GOVERNMENT OF TAMILNADU

PUBLIC WORKS DEPARTMENT

WATER RESOURCES DEPARTMENT

TRICHY REGION,
TRICHY.

ADB IND(44429):CLIMATE ADAPTATION THROUGH SUB-BASIN DEVELOPMENT PROGRAM

PROJECT OF VENNAR SUB-BASIN OF CAUVERY BASIN

DETAILED PROJECT REPORT

Infrastructure Improvements and Reconstruction Works

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CLIMATE ADAPTATION THROUGH SUB-BASIN DEVELOPMENT PROGRAM (CASDP) IN CAUVERY DELTA

Section-I

CHECK LIST

SI. No.	Item	
1	Was the original project given investment clearance by Planning Commission	Not applicable as most of components of the project were taken up prior to the date when Planning Commission issued circular for clearance of project. Moreover this is a very old system.
2	Has the performance evaluation of the existing project been carried out?	Yes
3	Have the salient features of the project as envisaged at the time of execution of project and as at present, been indicated?	Yes, to the extent as the information is available
4	Have the irrigation potential of the existing project as originally envisaged, potential created and utilised and reasons for variations been indicated?	No change in irrigation potential
5	Has the culturablecommand area been actually assessed and compared with that at the time of planning of the project and shortfalls/excesses, if any, discussed	No change in CCA
6	Has the hydraulic survey of canal/distribution system been carried out?	Yes
7	Have the deficiencies In the existing irrigation system been identified	Yes
8	Has the need for modernisation been justified?	Yes

11. Benefits- Additional- annual
<u>Agricultural</u>

Annual Net Benefit of Project-1 - 16959 INR Lakhs

(Table 24.6 Agricultural Annual Net Benefits)

12.0 Revenue (Rs)

Paragraph No.		Item	Existing (INR)	Proposed (INR)
12.1	Revenue	(a) Irrigation	nil	nil
		(b) Domestic Water Supply	Not available	Existing ratesto continue
		(c) Industrial Water Supply	Not available	Existing rates to continue
		(d) Power	Not available	Existing rates to continue
		(e) Others	Not available	Existing rates to continue
12.2	Revenue	Irrigation Cess (Other than water rates)	Nil	Nil
12.3	Revenue	Recovery of betterment levy	Nil	Nil
12.4	Revenue	Other Sources (If any)	Nil	Nil
Total	Revenue		Nil	Nil

9	Have the hydrological studies been reviewed, compared with those made at the time of preparation of the original project if available and reasons for variations recorded in respect of: (i) rainfall (ii) runoff (iii) flood (iv) sediment (v) ground water (vi) Evaporation	Hydrological studies at the time of preparation of original project are not available. Hydrological studies for the six rivers included in the project have been carried out.
10	(a) Have changes in the upstream withdrawals/diversions for industrial use, power generation, drinking requirement andother developments in the upper catchment to the extent which can be collected with reasonable efforts been described? (b) Have the changes in power generation/consumption In power for the lift irrigation scheme been described?	(a) No changes are envisaged. (b) Data on existing and proposed power projects in the project area has been collected. (c) Power required for the pumping schemes in the project area has been estimated keeping in view the electrical and mechanical equipment to be installed as replacement of the existing equipment as part of rehabilitation of the schemes.
11	Have the semi-detailed soil surveys been carried out for the entire command (if not entire command then extent covered) and soil and land irrigability classification brought- out in the report? (For the Project to be acceptable, semi detailed soil survey in at least 50% of command should have been carried out	No. Secondary data available on type of soils in the area have been collected. In the project it is proposed to improve the infrastructure on main channels only and there is no proposal to take up works on distributaries, minors, sub-minors and water courses, field channels and drains (Class A, B, C, D, E, F, and G channels) and OFD works.
12	Is the Crop Water Requirement determined by the modified Penmen method?	Yes, crop water requirement has been estimated as per CWC guidelines.
13	Have water requirements for other uses been worked out?	There is no proposal to alter the existing water availability and utilisation. The improvements to the existing infrastructure will improve the efficiency and performance of the system and also provide flood protection and drainage improvement in the area particularly keeping in view the impact of climate change.
14	Has justification for the proposed cropping pattern been furnished?	The dominant crop in the area is paddy with little area under black/green gram and sugarcane. The climate, soil and water availability do not permit major change in it. However, it is proposed to encourage less water consuming varieties of paddy such as SRI variety.

15	Have the cropping pattern & proper cropping calendar been devised with a view to maximise the production and canal closures for maintenance etc. ensured? Have these been concurred by the Agriculture Department?	Yes. Agriculture department has been extensively consulted.
16	Are the areas and percentage of CCA that will be irrigated during Kharif, Rabi, two seasonal, hot weather and perennials been indicated and compared with cropping pattern as existing prior to taking of the project, originally envisaged and actually developed after completion of the project?	Water is available for Eight months period from June to January only. Two seasonal crops are grown in a small area where fresh ground water is available. Two crops of paddy are grown in the area where surface and ground water is available. In other areas only one crop of paddy is grown. Practically there are no hot weather crops in the area. In small area two seasonal crops are grown.
17	Is the justification furnished for continuing with/or taking up perennial and hot weather crops from the reservoir?	It is not proposed to encourage perennial and hot weather crops.
18	Have the most suitable depths and frequencies of irrigation to be adopted, based on the characteristics of the' 'soil and crops been worked out?	Yes.
19	Have the values of conveyance efficiency, field application efficiency and overall water use efficiency been indicated with basis thereof?	Yes on the basis of data/information available in Cauvery Modernisation Project prepared by the PWD, Government of Tamil Nadu. Field tests to assess the efficiency of existing system have not been carried out.
20	Has the pattern of releases (10 daily/monthly) from the diversion/storage headworks been worked out &compared with these envisaged originally	There is no reservoir in the project area. Releases of water are made from Mettur reservoir outside the project area keeping the availability of water in the reservoir and water demand in view.
21	Has the canal been redesigned to cater for peak requirement with 10 percent increase (20% for small reservoirs) for rush irrigation. If not, have the alternative proposals for carrying therequired discharge been discussed?	The main channels in Vennar system are peculiar in the sense that they are the natural streams that carry irrigation supplies as well as drainage from the area. These have evolved over a long period and cause flooding and drainage congestion when there is intense rainfall in the area. Over the years, these have silted up and there is lot of vegetative growth. The banks are steep and do not have freeboard as required by BIS Codes. In most of the reaches there are no inspection roads. As a result, there are bank failures in monsoon season and pose problems in effective monitoring and transportation of materials for quick repairs.

		It is, therefore, proposed to resection them which includes clearing of vegetation, desilting, flattening of bank slope, raising the height to provide proper freeboard and increase the top width to provide access. Since these channels also carry surface runoff from the adjoining area, their capacity is much more than the normal irrigation supply. The improvements/reconstruction of head sluices, drainage sluices, drain infalls and cross regulators will help in improving irrigation management. Since these channels outfall in to the sea, there is ingress of sea water inland. To check it, regulators have been constructed near the outfall in to the sea. These also serve for managing irrigation release in to the A and B Class channels. In some cases these are located 10 – 20 km upstream and lot of area is affected by sea water. It is therefore, proposed to construct new regulators near the outfall in to the sea to control ingress of sea water and provide fresh water storage upstream for various purposes.
22	Whether supplementation from ground water has been considered?	The ground water in deep aquifers in most of the project area is saline limiting its use for agriculture. Fresh water is available only in shallow aquifer. It is already fully exploited for supplementing irrigation in times shortage of irrigation supply from Mettur reservoir.
23	Are the supplies available sufficient to meet the requirements for ensuring 75 per cent dependability? If not. have the possibilities of augmenting the supplies been discussed either by increasing the storage or supplementing by ground water etc.?Have the revised reservoir operation tables been furnished?	The availability of water is regulated by Cauvery Water Dispute Tribunal Award which has apportioned available water at 50% dependability among the basin states. There are numerous minor tanks in the area which store surplus water.
24	Has a study of the ground water potential of the command area, the present level of the ground water use and the scope of future ground water utilisation, been carried out and included in the project report?	Yes,
25	Have the economics of ground water development been studied	Yes

26	Has the possible impact on ground water recharge on account of lining of the-system been kept-in view in the scheme of ground water utilisation?	Lining of main channels is not proposed.
27	Has the possibility of the ground water for irrigating areas not commanded by the canal system been considered	Yes. High ground on sea side of Vedharanyam canal is proposed to be irrigated from the new Tail End Regulator proposed on Harichandra river.
28	Has the quality of surface water as also ground water & drainage water, if intended-for irrigation use, been tested?	No. Results on quality of ground water collected from the PWD been used.
29	Have the requirements of drainage in the command area, been studied and a suitable integrated drainage plan drawn- up and provided for in the cost estimate?	No. The activities in this project are confined to main channels. However the capacity of one of the drain infall on Harichandra river has been reviewed in view of the provisions of IS code on surface drains and it has been proposed that capacity of all the drain infalls and drainage sluices to be reconstructed be reviewed at before construction and construction taken up accordingly.
30	Have the arrangements for the following been considered and provided for? (a) Execution of OFD works (b) Training programmes for field staff and fanners - existing positionand proposals for strengthening (c) Participatory Irrigation Management (PIM), Water Users Associations (WUA), and turnover of the system to WUAs. (d) Provision of extension services (e) Providing important inputs like seeds, fertilizers etc.	The activities in this project are confined to main channels. (a) No, OFD works are not proposed as a part of this project (b) Training programme for field staff and farmers have been discussed in the report. (c) As above (d) Yes (e) Yes
31	Have adequacy of road communication facilities and if not, the necessity of improvements been- discussed and provided for'?	Yes.
32	Have matters about the improvement inreliability/dependability of the annual Irrigation in the existing/proposed command area been discussed in the light of modernisation?	Yes. The availability of water is regulated by Cauvery Water Dispute Tribunal Award which has apportioned available water at 50% dependability among the basin states. There are numerous minor tanks in the area which store surplus water.

33	Have the net benefits due to the project been estimated and concurred by the Agricultural Department?	Yes, net benefits have been estimated on basis of inputs received from State Agriculture Deptt.
34	Has the concurrence of the State Finance Department been obtained for taking up the project at the estimated cost	Yes, In the State budjet for the year INR 2000 millions was allotted
35	Whether the scheme has already been started? If so, is the present stage of construction indicated	Yes, In the State likely commencement is in the last quarter of 2014
36	Is the scheme included in the plan? If not, what is the present position regarding its inclusion in the plan?	Yes, included in the state plan
37	Have the year wise requirement of funds been indicated	Yes
38	Is the scheme covered under state sector or Central sector?	State Sector
39	Is the scheme covered or proposed to be covered under any foreign assistance/aid agreement	Yes, 70% of this scheme cost to be met out from loan assistance by Asian Development Bank under Climate Adaptation through Sub-basin Development Program (CASDP)
40	Are the detailed cost estimates included in the Report	Yes
41	Has the benefit-cost ratio been worked out? Whether depreciated cost of completed works has been included in the calculations?	Yes. The existing works are more than 50 years old and have outlived their useful life. The irrigation system is likely to collapse within next 2-5 years if improvements are not undertaken. Therefore, the depreciated cost of existing works has not been considered
42	Whether Internal Rate of Return (IRR) has been worked out?	Yes
43	Are the financial returns attached?	Yes
44	Are there any special reasons to undertake the project if it is unproductive and whether these have been recorded in the Report?	The project is economically viable.

45	Have the rates of betterment levy proposed, the period of recovery and the estimated total recovery been indicated?	No
46	Are there any charges levied for irrigation facilities as distinct from water charges?	No
47	Are the water rates for different crops indicated?	The Go TN does not collect any water charges except the land revenue.
48	Have the rates of betterment levy, water charges, etc. been compared with those obtained in other regions of the State?	Not applicable
49	Has the concurrence of the State Revenue Department been obtained for these rates	Yes
50	Have the O&M aspects (both financial as well as management) been discussed? How are the O&M costs proposed to be met?	Yes. O&M costs will be met through state budget
51	Have the programme of construction and the expenditure involved been furnished?	Yes
52	Has the requirement of staff been estimated and furnished with justification?	Yes. This has been explained in Chapter 22 of DPR.
53	Has the adequacy of the existing irrigation laws and revision, if any, considered necessary been discussed?	Yes. These are explained in the Main report of CASDP
54	Has the impact of the scheme on the overall development of water resources in the basin/state been discussed?	Yes. This is explained in the Main Report of CASDP
55	Whether views of water users about proposed works in modernisation project been obtained and described in the Report?	Yes. This has explained in the Social Survey Report of CASDP
56	Have environmental/ecological aspects been discussed in the Report & environmental clearance obtained from MOEF	Yes, Initial Environment & Ecological assessment been made. Clearance of MoEF is yet to be obtained.

57	Does the project involve acquisition of forest land? Has the MoE&Fbeen approached for clearance under Forest Conservation Act 1980?	No. Therefore, MoE&F has not been approached for this purpose
58	Does the project involve any re-settlement? Whether rehabilitation of PAPs provided for	Yes. This has been explained in Chapter 18 of DPR.
59	Does project involve rehabilitation of SC/ST population? Has the rehabilitation package for them been cleared by Ministry of Social Justice & Empowerment	No. SC/ST population is not being affected under the project. Therefore, not applicable
60	Have the socio economic studies (bench mark surveys) been carried out?	Yes. A separate Social Survey Report has been prepared and submitted.
61	Have the interstate aspects been examined & discussed?	Yes, the project does not have any interstate aspects as utilisation is within the water share of Tamil Nadu allocated by CWDT.
62	Have the list of on-going programs of Agriculture Department in Command Area been given?	Yes
63	Have the provisions of Indus Water Treaty, 1960 for schemes on western rivers of Indus Basin been examined and discussed	Not applicable

CLIMATE ADAPTATION THROUGH SUB-BASIN DEVELOPMENT PROGRAM (CASDP) IN IN CAUVERY DELTA

Section-Z

SALIENT FEATURES

1	Name of the project	The Climate Adaptation through Sub-Basin Development Program (CASDP)
2.0 2.1	General data District(s)	 Thanjavur, Thiruvarur and Nagapattinam
2.2	Tehsil(s) / Taluka(s	Eight Talukas in Thanjavur district and seven talukas each in Thiruvarur and Nagapattinam districts
2.3	River / tributary	The Cauvery Delta contains three irrigation systems namely, the Cauvery, Vennar & Grand Anicut and One drainage system Coleroon. The project area covers six branches of Vennar System, namely, Adapar, Harichandra, Pandavayar, Velliayar, Valavanar and Vedharanyam Canal. Pumping schemes in these river basins are also included in the project.
2.4	Location of dam / diversion structures	Mettur dam (11degree 48minute 58second N, 77degree 48minute 38second E): Salem district, Tamilnadu State – Storage reservoir Upper Anicut (10degree 52minute 58second N, 78degree 34minute 58second E):: Trichinapalli district, Tamilnadu State – Cauvery river branches in to two rivers, namely, the Cauvery and Coleroon Grand Anicut (10degree 49minute 48second N, 78degree 48minute 36second E):: Thanjavur district, Tamilnadu State – Built in about 200 AD. River Cauvery bifurcates in to two rivers, Cauvery anVennar. It regulates release of water in to Grand Anicut Canal, Vennar and Cauvery rivers and flood water is diverted to Coleroon river through Ullar drain VVR head Regulator (10degree 49minute 15second N, 79degree 3minute 12second E):: Thanjavur district, Tamilnadu State - The Vennar river branches in to Vettar, Vennar and Vadavar rivers and water is released in to these rivers in fixed proportions. Flood water generated from catchment area between Grand Anicut and VVR head regulator is released in to Vettar branch. Koriayar Head Regulator (10degree 47minute 25second N, 79degree 23minute 51second E): Thanjavur district, Tamilnadu State – Vennar river branches in to Vennar, Paminiayar and Koriayar rivers

		Pandavayar Regulator (10degree 45minute 46second N, 79degree 24minute 34second E): Thiruvarur district, Tamilnadu State - Vennar branches in to Pandavayar and Vennar rivers. Velliayar Regulator(10degree 28minute 51second N, 79degree 44minute 50second E)::Vennar branches in to Veilliayar and Vennar rivers. Vennar river joins Harichandra. Mulliayar Head Regulator(10degree 28minute 51second N, 79degree 44minute 50second E):Thiruvarur district, Tamilnadu State - It is across Koriayar river and this divides the river in to Ayyanar, Harichandra, Mulliayar and Koriayar rivers. Adapar Regulator: 10degree 36minute 47 seconds N, 79degree 33minute 9seconds E) Thiruvarur district, Tamilnadu State. Valavanar Origin (10degree 31minutes 42seconds N, 90degree 38minutes 41seconds E) Vedharanyam Canal (10degree 44minutes 38seconds N, 79degree 30minutes 15seconds E)	
2.5	Name of river/basin	Cauvery River basin – Vennar Sub Basin	
2.6	Longitude &Latitude (at Metturdam)	11º48'58"N 77º48'38"E	
3.0	Socio-economic aspects	Original	Revised
3.1	District(s) benefited	Thanjavur, Thiruvarur, Nagapattinum	Thanjavur, Thiruvarur, Nagapattinum
Original (annual house hold income)			
3.2	a) Farming : b) Agriculture labour: c) Livestock: d) Fisheries: e) Petty trading: f) Artisan : g) Business: h) Service (govt+private) : Source: Social Survey, CASDP (2014)	Rs.44,288 Rs. 19,382 Rs.16,520 Rs.48,856 Rs.23,182 Rs.12,500 Rs.68,820 Rs.78,842	Post – Project assessment to be done to estimate the enhanced income levels

3.3	Land holdings a) landless b) Marginal (lha) c) Small (1-2 ha) d) Medium (2 – 4ha) e) Large (4-10h) f) Average Source: Social Survey, CASDP (2014)	: 8.4% : 38.7% : 23.5% : 26.9% : 2.4% : 2.0 ha	No Change
		Original	Revised
3.4	Population benefited Original (2011) Thanjavur Thiruvarur Nagapattinam **a)Total for three districts** In Project 1 of CASDP about 73% of the population in Thiruvarur and Nagapattinam districts is estimated to be benefited. Project 2 and Project 3 will include Thanjavur District, in addition to Thiruvarur and Nagapattinam Districts b) Scheduled Caste c) Scheduled Tribe d) Other backward castes	: 24,05,890 : 12,34,277 : 16,16,450 **: 52,86,617** : NA : NA : NA	No Change
4.0 4.1	Hydrological data Catchment area at dam site(sqkm)	42217	No Change
		Original	Revised
4.2	(a) Maximum annual rainfall	1774mm	No Change
	(b) Minimum annual rainfall	653mm	No Change
	(c) Mean annual rainfall	1192mm	No Change
	d) 75% dependable annual rainfall	933mm	No Change
4.3	Annual runoff (Thousandmillion cubic feet) (a) Average	508	No change
	(b) Maximum	NA	No change
	(c) Minimum	NA	No change
	(d) 75% dependability	451.4	No change
4.4	Design flood	12914.6 Cumecs	No Change

5.0 Ground Water

		Present	Proposed
5.0	<u>Water utilization(Mcum)</u> (a) Reservation for upstream use	Not applicable, as the ground water utilisation from Vennar basin has been considered	No change
	(b) Reservation for downstream use (MCM)	200MCM Present data is not adequate and reliable to estimate availability and present utilisation of ground water accurately	No change. Ground water monitoring is proposed for accurate and reliable estimates of ground water.
	(c) Utilisation through the project (mm)	1697	No change. Ground water monitoring is proposed for accurate and reliable estimates of ground water.
	(i) Irrigation (mm)	1160	1160
	(ii) Power Generation	NA	Nil
	(iii) Drinking water and Industrial use	46	46
	(v) Others,	NA	NA
	(d) Water saved through modernisation	Nil	Nil
6.0	<u>Ground water (M cum)</u> (a) Potential	1200	
	(b) Present use	80% of availability for irrigation and water supply.	
	(c) Proposed use after modernisation	1200	
	(d) Balance for future utilisation after modernisation	Nil	
		Original	Revised
7.0	<u>Reservoir data</u> **(a) Storage (TMCft)** (i) Gross storage (ii) Dead storage (iii) "Live-Storage (iv) Annual carry over	95.66 2.19 93.47 --	No Change
	(b) Elevation (El-ft) (i) .Maximum waterlevel (MWL) (ii) , Full reservoir level (FRL) (iii) Lowest water level (LWL) (iv) Dead storage level (DSL)	(+) 242.620m (+) 240.790m (+) 204.220m (+) 204.220m	No Change

	(v) River bed level (RBL) (vi) Irrigation outlet level (lOL) 1) Low Level Sluice Level 2) High Level Sluice Level 3) Dam Power House 4) Tunnel Power House	(+) 190.500m (+) 204.220m (+) 219.460m (+) 195.070m (+) 204.220m	
	(c) Water spread area (sq.km) at (i) Dead storage level (ii) Full reservoir level (iii) Maximum water level	--- 138.750 Sq.km 153.460 Sq.km	
	d) Water Quality Reservoir/Canal/River (downstream) (i) Physical	Test Results attached	
	(ii) Chemical	Test Results attached	
	(iii) Bacteriological	Test Results attached	

8.0 Canal system (Irrigation) –Information to be furnished for each Main/Branch canal separately .

Sl. No.	Parameter	Name of branch rivers (Existing/Proposed)					
		Adapar		Harichandra		Velliayar	
		Existing	Proposed	Existing	Proposed	Existing	Proposed
a	Nature of branch river	Irrigation – cum - Drainage	Irrigation – cum - Drainage	Irrigation – cum Drainage	Irrigation – cum - Drainage	Irrigation – cum - Drainage	Irrigation cum - Drainage
b	Length (km)	44.5	44.5	43.6	43.6	47.9	47.9
c.1	Normal Supply Level (m)	F +8.210m R +8.010m	F +8.210m R +8.010m	F +12.595m R +12.320m	F +12.595m R +12.320m	F +16.480m R +15.580m	F +16.480m R +15.580m
c.2	Maximum Water Level	F +9.370m R +9.150m	F +9.370m R +9.150m	F +12.790m R +12.595m	F +12.790m R +12.595m	F +16.480m R +15.660m	F +16.480m R +15.660m
c.3	25 year High Flood Level (m)	NA	+ 8.740m	NA	+ 12.360m	NA	+ 16.900m
d.1	Normal Supply Discharge at canal head (m3/sec)	1.02	1.02	17.188	17.188	26	26
d.2	Maximum Supply Discharge at canal head (m3/sec)	1.54	1.54	25.678	25.678	NA	NA
d.3	25 year High Flood Discharge (m3/sec)	31.15	31.15	61.99	61.99	32.77	32.77
e.1	Length of A – Class Channels(in Kms)	60	60	163.80	163.80	161	161
e.2	Length of B – Class Channels (in Kms)	138	138	346.50	346.50	280	280
e.3	Length of C – Class Channels	5	5	46.50	46.50	177	177
f	No. of villages covered	28	28	63	63	75	75
g. 1	Gross Command Area (GCA) (ha)	-	-	-	-	-	-
g.2	Culturable Command Area (CCA) (ha)	11548	11548	13822	13822	12622	12622
g.3	Annual Irrigation (ha)	11548	11548	13822	13822	12622	12622
g.4	Intensity of Irrigation	100	100	100	100	100	100

S. No.	Parameter	Name of branch rivers (Existing/Proposed)					
		Pandavayar		Valavanar		Vedharanyam Canal	
		Existing	Proposed	Existing	Proposed	Existing	Proposed
a	Nature of branch river/drainage channel	Irrigation – cum - Drainage	Irrigation – cum - Drainage	Drainage	Drainage	Navigation – cum – Drainage. Navigation is defunct.	Drainage
b	Length (km)	38.2	38.2	19.3	19.3	39.6	39.6
c.1	Normal Supply Level (m)	+ 17.000m	+ 17.000m	Not applicable	Not applicable	Not applicable	Not applicable
c.2	Maximum Supply Level	+ 18.180m	+ 18.180m	Not applicable	Not applicable	Not applicable	Not applicable
c.3	25 year Flood Level (m)	NA	+ 15.440 m	+ 1.450m	-	+ 1.600m	-
d.1	Normal Full Supply Discharge at canal head (m3/sec)	-	Same as original	Not applicable	Not applicable	Not applicable	Not applicable
d.2	Maximum Full Supply Discharge at canal head (m3/sec)		Same as original	Not applicable	Not applicable	Not applicable	Not applicable
d.3	25 year High Flood Discharge (m3/sec)	78.17	-	324.40	-	52.50	-
e.1	Length of A – Class Channels	144.85	144.85	Not applicable as it is a drainage channel. There are tributary drains	NA	Not applicable as it is a drainage channel. There are tributary drains	NA
e.2	Length of B – Class Channels	297	297	NA	NA	NA	NA
e.3	Length of C – Class Channels	96.60	96.60	NA	NA	NA	NA
f	No. of villages covered	108	108	22	22	21	21
g. 1	Gross Command Area (GCA) (ha)	NA	NA	NA	NA	NA	NA
g.2	CCA/Drainage Area (ha)	11548	11548	15970	15970	19720	-
g.3	Annual Irrigation (ha)	760	17535	-	-	-	-
g.4	Intensity of Irrigation %	100	100	Not Applicable	Not Applicable	Not Applicable	Not Applicable

9.0 Power

S.No.	Parameter	Existing	Proposed
a	Capacity	This project not connected with this.	
i	Installed Capacity (MW)		
ii	Unit size		
iii	Size of power house		
iv	Type of turbine		
v	Rated head (m)		
vi	Rated/Design Unit discharge		
vii	Specific speed		
viii	Generator type		
ix	Capacity		
x	Voltage		
b	Power Benifits		
i	Firm Power		
ii	Energy		
c	Evacuation System		

10. Cropping pattern (crop wise) - Season wise

Name of Crop	Pre-project (% of CCA)	Planned Originally (% of CCA)	Actually Achieved(%of CCA	Proposed (% of CCA)	Remarks
Kharif					
Paddy (Kurvai) (May – August)	Not available	Not available	6.3 (Kuruvai and Thaladi)	13.8	
Paddy (Thaladi)sepember/October – March)	Not available	Not available			
Paddy (Sambha) (July/August – January)	Not available	Not available	56.80%	58.4	
Sub-total (Kharif)			63.1	72.2	
Summer					
Black Gram/Green Gram/Sesame	Not available	Not available			
Sub-total (Summer)					
Perennial					
Sugarcane	Not available	Not available			
(Sub-total perenneial)	Not available	Not available			
Grand total					

13.0 Cost

Item	Estimated Cost – Financial (INR Million) @ 2013-2014 SOR Of PWD
(a) Irrigation, flood control & Pumping Schemes	81,77.23
(b) Domestic Water Supply	No works are proposed for these items. The cost, therefore, is nil.
(c) Industrial Water Supply	
(d) Power	
(e) Others	
Sub – total (INR Million)	81,77.23
Completed works (Original)	Works are more than 50 years old. Original cost is not available.
Completed works (Depreciated)	Existing works have outlived their useful life. Depreciated cost is nil
Total Cost (INR Lakhs)	81,772.25
Maintenance of Head works (1% of Estimated Cost)	817.72
Interest on capital @ 10%	8,177.23
Depreciation on civil works @ 2%	1,635.45
Pumping System Depreciation on Electrical & mechanical works @8.33% of capital cost	101.92
O&M @ INR 180/ha for 87532 Ha	157.56
Total Annual cost (INR Lakhs)	**10,889.87**

14.0 Benefit Cost Ratio

	Financial	Economic
Overall @12% rate of interest	1.69	1.69
As per CWC norms		

1. Introduction

1.1. Background

The Climate Adaptation through Sub-Basin Development Program (CASDP) supports the implementation of the Government of India's National Action Plan on Climate Change (NAPCC) of 2008 and its National Water Mission (NWM). In support of the Government the Asian Development Bank provided technical assistance (ADB TA – 7417 – IND: Support for the NAPCC, 2010-2011) for the preparation of profiles of three contrasting sub-basins, the Sutlej in Punjab (for glacial and snow-fed systems), the Kshipra in Madhya Pradesh (for groundwater development system) and the Cauvery Delta in TamilNadu (for coastal systems).

The Climate Adaptation through Sub-Basin Development Program (CASDP) aims to establish institutions and systems in the State of Tamil Nadu to help local communities adapt to climate change with advancement of integrated water resources management (IWRM). The Water Resources Department of the Public Works Department, Government of Tamil Nadu is the executing agency. The proposed program follows another program. Support will be provided to conduct surface water, groundwater, and coastal modeling, improve drainage and flood control infrastructure, and sustainable use of scarce water resources.

CASDP is expected to comprise a sequence of projects in the Cauvery River Delta sub-basin, starting with the Vennar irrigation and drainage system which will deliver (i) climate resilient hydraulic infrastructure for irrigation and drainage, (ii) reduced flood frequency and flood damage (iii) no further spread of saline intrusion (iv) greater integration of water resources management and (v) increased efficiency of water use, particularly for irrigation.

The outcome of CASDP is expected to be efficient climate resilient water resources management in the Cauvery River delta and the impact is expected to be sustained, or even improved, productivity and household income in the medium and long term.

Under Rule 110 the Honorable Chief Minister of TamilNadu announced the Scheme in Legislative Assembly on 07.05.2012 with an loan assistance of Rs.1092/- crores (210 Million USD) and state share of Rs.468/- crores (90 Million USD) for the execution of CASDP.

A PPTA (Project Preparatory Technical Assistance) Consultancy team was set up by the Asian Development Bank (ADB) to address the Cauvery delta issues and to assist the TamilNadu Water Resources Department. The Purpose of the PPTA consultancy (ADB TA – 8166-IND Climate Adaptation through Sub-Basin Development) was to prepare an investment plan that will deliver the proposed CASDP objectives in the Cauvery River delta. The Asian Development Bank (ADB) and the Government of Tamil Nadu intend that the investment plan will be implemented through a stand alone project that will fund over 4 year period.

The Project area includes six rivers / drains, namely Harichandranathi river, Adappar river, Pandavayar river, Vellaiyar river, Valavanar drain and Vedaranyam Canal, in the Vennar irrigation system.

The WRD and PPTA team held discussions about the works to be undertaken for reconstruction, repair, desilting, standardisation of river banks, construction of new tailend regulators and dredging etc., in the Project area. Based on the above discussion the cost estimates are prepared for the above works.

An amount of Rs.20000 Lakhs (US$ 33.333 million) was allotted in the state budget estimate for the year 2014-2015 for implementation of this work.

1.2 Water Resources Issues in the Cauvery Delta

1.2.1 Introduction

The Cauvery sub-basin in Tamil Nadu has the largest area of agricultural land in Tamil Nadu and is a significant contributor to total national agricultural output. However the sub-basin lies in a marginally semi-arid region where the availability of water resources is limited and variable. Therefore maximum efficiency of water supply and use is a clear imperative across all water using sectors. The agricultural sector accounts for almost all water use in the sub-basin, but the irrigation and drainage systems are very old adaptations of natural drainage systems, particularly in the delta, which for strategic reasons have received only essential maintenance in the modern era. According to government tests bed losses in the rivers and main canals are typically 55%.

The consequences of these environmental and infrastructure factors include low agricultural productivity due to water shortages, insecure rural livelihoods, high vulnerability to natural disasters such as floods, droughts and tidal surges due to limited and only partially maintained defences, inefficient water use, over-abstraction of groundwater and disturbed ecosystems.

Therefore the long term aims of water resources managers in the Cauvery sub-basin should include politically acceptable measures to improve:

- **(i)** Water use efficiency - more productivity per drop of water through modernising water distribution infrastructure and field irrigation technologies, more reliable water supplies less waste through optimising consumption and greater conservation,
- **(ii)** social equity - fairer distribution of water so that the difference between livelihoods in the head-end and tail-end areas are reduced or ideally eliminated,
- **(iii)** environmental sustainability - identify appropriate environmental targets and manage to reach them as measured by key performance indicators such minimum standards for river flow, river and groundwater levels and water quality, flora and aquatic invertebrate populations and higher aquatic fauna.

It is therefore recommended that options for achieving these important water management measures are investigated and tested during follow on follow on projects and that an appropriate tailor-made sustainable and integrated water resources management system can be evolved for the Cauvery sub-basin.

1.2.2 Cauvery River

The Cauvery River is one of the major rivers flowing east from the Deccan plateau. It flows through the States of Karnataka, Kerala, Tamil Nadu and the Karaikkal enclave of the Union Territory of Pondicherry and has a total catchment area of 81,155 km^2. It is the only major river and the only perennial flowing through Tamil Nadu and its catchment extends over 34% (44,016 km^2) of the area of Tamil Nadu and Karaikkal. The total population of the sub-basin was 72.14 million in 2011 of whom 37.19 million were rural.

The Cauvery delta has a geographical area of 6,900 km^2 and a gross irrigation extent of 5,220 km^2 which is about 48% of the total area irrigated by canals in Tamil Nadu. Irrigation water to the delta is supplied from the Cauvery River at the Grand Anicut via the Cauvery and Vennar rivers and their 36 natural branches and a distribution network of 29,881 distribution canals with a total length in excess of 22,400 km. Many of these canals and their irrigation infrastructure are in a poor state of repair.

The total annual and monthly surface water resources of the Cauvery basin in Tamil Nadu are limited by an inter-state water sharing rule. They are also naturally unreliable due to highly variable monsoon rains. Without substantial abstractions of fresh groundwater in the delta, agricultural output and rural incomes would be significantly lower. However the quantity and extent of fresh groundwater is limited due to variable recharge and saline aquifers in the south-east quadrant of the delta. There are signs of over-abstraction of groundwater.

Damaging floods and droughts are endemic due to erratic monsoon conditions. There have been three major floods and one major drought in the delta since 2000 causing $70.4 million of damage in Thiravarur and Nagapattinam Districts in the Cauvery delta according to local Government records. Climate change projections for the delta indicate slightly less surface water stress during the irrigation season but significantly more flood risk.

1.2.3 Availability of Water Resources

The water resources of the Cauvery River sub-basin in Tamil Nadu, including the agriculturally important delta, comprise river inflows from neighbouring upstream states, groundwater from two principal aquifers and direct rainfall, particularly during the north-east monsoon (November-December). However the availability of each of these sources is variable.

1.2.3.1 Surface Water

Flow in the Cauvery River and the volume of water stored in the Stanley reservoir are the major determinants of the annual cropping schedule in the Cauvery River sub-basin. A poor SW monsoon in Karnataka limits flows in the Cauvery River and the amount of water stored in the reservoir and therefore reduces the amount of surface water available for irrigation during the rice growing season (June-January). In the period 1990 to 2013 the Stanley reservoir filled (93.5 TMC) completely in only 10 years out of 24 years and was less than half full (46.8 TMC) in 6 years (notably during the severe drought from 2002 to 2004).

The sharing of Cauvery River waters between the riparian states (Karnataka, Kerala, Tamil Nadu, Pondicherry) had been disputed for many years until February 2013 when the Supreme Court upheld the water allocation decision of the Cauvery Waters Dispute Tribunal made in 2007. The allocation to Tamil Nadu, while fair, is insufficient to meet all demands in the sub-basin. Furthermore there is insufficient storage capacity in the sub-basin in Tamil Nadu to sustain surface water supplies throughout the year or to conserve excess water.

1.2.3.2 Groundwater

Groundwater is a vital source that is widely used to compensate for unreliable surface water supplies. However in the Cauvery delta there are many areas with limited groundwater availability or with saline groundwater. The characteristics and sustainable yields of the fresh water aquifers in the Cauvery sub-basin are not fully understood.

There are two principal fresh water aquifers. The upper unconfined alluvial aquifer is heavily exploited for irrigation and drinking water but records show that it normally recovers fully each year following the north-east monsoon. The lower confined sandstone aquifer, which was artesian in the 1960s but has been increasingly exploited since then for irrigation, has lost pressure and appears to have reached a new equilibrium at a piezometric head 4 to 5m below 1960s levels.

The Central Ground Water Board categorizes the ground water situation by administrative blocks. Of the 35 blocks in Cauvery delta, 16 are semi-critical, fully exploited or over-exploited and 8 blocks are unusable due to salinity.

1.2.3.3 Rainfall

Direct rainfall is also a vital additional source of water, but both the south-west and north-east monsoons are unreliable. Normally the south-west monsoon delivers only light rains in Tamil Nadu. The north-east monsoon (November to December) is well timed to supplement surface water in the latter part of the irrigation season when surface water inflows from the Cauvery River fall but it is notably erratic. Average rainfall during the north-east monsoon is 750 mm but it is less than 500 mm in 2 out of 10 years. Consequently, where groundwater is not available, crops are vulnerable at this time of the year.

1.2.4 Water Resources Management

1.2.4.1 Policy Framework

The Government of India's National Water Policy 2012 recognises numerous water resource issues in India and proposes the introduction of modern water resources management principles and best practices to address these issues. These include integrating the planning, development and management of water resources by river basin units, and treating water as a shared resource on a socially equitable and environmentally sustainable basis through transparent, informed and participatory decision making.

The policy prioritises safe drinking water, then food security followed by the maintenance of minimum ecologically acceptable river flows and water levels. After these priority allocations, remaining water resources should be conserved as much as possible. Recognising that the availability of water resources is limited and may become more variable due to climate change, the policy advocates greater control of water use, especially through more efficient irrigation practices, reduced pollution and reduced net losses.

However in India management of water resources is primarily a state responsibility. Tamil Nadu has a 1994/2002 state policy which focuses particularly on the government's objective to increase agricultural output. The Government of Tamil Nadu prioritises water supply, particularly for irrigation. Therefore in Tamil Nadu most water services are provided free of charge to users, especially surface water and groundwater for irrigation with few if any incentives for efficient use of the water provided.

1.2.4.2 Legislation

The National Water Policy proposes a holistic water framework law that states the responsibilities of central, state and local governments for the management of water resources. The policy recognises water as a scarce shared resource that requires careful management for domestic, agricultural, power generation, navigation and recreational purposes and ecological sustainability, and also recognises the likely impacts of climate change. The policy advocates enhanced water availability through greater demand management, water use efficiency and conservation, and the introduction of water pricing and improved institutional arrangements for the provision and regulation of water resources.

TamilNadu has a set of acts and regulations that has evolved over many years to govern the supply of water for domestic use and irrigation, maintenance of canals, rainwater harvesting, protection of riverbanks etc.

1.2.4.3 Water Services

In Tamil Nadu, surface water supply for irrigation is a public service provided by the Water Resources Department (WRD) of the Public Works Department (PWD) free of charge. Groundwater abstractions are to be regulated by the state government. Encouraged by free electricity and subsidised plant, use of groundwater for irrigation by individual farmers has proliferated over the last 30-40 years.

Surface Water Supply: Surface water for irrigation is distributed across the delta through a network of natural rivers and man-made canals. Conveyance losses from the main channels are typically 50% but much of this loss is recovered by infiltration to the groundwater system. Most of the irrigation infrastructure is old and in need of maintenance. Channel embankments and some structures are damaged or weak. Flooding by overtopping and breaching is common. At the operational level, water distribution to the irrigation systems through the canals are, based mainly on judgement of WRD staff in response to ad-hoc requests from farmers, with adjustments if any are made in response to rainfall forecasts or actual rainfall. At the farm level the application of irrigation water by field flooding is inherently inefficient.

Drainage: Surface water drainage in the irrigation command areas is provided by drains which discharge back to the rivers or designated main drains. In normal operation, much of the drainage water is reused in lower command areas. Storm runoff from intense local rainfall, common during the north-east monsoon in many years, overwhelms the drainage system causing local inundation of crops and infrastructure. During severe storms, usually associated with cyclones in the Bay of Bengal, the rivers and main drains become congested limiting field drainage further. Very high flows in the rivers and drains overtop and undermine the embankments, causing breaches and further flooding of adjacent land. Flooding of the Vellaiyar, Harichandra, Adappar and Mullaiyar Rivers and the Valavanar & Marraka Koraiyar Drains, caused by a cyclonic storm in November 2008, persisted for up to 25 days destroying crops and cutting off rural communities. Other recent major floods occurred in 2005 and 2010.

Water Users: Everybody needs water and therefore the water users comprise society at large, but there are always clear groupings, e.g. farmers, fishermen, rural households, urban households, industry, which require different water services in terms of quantity, quality, frequency, location etc. In the Cauvery basin, the most important current demands are for:

	Annual Water Demand				
	Irrigation (Mm^3)	Aquaculture (Mm^3)	Industrial and domestic (Mm^3)	Power (Mm^3)	Total (Mm^3)
Present	5007	66	75	18	5166
Future	5007* (4740**)	241	83	18	5349*(5082**)

* The irrigated area is not expected to increase significantly in the future because almost all irrigable land is already in use. Therefore irrigation demand is unlikely to increase.
** If the System of Rice Intensification (SRI) is adopted then irrigation demand will fall significantly.

1.2.5 Climate Change

Climate change studies (Srinivasan, ADB 2013) during the project preparation for CASDP indicate that moderate increases in mean annual rainfall and temperature can be expected in the period up to 2050 with corresponding moderate increases in runoff. While the increase in annual temperature is mirrored in monthly temperature, the increase in annual rainfall masks reductions of 16-23% in monthly rainfall from January to May and increases of 13% during the south-west monsoon from June to September and increases of 4% during the north-east monsoon from October to December. From an agricultural perspective this is a relatively benign outlook as increases in crop water requirements caused by higher temperatures may be satisfied by increases in rainfall at the optimum times. However the projections also show large increases in storm rainfall (19%) and storm runoff (29%). Therefore more frequent and serious flooding can be expected. In coastal areas flooding will be gradually exacerbated by rising sea levels of between 0.29m (low scenario) and 0.87m (high scenario) by 2100 (Dastgheib and Ranasinghe, ADB 2014). The 100-year tidal storm surge is estimated to be 0.74m.

1.3 State Government Responses to Water Resources Issues

The Government of Tamil Nadu's general response to state-wide water resources availability and management challenges includes the *Irrigated Agriculture Modernization and Water-Bodies Restoration and Management* (IAMWARM) project. But in the Cauvery River sub-basin, the government's response has been, until recently, inhibited by the long-running water sharing dispute with Karnataka and other riparian states. However, following a Cauvery Waters Dispute Tribunal ruling in 2007, which allocated 57% of the surface water yield of the Cauvery River basin to Tamil Nadu, the Tamil Nadu Water Resources Department prepared the *Cauvery Modernisation Project* (CMP, WRD 2008). Since the Supreme Court decision in 2013 to uphold the 2007 tribunal ruling the CMP has been superseded by the Cauvery Modernisation Proposal (WRD, 2013. *Proposal for Improvements and Rehabilitation of Irrigation Systems in the Cauvery Basin for Efficient Water Management*).

1.3.1 IAMWARM Project

The IAMWARM project is a World Bank assisted multi-departmental project designed to bring positive changes to irrigated agriculture in Tamil Nadu. The project involves multiple stakeholders both at facilitation and implementation levels and is being implemented in 60 sub-basins in Tamil Nadu. It aims to expand the area under irrigated agriculture through effective and efficient water management practices in order not only to produce more crops, meat, milk, and fish per drop of water but also to generate more income per drop. The project was formulated with World Bank assistance with a budget of $424.5 million (Rs.2,547 crore) over a period of six years from 2007.

The IAMWARM project aims to improve the service delivery of irrigation systems and productivity of irrigated agriculture with effective integrated water resources management in a sub-basin framework. The project has four components (i) irrigation systems modernisation in a sub-basin framework which seeks to improve bulk water delivery through modernisation of irrigation systems with a total command area of 617,000 ha, (ii) agricultural intensification and diversification to increase the productivity of agriculture-related activities through improved agricultural intensification and diversification of crops, micro irrigation, animal husbandry and inland aquaculture, (iii) institutional modernisation for irrigated agriculture which seeks to improve institutional capacity for, and participatory irrigation management, in irrigation service delivery through the WRD and water users associations (WUAs), (iv) improved institutional arrangements and capacity for sustainable water resources management including the creation of the State Water Resources Management Agency (SWARMA).

1.3.2 Cauvery Modernisation Proposal

The WRD has prepared a *Proposal for Improvements and Rehabilitation of Irrigation Systems in the Cauvery Basin for Efficient Water Management* (WRD, 2013) which supercedes an earlier proposal prepared in 2008 (WRO, 2008). This updated proposal for the rehabilitation of most of the irrigation infrastructure in the Cauvery River sub-basin. The proposal lists 182 check dams, 11,213 head sluices, 456 regulators, 223 aqueducts, 695 syphons and 679 drop structures and other allied structures in addition to lining of channels to improve conveyance efficiency. The estimated cost of the WRD proposal is $1.9 billion (50% from the Central Government; 50% from Tamil Nadu Government of which 45% can be foreign funded).

The rationale of the proposal is that irrigation infrastructure in the Cauvery sub-basin has been deprived of major financial investment for many years due to Cauvery waters dispute. Now that the final award of the tribunal has been legally upheld, this proposal has been submitted for Government of India financial assistance. During the preparation of CASDP it was noted that some of the proposed WRD investments overlap with those proposed under CASDP. This therefore led to the revision of the scope of CASDP outputs to exclude implementation of on-farm irrigation improvements.

1.3.3 Climate Adaptation through Sub-Basin Development Program (CASDP)

The Climate Adaptation through Sub-Basin Development Program (CASDP) supports the implementation of the Government of India’s National Action Plan on Climate Change (NAPCC) of 2008 and it’s National Water Mission (NWM). In support of the Government, the Asian Development Bank provided technical assistance (ADB TA-7417-IND: Support for the NAPCC, 2010-11) for the preparation of profiles of three contrasting sub-basins, the Sutlej in Punjab (for glacial and snow-fed systems), the Kshipra in Madhya Pradesh (for groundwater dependent systems) and the Cauvery delta in Tamil Nadu (for coastal systems).

The Cauvery delta was chosen because it potentially provides a good demonstration site for NWM objectives and the Government of India’s water resources reform agenda and lies within a river sub-basin where IWRM could address complex water resources issues such as limited availability of surface water, over-abstraction of groundwater, salinity, inefficient use of water and the likely impacts of climate change.

CADSDP aims to increase water security and decrease flood damage in the Cauvery delta to help local communities in the Cauvery Delta adapt to climate change. As such it is in alignment with the Cauvery Modernisation Proposal.

1.4 The Design of CASDP

1.4.1 Rationale

Section 1 explains that communities in the Cauvery delta, particularly in rural areas, are vulnerable to a number of water resources issues that negatively affect their livelihoods and well being. Water services for irrigation and domestic use are unreliable due to limited and variable availability of water resources, the distribution of water irrigation is inequitable due to the poor physical condition of irrigation infrastructure and the use of water is generally inefficient due to high distribution and field losses, highly consumptive crops i.e.paddy and low emphasis on water conservation. Floods and droughts are endemic. Climate change projections promise an intensification of floods, compounded in coastal areas by rising sea levels.

The Cauvery Modernisation Proposal (WRD, 2013) to address these issues in the Cauvery sub-basin includes major investments in the rehabilitation of irrigation systems and improved water resources management. CASDP has been designed in alignment with this proposal to make structural and non-structural climate adaptations in the water sector in the Cauvery sub-basin.

The structural investments will include extensive channel re-sectioning and raised embankment along the principal rivers, drains and coastal outlets in the Vennar and Cauvery irrigation systems, according to new engineering design guidelines and climate change projections, to reduce the frequency and impact of flooding. The structural investments will also include the repair and reconstruction of existing irrigation infrastructure and the construction of new infrastructure to improve water supply.

The non-structural investments and interventions will include greater use of decision support systems for the seasonal planning and operational control of irrigation water distribution, the assessment of flood risk in the Vennar and Cauvery systems and the preparation of flood risk maps and flood management plans.

1.4.2 Impact

The long term impact of CASDP is expected to be improved resilience to climate change of communities in the Cauvery delta. The aim is to provide a minimum standard of flood protection that will contain future floods with return periods up to 25-years and to improve the security and fair distribution of irrigation water supply and to increase mean annual crop yields and thereby rural livelihoods for both men and women. Indicators that this impact has been achieved will be that in 2050 average rural income per household will be increased from 2015 values and average annual flood damage per household will be reduced from values in 2015.

1.4.3 Outcome

The medium-term outcome of CASDP is expected to be that by 2025 irrigated agriculture has been resumed or introduced in currently unproductive land in tail end areas, sea water ingress into rivers and drains with tail end regulators has been eliminated and the annualised cost of flood damage has fallen significantly from 2000-10 values.

1.4.4 Outputs

There are two principal outputs of CASDP are:

- Output 1 - Integrated programs and infrastructure for the management of surface water, groundwater and salinity.
- Output 2 - Improved systems for water resources management.

These outputs are discussed in the flowing sections.

1.4.4.1 CASDP Output 1- Integrated programs and infrastructure for the management of surface water, groundwater and salinity

CASDP Output 1 will deliver structural adaptations for optimal use of surface water so that as many areas of the Cauvery delta are served with irrigation water equally and efficiently as possible. The programs required to achieve this include essential civil works, using new design guidelines developed during the preparation of CASDP for irrigation infrastructure in the Cauvery delta, to rehabilitate dilapidated surface water irrigation infrastructure so that it is fit for purpose to maintain normal irrigation supply levels in the surface water distribution system and deliver the correct quantities of irrigation water to as many areas as possible on a systematic and planned basis.

The civil works will include re-sectioning and bank strengthening of main channels and coastal outfalls to improve their resilience and conveyance capacity, and will include new, reconstructed and repaired regulators, head sluices, bed dams and other minor structures. The works will also include the rehabilitation of existing pumped irrigation schemes.

The civil works will also improve the management of floods through increased conveyance of the rivers and main drains, strengthened embankments raised to accommodate at least the 25-year flood and principal regulators designed to pass the at least the 50-year flood.

The activities and timetables required to deliver Output 1 of CASDP are:

- Implement new design guidelines for the drainage system by January 2015.
- Implement structural improvements to the Vennar and Cauvery systems by December 2018 (4 years).
- Rehabilitate the head works of lift irrigation schemes in the Vennar and Cauvery systems by December 2018 (4 years)

The programs also include vital groundwater monitoring and investigations to determine sustainable yields of the fresh water aquifers, the most effective means of increasing their recharge and the dynamics of the saline water aquifers. The investigations will be followed by the development and implementation of conjunctive use plans and viable groundwater recharge schemes designed to increase the security of water supply in all areas of the delta.

The measurable performance indicators and targets for Output 1 will be that by 2018:

- Capacities of of principal irrigation and drainage channels are standardised to withstand 25-year design flows taking climate change impact into account.
- 90% of regulators and head sluices are in full working order.
- Existing tail-end regulators are rehabilitated and new tail-end regulators are constructed.
- Coastal outlets are stabilized and maintained.
- The head works of lift irrigation schemes are rehabilitated.

1.4.4.2 CASDP Output 2- Improved Systems for Water Resources Management

CASDP output 2 will deliver non-structural adaptations designed to deliver more efficient management through three main initiatives (i) greater coordination of public water services provided by the Government (particularly the Water Resources Department, the Groundwater Department and the Agriculture Department), (ii) capacity development of Government officers in monitoring the availability of groundwater and surface water resources and water use, and in decision making supported by an appropriate decision support system (DSS) and (iii) flood risk management plans for the most flood prone catchments.

The activities required to deliver Output 2 of CASDP are:

- Implement telemetered networks in the Vennar and Cauvery systems to monitor climate, surface water and groundwater levels and flows by December 2018 (4 years).
- Implement a decision support system for water resources management in the Cauvery sub-basin by December 2015.
- Implement flood risk management plans for the most flood prone catchments that include measures to raise public awareness and readiness, flood forecasting and warning services, planned government and communal responses and post-disaster damage assessment and reparation procedures.

The measurable performance indicators and targets for Output2 will be that by 2018:

- Surface water and groundwater monitoring network will be fully operational.
- The stage-discharge rating of each regulator is calibrated through the flow range and routinely updated through a programme of direct flow measurements.
- WRD staff use a DSS to support routine decisions on equitable and efficient distribution of surface and ground water.
- WRD field hydrology team perform routine flow measurements, operate and maintain monitoring stations. WRD AEEs and AEs process, analyse and interpret data using a DSS.
- WRD staff perform gender sensitive post-flood surveys and map flood extents in order to determine the depth, duration, water velocity of the floods that will be used to update flood risk assessments and improve the timeliness and precision of flood forecast and warnings.
- Once triggered by flood warnings issues by WRD, Flood disaster management plans are implemented in each affected district by the District Collectors , resulting in a significant reduction in flood damage in monetary terms.
- Distribution of irrigation water is more equitable use of surface water and the irrigated area in tail end taluks increases significantly.

1.4.5 Implementation of CASDP

1.4.5.1 Finance

CASDP will be funded as a stand alone project (ADB, 2008) with a total value of $152 million (INR 912 crores), $106.4 million from an ADB loan and $46 million from the GoTN.

Tranche	Description	Budget		Timetable
		$ million	**INR crores**	
1	Vennar irrigation system on the Adappar, Harichandra, Vellaiyar and Pandavanar rivers, the Valavanar Drain and the Vedharanyam Canal and straight cuts.	152.00	912.00	2014-2018

Each project will require feasibility studies and the preparation of Detailed Project Report (DPRs) for approval by the ADB and GoTN. The DPR for the Project has been prepared jointly by the Tamil Nadu Water Resources Department (WRD) and ADB's PPTA consultants (Mott MacDonald). Preparation of the DPRs for follow on project will be one of the activities to be carried out during the execution of this project along with essential preparations such as groundwater investigations, topographic surveys etc.

A Facility Administration Manual (FAM) has been prepared for the day-to-day administration of the stand alone project and implementation of the Program. The FAM sets out in detail the implementation plans, project management arrangements, costs, financing arrangements, financial management procedures, procurement plans, requisite consultancy services, performance monitoring/evaluation/reporting systems, communication plans and social, environmental and corruption safeguards.

