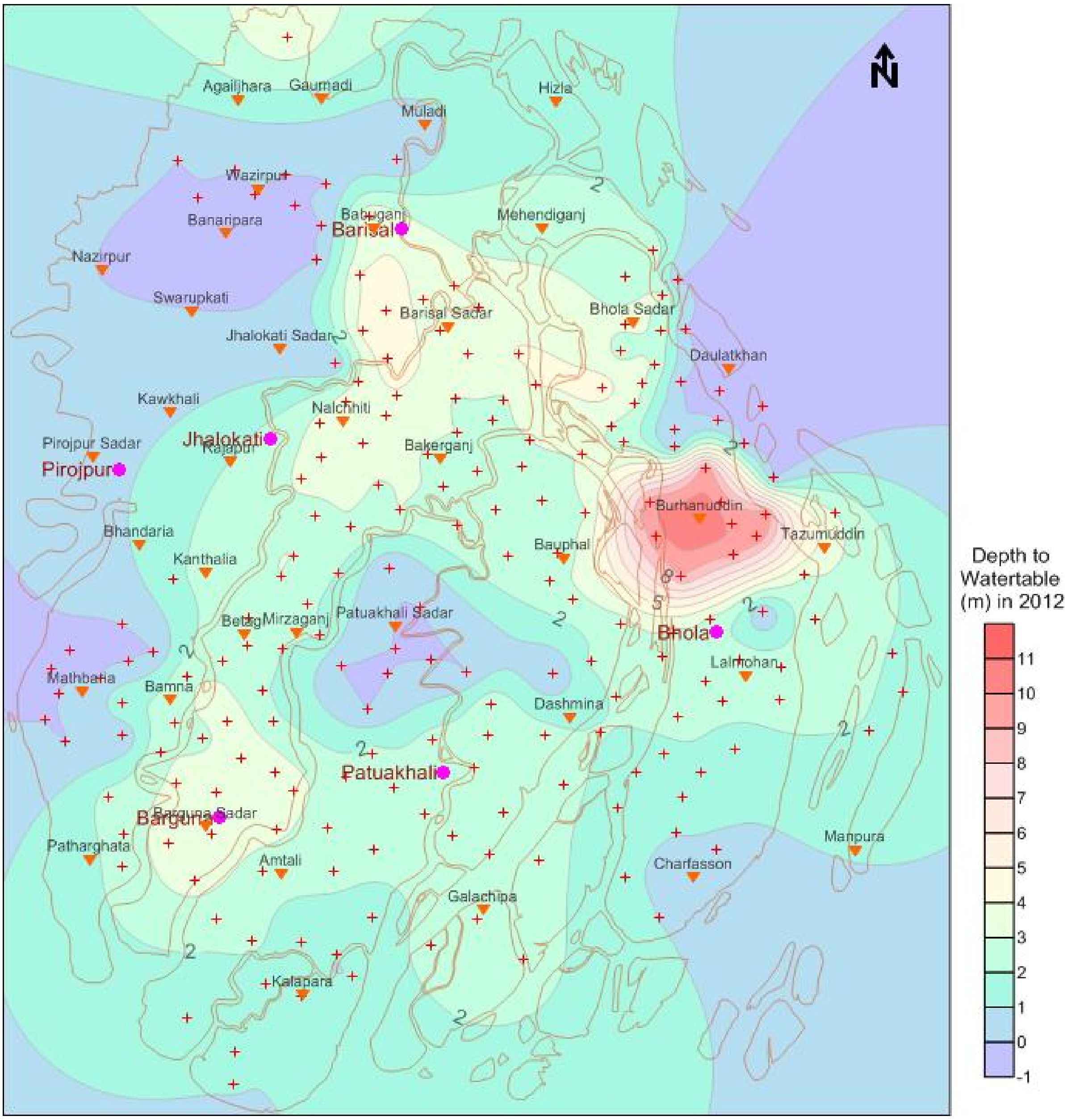


Fig 5.5 Depth to groundwater (m) for 196 deep tube wells (> 150 m) in 2012.

5.3 Groundwater quality for Barisal Division

64. The distribution of chloride measured in 40 deep tube wells in 2011 (Ravenscroft et al. 2012) is shown in Fig 5.6. The recommended chloride limit for Bangladesh is between 200 and 600 mg/l. The areas of very high chloride levels (>1000 mg/l) in Fig 5.6 are located at Kanthalia, Bhandaria and Mathbharia. These areas also correspond to moderate to low groundwater potential areas due to the presence of inter-bedded clay and silty clay layers. Elevated chloride levels (700-800 mg/l) also occur at Pirojpur and Agailjhara which also coincide with areas of low groundwater potential. The chloride level in the deep aquifer south of Barguna has a measured value of 892 mg/l. The bore here is very close to the coast and it is possible that this bore may be experiencing seawater intrusion impacts. The lithological log for this well needs to be located and examined and regular monitoring at this location is needed to ascertain if the deep aquifer is being impacted by salinity intrusion.

65. In the remaining coastal areas, groundwater in the deep aquifers has a lower chloride range (<500 mg/l). The districts with low chloride levels in the deep aquifer are Bhola, Patuakhali, Barisal and parts of Barguna. This covers a large area however, due to the variability of the aquifers it is probable that there are pockets of high salinity groundwater that are not shown in Fig 5.6.

66. The map of chloride distribution shown in Fig 5.6 is based on 40 sampled points consequently the results need to be interpreted with caution. It should be noted that the number of sampling points are on the low side considering the variability encountered in these aquifers. There is a clear need to undertake a survey of deep aquifers in the Barisal Division to locate and identify wells which can be used for water quality monitoring. This type of data would guide the selection of suitable locations for deep tubewells for community water supply.

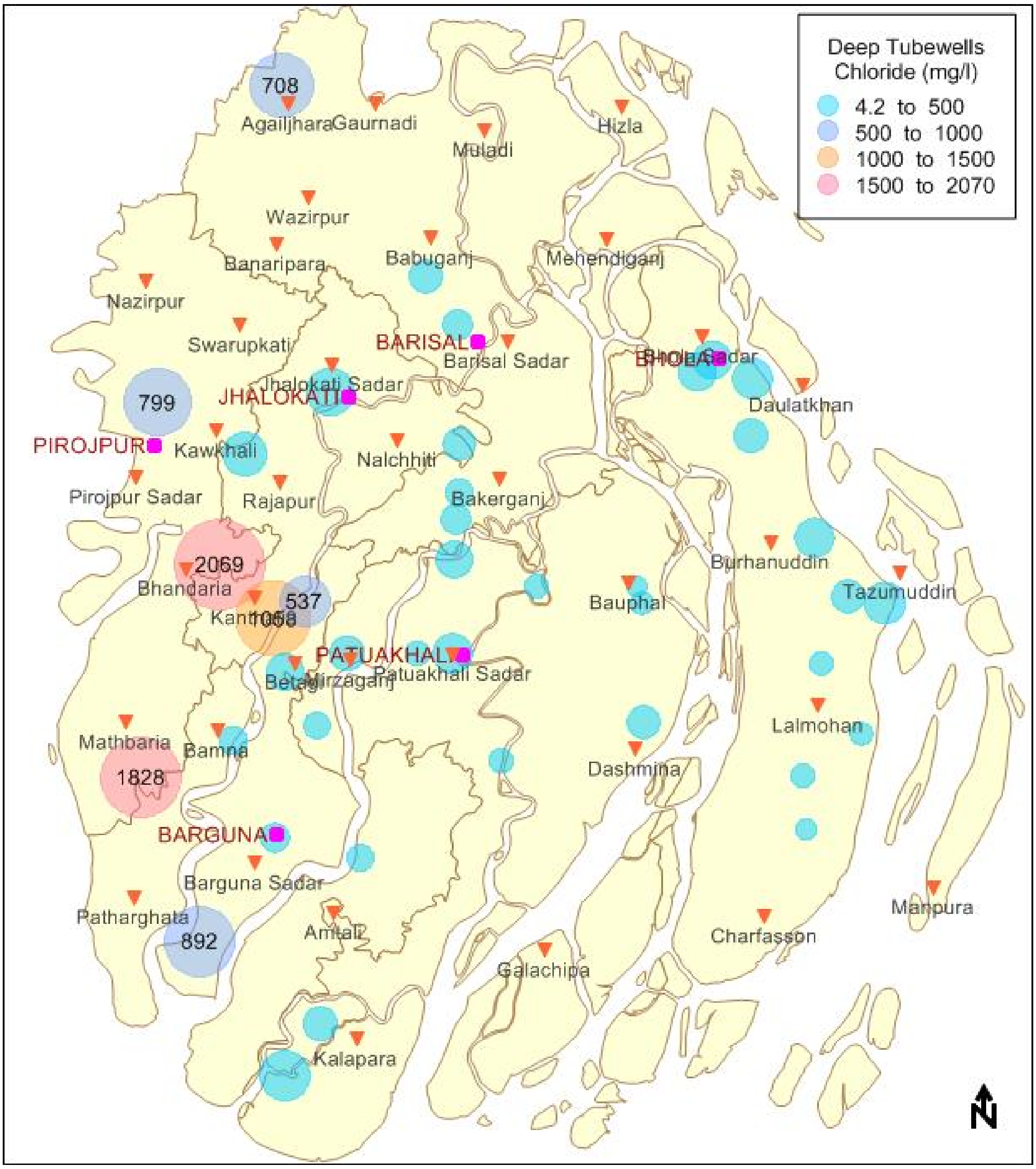


Fig 5.6 Distribution of chloride (mg/l) from 40 deep tube wells (> 150 m).
Source of data: Ravenscroft et al. (2012).

67. The distribution of arsenic measured in 40 deep tube wells in 2011 (Ravenscroft et al. 2012) is shown in Fig 5.7. The recommended limit for arsenic in drinking water for Bangladesh is between 0.05 mg/l. The WHO guideline value is 0.01 mg/L. The 40 deep tubewells sampled in 2011 show the deep aquifer has very low arsenic levels well within the Bangladesh standard for potable water and is also below the WHO provisional guideline value of 0.01 mg/l.