The Program will be executed by the WRD through a dedicated Project Management Unit (PMU) under the direction of a Project Director with Superintending Engineer rank and three Project Implementation Units (PIUs) under the supervision of PMU.

The activities that will take place during the Project are described in Section 3.6.1 and 3.6.2.

Activities of follow on projects are briefly outlined in Section 3.6.3. These cannot be specified precisely until the projects are prepared during this Project, but because of the broadly similar environmental and water management characteristics across the Cauvery irrigation systems, they are likely to be broadly similar to the activities during this Project.

1.4.3.2 Management of CASDP

A program management unit (PMU) will be established in the WRD Trichy Regional Chief Engineer's office for overall project management which includes implementation of Project and planning and preparation of follow on projects. The core functions of the PMU will include (i) design and planning, (ii) procurement of goods, works and services, (iii) contract supervision and quality assurance control, (iv) program finance management, (v) implementation of environmental and social safeguards, and (vi) program benefit monitoring and evaluation.

For this Project three project implementation units (PIU) will be established in Thiruvarur, Nagapattinam and Thiruthuraipoondi to oversee the day to day implementation of project activities. The core functions of the PIU will include: (i) construction supervision, (ii) contract management, (iii) quality assurance control, (iv) monitoring of implementation of resettlement and environmental management plans, (v) conducting stakeholder consultations and (vi) addressing any project related grievances.

The Governments of India and Tamil Nadu and the Asian Development Bank (ADB) intend that the CASDP will be implemented through a stand alone project investment plan valued at $152 of which $101 million is to be a loan and $51 million is to be provided by the state government.

1.4.5.3 Social Safeguards

A resettlement framework has been prepared for the entire CASDP Program and a resettlement plan for this project. A total of 220 residential and commercial structures will be affected by Project representing 100 residential structures, 17 commercial structures, 6 commercial-cum-residential structures and 97 sheds. All these people are squatters or encroachers on the public land. The entitlement matrix has addressed the requirements of ADB and the 2013 land acquisition and resettlement and rehabilitation law of India, and also refers to resettlement precedents set during the recent World Bank assisted Tamil Nadu Road Sector Project: Kumbakonam Bypass Extension, 2009. The total number of squatters or encroachers are to be verified by the Revenue Department.

1.4.5.4 Environmental Safeguards

An Environment Assessment Review Framework (EARF) for CASDP and an Initial Environmental Assessment (IEE) for the Project have been prepared in accordance with the ADB Safeguard Policy Statement (2009).

Some of the interventions proposed under the Project fall within the coastal regulation zone and therefore require prior clearance from the Coastal Zone Management Authority. Therefore, under the Coastal Regulation Zone (CRZ) Notification procedure (2011) and the EIA Notification procedure (2006), applications for CRZ clearance and TOR for the necessary EIAs have been prepared.

1.4.6 Execution of Project

A detailed project report (DPR) has been prepared for CASDP Project according to Government of India Guidelines (CWC, 2010). The structural climate adaptations to be implemented under Output 1 of this Project comprise and the non-structural climate adaptations under Output 2 are summarised in the following sections.

1.4.6.1 Project Output 1 - Integrated Programs and Infrastructure for the Management of Surface Water, Groundwater and Salinity

The structural adaptations to be implemented under Output 1 of this Project comprise:

- Re-sectioning and bank strengthening of six main channels totalling 235km to improve their resilience and flood conveyance capacity
- Improved conveyance of three straight cuts between the Vedharanyam canal and the sea
- Construction of new regulators, reconstruction of existing dysfunctional regulators and repair of existing damaged regulators
- Work (new, reconstruction and repair) on 147 irrigation head sluices off-taking from the main channels
- Work on 20 bed dams and grade walls within the main channels
- Work on 93 other minor irrigation and drainage structures
- Upgrading of 13 pump stations comprising new pumps and electrical systems and repairs to pump houses

Additional structural measures (e.g. flood retention areas, new or enlarged drains) are excluded from this Project because the WRD has determined that new land cannot be acquired by the government for these purposes.

1.4.6.2 Project Output 2 - Improved Systems for Water Resources Management

The non-structural adaptations to be implemented under Output 2 of Project comprise:

Monitoring: A vital foundation for effective water resources management is knowledge and understanding of the spatial and temporal availability of water resources within a coherent hydrologic unit e.g. a river basin. In the Cauvery basin this knowledge and understanding is incomplete due to shortages of data and information of many types including:

- topographic and drainage network maps,
- DEMs
- cropped areas,
- rainfall intensity,
- river, canal and drain flows and water levels,
- groundwater levels,
- water quality,
- sediment loads,
- irrigation requirements,
- groundwater abstractions,
- tide levels

Therefore, starting in the Cauvery delta with the Harichandra, Vellaiyar and Pandavayar Rivers and its adjacent command areas, a limited intensification of water resources monitoring and assessment is proposed on a trial basis during CASDP Project. This will be delivered as part of the CASDP Project investments together with a simple decision support system (DSS) comprising hardware and software that will capture the data automatically and process, analyse, interpret, report and archive it.

Decision Support System (DSS): A simple DSS will be developed during Project to support WRD in key decision making such as (i) facilitating irrigation planning and efficient water distribution for the systems (on seasonal and 10-day time scales) based on actual needs, both for surface water and groundwater, (ii) fine tuning release of water to actual needs in individual command areas according to antecedent soil moisture and forecast rainfall, (iii) detecting and responding to distribution system problems and breakdowns and (iv) integrated operation of dams, head regulators, cross regulators and tail regulators to maintain appropriate flows and water levels during both normal supply and flood periods. Initially a simple DSS is proposed on the Harichandra, Vellaiyar and Pandavayar rivers comprising surface water and groundwater databases containing hydro-meteorological, hydrological and hydrogeological data and irrigation command area information. Four main inputs into the proposed simplified DSS are proposed (i) field monitoring equipment, (ii) computer hardware and database software, (iii) a programme of flow measurements to calibrate discharges through regulators and (iv) a watering schedule calendar in the form of a simple spreadsheet.

The simple DSS will be accessible to WRD decision makers through a user-friendly computer interface which will allow them to inspect up-to-date river levels, flows, water demands throughout an irrigation system and to adjust surface water deliveries to actual needs considering groundwater availability and recent rainfall in the command areas.

Capacity Development: WRD staff will need regular and intensive capacity development in monitoring the irrigation systems, updating and maintaining the databases, use of the information generated, and dissemination of information to farmers and other stakeholders. Beside this, an overall capacity building program in climate-resilient integrated water resources management will need to be developed to gain knowledge and upgraded skills in using climate change projections and new criteria for engineering designs, setting up and using hydraulic and hydrologic modelling for design and planning, flood forecasting and warning, and working with farmers to manage surface water and groundwater resources more efficiently and equitably.

1.4.7 Execution of CASDP follow on projects

The preparation of follow on projects in the balance Vennar and the Cauvery irrigation systems respectively is expected to take place simultaneously during the implementation of this Project. The structural climate adaptations required in these irrigation systems are likely to be broadly similar to those required under Output 1 of this Project in the lower Vennar system i.e. optimised use of surface water; rehabilitation of dilapidated surface water irrigation infrastructure including re-sectioning and bank strengthening of main channels and coastal outfalls; new, reconstructed and repaired regulators, head sluices, bed dams and other minor structures; rehabilitation of existing pumped irrigation schemes; increased flood protection.

The non-structural climate adaptations required under follow on projects are likely to be extensions and elaborations of the adaptations required under the Project i.e. further upgrading of the surface water, groundwater and meteorological monitoring network and the DSS with the necessary additional capacity development of Government staff.

Depending on their outcomes during this Project the groundwater sub-projects could be replicated or expanded in follow on projects.

A more sophisticated DSS is recommended to support the maximization of water use efficiency and fully reap the benefits of integrated water resources management within the Cauvery Delta. This more sophisticated DSS could include hydrologic and hydraulic models that would guide the operators of the irrigation and drainage systems on a daily basis and provide comprehensive assessments of water resources management options on a seasonal basis. Further development of the DSS could include flood forecasting (using links to the India Meteorological Department and the CWC) and flood warning.

1.5 RIVER BASINS

1.5.1 India

The river systems of India can be classified into four groups viz.

(i) Himalayan rivers.
(ii) Deccan rivers,
(iii) Coastal rivers, and
(iv) Rivers of the inland drainage basin.

The Himalayan rivers are formed by melting of snows and glaciers besides monsoon rainfall run-off and therefore, have continuous flow throughout the year. During the monsoon months, Himalayas receive very heavy rainfall and rivers swell, causing frequent floods. The Deccan rivers, on the other hand, are rainfed and therefore, fluctuate in volume. Many of these are nonperennial. The coastal streams, specially on the west coast, are short in length and have limited catchment areas. Most of them are non-perennial.The streams of inland drainage basin of western Rajasthan are few and far between. Most of them are of ephemeral nature. Besides these, there are the desert rivers, which flow for some distance and are lost in the desert.

On the basis of catchments, the river basins of India could be divided into three groups, viz.

(i)	Large River Basins	River basins with catchment of 20,000 km^2 and above.
(ii)	Medium River Basins	River basins with catchment area between 20,000 and 2000 km^2
(iii)	Minor River Basins	River basins with catchment area below 2000 km^2

According to the above classification, the number of major and medium river basins in India are 12 and 46 respectively and these contribute over 90% of the total run-off. Major rivers alone contribute more than 84% of the total run off. The rivers are well spread over, excepting the Thar desert in Rajasthan. Minor rivers account only for about 8% of the total run-off.

The Cauvery which is one of the east flowing Deccan rivers is a major river flowing through the States of Karnataka, Kerala and TamilNadu and the Union Territory of Puducherry. It is the only major river flowing through Tamil Nadu and its catchment extends over 34% of the physical area of TamilNadu.

1.5.2 Tamil Nadu

An attempt to demarcate the areas of the main and minor catchment basins of Madras Presidency was first made by Captain Pennyquick in the year 1884 and a map was also prepared by him titled as "General Irrigation Map of the Madras Presidency to illustrate the rainfall and water supply available by River Basins".

In 1978 a River Basin Map of TamilNadu was prepared by the Irrigation Department demarcating 33 east flowing river basins and one west flowing river basin. Later in 1987, the State Planning Commission, while wanting to make an assessment of the Water Resources of TamilNadu, commissioned a Committee of Experts who adopted the same demarcation of 34 river basins.As per the norms of the Central Water Commission for the classification of River basins referred to above, there is one large River basin, 10 medium River basins and 22 minor River basins in TamilNadu, besides the west flowing river basins, that emanate from TamilNadu. They are all detailed below in **Table 1.5.1** with their catchment extents.

Table 1.5.1 River Basins in TamilNadu

SL. No	River basin	Drainage area (**km**^{2}.)
I. Large River basin (20000 km^2 & above)		
1.	Cauvery	44016
II. Medium River basins (between 2000 & 20000 km^2)		
1	Palar	12125
2 & 3	Ponniar & Malattar	10457
4	Vellar (North)	10197
5	Vaigai	7031
6	Tambaraparani	5969
7	Kortalaiar	3765
8	Gundar	3610
9	Vaippar	3100
10	Manimuthar	2864
11	Kottakarai Ar	2166
		61283
III Minor River Basins (below 2000 km^2)		
1	Varahanadhi	1937
2	Vellar (South)	1932
3	Agniar	1875
4	Ongur	1616
5	Koluvanar	1365
6	Korampallam Ar	1206
7	Uttarakosamangai Ar	902
8	Vembar	892
9	Karimaniar	858
10	Adayar	857
11	Nambiar	843
12	Kodayar	805
13	Gadilam	800
14	Araniar	763
15	Ambuliar	760
16	Cooum	682
17	Kallar	672
18	Pambar	556
19	Palavar	515
20	Hanuman Nadhi	422
21	Valliar	352
		20608
IV West Flowing rivers		**4098**
Grand Total		**130004**

The Institute for Water Studies, when they prepared a Report "State Framework Water Resources Plan of TamilNadu" in 1999, grouped the minor basins together and listed 17 river basins in TamilNadu for study purposes.

1.6 THE CAUVERY BASIN

1.6.1 Description

The river Cauvery rises at Talakaveri on the Brahmagiri ranges of the western ghats in the Coorg District of Karnataka. Cauvery then passes through Karnataka and TamilNadu. The length of the main river as it passes through Karnataka and TamilNadu is 800 km, of which 320 km lies in Karnataka, 416 km in TamilNadu and the remaining length of 64 km forms the common boundary between the States of Karnataka and TamilNadu. The lengths of the tributaries of Cauvery in various States is given in the statement in Table 1.5.1.

1.6.2 Drainage Area

The drainage area of the river Cauvery in the three States including the Union Territory of Puducherry are as under:

	in km^2.
Karnataka	34273
Kerala	2866
Tamil Nadu (including Puducherry)	44016
Total	81155

The Cauvery Water Disputes Tribunal has divided the Cauvery basin upto the Lower Coleroon Anicut into 16 sub-basins. The Map of Cauvery basin with the 16 sub basins is given in Figure 1.1. The names of the sub-basins with their catchment area are given below in Table 1.6.2

Table 1.6.1 Cauvery Basin: Basin and Tributaries

Sl. No	River / Tributaries	Total Length (km)	Length (km) /Location (km)	
1	Cauvery	802	381	in Karnataka
			64	common boundary
			357	in Tamil Nadu
2	Harangi	50		Entirely in Karnataka
3	Hemavathy	245		do
4	Lakshmanathirtha	131		do
5	Kabini	230	60	Kerala
			170	Karnataka
6	Suvarnavathy	88	58	Karnataka
			30	Tamil Nadu
7	Shimsha	221		Entirely in Karnataka
8	Arkavathy	161		Entirely in Karnataka
9	Palar	100	60	Tamil Nadu - Karnataka border
			40	Tamil Nadu
10	Bhavani	242	32	Kerala
			210	Tamil Nadu
11	Noyil	155		Entirely in Tamil Nadu
12	Amaravathy	214	30	Kerala
			184	Tamil Nadu
13	Ponnaniar	80		Entirely in Tamil Nadu

FIGURE 1.1


CAUVERY RIVER BASIN
SUB BASIN MAP
50 25 0 50 Kilometres
SUB BASIN NAMES
1. Moyar
2. Bhavani
3. Palar Kothalahalla
4. Santhanamuthu Thottahalli
5. Chinnar
6. Sarabanga - Mettur &Thoppair Dams
7. Noyil
8. Amaravathi
9. Thirumanimuthar
10. Karaipottanor
11. Ayaru
12. Ponnaniyar
13. Kulaiyaru & Nandiyar
14. Marudayaru
15. Colleroon
16. Cauvery Delta
17. (Cauvery Lower) Vennar Delta
18. Grand Anicut Canal Sub Basin
N
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14
15
16
17
18
GOVERNMENT OF TAMILNADU
INSTITUTE FOR WATERSTUDIES PWD . WRO
TAMILNADU STATE CENTRE FOR REMOTESENSINGAPPLICATION
THARAMANI , CHENNAI - 600 117

Table 1. 6.2 Area of the Sub-Basins of Cauvery Fig. in sq.km.

Sl.No	**Sub-basin**	**Area of the sub-basin (km^2)**	**State wise break - up**		
			Kerala (km^2)	**Karnataka (km^2)**	**Tamil Nadu (km^2)**
1	Thala Cauvery	3519	---	3519	---
2	Hemavathy	5410	---	5410	---
3	Lakshmanathirtha	1690	---	1690	---
	Total upto KRS	**10619**	**0**	**10619**	**0**
4	Kabini	7414	1920	5282	212
5	Suvarnavathy	2858	---	2278	580
6	Shimsha	9700	---	9700	---
7	Arkavathy	4351	---	4184	167
8	Palar	3214	---	1870	1344
9	Chinnar	4061	---	100	3961
	Total upto Mettur	**42217**	**1920**	**34033**	**6264**
10	Bhavani	6455	562	240	5653
11	Noyyil	3972	---		3972
12	Amaravathy	8547	384		8163
13	Thirumanimuthar	5564	---		5564
14	Ponnaniar	3374	---		3374
15	Upper Coleroon	3082	---		3082
	Total 15 sub-basins	**73211**	**2866**	**34273**	**36072**
16	Cauvery Delta	**6739**	**---**	**---**	**6739**
	Total 16 sub-basins	**79950**	**2866**	**34273**	**42811**
	Area below LCA	**1205**			**1205**
	Total area of the basin	**81155**	**2866**	**34273**	**44016**

Administration Units in the Cauvery basin - the District wise and sub-district wise particulars of Cauvery basin in each basin State are as below:-

State	**Districts or Sub – Districts**
Karnataka	Kodagu (Coorg), Mysore, Hassan, Mandya, Bangalore, Tumkur, Chickmagalur and Kolar
Kerala	Wyanad, Idukki and Palghat.
Tamil Nadu	Nilgiris, Erode, Coimbatore, Salem, Namakkal, Dharmapuri, Karur, Dindugal, Tiruchirapalli, Perambalur, Ariyalur, Thanjavur, Tiruvarur, Nagapattinam, Pudukottai and Cuddalore.
Puducherry	Karaikal

1.6.3 Population:

The population in the Cauvery basin as per 2011 Census is **166.86** million of which 40% is urban and 60% are rural as follows:

State	**Urban**	**Rural**	**Total**
Karnataka	23578175	37552529	61130704
Kerala	15932171	17455506	33387677
TamilNadu	34949729	37189229	72138958
Puducherry (Karaikal)	98181	102133	200314
Total in the basin	**74558256**	**92299397**	**166857293**

1.6.4 Tributaries of Cauvery

The Cauvery river has many tributaries in Karnataka, Kerala and Tamil Nadu. The tributaries in Karnataka are Harangi, Hemavathi,Lakshmanathirtha, Suvarnavathy, Shimsha and Arkavathy. One of its main tributaries, Kabini, originates in Kerala, passes through Karnataka and joins the Cauvery, near T.Narsipur, below the KRS reservoir. Another tributary in Kerala is the Pambar, which passes through Tamil Nadu and takes the name of Amaravathy and joins the river Cauvery below Mettur near Karur. The tributary Bhavani originates in Tamil Nadu, enters Kerala and again re-enters Tamil Nadu to join Cauvery at Bhavani below Mettur, north of Erode.Another tributary viz., Noyyil, originates in the Coimbatore district in TamilNadu and joins the river Cauvery near Kodumudi. There are two other minor tributaries, Palar on the right and Chinnar on the left, which join the water spread area of Mettur and contribute their flows to Mettur reservoir.

1.6.5 Unique feature of Cauvery:

The Cauvery enters the State of TamilNadu at one point, which offers good scope for measuring the flows that enter from the upper State, and is useful for defining the water share between the States. This is unique in the sense that no other major Inter State river in the country has its topography so defined that it enters from one State to another through one single route.

1.6.6 Upper Anicut:

As the river rolls down through the gorge it has itself carved in the Eastern Ghat ranges, it takes a turn towards south and enters the Mettur reservoir. Thereafter it continues to flow south until the tributary Bhavani joins and turns to flow by and large towards the east. Following the general topographical features, the river flows in the plains, widening its bed and in mild and milder slopes, the slope coming down to as low as about 1 / 3500 towards the sea end. The river drops the sand and silt in its course and starts its deltaic sojourn from the Upper Anicut.

At the Upper Anicut 177 km from Mettur, the river splits into two branches,the northern branch being called the Coleroon, essentially serving as a flood carrier, and the southern branch retaining the name of the parent river Cauvery, essentially carrying discharges released for irrigation. The Upper anicut was constructed across Coleroon in

1836 at this point to facilitate diversion of the low supplies of the river for irrigation in the Cauvery Delta. A flood regulator was constructed later on the Cauvery arm also in 1977 for regulation of irrigation flows. Some 30 km below, the surplus of Cauvery released from the Grand Anicut flows through Ullar, a short link and joins Coleroon, thus forming an island between Cauvery and Coleroon called Srirangam, which is ranked as the first in the 108 Divya Desams for Vaishnavites where Lord Sri Ranganatha has his abode in a big temple, centuries old.

1.6.7 Grand Anicut

The Grand Anicut, constructed during the second century A.D. by a Chola King, Karikala Chola, is really a Grand structure as the name itself implies, but has come up as a structure constructed in an emergency when the river Cauvery breached its left flank and rushed down to flow through the adjacent Coleroon on the left with the deltaic lands served by Cauvery left high and dry.

16.8 The Delta

At the Grand Anicut complex, the river Cauvery splits into two, Cauvery and Vennar, each provided with Head Regulators. These natural rivers act as the main irrigation canals for the supply of water to the fields in the Delta. These rivers, in turn, divide and sub-divide into a number of branches, which form a network all over the Delta, and distribute the Cauvery waters in the vast irrigation system. These rivers also carry the local drainages and act as irrigation-cum-drainage rivers in the lower part. Occasionally these rivers are to carry the floods too which reach the Grand Anicut.The Grand Anicut canal, whose head regulator also is located in this complex, is the one designed and executed as the canal component of the Mettur Reservoir Project to irrigate an extent of 2,56,000 acres with its own system of branch canals, distributaries, minors and water courses. This ayacut is just adjacent to the old Delta to its south.

1.6.9 Tail End Regulators:

There are 26 tail end regulators, of which 15 are on the rivers of the Cauvery arm and its distributaries and 11 on the rivers of Vennar arm and its distributaries. Of the 15 regulators in the Cauvery arm, 9 are in Tamil Nadu State and 6 in Karaikal area of the Union Territory of Puducherry. In Vennar arm, all the tail end regulators are in Tamil Nadu. These Regulators serve the dual purpose of heading up the irrigation waters for commanding the ayacut and at the same time holding up the saline back waters of the sea.

1.6.10 Rainfall:

There are in all 224 existing rain gauge stations (reporting to Indian Meteorological Department) within the Cauvery basin. These rain gauge stations are more or less uniformly distributed over the entire basin and their number is fairly adequate. In view of the reasonably good network of rain gauge stations in this basin, sub-catchment and sub-basin rainfall averages have been worked out as the arithmetic means of the normals of the rain gauge stations in the respective sub-catchments and sub-basins.

The rainfall in the basin varies from State to State. In the State of Kerala, normal annual rainfall in the basin is about 2873 mm. In the high ranges of the Western Ghats, it is as high as 4435 mm at Vayithri in Kozhikode District but is as low as 1349 mm at Marayur in Kottayam District. Most of the rainfall occurs in that part of the Cauvery basin in Kerala and Karnataka during the South West Monsoon which commences from June and lasts till September end. A notable feature of the south west monsoon is that the coefficient of variation (%) is as low as 15 and is more dependable in the time of onset and the amounts of rainfall it gives.

In the Coorg District of Mysore lying in the head reach of the Cauvery basin, the normal annual rainfall is of the order of 2400 mm and most of the rainfall is received during the South West Monsoon. The variation of normal annual rainfall in the district is very much marked, as the normal annual of rainfall at Bhagamandala is 6032.3 mm, while it decreases to 1120.0 mm at Fraserpet in the north of the district. The other districts of the Karnataka State constituting the Southern Maidans, through which the river flows after descending from the western ghat hills and which falls in the rain-shadow zone of the Western Ghats, receive on an average only about 691 mm (Mandya district) to 761.9 mm. (Mysore district).

In Tamil Nadu, the average annual rainfall in the Cauvery basin upto the confluence with Amaravathi, is 1010.4 mm. The average annual rainfall is maximum in the Nilgiris, wherein the average annual rainfall at Devala is 4045.8 mm. The contributions of both the South West Monsoon and the North East monsoon towards the rainfall in the basin upto the confluence with Amaravathi are almost equal and are of the order of 390.4 mm and 387.9 mm respectively. The (undivided) districts of Thanjavur and Tiruchirapalli are influenced more by the North East monsoon. The rainfall contribution by the North East monsoon to this portion of the basin from the confluence with Amaravathi upto the confluence with the Bay of Bengal is 526.7 mm, while South West monsoon contributes an average rainfall of 299.1 mm only.

Both the monsoons are, of course, of importance to the Basin. While the influence of the South West monsoon rainfall in the hills in the Coorg district of Karnataka and Wyanad district of Kerala is of prime importance for the water potential in the basin, these hilly tracks form only a small proportion of the area of the Cauvery catchment, but it is on the run-off from this small area that in a normal year a large part of the annual flow of the river is available during the south west monsoon. During the north east monsoon (October to December), the maidan area below the hilly tracts, more particularly the southern and eastern parts of the catchment gets its flow. The North East monsoon is the main source of water supply for the minor irrigation tanks which are numerous in Tamil Nadu, where the topography and soil types favoured their formation.

Apart from the two monsoon periods, some rainfall takes place in all the districts of the basin, during the hot months (March - May). In the Karnataka part the pre-monsoon rains are usually predominant and start in May itself. In the Nilgiris in Tamil Nadu, substantial rainfall takes place during the period of summer months. The district has a much higher rainfall and a much better distribution over the year, the average annual rainfall being about 1930 mm.

The Cauvery basin upto Mettur Dam is mostly under the influence of the South West monsoon. Downstream of Mettur Dam, the Cauvery catchment is under the influence of the North East monsoon and the high floods due to this monsoon usually occur in November.

On account of high intensive rainfall in the Northeast Monsoon, sometimes recording even 200 to 250 mm in a day, the utilisable rainfall is comparatively low and floods and drainage congestion ensue. In the Cauvery Delta, the river channels of the Cauvery and the Vennar sub-basins serve as irrigation-cum-drainage channels in large extents particularly below one third of the Delta below Grand Anicut. At the tail ends of these channels, regulators have been constructed to facilitate heading up of the irrigation waters to serve the channels taking off above from the rivers. The nonutilisable rainfall passes on to the sea through these tail end regulators,which are kept open when heavy rainfall occurs and drainage congestion takes place.

1.6.11 Soils:

The principal soil types found in the basin are (a) black soils, (b) red soils, (c) laterites, (d) alluvial soils, (e) forest soils and (f) mixed soils. These are briefly described below:

Black soils are found in all the districts of Tamil Nadu except the Nilgiris. These soils generally occur in semi-arid conditions with an annual precipitation of 500 - 1000 mm and are moisture- retentive and fertile.

Red soils occupy large areas in the basin. In Kerala, they are derived from the micaceous or granite rocks under the influence of weather and climatic conditions. In the southern maidan in Mysore, they are predominant. In the Madurai, Coimbatore and Salem districts of Tamil Nadu the red soils cover more than 60 percent of the cultivated area. Generally, red soils are less fertile but those of Coimbatore district are clayey in nature which makes them comparatively more fertile. Unlike the heavy black soils, red soils do not retain moisture well. The normally loamy structure of the red soils or the intermixture of fine and thick particles makes them suitable for the cultivation of a larger variety of crops than the black soils.

Laterite soils are found in the Coorg area in Mysore State. These soils exhibit a loamy or clayey surface with a lot of pellet concretions of varying thickness followed by laterite horizons. In the highland areas, the top soils have been eroded leaving behind slag-like masses of laterite. They occur generally on highland plateaus and are sometimes devoid of the vegetative cover.

Alluvial soils are found in the Cauvery delta. They are also found in the belt along the river in Tiruchirapalli district. The deltaic alluvium is the most fertile. The alluvial soils in the coastal reach are known as coastal alluvium. They are generally less fertile and on account of inundation by sea water, some of the profiles contain an appreciable amount of salts.

Forest soils occur in the Nilgiri district and are generally porous in texture. In addition to the distinct soil types described above, combination of these types such as mixed red and black soils, etc. also occur. The properties of such soils are those of the constituent soil types.

1.6.12 Development of Irrigation:

Irrigation has been in vogue for centuries in the Cauvery basin through tanks and diversion from anicuts. Several irrigation systems, all in the nature of run-of-the-river systems leading to open channels taking off on either side from diversion structures, were created in the Cauvery basin both in Karnataka and Tamil Nadu over a long period of time. Such systems had an earlier start in the lower regions of the Cauvery basin especially the Cauvery Delta at the tail end, because of the natural conditions and topography that were conducive for such systems being created, with the then knowledge of providing irrigation structures within the purview of the local rulers.

In the upper regions of the Cauvery basin, particularly in the tributaries Hemavathi, Kabini, Bhavani and Amaravathi, a number of small diversion structures with canals taking off from either or both the banks to irrigate long, thin, ribbon-like strips of the command areas were developed over a period of time. With copious supply of water in the river system through the south west monsoon, the river carried high run-off and some times even floods inundating the Cauvery Delta at the end which often submerged and spoiled the cropped areas. With the cessation of the south west monsoon, the flows in the river used to come down. With such low flows in the river systems, even the crops in the large Delta in Tamil Nadu suffered for want of adequate supplies at the right times. Perhaps because of the uncertainties and the large variation in the flow in the river, no attempts were made to extend the command areas in the upper regions of the basin. In the lower regions, where a number of large irrigation systems could be created, in the Cauvery Delta, the crops suffered for want of adequate supplies at the time they were maturing just after the south west monsoon. The heavy short spells of the north east monsoon could not also sustain the crops in the large Delta until they matured and there were frequent failures of crops. Some times with the monsoon rains becoming intense and cyclonic, floods were created in the lower part of the Cauvery Delta resulting in the submersion and damage to crops. Thus the need for storages in the Cauvery basin for holding and using the south west monsoon yield in the river and regulating the flows to ensure irrigation throughout the crop period in both the States and also in the Cauvery Delta was keenly felt even by the end of the nineteenth Century.

At the start of the last century, irrigation in Mysore (Karnataka) was mainly from direct diversion channels from the rivers to the extent of nearly one lakh acres. The system of tank irrigation was widespread and nearly 2 lakh acres were under irrigation from such tanks in the basin. With the creation of the Krishnarajasagara, development of irrigation received a fillip and by 1956, the irrigation from major and medium systems had increased to 3 lakh acres in Karnataka . The minor irrigation increased by 20000 acres to 2.20 lakh acres. Subsequently, a few other reservoirs like Nugu, Marconahally etc., were formed and the extent of irrigation under major, medium and minor irrigation schemes in Karnataka increased to 4.4 lakh acres by 1971. At the same time, the minor irrigation went upto 2.40 lakh acres. Thus the total extent irrigated was nearly 6.8 lakh acres.

The irrigation development in Tamil Nadu started much earlier and some of the systems like the Cauvery Delta are centuries old. At the end of the 19^{th} century, nearly 14 lakh acres were under major irrigation systems and 2.2 lakh acres under minor irrigation, totalling to 16.2 lakh acres. With the construction of Mettur Dam in 1934 and coming into operation of the Lower Bhavani and Amaravathi projects on the tributaries in 1950s, the area under irrigation increased to 20.7 lakh acres and under minor irrigation, to 2.40 lakh acres. By 1971, the total area under major and medium irrigation schemes increased to 25.3 lakh acres and under minor irrigation, to 2.90 lakh acres totalling to 28.2 lakh acres.

The utilisation of the Cauvery waters in Kerala was very little and it was only through minor irrigation. There was no major and medium irrigation use till 1971 in Kerala.

Thus the total area irrigated in the Cauvery basin was about 35 lakh acres asin 1971.

1.6.13 Storages in the Cauvery basin:

The development of irrigation in the basin upto the pre-independence stage is mainly through diversion structures, which existed from time immemorial. There were only two storages one in Karnataka, the KRS with a capacity of 45 TMC (net) [49 TMC gross] and one in Tamil Nadu, the Mettur, with a capacity of 93.5 TMC (net) [95.6 TMC gross]. Since independence, more reservoirs were taken up both by Karnataka and Tamil Nadu under the Five Year Plans. As per the data collected by the Cauvery Water Disputes Tribunal, the total storage capacity of the reservoirs in the Cauvery basin has increased from 145 TMC Gross to 330 TMC Gross (139 TMC net to 310 TMC net) as shown below:-

Summary of Storage Capacities in Cauvery basin

Sl.No.	Period	Capacity (in TMC)	
		Gross	Live
i)	Storages built before 1972	206	197
ii)	Storages built after 1972	90	82
iii)	Storages proposed in Kerala	21	19
iv)	Small storages below 1 TMC Capacity	13	12
	Total	**330**	**310**

The details of the reservoirs are given in the statement in Table 1.6.3

Table 1.6.3 Storages built (1.00 TMC and above) before 1972 in the Cauvery Basin

l. No.	Name of Reservoir and Sub-basin	Year of		Storage Capacity (TMC)		Installed Capacity MW
		Start	Completion	Gross	Live (Effective)	
1	2	3	4	5	6	7
I	KERALA			NONE		
II	TAMIL NADU					
(A)	Irrigation					
1	Mettur (Cauvery)	1925	1934	95.660	93.500	240
2	Lower Bhavani (Bhavani)	1948	1953	32.800	32.055	8
3	Amaravathy (Amaravathy)	1953	1952	4.047	3.968	
	Total of (A)			132.507	129.523	248
(B)	Power					
1	Mukurthi (Bhavani)	1937	1941	1.800	1.792	
2	Pykara (Bhavani)	1946	1956	2.000	1.950	72
3	Upper Bhavani (Bhavani)	1956	1962	3.572	3.012	Kundah P.H. I to V & Moyar : 491
4	Porthimund (Bhavani)	1960	1967	2.123	1.993	
5	Emerald (Bhavani)	1956	1962	3.365	3.300	
6	Avalanche (Bhavani	1956	1962	2.171	2.136	
7	Pillur (Bhavani)	1960	1967	1.568	1.233	
	Total of (B)			16.599	15.416	563
	Total of (A) + (B)			149.106	144.939	811
III	KARNATAKA					
1	Krishnarajasagar (Upper Cauvery)	1911	1931	49.452	45.051	
2	Marconahalli (Shimsha)	1938	1940	2.400	2.260	
3	Nugu (Kabini)	1946	1959	5.440	4.893	
	Sub-Total (Karnataka)			57.292	52.204	
	Grand Total (I + II + III)			206.398	197.143	

TABLE 1.6.3 (contd...)

Storages built (1.00 TMC and above) proposed in the Cauvery Basin as on 1972

Sl. No.	Name of Reservoir and Sub-basin	Storage Capacity (TMC)	
		Gross	Live (Effective)
1	2	3	4
I	KERALA		
1	Noolpuzha (Kabini)	3.030	2.702
2	Thirunelly (Kabini)	3.602	3.496
3	Thonder (Kabini)	2.895	2.225
4	Peringottupuzha (Kabini)	3.355	3.205
5	Kallampathy (Kabini)	2.702	2.502
6	Kadamanthodu (Kabini)	1.805	1.706
7	Cheghat (Kabini)	1.700	1.501
8	Chandalipuzha (Kabini)	2.101	1.992
	Total of (I)	21.190	19.329
II	TAMIL NADU	Nil	Nil
III	KARNATAKA	Nil	Nil
	Grand Total (I + II + III)	21.190	19.329

TABLE 1.6.3 (contd...)

Storages built (1.00 TMC and above) after 1972 in the Cauvery Basin

Sl. No.	Name of Reservoir and Sub-basin	Year of		Storage Capacity (TMC)	
		Start	Comple-tion	Gross	Live (Effective)
1	2	3	4	5	6
I	KERALA				
1	Karapuzha (Kabini)	1974	NA	2.700	2.541
2	Attappady (Bhavani	1975	NA	2.295	2.144
3	Banasurasagar (Kabini)	1980	NA	5.889	5.050
	Sub-Total - I			10.884	9.735
II	TAMIL NADU				
1	Palar - Porandalar (Amaravathy)	1970	1978	1.524	1.404
	Sub-Total - II			1.524	1.404
III	KARNATAKA				
1	Kabini (Kabini)	1959	1974	19.520	16.000
2	Harangi (Harangi Upper Cauvery)	1964	1974	8.500	8.073
3	Suvarnavathy (Suvarnavathy)	1965	1984	1.260	1.259
4	Hemavathy (Hemavathy Upper Cauvery)	1968	1979	37.103	35.760
5	Manchanabele (Arkavathy)	1970	-	1.222	1.061
6	Taraka (Kabini)	1970	-	3.940	3.205
7	Arkavathy (Arkavathy)	1975	-	1.587	1.430
8	Votehole (Hemavathy Upper Cauvery)	1976	-	1.510	1.366
9	Yagachi (Hemavathy Upper Cauvery)	1984	-	3.601	3.269
	Sub-Total - III			78.243	71.423
	Total (I + II + III)			90.651	82.562

1.7 THE CAUVERY BASIN IN TAMIL NADU

1.7.1 Extent:

The Cauvery basin area in Tamil Nadu is 44016 sq.km. including Karaikkal region in the Delta under the Union Territory of Puducherry and this is more than 50% of the total Cauvery basin area. This basin area in Tamil Nadu constitutes more than one third of the geographical area of Tamil Nadu. The Cauvery is the only major river basin in the State and also the only perennial river in the State.

Of the 16 sub-basins in which the Cauvery basin has been divided for discussion before the Cauvery Water Disputes Tribunal, 7 sub-basins lie in Tamil Nadu.The 7 sub-basins are spread over 11 districts (undivided) and the percentage of the area of the district lying in the basin is as below:

S.No	Name of District	Basin area in the district in sq. km.	percentage to district area
1	Dharmapuri	3644	38.03
2	Salem	5768	66.80
3	Coimbatore	3927	52.57
4	Nilgiris	2036	80.03
5	Erode	8233	100.00
6	Tiruchirapalli	8333	74.90
7	Perambalur		
8	Ariyalur		
9	Thanjavur	6551	79.72
10	Thiruvarur		
11	Nagapattinam		
12	Pudukottai	404	8.66
13	Cuddalore	932	8.55
14	Dindugal	4011	64.00
15	Madurai	29	0.43
	Total	**43868**	

1.7.2 Irrigation Development:

The Development of irrigation in Tamil Nadu dates back to centuries. It is said that irrigation in the Cauvery Delta was in practice even when irrigation was in vogue in the Indus valley in India and the Mesopotamian valley in Persia. The Cauvery being a perennial river flowing into Tamil Nadu with its vast Delta at its tail end is the main source of irrigation water in the State.

The Grand Anicut across the Cauvery, deriving the name because it is a Grand old structure, built by Raja Karikala Chola around 200 AD can be said to be the oldest structure in the World, built across a flowing river on a sandy river bed, still functioning as the main regulating structure for the Cauvery facilitating irrigation in about 12 lakh acres. The Cauvery Delta is served by this Anicut and the rivers Cauvery and Vennar and their 36 branches and 29881 distribution network of main channels and minors running to more than 14000 miles or 22400 km. The details are given in **Table 1.7.1.**

In 1863, a private company called the "Madras Irrigation Company" was floated to develop irrigation in the Cauvery Delta but later on, this was acquired by the British Government. In the Madras Presidency, about 4.2 M.ha.(10.532 M.acres) was irrigated in the beginning of the 19th century, out of which 0.54 M.ha. (1.33 M. acres) was in the Cauvery basin. Apart from the Cauvery Delta, in the upper region of the Cauvery basin in Tamil Nadu in the tributaries like Bhavani, Amaravathi and Noyyil, a number of small diversion structures with canals taking off on one or both banks to irrigation long, narrow, strips of the command areas were developed over a period of time.

Table 1.7.1

STATEMENT SHOWING THE NUMBER OF A, B, C, D, ETC., CHANNELS WITH THEIR TOTAL LENGTH IN CAUVERY DELTA.

	Cauvery Sub-Basin				Vennar Sub-basin				Total			
	No	M.	F.	Ft.	No.	M.	F.	Ft.	No.	M.	F.	Ft.
A. Class Channel	922	2011	7	274	583	1439	1	547	1505	3451	1	161
B. Class Channel	5812	2933	7	236	3932	2480	4	437	9744	5423	4	913
C. Class Channel	5891	1956	5	610	5191	1901	7	384	11082	3858	5	334
D. Class Channel	2752	791	4	232	2566	838	3	654	5318	1630	0	226
E. Class Channel	914	223	7	177	837	194	0	296	1751	417	7	473
F. Class Channel	279	71	4	181	178	29	7	106	457	101	3	287
G. Class Channel	24	7	2	33	-	-	-	-	24	7	2	33
Total									29881	14890	1	447

Table 1.7.1 (contd...)

LIST OF MAIN RIVERS IN THE CAUVERY DELTA WITH EXTENT OF AYACUT UNDER THEM

Serial number and name of		Whether solely irrigation or irrigation - cum - drainage or purely drainage	Length in Miles	Ayacut in acres
I. Cauvery and its branches -				
1. Cauvery river	Main River	Irrigation.	75-3-0	1,27,528
2. Arasalar "	Do	Irrigation-cum-Drainage	44-0-0	19,387
3. Kudamurutty	Do	Irrigation.	37-0-0	27,244
4. Nattar	Branch River	do	27-0-0	21,660
5. Keerthimanniar	Do	do	8-0-0	11,630
6. Noolar "	Do	Irrigation-cum-Drainage	9-4-0	19,985
7. Vanjiar "	Do	do	12-0-0	6,227
8. Nandalar "	Do	do	33-3-0	5,157
9. Veerasholan"	Do	Irrigation	32-0-0	42,927
10.Manjalar "	Do	Irrigation-cum-Drainage	22-0-0	16,453
11.Mahimalayar	Do	Do	25-0-0	11,927
12. Manniar "	Do	Do	36-0-0	38,022
13. Pudumanniar or Palavar III Reach	Do	Do	25-6-0	33,355
14. Palavar II Reach	Do	Drainage	12-4-0	0
15. Palavar I Reach	Do	Irrigation-cum-Drainage.	16-6-0	4,023
16. Vikramanar	Do	Irrigation.	9-4-0	22,952
16 (a) Solasundamaniar	Do	Do	9-0-0	8,686
17. Petharasanar	Do	Do	3-0-0	2,427
18. Mudikondan River	Do	Do	39-0-0	1,488
19. Puthar "	Do	Do	31-0-0	15,101
20. Velappar "	Do	Irrigation-cum-Drainage.	21-5-0	19,074
21. Thirumalarajan "	Do	Do	42-0-0	13,584
22. South Rajan Channal and Kumukkimaniar	Do			25,000
Total			571-3-0	4,93,887

II. Vennar and its branches- 23 Vennar River	Main River	Irrigation-cum-Drainage		
23. Vennar	Do	Do	70-0-0	1,20,042
24. Vettar	Do	Do	63-0-0	54,361
25. Koraiyar	Branch River	Do	41-4-0	57,193
26. Vadavar	Do	Do	18-0-0	14,859
27. Pamaniar	Do	Irrigation	33-0-0	37,344
28. Mulliar	Do	Irrigation-cum-Drainage	25-0-0	22,034
29. Adappar	Do	Irrigation	25-0-0	13,448
30. Ayyanar	Do	Irrigation-cum-Drainage	25-0-0	3,361
31. Harichandranadhi	Branch River	Irrigation-cum-Drainage	23-0-0	31,866
32. Vellayar	Do	Irrigation	24-3-0	29,438
33. Pandavayar	Do	Irrigation-cum-Drainage	18-0-0	23,471
34. Shullanar	Do	Do	24-1-0	4,767
35. Odambogiar	Do	Do	10-0-0	32,020
36.Kattar	Do	Do	26-0-0	1,666
37. Kaduvayar				19,427
Total			427-4-0	4,65,307
Grand Total			998-7-0	959,144
			(or) 959,150 acres	

1.7.3 Irrigation in 1901-02:

The details of the schemes and the gross area irrigated under them as in 1901 were as follows:

Sl. No.	System	Gross area irrigated (Lakh ha /Lakh acres)
1	Cauvery Delta System	3.804/9.400
2	Lower Coleroon Anicut	0.44/ 1.090
3	Sethiathope Anicut system	0.285/0.703
4	Kattalai Scheme in Cauvery	0.134/0.331
5	Salem Trichy Channels taking off from Cauvery	0.256/0.880
6	Kodiveri Anicut channels in Bhavani	0.081/0.200
7	Kalingarayan Anicut channel in Bhavani	0.0840.207
8	Old Amaravathi Channels	0.187/0.463
9	Noyyil River Channels	0.69/0.171
	Total	**5.445/13.445**

Besides, there was an extent of 2.190 Lakh acres irrigated under the minor irrigation tanks thus making the total irrigation as in 1901 to 15.635 lakh acres. The entire area was mostly raising paddy.

1.7.4 Irrigation in 1928-29

Since 1901, the anicut and diversion schemes already in operation, were continuing in 1928-29 with necessary improvements then and there and the area irrigated under them as in 1928-29 was as follows:

Sl. No.	System	Gross area irrigated (Lakh ha/ Lakh acres)
1	Cauvery Delta System	4.13/010.205
2	Lower Coleroon Anicut	0.484/1.196
3	Sethiathope Anicut system	0.285/0.703
4	Kattalai Scheme in Cauvery	0.153/0.379
5	Salem Trichy Channels taking off from Cauvery	0.356/ 0.880
6	Kodiveri Anicut channels in Bhavani	0.088/ 0.217
7	Kalingarayan Anicut channel in Bhavani	0.092/0.226
8	Old Amaravathi Channels	0.187/ 0.463
9	Noyyil River Channels	0.069/0.171
	Total	**5.844/ 14.440**

The area under minor irrigation tanks as in 1928-29 was 2.21 Lakh acres. Thus the total irrigation as in 1928-29 was 14.440 + 2.210 = 16.65 lakh acres and almost the entire area was raising paddy.

1.7.5 Development Between 1928 and 1956

1.7.5.1 Kattalai Bed Regulator

The construction of Kattalai Bed Regulator across Cauvery near Mayanur in Karur district was taken up during 1931 and completed by 1933. This work consists of a bed regulator across Cauvery at Kattalai and excavation of the South Bank Canal connecting the river channels existing in the vicinity on the right bank of Cauvery, the North bank Canal connecting the river channels existing in the vicinity on the left bank of Cauvery and the Kattalai High Level Canal taking off at Mile 0 / 5 of the South Bank Canal to irrigate a new extent of 19000 acres lying to the right of South Bank Canal. This Bed Regulator in the shape of a low weir (anicut) facilitated better drawal through these channels.

1.7.5.2 Mettur Reservoir

Mettur Reservoir was taken up after the conclusion of the 1924 Agreement, in 1925 and the dam was completed in 1934. The reservoir has a capacity of 93.5 TMC and will remain as the largest reservoir in Tamil Nadu. The waters stored in the reservoir were intended to stabilise the Delta irrigation. Also, it was envisaged that with the coming up of a storage reservoir at Mettur it will be possible to hold the river freshes and floods, which will not only help to regulate the supplies to the Delta irrigation (which was hitherto on the run-of-the-river basis in an inundation irrigation mode), but also to extend irrigation to a new area of about 3.01 lakh acres allowed in the 1924 Agreement, possible as a result of such regulation. The new command was localized adjacent to the Cauvery Delta to the south, fed by the Canal taking off from the Grand Anicut Complex itself and called the Grand Anicut Canal.

1.7.5.3 Mettur Canals Scheme

The anticipated development of ayacut under the Grand Anicut Canal of the Cauvery Mettur Project did not take place even after a period of 10 to 15 years after the construction of Mettur Project and the actual area developed came to only 2.56 lakh acres as against 3.01 lakh acres permitted under the 1924 Agreement. To make good the shortfall of 45,000 acres, the Mettur Canal scheme which was contemplated by Mr. Moses even in 1904 was taken up for investigation. This scheme was sanctioned and taken up in 1949 with the approval and sanction of the Government of India and completed in 1957 to extend irrigation to a new extent of 45000 acres in Salem and Periyar Districts. The Canal system takes off directly from the Mettur reservoir on its right side and has two branches viz. the East Bank Canal feeding 27000 acres in the Salem District and the West Bank canal feeding 18000 acres in Periyar District (earlier Coimbatore District).

1.7.5.4 Jedarpalayam Regulator

The Raja Channel, which is one of the several old Cauvery channels forming part of the “Salem Trichy Channels” was taking off through a leading channel from the left bank of the river Cauvery, 18 miles below Erode bridge. This channel together with its branch Kumarapalayam channel irrigates a total extent of about 10000 acres in the Salem District. As there were no diversion works at the head of the channel, a Korambu, a temporary nanal grass obstruction was being put up across the river every year to divert the requisite discharge into the channel.

After the construction of Mettur reservoir, the flow in the Cauvery is being regulated with reference to the demand in the Delta with consequential variations in the river rendering the maintenance of the Korambu at the head of Raja channel difficult. Further to ensure full supply to the channel, special issues had to be let down from the Mettur reservoir even when on account of rains the Delta did not need any supply. To avoid such situations and also the difficulty in forming and reforming the Korambu year after year depending on the variations of flow in the river, a bed regulator was constructed across the river at the head of the leading channel which is known as the Jedarpalayam Bed Regulator. This work was taken up in 1949 and completed in 1950.

1.8 CAUVERY DELTA SYSTEM

1.8.1 A Brief Narration

Cauvery Delta lies between upper anicut and Bay of Bengal and it irrigates Trichy, Thanjavur, Thiruvarur, Nagapattinam and part of Pudukkottai Districts. This Delta consist of 3 Sub Basins such as Cauvery Sub Basin, Vennar Sub Basin and G.A.Canal system Basin.

The Cauvery Delta, spread over the physical, geographical area of 6.9 lakh ha. (17.06 lakh acres) has an irrigation extent of 3.79 lakh ha. (9.34 lakh acres.) net and 5.22 lakh ha (12.90 lakh acres) gross (including Karaikal Region) and holds the most extensive irrigation system in Tamil Nadu State. This has been known at one time as the "granary of the Peninsular India". The total net area irrigated in the State as in 2006-07 under various sources is about 28.9 lakh ha, of which the area under Government canals is about 7.8 lakh ha. The extent in the Cauvery Delta System alone forms about 48% of the area irrigated under canals in the State.

The Grand Anicut or 'Kallanai' as locally called in Tamil, constructed by King Karikala Chola in the Second Century AD, marks the first step in taming the river Cauvery and bringing irrigation facilities to this large extent in the Delta. The construction of this anicut more as a breach closing exercise also provided necessary head to draw the irrigation supply required for the Delta and pass on the flood surplus into the Coleroon through the Ullar below the Grand Anicut.

The water of Cauvery, Vennar and G.A Canal in Cauvery Delta is regulated for irrigation. After irrigation, the excess of water drains in to the large drain and finally confluences in to the sea.

The nearly flat, fan-shaped Delta of the Cauvery river slopes gently towards the sea over a distance of 160 km (100 miles). The sunlight and temperature are good year-round for tropical growth. Rice has been raised in the Delta for centuries. The Cauvery alluvium in the Delta presents minimum of production or utilization problems. Moving downstream, the low lying soils near the coast pose problem of salinity. In the Cauvery and Vennar subbasins in the Delta, an extent of 1.90 lakh ha. (4.69 lakh acres) and 1.88 lakh ha. (4.65 lakh acres) respectively are irrigated. The Delta which was wholly located in the Thanjavur district previously, is now spread over three districts after trifurcation of Thanjavur district, lying 61% in Thanjavur district and fully covering Tiruvarur and Nagapattinam districts.

As seen above, out of the total workers (workers and marginal workers) in the rural area, the cultivators and agricultural labour form about 65.6% in Thanjavur and Tiruvarur districts and 61.3% in Nagapattinam district.

1.8.2 Land Holdings

The operational land holding and sizes in the Delta districts with the percentage to the total holdings is as below:

Status	No. of Holdings	% to the Total Holdings	Total area (ha.)	% to the total Area
Marginal (less than 1 ha)	476729	75.8	182598	34.0
Small (1 to 2 ha)	93451	14.9	131735	24.6
Semi-Medium (2 to 4 ha)	43023	6.8	117000	21.8
Medium (4 to 10 ha)	13812	2.2	78102	14.6
Large (10 ha & above)	1565	0.2	27141	5.1
Total	**628580**	**100.0**	**536576**	**100.0**

Source: Agro Stat - 2006 Published by Commissioner of Agriculture, Department of Agriculture, Chepauk, Chennai - 5, Page 312

Thus 91% of the holdings, comprising about 58.6% of the area are covered under marginal and small holdings.

1.8.3 Rainfall

The normal rainfall in the Cauvery Delta districts is as follows:

District	South west monsoon	North east monsoon	Other periods	Annual
	(mm)	(mm)	(mm)	(mm)
Thanjavur	342.0	545.7	165.3	1053.0
Tiruvarur	301.8	665.4	162.7	1129.9
Nagapattinam	274.1	886.4	181.2	1341.7

Source: Season and Crop Report, Tamil Nadu, 2006-07, Department of Economics & Statistics, Chennai 600 006, Pages 51 - 56.

This shows that as is natural, rainfall decreases from the coast as one travels towards land.

1.8.4 Barrage on the Cauvery Arm

After the construction of KRS and Mettur Reservoir, the floods in the river got reduced. Since releases in the river for irrigation are controlled at Mettur, diversions through the Coleroon arm at Upper Anicut considerably reduced and this caused increased silting on the Coleroon bed. The Cauvery arm which was provided with only a grade wall at its head began drawing flows beyond its capacity during floods. This necessitated the construction of a barrage at the head of the Cauvery arm too. This structure is known as Cauvery Barrage. Thus as at present, at the head of the Delta viz. Upper Anicut, we have barrage structures both on Cauvery and Coleroon arms giving adequate facilities to regulate the flows in Aganda Cauvery both in normal times and also during heavy floods.

Salient features of the Upper Anicut **are:**

Cauvery Barrage:

Design flood discharge	5100 m^3/s (180000 ft^3/s)
MFL in front	76.55 m
Sill level of the Barrage	72.00 m (236.22 ft) (same as the crest of the Cauvery Dam)
Pond level	74.45 m (244.24 ft)
Pond storage	2.6 M.cum (91 M.cft)
No. and size of vents	41 Nos. 12.00 m x 2.45 m

Coleroon Regulator:

Maximum flood discharge	7643 m^3/s (270000 ft^3/s)
MFL front	76.55 m (251.14 ft)
North Branch	
Sill level	72.63 m (238.29 ft)
No.& size of vents	10 Nos. 12.19 m x 1.82 m
South Branch	
Sill level	72.63 m (235.29 ft)
No.& size of vents	45 Nos. 12.19 m x 1.82 m

1.8.5 Grand Anicut

The two arms of the river Cauvery viz., the Cauvery and the Coleroon, after the bifurcation at Upper Anicut, flow close to each other for about 32 km below the Upper Anicut. At this location they are linked by Ullar, which drains the floods of Cauvery into Coleroon through the Grand Anicut. The landmass in between Coleroon and Cauvery from Upper Anicut to this Ullar is the famous holy Srirangam island. The Cauvery at this location branches into two irrigation rivers viz., Cauvery and Vennar. They were earlier drawing their supplies through open heads. Difficulties caused by the presence of the interlinking course, Ullar in maintaining the required supplies in Cauvery for irrigation was overcome by the construction of an Anicut on the left bank of Cauvery. This Anicut built by Raja Karikala Chola in about the second Century A.D. is known as the "Grand Anicut". This is located at a distance of about 16 km from Tiruchirapalli town.

This structure which is a grand old one as its name itself implies, is a marvellous piece of hydraulic structure built across a mighty river on its sandy bed at a time when building science had not developed enough to build safe structures on permeable foundations. Perhaps this is the oldest such structure of this magnitude still serving the purpose for which it was made. The credit should go to those builders in that, this structure is serving to this date excellently well with a few modifications by nature of improvements to the structure.

No recorded information is available as to how they founded this structure nor the manner of its construction. It is believed that large cyclopean stones from long distances would have been brought and dumped across the course and continuously replenished as these boulders sank into the sandy bed to get lodged well in the clay layer below until the structure rose above the water level. It has not been possible to explore and detail the foundation actually. Such a course has not been advised either, considering the importance of this structure to the Delta irrigation. The foundation base even on date is so stable and massive that successive generations have thought of only improvements and modifications to the structure without meddling with the foundation base lest they may disturb the already settled mass.

The Anicut as seen consists of a core of rough stones buried in the clay bed below and covered with a facing of rough stone in mortar. A portion of the crest is built with a curved top and the rest with a series of steps, the foot of the solid dam being protected by a rough stone apron. The Anicut is 329 m (1080 ft) long, 12.2 to 18.3 m (40 to 60 ft) in width and 4.75 to 5.49 m (15 to 18 ft) in height.

The construction of the Grand Anicut marks the first step in the taming of the river Cauvery and ensuring irrigation facilities to the large extent in the Delta. The main function of the anicut is to provide the necessary head to draw the supply required for the Delta and pass down the surplus into Coleroon.

1.8.6 Improvements to the Original Structure (G.A.)

In 1804, Captain Coldwell repaired the Anicut and provided dam stones (2'- 3" high) on the crest and raised the river embankments thus forcing more water into Cauvery and Vennar.

In 1830, ten scouring sluices of size 3' x 4' were built by Sir Arthur Cotton with sill at 179.60' to scour the silt deposit in front of the Anicut and the canal head.

In 1840, a bridge was built over the Anicut using the existing work as foundations.

In 1886, the dam stones were removed and automatic falling shutters 2' - 10" high were fitted on the crest of the Anicut.

In the same year Head Regulators were constructed across the Cauvery and Vennar immediately downstream and at right angles to the Grand Anicut, for distributing the available flow between these two rivers and also for excluding the flood from these rivers.

In 1889, the falling shutters over the crest of the Anicut were removed and 5 ft. high lift shutters of 32 ft. span were provided in all the 30 arches of the bridge.

In 1909, three of the Arches in the scouring sluices portion were washed away and this portion was subsequently restored. Five vents of 20' x 10' provided with radial shutters were built at the right end of the Grand Anicut to serve as new scouring sluices. To deflect the low water course away and protect the foundations of the Grand Anicut from scour, a 1100 ft. long grade wall was constructed in the bed, upstream of the Grand Anicut.

In 1924, a record flood of 4.75 lakh c/s passed over the Mettur dam site. A bye-wash capable of discharging 98600 c/s into Coleroon in the event of extraordinary flood, was constructed about a mile upstream of the Grand Anicut.

During 1925-34, simultaneously with the construction of the Mettur Dam and the excavation of the Grand Anicut canal, a new Head Sluice with six vents of 30' x 5 ½' each was constructed on the right bank of Cauvery to serve as the Head Regulator of the Grand Anicut Canal.

The Grand Anicut or "Kallanai" as locally called in Tamil is a name loosely applied to the group of structures in the complex comprising of:

i. The Grand Anicut proper i.e., the dam with the lift gates constructed across Ullar.
ii. A Block of 5 scouring sluices on the right end of the Grand Anicut.
iii. Regulators at the heads of Cauvery and Vennar.
iv. The Regulator at the head of the Grand Anicut Canal.

Salient features of the Grand Anicut are:

Grand Anicut	
Total length	329.2 m (1080 ft).
Surplus vents- No, size & sill	30 Nos. 9.8 x 1.5 m (32' x 5';) +57.7 m(189.30 ft)
Scour vents - No, size & sill	5 Nos. 6.1 x 3.1 m (20' x 10')+54.6 m(179.25 ft.)
Flood discharging capacity	3327 m^3/ s (117500 cusecs)
MFL front and rear	60.8 m (199.60 ft) / 48.6 m(192.25 ft)
Cauvery Head Regulator	
Total length	179.5 m (589 ft).
No. & size of vents and sill	42 No 3.1 x 2.7 m (10' x 9'); +56.2 m (184.25 ft)
MFL front and rear	60.8 m (199.60 ft) / 57.7 m (189.15 ft.)
Maximum supply	441 m^3/ s (15587 cusecs)
Normal supply	371 m^3/ s (10391 cusecs)
Vennar Head Regulator	
Total length	141.1 m (463 ft).
No. & size of vents and sill	33 Nos. 3.1 x 3.4 m (10' x 11' 4"); +56.2 m (184.25 ft.)
MFL front and rear	60.8 m (199.60 ft.) / 59.2 m (194.25 ft).
Maximum supply	377 m^3/ s (13295 cusecs)
Normal supply	251 m^3/ s (8863 cusecs)
G.A.Canal Head Regulator	
Total length	66.5 m (218 ft)
No. & size of vents and sill	6 Nos. 9.1 x 1.6 m (30' x 5' 3"); +56.2 m(184.25 ft).
MFL front and rear	60.8 m(199.60 ft). /58.8 m(192.92 ft).
Maximum supply	116 m^3/ s (4100 cusecs)
Normal supply	99.1 m^3/ s (3500 cusecs)

The maximum and normal supply to be maintained is worked out adopting a duty of 30 ac./cusec and 45 ac/cusec respectively for the Cauvery, and 35 ac/cusec and 52½ ac./cusec respectively for the Vennar.

It is inevitable that the Cauvery arm below Upper Anicut is also to serve as a flood carrier for the drainage that flows in between the Upper anicut and the Grand anicut and dispose of the floods through the Grand Anicut. It is not advisable to send down any flood flows below Grand Anicut into the Delta which should be disposed of through the Grand Anicut. All the components of the structure were therefore checked up and strengthened with this view in 1977.

During the operation of the gates, situations arose when the head discharge had to be throttled quite frequently. With the head operated through screw gear shutters, the operation took time and insistence on accuracy of discharges and uniform height of shutter opening became difficult. Electrification of the hoisting machinery of these regulators have now been done to overcome these bottlenecks and to improve the operational efficiency.

The Cauvery at Grand Anicut sub divides into two main irrigation rivers viz., Cauvery and Vennar which sub divide further into 21 and 15 rivers respectively to feed the Delta through a network of main channels and numerous branches distributaries and sub distributaries. The details of the branch rivers and the canal network of the Cauvery Delta system have been furnished in figure 1.4. The details of the Tailend Regulators of Various Rivers of the Cauvery Delta System have been furnished in **Table 1.8.1**

Figure 1.4

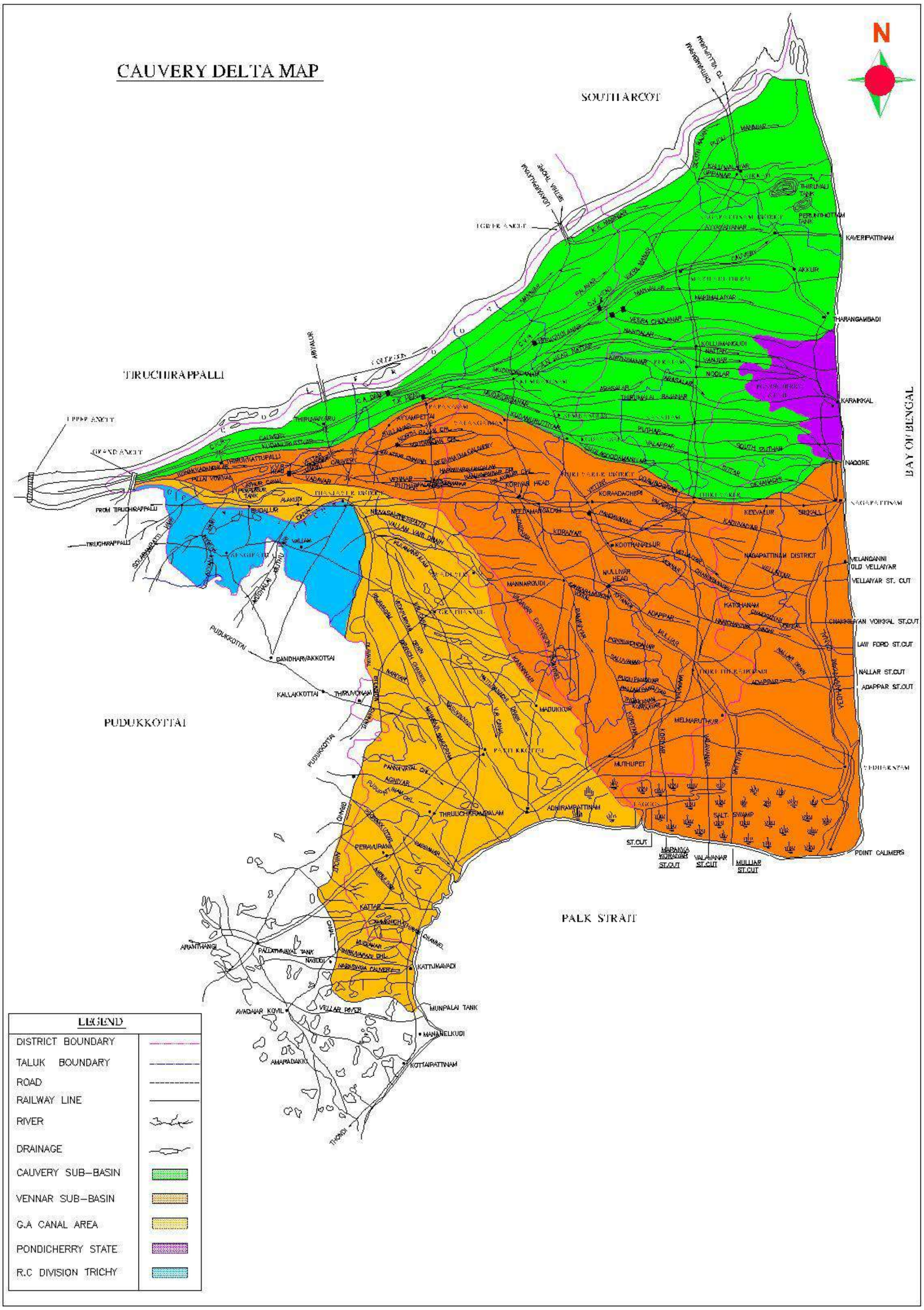

CAUVERY DELTA MAP
N
SOUTH ARCOT
TIRUCHIRAPPALLI
PUDUKKOTTAI
BAY OF BENGAL
PALK STRAIT
KAVERIPATTINAM
THARANGAMBADI
KARAIKKAL
NAGORE
NAGAPATTINAM
VELANGANNI
POINT CALIMERE
MUTHUPET
ADIRAMPATTINAM
MANNARGUDI
GRAND ANICUT
UPPER ANICUT
LEGEND
DISTRICT BOUNDARY
TALUK BOUNDARY
ROAD
RAILWAY LINE
RIVER
DRAINAGE
CAUVERY SUB-BASIN
VENNAR SUB-BASIN
G.A CANAL AREA
PONDICHERRY STATE
R.C DIVISION TRICHY

Table 1.8.1

List of Tail End regulators in the Cauvery sub basin

Sl. No	Name of the river	Name of the regulator
1	Mahimalayar	Kannappan Moolai
2	Mahimalayar	Arabi
3	Cauvery	Melayur
4	Pudumanniar	Pudumanniar surplus
5	Kittiyanai Uppanar	Kittiyani surplus
6	Manjalar	Annappanpettai
7	Southrajan	Pillpadugal

List of Tail End regulators in the Vennar sub basin

Sl. No	Name of the river	Name of the regulator
1	Vettar	Odacherry
2	Kaduvaiyar	Vadugacherry
3	Vellaiyar	Eravaikadu
4	Harichandra river	Brinjimoolai
5	Adappar	Umbalacherry
6	Mulliyar	Thanikottagam
7	Manankondaner	Adahanur
8	Marakkakoriyar	Idumbavam
9	Valavanar	Thondiyakadu
10	Koriyar	Jambuvanodai
11	Paminiyar	Thoppathana-veli

1.8.7 Monsoons and their influence :

The south west monsoon occurring in June to September does not cause either drainage or flood problems, as the impact of the monsoon is in the Western Ghats in the upper reaches of the Cauvery basin. The heavy flows occurring in the river during the south west monsoon are easily absorbed in the numerous reservoirs that have come up in the upper reaches of the Cauvery basin in Karnataka and Kerala. The over flows from these reservoirs are impounded in the Mettur reservoir and even if it surpluses, the flows are diverted into the Coleroon and partly in Cauvery at the Upper anicut since barrages are now available both on Cauvery and Coleroon and flood regulation through both Cauvery and Coleroon is now possible. The flood diverted through Cauvery arm is discharged through the Grand Anicut to flow back to Coleroon keeping the Cauvery Delta safe except to drain the rainfall - runoff from the Delta itself.

The Cauvery Delta receives normally about 300 mm of rainfall during the south west monsoon period. These rains are fully utilized by the crops and there is no problem of drainage or submersion during this period. Irrigation deliveries are regulated taking into account the effective rainfall.

The north east monsoon which generally starts in the third week of October gives normal rainfall of about 700 mm, the highest being in November.

Unlike the south west monsoon which starts from the west and slowly travels towards the east, gradually dissipating itself into a few haphazard showers by the time it reaches the East Coast, the storm direction of the north east monsoon is from the Coast and towards inland gradually weakening as it travels inland. This monsoon is generally accompanied by depressions which sometime intensify as cyclones. This factor complicates the drainage problem in the Delta, because by the time the upland catchment forces the flood waters down the Vennar, the lower reaches of the Delta are already fully congested with the flood generated in the Delta itself. Far from being able to receive any part of the vast quantities of waters that the rivers bring down, the fields that drain into these rivers are themselves in need of adequate drainage during this period of intense north east monsoon, more because of the vast extent. At this point of time the entire Delta is covered with standing crops at various stages of growth and harvest.

As already detailed earlier, it is the north east monsoon that causes more harm and damages to crops and property in terms of heavy inundation of the cropped lands towards the coast. Paddy crop cannot survive submersion for more than 5 to 7 days and there have been times when large extents of crops have been lost with the flood waters unable to get drained to the sea, for at that time the sea also will be rough refusing to take in flood flows.

Historical records of Severe Cyclones which crossed Tamil Nadu during the period from 1970-1999 are enclosed in **Table 1.8.2**

1.8.8 Floods and Drainage in the Delta

The flood problems in the Delta may be classified under two distinct categories, the first being that caused by extraneous floods entering the Delta from upland catchments viz., catchment lying between Upper Anicut and Grand Anicut and the dry upland tracts lying South West of the Delta and draining directly into the Delta below Grand Anicut, and the second, caused from the rainfall within the Delta itself.

1.8.9 Floods from the catchment lying between Upper Anicut and Grand Anicut

The Cauvery arm below Upper Anicut has to serve as a flood carrier also for the drainages that flow between the Upper Anicut and Grand Anicut and dispose off the floods. The upland drainages like Pungal river, Kulithalai Kattuvari, Kodamurutty, Koraiyar, etc., joining the Cauvery above Grand Anicut swell the river flows. This generally occurs during the north east monsoon period and is flashy in nature. The catchment between Mettur Dam and Upper Anicut is also likely to generate some flows during the north east monsoon but the magnitude is small due to the low intensity of rainfall in this area. However, these flows combined with the freshes collected from the catchment between Upper Anicut and Grand Anicut cause a greater impact at the Grand Anicut Head and in such circumstances the Cauvery and Vennar were heavily charged in the past. The head regulators of Cauvery and Vennar at Grand Anicut have been vastly improved during recent years (1972-74), to facilitate diversion of these floods also through the surplus vents and the Grand Anicut itself into Coleroon, avoiding their impact on the Delta. It may, therefore, be assumed safely that there is no flood threat to the Cauvery Delta due to flood flows generated from the catchment areas lying between Upper Anicut and Grand Anicut.

Table 1.8.2

Historical records of Severe Cyclones which crossed Tamil Nadu during the period from 1970-1999

Sl. No.	Date	Landfall/Devastation
1	December 1-8,1972	Crossed Tamilnadu coast close to and north of Cuddalore at 2330 UTC on 5th December and was within 50 km WNW of Cuddalore at 0300 UTC on December 6. Maximum wind speed recorded at Cuddalore was 111 KMPH to 148 KMPH (60-80) between 2230 UTC of 5th & 0230 UTC of 6th.80 People killed and 30,000 people rendered homeless in Madras due to flood.Total loss Rs. 40 crores.
2	November 8-12, 1977	Crossed Tamilnadu coast within 10 km to south of Nagapattinam early in the morning of 12th around 2230 UTC of 11th. Weakened into a cyclonic storm by that evening over interior parts of Tamilnadu and emerged into Laccadives off North Kerala coast on the morning of 13th as a deep depression .Maximum wind recorded about 120 KMPH (65 kt) on 12th morning at Thanjavur, Tiruchirapalli and Pudukottai.560 people died and 10 lakh people rendered homeless. 23,000 Cattle heads perished. Total damage to private and public property estimated to be Rs. 155 crores.
3.	November 19-24, 1978	Crossed between Kilakkarai and Rochemary and Ramanathapuram District of Tamil Nadu. On 24th.evening as a severe storm and emerged into the Arabian Sea off Kerala coast as a deep depression on 25th morning. Batticola of Sri Lanka reported maximum wind speed northerly 145 KMPH (78 kt).In India 5,000 huts damaged and total damage estimated to be around Rs. 5 crores. In Sri Lanka, 915 people died and one million people affected One lakh Houses were damaged in Sri Lanka.
4.	November 9-14, 1984	Crossed between Sriharikota and Durgarajupatnam between 0800 and 0900 IST. Sea water of 2 feet height entered the village Durgarajupatnam on14th and reached 3 km inland from the coast. 54 lives in Tamil Nadu were lost. Live stocks perished were 90650. Number of buildings destroyed completely were 3,20,000 in A.P

5.	November 27-30, 1984	Crossed south Tamil Nadu coast near Nagapattinam in the afternoon of December 1 near Karaikal. About 35,000 people were affected in East Thanjavur and South Arcot districts of Tamilnadu.50,000 acres of land was submerged in Thanjavur districts.
6.	11-15 Nov. 1991	Crossed Tamil Nadu Coast north of Karaikal 185 people died and 540 cattle perished 16 people died in A. P.
7.	11-17 Nov. 1992	Crossed near Tuticorin (Tamil Nadu).175 people died and 160 reported missing. Damage to standing crops due to flood was reported
8.	01- 04 Dec. 1993	Crossed on 4th Nov. 30 Km North of Karaikal.100 People died in Tamil Nadu.
9.	28 Nov.-06 Dec1996	Crossed near Chennai around 2100 on 6th Dec.1996.The cyclone persisted for 9 days which is reported to be very long life compared to any cyclone in the Indian Ocean. It caused severe damage to life and property.

Source : http://www.imd.gov.in/section/nhac/static/cyclone-history-bb.htm

1.9 VENNAR BASIN

1.9.1 A Brief Narration

The River Vennar originates from Grand Anicut across Cauvery River at Km 27.26 below upper Barrage. It traverses through Thanjavur, Thiruvarur and Nagapattinam District and empties in to Bay of Bengal by branching off into number of rivers. It irrigates an extent of 4.96 Lakhs acres in the above three districts besides serving as drainage carrier.

The Vennar at LS 55.270 Km at Thenperambur Village (V.V.R. Head) trifurcates as Vennar, Vettar and Vadavar and again the Vennar at LS 96.120 Km at Needamangalam Village trifurcates as Vennar, Koraiyar and Pamaniar (Koraiyar Head)

The main Vennar river again bifurcates as Vennar and Pandavayar at LS 108.730 Km. At LS 110.54Km Vennar again bifurcates into Vellaiyar and Vennar. The Pandavayar river finally infalls into Vellaiyar river. The Koraiyar river at LS 122.150 Km branches as four river cum drainages namely Koraiyar, Ayyanar, Mulliyar and Harichandranathi. Mulliyar again bifurcates as Mulliyar and Adappar at LS 130.236 Km in Kottur Village. All these branch rivers namely Vellaiyar, Harichandranathi, Mulliyar, Adappar and Koraiyar infalls into Bay of Bengal.

The river network of Vennar Sub-Basin is shown in **Figure 1.5.** The Hydraulic Particulars and the details of various regulators in Vennar Sub-Basin is shown in **Table 1.9.1 .**

Normally the floods generated from the catchment below Grand Anicut and a vast area lying south of Grand Anicut Canal surrounded by Kulathur, Gandarvakkottai, Vallam, Sengipatti and Thiruverumbur spreading over four Taluks in two District, directly enter river Vennar after crossing Grand Anicut Canal. Whenever heavy downpour occurs in the above area there will be flash and heavy flood entering Vennar River and spiting it regularly.

The floods generated in this section through the drainage "varis" crossing the Delta are the notorious ones as they are carried directly into the Vennar Sub Basin through the cross masonry structures on the Grand Anicut Canal and cause several breaches lower down and submerge large extents of irrigated lands. The major drains in this region and their discharge capacities are as follows:-

Adappanpallam vari	254 m^3/s/8935 ft^3/s
Veliampatti vari	385 m^3/s /13596 ft^3/s
Sholagampatti vari	844 m^3/s /29806ft^3/s
Indalur vari	822 m^3/s /31148 ft^3/s
Mudalamuthu vari	599 m^3/s /21154 ft^3/s

These are the observed discharges during 1920 floods, when the catchments were not intercepted and the command areas not fully developed. Over the period of years since 1920 several Minor irrigation developments have taken place and the Grand Anicut Canal has been laid across in 1934. The provisions given in this main canal for disposing the drainage flows at different locations are as follows:

Description	**G.A.Canal crossing mileage (R.D.)**	**Discharge (ft^3/s)**
Sholagampatti vari	4 / 0755	439 m^3/s /15500 **ft^3/s**
Ayyanavaram vari	5 / 5354	164 m^3/s / **5793 ft^3/s**
Nandasampatti vari	5 / 9930	78 m^3/s / **2747 ft^3/s**
Chitrakudi vari	8 / 6560	81 m^3/s / **2859 ft^3/s**
Mudalamuthu vari	9 / 9844	203 m^3/s / **7163 ft^3/s**

In order to minimize the danger to the Delta, these floods must either be detained upland itself during critical periods or be diverted elsewhere.

The drainage of the Cauvery Delta has several to be considered. This one million plus acre coastal Delta has both favorable and unfavorable ones. Topographically, the Delta has good drainage gradient for the upper twothirds of the area; the lower portion, however, is very flat, and faces the sea at the widest portion of the Delta. Some of the lower Delta areas are actually below mean sea level, which, of course, is an adverse topographic feature from an agricultural point of view.

Almost the entire project area is agriculturally oriented and utilized for the production of rice. Rice plants do not have the same set of requirements for drainage and aeration of the root zone which most other field crops have. The immediate drainage requirements of the area therefore are considered only in the view of protection from excessive and / or long duration inundation.

Approximately 40,000 acres of agricultural land are subject to acute flooding and submersion in the lower Delta area. The problem here is to find ways to dispose expeditiously of this rainfall excess. The sea is the only outlet and is nearby, but some unfavorable factors are found which, together with the unfavorable topographic conditions, have compounded the drainage problem. The tidal variation is in the order of four feet; in flat topography this permits a considerable ingress of seawater inland during high tides. Further the strong littoral currents, from south to north tend to form bars which effectively close the drainage outlets and create an obstruction for drainage into the sea, until the flood inland heaves and is able to cut across the bars, opening their mouths..

Drainage is a complex problem in the old Delta. Of the 1620 kms of river network in the Cauvery Delta, about 523 km length serves purely as irrigation rivers and the rest function as irrigation cum drainage system. The topography of the Cauvery sub basin gently falls towards the sea and also towards Vettar. The percentage drainage of rainfall run off in the Cauvery sub basin is less than the runoff in the Vennar sub basin. The Vennar sub basin is hence inundation-prone.

During November 2005 heavy rainfall on a single day and this resulted in a heavy flood discharge of 851 Cumecs (30061 Cusecs) in to the Vennar below Grand Anicut Head and above Vennar Vettar Regulator causing extensive damages to Vennar Sub-basin in all forms viz. Breaches in the river Vennar and its branches, branches in the main highway from Trichy to Thanjavur, inundation and submersion of thousands of acres of irrigated and inhabited lands involving heavy expenditure for the Government in carrying out flood protection and restoration works, relief works etc., Thus the flood menace has become a regular agonizing feature to Vennar river sub basin during every monsoon season.

1.9.2 Details Of Main Drain & Stages Of Drains During The Flood

In the Delta area total No. of Main Drains are 56, In that 19 Nos. of Drains are in Cauvery Sub Basin 29 Nos. of Drains are in Vennar Sub Basin and 7 Nos. of drains are in G.ACanal System..

During the irrigation time there are no damages in Cauvery Delta but in the north east monsoon period of October to December the heavy rainfall occurs, it causes heavy damages to the irrigated lands, Roads and public Residence. Since the public and formers are heavily affected by the flood.

During the last 12 years the following years viz. 1999, 2005, 2008, and 2010 the rainfall in the delta area is more than the normal. Among the above mentioned drains, the following drains are badly affected:

1. Sullanar
2. Vettar
3. Odambogiyar
4. Vellaiyar
5. Harichandranathi
6. Koraiyar
7. Paminiyar
8. Mulliyar
9. Manangondanar
10. Marakkakoraiyar
11. Kannanar
12. Sakkilian Voikkal
13. Adappar
14. Kulaiyar
15. Pokkuvoikkal
16. Manankettan Drain
17. Malliyanar
18. Nallar
19. Annapillai Voikkal
20. Valavanar
21. Kilaithangiyar

The drains in Thiruvarur, Nagapattinam & Thanjavur District were heavily damaged during these floods. Some of the drains originate in the higher lands of

Thanjavur & Pudukkottai District and they carry flood water along their channels to overload the tail end of the drains as they are unable to discharge into the sea.

1.9.3 Needs And Necessity Of The Scheme

The existing discharging capacity of the rivers and drains are not sufficient to clear flood water and the both sides banks of the river saw drainage are below the maximum flood mark in most of the places.

The existing drainage inlets are having structures which are in completely damaged condition. It leads the damages to existing banks during North East Monsoon and also shoals formed in the centre of the rivers and drainages hinder free flow of water.

The existing cross masonries in the rivers and drainages are constructed before more than 100 years. At present some structures are in fully dilapidated condition and some structures having major repair. It is essential to desilt the rivers and Standardise the existing bank by using conveyance of earth.

1.9.4 Vedaranyam Canal and its Function

The Vedaranyam canal, parallel and close to the Bay of Bengal was excavated between 1863 and 1867 for inland navigation. It enters the sea in Nagapattinam port area in the north and at the southern end it joins the sea at Thopputhurai. The length of the canal is 57 km. In the past the canal was used as means of inland water transport and it was of special use for carrying salt from Vedaranyam to Nagapattinam port. With the forming of roads between Vedaranyam and Velanganni and availability of other mode of conveyance such as railways, the importance of the canal as a means of navigation declined.

1.9.5 The Straight Cuts

The flood waters entering the Vedaranyam canal are at present drained through the straight cuts to the sea at the following points.

a) Vellaiyar straight cut
b) Chakkilian voikkal straight cut
c) Lawford straight cut
d) Nallar straight cut
e) Adappar straight cut
f) Mulliyar Straight cut
g) Valavanar Straight cut

The straight cuts are generally blocked at their outfalls to the sea by sand bars and in some cases the channels are heavily silted. The straight cuts have received minimal maintainance during recent decades.

When floods occur during north east monsoon period, water levels in the Vedaranyam canal rise due to the large volume of flood water entering from the rivers exceeding the capacity of the poorly-maintained straight cuts,resulting in vast areas of low-lying land close to the coast. Being inundated.

The problems regarding the south bound drains are that they bring in large volumes of discharges into the lagoon. The main flood carriers here are the Pamaniar and Koraiyar which is at the southern most end of the Delta. The other rivers which are infalling into the lagoon are Valavanar, Marakkakoraiyar, and Kilaithangiar. The drainage flows carried into the lagoon by these south bound rivers is estimated at 729 m^3/s (25,730 ft^3/s). In addition to the above problems, the general elevation of the land very near the coast is very low (many places being situated below mean sea level) and large areas are prone to inundation for longer durations. This is another chronic problem. The straight-cuts mentioned above fail to function at times of high tide levels. An effective solution is to dredge the straight cuts.

1.9.6 Pumping Schemes

There are 28 Nos pumping schemes and out of it 26 Nos is in operation in the Cauvery Delta listed separately in **Table 1.9.2**

All these schemes came into operation between 1951 to 1991. The principle objective of the pumping schemes is to supply water for irrigating the high level command area by pumping the tail end river drainage water, which is going waste into the sea. They provide irrigation facilities to an extent of 21757 acres within the Delta.

1.9.6.1 Operating schedule & Distributaries system

As a general rule, the pumping schemes are expected to commence with the commencement of the drainage flow, after the development of the Delta ayacut around 15th August. The closure of operation will be around 15th of February.

In all the pumping schemes, except the one in Kollukadu, the pumped water is being conveyed from the delivery sump through main channel and distributed to field through direct sluices and field bothies and field to field in some places. In the pumping scheme at Kollukadu, the pumped water is distributed to the field through tanks. The designed time of pumping is 16 hours per day in two shifts of 8 hours each. Initially the pumps were operated with qualified pump operators.

Table 1.9.2

LIST OF PUMPING SCHEME

Sl.No.	Name of Pumping Scheme
1.	Velankanni
2.	Vilunthamavadi
3.	Aymoor – I
4.	Aymoor – II
5.	Oradiyampulam
6.	Umbalachery
7.	Mulliyar (Thagattur)
8.	Ayakkaranpulam
9.	Manakondanar
10.	Thennadar
11.	Vanduvanchery
12.	Valavanar & Karpaganatharkulam
13.	Keelathondiyakadu
14.	Karaiyankadu
15.	Vilangadu
16.	Melathondiyakadu
17.	Thillaivilagam
18.	Mangal
19.	Pamanimullur
20.	Segal
21.	Korukkaithalaikadu
22.	Thenpathi Thalaiyamangalam
23.	Moovanallur (Abandoned)
24.	Kollukadu
25.	Payyundarkudikadu
26.	Okkanadukeelaiyur
27.	Chinnaparuthikkottai
28.	Arasapattu

1.9.6.2 Present Status

In nearly 1/3 rd of the pumping schemes the ayacut developed is less than 50% of the registered ayacut. In the Orathanadu block the gap between the ayacut developed and registered ayacut is more. The problems faced are:

- The motors and pumps installed in these schemes have served for more than 30 to 40 years old and spares are not available in the market. Since they are very near to the coastal area, the pipes and other installations are affected with corrosion.
- The motors and pumps installed in these schemes are worn out and their efficiency is about 50% to 60%.
- Whenever there is a delay in the release of water from Mettur Reservoir or the failure of monsoon, the commencement of pumping will be delayed.
- The main channel of the scheme is formed in embankment so as to convey the water to the high level lands. In the long run, due to settlement of soil, the designed gradient of the channel is disturbed. Hence there is difficulty in conveying the pumped water to the entire ayacut in most of the schemes.
- The lined supply channels of these schemes were damaged fully and this causes difficulty in supplying water to the command area.
- In the absence of the qualified permanent pump operators, it is difficult to operate and maintain the pumping schemes.
- The pump rooms and staff quarters are fully damaged and many buildings need reconstruction.
- The cross masonries and cross drainage works are also in damaged conditions and need rehabilitation and reconstruction.
- The schemes in Cauvery Delta system are being maintained with the grant under the head of 2701 – 01 – 101 – CDS and 2701 – 03 – 121 – CMP. The funds allotted under the above heads are not sufficient to meet the major repairs of the equipments and maintenance of the canal system.

1.9.6.3 The improvements proposed

The ayacut now benefited is only 5216 ha (12889 acres) against the design ayacut of 8805 ha (21757 acres). There is a gap of 3589 ha (8868 acres) in the registered ayacut itself.

In order to revamp the functioning of the schemes to the designed status and bridge the ayacut gap, rehabilitation of pumping schemes becomes necessary.

The following works are to be carried out in all the 29 pumping schemes in the Cauvery Delta area, so that assured supply to the high level command area could be normalized.

1. The motors and the pumps are to be repaired and renewed
2. All the pump rooms are to be repaired / reconstructed.
3. All the lined supply channels to be renovated
4. Cross masonries and cross drainage works are to be repaired / reconstructed
5. Human resources to the required strength to be posted

Figure 1.5

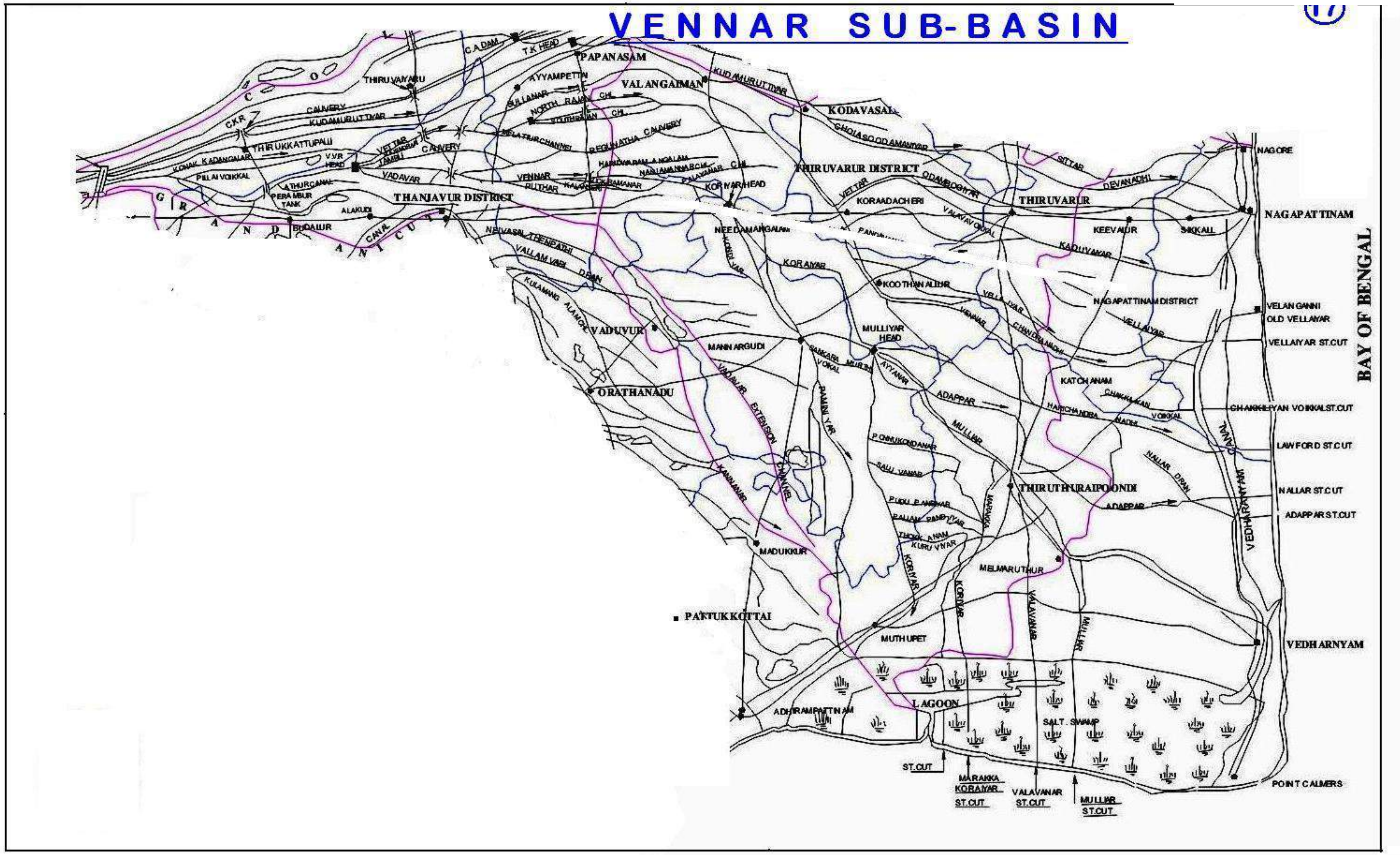

VENNAR SUB-BASIN
PAPANASAM
VALANGAIMAN
KODAVASAL
THIRUVARUR DISTRICT
THANJAVUR DISTRICT
THIRUVARUR
NAGORE
NAGAPATTINAM
BAY OF BENGAL
VADUVUR
ORATHANADU
MADUKKUR
PATTUKKOTTAI
THIRUTHURAIPOONDI
MUTHUPET
LAGOON
SALT. SWAMP
VEDHARNYAM
POINT CALMERS
NAGAPATTINAM DISTRICT
KOOTHANALLUR
MULLIYAR HEAD
MANNARGUDI
NEEDAMANGALAM
THIRUKKATTUPALLI
THIRUVAIYARU
ADHIRAMPATTINAM
MELMARUTHUR
VEDHARANYAM CANAL

Table 1.9.3

Hydraulic Particulars Of Head Regulators at the VVR Head Regulator

Vennar

		Head Regulator		
Feature	**Units**	**Vennar**	**Vettar**	**Vadavar**
Sill level	(m)	41.450	41.450	41.450
N.S.L.	(m)	42.970	43.280	42.970
No. of vents	Number	29	17	10
Vent Size	(m)	3.05 x 1.52	3.05 x 1.83	3.05 x 1.52
Maximum Discharge	(ft^3/sec)	8143.00	2845.00	1632.00
	(m^3/s)	230.58	80.56	46.21
Normal Discharge	(ft^3/sec)	5429.00	1897.00	1093.00
	(m^3/s)	153.73	53.71	30.95
Ayacut in Regulator	(acres)	288400	100803	58089
	(ha)	116711	40793	20270

Table 1.8.1 (cont….)

<u>Details of VVR head Regulator at 55.270 k.m</u> Sill level + 41.450m (136 ft)

Sl. No.	Description	Vadavar Regulator	Vennar Regulator	Vettar Regulator	Jambu cauvery	Rajendran	Total
1	Ayacut (acre)	72889	288516	10084	6305	1492	
2	No of Vents	10	29	17	1	1	
3	Vent size (m)	1.52 x 1.52	3.05 x 3.50	3.05 x 3.50	3.05 x 3.50	1.20 x 1.20	
4	Shutter size (m)	1.52 x 1.52	3.05 X 1.67	3.05 X 1.83	3.05 x 1.52	1.20 x 1.20	
5	NSL (m)	F +43.32 R +43.16	F +42.75 R +42.67	F +42.29 R +42.01	F +42.29 R +42.14	F +42.75 R +41.84	
	NSD Qsec	1105	5491	1919	120	28	8515
6	MSL (m)	F +43.46 R +43.31	F +43.08 R +42.98	F +43.08 R +42.75	F +42.60 R +42.34	F +43.09 R +42.14	
	MSD Qsec	1651	8231	2878	180	40	12760
7	MFL (m) (1920)		F +44.87 R +44.25	F +44.87 R +44.04			
	MFD (1920) Qsec	-	24883	14586	-	-	39469

8	MFL (m) (1930)		F +45.12 R +44.50	F +45.02 R +44.19			
	MFD (1930) Qsec	-	26095	15017	-	-	41112
9	MFL (m) (1939)		F +44.90 R +44.28	F +44.93 R +44.10			
	MFD (1939) Qsec	-	25031	14760	-	-	39791
	MFL (m) (1999)		F +43.55	F +43.55			
	MFD (1999) Qsec	1554	16137	12618	180	40	30529
11	MFL (m) (2005)		F +43.75 R+43.05	F +43.75 R +43.36			
	MFD (2005) Qsec	605	17035	12421	-	-	30061
12	MFL (m) (2008)		F +43.85 R +43.11	F +43.85 R +43.50			
	MFD (Qsec) (2008)		17633	13100			30733

Table 1.8.1 (cont….)

Hydraulic Particulars of Rivers at Korayar Head (122.150k.m)

Description	Vennar		Korayar		Pamaniyar	
	Level (in m)	Depth	Level (in m)	Depth	Level (in m)	Depth
Sill Level	20.610	_	20.625	_	20.630	_
N.S.L FRONT	22.660	2.050	22.660	2.035	22.660	2.030
N.S.L REAR	21.945	1.335	22.245	1.620	21.830	1.200
M.S.L FRONT	22.960	2.350	22.965	2.340	22.960	2.330
M.S.L REAR	22.255	1.645	22.115	1.485	22.685	2.060
N.S.Discharge	1795c/s		2304c/s		730c/s	
M.S.Discharge	2692c/s		3456c/s		1070c/s	
Ayacutes	94219acres		120957acres		38357acres	
No.of vents	14Nos		9Nos		4Nos	
Size of vents	3.05X3.05+0.60		3.05X3.05+0.60		3.05X1.05	
Height of shutter	1.52m		1.91m		1.52m	

2 Hydrology

2.1 Rainfall

Annual rainfall in the Vennar system is highly variable ranging between 1774 mm and 653 mm with an average of 1192mm (Figure 2.1). The north-east monsoon (October to December) ranges between 1331 mm and 316 mm with an average of 782mm, contributing most of the annual total in many years. Average monthly rainfall (Figure 2.2) shows the relative importance of the north-east monsoon compared with the south-west monsoon (June to August) when, typically, monthly rainfall is not significantly different to that in the dry season (January to May).

Occasional cyclonic storms during the north-east monsoon bring prolonged intense rain falling causing flooding as rivers overtop their banks and drainage of runoff from fields is impeded. In recent years serious flooding occurred in November 2008, November 2010 and September 2005 (the 2005 flood was caused by the Cauvery River bursting its banks and bypassing the Grand Anicut).

In 2008 rainfall over the period 20th-30th November averaged 643mm in the Vennar system. Individual rain gauge totals ranged from 421mm at Mulliyar Head to 865mm at Muthupettai. The peak of the storm occurred over 5 days (24th-28th November) when 560mm was recorded across the system. Detailed analysis of the frequency of annual maximum daily rainfall from 10 rain gauges in the Vennar system over the period 1981-2012, shows that a 5-day total of 560 mm has a return period between 20 and 50 years (see Table 2.1).

Table 2.1: Frequency of Extreme Rainfall in the Vennar System

Return Period Years	Daily rainfall mm	5-Daily rainfall mm
2	121	259
10	198	441
20	228	511
50	269	601
100	301	668

2.2 River Flow

In the Cauvery River sub-basin in Tamil Nadu, including the Cauvery delta, annual and seasonal river flow is variable, depending primarily on the quantity of rainfall falling in Karnataka and Kerala states during the south-west monsoon (June to August). The north-east monsoon (November to January) generates relatively little flow in the Cauvery River but its contribution to meeting crop water requirements is very important because river flows normally fall sharply from September onwards.

The average annual yield of the Cauvery River basin is 20,955 MCM (740 TMC) of which 11,865 MCM (419 TMC) is officially allocated to Tamil Nadu according to the Cauvery Waters Dispute Tribunal decision (2007). Of this allocation, 5434 MCM (192 TMC) has to be released from Karnataka according to a prescribed monthly schedule ranging from 1416 MCM (50 TMC) in August to 71 MCM (2.5 TMC) in May. Some of this water is stored in the Stanley Reservoir upstream of Mettur Dam to provide supplementary releases according to demand and antecedent rainfall in the irrigation command areas. Other demands such as municipal water supply and industry are relatively small. The Stanley Reservoir has an effective storage of 2648 MCM (93.5 TMC).

The irrigated area in the Cauvery sub-basin in Tamil Nadu is approximately 6,94,000 ha of predominantly paddy. Approximately 5,84,000 ha of this area are in the Cauvery delta in Thanjavur, Thiruvarur and Nagapattinam Districts, of which about 1,88,000 ha are in the Vennar system. A further 1,10,072 ha are located upstream of the Grand Anicut in Erode, Salem, Namakkla and Tiruchirapalli Districts.

The flow in the Cauvery River and the volume of water in the Stanley reservoir in June each year are variable and are the major determinants of the cropping area and, providing the north-east monsoon is sufficient, whether or not two rice crops can be grown successfully. This variability is reflected in the annual flow in the Vennar River at the VVR head regulator (Figure 2.3) which, in the period 1996-2011, varied between 1954 MCM (69 TMC) in 2006 and 311 MCM (11 TMC) in 2003 with an average annual flow of 1260 MCM (44.5 TMC).

The total annual outflow from the Vennar system through the 11 downstream tail-end regulators varies between 2039 MCM (72 TMC) and 425 MCM (15 TMC) with an average of 1218 MCM (43 TMC). Whereas most of the inflow occurs between June and October (Figure 2.4), during and following the south-west monsoon, most of the outflow occurs in November and December, during the north-east monsoon, indicating that the outflow is mostly runoff of local rainfall and that the inflow is mostly consumed within the system.

During normal operations the distribution of water within the Vennar system mirrors demand. WRD data shows a broadly consistent distribution from the head regulators. Approximate percentage shares are shown in Table 2.2. During flood situations however, the system is operated in flood management mode which fully opens head regulators on all the rivers except the Vadavar, Mullaiyar, Ayyanar and Harichandri Nadi which are effectively isolated.

Table 2.2: Flow Distribution at Regulators in the Vennar System

Regulator	**Receiving Channels and Average Percentage Share**							
Normal Operations								
VVR	Vettar	28%	Vennar	33%	Vadavar	39%		
Koraiyar	Vennar	38%	Koraiyar	45%	Pamianar	17%		
Mulliyar	Koraiyar	34%	Mulliar	30%	Ayyanar	4%	Harichandranathi	32%
Pandavayar	Vennar	50%	Pandavayar	50%				
Vellaiyar	Vennar	50%	Vellaiyar	50%				
Pandidhakudi Dam	Vennar	80%	Adiveeraramanar	20%				
Moovarkottai	Vadavar Extension Canal	75%	Vadavar surplus	25%				
Flood Operations								
VVR	Vettar	43%	Vennar	57%	Vadavar	0%		
Koraiyar	Vennar	60%	Koraiyar	38%	Paminyar	2%		
Mulliyar	Koraiyar	100%	Mullaiyar	0%	Ayyanar	0%	Harichandranathi	0%
Pandavayar	Vennar	66%	Pandavayar	34%				
Vellaiyar	Vennar	52%	Vellaiyar	48%				
Pandidhakudi Dam	Vennar	100%	Adiveeraramanar	-				
Moovarkottai	Vadavar Extension Canal	0%	Vadavar surplus	0%				

2.3 Droughts

A poor south-west monsoon in Karnataka limits flows in the Cauvery River and the amount of water stored in the Stanley reservoir and therefore reduces the amount of surface water available for irrigation during the rice growing season (June-January) in the Cauvery sub-basin in Tamil Nadu. The potential annual irrigation demand for two rice crops in the Vennar system is approximately 2407 MCM (85 TMC), but average annual flow in the Vennar River at the VVR head regulator (Figure 2.3) is only 1260 MCM (44.5 TMC) and is less than 850 MCM (30 TMC) in 2 out of 10 years. Clearly therefore, for two rice crops to grow successfully it is necessary for the north-east monsoon to contribute an average of 1147 MCM (40.5 TMC) and as much as 1557 MCM (55 TMC) in 2 out of 10 years.

However the north-east monsoon in Tamil Nadu is notably erratic. Analysis of rainfall amounts recorded in the Vennar system between October and December indicates an average of 750 mm with a standard deviation of 241 mm. Typically, less than 500 mm falls on the Vennar system during the north-east monsoon in 2 out of 10 years. This is equivalent to 325 MCM (11.5 TMC) of effective rainfall. Clearly therefore a poor south-west monsoon in Karnataka, followed a poor north-east monsoon in Tamil Nadu, creates a drought situation and has serious consequences for agriculture in the sub-basin. This was the case in 2002 and 2003.

Where sufficient groundwater is available, the shortfall in surface water can be made up. However there are many areas in the Cauvery delta with limited groundwater availability or with saline groundwater. Consequently in such areas drought impacts are especially severe.

2.4 Climate Change

According to studies carried out during the preparation of CASDP by ADB (Srinivasan, 2013; Dastgheib and Ranasinghe, 2014) and by the main PPTA team the following climate changes are expected in the Vennar system by 2050:

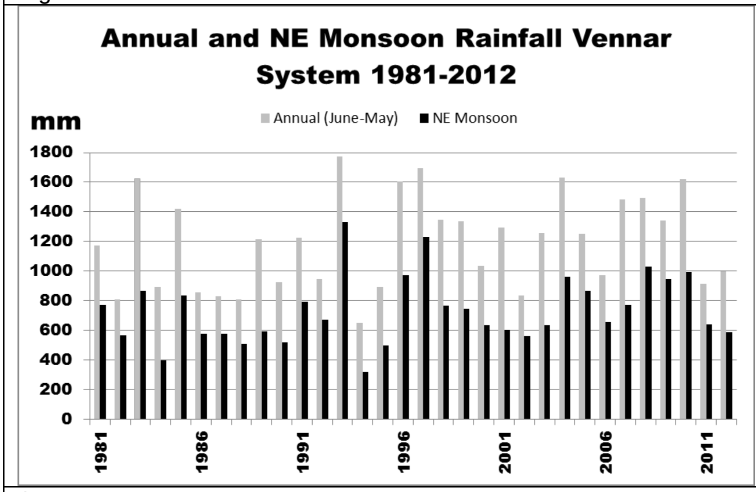
Variable	Now	2050	Change
Mean annual rainfall mm	1141	1173	+3%
Mean annual temperature ^{0}C	28.7	29.9	+1.2^o
Mean annual rainfall runoff Mm^3	1310	1390	+6%
Mean November rainfall runoff Mm^3	570	600	+5%
100-year daily rainfall mm	301	361	+20%
100-year 5-day rainfall mm	668	802	+20%
100-year 5-day peak rainfall runoff m^3/s	4660	6030	+29%
100-year 5-day rainfall runoff Mm^3	1120	1480	+32%
Sea level rise m High projection Low projection	 0 0	By 2100 0.87 0.29	By 2100 870 mm 290 mm
100-year tidal surge m	0.74		
Source: WRD, Srinivasan, Dastgheib and Ranasinghe processed by Mott MacDonald			

These projections show that moderate increases in mean annual rainfall and temperature can be expected with corresponding moderate increases in the runoff of rainfall. While the increase in annual temperature is mirrored in monthly temperature, the increase in annual rainfall masks reductions of 16-23% in monthly rainfall from January to May and increases of 13% during the south-west monsoon from June to September and increases of 4% during the north-east monsoon from October to December. From an agricultural perspective this is a relatively benign outlook as increases in crop water requirements caused by higher temperatures will be offset by increases in rainfall.

However the projections also show large increases in 100-year storm rainfall (29%) and storm runoff (32%). Therefore more frequent and serious flooding can be expected. In coastal areas flooding will be exacerbated by rising sea levels.

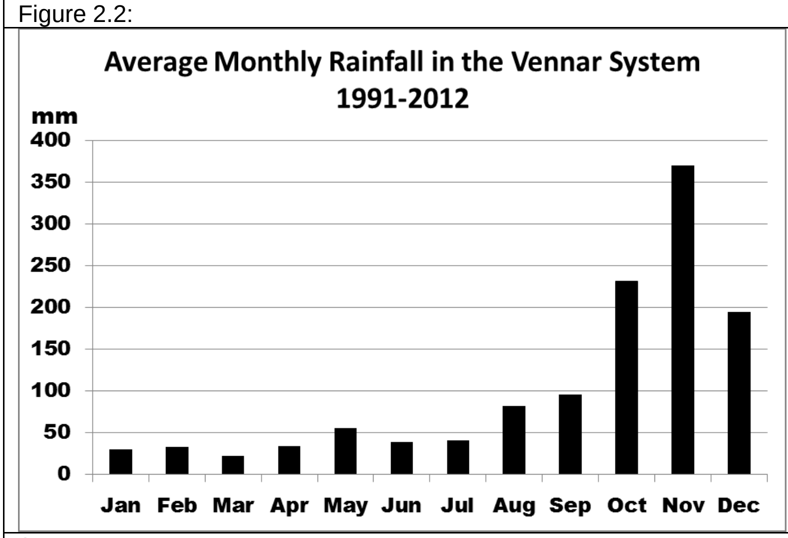
The detailed Hydrology has been provided in Annexure-6 Surface and Groundwater Modelling.