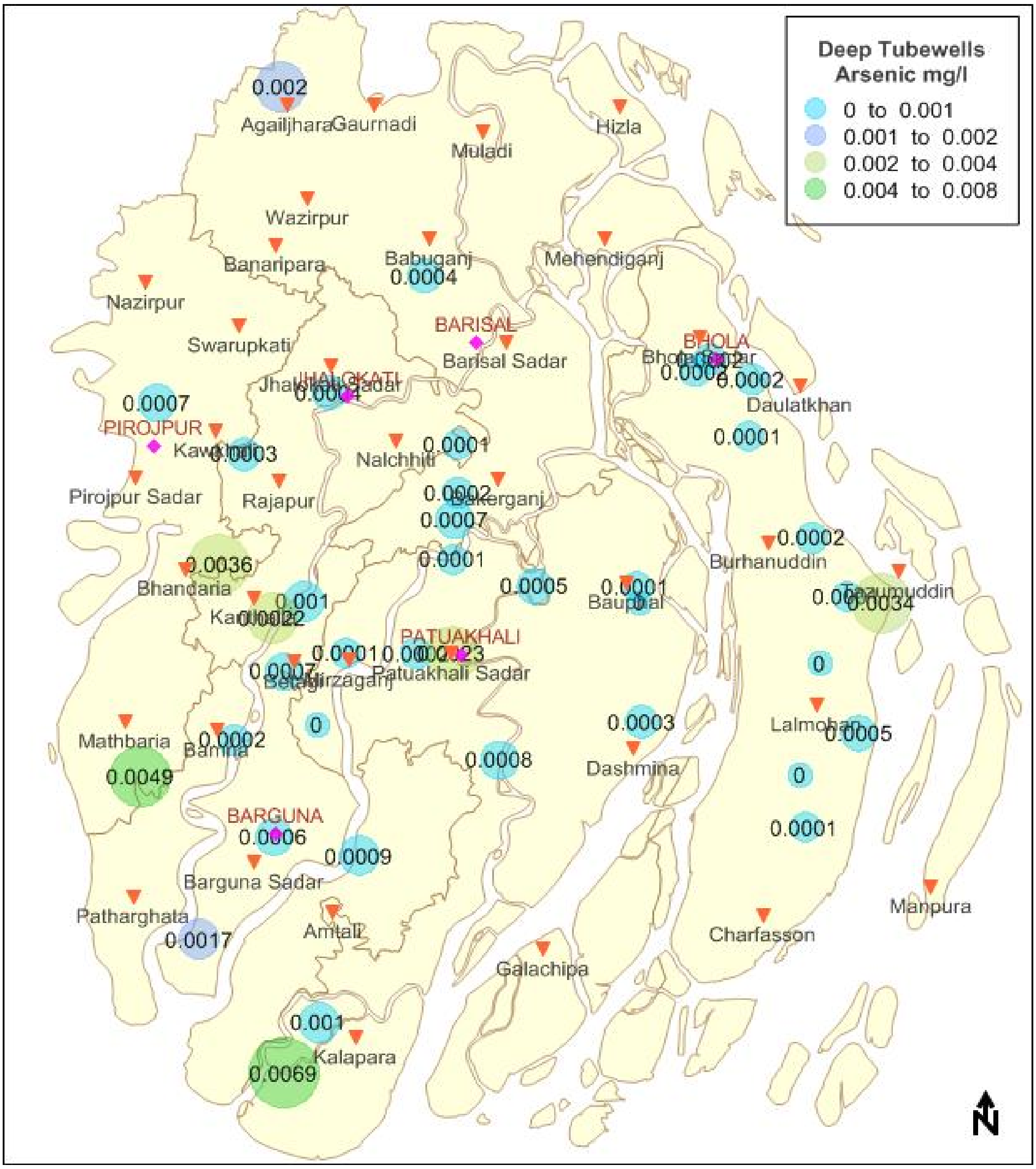


Fig 5.7 Distribution of Arsenic (mg/l) from 40 deep tube wells (> 150 m).
Source of data: Ravenscroft et al. (2012).

68. A second data set for arsenic measurements was obtained from DPHE which was undertaken for the National Water Quality survey in 2009. This survey covered 200 deep tubewells over 150 m in depth. These wells are mostly in the upper deep aquifer although some of these measurements may also correspond to the lower deep aquifer. Of these sampled points 193 deep tubewells have arsenic values less than 0.01 mg/l (WHO provisional guideline) and 198 deep tubewells have arsenic values less than 0.05 mg/L (Bangladesh standard for potable water).

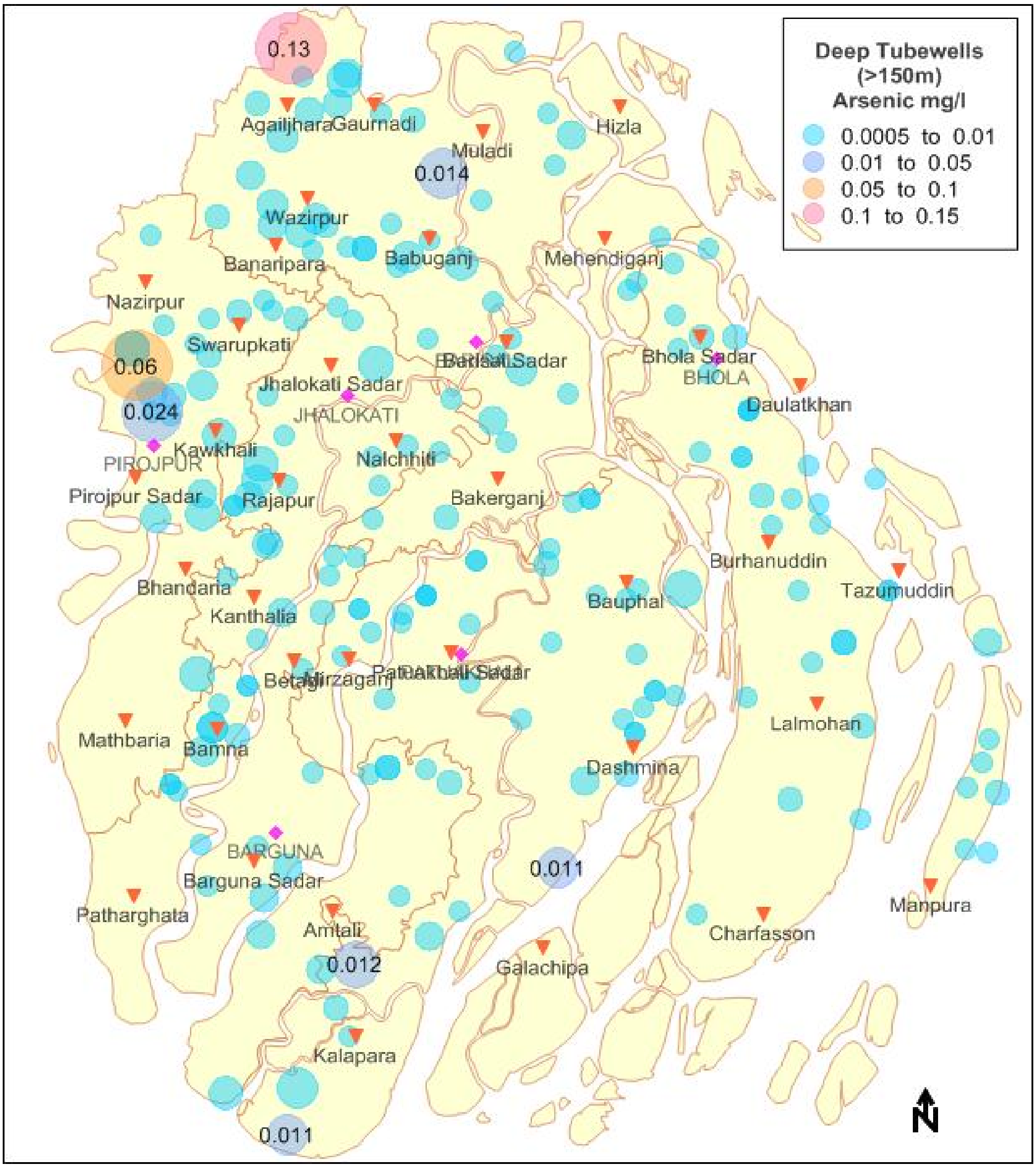


Fig 5.8 Distribution of Arsenic (mg/l) from 200 deep tube wells (>150 m)
Source of data NWQS (2009)

69. There are two deep tubewells which exceed the Bangladesh standard. The deep tubewell south of Nazirpur has a measured arsenic concentration of 0.06 mg/l, and the tubewell north of Agailjhara has an arsenic concentration of 0.13 mg/l. Both these wells need to be examined with a borehole camera to ascertain the possibility of casing leaks or splits. Details of when the bore was constructed and the lithological information for these bores also need to be examined with continued monitoring. Both these wells are in excess of the 0.05 mg/l limit for arsenic and consequently are not safe for potable water use. Considering that a number of deep tubewells around Agaijhara and to the south of Nazirpur are arsenic-safe, it is more than likely that the well casing has been compromised.

6. Coupled flow and salinity model through Amtali

6.1 Model Location

70. The Amtali Pourashava in Barguna District was selected to construct a coupled flow and density transport model. The 2-dimensional cross section model was constructed starting south of Patuakhali Sadar in Auliapur Union through Amtali Upazila to the southern coastal boundary shown in Fig 6.1.

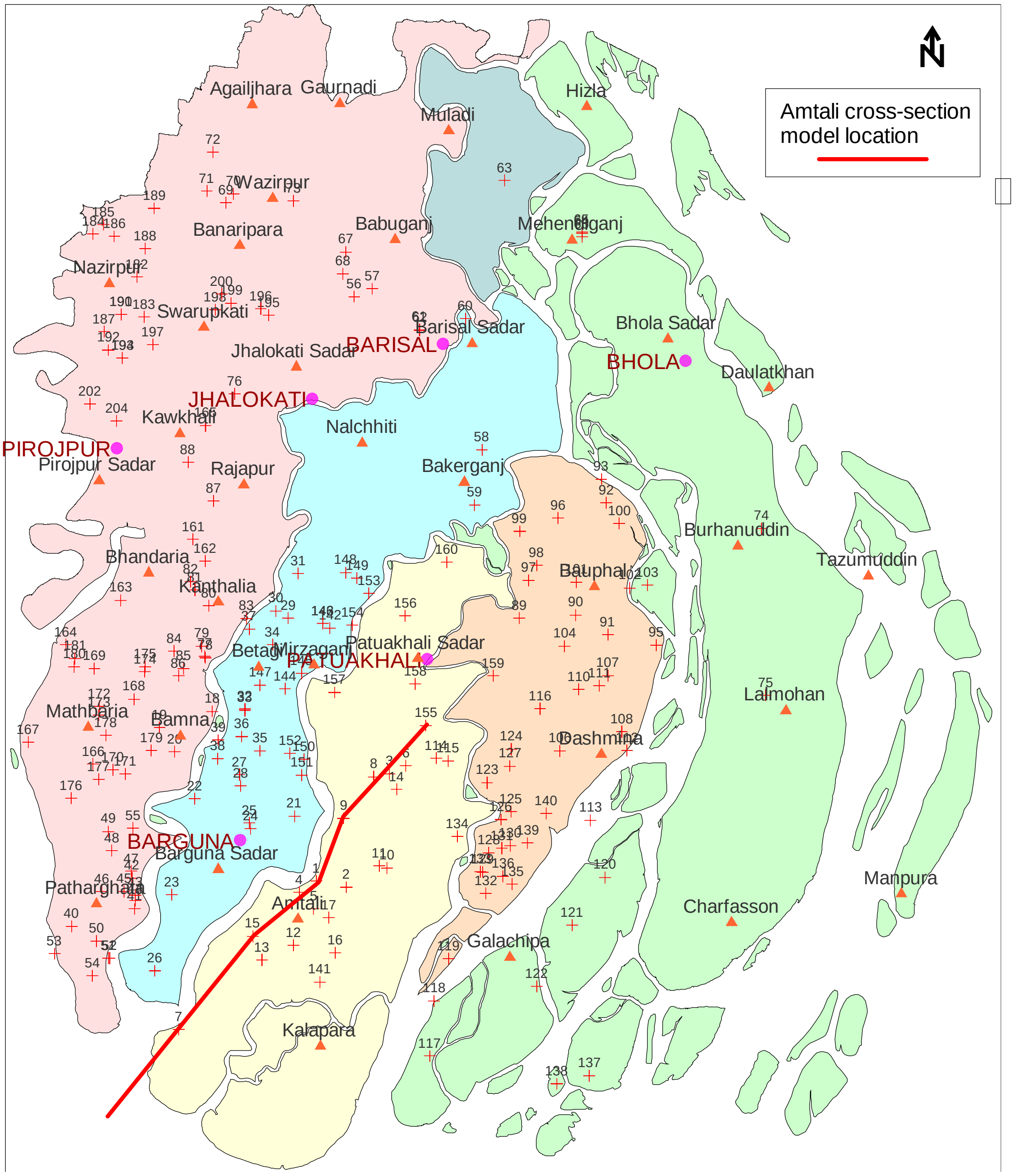


Fig 6.1 Location of cross-section model through Amtali Upazila in Barisal Division.

6.2 Modelling software

71. A coupled flow and density dependent model SEAWAT was used for development of the cross section model going through Amtali and to the coast. SEAWAT combines both MODFLOW and MT3D and allows for density variation of the fluid mass. Accounting for variation in density is an important feature as concentrations near the coastal interface vary from a few hundred mg/l upwards of 35,000 mg/l.

6.3 Conceptual model

72. The Amtali cross-section model follows the length of the Amtail Upazila as shown in Fig 6.1. The model covers the upper deep aquifer and the lower deep aquifer. These aquifers are generally defined at depths of 150 to 300 m for the upper deep aquifer and 300 to 390 m for the lower deep aquifer. The depths are general guidance only. There is considerable variation in the thickness of these aquifers and it is not unusual that the upper deep aquifer could extend to depths of 320 or 330 m. Over 200 borelogs covering Barisal division were analysed to determine the thickness and to estimate the groundwater resource potential for these aquifers as discussed in the previous section. The shallow aquifer which has high concentrations of arsenic was not modelled. The premise for doing so was based on two factors, availability and access to data was limited, and most of the water supply wells were tapping the deep aquifers which contain arsenic-safe water and generally water of low salinity.

73. The conceptual model shown in Fig 6.2 has two major aquifers the upper deep aquifer and the lower deep aquifer. Overlying the upper deep aquifer is a thick sequence of clay which serves as an aquitard separating the upper deep aquifer from the shallow aquifer and has higher salinity concentrations than the water bearing sands. The upper and lower deep aquifers are separated by a thin layer of clay, sand and clay layers. The thin sand layer shown in Fig 6.2 is about 10 to 20 m in thickness and is generally not tapped. The upper and lower deep aquifers form more productive aquifers as they are thicker sequences of sand and more productive aquifers. The conceptual model formed the basis for model design and construction for the numerical model.

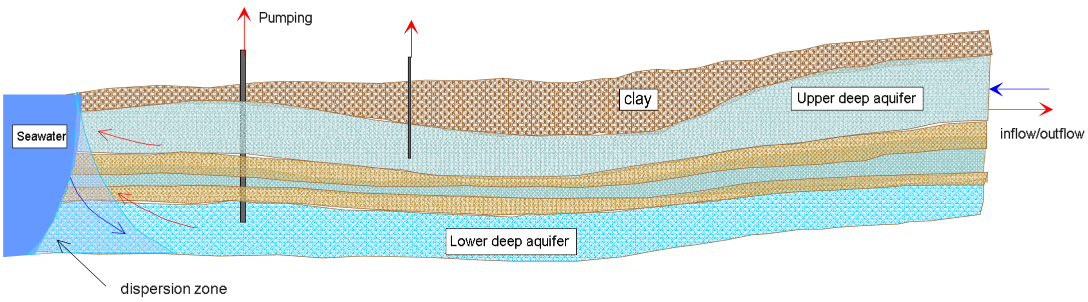


Fig 6.2 Conceptual model for Amtali cross-section showing the upper and lower deep aquifers and aquitards.

74. The Amtali Upazila was selected as a test case to demonstrate the benefits of developing a model which can be used to assess groundwater management issues and in particular to develop an understanding of the impact of pumping and sea-

level rise on the deep aquifer resources. Thus in the section on Model Scenarios we seek to enhance understanding of increased pumping of groundwater from the deep aquifers and how this will impact sustainability, and impacts of climate change such as sea level rise coupled with increased demand for groundwater for increasing population in coastal communities. The question of sustainability is an important one, as a significant number of wells are relied on for drinking water in coastal communities. Thus with the twin impacts of increasing population and climate change it is prudent to assess the risk to supply.

6.4 Model design and construction

75. Where a flow model is required the modelling framework usually consists of defining the major aquifers and aquitards, and having the number of model layers correspond to the number of aquifers. For a variable density flow model such as SEAWAT the grid resolution in the vertical direction requires a much greater level of detail to represent the complex flow patterns, particularly near areas of high concentration gradients which typically occur along boundaries or near sources and sinks. Typical sinks are pumping wells. The model layers for the cross section model consists of 12 active layers as shown in Fig 6.3 for the Amtali cross-section model. All layers are confined aquifers. The grid structure adopted for the cross section model is a 400 x 400 m grid.

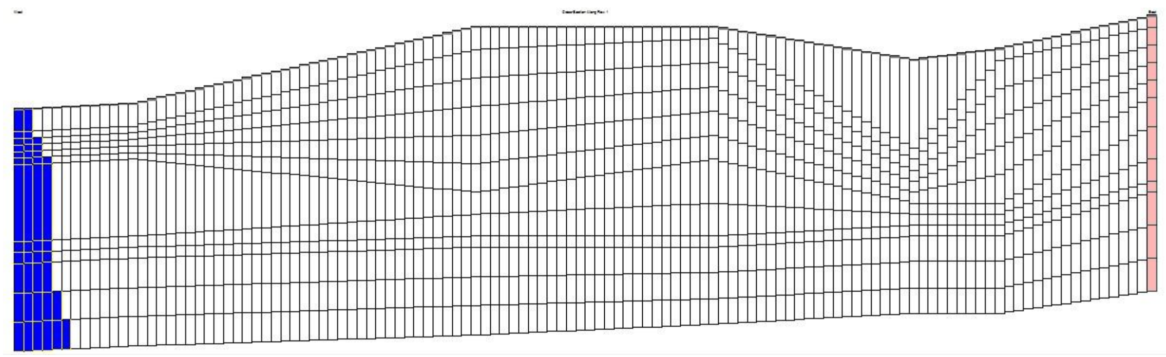


Fig 6.3 Grid structure and layers for the Amtali cross-section model.

76. It is important to note that there are aquifers and aquitards above the top model layer but these are not modelled as discussed previously since the focus of this study is on the deep aquifers which offer a reliable supply of drinking water for coastal communities. The construction of model layers was undertaken using bore logs for bores along the Amtali cross section.

6.5 Boundary conditions

77. The model extends beyond to coast under the sea bed. The boundary condition on the southern model boundary (shown as west) designated by blue cells defines an assumed seawater interface. There is no data to verify the exact location of the interface, nor the distance from the coast. Thus the first model run undertaken with no pumping forms the base scenario which can be used to compare relative changes. The boundary condition on the northern boundary (shown as east) of the cross section model is defined by general head boundaries which allow for flow across the boundary dependent on a specified head along the boundary.

78. The boundary conditions for the cross section model are shown above in Fig 6.3. The western cells in layer 1 to 12 are defined as time varying heads representing the mean sea level and constant concentration of 35 kg/m^3 (35000 mg/l) to represent the seawater interface. The variation in mean monthly sea level at Patharghata from July 1969 to June 2009 is shown in Fig 6.4.

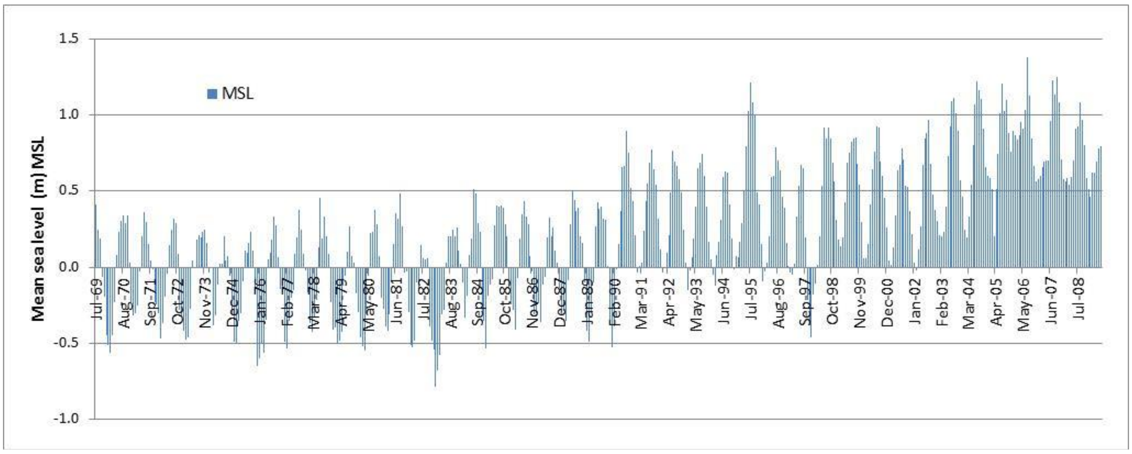


Fig 6.4 Mean monthly sea level at Patharghata from July 1969 to Jun 2009 (m MSL).

79. The mean monthly sea level at Patharghata shows a stable trend from 1969 till the mid 1980's and then a clear rising trend. Comparison of the mean monthly sea levels shows a similar rising trend for every month over the last 50 years. A rise in sea levels due to climate change is estimated to be a further 0.58 m by 2065. This would result in increased salinity intrusion, increased risk of land salinisation in the coastal zone and further inland movement of the seawater interface. This will have a more direct effect on the shallow aquifers. Coupled with increased groundwater pumping from the deep aquifers there is increased risk of saline intrusion with consequent impacts on coastal wells used for water supply. The model will be used to assess the extent of this impact and the risks to the deeper aquifers.