Figure 2.1



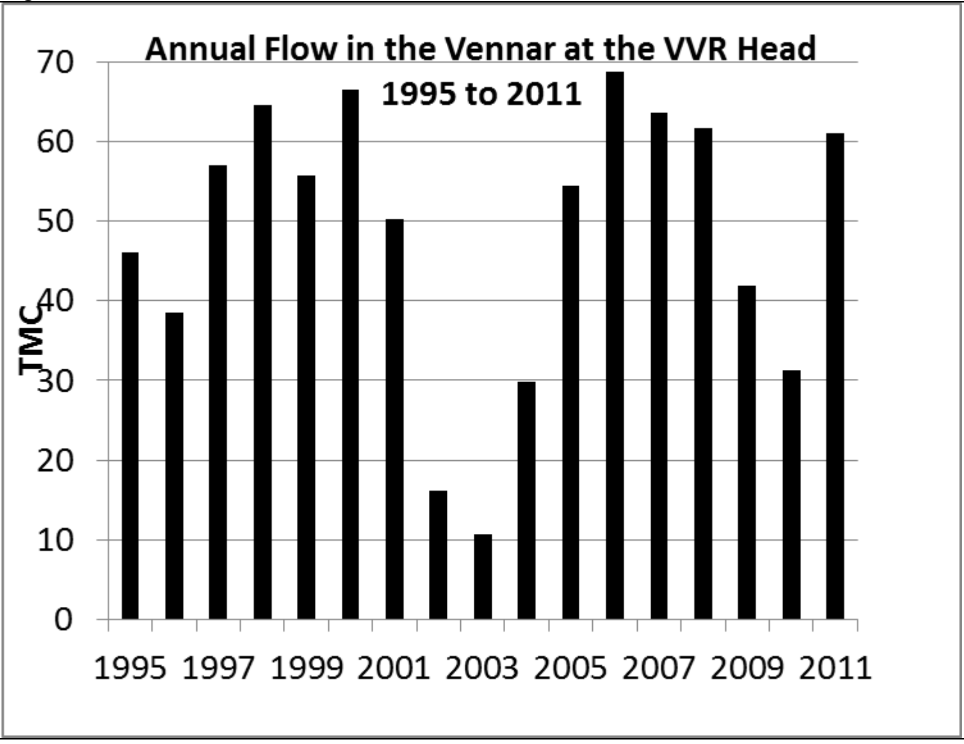
Source: WRD

Figure 2.2:



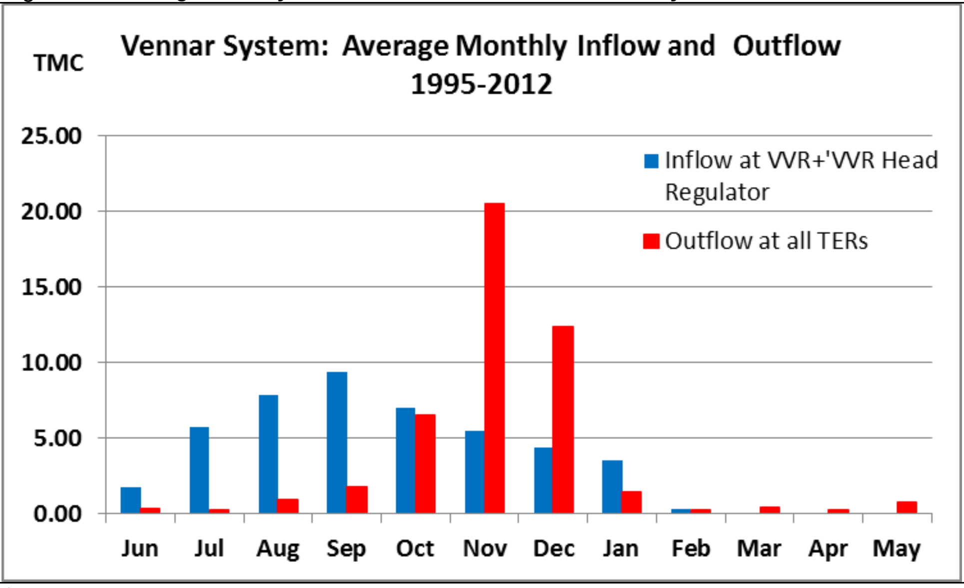
Source: WRD

Figure 2.3



Source: WRD

Figure 2.4 **Average Monthly Inflows and Outflows in the Vennar System**



Source: WRD

3 Reservoirs

Prior to the construction of major dams in the Cauvery Basin in the 1930s, farms were irrigated from run-of-river flows generated mainly during the SW monsoon. After the SW monsoon ended (generally in September), river flows reduced and irrigated crops, particularly in the Cauvery Delta, became dependent on rainfall from the NE monsoon during the latter part of the growing season.

After construction of the Krishna Raja Sagar (KRS) dam in Karnataka (49 TMC gross) in 1924, and the Mettur dam (95.6 TMC gross) in Tamil Nadu in 1934, it became possible to regulate flows in the Cauvery River so that surface water irrigation was feasible throughout the cropping season in years with normal rainfall. Since then a number of other dams have been constructed and the total storage capacity of the reservoirs in the Cauvery basin has increased to 330 TMC gross (CMP, 2008).

This Project works will be located downstream of the storage reservoirs in the Cauvery basin, and hence will not impact them. In addition, there is no water storage provision on the six Project rivers as the relatively flat topography of the delta and intensive land use provides little scope for providing storage. The details about the upstream water storage reservoirs are presented in Chapter 1.

4 Barrages (Anicuts)

Irrigation water for the Cauvery Delta, including the Vennar system, is provided by releases from the Mettur Dam. The water is diverted into the Vennar System at the Grand Anicut through the Vennar-Vettar-Vadavar (VVR) Head Regulator. The Grand Anicut is operated well and it is adequately maintained.

Flood flows in the Cauvery are diverted at the Grand Anicut into the Coleroon River through the Ullar Channel. No flood flows are released from the Cauvery River into the Vennar System at the Grand Anicut unless the anicut is by-passed as happened in 2005.

This Project starts downstream of the Grand Anicut and this Project funds are not required to continue the successful operation and maintenance of the Grand Anicut. The details about the Grand Anicut have been furnished in Chapter 1.

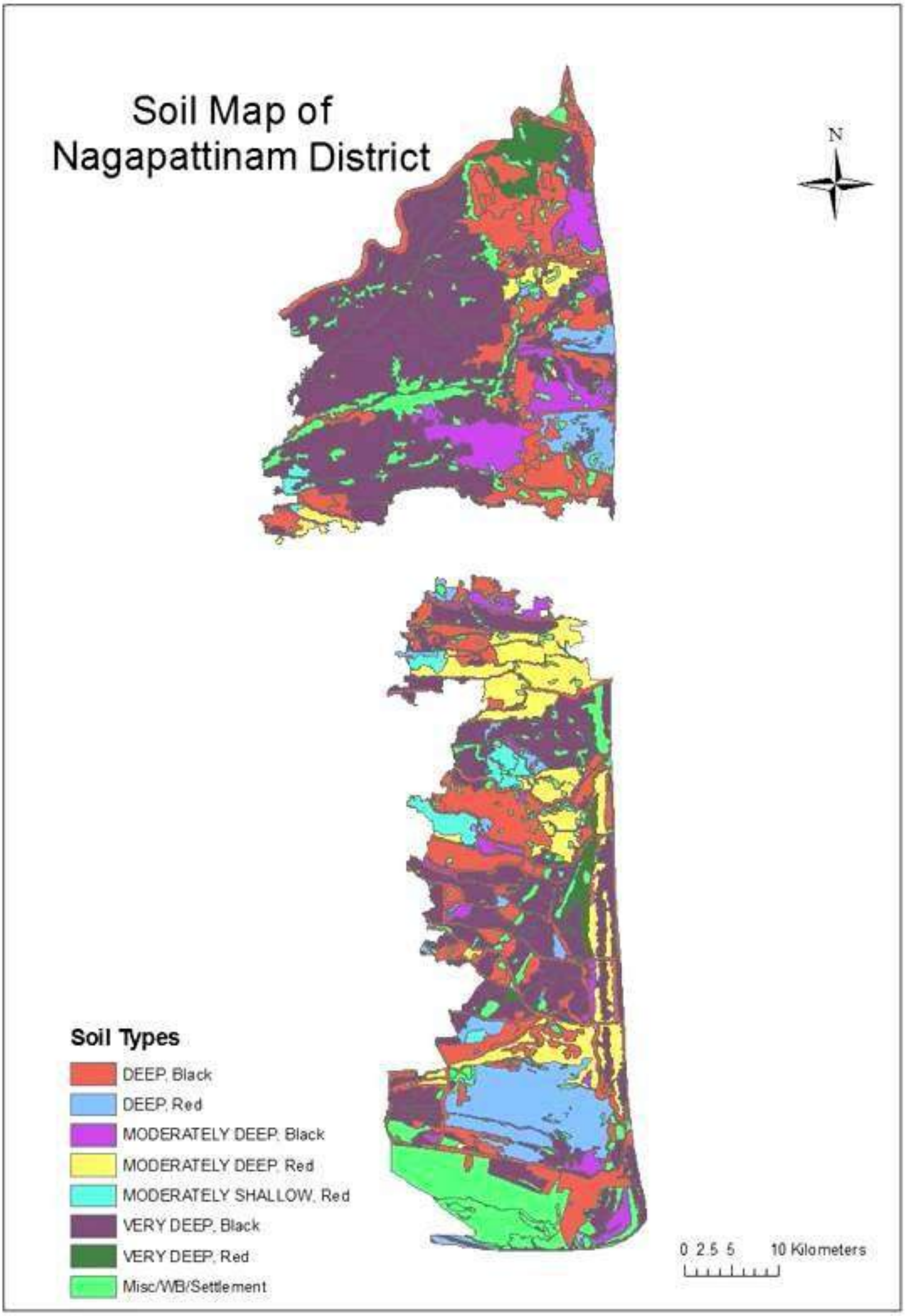
5. Land Potential

5.1 Soils

The Vennar System is located in the southern parts of Nagapattinam and Thiruvarur Districts and in the east of Thanjavur district (See Figure 1.1). The major soil types of these three districts are:

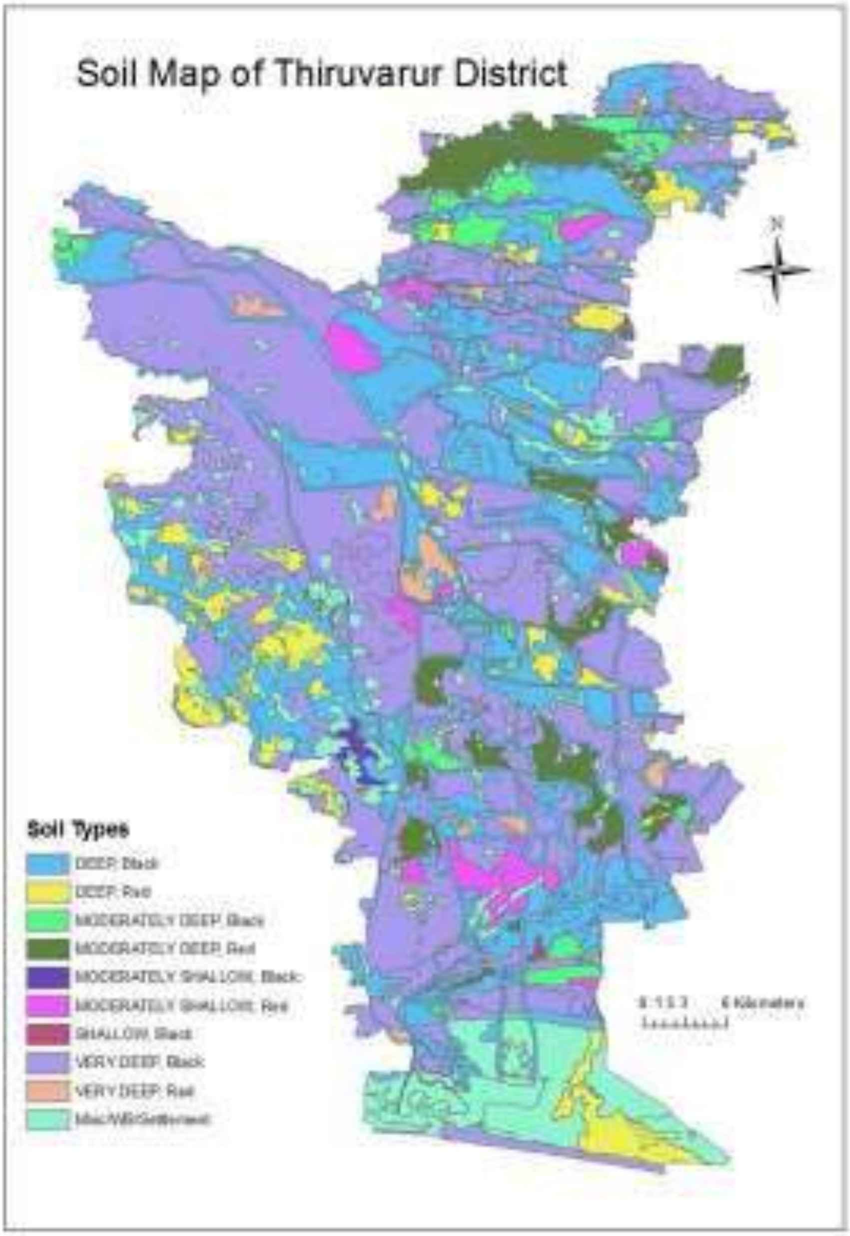
Nagapattinam: Sandy Coastal Alluvium and Black Soil types cover 89 per cent and 7 per cent respectively of the district (see Figure 5.1). The soils of the district are mainly of alluvial origin and vary greatly in quality. The district is mostly a plain, formed by coastal processes. The land elevation of the eastern part is within a few meters of sea level. The most fertile soil is found in the north. The least fertile soils are found south of Nagapattinam where the soil is saline and drainage is very defective. The main source of irrigation water in the districts is the rivers. There are also a few rainfed tanks and limited scope for wells due to saline groundwater. The tanks and wells occur mostly in the upland regions. About 7% of the land is affected by water logging and is marshy land and 56% is prone to floods. About 4% of the land available for cultivation suffers from salinity/alkalinity and 18% is coastal sand. Overall about 85% of the land has soil problem.

Figure 5.1 Soils Map of Nagapattinam District



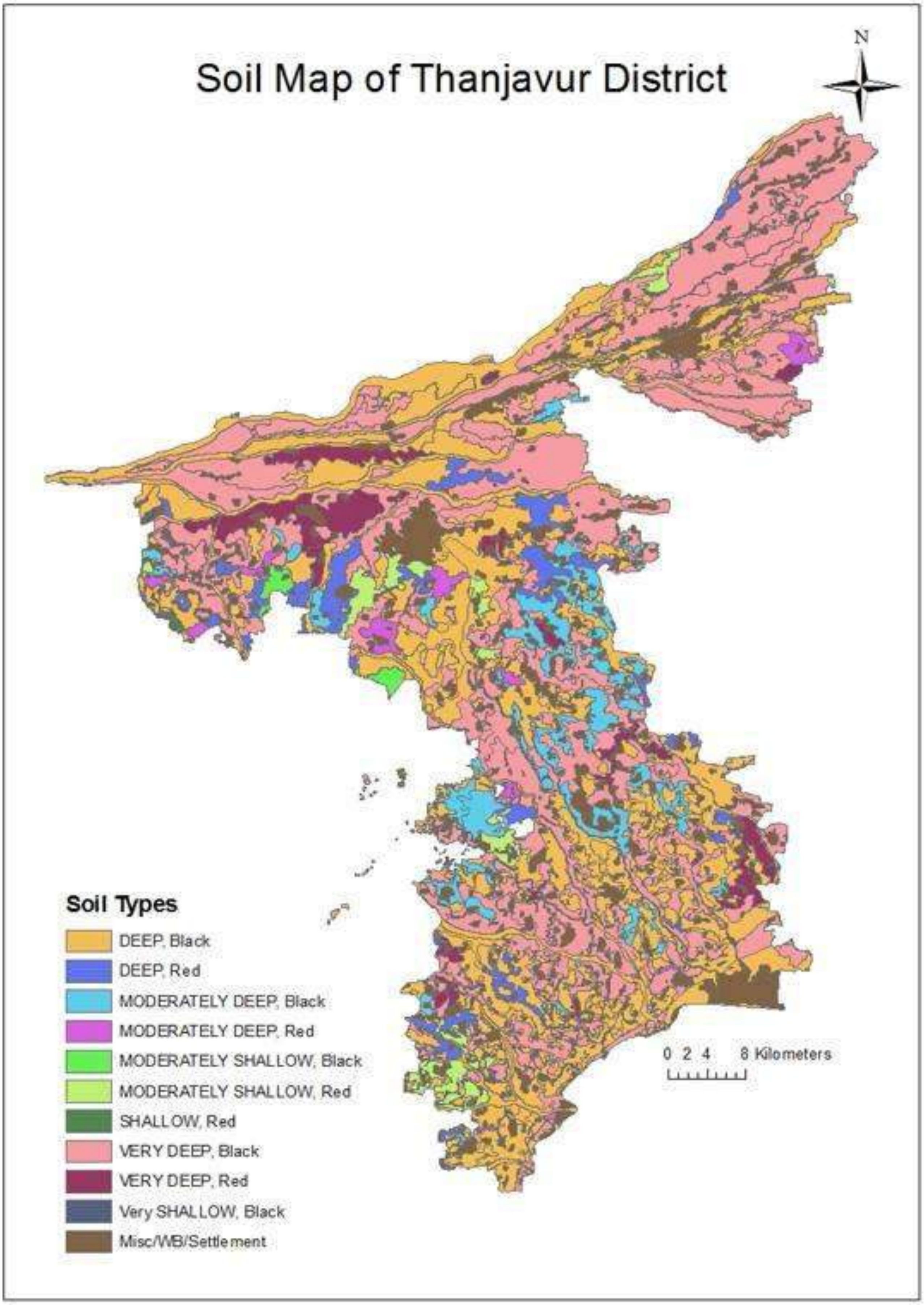
Thiruvarur: The soils of the district are mainly alluvial. The plain of Thiruvarur district is a plain with a gentle slope towards the east in the northern and central parts and towards south in the southern part. The maximum land elevation is about 30 masl in the western part of the district. The major part of the district is delta plain. Sedimentary high land having pediment and buried pediment landforms are found in Mannargudi and towards the west of the district. Sedimentary plain consists of various landforms like natural levee, swale and marshes. , Lagoon, back water coastal plain and beach ridges are found in the southern part of the district.

Figure 5.2 Soils Map of Thiruvarur District



Thanjavur: Thanjavur district is made up of cretaceous, Tertiary and Alluvial deposits. Very deep red soils constitute a major area (37%) of the district, followed by moderately deep block soils (12%), moderately deep red soils (6%). Deep red soils and very shallow black soils constitute 4% each, followed by moderately shallow black soils (2%).

Figure 5.3 Soils Map of Thanjavur District



5.2 Land Use

Nagapattinam: The total area of the district is 2,716 km^2. This district has a net cultivated area of 153,000 hectares which is 57% of the total area. Forest cover is very minimum accounting for only about 2% of the land. The area of fallow land increased slightly over the past three years. The land not available for cultivation covering barren and uncultivable land and land put to non-agricultural uses, accounts for 30%. The other uncultivated lands including permanent pastures and miscellaneous tree crops and groves not in the net area sown cover 4 %. The area coming under fallow is about 8 %.

Thiruvarur: The total area of the district is 2,097 km^2 of which 237,715 hectares 69 % is cultivated land. Thiruvarur district is more suitable for cultivation of paddy. Other important crops grown in the district are black gram, green gram, cotton, sugarcane, sesame, groundnut etc., and the major cash crops are paddy, black gram, green gram, cotton. The land use pattern of the district includes land under trees occupies (nearly 18 %), while the area of fallowland is 14 %. The land under non agricultural use is (18 percent) which is a cause for concern as the growth of non-agricultural activities will reduce the potential for agricultural growth in the district. The current fallow and other fallow lands occupying 5.5 and 3.5 percent respectively couldbe reduced considerably by encouraging horticulture.

Thanjavur: This district has witnessed significant changes in the land use over the last decade which illustrates the nature of the problems confronting the future development in agriculture. During the period between 2001-02 and 2010-11 the net sown area (NSA) registered only a marginal change of less than three per cent, the gross cropped area declined from 270,000 ha in 2001-02 to 259,000 ha in 2010-11. In other words, the share of GCA to total gross area was reduced from 80 % to 76% within a decade. This was mainly due to decline in the double cropped area from 67,000 ha to 62,000 ha. In the total area of the district, the ratio of non-agricultural land has significantly gone up from 23 % in 2001-2002 to 24 % in 2010-2011, that is around a five per cent increase over the decade. The increase was due to rapid urbanization and industrialization at the cost of viable agricultural lands. This has a negative impact on agriculture sector. In addition, the transfer acted as a catalyst for transfers of water and labour from the agriculture to the non-agricultural sector. It is important to note that the land under fallow has increased more than two and half times from 5,759 ha to 13,001 ha during last decade.

6. CROPPING PATTERN AND CROP WATER REQUIREMENTS

6.1 Details of Current Cropping Pattern and Crop Calendar

6.1.1 Current Cropping Pattern

The baseline current cropping pattern for the three districts of the Vennar system is presented in Table 6.1. Paddy predominates with 61 % of land area planted to the crop. The overall average cropping intensity is 167% with 33% of the area planted with a double crop of Kuruvai paddy (110-115 days duration) from June to October, followed by Thaladi paddy (135 days) from October to January/February. On the other 66% of land, a Samba paddy (155-160 days) is grown from August to January/February. Samba paddy predominates in the southern part where groundwater is not available because of salinity problems and farmers are solely reliant on surface water. The samba area includes the whole of Nagapattinam district and the southern four blocks of Thiruvarur district. The double cropping of paddy is practiced in all the blocks of Thanjavur that are in the Vennar System and the northern blocks of Thiruvarur where most farmers have access to tube wells and hence are able to double crop or very occasionally triple crop rice. The restrictions on the double cropping of rice applies to over 50% of the cultivated land due to water constraints in the middle and lower parts of the system, resulting from inadequate surface water availability in the tail end regions and the prevalence of saline groundwater negating the use of tubewells. A detailed review of cropping patterns options is presented in Annexure 1.

Table: 6.1 Current Cropping Pattern for Vennar System (area x1000 ha) by District

Crop	Thanjavur	Thiruvarur	Nagapattinam	Total	% Total Area
Rice	150.2	151.6	170.8	472.6	60.7
Pulses	40.2	80.4	85.2	205.8	26.4
Groundnut	15.9	7.8	3.7	27.4	3.5
Sesame	12.8	2.7	-	15.5	2.0
Sugar cane	15.5	-	6.4	21.9	2.8
Coconut	30.3	5.3	-	35.6	4.6
Total				778.8	100.0
Cropping Intensity	130	182	176	167	
% of Vennar System	27	55	18	100	
% of District	23	66	19	100	

Source: Agricultural Contingency Plan-District Agricultural Profile (2208-09) Tiru and Water Management Technologies, Water Management Centre, Tamil Nadu Agricultural University, Coimbatore.

The main winter (January to April) crops grown across the system are pulses of which black gram (crop duration 75-80 days) is preferred to green gram (65-70 days) by about 2:1, and accounts for 26% of the cropped area. Gram crops rely on residual moisture and are usually not irrigated, although sometimes where groundwater is available, they are irrigated. The other major winter crops grown include groundnut (95-115 days), sesame (75-90 days) and small areas of maize (90-120 days), plus minor vegetables, which collectively account for only about 6 % of the gross sown area. These crops have an average duration of 75-90 days and are planted normally in January. A biannual crop of sugar cane is grown on 3 % of the land, particularly in Thanjavur. Long term perennial tree crops, mainly coconut but also including banana, mango and other fruit tree crops are grown on around 5 % of the gross land area especially in Thanjavur where copra is an important product.

6.1.2 Paddy Cultivation in Vennar System

The most common system of lowland paddy cultivation in the Vennar System is transplanting and also by direct seeding into fields that are continuously flooded with 0.05 to 0.15 m of water throughout the growing season. Land preparation includes soaking, ploughing and puddling i.e. harrowing until a soft muddy layer of 0.05 to 0.25 m is formed in saturated conditions. The water requirement for land preparation is estimated at 200±150mm, but can reach as high as 900± 650 mm for long duration paddy. The higher water requirement for land preparation is required for loamy sandy soils, while clay soils require less water. Field water application during crop growth periods varies from 500 - 800 mm to more than 3000 mm. Most wet season paddy irrigation is by gravity (cascades from plot to plot) while dry season paddy cultivation requires pumping in some places.

6.1.3 Rice Water Requirements and Productivity

The average total water requirements and specific water use for paddy production under different conditions can be roughly estimated as 550 to 950 mm/crop, based on an evapotranspiration, which is the water actually consumed by the plant, plus any additional water used. The water requirement, yield and specific water use for different types of paddy production are shown in Table 6.2.

Table 6.2 Gross water requirement, yield and specific water use for different types of paddy production

Production system	Total Gross Water Requirement	Yield	Specific Water Use	Water Productivity
	m^3/ha	t/ha,	m^3/kg	kg of rice/m^3 of water
rainfed upland paddy (evapotranspiration only)	5500	1.25	3.6	0.28
rainfed lowland paddy (evapotranspiration + impounded rainwater)	10,000	2.5	4.0	0.25
irrigated upland paddy (evapotranspiration + supplementary irrigation)	10,000	2.5	4.0	0.25
irrigated lowland/deepwater paddy (evapotranspiration and full irrigation)	16,500	4.5	3.7	0.27

Irrigated lowland is the dominant system in the Vennar System. It is the most productive in terms of yield and it produces the highest yield per m^3 of water but, it is the least efficient in terms of water use per ha or the amount of water required for evapotranspiration divided by the amount of water diverted into the system. Water productivity in the Vennar System is low as the water productivity elsewhere in India is typically 0.4±0.2 kg per m^3 of water. Total water productivity or paddy production can be increased by better management of water drained from one field to irrigate paddy in another field.

There is no absolute technique available to measure exact irrigation water requirement of paddy but literature and research reveals that requirement varies depending on soil, climate, irrigation system, variety (long duration varieties require more water) and other management practices.

Typical water requirements and water use for paddy are:

- Water requirement: Nursery – 40 mm; main field preparation - 460mm; panicle initiation & flowering – 417; flowering – maturity – 123 mm. Total 1240 mm

- Water use: land preparation (150-250 mm); evapotranspiration (500-1200 mm); seepage and percolation (200-700 mm); mid season drainage (50-100 mm). Total (900-2250 mm)

6.2 Details of Original Cropping Pattern and Crop Calendar

The Cauvery Delta including the Vennar System has been the rice bowl of Tamil Nadu for millennia. From the early 1800's, rivers of the Vennar System have been enhanced to improve the delivery of irrigation water and the removal of floodwater. Depending on the availability of water, farmers have grown one, two or three rice crops. Since the construction of storage dams in the upper Cauvery catchment in the early 20th century, the availability of irrigation water has been more reliable at least in the main growing season from August to January and rice still is the dominant crop.

6.3 Future Cropping Patterns

Crop and agricultural data was collected from agricultural and irrigation research facilities and the departments of agriculture in Thanjavur, Thiruvarur and Nagapattinam Districts.

The selection of an alternative generic cropping pattern for the Vennar system has been developed based on an empirical analysis of existing data and the results from the CASDP PPTA Social Survey (Mott MacDonald 2014). Consideration was given to water use efficiency ("best crop per drop") plus the relative profitability of the various crop options, as it is no use replacing one crop with another of lower financial return. In addition, there was the need to determine the aim of the alternative cropping pattern: whether it is to forecast a cropping system which is more productive under improved water availability and management, and/or it is to improve water use efficiency (WUE) where rice is replaced with more water efficient crops.

As a starting point it is useful to consider the water requirement and WUE of major crops shown in Table 6.3. It should be noted that paddy is probably the best crop to be grown during the north-east monsoon because of the high rainfall and the related land inundation. Also the climate can cause causes serious problems with pests/disease for alternative crops to rice. This leaves the south-west monsoon season where rice could be replaced to a certain extent by other crops such as pulses, oilseeds (soya bean and groundnut) and maize, and possibly some high value vegetables. In the summer season, with irrigation only from groundwater, other crops could include pulses, oilseeds and cotton. If water saving is an aim then the cultivation of long term crops which rely on a constant supply of irrigation water, for example sugarcane and banana, should not be proposed.

Table 6.3 Water Requirements and Water Use Efficiency for Different Crops

Crop	Duration (days)	No. of Water applications	Water Requirement (mm)	Productivity (kg/m^3)	Quantity of Water Required (m^3/kg)	WUE (kg/ha/mm)
Rice	110-160	20	1250 (900-2500)	0.41	2.44	4.1
Sugarcane	360	24	2200	4.05	0.25	40.5
Groundnut	105	9	510	0.21	4.26	2.1
Sorghum	105	8	500	0.80	1.25	8.0
Maize	100	12	500	0.93	1.08	9.3
Millet	95	10	310	0.88	1.13	8.8
Cotton	165	10	600	0.33	3.00	3.3
Black gram	65	6	280	0.25	4.00	2.5
Soyabean	85	8	320	0.47	2.13	4.7
Sesame	85	3	114	0.25	4.00	2.5

Source: TNAU (2003). Water Management Technologies.Water Management Centre. Tamil Nadu Agricultural University. Coimbatore-641 003.

The systems developed for the System of Rice Intensification (SRI) can have a significant impact on the amount of water required to cultivate the crop while still maintaining high yields and productivity. In many cases a gross water saving of around 50% can be achieved (8,000 m^3/ha for the SRI system as compared to 16,500 m^3/ha for the current traditional systems). This method is already used in some blocks of Thanjavur and Thiruvarur districts and its further expansion in these locations would have a significant impact. Also if water management and control are improved in single cropped Samba rice cultivation areas, the overall saving in water used across the Vennar System could be significant.

6.4 Assessment of Effective Rainfall and Crop Water Requirements

6.4.1 Potential Evaporation and Effective Rainfall

The general climate regime of the Cauvery delta was described in Chapter 2. The Cauvery delta has a tropical climate, with mean annual rainfall of around 1200 mm. The south-west and north-east monsoons are the dominant sources of precipitation providing almost 80% of the total annual rainfall. The north-east monsoon is associated with cyclonic storms causing widespread damage to crops and property as result of flooding. Inter-annual rainfall variability also causes significant damage to agriculture as a result of drought. Intra-seasonal variability also causes frequent crop failures and loss to major agricultural resources.

The climatic norms in the Cauvery delta and more particularly the Vennar System were determined using station data at Tiruchirappalli and Nagapattinam plus meteorological data from the FAO CLIMWAT database. Figure 6.1 and Figure 6.2 show potential evapotranspiration and effective rainfall for Tiruchchirappalli and Nagapattinam respectively using the FAO CROPWAT8 package. CROPWAT 8uses the FAO Penman method in the calculation of ETo, and calculates effective rainfall using the USDA Soil Conservation Service method.

Figure 6.1: Climatic Norms for Tiruchirappalli

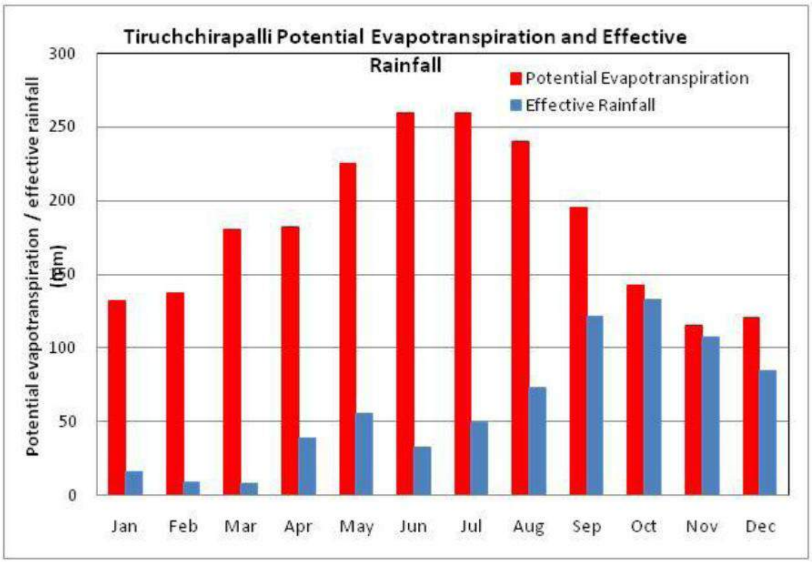
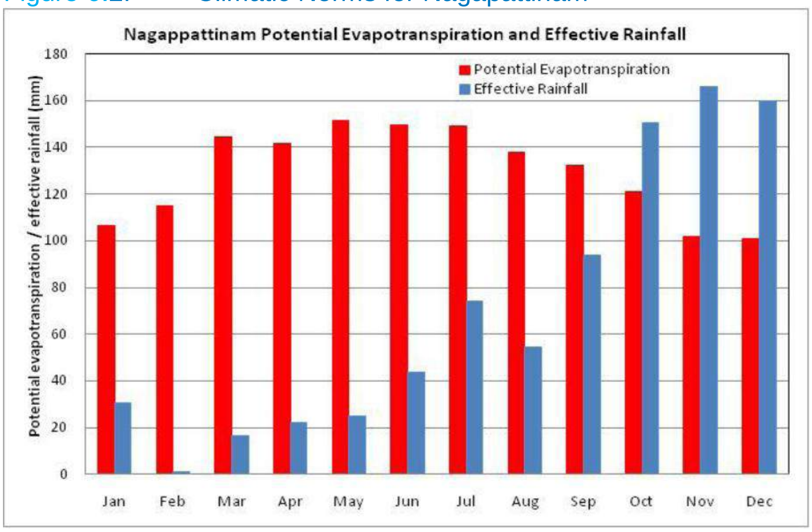


Figure 6.2: Climatic Norms for Nagapattinam



Considering each station in more detail:

Tiruchirappalli: Mean daily temperatures range from a low of about 25^oC in December to a high of about 32^oC in May. April, May and June are the hottest months with mean daily maximums close to 31^oC. The mean daily temperature range is typically about 8^oC. The maximum range occurs in May and the minimum in December. Relative humidity is at its lowest in June, averaging 60%, and peaks in November at 73%. Wind speeds are generally in the range of 1.5 to 6.3 m/s, and are highest in June to July. Solar radiation is at its peak in March and low in November. The climatic parameters combine to give an annual potential evapotranspiration at of 2191 mm, with peak evapotranspiration in June, July and August. The peak daily rates of evapotranspiration occur in July with a mean of 8.4 mm/day. It is clear from Figure 6.1 that the effective precipitation is far short of potential evapotranspiration. Mean annual rainfall is 902 mm, and the computed mean annual effective rainfall is 726 mm.

Nagapattinam: Mean daily temperatures range from a low of about 25^oC in December to a high of about 31.4^oC in May. May and June are the hottest months with mean daily maximums close to 31^oC. The mean daily temperature range is typically about 8^oC. The maximum range occurs in May-June and the minimum range in November-December. Relative humidity is very high throughout the year, being at its lowest in July when it averages 76%, and peaking in October at 90%. Wind speeds are generally in the range of 1.7 to 3.6 m/s, and are highest in March to June. Solar radiation is at its peak in March and lowest in December. The climatic parameters combine to give an annual potential evapotranspiration at of 1552 mm, with peak evapotranspiration in May and June. The peak daily rates of evapotranspiration occur in May with a mean of 4.9 mm/day. It is clear from Figure 6.2, that except for the months of October, November and December, the effective precipitation is far short of potential evapotranspiration. Mean annual rainfall is 1421 mm, and the computed mean annual effective rainfall is 837 mm.

The main climate parameters for the two stations are summarized in Table 6.4.

Table 6.4 Comparison of Climate Parameters in Tiruchirappalli and Nagapattinam

Parameter	Tiruchirappalli	Nagapattinam
Mean Daily Temperature		
-December	25^oC	25^oC
-May	32^oC	31.4^oC

Mean daily temperature range	$8^{o}C$	$8^{o}C$
Relative Humidity		
-June (low)	60%	
-July (low)		76%
-October (peak)		90%
-November (peak)	73%	
Wind speeds	1.5-6.3 m/s	1.7- 3.6 m/s
Potential ET	2191 mm	1552 mm
Peak daily ET	8.4 mm/day	4.9 mm/day
Mean annual Precipitation	902 mm	1421 mm
Mean effective rainfall	726 mm	837 mm

Temperatures in the two locations are similar. The main climatic difference between the locations are that the humidity and rainfall are higher at Nagapattinam on the coast. The higher humidity reduces the coastal potential evapotranspiration. Overall, the effective precipitation is far short of the potential evapotranspiration in both locations although the deficit is greater inland.

6.4.2 Agro-climatic Zone

Based on rainfall distribution, irrigation pattern, soil characteristics, cropping pattern and other physical, ecological and social characteristics, Tamil Nadu State is classified into seven agro-climatic zones and the Vennar System is located in *Zone 4 – Cauvery Delta Zone*. This zone covers the Cauvery Delta area in Thanjavur, Nagapattinam and Thiruvarur Districts and also the taluks of Musiri, Tiruchirappalli, Lalgudi, Thuraiyur and Kulithalai in Tiruchirappali District, and the taluk of Aranthangi in Puddukottai district and the taluks of Chidambram and Kattumannarkoil in Cuddalore District.

The growing season for paddy in the Cauvery delta is generally from June to February. The first crop, Kuruvai, is of short (105 days) duration and is planted in June / July and harvested in September / October. The second crop, Thaladi, has about 135 days duration, and is planted during October / November and harvested in January / February. The long duration crop, Samba is planted in the single crop lands during August / September and harvested in December / January and is of about 150 days duration.

A cash crop of pulses, either black gram or green gram, is sown, mixed with wild indigo or wisteria (Sesbaniaspeciosa) as a green manure crop in the lands under paddy, just prior to harvest of paddy. The pulse and green manure crops grow with residual moisture and dew in the early stages and with summer rains in the later stages.

Groundwater pumped from tubewells is used for raising advance paddy nurseries and for supplementing canal flows when they are inadequate. Farmers on the higher delta land in Thanjavur and to lesser extent Thiruvarur districts, where groundwater is favourable, are normally double cropping by using groundwater when canal water supplies are not available.

The Cauvery Waters Dispute Tribunal (CDWT) in its final order in 2007 assumed the irrigation season is restricted to June to January and that crops grown after 31st January are irrigated with groundwater.

6.4.3 Water Requirement and Irrigation Schedule

The water requirement and irrigation schedule for the main crops in the Vennar Basin are shown in Table 6.4

Table 6.4 Water Requirements and Irrigation Schedule for the Main Crops.

Crop	Water requirement (mm)	Irrigation schedule (IW/CPE)	Irrigation Interval (days)	Critical stages for moisture stress
Rice	1250 (900-2500)	5 cm on disappearance of previously ponded water	4	Tillering, panicle initiation, flowering & milky stages
Maize	500-600	0.8	10-12	Knee-high, tasseling, silking and maturity
Pulses	250-300	0.4	10-12	Vegetative & flowering
Sesame	100-200	0.4	10-12	Vegetative & flowering
Groundnut	450-550	0.6	10-12	Flowering, peg formation & pod development
Cotton	600-650	0.4	10-12	Square formation, flowering & boll formation
Sugarcane	1800-2000	0.75 (0.5)	7-8	Early vegetative, grand growth & maturity phases
Banana	2000-2200	0.8	7-8	Adequate moisture required throughout crop period & especially during fruit development stage
Chillies	650	0.8	7-8	Flowering, fruit setting & enlargement

Note: IW is Irrigation Water. CPE is Cumulative Pan Evaporation
Source: TNAU (2003). Water Management Technologies .Water Management Centre. Tamil Nadu Agricultural University. Coimbatore-641 003

The dominant rice crop has a high water requirement when compared to other field crops plus needs frequent irrigations to keep water ponded on the field. Sugar cane and bananas also have high water requirements as they need year round watering.

6.5 Assumed conveyance efficiencies

Irrigation water is a limited resource and therefore should be used very efficiently. The main inefficiencies are losses that occur during conveyance, run off, seepage and deep percolation. Uneven spreading and inadequate filling of the root zone are other causes of low irrigation efficiency. Application efficiency is defined as the ratio of the water volume stored in the soil root zone to the water volume applied by the irrigation system. Thus, water applied by the irrigation system and not being made available to be taken up by plant roots is wasted and reduces irrigation efficiency. The major causes for reduced irrigation efficiency are drainage of excess irrigation water to soil layers deeper than the depth of active roots. Leakage of irrigation water to deep soil layers could result in pollution of the water table.

From 1983 to 1998, PWD's Institute of Hydraulics and Hydrology at Poondi carried out research studies in the Cauvery Delta and determined that average seepage losses in lined channels was 7 % and in unlined channels was 11% (CMP 2008). In a separate study, flow particulars were collected from 1978 to 1989 and analysed to determine that the overall average loss of water in the Vennar River was 10%.

In the Government of Tamil Nadu's statement of crop water requirements submitted to the Cauvery Water Disputes Tribunal, the efficiency of the irrigation systems in the Cauvery basin was taken as 55-60% (CMP 2008).

6.6 Irrigation Water Requirements

Current deliveries of irrigation water are not being altered under CASDP Project. Irrigation deliveries will be maintained at their present levels as long as the distribution system is maintained in its present stage.

7 Aquaculture

7.1 Introduction

Shrimp farming is the major aquaculture activity in the Vennar system and requires significant amounts of clean water to support the shrimps, replenish oxygen and remove waste. Land-based aquaculture systems impact the environment by not only using water and returning it in a more degraded form but also consuming water through evaporation from the pond surfaces and seepage to groundwater.

Initially *Penaeus monodon* (Tiger shrimp) was farmed with marine and brackish water in the Vennar system. As *Penaeus monodon* grow better in water with a salinity of 15-25 ppt, shrimp farms were located on the coast where sea water or saline groundwater could be accessed. However, in the late 1990's, the production of tiger shrimps collapsed due to disease. Shrimp farming did continue but at a much smaller scale.

In about 2009, a different shrimp variety, L. *vannamei*, was introduced to India and shrimp farming again became profitable in the Vennar system. The area of ponds increased, partly due to the expansion of shrimp farming inland into fresh water areas because L. vannamei is tolerant to a wider salinity range (0.5 to 35 ppt) than *Penaeus monodon*. The best growth of L. *vannamei* is reportedly in low salinity waters and therefore inland shrimp farmers put salt into fresh water to maintain water salinity at 0.5ppt.

7.2 Area of Shrimp Farming

The estimated area of coastal brackish shrimp farms in the Vennar system is shown in Table 7.1 The estimate is based on information received from shrimp farmers, representatives from shrimp farmers' associations, grass root representatives, NGO's, volunteers and others who are involved in shrimp production. However, only about 60% of the farms in the coastal belt were in operation in March 2014, which means that about 1384 ha of ponds are actively producing at present. The reasons why 40% are inactive include problems with land ownership, water quality, soil texture, social issues and financing.

The area of inland shrimp farms that use fresh water is estimated to be about 500 ha.

Table 7.1 Shrimp farms in the Vennar System

River/ tributary/canal	Area of Brackish Water Shrimp Farming (ha)
Valavanar	20
Maraka Koraiyar	15
Jabuwanodai	140
Koraiyar	50
Paminiyar	180
VC Thopputhurai	55
VC Kodiakarai	95
Kodiakadu	30
VC Periakuthagai	30
VC Thethakudi south	15
VC Pushpavanam (Near Marapalam)	15
Periakuthagai RF (Reserved Forest)	5
VC Kallimedu	70
Talainayar RF (Reserved Forest)	30
Maharajapuram east (Opp to Adapar st cut)	70
Vandal – Velankani (Thalainayar Road)	60
Oradiampakkam-Umblacherry (Between Thalainayar Velankani Road)	60
VC Vezhakulam-Thirukulam	35
Vellapallam-Pidarikulaum (Near Thalainayar RF)	50
Karapidagai South	110
Karapidagai North	90
Chinnathumbur	15
Periathumbur	10
Thalaiyamazhai	50
Thandankulam Pond	12
Vettaikaran Iruppu (Near Lawford St Cut ECR both sides)	250
Vilunthamavadi (Near Chkilian Vaikal St Cut ECR both sides)	120
Kannithoppu (ECR both sides between Thirupoondi Kilapadagai-Kannithoppu-Kameshwar Road)	550
Vellaiyar St Cut-Periathumbur	25
Vadakadu (Near Muthupet RF)	50
Total Area Under Shrimp farming	**2307**
Active Shrimp Farming Area as on March 2014 (60%)	**1384**

Source: Primary information from farmers and associations

Note: VC denotes Vedharanyam canal

7.3 Water Use

The average evaporation and infiltration water losses from shrimp ponds are about 1,500 mm/yr and 2,000 mm/yr respectively, totaling 35,000 m^3/ha/year. (M. C. J. Verdegem and R. H. Bosma / Water Policy 11 Supplement 1 (2009) 52–68). Various techniques help to reduce infiltration and floating macrophytes or synthetic reflection covers can diminish evaporation. Unfortunately, such techniques are difficult or costly to apply; hence farmers seldom try to control infiltration or evaporation losses. The most practical option to reduce relative water wastage in ponds is to increase the production per unit surface area, that is to increase the stocking rate.

7.4 Future Development of Shrimp Farms

Future development of shrimp farms is dependent on regulations, international markets and other factors. Inland, the area of shrimp farms may increase due to the environment being suitable and the high returns when compared to agriculture. In the coastal zone, only 60% of shrimp farms are currently being utilised and so any future growth is likely to initially utilize the dormant 40% (about 923 ha). The new tail end regulators proposed under CASDP Project will provide more fresh water, which could be used to re-activate about 277 ha (or 30 %) of the inactive shrimp farms.

7.5 Best Management Practices

Many aspects contribute to BMP (Best Management Practices) for shrimp farming. Of primary concern to the protection of water resources are the following:

- Aquaculture should be correctly positioned and practiced according to the suitability of the water resource, any zoning implications, and the integration of the aquaculture activities with other uses of the same water resource;
- Quantitative control measures should be put in place to limit production to levels that can be sustained by the water resource;
- Effluent discharge and waste control, as these relate to the water resource, should be controlled and monitored;
- Consideration should be given to infrastructure safety and the impact of aquaculture infrastructure on other users of common water resources;
- Systems should be in place for the detection of water resource degradation and negative impacts on other water resource users;
- A clear understanding should be developed regarding accountability associated with the entitlement and authorisation of the sustainable use of water for aquaculture; and
- Attention should be given to the potential impact of aquaculture chemicals, feeds, diseases and exotic organisms on water resources.

8 Horticulture

Horticultural production in the three districts in the Cauvery delta (Thanjavur, Thiravarur, Nagapattinam) is very small when compared to the production rice or pulses and other field crops. Horticultural crops are grown on less than 2% of the land area of the three districts. The main horticultural crops are fruits (especially bananas), vegetables, plantation crops, spices and condiments. There is scope to expand horticultural production to meet the needs of the increasing urban population and to be a factor in crop diversification but it will take decades to change the dominant rice culture of farmers.

9 Others

In the south-east corner of the Vennar System at the southern end of the Vedharanyam Canal, there is an extensive area of salt production, based on the hyper-saline waters of the eastern sea lagoon on the south coast of the Cauvery delta. Salt has been produced in this location for centuries. The Vedharanyam Canal was built to facilitate movement of salt from the salt fields by barge to Nagapattinam Port, for distribution throughout India. This Project will not impact salt production or the salt fields.

10. Water Demand

10.1 State level

At the macro level, the State Framework Water Resources Plan (Government of Tamil Nadu, 2012) places the annual water availability of surface and ground water at 46,540 MCM (1643 TCM) while the demand is assessed as 54,395 MCM (1921 TCM) in 2001. The demand is projected to go up to 57,725 MCM (2021 TCM) by 2050. The major demand comes from agriculture, domestic and industry.

While the demand for agriculture is likely to remain at 35,917 MCM (1268 TCM) in the foreseeable future, rapid urbanization will place heavy stress on domestic use, which is projected to increase by more than 50 per cent from 2222 MCM (78 TCM) in 2001 to 3460 MCM (122 TCM) in 2050.

Industrial water demand is projected to increase by 27 per cent from 1555 MCM (55 TCM) in 2001 to 1985 MCM (70 TCM) by 2050. Thermal power plants account for the highest proportion of industrial water use. Other industries include chemicals, distilleries, oil refinery, textile dyeing, steel, fertilisers, pharmaceuticals, petrochemicals, paper and pulp, sugar, electroplating etc. The Government of Tamil Nadu has indicated that water security, i.e. provision of drinking water to the people will be the highest priority of the Government. The State Framework Water Resources Plan also states that about 3.5% (1600 MCM) (56.5 TCM) would be kept aside for minimum flow in rivers for ecological purpose by 2050.

10.2 Basin level

As at the state level, water demand in the river basins of Tamil Nadu can be grouped under three major categories i) water for agriculture and allied livelihood supporting activities, ii) water for drinking and iii)water for commerce and industries. While irrigation is primarily controlled and managed by the Water Resources Department, the constitutional amendments made in 1986 (73rd and 74th amendments of the constitution of India) empower the local governments (both urban and rural) to undertake drinking water service delivery.

WRD identified eight key environmental concerns in the 17 river basins in the state (State Framework for Water Resources Plan, GoTN, 2010). The concerns are i) catchment degradation ii) siltation iii) excessive surface water extraction iv) seawater intrusion v) municipal sewage pollution vi) industrial affluent pollution vii) weed growth and viii) water logging & salinity. Based on the magnitude of the environmental problem, the concerns in each basin were placed into one of three categories: i) severe, ii) moderate and iii) insignificant.

For the key environmental concerns are shown in Table 10.1. The magnitude of the impact of each of these concerns was classified as "severe" for six of the eight concerns, and 'insignificant' for the other two concerns. There were no environmental concerns categorized as 'moderate'. The environmental concerns in the Vennar system areare similar to those in Cauvery basin, and some of these concerns including sea water intrusion, weed growth, over-abstraction of groundwater, water logging and salinity will be addressed during CASDP.

Table 10.1: Key environmental concerns in Cauvery Basin

Environmental Concern	Assessment	Environmental Concern	Assessment
Catchment degradation	Severe	Municipal sewage	Severe
Siltation	Severe	Industrial effluent	Severe
Over extraction GW	Insignificant	Weed growth	Severe
Sea water intrusion	Severe	Water logging and salinity	Insignificant

Source: State Framework for Water Resources Plan, GoTN, 2010

10.3 Agricultural Demand in Vennar System

The crop water requirements for the main paddy crops are shown in Table 10.2.

Table 10.2 Gross Crop Water Requirements (CWR)

Month	Paddy Kuruvai/Samba/ Thaladai (mm)	Paddy Kuruvai/Samba/ Thaladai with SRI (1) (mm)	Dry (grains & pulses) monsoon (mm)	Dry (grains & pulses) summer (mm)
Jan				110
Feb				285
Mar				320
Apr				115
May				
Jun				
Jul	80	77	35	
Aug	295	283	97	
Sep	304	292	95	
Oct	295	283	65	
Nov	121	114		
Dec				
Total	1095	1049	292	830
Less effective rainfall (mm)	482	462	129	365
Total Net CWR (mm)	613	587	163	465

Note (1) SRI : System of Rice Intensification

(2) Ratio of Effective rainfall to total CWR to = 0.44

Source: CROPWAT (FAO)

The water consumption per unit area of crop is summarised below in Table 10.3. Climate projections for the Cauvery delta made during the PPTA (Srinivasan, 2013) suggest that the impact of climate change will be to reduce crop water consumption by 6.7% based on projected changes up to 2050 (see Agriculture Systems Report, DFR Document Nr:19).

Table 10.3: Water Consumption for Main Vennar System Crops

Crop name	**Diversion at headworks**	**Water consumed**
	m³/ha	**m³/ha**
Dry (non-paddy grains and pulses) July-December	3,490	1,634
Dry (non-paddy grains and pulses) January-April	0	4,646
Paddy Kuruvai/Samba/Thaladai July-November	18,328	6,131
Paddy Kuruvai/Samba/Thaladai (SRI) July-November	13,838	5,877

Source: Mott MacDonald 2014

System water requirements have been calculated for six scenarios and are presented in Tables 10.4 and 10.5. The six scenarios are:

(i) The existing cropping pattern based on cropping patterns for coastal area of Vennar System using surface water;

(ii) The existing cropping pattern based on cropping patterns for inland area of Vennar System where there is conjunctive use of surface and groundwater;

(iii) An increase in the cultivation of SRI paddy replacing traditional paddy cultivation by 25% in coastal area of system;

(iv) An increase in the cultivation of SRI paddy replacing traditional paddy cultivation by 25% in inland area of system;

(v) No paddy cultivation across the whole system with the cultivation of semi-dry crops instead of paddy;

(vi) Improved paddy cultivation using 25% SRI paddy impacted by climate change anticipated in year 2050 for the whole system.

Table 10.4: Water Requirements for Selected Cropping Patterns

	Current CP Coastal (i)			**Current CP Inland (ii)**			**Future CP SRI Coastal (iii)**		
	Area	**Area**	**Water Vol**	**Area**	**Area**	**Water Vol**	**Area**	**Area**	**Water Vol**
Crop	**%**	**ha**	**Mm^3**	**%**	**ha**	**Mm^3**	**%**	**ha**	**Mm^3**
Semi-dry July-November	0	0	0	0	0	0	0	0	0
Semi-dry January-April	15	12,900	111	40	34,400	296	15	12,900	111
Paddy Kuruvai/Samba/ Thaladai July-November	100	86,000	1,576	90	77,400	1,419	75	64,500	1,182
Paddy Kuruvai/Samba/ Thaladai (SRI) July-November	0	0	0	0	0	0	25	21,500	298
Total area (gross)	115	98,900	1,687	130	111,800	1,715	115	98,900	1,591
Total area (net)	100	86,000	-	100	86,000	-	100	86,000	-

Note: total irrigated cropland in the Vennar System of 172,000 ha is allocated to 50% as inland (86,000 ha) and 50% as coastal (86,000 ha), based on available data.