80. The model cross-section extends in a south-westerly direction to the coast and 1200 m off-shore. The location of the seawater interface is assumed as there is no information on how far the aquifers extend below the sea-bed, nor the precise location of the interface. The criteria for evaluation would be how the interface responds to changes in pumping and sea level rise. The eastern model boundary is defined as a general head boundary to allow for regional groundwater flow.

81. The preferred approach was to develop a multi-layer 2-D density corrected transient numerical groundwater flow model with solute transport capability for the Amtali cross-section. The SEAWAT model offers a reasonable choice as density correction is applied in SEAWAT. Moreover, the cross section model offers a good starting point for understanding flow and salinity dynamics in the deep aquifers in the coastal zone.

6.6 Hydraulic properties

82. The initial selection of aquifer parameters was based on the dominant aquifers and guidance from previous studies undertaken in coastal areas. The main hydrogeological units for the Amtali cross-section model is an upper deep aquifer

comprising of medium to coarse sands which is overlain by an aquitard comprising of clay and silty clay (Fig 6.5 and Fig 6.6).

83. The initial estimated hydraulic conductivity for the upper deep aquifer was 5 m/d and specific storage was 4E-5 m^{-1}. For the clay layers overlying and underlying the upper deep aquifer the initial estimated hydraulic conductivity was 0.2 m/d and specific storage was 1E-6 m^{-1}. Below the lower confining layer is a sand layer of approximately 10 to 20 m thickness. The hydraulic conductivity of this layer is estimated at 3 m/d. Underlying this layer is another thin sequence of clay and silty clay. Below this third confining unit lies the lower deep aquifer which is the source of good quality groundwater for the municipal water supply bores at Amtali. Other than a select few deep bores that penetrate the lower deep aquifer, most of the bores in Barisal Division are not drilled deep enough. Thus the lower boundary of the lower deep aquifer has largely been estimated from the depth of the two bores at Amtali. Other similar deep bores at Galachipa and other areas also show a thick sequence of sands below 330 m. The initial hydraulic conductivity for the lower deep aquifer is estimated at 7 m/d shown in Fig 5.5 and specific storage at 5E-5 m^{-1} shown in Fig 6.6.

84. During model simulation runs it was necessary to revise these initial estimates of hydraulic conductivity and specific storage as pumping was inducing significant declines in groundwater levels. We know from evidence based measurements at Amtali and Galachipa over a 12 year period 1999 and 2012 that there has been no significant decline in heads nor a significant increase in salinity. Due to this the initial values of hydraulic conductivity were increased to 6 m/d for the upper deep aquifer, and to 12 m/d for the lower deep aquifer. Significantly, the specific storage was also increased to 4E-3 m^{-1} for the upper deep aquifer and 8 E-3 m^{-1} for the lower deep aquifer.

85. Access to improved information is necessary to calibrate the model, and for future models that will be required for the coastal zone. A regional groundwater model for Barisal Division would be very useful for improved management of groundwater such that sustainability of the system is preserved for coastal communities. Data on the hydrogeology, aquifer geometry and aquifer parameters, together with historical records of temporal data such as water levels and pumping provide a platform on which to base a numerical model. The reliability of model predictions depends on the extent and accuracy of the spatial and historical data that are available. In addition the bore logs of over 200 deep bores have provided much needed information on the aquifer and the hydrogeology of the borefields and have been utilised to design the model framework.

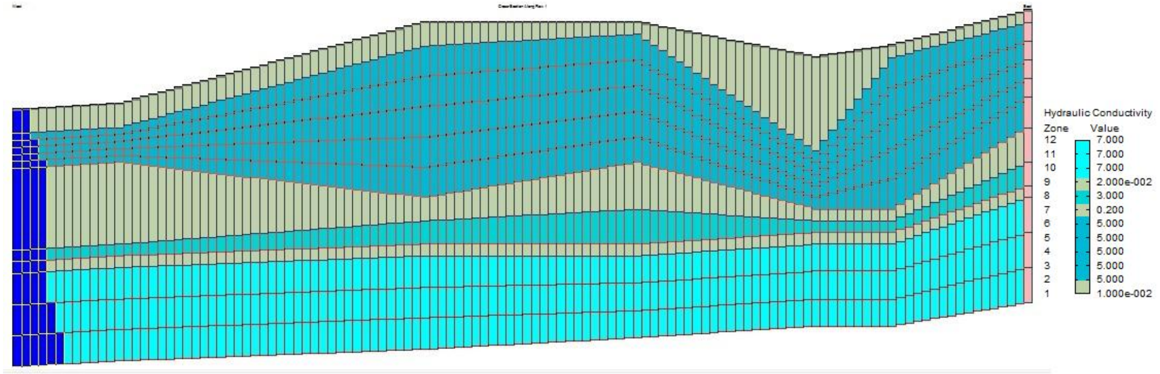


Fig 6.5 Estimated hydraulic conductivity (m/d) for the Amtali cross-section model.

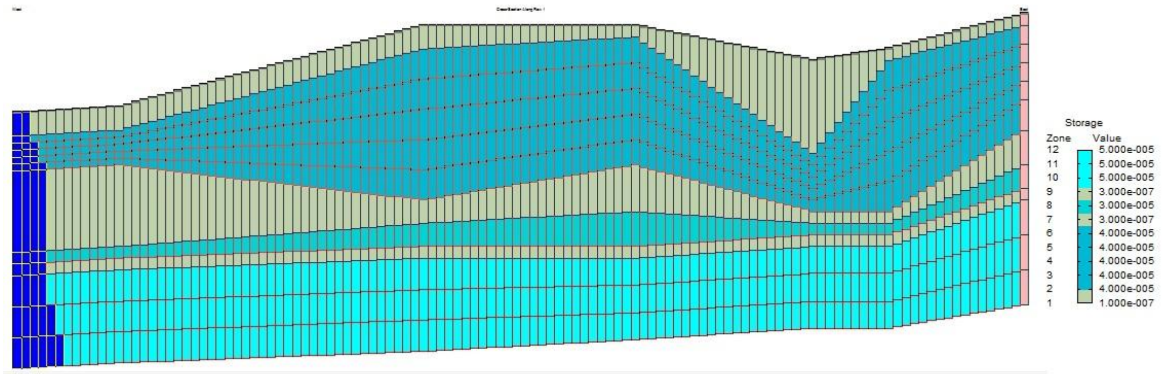


Fig 6.6 Estimated specific storage (m^{-1}) for the Amtali cross-section model.

86. Improvements can always be made, particularly since there are a number of NGO's and government organisations drilling deep bores in the coastal zone. However, there is no mechanism for licensing bores, nor any guidelines for the minimum amount of information that needs to be collected and archived. The DPHE is the logical agency for archiving and storing borelogs and other aquifer information as they already have an Aquifer Database Inventory Program in place. The Groundwater Circle within BWDB is also another source of information. A framework for sharing and public access to this data is required so that future project outcomes are enhanced based on all available information. Ultimately this will benefit local communities, and improve the impact of development projects in-country.

6.7 Groundwater Pumping

87. There are no records of groundwater usage from various wells in the coastal areas. This results in a considerable degree of uncertainty for model development. It is recommended that all municipal water supply bores be individually metered so that accurate records are available for future modelling studies as well as for improved water accounting and management of the borefields.

88. For this study groundwater usage was estimated from population statistics for various Unions in the Barisal Division. The average water consumption was

estimated at 100 l/person/d (Z. Alamgir pers comm). The spatially distributed estimated water usage is shown in Fig 5.6.

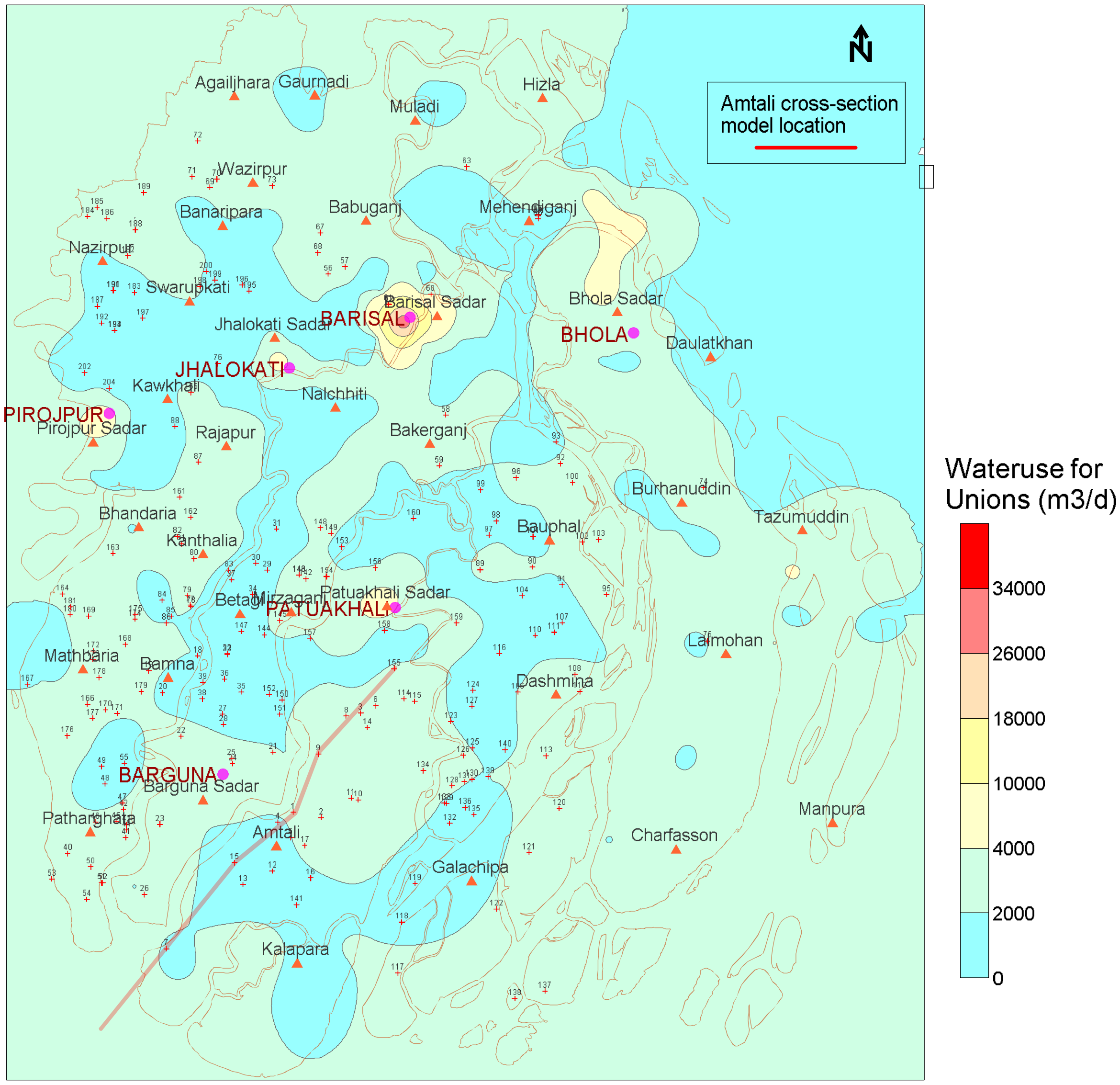


Fig 6.7 Estimated groundwater usage (m^3/d) for Unions in Barisal Division.

89. Fig 6.7 shows that most of the usage is below 4000 m^3/d for most Unions, except for the major towns where estimated usage is between 10,000 and 18,000 m^3/d, the exception being Barisal Sadar with estimated usage up to 32,000 m^3/d. It should be noted that not all of this is from groundwater. Some towns like Pirojpur are supplied by surface water. However, for the Amtali cross section most of the water is from deep tube wells. Spatial estimates of groundwater usage were estimated for 400x400 grids used in the model.

6.8 Model Scenarios

90. The Amtali cross-section model was used to run three scenarios. The scenarios include:

- Model simulation from 1969 to 2009 with zero pumping;
- Model simulation from 1969 to 2009 with pumping estimates based on population; and
- Model simulation from 2009 to 2065 with increased pumping and sea level rise.

6.8.1 Model simulation from 1969 to 2009 with zero pumping

91. The first scenario involved simulating the model from 1969 to 2009 with no pumping to examine the pre-development groundwater resource. Fig 6.8 shows the distribution of heads in the deep aquifers along the Amtali Upazila. The water levels range from 1.5 to 3.2 m and remain above mean sea level.

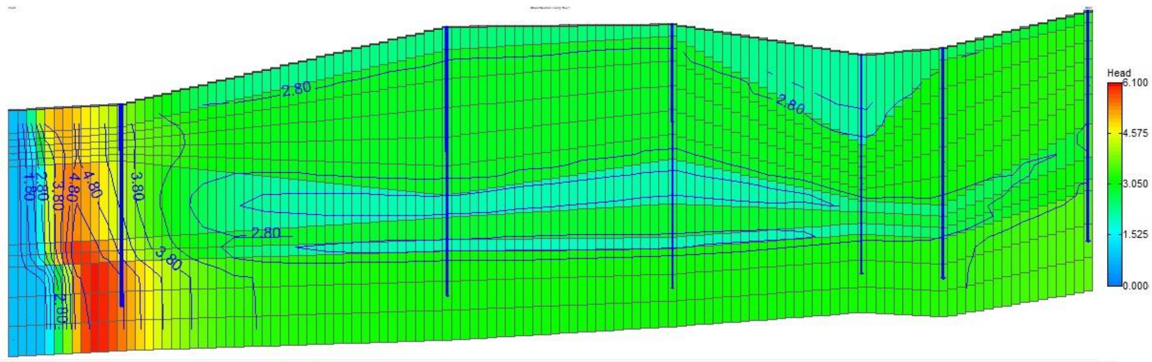


Fig 6.8 Head (m MSL) in June 2009 for deep aquifers for the Amtali cross-section (no pumping)

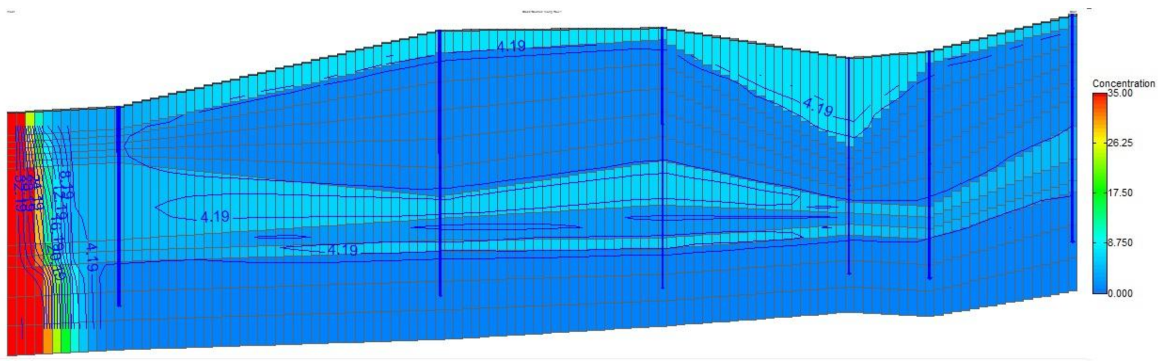


Fig 6.9 Salinity concentration (kg/m^3) June 2009 for deep aquifers for the Amtali cross-section (no pumping)

92. Fig 6.9 shows the salinity distribution in the deep aquifers which range from a low of 0.2 to 0.5 kg/m^3 for the lower and upper deep aquifers to 6 kg/m^3 for the clay layers that separate these aquifers. The seawater interface to the south has salinity concentrations of 35 kg/m^3 and shows salinity intrusion from 800 to 1200 m from

the interface. This is most likely due to the mixing of freshwater from the aquifer and seawater near the interface.

6.8.2 Model simulation from 1969 to 2009 with pumping estimates based on population

93. A second scenario was undertaken to determine the impact of pumping from the deep aquifer. Pumping was based on population density and an estimated water use of 100 l/person/d. The spatial distribution of the estimated water use was discussed earlier and shown in Fig 5.6. Water use was varied linearly from 1969 to 2009 as the population increased. The use of population statistics to estimate water use is an approximate method. A more robust approach would be to identify all the wells in the area and to estimate usage for each well. It will not be possible to meter ever single well, nor is it necessary, however, knowing the locations of all wells, their use (domestic or irrigation), and the number of households it serves would improve estimates of groundwater usage. It is however necessary to meter all municipal water supply wells and irrigation bores as these are typically large users of groundwater.

94. Fig 6.10 shows the simulated heads in June 2009 for the Amtali cross-section model with pumping distributed over the entire length of the cross-section for the upper deep aquifer. The range of pumping varies from 1.5 m^3/d for a single grid cell up to 10 m^3/d. There is also a bore pumping at 1250 m^3/d in layer 12 which corresponds with the lower deep aquifer. The relatively higher pumping from this location represents the Amtali Municipal water supply bore. The impact of high extraction rates is shown by the blue colour in the lower mid-section of the cross section.

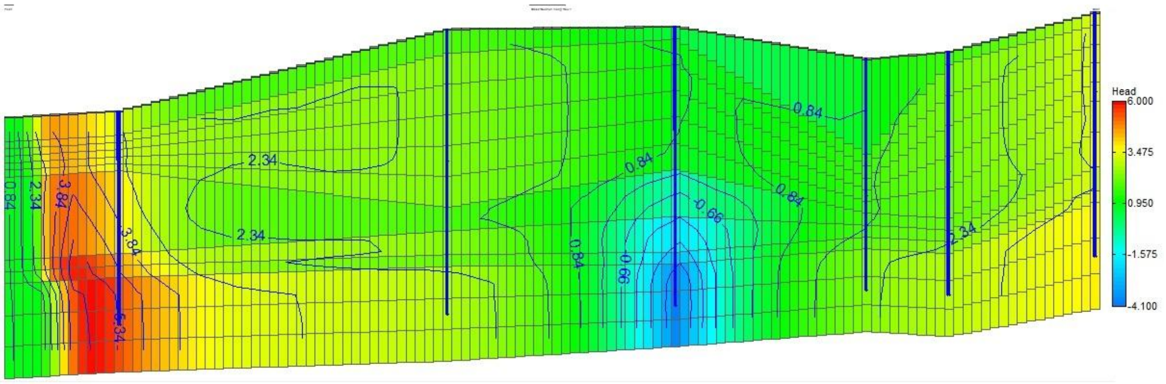


Fig 6.10 Head (m MSL) June 2009 for deep aquifers for the Amtali cross-section (with pumping).

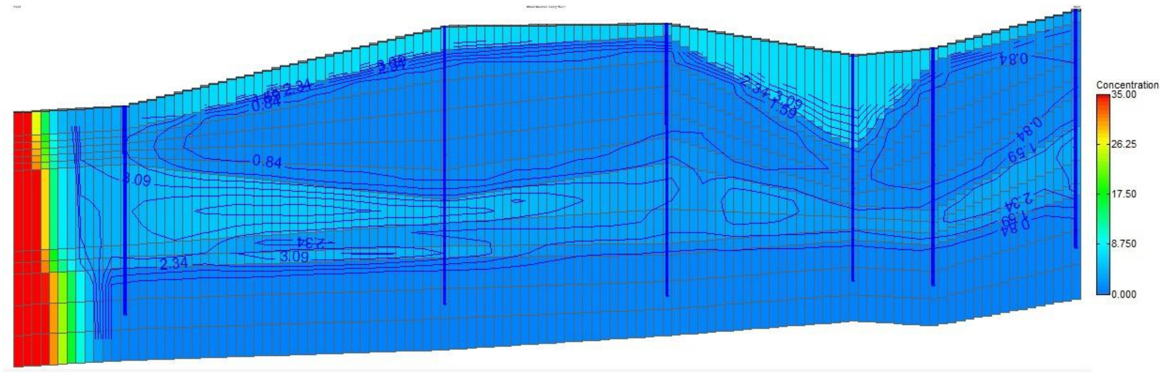


Fig 6.11 Salinity concentration (kg/m^3) June 2009 for deep aquifers for the Amtali cross-section (with pumping).

95. Fig 6.11 shows salinity concentrations for the Amtali cross-section in June 2009 for the pumping scenario. The seawater interface remains stable with pumping and does not show significant movement inland. The main reason for this is that the groundwater withdrawn from the upper deep aquifer is a small amount as most individual households rely on deep hand tube wells where small quantities of water are withdrawn. The only known high yielding wells are the Municipal wells at Amtali which are located in the lower deep aquifer and are considerably deeper.

96. Fig 6.10 and 6.11 show temporal salinity response for the municipal water supply bore at Amtali. The salinity levels show a very slight increase over the 40 year period for both the upper and lower deep aquifer. For the upper deep aquifer the salinity increased by 0.2 kg/m^3 (200 mg/l) over 40 years, and for the lower deep aquifer by 0.1 kg/m^3 (100 mg/l) which is consistent with measured values that show very little change in salinity between 1999 and 2011. It should be noted that the Amtali model is very much a conceptual model, as detailed information on water levels and salinity are required in order to undertake proper calibration of the model.