Table 10.4 Water Requirements for Selected Cropping Patterns (continued)

	Future CP SRI Inland (iv)			No Paddy Cropping (v)			Future CP SRI & CC (vi)		
	Area	**Area**	**Water Vol**	**Area**	**Area**	**Water Vol**	**Area**	**Area**	**Water Vol**
Crop	**%**	**ha**	**Mm³**	**%**	**ha**	**Mm³**	**%**	**ha**	**Mm³**
Semi-dry July-November	0	0	0	100	172,000	600	0	0	0
Semi-dry January-April	40	34,400	296	50	86,000	740	28	48,160	387
Paddy Kuruvai/Samba/ Thaladai July-November	67	57,620	1,056	0	0	0	71	122,120	2,088
Paddy Kuruvai/Samba/ Thaladai (SRI) July-November	23	19,780	274	0	0	0	24	41,280	533
Total area (gross)	130	111,800	1,626	150	258,000	1,340	123	211,960	3,008
Total area (net)	100	86,000	-	100	172,000	-	100	172,000	-

Note: total irrigated cropland in the Vennar System of 172,000 ha is allocated to 50% as inland (86,000 ha) and 50% as coastal (86,000 ha), owing to the lack of substantive data.

Analysis of the data shows that the gross water requirement (at the headworks) is 3,402 Mm³ for the current cropping pattern (total of scenarios (i) and (ii) for coastal and inland cropping systems) and reduces to 3,216 Mm³ for the assumed future cropping pattern (total of scenarios (iii) and (iv), for coastal and inland cropping systems with SRI). Cessation of paddy cultivation under scenario model (v) would reduce the gross water requirement to 1340 Mm³ which is a reduction of 60%. The net water requirements will be less than this because of return flows. It is estimated that the impact of climate change as presented in scenario (vi) will reduce the water gross requirement to 3,008 Mm³, which is 88 % of current and 94 % of future cropping water requirements.

10.4 Water Demand for Aquaculture

10.4.1 Present Water Use

Shrimp farming is the major aquaculture in the Vennar System. Shrimp production requires a constant depth of 1m to 1.2 m/ha. An average of 75 % additional water is required to maintain the required to depth during the 120 days of the shrimping season. Thus, with two shrimp harvestsharvests per year, the annual water requirement is 35,000 m^3

In the Vennar System, the area of ponds actively producing *L.vennamei*, the only species of shrimp used commercially, is 1884 ha (1384 ha on the coast and 500 ha inland), which computes to an annual water requirement of 48 Mm^3 (1.73 TMC) in coastal areas and 18 Mm^3 (0.9 TMC) inland. 43% of the total water requirement is actually consumed during production while 57% is returned as drainage downstream. Therefore, the annual volume of water used in shrimp production is 28 Mm^3 (1.0 TMC).

10.4.2 Future Water Use

Future aquaculture production is extremely vulnerable to regulations, international markets, and other factors. Considering these variables, future ndemand could be:

- In 5 years (by 2020), if *L.vennamei* production continues to be viable, the estimated increase in the area of shrimp farming will be 5000 ha inland, with land being converted fromproductive agriculture. The increase in demand will require 175 Mm^3 (6.25 TMC) of which 75 Mm^3(2.7 TMC) would be consumed

- In the coastal zone, the area under shrimp farming has covered almost all the potential area for shrimp culture, and there are few opportunities to add more area, expansion in the area of ponds is elikely to be small or negligible.

- Currently, there are 923 ha of inactive shrimp farms on the coast because of land ownership, water quality, soil texture, or social problems. The newtail end regulators proposed under CASDP Project will make more fresh water, available which may activate about 277 ha (30 %) of the inactive farms and increase their productivity.

10.5 Power Generation

Use of water in a thermal coal-fired plant is estimated to be in the range of 1.7 to $8.0m^3$ per MW of power production (Source: Water Balance and Water Conservation in Thermal Power Stations, Bulletin on Energy Efficiency, Volume 7, Issue 3, December 2006). This puts the total water demand for thermal power plants in the two districts (as shown in Table 14.1) at a minimum of 16,923 m^3 and a maximum of 79,640 m^3 per day, of which 98% is seawater.

10.6 Industry

The TWAD Board Act, 1970 has a provision to execute water supply and sewerage schemes for industries and institutions. The schemes are executed by the Board on a commercial basis. The current industrial water supply and the quantity allotted under the jurisdiction of the Chief Engineer (Thanjavur Circle, TWAD) are shown in Table 10.5.

Table 10.5: Industrial Water Supply

Industry	Water source	Quantity (litres/day)
TNEB Gas Plant	CWSS to Gas Based power project and 77 habitations and Kuthalam UTP in Thanjavur and Nagapattinam Districts	225,000
LANCO (Aban) Power Plant	CWSS to TNEB Gas plant and 77 habitations in Kuthalam Union	100,000
SIDCO Thuvakudi, SIDCO, Valavanthankottai and Food Craft, Thuvakudi	CWSS to Thiuverumbur UTP, Thuvakudi Municipality, Koothappar RTP and 97 other habitations in Thiruverumbur union and 17 private beneficiaries in Trichy District	1,294,000
SIPCOT and Indian Oil Corporation	CWSS to Pudukkottai Municipality, 3 Town panchayats and 15 habitations in Pudukkottai, Trichy and Karur districts	515,000
Total		2,134,000

Source: CE-TWAD Board, Thanjavur

The projected domestic and industrial water demand for 2025 is estimated to be 82.46 MCM. The district-wise break-down is indicated in the Table 10.6.

Table 10.6: Domestic and industrial demand

District	Demand in MCM (Year 2025)
Thanjavur	43.18
Thiruvarur	19.01
Nagapattinam	20.27
Total	82.46

Source: District Estimates, Technical Report Series, CGWB, 2008

10.7 Return flow from Domestic, Commercial and Industrial Water Use

The return flow of domestic, commercial and industrial use is likely to be in the range of 10 to 30**%.**%[1]. There are no major industries in the Vennar sub-basin that require industrial effluent treatment. However, a number of polluting industries such as tanneries, chemical and textiles are located upstream of Mettur Dam. The Government of Tamil Nadu is making an effort to control pollution in Cauvery basin by imposing a ban on setting up of highly polluting new industries within a radius of five km from the river. (Source: Tamil Nadu Development Report, 2005, Planning Commission, Government of India**).**).

10.88 Drinking water demand:

The population in the three project districts is estimated to grow between 8 to 10% between 2011 and 2021. The population in 2011 and the projected population (2021) are provided in Table 10.7.

Table 10.7: Projected population of the three Vennar System Districts

District	Population (2011)	Projected population (2021)
Thanjavur	2,402,781	2,425,025
Thiruvarur	1,264,277	1,390,705
Nagapattinam	1,488,839	1,637,725
Total	5,155,897	5,453,455

Source: Growth of Population Density, T. Sangeetha and R Baskaran, Department of Earth Sciences, Tamil University, Thanjavur, 2010 . District Estimates, Technical Report Series, CGWB, 2008. TWAD Board, Thanjavur, 2011.

[1] Prediction of irrigation return flows through a hierarchical modelling approach, Dr. S. Mohan and Vijayalaxmi DP, Department of Civil Engineering, Indian Institute of Technology, Chennai

Table 10.8 summarizes the habitations and towns covered by the TWAD Board in the Vennar system and the source of the water. Cauvery and Coleroon are the two important rivers from where water is sourced primarily using infiltration wells. In some locations surface water is supplanted by drawing water from groundwater sources.

Table 10.8 Drinking water status and surface source

District	Villages	Habitations	Drinking water status	Towns	Surface source for drinking water
Thanjavur	589	3902	Fully covered=3748 Partly covered=154	25	Cauvery and Coleroon
Thiruvarur	430	2582	Fully covered=2521 Partly covered=61	11	Cauvery
Nagapattinam	434	2872	Fully covered=2521 Partly covered=351	13	Coleroon
Total for Vennar system	1019	9356	8900	49	

Source: TWAD Thanjavur, 2011

The TWAD Board sources drinking water from 8 schemes in Thanjavur and 8 schemes in Thiruvarur and Nagapattinam at a total rate of 236.81 MLD. With increasing population and increased per capita consumption, the situation is likely to change significantly and the estimated demand in 2021 will increase by 15 to 20%.

10.9 Summary of Demand

The water demand in the Vennar System is summarised in Table 10.9.

Table 10.9 Annual Water Demand

	Demand (Mm^3)				
	Irrigation	Aquaculture	Industrial and domestic	Power	Total
Present	5007	66	75	18	5166
Future	4740*	241	83	18	5082
Climate Change	4427*	265	99	18	

Note: * Demand reduced due to farmers changing to SRI (see Section 10.3)

11. Impact of Proposed Works

11.1 Project and Adjoining Areas

The Cauvery River basin is located in Karnataka, Kerala and Tamil Nadu States and the enclave of Karaikal in the Union Territory of Pondicherry.

At the Upper Anicut (barrage), 177 km downstream from Mettur dam, the Cauvery River splits into two branches, the Coleroon and Cauvery Rivers. The Coleroon River is used to irrigate the northern extremities of the delta and also serves as a flood carrier.

On the Cauvery River some 30 km downstream of the Upper Anicut, is the Grand Anicut, where head regulators divide the flow between the Cauvery System, Vennar System and Grand Anicut Canal System. At the Grand Anicut, surplus flows including flood flows are diverted through the Ullar channel to the Coleroon. A particular feature of the Cauvery Delta systems is that the rivers are used to supply irrigation water as well as to remove drainage water.

The Vennar System has seven head regulators at major river bifurcation points. It has a number of intermediate regulators, that facilitate the distribution of irrigation flows, and tail-end regulators that serve the multipurpose of raising water levels to provide irrigation to low lying command areas and preventing tidal backwater flows into the system.

Along the eastern coast from Point of Calimers to Nagapattinam, the Vedharanyam Canal was constructed between 1863 and 1867 as a navigation canal to transport salt produced in the area south of Thopputharai to the port at Nagapattinam in the north. Between the Venharanyam Canal and the east coast there is a 3-4 km strip of sand dunes. Five straight cuts were constructed through the sand dunes to directly link the Vedharanyam Canal to the sea to supplement the flow through two ‘natural’ outlets at Vedharanyam in the south and Velankanni in the north. Sections of the Vedharanyam Canal and some of the straight cuts are heavily silted and sand bars have developed at the outfalls which obstruct flow to the sea. The canal is no longer used for navigation and is now solely a drainage carrier for the east bound rivers of the Vennar system. There is however a government proposal to re-establish navigation on the Vedharanyam Canal.

On the southern coast along the Palk Strait from Point Calimers to Adirampattinam the rivers of the Vennar System cross 4-6 km of tidal sand/mud flats into one of two large sea lagoons that are connected to the sea through 1-2 km wide openings. The sea lagoons are an ecologically sensitive area, in part because on the western side there is the largest extent of mangrove forest in Tamil Nadu.

Outflows from the river channels to the sea are influenced by tidal patterns and storm surges related to cyclones and tropical depressions and, on rare occasions, tsunamis. The normal tidal range is relatively small being about 0.6 m. A study of tides carried out during the PPTA (Dastgheib and Ranasinghe,2014) indicates that sea level is expected to rise between 0.87 m (high scenario) and 0.29 m (low scenario) and that the 100-year storm surge is approximately 0.74m.

11.2 Project Description and Proposed Works

This Project covers six rivers/drains of the Vennar System, namely the Pandavayar, Velliayar, Harichandra, Adappar, Valavanar and Vedharanyam. The proposed works include re-sectioning which includes widening, desilting, removal of vegetation, smoothening of undulating river bed, standardisation of river banks, and protection of banks against slides etc.; reconstruction of severely damaged structures, repairs/rehabilitation of damaged structures, and construction of new structures- the tail end regulators retaining walls and gated structures at open drainage in-falls in particular.

11.3 Aims and Objectives of the Proposed Works

The main focus of the works is to contain flood waters within the river channels and prevent bank overtopping and slides. The works will also help to prevent backflow of flood water into drainage catchments through open in-falls and allow quicker drainage of water accumulated in the catchments, once the water levels in the rivers decrease. The standardised banks also provide better access for rescue and relief operations in floods and for operation and maintenance of various control structures. The works will result in better management of floods. Flattening of bank slopes, increased freeboard and top width of the banks will make them sustainable even if flow rates increase as a result of climate change. Similarly, the river system will be more resilient to sea level rise.

It is envisaged to keep water deliveries for irrigation unchanged, but the repaired, reconstructed and new irrigation structures will help WRD to manage irrigation deliveries better. The storage of fresh water in river upstream of the new tail end regulators will increase in availability of fresh water for irrigation in low lying areas by pumping method.

11.4 Inter-state Aspects

The surface waters of Cauvery basin have been allocated among the basin states and each state is free to use its share of water in the manner it deems appropriate. The Mettur dam, in the upper reaches of the Cauvery river in Tamil Nadu, is the main storage dam in the state. The proposed works do not envisage any change in water utilisation in the Vennar basin. And thus there are no interstate aspects to the project.

11.5 Impact on Upstream Area

The outcome of this proposed Project works will be a decline in the duration and levels of floods by increasing the carrying capacity of the channels to discharge floodwaters more quickly to the sea. This Project will not impact upstream areas or projects.

11.6 Impact on Downstream area

This Project works cover the entire lengths of the Pandavayar, Velliayar, Harichandra, Adappar, Valavanar and Vedharanyam channels from their head regulators to their the open sea to the south. The works are expected to improve drainage and may even enhance the volume of water being released to the sea lagoons which would benefit the mangrove forest.

12. Interstate and International Aspects

The Cauvery River is not an international river. It is however an interstate river involving Karnataka, Kerala, Tamil Nadu & the Karaikkal District of the Union Territory of Pondicherry. Allocation of the surface water resources of the Cauvery Basin between the states has been a contentious issue for many years and the subject of prolonged tribunal proceedings. In 2007, the Cauvery Water Disputes Tribunal determined that the water yield of the Cauvery Basin in a normal year is 740 TMC and made annual allocations of 419 TMC to Tamil Nadu, 270 TMC to Karnataka, 30 TMC to Kerala, 7 TMC to Pondicherry and reserved 14 TMC for environmental protection and flow to the sea.

The project will not affect these allocations. Indeed in some respects the project is a consequence of the long tribunal proceeding and the strict water quotas given.

12.1 Agreements:

By the end of 19th century, the Mysore Government began taking steps to increase the irrigation from the Cauvery and its tributaries, which caused considerable anxiety to the lower State of Madras (Tamil Nadu), which took up the case with the Government of Mysore and Government of India. To safeguard the requirements of Tamil Nadu, an Agreement was reached in 1892 to prevent construction of further works by Mysore without the consent of Tamil Nadu. In 1924, another Agreement was reached to construct Krishnarajasagar reservoir and other offset reservoirs in Mysore. The Rules of Regulation framed to implement the 1924 Agreement prescribe the quantities of flow to be let down for the use of the lower Riparian State viz., Tamil Nadu on a day-to-day basis. The 1924 Agreement itself provides for reasonable uses by the upper riparian State after ensuring the flows due to the lower riparian State. Under this Agreement, the States are free to extend irrigation facilities effected solely by improvement of duty without any increase of water use. The 1924 Agreement provides for a review at the end of 50 years, only to see whether any further surplus quantities would be available beyond what has been contemplated for use in that Agreement with a view to allocate such surplus.

By the order of the Cauvery Water Disputes Tribunal (CWDT), the 1892 and 1924 Agreements between the then Government of Madras and the Government of Mysore so far as they related to the Cauvery river system have been superseded.

12.2 The Cauvery Fact Finding Committee:

Negotiations on the Cauvery waters issue were going on in the late 60s. In spite of several meetings held in 1970 between the Chief Ministers of the States, under the auspices of the Government of India with the Minister for Water Resources of Government of India participating, the issue could not be settled. Reference was also made to the Government of India to constitute a Tribunal. When the negotiations were resumed in 1972, a Committee by name the Cauvery Fact Finding Committee (CFFC) was appointed by the Government of India at the instance of the then Prime Minister of India with a retired Judge and experts in Irrigation and Agriculture from other States. The Committee gave the following important findings.

Description	Karnataka	Kerala	Tamil Nadu	Total
Area benefited (cropped area) in lakh acres	6.83	0.53	28.21	35.57
Water utilised in TMC	177.00	5.00	566.00	748.00

The water utilised (furnished above) was based on the data of 38 years ending with 1971-72 and the area furnished is the total developed area as in 1971-72. The Committee also arrived at the yield of the Cauvery basin as about 670 TMC on 75% dependability basis and as about 740 TMC on 50% dependability basis.

The Committee held the view that it became obvious that the Cauvery River is already over - burdened with the existing commitments and new uses could be had only by saving water in the existing projects.

12.3 Cauvery Water Disputes Tribunal (CWDT):

Negotiations further continued between the States several times under the agencies of Government of India with the data collected by the CFFC but of no avail. Left with no alternative and with no sign of any solution emerging through negotiation, the Government of Tamil Nadu in their letter dated 06.07.1986 requested the Government of India to constitute a Tribunal for resolving the Cauvery Waters issue. The Supreme Court of India, on the petition filed by the Tamil Nadu Cauvery Neerpasana Vilaiporulgal Vivasaigal Nala Urimai Padugappu Sangam, in which the Government of Tamil Nadu also impleaded themselves, observed in their order dated 04.05.1990 that

"26 attempts within a period of four to five years and several more adjournments by this court to accommodate these attempts for negotiation were certainly sufficient opportunity and time to these two States at the behest of the Centre or otherwise to negotiate the settlement. Since these attempts have failed, it would be reasonable undoubtedly to hold that the dispute cannot be settled by negotiations........."

and directed the Central Government to constitute a Tribunal within one month for resolving the Cauvery Water Dispute. In pursuance of this, the Government of India constituted the Cauvery Water Disputes Tribunal (CWDT) and notified it on 02.06.1990.

The CWDT had its first sitting on 27.07.1990 when the Government of Tamil Nadu approached it with a petition seeking an Interim Order to restrain the State of Karnataka from proceeding with their new projects and also to ensure flows to Tamil Nadu on a monthly basis to safeguard its irrigation, making out a case that the flows to Tamil Nadu were already dwindling with Karnataka impounding what all they get in their rivers in their new reservoirs until they are full, and taking a stand that 1924 Agreement has expired in 1974 and hence Tamil Nadu should be fortified with some Interim Orders until the CWDT gives its final decision. The CWDT pronounced its Interim Order on 25.06.1991, in which the State of Karnataka was directed to release water from its reservoirs so as to ensure 205 TMC at the Mettur reservoir in a year from June to May in a prescribed monthly pattern, of which 6 TMC is to be given to the Karaikal region of the Union Territory of Puducherry. The Tribunal also directed that Karnataka shall not increase its area under irrigation beyond the existing 11.2 lakh acres as mentioned in the K-V statement the Karnataka has filed before the Tribunal.

The Tribunal continued its deliberations. The basin States filed their Statements of Case with counters and rejoinders and all the technical information called for. The States also produced their expert witnesses as per the directions of the Tribunal. In all, 20 witnesses (Tamil Nadu - 9, Karnataka - 6, Kerala - 4 and Puducherry - 1) were presented and they were extensively cross - examined. The cross examination started in January 1994 and ended in December 2001. The depositions and cross examination recordings run to more than 5000 pages. Thereafter the parties advanced their arguments and counter arguments which were concluded in April 2006. The Tribunal gave its final Order and Report as per Section 5 (2) of the ISRWD Act on 05.02.2007.

The claims made by the basin States are as below:-

Sl.No.	State	As claimed	
		Area in Lakh Acres	Total Quantum of Water in TMC
1.	Tamil Nadu	29.27	566.000
2.	Karnataka	27.29	465.000
3.	Kerala	4.44	99.800
4.	Union Territory of Puduchery	0.43	9.355
	Total	**61.43**	**1140.155**

The Tribunal accepted the assessment of yield of the basin made by the CFFC at 50% dependability as 740 TMC and set out to allocate the same to the party States their share. Since the claim made by the States far exceeds the availability, the Tribunal adopted certain principles for allocation of water among them as below:-

They categorised the extent of ayacut to be considered by them as under in the order of importance.

(i) Areas which were developed before the agreement of 1924.

(ii) Areas which have been contemplated for development in terms of the 1924 Agreement .

(iii) Areas which have been developed outside the agreement from 1924 upto 2.6.1990, the date of the constitution of the Tribunal (i.e. from 1924 to 1990).

(iv) Areas which may be allowed to be irrigated on the principle of equitable apportionment.

After having determined the areas in the Cauvery basin over which the States of Tamil Nadu and Karnataka are entitled to irrigate from the waters of river Cauvery, it has also been examined to determine the nature of crops that should be grown by the two States keeping in view the following criteria namely:

(i) No note need be taken of the double crop / perennial crop *de hors* what is specifically provided in the 1924 Agreement.

(ii) No area for summer paddy need be considered; and

(iii)The area under summer paddy existing prior to 1924 if any may be allowed a semi-dry crop.

The area permitted and the quantum of water as apportioned by the Tribunal is as below:-

Area in lakh acres
Water requirements in TMC

Description	States				
	Kerala	Karnataka	Tamil Nadu	UT of Puducherry	**Total**
i) Area	1.93	18.85	24.71	0.43	45.92
ii) Irrigation requirement	27.90	250.62	390.85	6.35	675.72
iii) Domestic & industrial water requirement projected for 2011	0.35	1.85	2.73	0.27	5.20
iv) Water requirement for environmental protection	-	-	-	-	10.00
v) Inevitable escapages into sea	-	-	-	-	4.00
vi) Share in balance water (based on population)	1.51	17.64	25.71	0.22	45.08
Total	**29.76**	**270.11**	**419.29**	**6.84**	**740.00**
	30.00	**270.00**	**419.00**	**7.00**	**726.+14 =740.0**

The Tribunal also directed that "the use of under groundwater by any riparian State and UT of Puducherry shall not be reckoned as use of the water of the river Cauvery." (Clause XII). They have however indicated that the States may have to plan for use of groundwater to meet at least 50% of their drinking water needs and provided surface water for drinking waters only for 50% of the need, based on population.

The CWDT has allowed 24.70 lakh acres to be irrigated in TamilNadu as detailed below:

Sl No	Description	Area (Lakh Acres)
1.	Below Grand Anicut	14.43
2.	Between Mettur and Grand Anicut	2.72
3.	In Bhavani Sub basin	2.58
4.	In Amaravathi Sub basin	0.57
5.	In Noyyil Sub basin	0.17
6.	Irrigation projects taken up after 1974	0.79
7.	Minor Irrigation under tanks , pick-ups etc	3.45
	Total	**24.71**

In respect of waters to be utilised for irrigation, the Tribunal has stipulated that the State of Karnataka shall make available 192 TMC at the Interstate contact point (presently identified as Billigundulu), but a choice of any other contact point between Billigundulu and Mettur in the common reach has been clearly given, which has been split up into a monthly pattern. In arriving at the quantum of 192 TMC, the Tribunal has adopted the following procedure.

Sl. No	Description			TMC
1.	Total yield of the basin at 50% dependability.(CFFC)			740
2.	Yield at Mettur reservoir (CFFC)			508
3.	Yield generated in Tamil Nadu area above Mettur reservoir			25
4.	(a) Yield available below Mettur (740 - 508)			232
	(b) Deducting following uses			
	(i)	Allocation to Kerala in Bhavani sub basin	6	20
	(ii)	(Amaravathy) Pambar sub basin	3	
	(iii)	Allocation to UT of Puducherry	7	
	(iv)	Inevitable escapages into sea	4	
			20	
	(c) Balance available for use in Tamil Nadu (232-20)			212
5.	Total water available for use in Tamil Nadu (212 + 25)			237
6.	Allocated share of Tamil Nadu			419
7.	Balance to be made available at the Interstate contact point (419 - 237)			182
8.	Allocation for environmental protection to be made available at that point			10
9.	Total delivery to be made at the Interstate border (182 + 10)			192

As per this procedure, the quantum of flows that would be available at Mettur would work out as 217 TMC (i.e. 192 at Billigundulu + 25 between Billigundulu and Mettur) annually exclusively for Tamil Nadu, as against 205 TMC given in the Interim Order which includes 6 TMC for Puducherry. Out of the yield of 232 TMC below Mettur, Kerala has been allocated 9 TMC (6 TMC in Bhavani and 3 TMC in Amaravathi) and Union Territory of Puducherry 7 TMC. Also 4 TMC has been provided for "inevitable escapages". Thus a quantity of 20 TMC has to be deducted from the yield below Mettur. The quantity available to Tamil Nadu below Mettur will then be (232-20)= 212 TMC.

The total flow available to Tamil Nadu as per the Final decision of the Tribunal will be 429 TMC which of course includes 10 TMC allotted for environmental purposes. (419 + 10 TMC).

The CWDT in its final order has retained the cropping pattern in the Cauvery Delta Zone ie. the Cauvery Delta System the Lower Coleroon Anicut System and the Cauvery Mettur Project. In respect of other systems above grand anicut the existing 2nd crop paddy has been replaced by semidry crops. The Irrigation season in general has been restricted to June to January. The crops grown beyond 31st January will have to be sustained with Ground Water.

The Cauvery Water Disputes Tribunal (CWDT) forwarded its final order to the central government for further necessary action.

And Whereas, the Supreme Court has given its direction on 4th February 2013 which reads as under:

> "Section 6 of the Inter State River Water Disputes Act, 1956 mandates the Central Government to publish the decision of the Tribunal in the Official Gazette. Although no time frame is provided for publication of such decision by the Tribunal, but in absence thereof, publication has to be done within reasonable time.
>
> Since more than five years have already elapsed, we direct the Central Government to publish in Official Gazette the final decision given by Cauvery Water Disputes Tribunal dated the 5th February 2007 as early as may be possible and in no case later than the 20th February 2013. Needless to say that publication of the final decision of CWDT in Official Gazette shall be without prejudice to the pending proceedings."

Now, therefore, in exercise of the powers conferred by section 6 of the said Act, the Central Government published the Order of the Tribunal in the Gazette of India No. 373 / New Delhi, Tuesday, February 19, 2013 / Magha 30, 1934.

13. Canal System

13.1 Climate Resilient Adaptations in the Vennar System

13.1.1 Description of the Vennar Irrigation and Drainage System

The layout of the main channels and drains of the Vennar system is shown schematically in Figure 13.1. Ten main river channels convey both irrigation and drainage water and 10 other rivers are primarily drainage channels (for example, the Valavanar and Nallar Drains).

The main channels of the Vennar System are old river channels that have been modified and adapted over centuries to carry irrigation, drainage and flood flows. The physical characteristics of the channels are very variable. Some reaches have a uniform cross section and a straight alignment while the cross section of other reaches varies within a short distance and the alignment is winding. Some reaches are overgrown with vegetation while other reaches are quite open. Many reaches are not accessible by road on either bank.

Irrigation flows into the system come from releases from the Mettur Dam via the Grand Anicut. Irrigation water is provided for varying periods each year as shown in Table 13-1. Releases are based on the availability of water in the reservoir at Mettur Dam, rainfall in the system and the demands of farmers. Typical flows in the main channels during the irrigation season are shown in Figure 13.2. Flows are adjusted throughout each period, resulting in very variable inflows to the Vennar system at the VVR head regulator, as shown in Figure 13.3.The changes in flow seems to be in response to the rainfall that is also shown in Figure 13.3. Balancing the rainfall and irrigation requirements is certainly a major challenge for WRD.

Water levels and flows in the main channels are managed by adjustable head regulators (HER) and cross regulators (CRR) plus fixed weirs (bed dams (BED or grade walls (GRW)). In addition, at the lower end of the channels, adjustable tail end regulators (TER) manage drainage flows and prevent the backflow of seawater. Discharges are calculated from the orifice equation using measured upstream water level, areas of gate openings and number of gates open. For normal conditions, there is usually free (modular) flow through the gates and use of the orifice equation is appropriate, but for higher flood flows the gates may become submerged from downstream (non-modular flow) and the use of the orifice equation may overestimate flows. Water levels are not measured along the river channels or in the Vedharanyam Canal or in the straight cuts.

Irrigation water is distributed from the main channels to fields through irrigation head sluices (IHS) located on the banks of the main channels. Irrigation head sluices have one or more vertical moveable gates and are optimally located close to cross regulating structures although many are remote and subject to variable channel water levels. Downstream of irrigation head sluices, water is distributed through a network of smaller canals and field channels distributing water to fields.

Drainage is provided by a network of field and collector drains connected to the main channels. Flows from some drains to the main channels are managed by drainage infall sluices (DIS) but many drains have open infalls with no structures.

Figure 13.1: Schematic Layout of Vennar System

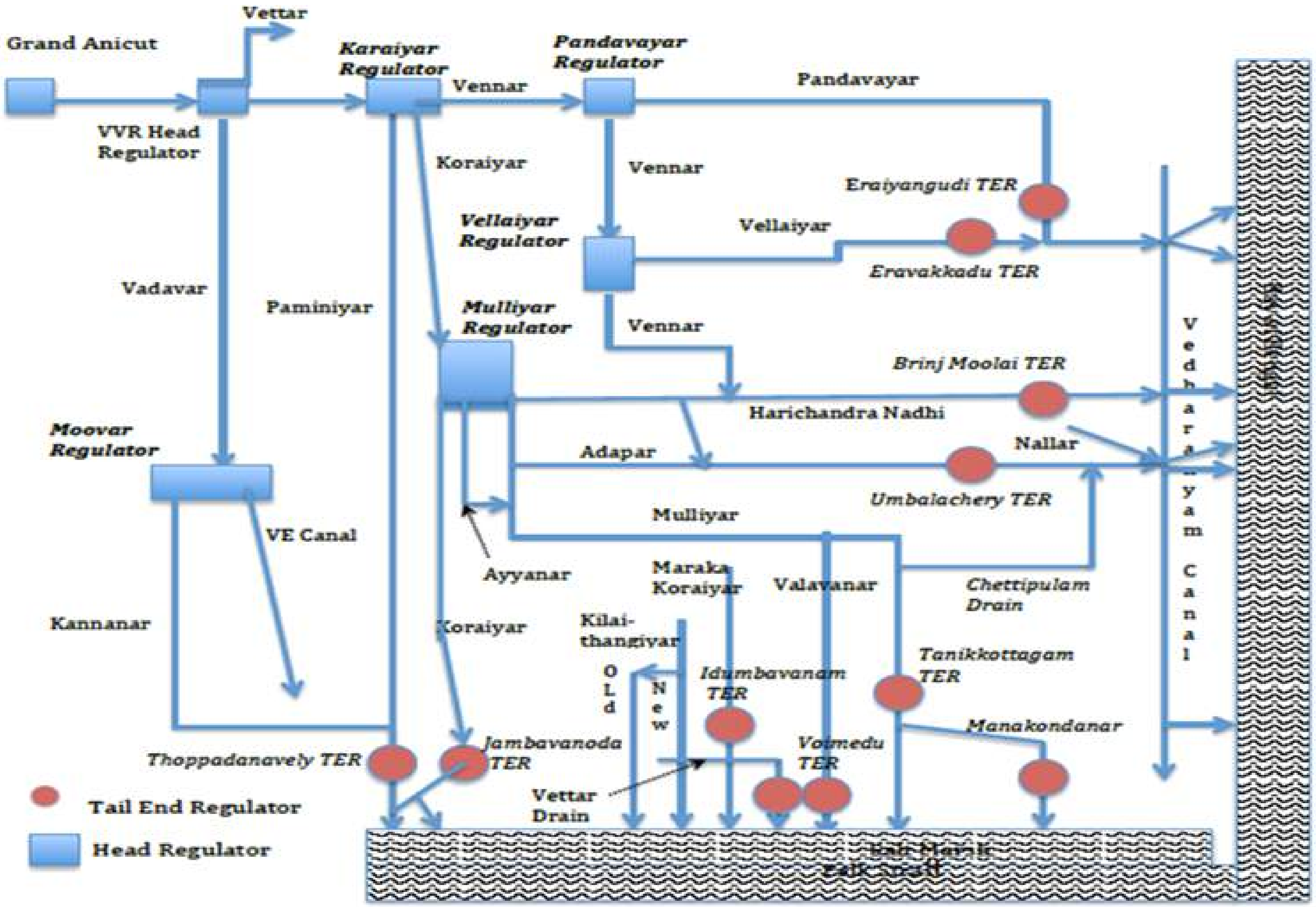


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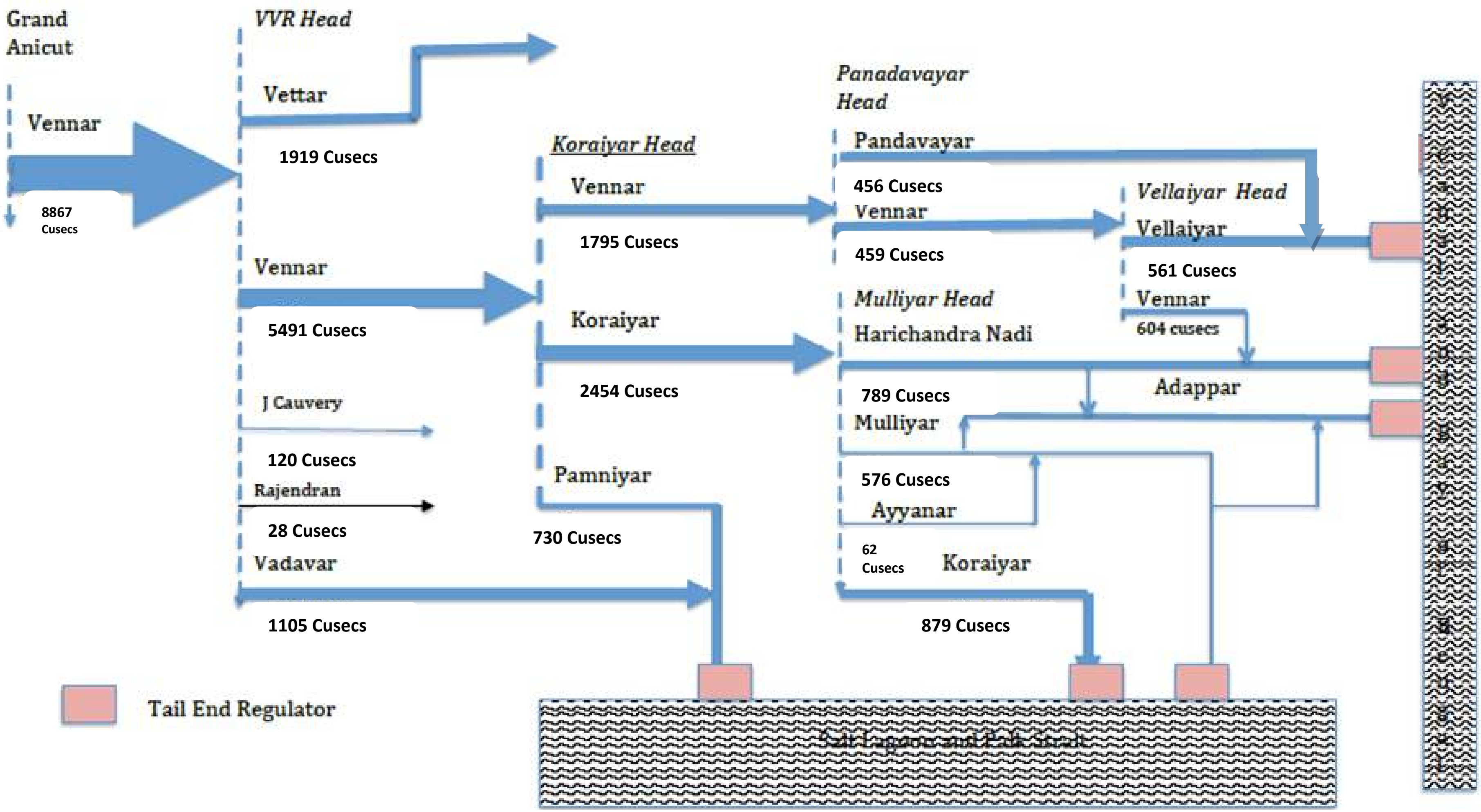
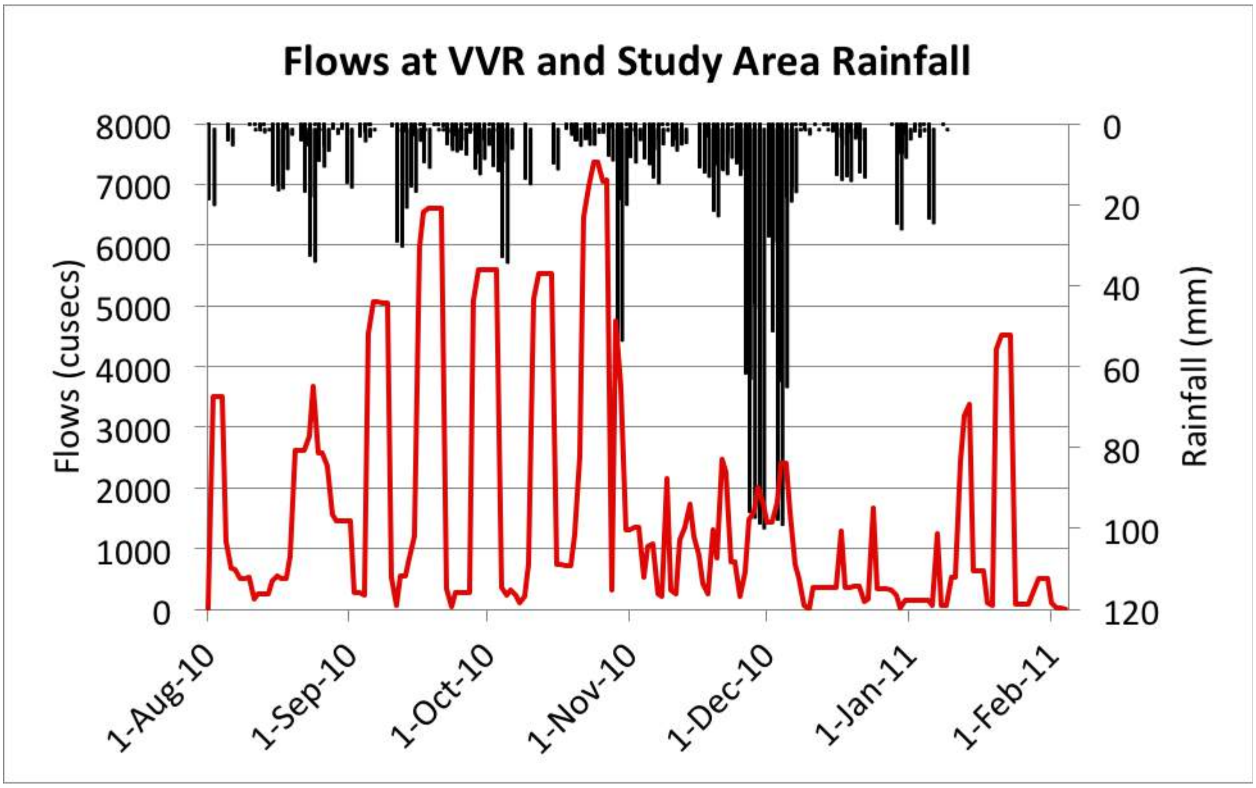
Figure 13.2 : Typical Irrigation Flows through Main Channels



Source: Mott MacDonald

Figure 13.3 : Flows at the VVR head regulator between August 2010 and February 2011



Source: Mott MacDonald

Table 13-1: Irrigation Water Delivery Periods

Start of Deliveries	End of Deliveries
31 July 2005	1 Feb 2006
16 June 2006	13 February 2007
21 July 2007	17 January 2008
16 June 2008	5 February 2009
1 August 2009	4 February 2010
1 August 2010	4 February 2011
10 June 2011	15 February 2012

Source PWD (2013)

Flows are apportioned to different channels in the Vennar system at five head regulators (VVR, Koraiyar, Pandavayar, Vellaiyar, Mulliyar - see Figure 13.1). The division of flows is meant to follow a specified percentage allocation to each channel but in practice there is some deviation. Flows out of the Vennar system are managed by 11 tail end regulators at the lower end of the channels. Several drains, such as the Old and New Kilaidhangiyar drains, have no TER and some TERs, such as Umbalachery on the Adappar, Brinj Moolai on the Harichandra and Thanikkottagam on the Mulliyar, are up to 10 km upstream of the end of the channel. TERs are kept closed to back up water for irrigation head sluices immediately upstream, except during the flood season (October to December) when TERs are opened to allow floodwater to discharge to the sea.

13.1.2 Floods

During floods on the Cauvery River, floodwaters are diverted at the Grand Anicut into the Coleroon River via the Ullar River and no flood flows are released into the Vennar System. Hence, any flooding in the Vennar system originates from rain falling within the system downstream of the Grand Anicut. A rare exception to this rule was in 2005, when the Cauvery River reportedly breached its banks upstream of the Grand Anicut and flood water by-passed to the south of the Grand Anicut, before flowing into the Vennar River between the Grand Anicut and the VVR Head Regulator.

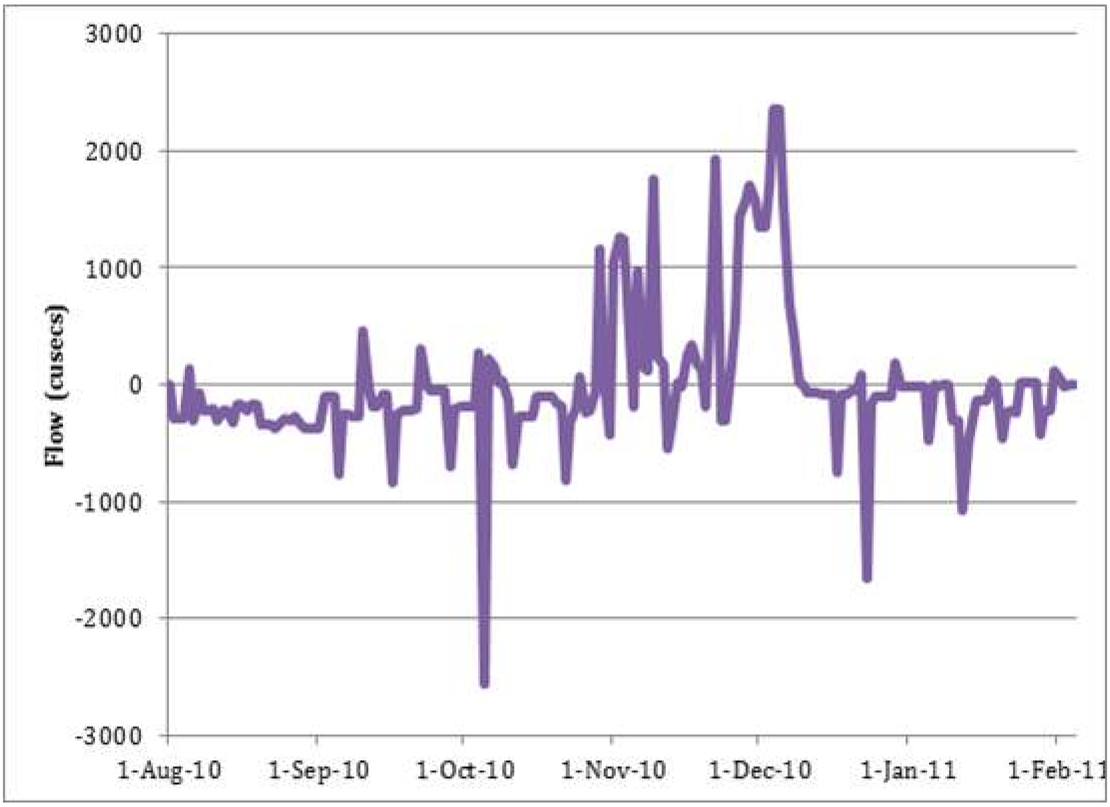
Although there are no planned flood releases into the Vennar at the Grand Anicut, there can be significant flood flows in the Vennar at the VVR Head Regulator due to storm drainage from five drains that outfall into the Vennar River between Grand Anicut and the VVR Head Regulator. For example, on 28 November 2008, the flow in the Vennar at the Katchamangalam check dam (chainage 11 km downstream of the Grand Anicut) was 14.2 m^3/s (500 cusecs) but the flow increased to 841.7 m^3/s (29,724 cusecs) at the VVR head regulator (Chainage 55km downstream of the Grand Anicut). The five drains serve the area to the south of the Vennar River and the Grand Anicut canal and to the west of Thanjavur city. They cross the Grand Anicut canal through syphons. They are unregulated and flows are not measured.

The contribution of flows from the five drains can be significant, as shown in Figure 13.4. Flows between 1 August and late October 2010 were greater at Katchamangalam Anicut than at VVR indicating seepage losses along the channel. However from late October through mid-December during the NE monsoon, flows were consistently higher at VVR than at Katchamangalam indicating an inflow of drainage water along the reach. From mid-December onwards, flows at Katchamangalam were again higher than flows at VVR, although less was lost to seepage, due in part probably to the catchment being saturated.

Flood flows originating upstream of the VVR are managed by diverting them at the VVR head regulator into the Vennar and Vettar channels as shown in Figure 13.2. Flow in the Vennar is then divided at the Koraiyar Head between the Vennar and Koraiyar channels. Downstream of the Koraiyar Head, flow in the Vennar is further divided at the Pandavayar Head into the Pandavayar and Vennar channels and subsequently at the Vellaiyar Head into the Vennar and Vellaiyar channels. Flood flows in the Koraiyar channel are confined to the Koraiyar channel downstream of the Mulliyar Head with no flood flows being released to the Harichandra, Mulliyar or Ayyanar channels.

During floods, flows along most channels increase, implying that drainage water is entering the channels along their length. The exception is in the north east of the system where flows along the Pandavayar, Vellaiyar, Vennar and Harichandra channels decrease indicating that water is going into storage on their respective flood plains.

Figure 13.4: Differences in Flows Between Katchamangalam and VVR Head Regulator



Source: Source PWD (2013)

Diverting the flood flows into specific rivers, particularly the Koraiyar, compromises the design of the tail end regulators (TERs) as shown in Table 13-2. In 2008, the peak flow at the Jambavanodai TER was 11,445 cusecs, compared to the design flow of 2,523 cusecs, and caused the left bank of the structure to be seriously eroded. The TER structure was subsequently extended by construction of a fixed weir on its left bank. In the 2008 flood, flows calculated at regulators upstream of the TERs draining into the Vedharanyam canal were greater than flows calculated through the TERs. This implies that the TERs were drowned and that the calculation of flow using the orifice equation was not applicable under those circumstances. Measurements are only made of water levels upstream of the TER. During field visits, discussions with local people found that during floods, water levels either side of TERs were usually similar, indicating that there were no significant head losses through the TERs and that the capacities of the TER was not the main constraint on outflows.

Table 13-2: Design and Maximum Flows at TERs

Channel	TER	Design (cusecs)	Maximum Flows (cusecs)				
a) Main irrigation-cum-drainage channels							
		2005	**2008**	**2009**	**2010**	**2011**	**2012**
Paminyar/Kannanar	Thoppadanaveli	7348	12000	6110	9387	8862	5885
Koraiyar	Jambavanodai	2523	11445	4447	10931	8169	2355
Mulliyar	Thanikkottagam	1253	475	390	950	632	680
Adappar	Umabalachery	905	942	762	914	822	822
Harichandra	Brinj Moolai	2097	2178	1487	3305	1622	1904
Vellaiyar	Eravakkadu	1124	1424	694	1224	633	877
Pandavayar	Eraiyangudio	2050	2050	1505	1840	967	1641
b) Main drainage channels							
Valavanar							
Maraka Koraiyar		2035	4675	3252	3108	8012	1884
Manankondanar			No Data				
Kilaidhangiyar (Old)	No TER						
Kilaidhangiyar (New)	No TER						

Flows occur through TERs for only a limited number of days each year as shown in Table 13-3. For example, the number of days flow was recorded at Idumbavanam TER ranged from 9 days in 2012 to 55 days in 2009. Interestingly, during the peak flood year of 2008, the Idumbavanam TER was open for only 36 days which was less than during the following three years, presumably because of more but less intense rainfall and runoff in those years than in 2008. This pattern of opening was similar to most other TERs. The TERs are closed for the rest of the year to back up water for irrigation head sluices upstream and to prevent saltwater intrusion.

Table 13-3: Number of Days Flow Recorded at TERs

Date	Eraiyangudio (Pandavayar)	Eravankkadu (Vellaiyar)	Idumbavanam (Maraka Koraiyar)	Thanikkottagam (Mulliyar)	Umabalachery (Adappar)	Brinj Moolai (Harichandra)	Jambuvanodai (Koraiyar)	Thoppathanaveli (Paminyar)
Oct 08 - Dec 08	25	24	36	33	35	31	36	32
Oct 09 - Jan10	24	30	55	42	49	49	52	53
Oct 10 - Dec10	24	22	49	34	35	43	40	27
Oct 11 - Dec 11	13	16	39	15	37	19	23	23
Oct 12 - Dec 12	13	8	9	10	10	10	8	7

Figure 13.5 : Flood Flows through the Main Channels on 28th November 2008

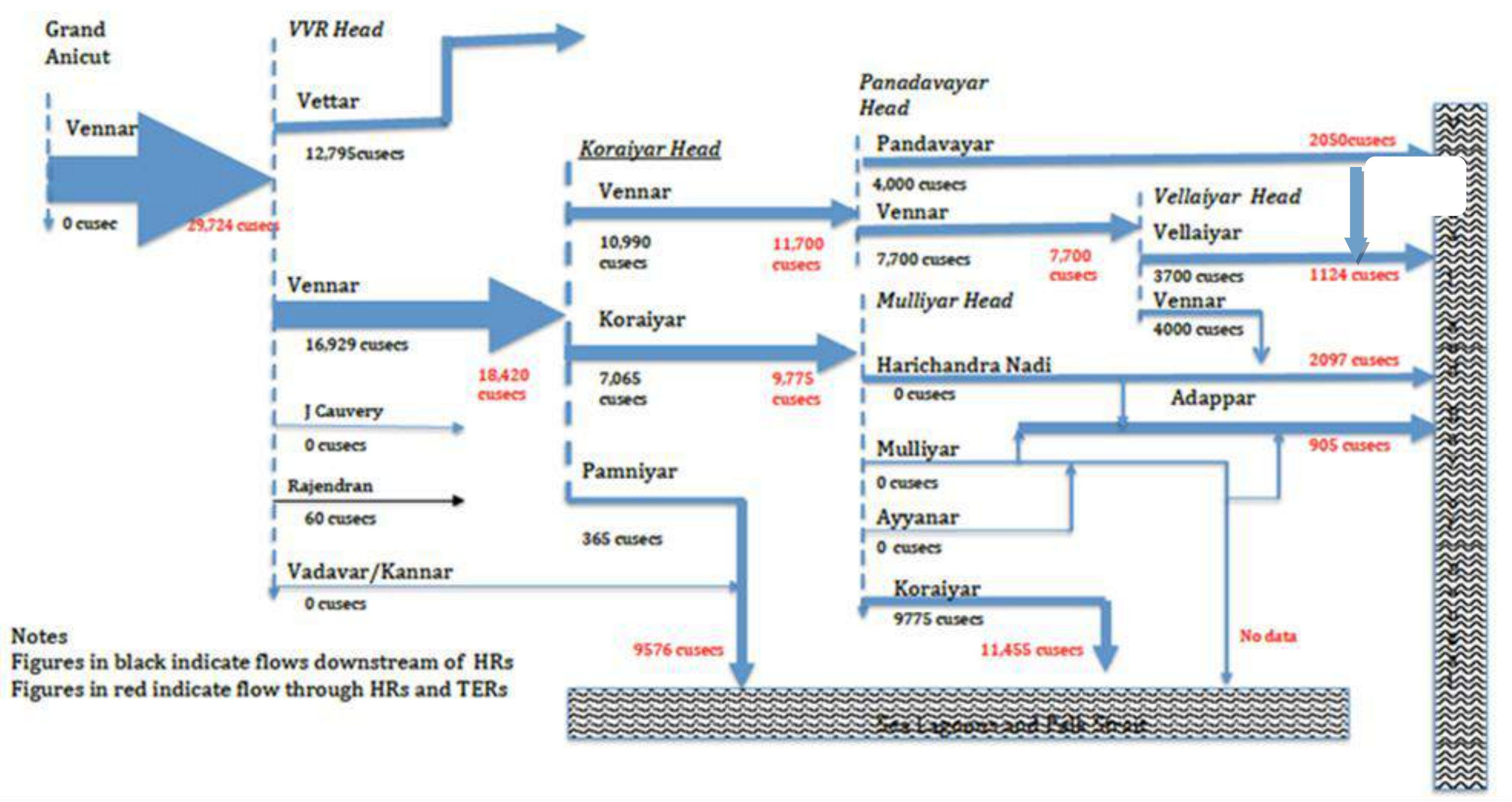
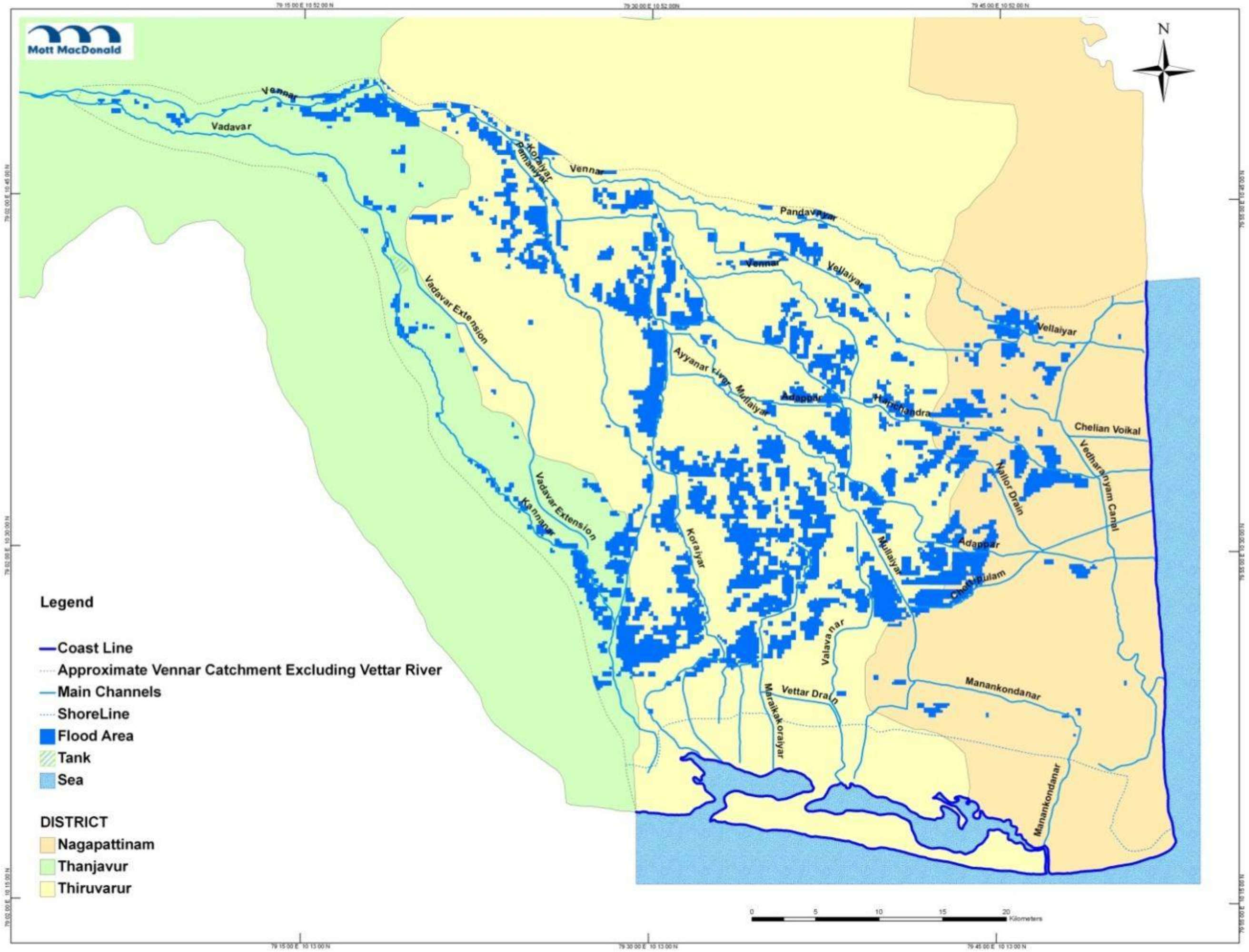


Figure 13.6 :   Flood Affected Areas 29 November 2008



Source: NRSC

The flood-affected areas in the Vennar system on 29 November 2008 are shown in Figure 13.6. The map is based on an analysis of Radarsat-2 SAR data by the NRSC. It shows that flooding was concentrated in the central and southern areas of the system. Reportedly, on this date, there was also extensive flooding along the Vedharanyam Canal, the Manankondanar Drain and the Valavanar Drain but this is not shown on the map. Figure 13.6 most likely indicates low lying areas where local runoff collected and excludes flooding that was considered to be tidal. It is evident from this map that while small areas of flooding are distributed across the study area there is a clustering of flooded areas along the rivers and that the extent of these flooded areas increases towards the coast. The extent of flooding can be better defined if an accurate DEM of the project area is made available.