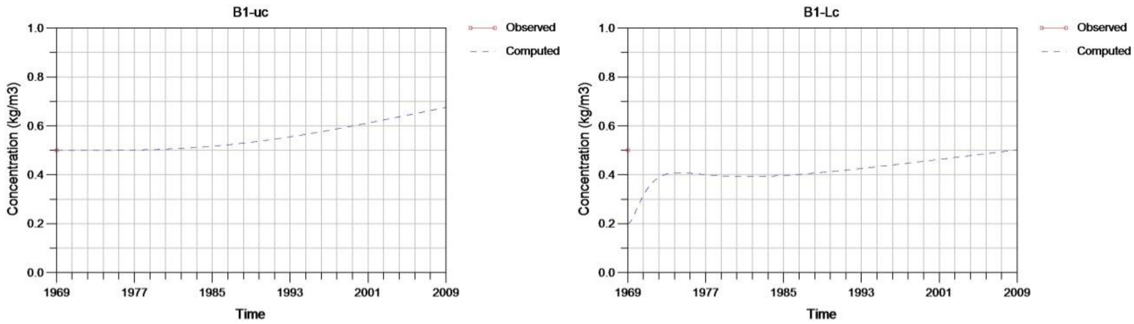


Fig 6.12 Temporal variation of head and salinity in the upper and lower deep aquifers for Amtali deep bore B1 (Amtali) from 1969 to 2009.

97. Fig 6.12 shows the impact of the seawater interface affecting bores close to the coastal boundary such as bore 7 in Chota Nishanbaria Chak Mouza (Barabagi Union). The salinity increase in the deep aquifer from 1969 to 2009 is about 120 mg/l. Although a small increase it is important as this bore is situated close to the coastal boundary.

98. Fig 6.12 also shows a significant salinity impact in the upper deep aquifer where salinity concentrations have increased from 0.6 kg/m^3 to about 2.6 kg/m^3 rendering potable supplies unusable. This needs to be checked to determine if this is a persistent salinity trend or if it is seasonal. There are also other bores close to the coastal boundary which may be affected in the medium term as both demand and sea-levels rise.

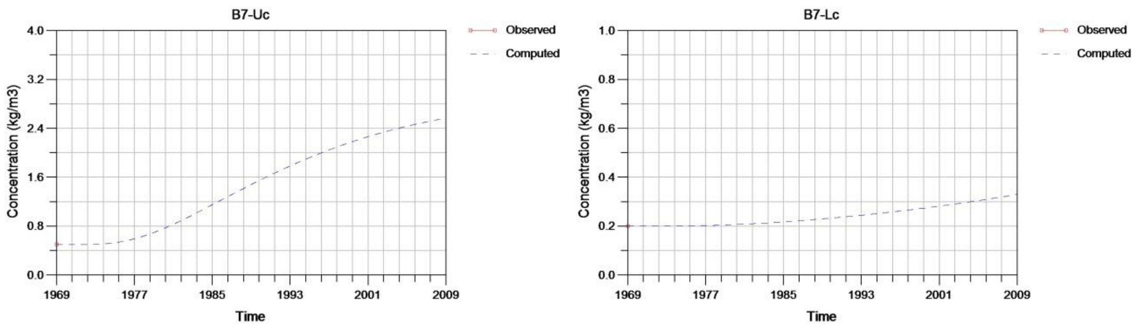


Fig 6.13 Temporal variation of head and salinity in the upper and lower deep aquifers for deep bore B7 (Barabagi Union) from 1969 to 2009.

6.8.3 Model simulation from 2009 to 2065 with increased pumping and sea level rise

99. A third model scenario was undertaken with projected pumping doubling from 2009 to 2040 and with projected sea-level rise. Fig 6.14 shows the sea-level rise projected from 2000 to 2065 for Bangladesh. These values were used to define the southern boundary condition for the model. The objective of this scenario was to examine the impact of both increased pumping and sea-level rise on the upper and lower deep aquifers.

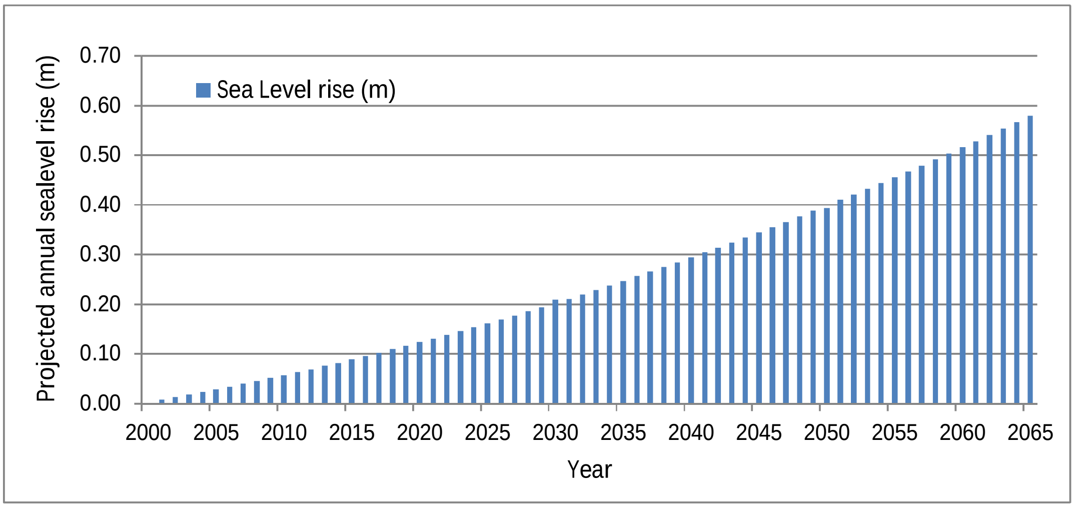


Fig 6.14 Projected annual sea-level rise from 2000 to 2065 for Bangladesh.
Source: Dr Dewan.

100. Figs 6.15 show the vertical distribution of head for the Amtali cross-section model. The main feature is the drawdowns experienced in the lower deep aquifer due to increased pumping from two locations at Amtali. Fig 6.16 shows salinity distributions for the cross section. There is a small ingress of the seawater interface which may affect bores close to the coastal boundary such as bore 7 in Chota Nishanbaria Chak Mouza (Barabagi Union). There are also other bores close to the coastal boundary which may be affected in the medium term as both demand and sea-levels rise. There are small variations and these are best seen by examining individual locations as discussed below in Fig 6.17 and Fig 6.18.

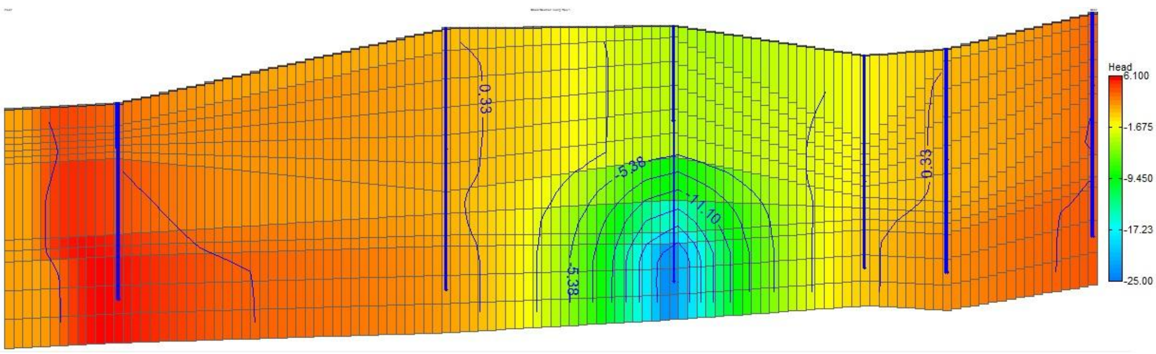


Fig 6.15 Head (m MSL) June 2040 for deep aquifers for the Amtali cross-section with increased pumping and projected sea-level rise.

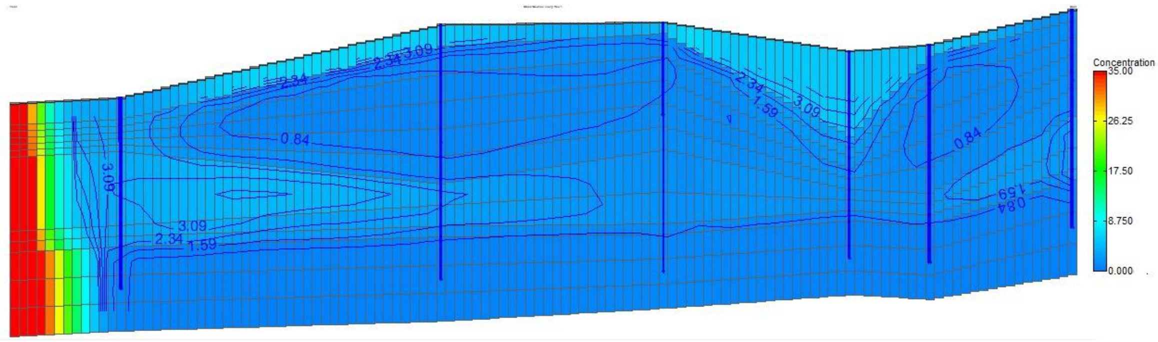


Fig 6.16 Salinity concentration (kg/m^3) June 2040 for deep aquifers for the Amtali cross-section with increased pumping and projected sea-level rise.

101. Fig 6.17 shows simulated response for heads and salinity concentration for bore B1 for the upper deep aquifer and the lower deep aquifer for Amtali from 2009 to 2040. The heads decrease by nearly 4 m over the simulation period and the salinity increases by 0.3 kg/m^3 (300 mg/l). The salinity increase is due mainly from salinity migration from the clay aquitards which are assumed to be of higher salinity and overlie and underlie the upper deep aquifer.

102. For the lower deep aquifer the heads decrease by over 23 m which is a cause for concern. In this simulation there are two Municipal water supply bores operating in the lower deep aquifer in the Amtali area which are operating from 1240 m^3/d in 2009 and increasing to 2600 m^3/d by 2040. Due to the fact that the model in this study is conceptual in nature we cannot predict with certainty that the aquifer will decline by 23 m. There are several factors that may affect this result. Firstly, the model uses estimated values of hydraulic properties. The usual procedure would be to modify these estimates during model calibration. However, due to the lack of access to temporal data the model calibration will need to be pursued at a later stage when data on salinity and water levels are made available of collected in future studies. Secondly, the model is 2 dimensional and has no provision for recharge as it is assumed that the upper layer is a confining clay layer. In realty this may not be the case particularly in areas where the confining layers are thin. Thirdly the lower deep aquifer may be deeper that the drilled depth which would increase the capacity of the aquifer. What the model does tell us is that there is a small decrease in heads in the upper confined layer because the extractions are assumed to occur from hand tube wells so the rate of pumping is low. However, when the pumping rates are high as in the lower deep aquifer there is a greater risk of larger drawdowns and consequently a greater need for regular monitoring of the water levels and salinity of the aquifer at this location.

103. Fig 6.17 also shows that salinities for the upper deep aquifer increase by 0.4 kg/m^3 (400 mg/l) during the 31 year simulation from 2009 to 2040. The pumping and operation of the tube wells should be such that salinities are not allowed to increase beyond 500 mg/l. Where salinity levels are already higher than 500 mg/l then regular monitoring of water levels, salinity and pumping rates should be undertaken to ensure that salinities remain below 1000 mg/l. This would allow a long term sustainable supply for coastal community. As the demand for potable water increases, it is only a matter of time before more deep wells are drilled to tap the lower deep aquifer. Thus a system of licensing and managing high extraction wells such as municipal water supply wells and irrigation wells may be required in the near future.

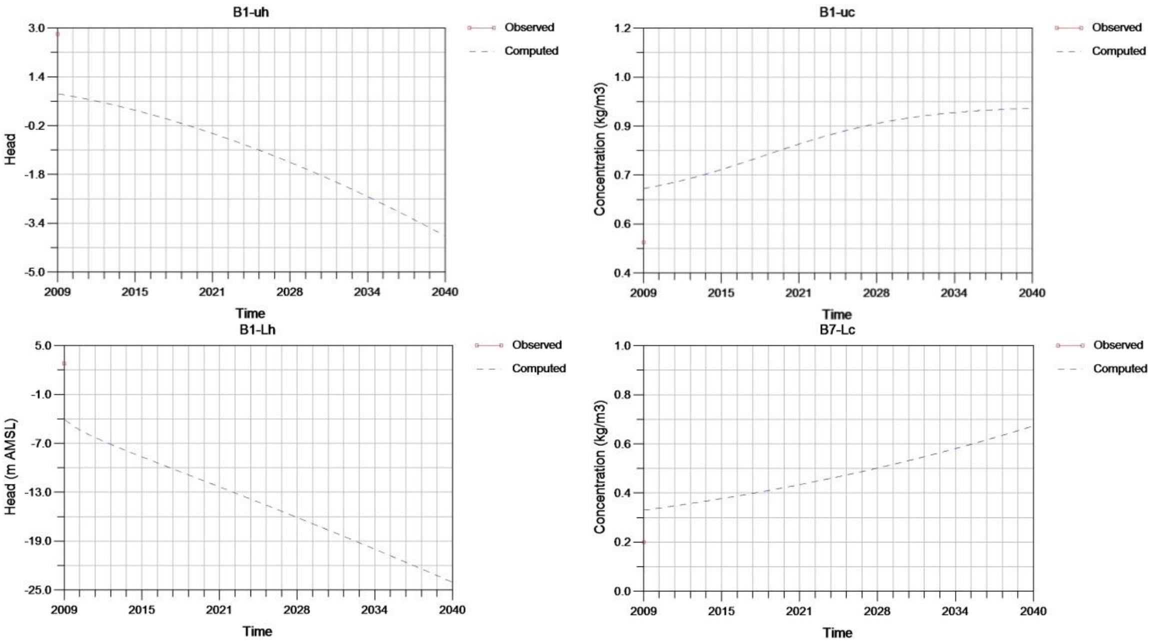


Fig 6.17 Head and salinity concentrations in the upper deep aquifer (top row) and lower deep aquifer (bottom row) for bore 1 at Amtali town area from 2009 to 2040.

104. Fig 6.18 shows head and salinity concentrations in the upper deep aquifer (top row) and lower deep aquifer (bottom row) for bore 7 at Chota Nishanbaria Chak Mouza near coastal boundary from 2009 to 2040. This is an important location as it is near the coastal boundary and would be a good site to monitor the impact of seawater intrusion in the upper and lower deep aquifers.

105. Fig 6.18 shows salinity increase of 0.4 kg/m^3 (400 mg/l) from 2009 to 2040. This is on top of a very high increase in salinity from 1969 to 2009 of over 2000 mg/l. Although the salinities seemed to have settled at 2.9 kg/m^3 (2900 mg/l) the water quality is well above 1000 mg/l making it unsuitable as a drinking water source. This would suggest that the proximity of this bore to the coast makes it vulnerable to seawater intrusion particularly with increased pumping and sea-level rise.

106. For the lower deep aquifer there is an increase in head of 0.6 m from 2009 to 2040 and increase in salinity of 0.4 kg/m^3 (400 mg/l) from 2009 to 2040. This is on top of the 120 mg/l rise simulated from 1969 to 2009. This again would suggest that the proximity of this bore to coast makes it vulnerable to seawater intrusion. Again we emphasise that the model is conceptual in nature as aquifer properties have been estimated and not calibrated. For robust predictions the models need to be calibrated for both heads and salinity in order to improve understanding of likely impacts.

107. We recommend a set of sentinel bores be used to provide communities with early warning of increasing seawater intrusion risk which could have an impact on their drinking water source.

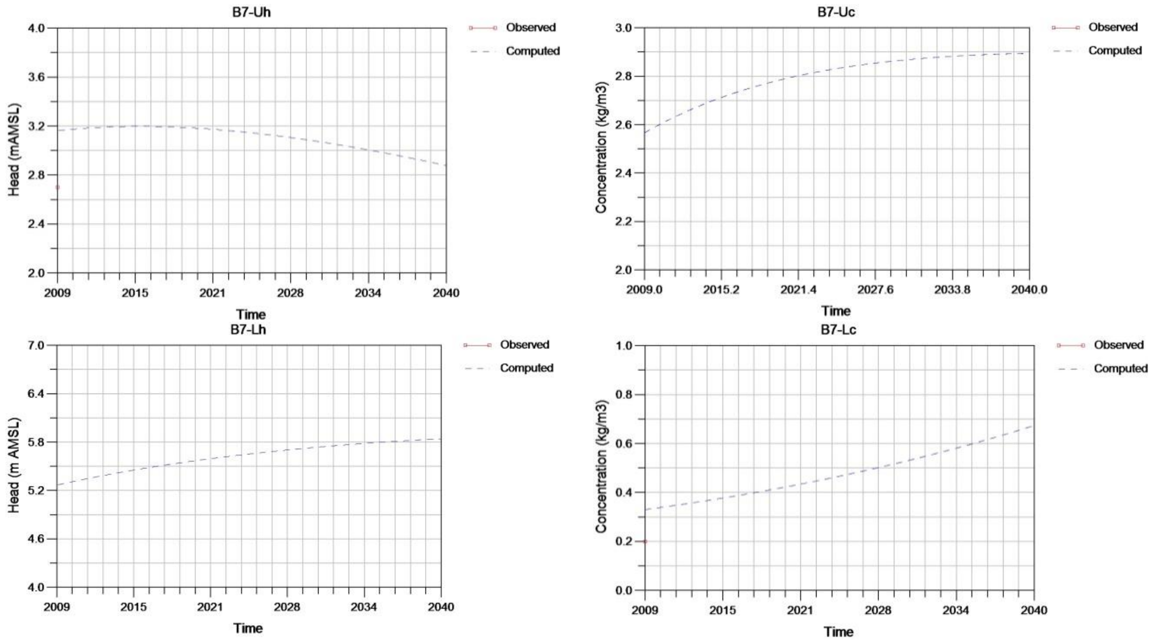


Fig 6.18 Head and salinity concentrations in the upper deep aquifer (top row) and lower deep aquifer (bottom row) for bore 7 at Chota Nishanbaria Chak Mouza near coastal boundary from 2009 to 2040.

7. Key Findings and Recommendations

7.1 Groundwater resource potential

108. The areas where the deep aquifer shows lower groundwater potential are areas north and south of Mathbharia, between Bhandaria and Mirzaganj. We emphasise that the lower resource potential of the deep aquifer is limited by the depth of penetration which results in a reduced aquifer thickness and consequently a lower transmissivity. We would recommend a deep drilling program to at least 390 m BGL similar to the Amtali bores in order to determine the resource potential of the lower deep aquifer, particularly in the vicinity of Mathbharia where there is an acute need for water supply.

109. It would also be noteworthy to undertake a survey of salinity levels in the existing wells before commencing drilling. Simply put the aquifer yields may be good but if the salinity is over 1000 mg/l it is not useable for potable supplies.

110. The groundwater maps provide guidance on areas of good groundwater potential and where there is increased probability of finding high yielding aquifers. Another good use of these maps would be to guide drilling programs in so far as to identify areas to avoid drilling. These areas are typically characterised by low transmissivity and low probability of finding suitable high yielding aquifers.

111. The map of chloride distribution is based on 40 sampled points consequently the results need to be interpreted with caution. It should be noted that the number of sampling points are on the low side considering the variability encountered in these aquifers. There is a clear need to undertake a survey of deep aquifers in the Barisal Division to locate and identify wells which can be used for water quality monitoring. This would guide the selection of suitable locations for deep tubewells for community water supply.

112. There are two deep tubewells which exceed the Bangladesh standard. The deep tubewell south of Nazirpur has a measured arsenic concentration of 0.06 mg/l, and the tubewell north of Agailjhara has an arsenic concetration of 0.13 mg/l. Both these wells need to be examined with a borehole camera to ascertain the possibility of casing leaks or splits. Details of when the bore was constructed and the lithological information for these bores also need to be examined with continued monitoring. Both these wells are in excess of the 0.05 mg/l limit for arsenic and consequently are not safe for potable water use. Considering that a number of deep tubewells around Agaijhara and to the south of Nazirpur are arsenic-safe, it is more than likely that the well casing has been compromised.

7.2 Amtali cross-section model

113. The Amtali cross-section model has been used to assess the long-term impact of increased groundwater usage from 1969 to 2009. This has shown there is negligible impact on sustainability of the system during this period for most locations along the transect. However, close to the coast the seawater interface may affect bores close to the coastal boundary such as bore 7 in (Barabagi Union). There are also other bores close to the coastal boundary which may be affected in the medium term as both demand and sea-levels rise.

114. Additional scenarios with sealevel rise and increased groundwater pumping from 2009 to 2040 showed increase in salinity for bores closest to the interface. Salinity

for bore 7 increased from 0.6 kg/m^3 in 1969 to 2.9 kg/m^3 (2900 mg/l), which is well above 1000 mg/l making it unsuitable as a drinking water source. This would suggest that the proximity of this bore to the coast makes it vulnerable to seawater intrusion particularly with increased pumping and sea-level rise.

115. The water levels for the lower deep aquifer at Amtali decreased by 23 m and salinities increased by 400 mg/l due to increased extractions to meet demand till 2040 which increases the risk of salinity migration from overlying clay layers. mg/l. When pumping rates are high as in the lower deep aquifer there is a greater risk of larger drawdowns and consequently a greater need for regular monitoring of the water levels and salinity of the aquifer at this location.