Flooding problems in the Vennar system are compounded by drainage congestion caused by water levels in the main channels being higher than the level of adjacent land for extended periods, thereby preventing water draining from the land and collector drains into the main channels. In addition, there is overtopping of embankments on some channels and backflow from channels onto adjacent land through un-regulated drainage outfalls. However the extent of flood flows into and out of the channels is not recorded unfortunately.

Discharges in the rivers are calculated at the head and tail-end regulators from the orifice equation using measured upstream water level, area of gate openings and number of gates open. There are no water levels measured at intermediate locations along the channels or in the Vedharanyam Canal or in the straight cuts. Hence it is difficult to determine precisely the flooding sequence.

Even during minor floods, water levels in the main channels are reportedly higher than adjacent land, and the problem becomes much worse during major floods. For example, the design flow at Jambavanodai TER on the Koraiyar Channel is 2523 cusecs. In 2008, the flow at the TER exceeded the design flow for nine days (25 November until 5 December), while in 2005 the flow at the TER exceeded the design flow for four days (27 to 30 November). The main channels do not have sufficient capacity to carry flood flows and allow land to drain sufficiently quickly to avoid crop loss.

13.1.3 Coastal Zones

13.1.3.1 Coastal Processes

The Cauvery Delta is a typical river delta, the land being originally formed from sediment deposited by river channels with contributions from marine sources. The coastal tip at Point Calimere exhibits ridge formations typical of coastal spit and cuspate shoreline development (Komar, 1998) indicating the historic growth of the southern area is likely to have progressed in a north to south direction; first forming a spit and then infilling behind as a result of deposition of fluvial and marine sediments. This area is also undergoing post-glacial isostatic uplift (UNESCO-IHE, 2013) which may have assisted in the historic ridge formations, and contributed to the shallowing of the Muthupet Lagoon (ICMAM, 2005). During the 20th century the shoreline along and adjacent to the Cauvery Delta has remained relatively stable.

A detailed study of coastal erosion for the entire Tamil Nadu Coast has been prepared (NCSCM, 2011). The study utilised mapping from 1972 and satellite imagery from 1991-2010 to assess the shoreline position and determine the extent of erosion or accretion. For the eastern coastal areas immediately south of Nagapattinam, the study found that the shoreline demonstrated low erosion. Continuing further southwards to around Thiruppoondi-East the shoreline was increasingly stable, while towards Point Calimere the study shows accretion. Rounding Point Calimere on to the southern coast along the Palk Straight the eastern portion of the coast is less stable and shows generally low erosion, further west the shoreline become stable and is accreting. A study by the Institute of Hydraulics and Hydrology (IHH, 2012) supported the findings of the NCSCM study.

Outfalls from the drainage channels are at sea level or below. There are two distinct coastal zones:

(i) The Eastern Coast along the Bay of Bengal from Point Calimere to Nagapattinam

The eastern coastline along the Bay of Bengal generally comprises sandy beaches backed by forest, agricultural land and urbanised areas. Sediment transport along the east coast is highly variable. Many literature references describe the sediment transport as being from the south towards the north. North of Nagapattinam this appears to be the case but analysis of satellite imagery of the coast south of Nagapattinam shows that the sediment transport along the east coast is from north Along the east coast, approximately 4km landwards from the shoreline runs a channel known as the Vedharanyam Canal. The canal was constructed to provide navigation for the transport of salt from Vedharanyam to Nagapattinam. It was formed by utilising existing river channels and lagoons within the delta, connecting them with sections of formal canal (Imperial Gazetteer of India, 1909). The canal originally had two sea connections; to the south near Vedharanyam and to the north near Nagapattinam.

The canal also receives flows from inland from the Vennar system through a complex system of channels. Discharge from the main rivers is controlled through the use of tail-end regulators which maintain water levels upstream and prevent salt water intrusion from the Vedharanyam Canal and from drainage outfalls from coastal irrigation command areas. During the 1960's to mid-1970's additional connections to the sea were cut from the Vedharanyam Canal directly to the Bay of Bengal in an attempt to accelerate the drainage of the canal during floods. A total of 6 straight cuts were formed along the coast.

An assessment was made of the straight cuts and natural outlets to the east coast south of Nagapattinam which found that:

- There is a high rate of sediment transport from north to south;
- Many of the outlets have become restricted or closed completely at their coastal extent;
- In general the narrower straight cuts (<30m wide inland) are closed or heavily restricted, showing that narrower outfalls are more susceptible to sediment transport than wider outfalls;
- The Vennar system generally drains adequately in spite of the restricted and closed straight cuts, except during heavy rainfalls in the system when the Vedharanyam Canal and straights cuts fail to discharge the floodwaters rapidly enough to prevent flooding.

Typically, tail-end regulators are fully closed in order to retain as much water as possible for irrigation because of the variability of rainfall. While the tail-end regulators are closed the irrigation and drainage system is isolated from the Vedharanyam Canal and the coastal outlets only deal with the tidal water exchange in to the canal. The tidal range is relatively small (typically about 0.6 m) along the coast. The canal and outlets have become silted over time resulting in relatively low flow through the outlets. The low volume of water passing through the coastal outlets allows sediment to settle and thus the outlets become restricted and then closed which constrains flows out of the Vedharanyam Canal.

When the TERs are shut the canal can cope with this constrained inflow and outflow of tidal water, but when the TERs are open, due to severe rainfall and runoff in the Vennar system, the restricted coastal outlets can cause backwater effects within the entire Vedharanyam Canal and adjacent parts of the Vennar system. The backwater effects are relative to the amount of rainfall and therefore more severe storms lead to increased backwater effect which leads to flooding of agricultural land as the system cannot drain.

The impact of flood flows on the coastal outlets is not currently understood in detail as there is no available data to assess the state and condition of the outlets pre- and post-storm flows. It is likely that the increased water volumes passing through the outlets would, to some extent, help to scour and reduce the restrictions in the outlets. However, the low frequency of these events means that sediment accumulation processes prevails, particularly on the narrower straight cuts.

Future sea level rise will potentially increase the rate of erosion along the shoreline and this will lead to increased sediment transport and may cause more rapid closure of the existing coastal outlets. Conversely the increase in sea level may increase the tidal flows into and out of the coastal outlets allowing them to naturally scour and maintain their depth, although the spits at the mouths of the outlets are still likely to migrate southwards. However if future sea level rise rates are similar to the low rates experienced historically along this coastline, then they are unlikely to significantly affect the overall coastal processes, with the exception of worsening the frequency of inundation.

In summary, in years without fluvial floods the sediment process dominates the hydraulics of the coastal zone causing restriction of the coastal outlets along the east coast. This causes a reduction in the drainage capacity that is required during periods of heavy rainfall. The consequences are flooding both along the Vedharanyam Canal and further upstream within the Vennar irrigation and drainage system. The impact of sea level rise is uncertain at present given the sparse available data. Further numerical modelling, to be undertaken during CASDP, will assist in informing further studies.

(ii) The Southern Coast from Point Calimere to Adhirampattinam along the Palk Strait

Along the south coast, from Point Calimere to Adhirampattinam, water from the Vennar System runs into the Kodiakkadu and Muthapet lagoons and intertidal sand/mud flat areas, known as the Great Vedharanyam Swamp (ICMAM, 2005), which subsequently discharge to the Palk Strait.

The eastern Kodiakkadu lagoon area consists mainly of sand and mud flats with a central lagoon which discharges along the southern coast. In the north and northeast of the lagoon a significant area is utilised for salt-pans, an important industry to the local economy. Within the lagoon there are significant areas that are cut with fishbone channels for mangrove replanting.

Discharges from the Vennar System occur at the northwest corner of the lagoon and there is evidence of straight cut channels through the sand and mud flats as well as naturally formed channels. The southern reach of the Vedharanyam canal is heavily silted and presently does not discharge into the northeast corner of this lagoon. There is a stark contrast between this north-east corner of the Kodiakkadu lagoon where there is little or no vegetation and the western Muthapet lagoon where mangrove is found. This may be as a result of hyper-saline conditions within the Kodiakkadu lagoon area (as suggested within the Muthupet Lagoon ICMAM 2005) caused by reduced inflows of fresh water as irrigation was extended in the Vennar system. This probably also explains the productivity of the salt pans.

The western Muthupet Lagoon is formed of wetland, tidal creeks and channels which are bordered by mangroves. The lagoon and its channels contain mainly saline and brackish waters. Freshwater discharges from the Vennar System enter the northern boundary of the lagoon through at least four channels, and discharge from the lagoon to the sea passes through a single opening of width greater than 1km.

Records show that in 1740 the area was covered with mangrove. Since then significant areas were felled for timber until the forests were taken over by the Tamil Nadu Forest Department. The remaining mangroves (dominated by Avicennia Marina) are typically classified as degraded with only 15% being classed as healthy. Degradation of the mangrove is due to the hyper saline conditions within the lagoon which is compounded by the reduction in discharge of freshwater due to the retention of waters within the Vennar System (ICMAM, 2005). There are currently significant areas of fishbone channels for the reinstatement of the mangrove forest.

13.1.4 Impact of Climate Change

Based on an analysis of the most relevant recent studies of climate change, inflows to the Vennar system from the Cauvery River at Grand Anicut are not expected to show significant change. Inflows generated within the Vennar System, however, are expected to change as a result of climate changes to the following variables:

Rainfall: Based on an analysis of rainfall events using different models, an increase of 20% in the volume of storm rainfall is projected. This is in accordance with changes adopted for many climate change impact studies worldwide. It is likely the future 5-year 24-hour rainfall will be approximately 442mm, virtually identical to the current 10-year 24-hour rainfall. The future 10-year and 20-year events will probably be slightly higher than the current 20-year and 50-year events.

Temperature: Analysis of four climate change scenarios carried out during the CASDP PPTA shows broad consistency (Srinivasan, 2013). An average increase of 1.5ºC over 50 years is projected. This represents around 0.03ºC per year, compared with the observed change of 0.02ºC per year. A slight acceleration of temperature increase is in keeping with general temperature projections.

Other Climate Data: Climate change may impact on other climate variables used in the modelling (wind speed, relative humidity and solar radiation) for assessing evapotranspiration. However, these generally have much less impact on evapotranspiration than temperature, and for modelling purposes they have been assumed to be unchanged. In addition, whilst there is consistency in projections of temperature changes, not much has been published regarding changes in the other variables.

Sea Level Rise: The rate of sea level rise is taken as 1mm/year. This rate is close to the rate determined for a high climate change scenario from analysis and projection of the historic tide data at Chennai carried out as part of the CASDP PPTA (Dastgheib and Ranasinghe, 2013). This rate has been adopted to take account of the accuracy of the numerical modelling and to provide a conservative approach to the assessment of sea level rise. Assuming a baseline year of 1990 the total sea level rise is projected to be 60mm by

2050. Many of the other studies on the impact of sea level rise along the Tamil Nadu Coast have adopted global averages of mean sea level rise in the range of 600 to 2000 mm by 2100 rather than the local datasets used by Dastgheib and Ranasinghe.

Storm Surges: ADB commissioned a study of storm surges for the Cauvery Delta coastline. Due to issues with procurement of tidal data, the study was delayed and completed in May 2014 (Dastgheib and Ranasinghe, 2014), too late to be included in this analysis.

The implications of sea level rise on coasts in general have been well studied and on relatively flat coastal plains the physical impacts can be summarised as (UNEP, 2010):

- Sea level rise will cause permanent submergence of low-lying areas;
- Sea level rise will increase the probability and depths of flooding; this may be compounded by other changes due to climate change such as increased storminess;
- Sea level rise will contribute to increased shoreline erosion rates
- 'Coastal Squeeze' will increase, caused by hard defences preventing movement of the shoreline

Although these factors will influence the coastal environment of the Cauvery Delta, in relative terms the amount of sea level rise expected there is significantly lower than the global average (Dastgheib and Ranasinghe, 2013).

Along the Cauvery Delta coast small increases in mean sea level in the order of 60mm by 2050 would have a minor impact on the amount of inundation caused during storms, and this would mean that the coastal settlements along the coast would be at marginally increased risk. In general for small rises in sea level it is anticipated that the natural processes will adapt over time, provided that the rise does not cause any critical limit to be exceeded, e.g. water levels beginning to regularly exceed the top of a beach crest.

13.1.5 Proposed Measures to Improve the Performance of the Six Rivers in this Project

To improve the performance of the six Project-1 rivers, the feasibility of the following measures was assessed:

Mitigation of Floods: The current drainage capacity of the six rivers of this project is unable to cope with the floods resulting from present climatic conditions. Man-made interventions and natural processes combine to impede drainage and aggravate flooding, particularly on low-lying agricultural land. Climate change will increase rainfall intensity and the frequency of intense storms and there will be small increases in sea level. Improving drainage to mitigate flooding and adapt to climate change focuses on one or more of the following:

- Management of flood flows in drains entering the Vennar River between the Grand Anicut and the VVR head regulator.
- Improving the conveyance efficiency of channels in the Vennar system.
- Improving performance of tail end regulators
- Increase discharge of flood flows to the sea.

Provision of storage or additional flood channels or easements to reduce flood peaks and flood duration was assessed but due to intensive land use within the Vennar System combined with the problems of acquiring land, the scope for these was found to be very limited and hence they were not considered further.

Rehabilitation of Pumped Irrigation Schemes: There are 13 government lift pump irrigation schemes located on the six Project-1 rivers. The electrical and mechanical equipment has not been replaced since the schemes were constructed in the 1960's. The performance of these schemes can be greatly improved by replacing the equipment with more efficient equipment that uses less energy.

Improving Irrigation Management: The delivery of irrigation flows to farmers is becoming more erratic and unreliable because the ageing structures and poor condition of the main rivers impede the efficient management of irrigation flows. Many irrigation management structures have deteriorated to an extent that they are no longer effective and are well past their useful life. Leakage through structures is significant. The approach was to assess the condition of existing structures and the need for reconstruction or repair and identify the need for additional structures required for more efficient flow management.

Updating River Management Systems: The present management process for floods and water distribution for irrigation is not entirely satisfactory. It does not utilise modern technologies to ensure efficiency and transparency. The management needs to become more systematic, efficient and based on scientific information to inform decision making, with specific targets that are explicit in terms of cost, water and other resources to meet environmental requirements.

13.2 Design

13.2.1 Design Process

The design process done by the PPTA consultants, Mott Mac Donald, is shown in Figure 13.7. The design process comprised of collecting information and data (topographic survey, weather data, asset survey), analysis of data and system performance (running the SWAT, HEC-RAS and Telemac2D models with existing conditions), initial design of measures, re-assessment of system performance (re-running the models with design conditions), and finalising designs based on model results and field assessment of the proposed designs.

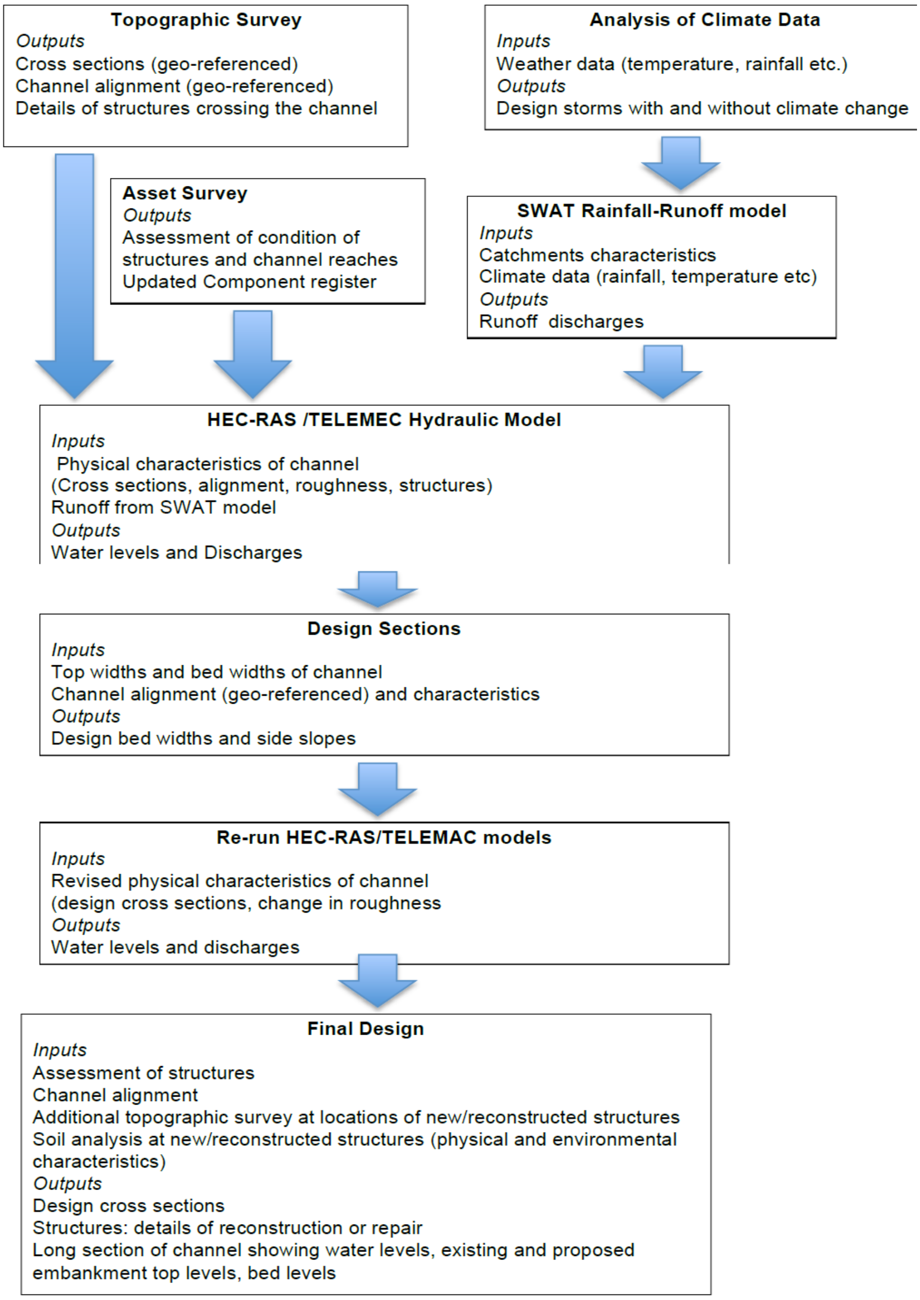
13.2.2 Design Criteria

Design guidelines for CASDP were based on the Bureau of Indian Standards (BIS) guidelines for planning, design, construction and operation and maintenance of various earthworks and structures (Mott MacDonald, 2014), and also on the guidelines and manuals of the Central Water Commission (CWC) and the instructions, in the form of notifications / technical circulars, prepared by the Tamil Nadu Engineers Association (TNEA, 2013), and issued by the Tamil Nadu State Government (Public Works Department) and its senior engineers (Chief Engineers/Superintending Engineers).The main criteria adopted for the design of the Project works are given in Table 13-4.

Table 13.4 : Main Design Criteria for the Project Works

Design Parameter	Criteria
Earthworks	
▪ Freeboard	1.00 m
▪ Side Slopes	1.5H to 1V
▪ Embankment Top Width (Tw)	5 m
Channels	
▪ Design Flow	Q25
▪ Structures-Design Flow	Q50
▪ Field Drainage-Design Flow	Q10

Figure 13.7 : Design Process

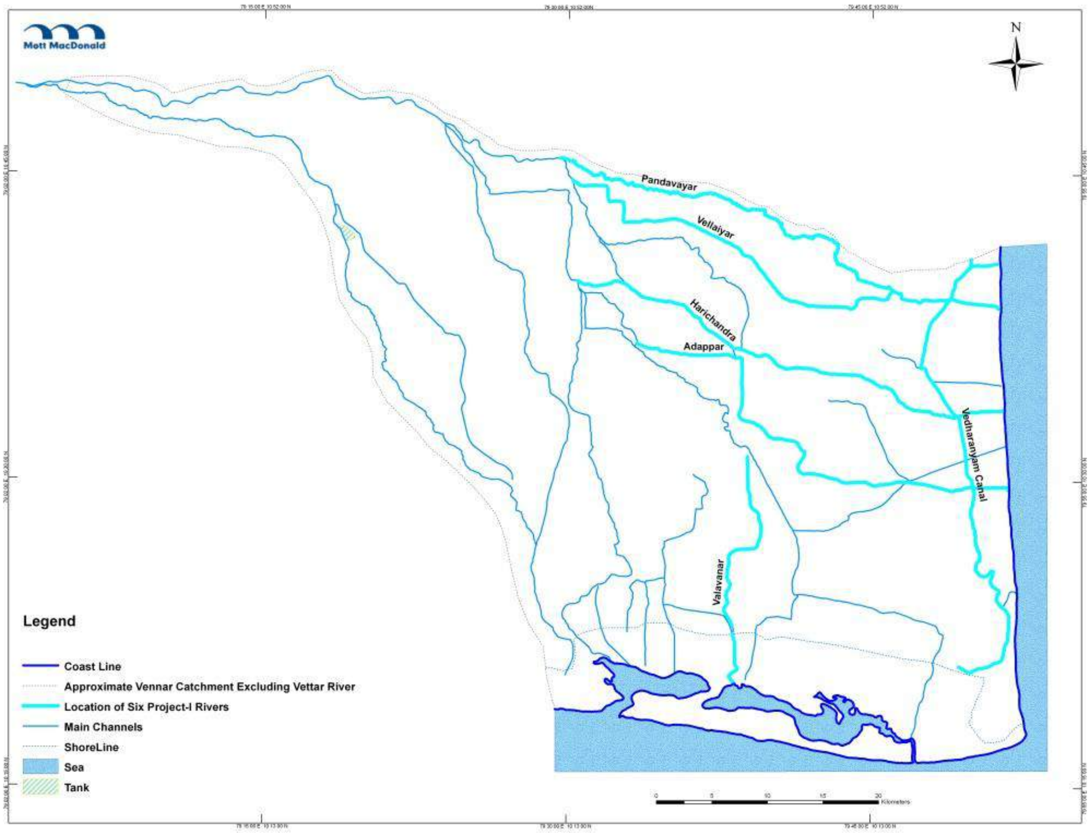


13.2.3 Topographic Survey

Due to the shortage of accurate and up-to-date information on the river channels, the Asian Development Bank commissioned Prime Meridian Survey Limited (PMSL) in 2013 to survey the sections of the river channels shown in Figure 13.8 as part of the PPTA. PMSL surveyed the alignment, levels and widths of cross sections at about 250 m intervals and also the main structures across the channels. PMSL prepared reports of the surveys that include geo-referenced alignment maps of the river channels, drawings of cross sections and drawings showing the main dimensions and levels of the cross structures (PMSL, 2013).

For the river channels not covered by the PMSL survey, WRD provided cross sections at 500 m intervals. The WRD cross-sections were not geo-referenced.

Figure 13.8 Rivers, Drains and Canal included in this Project



There are discrepancies (such as the chainages along the rivers) between the PMSL survey data and the WRD historic and recent survey data. The discrepancies were resolved on a case-by-case basis to try to ensure consistency in the presentation of information. The discrepancies are discussed for each river in Section 13.3.

The only topographic maps available for the project area are the 1:50,000 Survey of India maps. The contour interval on these maps is 5 m. There is no existing high-resolution digital terrain model (DTM) for the flood plain of the six Rivers of this Project, although selected flood zones are being surveyed as part of the PPTA but the DTMs from these flood zones are not yet available.

13.2.4 Asset Survey

Component Registers listing details of structures are available for Adappar, Harichandra, Vellaiyar and Pandavayar channels. There are no component registers for the Valavanar Drain or the Vedharanyam Canal. Furthermore, there are no as-constructed drawings or design information for the existing structures or channels.

The Vellaiyar and Pandavayar registers were prepared in the 1920's while the Adappar and Harichandra registers date from the 1970's. Since the compilation of the registers, numerous structures have been added, particularly road bridges and cross regulators. Details of some of the newer structures have been hand-written into the component registers.

In the absence of up-to-date records, designs or as-constructed drawings, an asset survey was carried out by WRD and the PPTA consultants to determine the current conditions of the physical assets along the channels.

Most of the appurtenant structures are brick masonry and although some are still functioning satisfactorily, many are in poor repair with subsiding wing walls, collapsed barrels and cracked brickwork. Many gates are in poor condition and unworkable while the downstream aprons and side protection on many structures need repair or replacement.

13.2.5 Analysis of Rainfall Data and Climate Change

Information on the analysis of rainfall data and climate change predictions are given in Chapter 2.

13.2.6 SWAT Rainfall-Runoff Model

During the NE monsoon (October to December) flooding in the Vennar system is common. The flooding of 2008 is evidence of the extreme nature of the flood events and the severe impacts on the system. The flooding during this period was caused by intense and prolonged rainfall resulting in high runoff which exceeded the capacity of the drainage system. Furthermore, flooding was exacerbated by tidal effects caused by the poor state of the tail regulators and straight cuts. The 2008 flood was used as the calibration event for hydrologic and hydraulic modelling by the PPTA team.

The hydrologic model chosen was the SWAT model. The primary purpose of the SWAT rainfall-runoff model is to simulate the transition of the precipitation falling directly into the Vennar system into surface storage, evaporation, runoff, soil moisture storage and infiltration to groundwater for a range of climate change scenarios. SWAT outputs provide inputs to the hydraulic model.

The Map Windows version of SWAT (MWSWAT) was used for this feasibility study. The model setup and model runs include the following key steps:

- **Automatic Watershed Delineation (AWD) -** DEM files obtained from SRTM and ASTER satellite imagery were pre-processed in MapWindow to extract a DEM covering the Vennar System. The 'Delineate Watershed' function of MWSWAT was used to delineate 112 rainfall catchments within the Vennar system. During this stage a stream network shape file and a shape file showing existing regulators as outlet points of the sub-basins were added to the 112 catchments. The threshold (minimum) area for catchment delineation was set at 2000ha. The catchments and stream reaches are shown in Figure 13.9.

- **Create Hydrological Response Units (HRUs) -** HRUs are used in the SWAT model to represent particular combinations of land use, soil type and slope range. Land use data for the Vennar system was derived from the USGS Global Land Cover Characterization (GLCC) database which has a spatial resolution of 1 km and 24 classes of land use. Twelve types of land use/land cover categories were identified, as shown in Table 13-5. A global soil map, produced by the Food and Agriculture Organization of the United Nations (FAO, 1995) and showing almost 5000 soil types at a spatial resolution of 10 km and soil properties for two layers (0-30 cm and 30-100 cm), was used to characterise soil types. The Vennar system typically consists of Sandy Loam, Sandy Clay Loam, Clay Loam, Loam and Clay soils. Using the HRU function of MWSWAT and applying threshold values for land use, soil and slope percentages, all delineated rainfall catchments were divided into multiple HRUs. A total of 471 HRUs in 112 catchments were created.

- **MWSWAT Setup & Run -** This step consisted of:
  - Defining the climate data - rainfall, temperature, relative humidity, wind speed and solar radiation,

- Writing the input databases related to soil, land use/land cover, plant growth, urban activities etc.,
- Setup information such as simulation period, PET estimation method, channel routing method and other options for the model run.

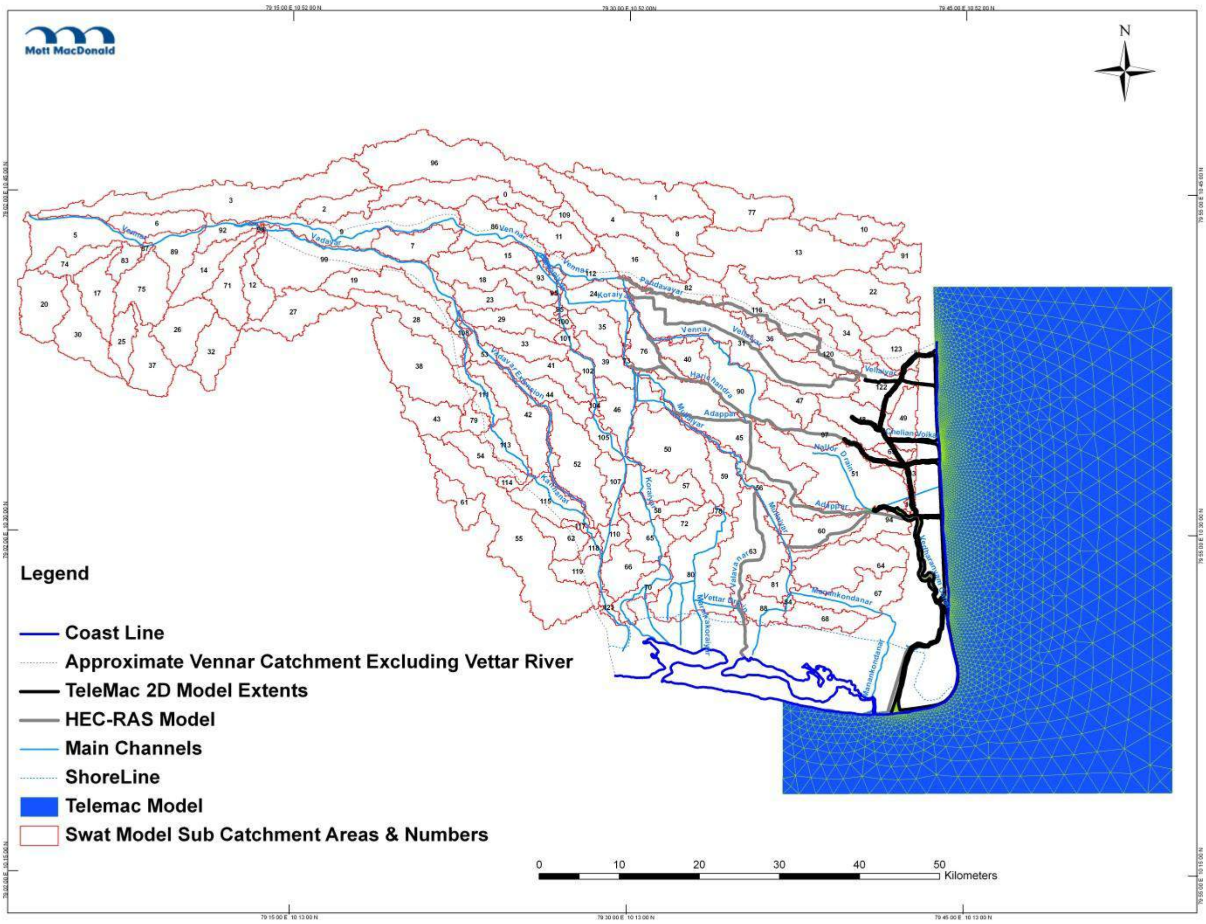
The climate data, except for rainfall, were based on the nearest of the climate stations. Rainfall data from WRD rain gauges was used because it had already been subject to considerable review and quality control. Potential evapotranspiration (PET) was calculated within the model from the four key climatic variables. Actual evapotranspiration was derived from PET, land use (crop type) and water availability.

SWAT simulation of the Vennar system was carried out for a period of 12 calendar years from 2001 to 2012. The observed rainfall event used for flood assessment is the 24th-28th November 2008 storm during which 560 mm fell. The return period of this storm is estimated to be 35 years. The storm total was factored to give 5-day storms for the 100-year event without climate change (802 mm) and with climate change (962 mm), an increase of 20%.

Table 13-5 : Predominant Land Use Categories in the Study Area

Categories of Land Use/Land Cover	
Dryland Cropland and Pasture	Savanna
Irrigated Cropland and Pasture	Deciduous broad leaf forest
Urban-medium density	Evergreen broadleaf forest
Cropland/Grassland Mosaic	Water bodies
Cropland/Wetland Mosaic	Barren or sparsely vegetated
Shrubland	Mixed Tundra

Figure 13.9 : MWSWAT Watersheds in the Vennar System



Source: Mott MacDonald

13.2.7 Hydraulic Model

There are two components to the hydraulic modelling. The river network is represented by a 1-dimensional model (HEC-RAS) while the coastal boundary is represented by a 2-dimensional model (TELEMAC2D). The TELEMAC2D model provides the downstream boundary condition for the HEC-RAS model and provides an effective means of simulating the hydrodynamics of the coastal processes, particularly the interaction with the Vedharanyam Canal with the sea.

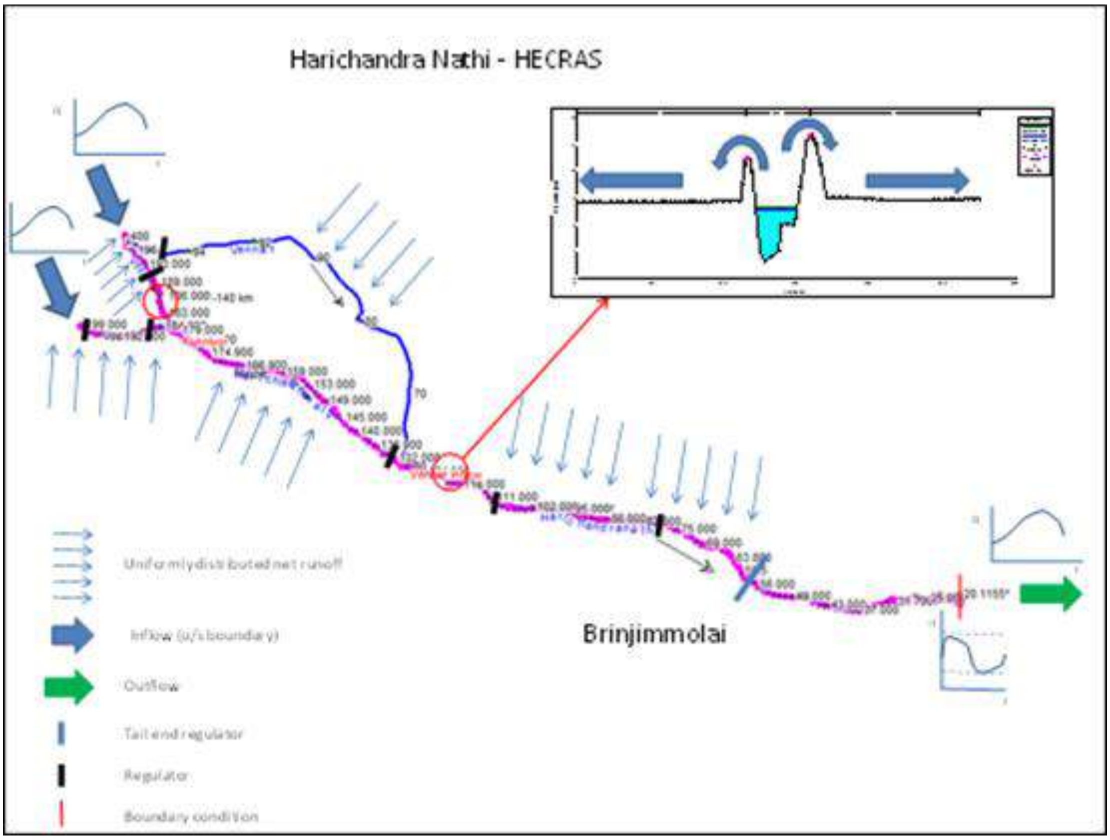
An accurate description of the river network to be modelled is the first and most important step in developing a reliable hydraulic model. In the case of the Vennar system this was a challenge due to the high density network of rivers, canals and drains, numerous inter-linkages (including bifurcations) and structures.

A preliminary network was developed and reviewed in detail with WRD before being finalized. Important linkages were included with the help of WRD as were the specific layouts at each head regulator.

The HEC-RAS model was constructed in phases to allow for controlled testing and validation. This section describes the model development for the Harichandra River. It illustrates the modelling method and the approach taken to assess options for flood mitigation. It also serves to explain how the available data impacts on the results.

A schematic of the HEC-RAS model is shown in Figure 13.. Lateral inflow hydrographs are used to represent drainage into the river. The inset illustrates a typical cross section and the use of lateral weirs to simulate out-of bank flow.

Figure 13.10: A Schematic of the HEC-RAS model for the Harichandra



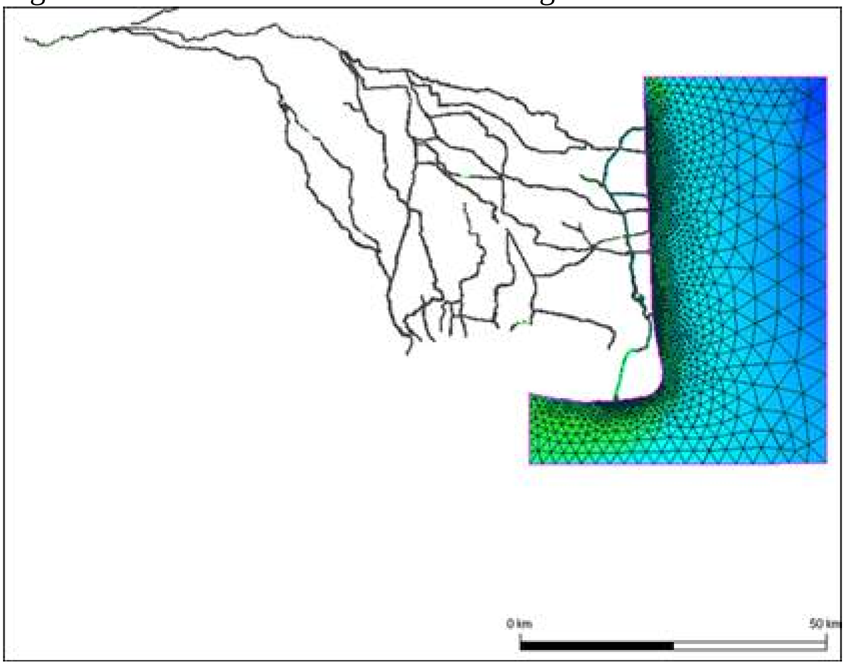
Source: Mott MacDonald

The Harichandra model has two upstream boundaries and one downstream boundary. The upstream boundaries are located at the Athiveeramanar and Harichandra head regulators. The modelled channel extends downstream beyond the Brinjimoolai TER to the sea. The downstream boundary condition is set at a mean high water spring tide (MHWS) level of 0.6m. This boundary was modified for the options assessment. In addition, the Ambodiyar head sluice is included in the model to control outflow to the Adappar. Lateral inflow hydrographs are used to represent inflows along the river with the flow distributed in accordance with command areas given in the component register.

The HEC-RAS model was tested under steady state conditions and then applied to unsteady state conditions. Currently there is insufficient topographic data available to model out-of-bank flows. Therefore where these are simulated, they are lost from the model. The 2004 NE monsoon period was selected for model validation.

The 2-dimensional mesh for the TELEMAC2D model is shown in Figure 13.11 . The density of the grid increases at the outfalls of the rivers where velocity gradients will be greatest and the terrain will be more variable. The TELEMAC2D model was used to determine flows in the Vedharanyam Canal and the straight cuts. Flows determined from the HEC-RAS models of the rivers that cross the canal were used as inputs to TELEMAC2D model along with tidal data and PMSL cross sections for the Vedharanyam Canal and the straight cuts.

Figure 13.11 : The TELEMAC2D model grid and the interface with HECRAS



Source: Mott MacDonald

Additional information and discussion on the hydrological and hydraulics model are given in Annexure 6.

13.3 Proposals for Adaptation to Climate Change in the Six Rivers of this Project

13.3.1 Introduction

Of the Six Rivers of this project the Harichandra, Adappar, Pandavayar and Vellaiyar rivers serve the dual purpose of conveying irrigation supplies and removing drainage and floodwaters. Flood flows in these rivers can be more than three times irrigation flows as shown on Figure 13.2 and Figure 13.5 respectively. The Valavanar drain and the Vedharanyam canal are single purpose drains and therefore do not have to cope with such a wide range of flows. The rivers follow natural courses with appurtenant structures such as embankments, regulators including tail end regulators, irrigation sluices, drainage inlets, drainage sluices and bed dams/low weirs added to them. The structures have been provided to:

- Confine flood flows (Embankments, Retaining walls, Revetments)
- Regulate water supplies for irrigation (Regulators including Cross Regulators (CRR) Tail End Regulators (TER), Irrigation Head Sluices (IHS), Bed Dams (BED))
- Collect and convey the storm runoff from command areas and/or the intermediate catchment area (Drainage Infall Sluices (DIS))
- Allow drainage water from the command area into the main river (drain inlets/drainage sluices)
- Allow irrigation or drainage water to cross a river channel without mixing (Irrigation Syphon (ISY), Drainage Syphon (DSY))
- Expedite discharge of floodwater to the sea (Straight Cuts)
- Prevent ingress of sea water in to the rivers and prevent lands and ground water from getting saline (Tail End Regulators)

The Six rivers of this project channels are unable to cope with the larger floods resulting from present climatic conditions and delivery of irrigation flows is compromised by old structures many of which are in chronic need for repair or replacement. Man-made interventions and natural processes combine to impede drainage and aggravate flooding particularly on low-lying agricultural land. Climate change is expected to increase rainfall intensity and the frequency of intense storms plus also result in small increases in sea level.

Improving drainage and irrigation deliveries plus adapting the Six rivers of this project to climate change requires action on one or more of the following:

1. Improving the conveyance efficiency of river channels
2. Improving the performance and reliability of structures.

3. Increasing flood flows to the sea.
4. Rehabilitating 13 pumping schemes
5. Monitoring groundwater recharge

Specific proposals for each of the Six rivers of this project are analysed and assessed in the following six sections 13.3.2 to 13.3.7.

13.3.2 Adappar

13.3.2.1 Description of the Adappar River

The Adappar River illustrates the typical characteristics of the rivers of the Vennar system. The alignment of the Adappar is shown in Figure 13.12 and the location of structures in the upper and lower reaches of the Adappar are shown schematically in Figure 13.13 and Figure 13.14 respectively.

The Adappar offtakes from the Mulliyar River at Chainage 130.236 km (see footnote [1]). In the 6.14 km upper reach from the Adappar Head Regulator to the Thiruvalanjuli Cross Regulator (Chainage 136.376 km) there are 4 Class B irrigation head sluices (IHS) supplying about 1.34 m^3/s to 673 ha and 12 infalls providing drainage to 2287 ha. The Head Sluice is rated as 1.54 m^3/s for irrigation flow. Flood flows in the Mulliyar are not diverted through the Adappar Head Regulator (See Figure 13.5). The combined drainage flows entering the Adappar upstream of the Thiruvalanjuli Regulator is 10.49 m^3/s. At the Thiruvalanjuli Regulator, all irrigation water is diverted into the B4-Thiruvalanjuli and B3- Kunnur canals on the right bank. Adjacent to the left bank of the Thiruvalanjuli regulator is the unregulated Pullithikudhi drain infall that discharges downstream of the regulator. There are no data on the Pullithikudhi catchment or flow or water level measurements.

From Chainage 136.376 km to Chainage 139.854 km there are no irrigation offtakes and Adappar serves only as a drain, collecting flows from six infalls with combined catchments of 339 ha plus the Pullithikudhi catchment. At Chainage139.9 km, the Adappar is joined by the Ambodiyar Link Canal[2] that provides irrigation water diverted from the Harichandra. Between Chainage 139.854 km and the Pamani Regulator at Chainage 149.469 km, there are seven irrigation head sluices, providing water to 2676 ha and 5 drainage infalls with combined catchments of 1672 ha.

[1] Chainages are measured by WRD as the distance downstream of the Upper Anicut

[2] The Ambodoyar Link Canal offtakes from the Harichandra upstream of the Keeranthi Regulator at Chainage 137.54 km. The Ambothirajan Channel also takes off from the Ambodoyir Link Canal/ Harichandra at the Keeranthi Regulator to provide irrigation water to 1360 ha on the left bank of the Adappar River between Chainage 139.854 km and Chainage 147.84 km.

Between the Pamani Regulator at Chainage 149.469 km and Umabalachery Tail End Regulator at Chainage 156.106 km, there are four drainage infalls, two irrigation head sluices irrigating 2071 ha plus two inlets to pumping stations irrigating 536 ha. Downstream of the Umabalachery TER until Chainage 169.025 km where the Adappar meets the Vendharanyam Canal and the Adappar Straight Cut, there are 10 drain infalls. Two of the drains, the Pokkuvoikkal and Nallar drain an extensive area with catchments of 4322 ha and 1181 ha respectively. Downstream of Chainage 162.31, the width of the Adappar channel increases from about 60 m to over 200 m as the river enters the lagoon.

There are few homesteads or habitations close to the Adappar along most of its length, although downstream of Pamani there are a few built-up areas close to the channel. There is no road access along the channel from the Head Regulator to the Pamani Regulator, except for few locations such as between Chainage 143 to 144.80 km.

In 2008, flooding in the Adappar occurred mainly in the middle and lower reaches (see Figure 13.6). Information about flooding is available from visual observations of where breaches took place, or anecdotal evidence from affected locals. There are no flow or water level data on the flood discharges through the numerous drain infalls.

Figure 13.12 Alignment of Adappar River

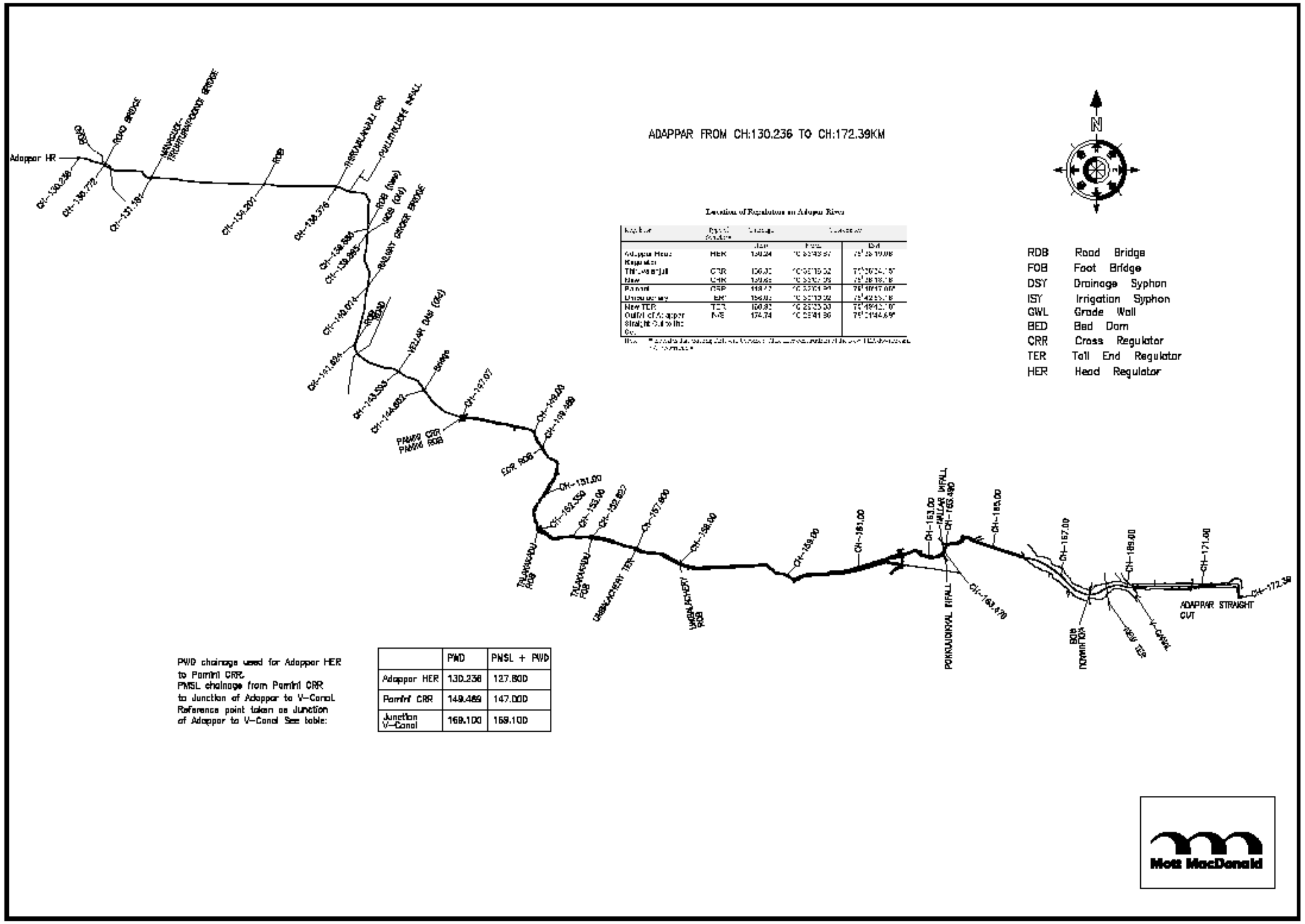
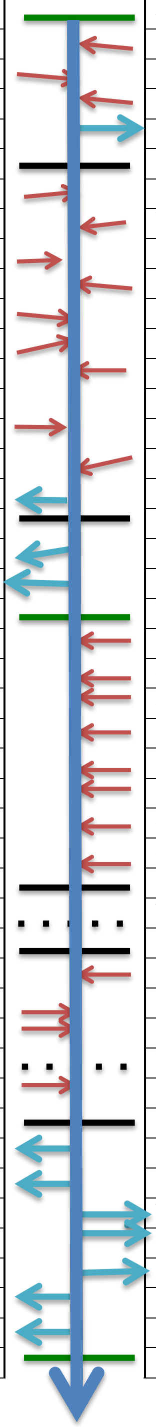


Figure 13.11 : Structures on Upper Adappar

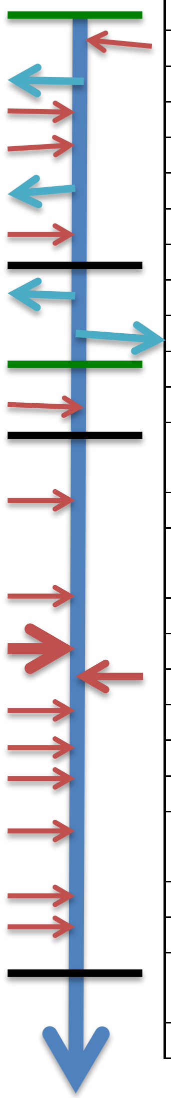
Distance (km)		Area / Discharge (ha/m^3/s)
130.236	Adappar HS	
130.409		
130.434	Kottor Drain #2	0.78/0.01
130.772		
130.911		
131.181	Road Bridge	
131.521	Therku S K Drain	30.30/0.13
131.816		
132.476	T. S Kottur Drain	72.00/0.31
132.496		
132.876	Essankudi Vadigal	98.65/0.43
133.651	Drain	85.21/1.37
133.661		
133.926	Drainage PS	No details
133.996	Drain	11.65/0.05
134.006		
134.051	B2 Keerakkular HS	134.99/-
134.201	Road bridge	
136.336	B3 Kunnur HS	260.30/-
136.354	B4Thiruvalanjuli HS	260.30/-
136.376	Thiuvalanjuli Reg.	3651.80/-
136.379		
137.551		
138.325		
138.432		
138.734		
139.592		
139.854		
139.874		
140.014	SI Railway Bridge	
140.094	Tiruvalanjuli Siphon	No data
141.624	Road Bridge	
143.153	Ambodiyarajan SS	
143.233	K. Kottagam Dr	70.41/1.13
143.413	Kunnar Vadigal	296.23/2.91
143.593	Vellar dam (old)	70.41/1.13
143.983	Kulayar drain	1257.75/7.64
144.802	Bridge	
147.397	Attakulam HS	202.35/-
147.397	Pamani HS	151.76/-
147.839		
149.066		
149.469		
149.469	Mullar Channel HS	38.44/-
149.69	South Rajan HS	1125.47/2.21
149.469	Pamani Regulator	No data



	Area / Discharge (ha/m^3/s)
Adappar HS	759.75/1.54
Kottor Drain #1	18.19/0.25
Kottor Drain #3	8.03/0.11
B1 M. Voikal HS	16.79/-
Road Bridge	
V S Kottur Drain	167.05/0.73
	72.00/0.31
Kottur Vadigal	14.48/0.50
Drain Infall	122.25/0.53
P. Voikel Drain	1658.37/6.07
Road bridge	
Thiruvalanjuli Reg	3651.89/-
Pullithikudhi Drain Infall	No data
Alivalam Drain	206.39/-
Andankarai Drain	No data
Drain infall no 1	46.45/-
Drain infall no 2	41.28/-
Drain infall no 3	44.51/0.65
Ambodoiyar open fall	195.06/-
Adandur drainage	No data
SI Railway Bridge	
Tiruvalanjuli Siphon	No data
Road Bridge	
	28.73/0.73
Vellar dam (old)	
Thiyagaraja Nallur HS	130.72/-
Subedar Channel HS	116.55/-
North Rajan HS	911.23/-
Pamani Regulator	No data

Figure 13.12: Structures on Lower Adappar

Distance (km)		Area / Discharge (ha/m³/s)
149.469	Pamani Reg.	
149.791		
150.651	Pamani Mullar PS	299.48/0.45
150.872	Drain	No data
150.912	Drain	No data
151.770	Korkkai PS	236/no data
152.240	S Kottogam Drain	414.41/3.61
152.627	Thalakadu f/ bridge	
156.867	U South RajanHS	1536.24/3.03
156.087		
156.106	Umbalachery TER	6940.00/34.61
156.862	Surplus outlet	
157.900	Umbalachery bridge	
160.087	M Kanni Reg.	No data
163.808	South Rajan Channel	647.52/7.11
163.310	North Rajan Infall	No data
163.470	Pokkuvoikkal Infall	4322.60/25.23
163.490		
163.634	Drainage infall	No data
164.855	Drainage infall	No data
166.042	Drainage infall	No data
167.494	Palayapokku Voikkal Infall	No data
167.520	Drainage infall	No data
168.540	Kallimadu drain	No data
168.850	Kallimadu road bridge	
169.025	Junction V Canal	



	Area / Discharge (ha/m³/s)
Pamani Regulator	
K Kottagam Drain	220.06/2.38
U North Rajan HS	535.01/1.06
Umbalachery TER	6940.00/34.61
Nallar Infall	1181.46/22.40
Junction V Canal	

Legend

- Irrigation outlet
- Drainage Inlet
- Cross regulator
- Road or railway bridge
- Drainage Siphon
- Main channel

13.3.2.2 Modelling to Assess Channel Improvements

Model Domain

The Adappar HEC-RAS model has two upstream boundaries and one downstream boundary. The upstream boundaries are located at the Adappar Head Regulator (130.236km) and the off-take of the Kottor channel from the Mulliyar River. The HECRAS model is terminated at the Vedharanyam Canal providing inflow to the TELMAC2D model of the canal and the coast. The drainage from surrounding land is derived from the results of the MWSWAT hydrologic model and is allocated to the appropriate reach of the river based on the SWAT sub-catchments. The flows are assumed to be distributed uniformly along each reach. As well as the Adappar head regulator, the Pamani and Umbalacherry tail end regulators are included in the HEC-RAS model. As PMSL cross sections are only available downstream of the Pamani Regulator it was necessary to use cross sections provided by WRD between the head regulator and Pamani Regulator. The WRD cross-sections are between 1km and 4km apart compared to the 100 to 200m intervals used by PMSL. Therefore the model results upstream of the Pamani Regulator must be treated with caution.