116. The pumping and operation of the tube wells should be such that salinities are not allowed to increase beyond 500 mg/l. Where salinity levels are already higher than 500 mg/l then regular monitoring of water levels, salinity and pumping rates should be undertaken to ensure that salinities remain below 1000 mg/l. This would allow a long term sustainable supply for coastal community. As the demand for potable water increases, it is only a matter of time before more deep wells are drilled to tap the lower deep aquifer. Thus a system of licensing and managing high extraction wells such as municipal water supply wells and irrigation wells may be required in the near future.

117. The Amtali model is a conceptual model as access to groundwater levels and salinity information is required for model calibration and for future modelling efforts. Improved mapping and modelling requires spatial and temporal data on water levels, salinity and groundwater usage data over a sufficient number of years for model calibration. A considerable body of data is available within various GOB agencies and with NGO's. Improved access to this data would result in improved outcomes for important national projects that contribute to poverty alleviation and improved resilience for coastal communities. Simply put there is increased economic costs to the country when access to data is limited as projects get done in a piecemeal fashion and where lack of data access hinders progress.

118. Access to improved information is necessary to calibrate the model and for future models that are required for the coastal zone. A regional groundwater model for Barisal Division would be very useful for improved management of groundwater such that sustainability of the system is preserved for coastal communities. Data on the hydrogeology, aquifer geometry and aquifer parameters, together with historical records of temporal data such as water levels and pumping provide a platform on which to base a numerical model. The reliability of model predictions depends on the extent and accuracy of the spatial and historical data that are available.

119. Improvements can always be made, particularly since there are a number of NGO's and government organisations drilling deep bores in the coastal zone. However, there is no mechanism for licensing bores, nor any guidelines of the minimum amount of information that needs to be collected and archived. The DPHE is the logical agency for archiving and storing borelogs and other aquifer information as they already have an Aquifer Database Inventory Program in place. The Groundwater Circle within BWDB is also another source of information. A framework for sharing and having access to this data is required so that future project outcomes are enhanced based on all available information. Ultimately this will benefit local communities, and improve the impact of development projects in-country.

120. It is not economically viable to meter ever single well, nor is it necessary, however, knowing the locations of all wells, their use (domestic or irrigation), and the number of households it serves would improve estimates of groundwater usage. It is however necessary to meter all Municipal water supply wells and irrigation bores as these are typically large users of groundwater. A survey needs to be designed to capture basic information (location, coordinates, lithology, water levels and water quality and surveyed levels).

121. There is a small ingress of the seawater interface which may affect bores close to the coastal boundary such as bore 7 in Barabagi Union. There are also other bores close to the coastal boundary which may be affected in the medium term as both demand and sea-levels rise. We recommend a set of sentinel bores be used to provide communities with early warning of increasing seawater intrusion risk which could have an impact on their drinking water source.

8. Strengthening groundwater governance in the coastal zone

122. Groundwater is a major natural resource in Bangladesh and plays a much more important role in the coastal areas where many coastal towns are dependent on freshwater supplies from the underlying deep aquifer system. In the long term as demand increases, there will be increased reliance on the groundwater from the deep system and for towns that are currently dependent on surface water supplies, conjunctive use of groundwater and surface water will be required, given that surface water may suffer from significant salinity intrusion in dry season. Thus town like Pirojpur that currently rely on surface water may be forced to look for other alternatives if salinity at the intake source increases during the dry season.

123. As the coastal zone develops over the next several decades, competition for land and water resources will intensify. Thus institutional arrangements and good governance in the water sector will be critical to managing development of groundwater resources in a sustainable manner. Improving water governance by capacity development at the pourashava level is recommended.

124. The implications of climate change on saltwater intrusion on the groundwater system of the coastal region in the Districts of Barguna, Patuakhali and Pirojpur will need detailed assessment. Given the importance of groundwater to the people in these coastal districts and for long-term development and sustainability, it will be vital to develop a regional model covering these districts to assess and manage risks associated with climate change.

125. Improved land and water management planning is required along with and a regulatory framework for licensing high yielding water supply wells and to determine allocations.

126. Projected population in the coastal zone is likely to double by 2050. This will increase demand on the groundwater system and with the impacts of climate change better management will be required to ensure water supplies during long duration droughts or longer than usual dry periods. There will also be additional demand for irrigation during the dry season to meet food security needs for the coastal zone.

127. The increased vulnerability of the coastal zone will increase the risks to livelihoods and the loss of coastal land to sea level rise will force people to migrate inland. The 0.88 m sea level rise scenario shows extensive coastal areas up to Patuakhali and Bhola will be impacted by salinity intrusion resulting in a significant loss of productive coastal land. This in turn may lead to higher population density in the new coastal areas due to migration and significantly increase water demand where it has not been anticipated.

128. Storm surges of 1 or more meters depth would affect additional coastal land and water resources, thus efforts to mitigate the impacts of storm surges and sea-level rise area priority for coastal towns.

129. The sustainability of groundwater resources in the coastal zone will become an increasingly important consideration as more wells are drilled to meet demand. There are many deep hand tube wells that need to be accounted for so an improved estimate of total groundwater extraction can be made. Similarly, there may be other deep wells being used for commercial use that need to be accounted for.

8.1 Operational management and monitoring of groundwater

130. At present no agencies have a programme in place to support or monitor deep tubewells. There are many reasons for this, not the least of which is the sheer number of tubewells in coastal areas. Other issues include problems with locating and identifying wells, as many of the wells do not have coordinates and some have inconsistent co-ordinate systems. Some records have approximate locations based on district and upazilla names, making the process of locating wells from approximate location descriptions problematic. There is no system for recording new deep tubewells, abandoned wells, or wells that have been relocated. Systematic purging of wells for salinity or water quality sampling is practically impossible because wells are used throughout the day. We are not suggesting here that every single well be monitored however, a systematic monitoring programme needs to be established using a network of dedicated observation wells that are easy to access and where routine observations are undertaken to improve the understanding of deep groundwater resources.

131. Building groundwater monitoring and management capabilities at the local government level is needed. The key recommendations are bi-annual monitoring of water levels and salinity, and monitoring groundwater usage for water supply wells owned by the Pourashavas. This can be supplemented by community surveys of groundwater usage for private deep tubewells.

132. We recommend metering of all municipal water supply wells and irrigation bores as these are typically large users of groundwater. A survey needs to be designed to capture basic information (location, coordinates, lithology, water levels and water quality and surveyed levels).

133. Several thousand deep tubewells have been drilled by NGOs in Bangladesh. Many of the databases do not have coordinates for these wells. It is recommended that in future projects a survey team is engaged to obtain GPS coordinates, location photos, and groundwater usage for improved groundwater mapping. Information of these wells needs to be brought under an integrated database so as to enable assessment of the resource and allow knowledge based future planning.

134. Bores close to the coastal boundary may be affected in the medium term as both demand and sea-levels rise. We recommend a set of sentinel bores be used to provide communities with early warning of increasing seawater intrusion risk which could have an impact on their drinking water source.

8.2 Future risks associated with groundwater abstraction from deep aquifers

135. In recent studies on water quality analysis for the deep tubewells in Barisal Division has found no evidence of deteriorating water quality for iron, arsenic, salinity and other water quality parameters. The risk of lateral salinity intrusion in the deep aquifer at Amtali and Galachipa seems to be very low, at least for the current level of extraction. Based on these observations it can be concluded that current pumping rates can be maintained. In the event that salinity levels increase or water levels drop significantly, water abstraction from production wells could be reduced to avoid the risk of saline water intrusion into the aquifer.

136. These findings confirm previous inferences that deep tubewells provide good quality potable water, and are also the most economic and socially acceptable

intervention for arsenic mitigation in Bangladesh. Although the GOB policy is to favour the use of surface water, most of the coastal communities seem to prefer direct use of deep groundwater.

137. With increasing depth, the deeper aquifers are increasingly separated from surface water bodies by clay and silt layers (aquitards). The long-term risks of pumping from the deep aquifers are (i) downward leakage of arsenic rich waters from shallow aquifers if downward gradients are created by excessive drawdowns in the deep aquifers; (ii) the downward leakage or lateral intrusion of residual salinity left from pockets of trapped high salinity groundwater.

138. Since access to safe drinking water is considered to be a fundamental and universal human right, restricting the use of deep groundwater is not an option. At the same time, there are no regulations to control excessive abstraction. Deep groundwater is important not only for potable water but also for irrigation which is essential for food production and food security for Bangladesh. We do not propose regulation, rather the introduction of principles and awareness for improved governance of groundwater as a shared community resource.

139. In the future there may be a need to find alternatives to deep groundwater in some areas due to deteriorating water quality. These may include (i) new surface water supply schemes; (ii) treatment of shallow or deep groundwater; and (iii) managed aquifer recharge schemes such as possible injection of treated surface water during the monsoon when surface water sources are plentiful.

140. For town like Mathbharia where the salinity of groundwater is beyond permissible level, other options can be explored. Managed aquifer recharge for the shallow saline groundwater are possible options along with surface water supplies and rainwater harvesting.

8.3 Sustainability of deep groundwater abstraction

141. Deep tubewells in the coastal regions have provided safe and reliable community water supplies for the past 13 years for Amtali and Galachipa and several other locations. The composition of the groundwater quality has remained stable and continues to provide safe potable water for these coastal communities, suggesting that the aquifers can continue to supply water for many decades.

142. Whilst sustainability of deep groundwater resources needs to be understood and implemented, this should be undertaken over a long time horizon as demand and risks to groundwater quality increase. This also gives enough time for alternative strategies (such as Managed Aquifer Recharge Schemes) to be developed and implemented. Additionally the use of brackish groundwater will need to be considered in future years.

143. Utilisation of groundwater storage for specified planning periods and other adaptive management strategies are being explored and advocated in Australia (Lawson et al. 2012) and in Bangladesh (Ravenscroft et al. 2013). With increasing demand for groundwater the modelling tools must be put in place to better understand the implications of increased groundwater abstraction and aquifer stress.

144. The formation of a Groundwater Users' Association that can progressively increase their capacity to monitor and manage groundwater and improve groundwater governance at the local level would assist in promoting the understanding of key resource sustainability issues. This would also provide for community support for

alternative water-saving technologies to be implemented in areas that may experience deteriorating water quality in the future.

145. A rights-based approach to further development of the deep aquifer is suggested, based on increased storage utilisation over a specified planning period augmented by adaptive groundwater management. This will allow for continued supply of potable and irrigation water for present and future generations, leading to continued improvements in the health and economic well-being of coastal communities.

146. Future studies may also wish to draw on the knowledge banks within IUCN who have successfully used mangroves to act as buffers for coastal areas.