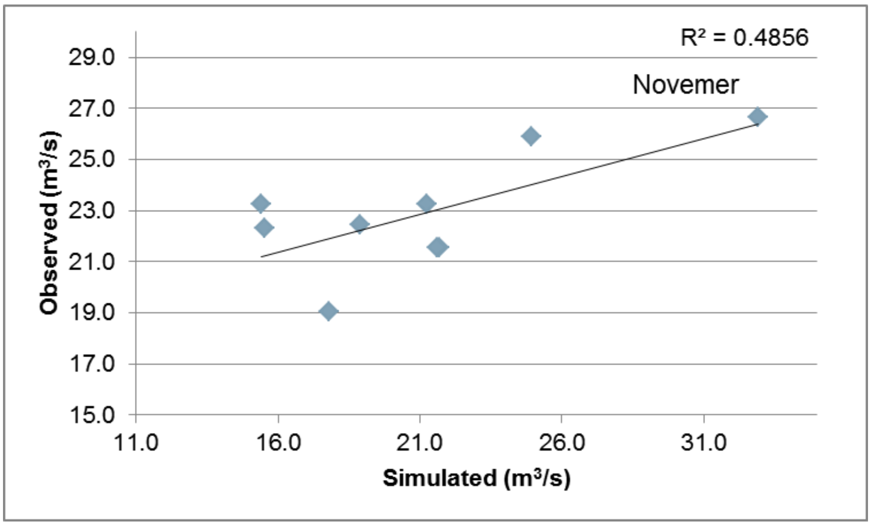
Validation

The HECRAS model was run for the period 2001 to 2012 and the simulated flow at the tail end regulator was compared with the flows recorded by WRD. Uncertainties include:

- Measurement errors (including the calibration and errors caused by by-pass flow);
- SWAT inflows into HEC-RAS;
- Assumed gate settings of regulators;
- Canal roughness; and
- The distance between the cross sections upstream of the Pamani Regulator.

In the absence of recorded level data, the tail end flows were used to adjust the SWAT inflows and to check on the volume of water that leaves the main channel as spill. The model does not simulate flood plain storage or the return of water to the main channel. Therefore, the validation has been limited to the comparison of observed and simulated peak flows as shown in Figure 13.13.

Figure 13.13: Observed and simulated annual maximum flows at Umbalachery Regulator



The comparison of annual observed and simulated peak flows at the Umbalachery regulator indicates that the simulated peak in the largest event (2008) was too large by 30-40%. The reason for this was almost certainly an overestimate of the peak runoff from contributing SWAT catchments caused by assumptions that runoff is not time lagged by travel time and also impeded by drainage congestion and that all the runoff drains to the Adappar river. Neither of these assumptions is necessarily correct because of congested drainage during large floods and the uncertainty over the destination of the runoff i.e. catchment runoff does not necessarily discharge to the river that irrigates the catchment . For these reasons the SWAT flows into the Adappar river in 2008 were reduced by 40%. The reduction in the SWAT flows is supported by the evidence from WRD and the field visits that the area draining to the river is not always contingent with the natural catchment.

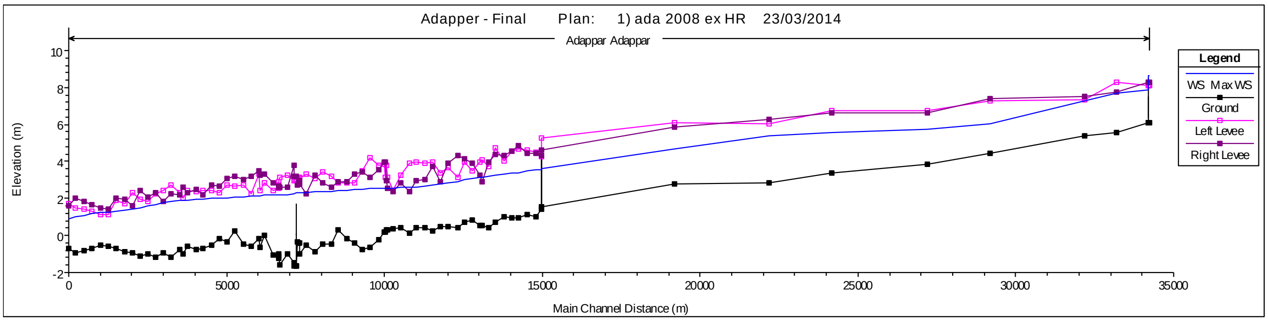
Furthermore, based on information from WRD that the Adappar head regulator is usually closed during floods, inflows into the Adappar model from the Koraiyar river were set to 10% of the SWAT flowsThese adjustments provided reasonable simulated levels and flows for the 2008 flood event.

Results

The model run for the 2008 event with the river in its existing condition indicates that the peak water levels over-topped the bank levels at several locations. These locations are broadly similar to the flooded areas indicated on the 2008 flood map (Figure 13.6), particularly the flooding that occurred upstream of Umbalacheri tail regulator and along the Chettipulam link canal.

The simulated long profile for one scenario is illustrated in Figure 13.14.

Figure 13.14: Simulated Long Profile for the Adappar upstream of the Chettipulam inflow



Note: PMSL survey data downstream of Chainage 15000; WRD data upstream of Chainage 15000

The validated model was run for climate change scenarios, and the results are shown in Figure 13.15 and 13.16.

Figure 13.15: Simulated long profile for the 25, 50 and 100 year events without Climate Change

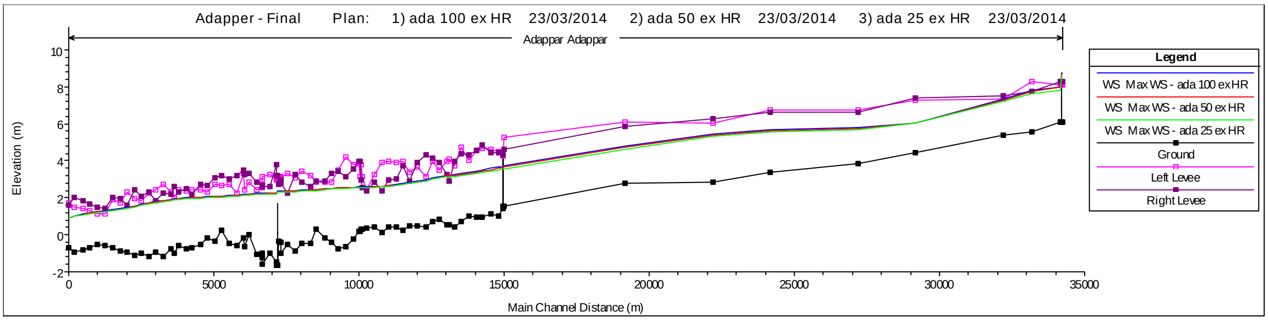
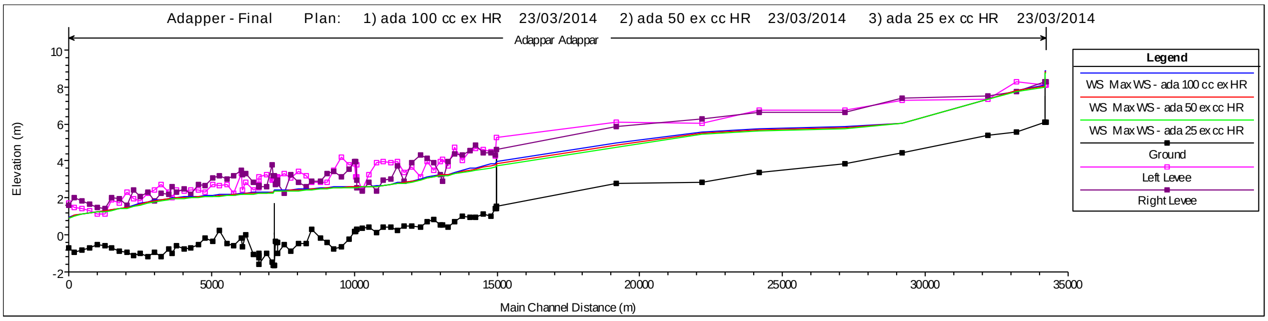


Figure 13.16: Simulated long profile for the 25, 50 and 100 year events with Climate Change



The simulated water levels appear to be relatively insensitive to the magnitude of the event as can be seen by the relatively small differences between the water levels shown in the two figures. This is due to the fact that once the water level exceeds the bank tops it leaves the main channel and flows onto an extensive flood plain with little change to the level in the main channel.

Feasibility Proposal for the River Channel

For the feasibility study, the option considered was to improve the conveyance efficiency of the river channel by re-sectioning[3] the channel and standardising[4] the banks (where required) to contain the design flood flow (Q25) with 1.0 to 1.5 m freeboard. The geometry of the model cross sections was adjusted to accommodate these changes and the model re-run to determine the impact on flows and water levels.

The results of the re-sectioning the channel are shown in Figure 13.17. In the upper reach from the head regulator to the Thiruvulanjuli CRR, the channel section is cleaned of vegetation and sand bars removed. The design channel will be about the same bed width as the existing channel and hence there is minimal impact on water levels. The width of the channel is relatively narrow as the flood discharge is small. From Thiruvulanjuli CRR to Pamini CRR, the bed width is increased to 25 m. From Pamini CRR to Umbalacherry CRR (existing TER), the design bed width is 30 m while Umbalacherry CRR to Chainage 165.90 km where the Adappar channel abruptly widens as it flows into the lagoon the design bed width is 40 m. The recommended side slopes are 1.5H to 1V. The impact of the works on water levels is shown on Figure 13.15.

The calculated discharges for Q25, Q25 with climate change (CC), Q50 and Q50 CC, and Q100 and Q100 CC and the respective water levels for the existing and post-project channel are shown in Table 13.6. Q25 discharges increase by about 30% with climate change and Q25 with climate change is greater than the Q50 without climate. Water levels increase by about 9 % with climate change.

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[3] Re-sectioning is defined as increasing the cross sectional area of the channel by clearing vegetation, increasing the bed width and raising the top level and width of side embankments.

[4] Embankment standardisation is defined as reforming the embankment along a river channel to comply with the design section.

Improvements to the Adappar Straight Cut were assessed as using the TELEMAC2D model as discussed in Section 13.3.7.

Discussion and Recommendations

The availability of flow records for this river has allowed validation of the assumptions pertaining to the SWAT inflows and the bank heights. Furthermore, the simulated water levels at regulators are not inconsistent with WRD observations during the 2008 event. Finally, there is consistency between the areas flooded in 2008 and the locations where the model simulates out-of bank flow. The model can therefore be used with confidence to model the design events and to appraise feasibility options. To improve confidence in the model it is recommended that water level and flow monitoring instruments are installed at the head and tail end regulators and selected cross regulators. It is important that the design and installation of this equipment conforms to current best practice. Improving the cross sections upstream of the Pamani regulator will give significant improvements in the prediction of water levels in this reach. The availability of a DEM to define the flood plain areas is essential for the accurate mapping of flooded areas and to simulate the movement of water between flood plain storage and the main channel.

Figure 13.17: Long Section of the Adappar (A4 Size. A3 size included in Annexure 5, Drawings.)

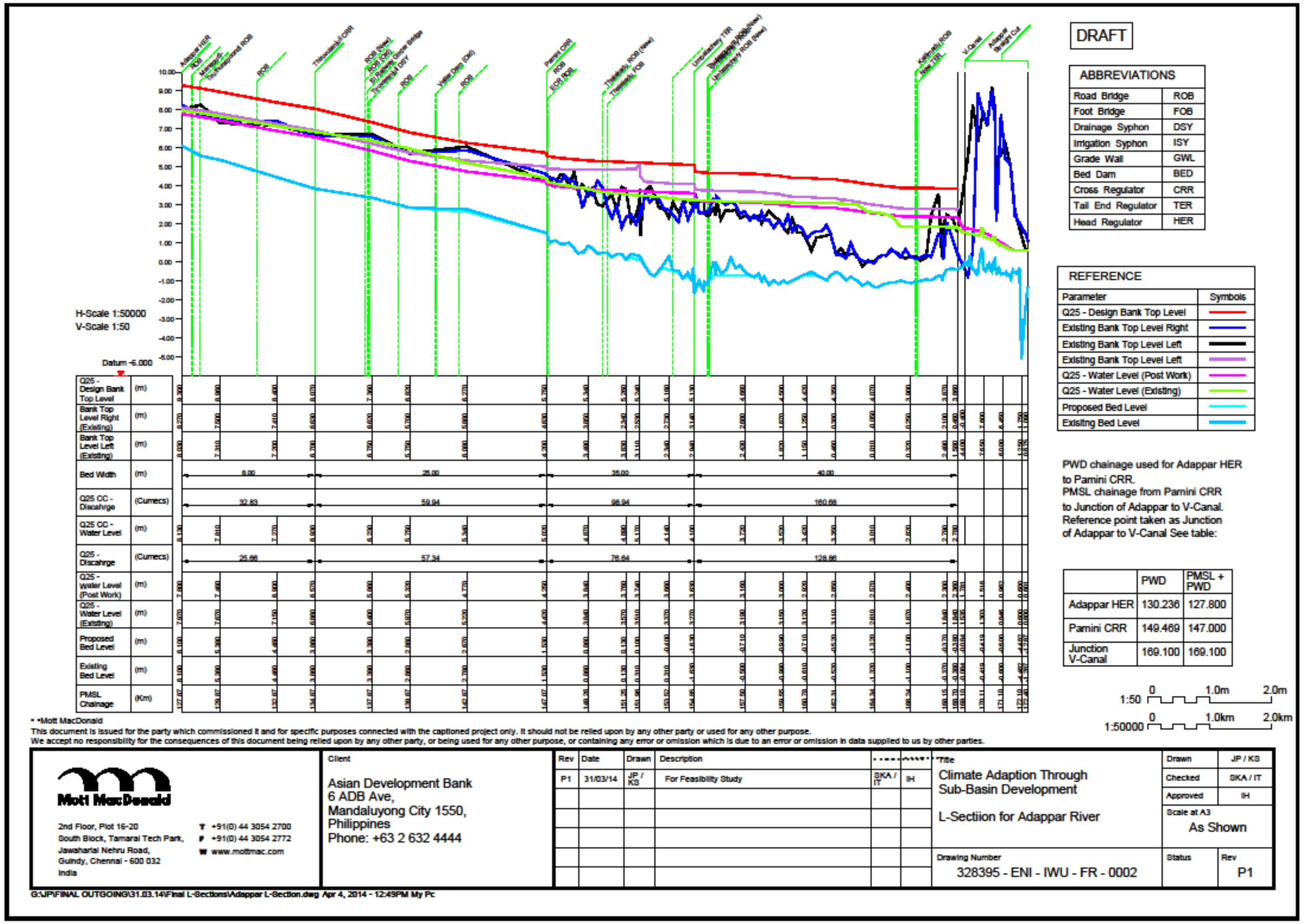

Table 13.6: Design Discharges and Water Levels for Different Floods, Adappar

Scenario	Name of Structure		Adappar HER	Tiruvalanjuli CRR	Pamini CRR	Umbalcherry CRR	New TER
Q25	**Discharge**	(m^3/s)	6.59	25.66	46.76	76.39	128.86
	WL existing	(m)	7.97	6.86	5.22	3.28	1.84
	WL post Project	(m)	7.80	6.57	4.77	3.63	2.36
Q25cc	**Discharge**	(m^3/s)	8.75	32.38	59.94	98.63	160.68
	WL existing	(m)	8.24	7.20	5.53	3.65	2.03
	WL post Project	(m)	8.13	6.93	5.34	4.11	2.78
Q50	**Discharge**	(m^3/s)	8.06	30.19	54.69	87.92	145.11
	WL existing	(m)	8.14	7.07	5.75	3.48	1.94
	WL post Project	(m)	8.02	6.79	5.62	3.89	2.58
Q50cc	**Discharge**	(m^3/s)	10.24	38.15	69.08	114.71	167.28
	WL existing	(m)	8.44	7.45	5.75	3.92	2.18
	WL post Project	(m)	8.35	7.18	5.62	4.34	2.87
Q100	**Discharge**	(m3/s)	8.78	33.97	62.30	102.88	164.52
	WL existing	(m)	8.27	7.25	5.57	3.61	2.02
	WL post Project	(m)	8.16	6.99	5.40	4.19	2.83
Q100cc	**Discharge**	(m^3/s)	11.70	44.04	79.18	123.28	205.27
	WL existing	(m)	8.85	7.94	6.01	4.26	2.36
	WL post Project	(m)	8.61	7.46	5.95	4.79	3.37

13.3.2.3 Improvements to Structures

The second feasibility option considered was to improve the performance and reliability of structures. As there was no up-to-date assessment, the structures of the Adappar were surveyed to assess their condition and identify the requirement for repair[5] or reconstruction[6] of existing structures or for new structures. The findings are summarized in Table 13.7. The complete list of structures is given in Annexure 2.

Table 13.7: Recommendations for Improving Structures, Adappar River

Name Of Structure	Total Number	Re-constructed	Rehabilitated/ repaired	New	No work
Regulators (head, cross and tail)	6	4	0	2	0
Irrigation Head Sluice	13	7	5	0	1
Drainage Sluice	14	4	7	2	1
Drainage Infall	24	6	7	9	2
Drainage Syphon	2	2	0	0	0
Irrigation Syphon	0	0	0	0	0
Bed Dam	0	0	0	0	0
Grade Wall	0	0	0	0	0
Road bridge	12	0	0	0	12
Foot Bridge	2	0	0	0	2
Railway Bridge	1	0	0	0	1
Other-drinking water pipeline	2	0	0	0	2
Total (1)	**76**	**23**	**19**	**13**	**21**

Note (1) in addition, there are two abandoned structures and 6 derelict structures that should be removed so that they do not impeded flow.

The new structures comprise of one new TER located 12.50 km downstream of the existing Umbalachary TER and one new CRR located at Chainage 139.68 to retain flood and drainage water.

Twelve drainage infall sluices will be constructed on open infalls to allow continuous road access along the side of the river channel and prevent backflow from the river into the drainage catchments. 23 structures need reconstruction and 19 structures need repair. The salient features of the design of the new and reconstructed regulators are shown in Table 13.8.

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[5] Repair is defined as the restoration of components of the structure to function as designed. Minor repairs include replacing plaster, replacement of a gate. Major repairs include replacement of one component of the structure such as a wing wall or sidewall.

[6] Re-construction is defined as demolition and removal of all components of an existing structure and construction of new structure including foundations on the same site.

Table 13.8: Salient Features of Designed Structures, Adappar

Name	Units	HER	Thiruvalanjuli CRR	New CRR	Pamini CRR	Umbalcherry CRR	New TER
Chainage	(km)	130.236	136.37	139.676	145	156.1	163.7
Design Flood	(m^3/s)	8.82	28.36	39.6	67.76	91.13	155
U/S River bed Level	(m)	6.1	4.46	3.55	1.53	-1.63	-0.78
D/S River bed Level	(m)	6.1	3.86	3.35	1.41	-1.63	-1.24
U/S FSL	(m)	8.74	6.59	6.3	4.34	3.59	2.49
D/S FSL	(m)	7.93	6.15	5.84	4.08	3.06	1.9
Channel Width	(m)	8	U/S 24m D/S 24m	U/S 25m D/S 25m	U/S 35m D/S 35m	U/S 30m D/S 31m	U/S 40m D/S 55m
Sill Level	(m)	6.325	5	4.65	1.82	0.01	0
Clear Waterway	(m)	1.8	9	12	18	18	36
No. and Size of Vents		2 vents Width = 0.9m Height = 3.02 m	3 vents Width= 3 m Height =2.2 m	4 vents Width= 3 m Height=2.3 m	6 vents Width = 3m Height = 3.1 m	6 vents Width = 3m Height = 4.2 m	9 bay Width = 4m Height = 3.1 m
Overall Waterway	(m)	3	11.4	15.6	24	24	45.6
Total Floor Length	(m)	7.29	20.36	23.2	19.4	45.26	30.7
U/S Floor Thickness	(m)	0.6	0.5	0.5	0.5	0.5	0.5
D/S Floor Thickness - Range	(m)	1.12	Variable from 0.54m to 1.3m	Variable from 0.83 m to 1.36 m	Variable from 1.02m to 1.41m	Variable from 0.98m to 2.66 m	Variable from 0.89m to 1.84m
Cutoff wall depth U/S	(m)	3.2	1.31	1.9	1.54	2.34	2.28
Cutoff wall depth D/S	(m)	4.01	1.75	2.16	1.94	2.95	2.17
U/S Protection (CC Blocks)		Thickness = 0.9 m Length = 9 m	Thickness = 0.6 m Length =9 m	Thickness = 0.6 m Length =8 m	Thickness = 0.6 m Length =9 m	Thickness = 0.6 m Length = 9 m	Thickness = 0.6 m Length =9 m
D/S Protection (CC Blocks)		Thickness = 0.9 m Length = 11 m	Thickness = 0.6 m Length =9 m	Thickness = 0.6 m Length =9 m	Thickness = 0.6 m Length =10 m	Thickness = 0.6 m Length = 8.5 m	Thickness = 0.9 m Length =11 m

Note: Structures were designed for Q50

The locations where fluming [8] and river training [9] is provided are shown in Table 13.9.

Table 13.9: Location of Fluming and River Training, Adappar

Chainage (km)		Length (m)	Type of Protection
From	To		
134.100	134.900	800	Retaining Wall
135.100	135.700	600	Retaining Wall
138.390	138.590	200	Retaining wall (Left Bank)
138.790	138.990	200	Retaining wall (Left Bank)

13.3.3 Harichandra River

13.3.3.1 Description of the Harichandra River

The Harichandra takes off from the Koraiyar River at the Harichandra Head Regulator at Chainage 121.142 km. The length of the river is 40 km and its alignment is predominantly west to east as shown in Figure 13.20.

The irrigation design discharge at the head regulator is 25.77 m^3/s serving an ayacut of 3600 ha through 56 irrigation head sluices. The purpose of the Harichandra as predominantly an irrigation delivery channel is illustrated by considering the middle reach (From Chainage 134.67 km to Chainage 140.4 km) shown in Figure 13.21. Along this reach, there are 12 irrigation head sluices of which 11 are on the right bank. Drainage from these 11 ayacuts flows into the Adappar river, not back to the Harichandra river. The Ambodiar HS provides water to the Adappar to irrigate 4747 ha in its lower reaches. The Ambodirajan HS irrigates 1360 ha on the Adappar left bank.

There are several large drainage infalls along the Harichandra. For example, the Vennar Chitar Infall adjacent to the Harichandra Head Sluice (at Chainage 121.16 km) has a catchment of 979 ha that is upstream of the Harichandra command area. Further downstream at Chainage 131.450 km, there is the Athiveeraramanar Chittar infall with a catchment area of 1193 ha but the channel is also connected to the Vennar river at the Athiveeramanar Regulator. In addition, the main Vennar River falls into the Harichandra at Chainage 138.48 km.

[8] Fluming is defined as provision of vertical retaining walls either side of a channel. Fluming is provided in reaches where it is not possible to re-section the channel with the standard trapezoidal section due to physical constraints such as lack of government land for widening the channel.

[9] River training is defined as provision of hard protection on one bank of the channel to prevent scour. The hard protection can be either inclined block protection or a vertical concrete retaining wall.

The upper reach of the Harichandra passes through rural areas with only occasional settlements nearby and poor road access. From about Chainage 126.03 km downstream, there is paved road access along at least one side of the river and there are several settlements/built-up areas close to the river, especially around road bridges.

Flooding on the Harichandra in 2008 took place mainly in the lower reaches where the bed slope flattens as the river enters the coastal plain (see Figure 13.6).

Figure 13.18: Alignment Map, Harichandra

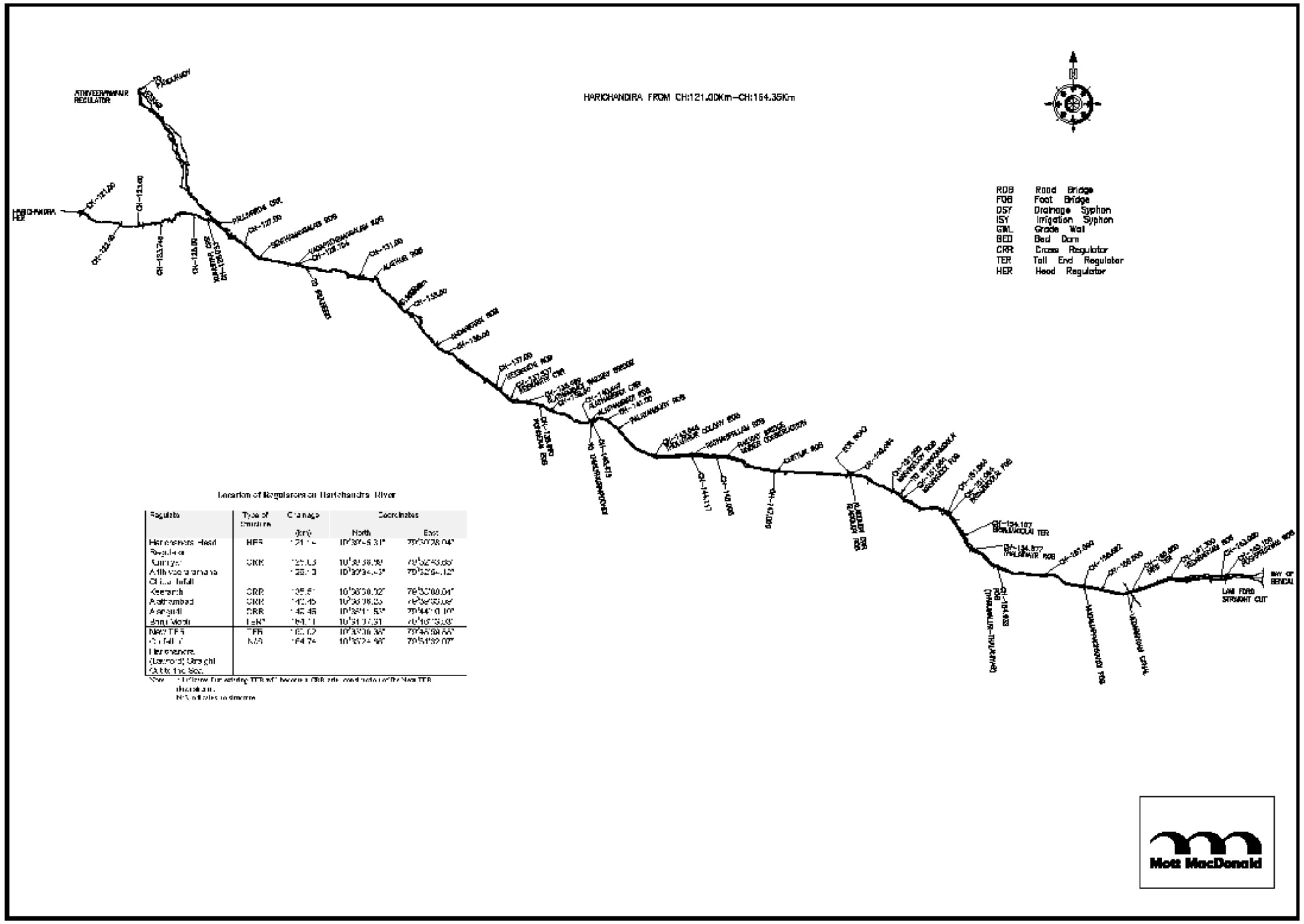
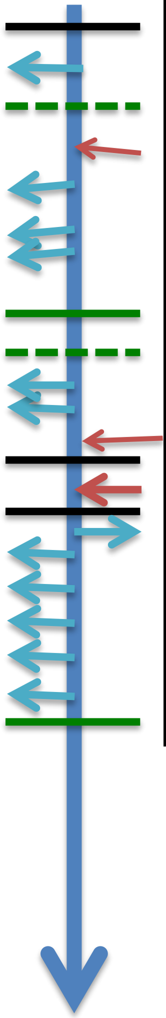


Figure 13.19: Structures on Middle Harichandra

Distance (km)		Area / Discharge ($ha/m^3/s$)
121.142	Harichandra HS	3600.58/25.77
134.673	Road bridge	
135.474	Keeranthi Voikal HS	No data
136.007	Andangarai Drainage syphon	2170.42/2.85
136.910		
137.600	Keeranthi state seed farm HS	No data
137.537	Ambodiar HS	4650.44/9.31
137.537	Ambodirajan HS	1360.672.72
137.537	Keeranthi Regulator	8724.78/12.03
137.537	Adanur Drainage Syphon	1822.44/3.90
137.730	Kurumbal HS	163.22/0.34
137.730	Kurumiyur HS	177.36/0.34
137.886		
138.469	Railway bridge	
138.479		
138.690	RCC road bridge	
139.052		
139.373	Manali HS	150.75/0.32
139.383	Sathanngudi HS	160.60/0.32
139.434	Palayangudi HS	134.53/0.27
139.897	Kodivinayan-gannallur HS	957.88/1.92
140.358	Sembiyaveleur HS	115.14/0.23
140.447	Alathambadi Regulator	6879.31/13.75



	Area / Discharge ($ha\&m^3/s$)
Road bridge	
Komal Vadikal Drain Infall	686.75/4.64
Keeranthi Regulator	8724.78/12.03
Nattuvoikal Drain Infall	1221.34/7.47
Railway bridge	
Vennar river infall	604.60/17.19
RCC road bridge	
Tholudur HS	26.26/0.05
Alathambadi Regulator	6879.31/13.75

Legend

	Irrigation outlet
	Drainage Inlet
	Cross regulator
	Road or railway bridge
	Drainage Siphon
	Main channel

13.3.3.2 Modelling to Assess Channel Improvements

Model Domain

The Harichandra model has two upstream and one downstream boundary. The upstream boundaries are located at the Athiveeramana and Harichandra head regulators (see Figure 13.18). The HECRAS model is terminated at the Brinji Moolai tail end regulator providing inflow to the TELMAC2D model. The drainage from surrounding land is derived from the results of SWAT and is allocated to the appropriate reach of the river based on the SWAT catchments. The flows are assumed to be distributed uniformly along each reach. PMSL cross-sections and reach lengths are used throughout the model. It was noted that the bed levels in the Athiveeramanar are higher than in the Harichandra giving a step at the junction between the two rivers.

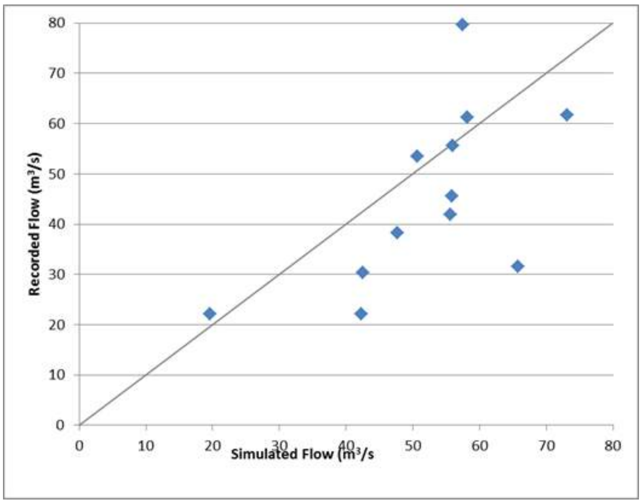
Validation

The HECRAS model was run for the period 2001 to 2012 and the simulated flow at the tail end regulator was compared with the flows recorded by WRD. Uncertainties include:

- Measurement errors (including the calibration and errors caused by-pass flow);
- SWAT inflows;
- Assumptions about the status of regulators; and
- Canal roughness.

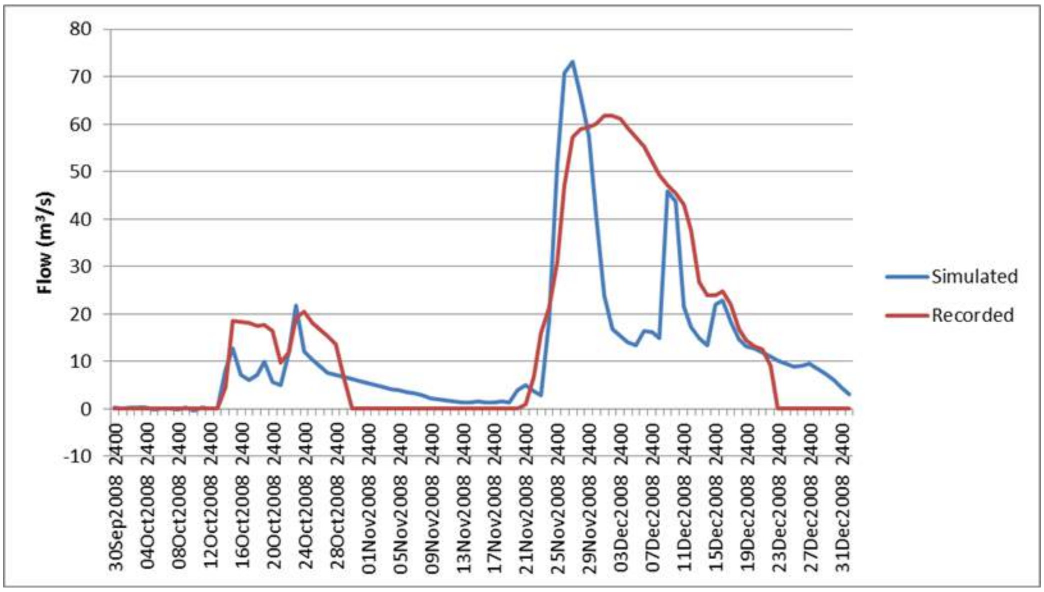
In the absence of recorded level data the tail end flows were used to adjust the SWAT inflows and to check on the volume of water that leaves the main channel as spill. The model does not simulate flood plain storage or the return of water to the main channel. Therefore, the validation has been limited to the prediction of peak flows. Figure 13.20 shows the comparison between simulated and recorded peak flows. It was found that the SWAT flows had to be reduced by 30% and that the inflow to the head of the rivers was limited to 10%. Although not perfect, this comparison does show a reasonable correlation between simulated and recorded peak flows, given the dependency on SWAT inflows and the lack of flood plain topography.

Figure 13.20: Simulated and Recorded maximum flood flows



Furthermore, a comparison of the simulated and recorded daily flows indicates that the HECRAS model is a reasonable fit to the recorded values as shown in Figure 13.20. Moreover, the plot confirms that the simulated recession should be treated with caution as there is evidence in the recorded flows that the recession is effected by storage and return flow.

Figure 13.21: Comparison of Simulated and Recorded Flow for November 2008



The reduction in the SWAT flows is supported by the evidence from WRD and field visits that the area draining to the river is not always contingent with the natural catchment. The low flow at the head regulators is supported by evidence from WRD who state that the gates are closed during flood flows.

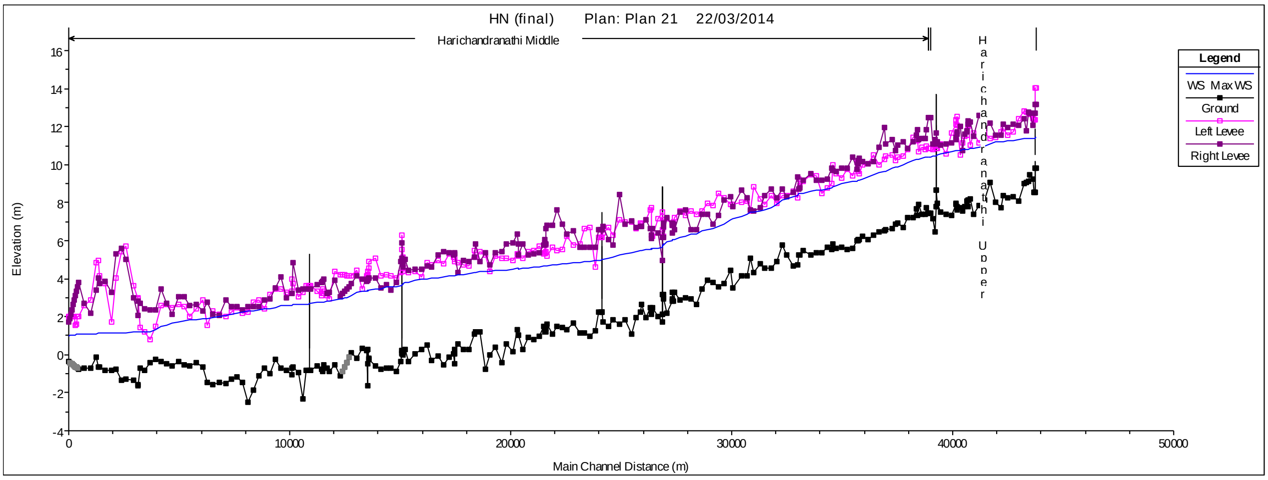
Channel roughness (Manning's n values) was set at 0.1 for out of main channel regions and 0.035 for the main channel.

Results

The model run for the 2008 event with the river in its existing condition indicates that the peak water levels over-topped the bank levels at several locations. These locations are broadly similar to the flooded areas indicated on the 2008 flood map (Figure 13.6). In particular the flooding upstream of Keeranthi, Alathampadi, Alangudi and Brinji Moollai regulators is replicated in the model.

The simulated long profile for one scenario is illustrated in Figure 13.22 None of the regulators were drowned or over-topped during the 2008 event which is consistent with the observations of WRD and evidence gathered during the field visits.

Figure 13.22: Simulated Long Profile for the Harichandra in its Existing State



Feasibility Proposal for the River Channel

For the feasibility study, the first option considered was to improve the conveyance efficiency of the river channel by re-sectioning the channel and standardising the banks (where required) to contain the design flood flow (Q25) with 1.0 m freeboard. The geometry of the model cross sections was adjusted to accommodate these changes and the model re-run to determine the impact on flows and water levels. After consideration, WRD determined that this option was not practical as government land was not available to widen the channel plus it would cause too much disruption to irrigation flows. Therefore a second option of re-grading[9] the bed and standardising the banks was assessed. The geometry of the model cross sections was adjusted to accommodate these changes and the model re-run to determine the impact on flows and water levels. This second option was acceptable to WRD.

[9] Re-grading is defined as the excavation of the channel bed to remove sand bars and vegetation to restore the channel to a smooth gradient.

The results of re-grading the channel and standardizing the banks are shown in Figure 13.23. The calculated discharges for Q25, Q25 with climate change (CC), Q50 and Q50 CC, and Q100 and Q100 CC and the respective water levels for the existing and post-project channel are shown in Table 13.10. Similar to the Adappar, Q25 discharges increase by about 20% with climate change and Q25 with climate change is greater than the Q50 without climate change. Water levels increase by about 15 % with climate change.

Figure 13.23 Long Section of the Harichandra River

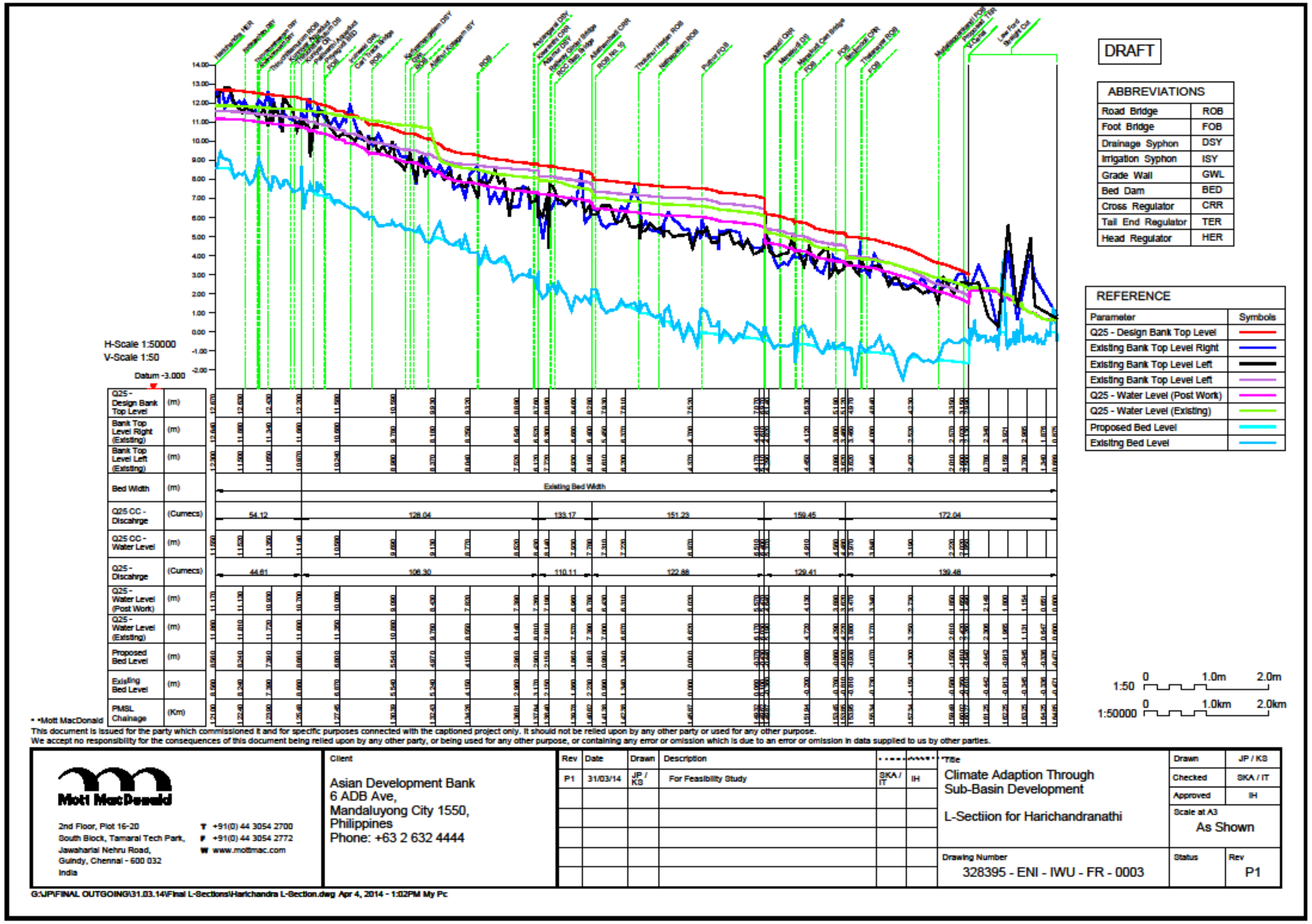


Table 13.10: Design Discharges and Water Levels for Different Floods, Harichandra

Scenario	Name of Structures		HER	Kunniyur CRR	Keeranthi CRR	Alathambadi CRR	Alangudi CRR	Brinjimoolai CRR	New TER
Q25	**Discharge**	(m^3/s)	7.35	37.90	106.30	129.41	139.53	129.41	139.53
	WL existing	(m)	11.86	11.60	8.01	7.39	6.03	4.22	2.42
	WL post Project	(m)	11.17	10.96	7.26	6.62	5.65	3.62	1.65
Q25cc	**Discharge**	(m^3/s)	7.35	54.12	128.04	133.17	151.23	159.45	172.11
	WL existing	(m)	12.12	11.84	9.22	8.14	6.74	4.95	2.77
	WL post Project	(m)	11.55	11.14	8.43	7.78	6.40	4.48	2.02
Q50	**Discharge**	(m^3/s)	7.35	50.56	120.53	124.94	140.31	147.6	159.02
	WL existing	(m)	12	11.72	8.82	7.89	6.49	4.69	2.65
	WL post Project	(m)	11.41	10.97	7.95	7.47	6.12	4.2	1.87
Q50cc	**Discharge**	(m^3/s)	7.35	62.09	152.12	158.38	178.72	187.74	202.38
	WL existing	(m)	12.64	12.41	10.39	8.53	7.15	5.42	3
	WL post Project	(m)	11.9	11.53	9.18	8.43	7.02	5.13	2.35
Q100	**Discharge**	(m^3/s)	7.24	56.84	140.64	146.64	166.51	175.64	188.61
	WL existing	(m)	12.26	12.00	9.55	8.31	6.91	5.14	2.85
	WL post Project	(m)	11.69	11.31	8.88	8.15	6.75	4.85	2.21
Q100cc	**Discharge**	(m^3/s)	7.21	70.31	179.03	186.98	213.26	225.38	242.5
	WL existing	(m)	14.67	14.55	12.98	7.75	6.71	5.12	2.9
	WL post Project	(m)	12.34	12.01	9.81	9.08	7.66	5.83	2.74

Discussion and Recommendations

The availability of flow records for this river has allowed validation of the assumptions pertaining to the SWAT inflows and the bank heights. Furthermore, the simulated water levels at regulators are consistent with WRD observations during the 2008 event. Finally, there is consistency between the areas flooded in 2008 and the locations where the model simulates out-of bank flow. The model can be used with confidence to appraise feasibility options. To improve confidence in the model for detailed design or the development of operational rules it is recommended that water levels and flow are recorded during flood flows and used to improve the calibration

The lower reach of the Harichandra downstream of the existing Brinjimoolai TER from Chainage154.107 km to the new TER at Chainage 160.020 km are located in CRZ-2 and CRZ-3 (See Figure 3.6A). Dredging would have to stop 100 m from the outfall to the sea to avoid interference with beach which is located in CRZ-1.

13.3.3.3 Improving Structures

In the absence of an up-to-date component register, the structures of the Harichandra were surveyed to assess their condition and identify the need for repair or reconstruction and for new structures. The findings are summarised in Table 13.11 and listed in more detail in Annex 3.

Table 13.11: Recommendations for Improving Structures, Harichandra River

Name Of Structure	Total Number	Re-constructed	Rehabilitated/ repaired	New	No work
Regulators (head, cross and tail)	7	2	4	1	0
Irrigation Head Sluice	56	31	18	2	5
Drainage Sluice / Drainage Infall Sluice	19	7	6	6	0
Syphon	7	5	1	0	1
Grade Wall	4	0	2	2	0
Road bridge	13	0	3	0	10
Foot Bridge	12	2	3	0	7
Railway Bridge	2	0	0	0	2
Other-drinking water pipeline	1	0	0	0	1
Total (1)	**123**	**48**	**38**	**11**	**26**

Note (1) in addition, there are 8 abandoned structures and 2 derelict structures that should be removed so that they do not impeded flow.

The new structures comprise of one new TER located 6 km downstream of the existing Brinji Moolai TER. The new TER is located as shown in Figure 3.6A. Two new irrigation head sluices will be constructed just upstream of the new TER to provide supplementary irrigation water to the lower reaches of the RajanVoikal canal on the right bank and water for shrimp farms and agriculture on the left bank. In addition, 5 drainage infall sluices will be constructed on open infalls to allow continuous road access along the side of the river channel and prevent backflow from the river into the drainage catchments plus two grade walls. 48 structures need reconstruction and 38 structures need repair.

The salient features of the design of the new and reconstructed regulators are shown in Table 13.12. In addition to the regulators, sample designs were prepared for a grade wall (at Chainage 133.70 km) and the Solvadiar Drainage infall (at Chainage 144.117 km) and the capacity of the Irrigation Head Sluice (at Chainage 144.579 km) was checked. Details of the two designs and the checking of the Irrigation Head Sluice are given in Annexure 3.

Table 13.12: Salient Features of Designed Structures, Harichandra

Name	Units	Keeranthi CRR	Brinjmoolai CRR	New TER	Grade Wall	Slovadiar Drainage Infall
Chainage	(km)	128.95	154.1	160.01	133.70	144.12
Design Flood (Q50)	(m^3/s)	117	140	149	106.63	9.2
U/S River bed Level	(m)	2.74	-0.43	-1.55	4.56	2.31
D/S River bed Level	(m)	1.75	-0.44	-1.52	4.35	2.31
U/S FSL	(m)	6.44	4.29	2.74	8.27	6.14
D/S FSL	(m)	5.91	3.9	2.48	8.11	6.1
Channel Width	(m)	U/S 30 m D/S 30 m	U/S 35m D/S 40m	U/S 40m D/S 50m	U/S 30m D/S 30m	U/S 4m D/S 4m
Sill Level	(m)	3.95	0.23	0	5.8	2.75
Clear Waterway	(m)	27	24	32	30	4
No. and Size of Vents		9 vents Width = 3 m Height = 3.1 m	8 vents Width= 4 m Height = 4.7 m	8 vents Width = 4m Height = 3.3 m	1 vents Width = 30 m Height =N/A	2 bay Width = 2m Height = m
Overall Waterway	(m)	36.6	32.4	40.4	30	5.2
Total Floor Length	(m)	39.52	38.37	32.4	29.11	27.52
U/S Floor Thickness	(m)	0.5	0.5	0.5	0.6	0.5
D/S Floor Thickness - Range	(m)	Variable from 1.11 m to 2.39m	Variable from 1.38 m to 2.37m	Variable from 1.48 m to 2.13 m	Variable from 0.96 m to 1.98 m	Variable from 0.86 m to 1.91 m
Cutoff wall depth U/S	(m)	1.83	2.17	2.03	1.83	1.88
Cutoff wall depth D/S	(m)	2.68	2.77	2.6	2.48	2.5
U/s Protection (CC Blocks)		Thickness = 0.6 m Length = 8 m	Thickness = 0.6 m Length =8 m	Thickness = 0.6 m Length =8 m	Thickness = 0.6 m Length = 7 m	Thickness = 0.9 m Length =5 m
U/s Protection (CC Blocks)		Thickness = 0.6 m Length = 10.5 m	Thickness = 0.6 m Length =10.5 m	Thickness = 0.6 m Length =10 m	Thickness = 0.6 m Length = 9.5 m	Thickness = 0.9 m Length =6.5 m

The locations of the fluming and river protection to be provided on the Harichandra are shown in Table 13.13.

Table 13.13: Location of Protection Walls/ Revetments, Harichandra

	Chainage (km)		Length (m)	Type of Protection
	From	To		
REACH I	123.200	123.500	300	Protection Wall RB&LB
	123.500	123.700	200	Protection Wall RB&LB
	123.800	124.000	200	Protection Wall RB&LB
	126.000	126.300	300	Protection Wall RB&LB
	126.500	126.600	100	Protection Wall RB&LB
REACH II	126.200	126.260	60	Protection Wall RB&LB
	126.970	127.050	50	Protection Wall RB&LB
	128.000	128.050	50	Protection Wall RB&LB
	128.200	128.250	50	Protection Wall RB&LB
	129.330	129.370	40	Protection Wall RB&LB
	129.690	129.790	100	Protection Wall RB&LB
	131.120	131.170	50	Protection Wall RB&LB
	131.440	131.490	50	Protection Wall RB&LB
	132.550	132.600	50	Protection Wall RB&LB
	135.500	135.550	50	Protection Wall RB&LB
	136.950	137.025	75	Protection Wall RB&LB
REACH III	139.250	139.500	250	Protection Wall RB&LB
	140.200	141.200	1000	Protection Wall RB&LB
REACH IV	147.550	148.100	550	Protection Wall RB
	147.700	148.030	330	Protection Wall LB
	149.600	150.050	450	Protection Wall RB&LB
	150.650	150.950	300	Protection Wall LB
	154.050	154.160	110	Protection Wall LB
	154.250	154.300	50	Protection Wall RB&LB
	160.010	160.160	150	Protection Wall RB&LB

13.3.4 Vellaiyar

13.3.4.1 Description of the Vellaiyar River

The Vellaiyar offtakes from the Vennar River at the Vellaiyar head regulator at Chainage 111.65 km. The alignment of the Vellaiyar River is shown in Figure 13.24.

The upper reach of the Vellaiyar has an interesting feature in that the channel passes through four 90^o bends before following a linear alignment downstream. Close to its confluence with the Pandavayar River, the channel again goes through a number of 90^o bends. Whether the river's present alignment is natural or man-made is not known. It is unfortunate that there are no records of how these rivers evolved. Designs or as-constructed drawings are not available for any Vennar System works.

The Vellaiyar channel is generally well-defined throughout though some cross sections are narrow and there are low points on the banks.

As part of their strategy to manage flood flows originating between the Grand Anicut and the VVR head regulator, WRD pass flood flows from the Vennar River into the Vellaiyar River as shown in Figure 13.5. The upper and middles reaches can generally accommodate the flood flow but the lower reaches towards its confluence with the Pandavayar become flooded (see Figure 13.5).

13.3.4.2 Modelling to Assess Channel Improvements

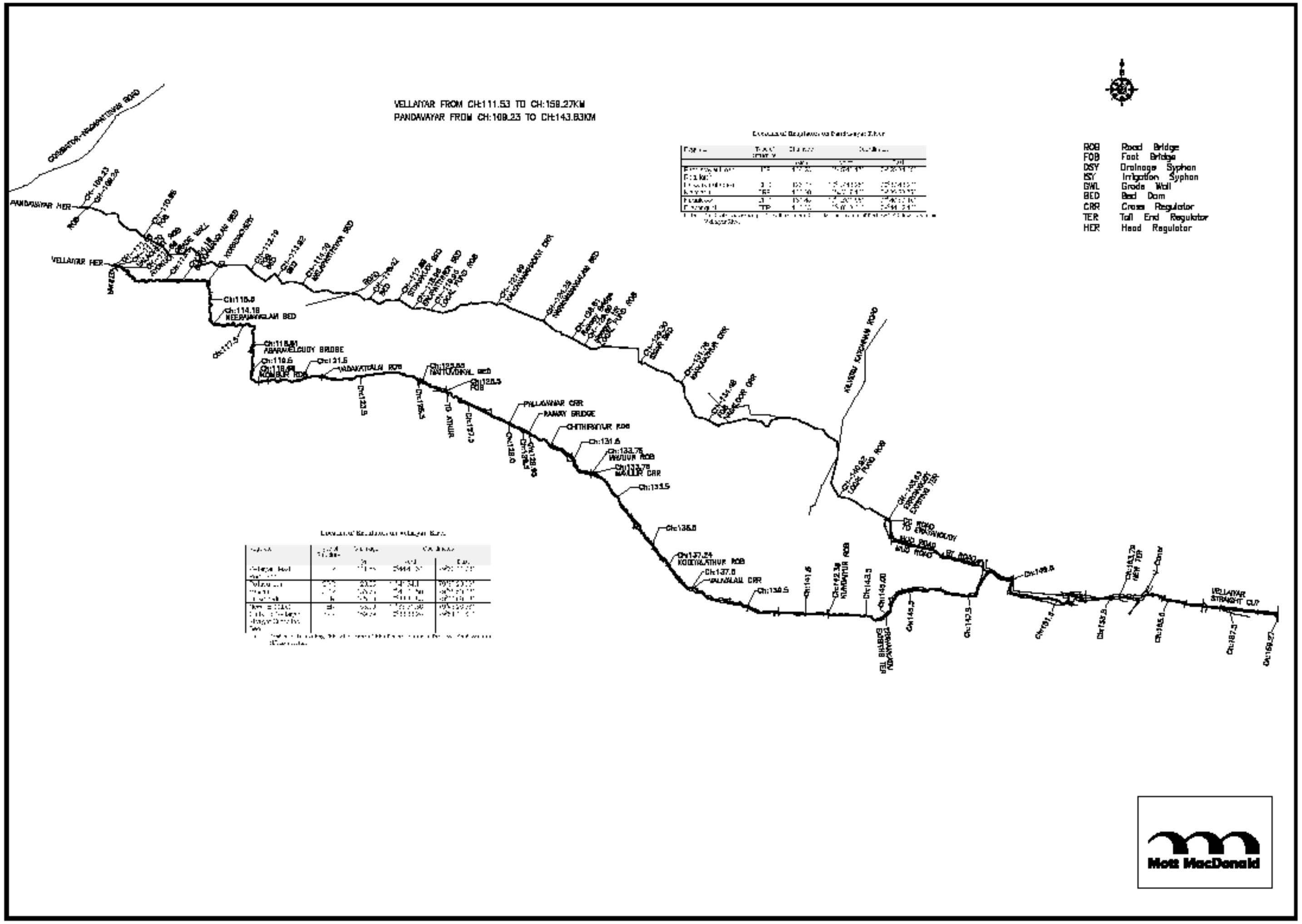
Model Domain.

A single HECRAS model was developed for the Pandavayar and Vellaiyar rivers. The model extends from the Pandavayar and Vellaiyar head regulators to the confluence of the two rivers and onto the downstream boundary at the Vedharanyam Canal where it provides inflow to the TELMAC2D model. The drainage from surrounding land is derived from the results of SWAT and is allocated to the appropriate reach of the river based on the SWAT sub-catchments. The flows are assumed to be distributed uniformly along each reach. Table 13.14 lists the regulators included in the HEC-RAS model.

Table 13.14: Regulators included in the Pandavayar and Vellaiyar HEC-RAS model

River	Regulator
Pandavayar	Head
Pandavayar	Kelyanamahadevi
Pandavayar	Nagalore
Pandavayar	Eriyangudi (Tail End)
Vellaiyar	Head
Vellaiyar	Pallavanar
Vellaiyar	Mavoor
Vellaiyar	Valivalum
Vellaiyar	Ervaikkadu (Tail End)

Figure 13.24: Alignment of the Vellaiyar and Pandavayar Rivers



PMSL cross sections are available downstream of the Vellaiyar head regulator to the Vellaiyar straight cut. On the Pandavayar River, PMSL cross sections are available only from the existing TER to its junction with the Vellaiyar River. PWD cross sections were used for the reach from the Pandavayar Head Regulator to the Existing Pandavayar TER.

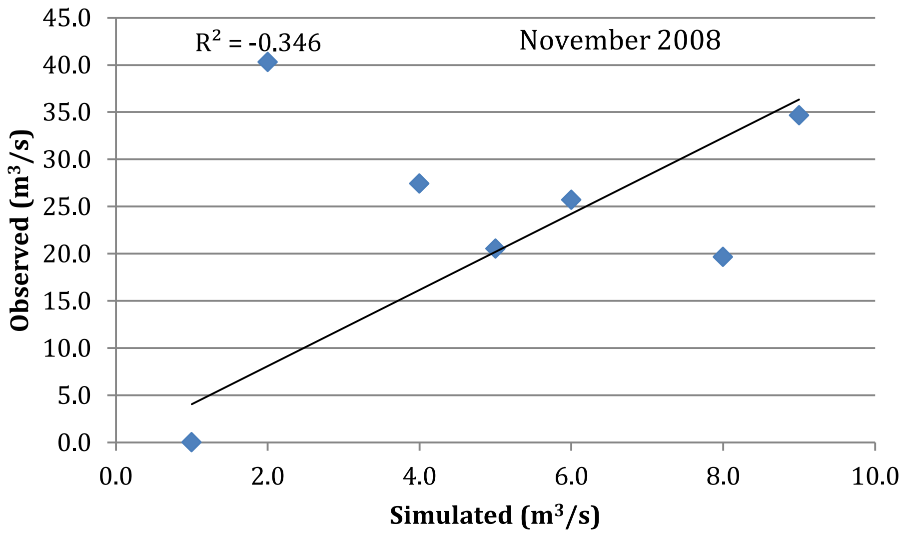
Validation

The HEC-RAS model was run for the period 2001 to 2012 and the simulated flow at the tail end regulator was compared with the flows recorded by PWD. Uncertainties include:

- Measurement errors (including the calibration and errors caused by by-pass flow);
- SWAT inflows;
- Assumed gate settings of the regulators; and
- Channel roughness.

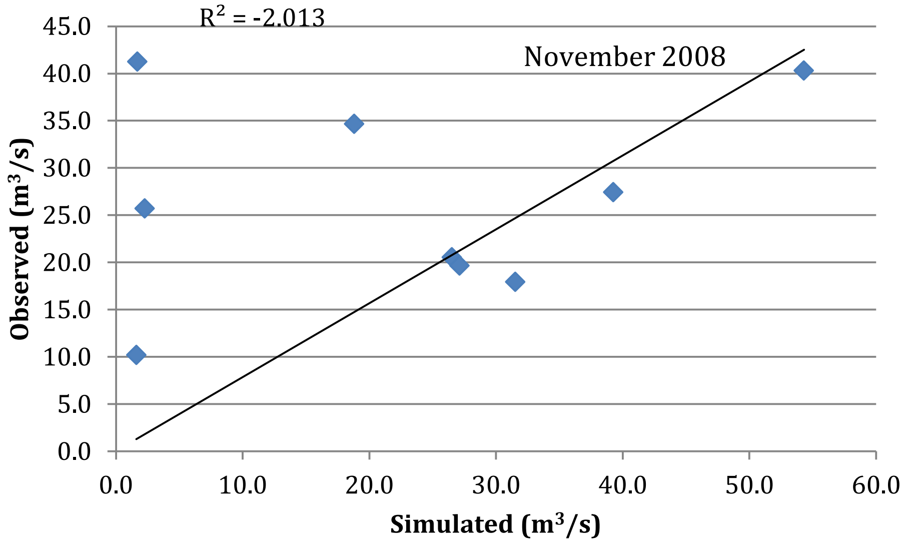
Recorded flows at both head regulators were input to the model. SWAT simulated flows were used to represent drainage that enters the rivers from rainfall catchments between the head and tail regulators. In the absence of recorded level data the tail end flows were used to adjust the SWAT inflows and to check on the volume of water that leaves the main channel as spill. The model does not simulate flood plain storage or the return of water to the main channel. Therefore, the validation has been limited to the prediction of peak flows and the results were reasonable for the Vellaiyar, as shown in Figure 13.25.

Figure 13.25 : Observed and simulated annual maximum flows at Eravankkadu Regulator (Vellaiyar)



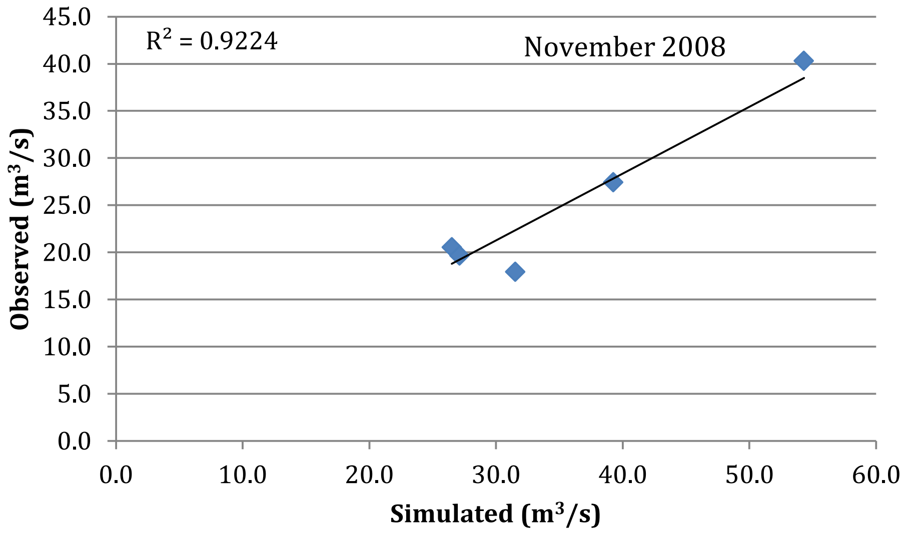
The validation for the Pandavayar River at the Erayankudi TER is poor when all annual maxima are included (see Figure 13.26). This could well be due to the poor data quality and by-pass flows as well as model set up. Given that for other rivers a reasonable validation could be achieved it is thought most likely that the large differences are due to measurement error.

Figure 13.26: Observed and simulated annual maximum flows at Eriyangudi Regulator (Pandavanar)



The outliers with very low simulated flows are caused by dubiously low recorded flows at the head regulator. When these points are removed the validation is quite reasonable as shown in Figure 13.27.

Figure 13.27: Observed and simulated annual maximum flows at Eriyangudi Regulator (Pandavanar) with dubious values removed

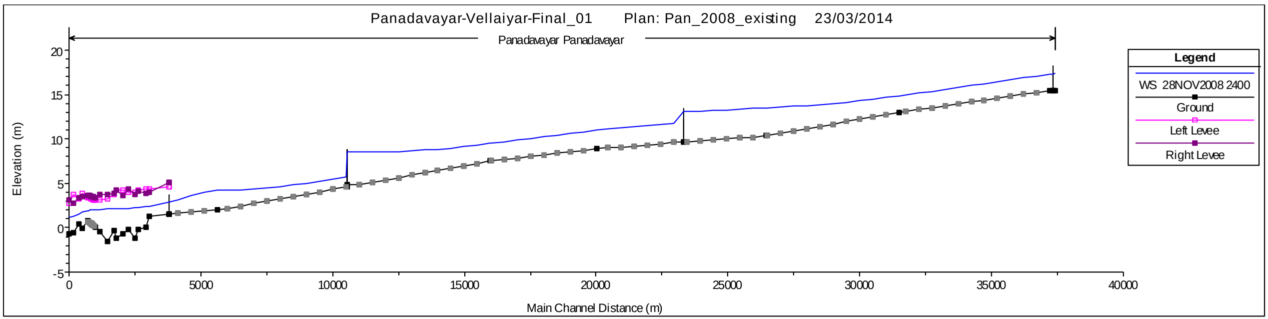


The inflows simulated by SWAT were reduced by 20% for an optimal fit. The recorded inflows at the head regulators were unadjusted. This exercise confirms that the modelled levels are reasonable and that the 2008 event can be used as the basis for design. Channel roughness (Manning's n values) was set at 0.1 for out of main channel regions and 0.035 for the main channel.

Results

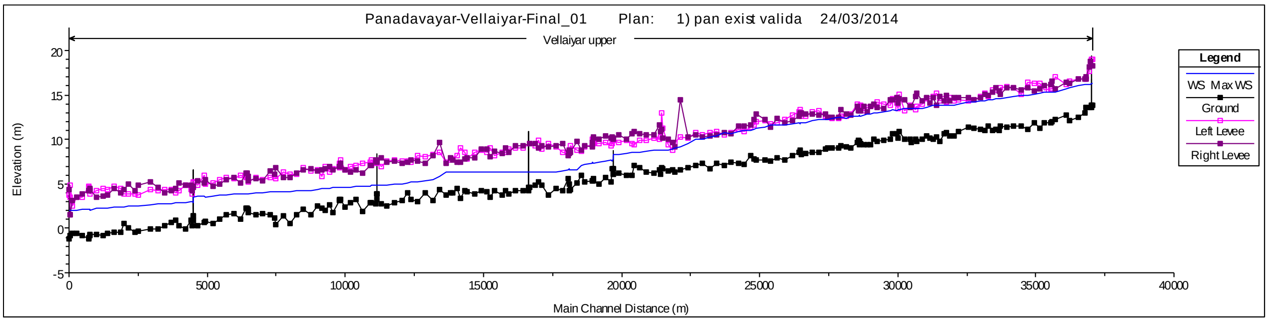
The 2008 flood map indicates that flooding occurred upstream of the regulators for both rivers and also at their confluence. The NRSC flood map (Figure 13.6) shows very little flooding associated with the Vellaiyar although it is recognised that the flood map is subject to some uncertainty. The model run for the 2008 event and the rivers in their existing state indicates that almost no flooding is simulated for the Pandavayar (see Figure 13.28). The model predicts the Kelyanamahadevi and Nagdoor regulators were inundated which is consistent with the flood map. However, these results should be treated with some caution as the model relies on crude idealised cross sections upstream of the Erayankudi tail end regulator.

Figure 13.28 : Simulated 2008 water levels for the Pandavayar river in its existing state



The model indicates very little flooding along the Vellaiyar river (See Figure 13.29). There is some flooding where the embankments are particularly low between the head regulator and the Pallavanar regulator. Localised flooding is also simulated upstream of the tail end regulator and the confluence with the Pandavayar river. This is broadly consistent with the 2008 flood map (See Figure 13.6).

Figure 13.29 : Simulated 2008 water levels for the Vellaiyar river in its existing state



The validated model was run for Q25, Q50 and Q100 with and without climate change and the results are shown in Figure 13.30 (without climate change) and Figure 13.31 (with climate change).

Figure 13.30: Simulated long profile for the 25, 50 and 100 year events (without climate change)

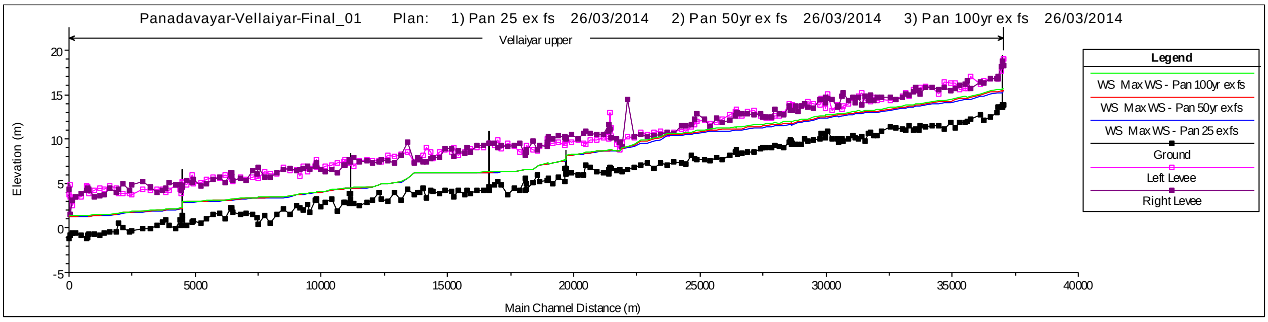
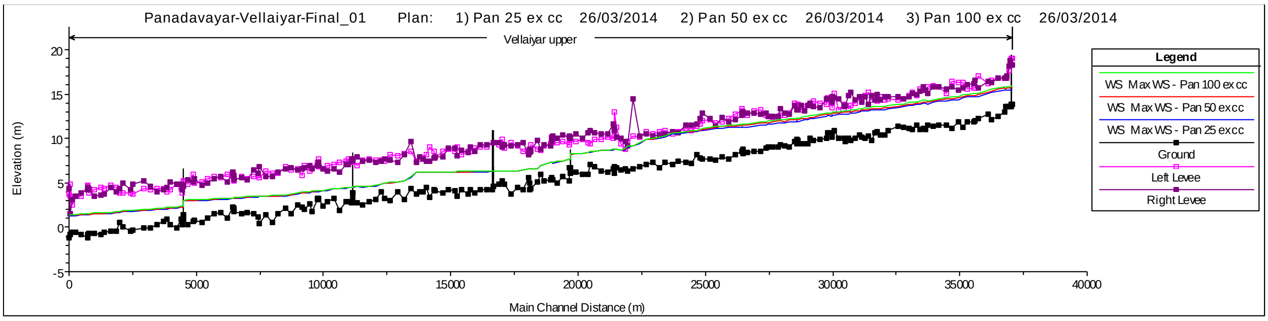
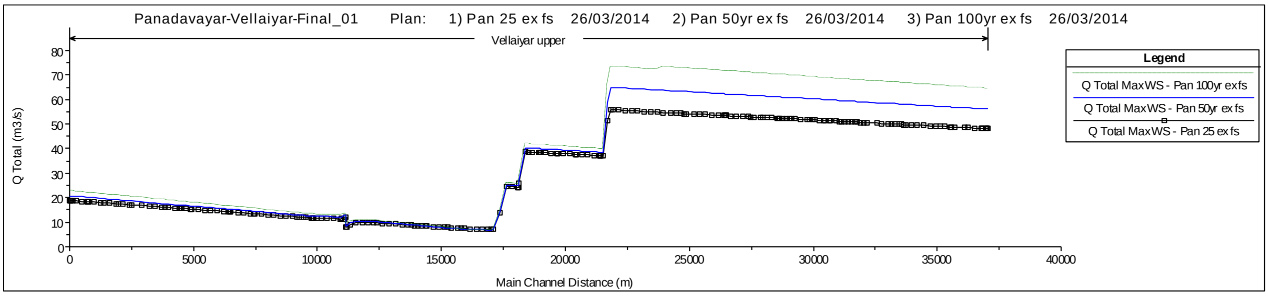


Figure 13.31 : Simulated long profile for the 25, 50 and 100 year events (with climate change)



The simulated water levels are very insensitive to flow. This is purely due to the flow going out-of bank as is illustrated in Figure 13.32. It is evident that once the minimum channel capacity is reached additional flow spills from the main channel leaving downstream water elevations almost unchanged.

Figure 13.32: The variation in flow with the design event for the Vellaiyar



Feasibility Proposal.

The feasibility option considered was regrading and standardizing the embankments to contain flood flows where required. Where there are particularly narrow cross sections, the channel would be widened over short reaches and bank protection provided where erosion was likely. Similarly for the Pandavayar where flooding is localized, the existing channel requires regarding and standardizing of the embankments, from the Head Regulator to the Existing TER. Downstream of the TER, there is scope to widen the channel over a short reach before its confluence with the Vellaiyar

The results of the re-grading the channel and standardising the banks are shown in Figure 13.33.

The calculated discharges for Q25, Q25 with climate change (CC), Q50 and Q50 CC, and Q100 and Q100 CC and the respective water levels for the existing and post-project channel are shown in Table 13.15. Similar to the Adappar and the Harichandra, Q25 discharges increase by about 25% with climate change and Q25 with climate change is greater than the Q50 without climate change. Water levels increase by about 10 % with climate change.

Figure 13.33 :	Long Section of the Vellaiyar River

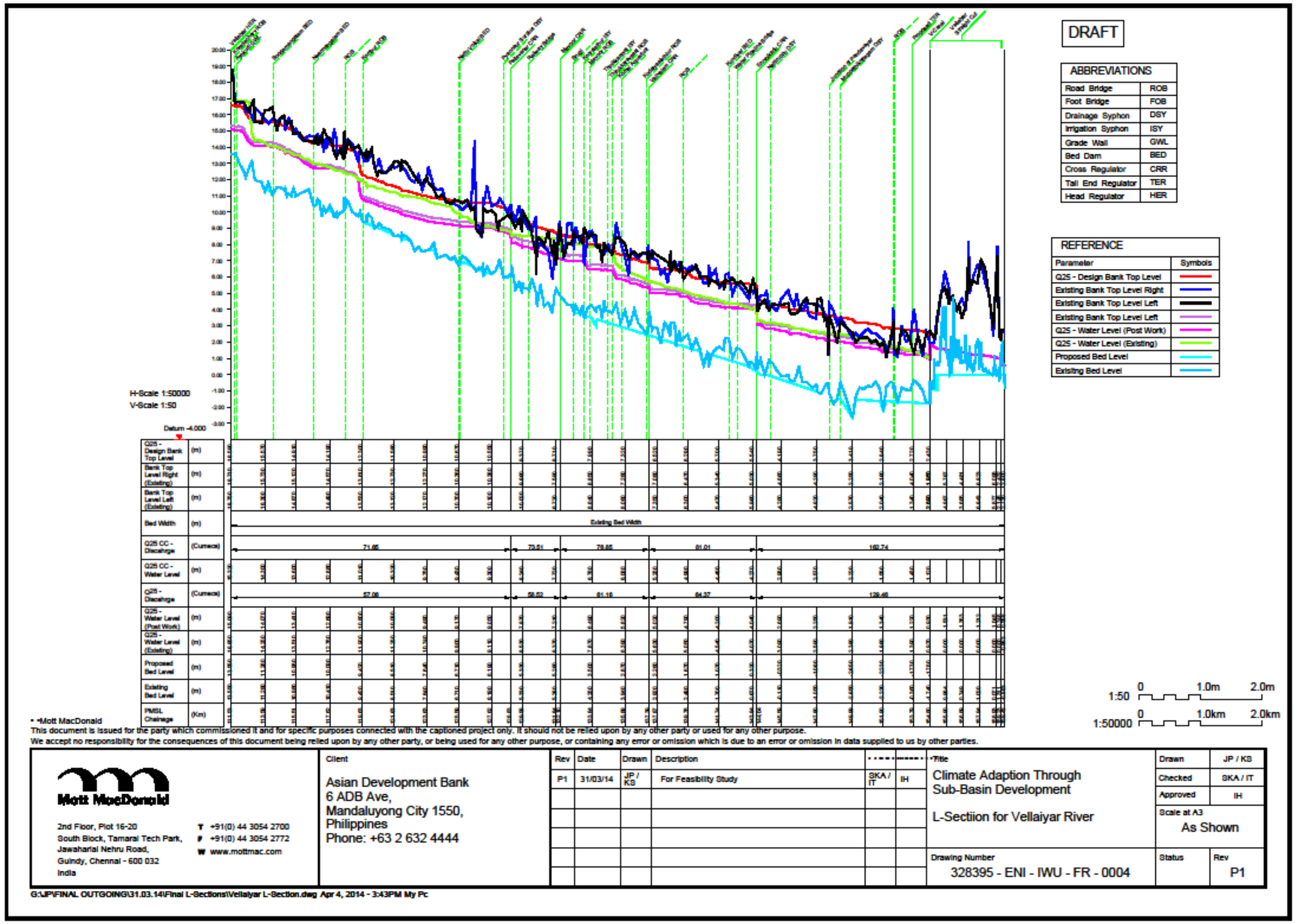


Table 13.15 Design Discharges and Water Levels for Different Floods, Vellaiyar

Scenario	**Name of Structures**		**Vellaiyar HER**	**Pallavanar CRR**	**Mavoor CRR**	**Valivalum CRR**	**Eruvoikadu CRR**	**New TER**
Q25	**Discharge**	(m3/s)	48.46	57.06	58.52	61.16	64.37	129.46
	WL existing	(m)	16.90	8.78	8.33	5.75	3.94	1.39
	WL post Project	(m)	16.34	8.60	7.07	5.36	4.03	1.22
Q25cc	**Discharge**	(m3/s)	60.96	71.65	73.51	76.85	81.01	162.74
	WL existing	(m)	17.22	9.62	8.77	6.05	4.15	1.60
	WL post Project	(m)	16.58	8.90	7.61	5.6	4.26	1.43
Q50	**Discharge**	(m3/s)	56.27	66.33	68.02	71.09	74.91	150.17
	WL existing	(m)	17.10	9.37	8.6	5.94	4.11	1.53
	WL post Project	(m)	16.49	8.78	7.44	5.51	4.22	1.36
Q50cc	**Discharge**	(m3/s)	71.38	83.31	85.52	89.42	94.28	190.27
	WL existing	(m)	17.48	10.14	9.15	6.25	4.24	1.74
	WL post Project	(m)	16.76	9.31	7.98	5.78	4.36	1.57
Q100	**Discharge**	(m3/s)	See Note (1)	See Note (1)	See Note (1)	See Note (1)	See Note (1)	See Note (1)
	WL existing	(m)						
	WL post Project	(m)						
Q100cc	**Discharge**	(m3/s)	See Note (1)	See Note (1)	See Note (1)	See Note (1)	See Note (1)	See Note (1)
	WL existing	(m)						
	WL post Project	(m)						

Note (1): HECRAS Model became unstable at higher flows may in part because several cross sections in the Upper Reaches were much narrower than their neighbours. Without further field survey, it was not possible to refine the model sections further. Hence the results are not given here.

Discussion and Recommendations

The availability of flow records for this river has allowed validation of the assumptions about the SWAT inflows and the bank heights. Furthermore, the simulated water levels at regulators are not inconsistent with WRD observations during the 2008 event. Finally, there is consistency between the areas flooded in 2008 and the locations where the model simulates out-of bank flow. The model can therefore be used with confidence to model the design events and to appraise feasibility options. To improve confidence in the model it is recommended that water level and flow monitoring instruments are installed at the head and tail end regulators and selected mid-regulators. It is important that the design and installation of this equipment conforms to current bets practise. Improving the cross sections upstream of the Erayankudi tail end regulator will give significant improvements in the prediction of water levels upstream of this structure. The availability of a DEM to define the flood plain areas is essential for the accurate mapping of flooded areas and to simulate the movement of water between flood plain storage and the main channel. It is particularly important for the comparison of out-of bank events.

13.3.4.3 Improvements to Structures

The existing component register was prepared in 1928 and has not been updated since then. Hence the structures of the Vellaiyar were surveyed to assess their current condition and identify the need for repair or reconstruction and for new structures. The findings are summarised in Table 13.16 and listed in more detail in Annex 3. Many of the structures on the Vellaiyar are in very poor condition as compared to structures on the Adappar or Harichandra. The lack of regular maintenance due to non availability of funds has resulted in several structures no longer functioning as designed due their dilapidated condition including absence of gates or collapsed barrels.

Table 13.16 : Recommendations for Improving Structures, Vellaiyar River

Name Of Structure	Total Number	Re-constructed	Rehabilitated/ Repaired	New	No work
Regulators (head, cross and tail)	6	2	3	1	0
Irrigation Head Sluice	35	23	12	0	0
Drainage Sluice	13	12	1	0	0
Drainage Infall	6	0	1	4	1
Drainage Syphon	4	2	2	0	0
Irrigation Syphon	0	0	0	0	0
Bed Dam/Grade Wall	7	0	6	1	0
Road bridge	13	0	0	1	12
Foot Bridge	0	0	0	0	0
Railway Bridge	1	0	0	0	1
Aquaduct	1	1	0	0	0
Total	**86**	**40**	**25**	**7**	**14**

One new TER will be provided 9km downstream of the existing Vellaiyar TER.

In addition, 4 new drainage infall sluices will be provided one bed dam/ grade wall. 40 structures will be reconstructed including 23 irrigation head sluices, 12 drainage sluices and 2 drainage syphons. 25 structures will be repaired.

The salient features of design of the major new or reconstructed structures are shown in Table 13.17. Full details of the design are given in Annexure 3.

Table 13.17: Salient Design Features of the New and Reconstructed Regulators, Vellaiyar

Name	Units	Mavoor CRR	Ervaikadu_Existing TER	New TER
Chainage (PWD)	**(km)**	133.78	145.0 km	152.515-km
Design Flood	**(m^3/s)**	67.91	73.41	148.18
U/S River bed Level	**(m)**	4.59	0.2	-1.74
D/S River bed Level	**(m)**	4.29	0.15	-1.8
U/S FSL	**(m)**	7.75	4.32	3.8
D/S FSL	**(m)**	7.49	4.08	3.74
Channel Width	**(m)**	U/S 19 m D/S 28 m	U/S 24 m D/S 27 m	U/S 55 m D/S 75 m
Sill Level	**(m)**	4.73	2.1	0
Clear Waterway	**(m)**	16.2	21	45.5
No. and Size of Vents		6 vents Width = 2.7 m Height = 3.6 m	7 vents Width= 3 m Height = 2.8 m	13 vents Width = 3.5m Height = 4.4 m
Overall Waterway	**(m)**	22.2	28.2	59.9
Total Floor Length	**(m)**	25.17	34.7	44.58
U/S Floor Thickness	**(m)**	0.5	0.5	0.6
D/S Floor Thickness - Range	**(m)**	Variable from 1.01 m to 1.70m	Variable from 1.07 m to 2.07m	Variable from 1.78 m to 2.74 m
Cutoff wall depth U/S	**(m)**	1.65	1.97	2.45
Cutoff wall depth D/S	**(m)**	2.2	2.57	3.37
U/s Protection (CC Blocks)		Thickness = 0.6 m Length = 9 m	Thickness = 0.6 m Length =8 m	Thickness = 0.6 m Length =9 m
U/s Protection (CC Blocks)		Thickness = 0.6 m Length = 9 m	Thickness = 0.6 m Length =10 m	Thickness = 0.6 m Length = 8.5 m

The length of protection walls to be provided on the Vellaiyar is shown in Table 13.18.

Table 13.18: Location of Fluming and River Training Works, Vellaiyar

Chainage (km)		Length of Protection Walls (m)	Type of Protection
From	To		
111.650	120.100	1800	Protection walls
120.100	129.950	1400	
129.950	139.730	1400	
139.730	153.650	800	

13.3.5 Pandavayar River

13.3.5.1 Description of the Pandavayar River

The Pandavayar River takes off from the Vennar River at the Pandavayar Head Regulator at PWD Chainage 109.23 km. The alignment of the Pandavayar River is shown in Figure 13.34.

The Pandavayar River generally follows a well-defined channel with high banks. Sections of the river are overgrown with vegetation and have sand banks.

The Pandavayar is primarily an irrigation channel as there are 49 irrigation head sluices and a total ayacut of 8504 ha. The first drainage infall is at Chainage 132.17 km, 25 km downstream of the Head Regulator. The ayacuts on the right bank drain into the Vellaiyar River.

As part of their strategy to manage flood flows originating between the Grand Anicut and the VVR head regualtor, WRD pass flood flows from the Vennar into the Pandavayar as shown in Figure 13.5. The upper and middles reaches can generally accommodate the flood flow but the lower reaches towards its confluence with the Vellaiyar become flooded (See Figure 13.6).

13.3.5.2 Modelling to Assess Channel Improvements

The Pandavayar model is described in Section 13.3.4.2 as the Pandavayar was modeled as part of the Vellaiyar model.

Feasibility Proposal

As floods are generally contained within the existing Pandavayar channel, the feasibility option considered was regrading and standardizing the embankments to contain flood flows (where required) from the Head Regulator to the Existing TER. Downstream of the TER, there is scope to widen the channel over a short reach before its confluence with the Vellaiyar

The results of the re-grading the channel and standardising the banks are shown in Figure 13.36. The calculated discharges for Q25, Q25 with climate change (CC), Q50 and Q50 CC, and Q100 and Q100 CC and the respective water levels for the existing and post-project channel are shown in Table 13.19. Similar to the Adappar and the Harichandra, Q25 discharges increase by about 25% with climate change and Q25 with climate change is greater than the Q50 without climate change. Water levels increase by about 10 % with climate change.

The Pandavayar joins the Vellaiyar River at Vellaiyar Chainage 149.35 km which is upstream of the coastal regulatory zone.

Figure 13.34 : Long Section of the Pandavayar River

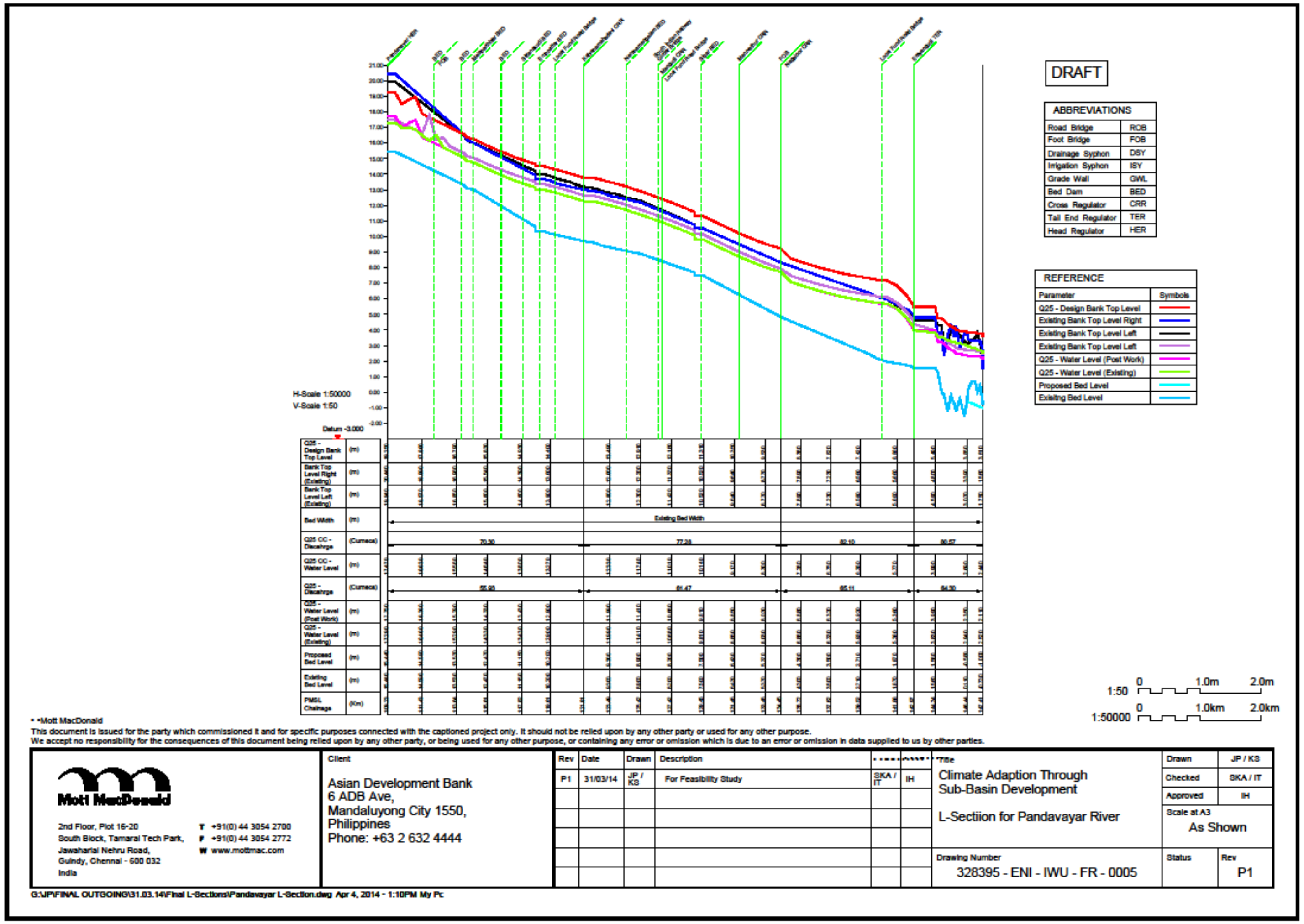


Table 13.19 : Design Discharges and Water Levels for Different Floods, Pandavayar

Scenario	Name of Structures		Pandavayar HER	Kalyanamahadevi CRR	Nagaloor CRR	Erayangudi CRR	Infall in Vellaiyar River
Q25	**Discharge**	**(m^3/s)**	-	55.93	61.47	65.11	64.3
	WL existing	**(m)**	17.29	12.26	7.73	3.99	2.52
	WL post Project	**(m)**	17.75	12.26	7.73	3.99	2.11
Q25cc	**Discharge**	**(m^3/s)**	65.76	70.30	77.28	82.1	80.57
	WL existing	**(m)**	17.47	12.63	7.94	4.59	2.85
	WL post Project	**(m)**	17.47	12.63	7.94	4.39	2.44
Q50	**Discharge**	**(m^3/s)**	60.72	64.92	71.36	75.81	74.4
	WL existing	**(m)**	18.56	12.49	7.87	4.41	2.73
	WL post Project	**(m)**	17.37	12.49	7.87	4.21	2.32
Q50cc	**Discharge**	**(m^3/s)**	77.02	82.29	90.39	96.04	94.5
	WL existing	**(m)**	17.68	12.97	8.32	4.89	3.08
	WL post Project	**(m)**	17.68	12.97	8.31	4.71	2.68
Q100	**Discharge**	**(m^3/s)**	**See Note (1)**	**See Note (1)**	**See Note (1)**	**See Note (1)**	**See Note (1)**
	WL existing	**(m)**					
	WL post Project	**(m)**					
Q100cc	**Discharge**	**(m^3/s)**	**See Note (1)**	**See Note (1)**	**See Note (1)**	**See Note (1)**	**See Note (1)**
	WL existing	**(m)**					
	WL post Project	**(m)**					

Note (1): HECRAS Model became unstable at higher flows, in part because the PWD Cross Sections were at variable spacing and showed a trapezoidal channel section. Without further field survey, it was not possible to refine the model sections further. Hence the results are not given here.

13.3.5.3 Improving Structures

Similar to the Vellaiyar, the component register for the Pandavayar was prepared in 1928 and has not been updated since then. Hence the structures on the Pandavayar were surveyed to assess their current condition and assess the need for repair or reconstruction or new structures. The findings are summarized in Table 13.20 and given in full in Annexure 2.

Table 13.20 : Recommendations for Improving Structures, Pandavayar River

Name Of Structure	Total Number	Re-constructed	Rehabilitated/ repaired	New	No work
Regulators (head, cross and tail)	6	0	6	0	0
Irrigation Head Sluice	49	25	12	0	12
Drainage Sluice and Infall	13	6	2	2	3
Bed dam/grade wall	8	0	6	1	1
Footbridge	6	6	0	0	0
Road bridge	4	0	0	0	4
Railway Bridge	1	0	0	0	1
Total	**86**	**31**	**35**	**3**	**17**

There are no new regulators proposed for the Pandavayar. Two new drainage infalls plus 1 new bed dam/grade wall are proposed. 31 structures will be reconstructed and 35 structures will be repaired.

13.3.6 Valavanar Drain

13.3.6.1 Description of the Valavanar Drain

The zero chainage point for the Valavanar Drain is taken as the downstream side of the Thiruthuraipoondi-Vedharanyam road bridge close to Thiruthuraipoondi town. Upstream of the road bridge, the Valavanar Drain is connected to two smaller drainage channels that are connected to the tail end of two irrigation channels on the left bank of the Mulliyar River as shown in Figure 13.35. The two smaller drainage channels, the Varambiyam and the Thiruthuraipoondi, pass under the Mulliyar River through syphons. A third small drain, the Ariyalur, joins the Valavanar just downstream of the zero chainage point.

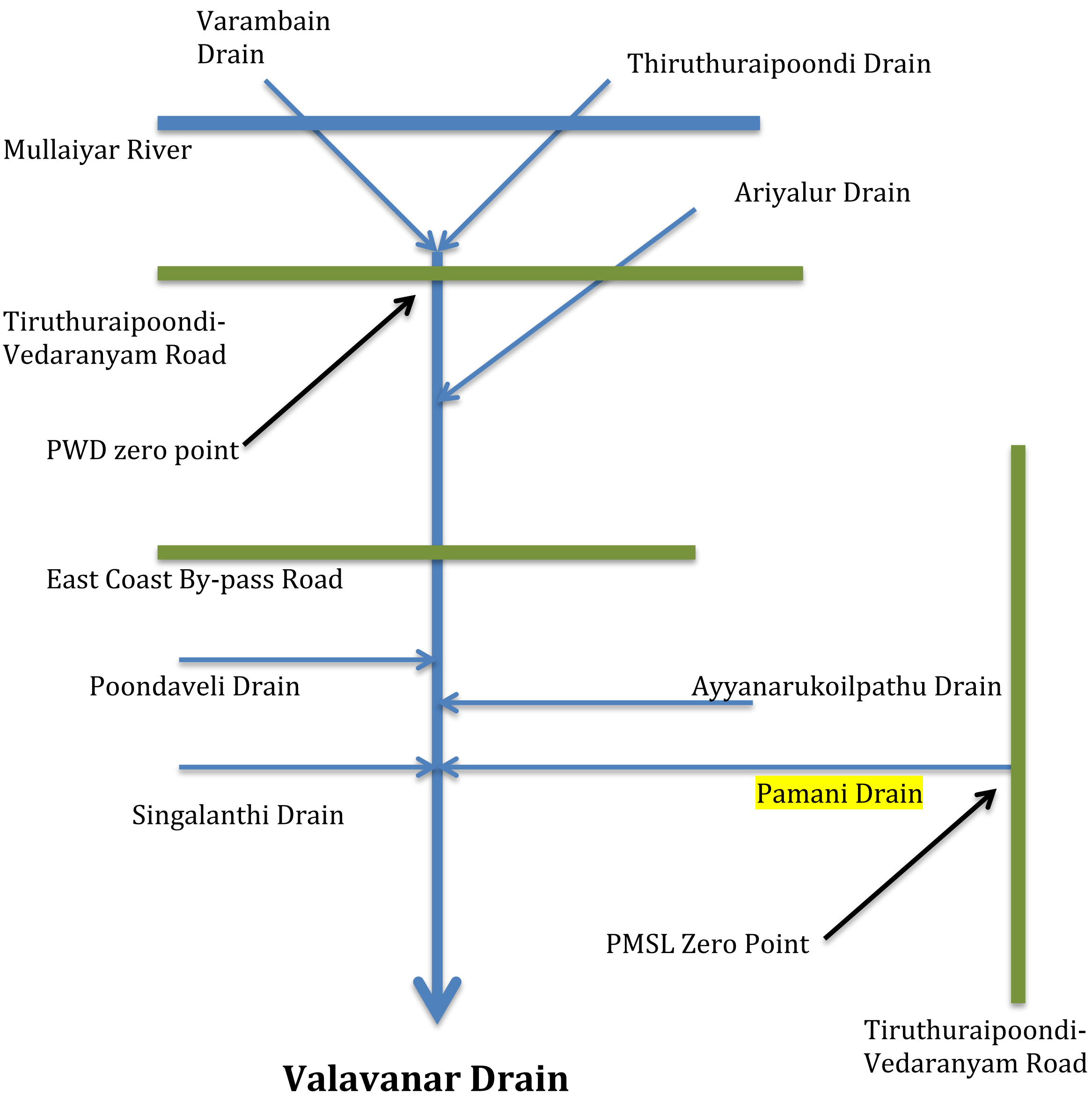
The Valavanar drain passes through low-lying land and drains local run-off plus drainage from irrigation and floodwaters from the Mulliyar River to the north and east and the Koraiyar/ Marakka Koraiyar to the west. The total catchment area for the drain is reportedly 15,977 ha although there is an absence of topographic maps at a suitable scale to verify the catchment area.

The elevation of the land along the Valavanar drain is close to sea level. For example, in the upper reach, the bed level of the drain at the railway bridge (Chainage 2.290 km) is +0.15 m. In the middle reach, the drain is above the level of adjacent land (as shown in Figure 13.38). At the start of the lower reach, the bed level of the bridge at Voimedu (also known as the Karpaganathar-Killam Road Bridge-Structure #54 at Chainage 16.450 km) is -1.13 m.

The drainage channel is well defined along most of its course, and the alignment is generally straight as shown in Figure 13.37. In the upper reach, the bed width increases gradually from about 10 m at the zero point to about 30 m at Chainage +6.570 km. Thereafter, the channel widens to between 80 m and 250+ m until the Thulasiappattinam Road Bridge at Chainage +13.700 km. Along this middle reach, the Pitchankottagam drain with bed width of 40 m runs parallel to the Valavanar drain and collects flows from drainage infalls on the left bank before discharging into the Valavanar at Chainage +13.450 km. The width of the channel reduces to about 80 m or less as it passes through higher sand ridges for about 3 km before widening again to 150 m to 250+ m and discharging to the sea lagoon.

The drain passes through mainly agricultural land that is less productive due to heavy soils, poor drainage and subject to periodic flooding. There are no villages or homesteads close to the drain, except for where the drain passes through the higher sand ridges between Chainage 13.450 and 16.450 km.

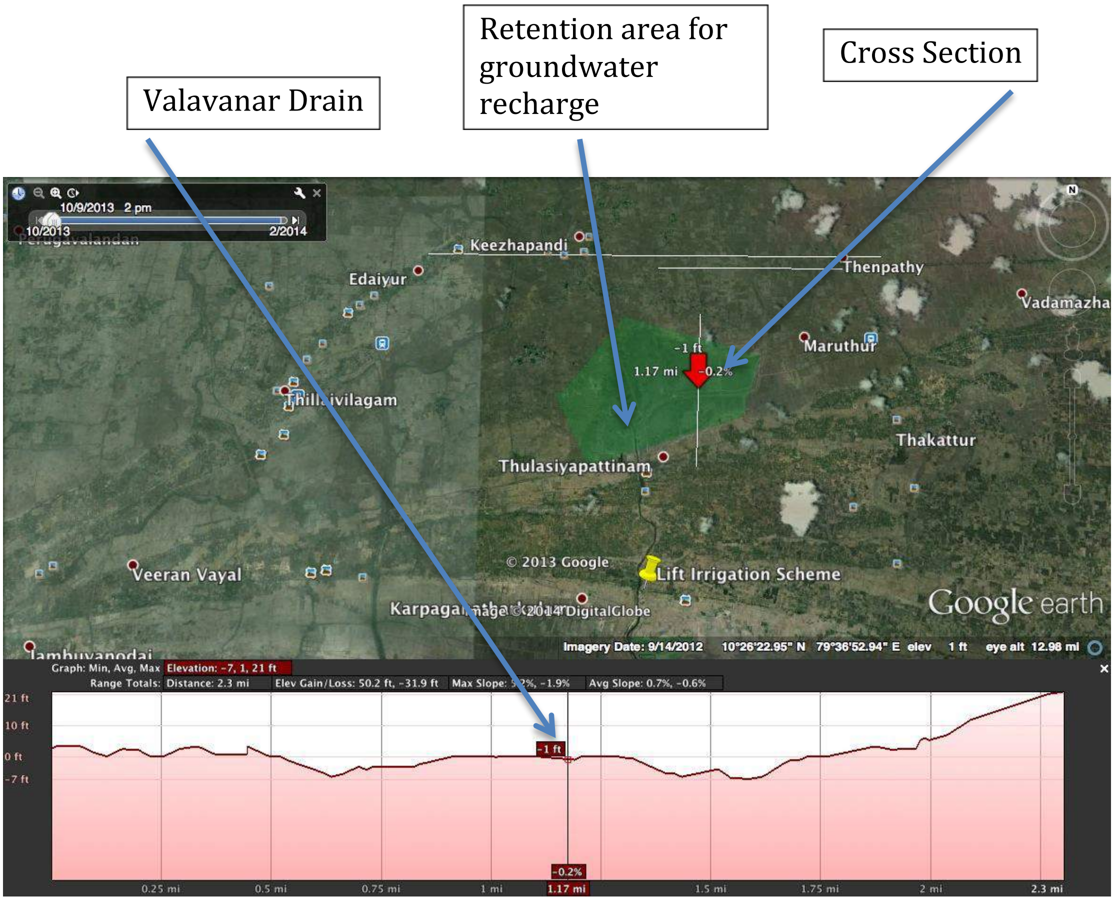
Figure 13.35: Schematic of the Head Reach, Valavanar Drain



The Chainages for features along the Valavanar provided by PWD are different from the Chainages surveyed by PMSL as shown in Table 13.21. PWD take the zero point of the Valavanar Drain as the Thiruthuraipoondi-Vedharanyam road bridge (see Figure 13.35). PMSL took the zero point as the Tiruthuraipoondi-Vedharanyam road bridge across the Pamani Vadikal.

The Chainages were checked by measuring the distance between various features on Google Earth, and the results are also shown in Table 13.21. As the PMSL chainages agreed with Google Earth measurements, the PMSL chainages were used in the design with an adjustment made to start the chainages at the PWD zero point, as shown in Table 13.21.

Figure 13.36: Cross Section of Lower Valavanar Drain at Chainage 11.50 km



There is no component register and a list of structures was prepared following a joint inspection of the drain. There are seven road bridges and one railway bridge crossing the drain. At Chainage 3.130 km, there is a derelict bed dam. There are no cross regulators or irrigation head sluices. Individual farmers pump water from the drain along its length. There are three WRD pumping schemes, the Valavanar, the Karaiyankadu and the Vanduvancheri schemes (located at Chainages 16.420, 13.800 and 13.550 km respectively) that lift water from the Valavanar drain onto the higher land of the sand dunes. The Tail End Regulator is in dilapidated condition and is no longer functional.

There are no flow or water level data for the Valavanar or the drains flowing into it. The existing TER is derelict and has not been used to measure flows for many years. Catchment data is also lacking for most of the drain infalls as shown in Annexure 3. There is anecdotal evidence about flood levels and the extent of flooding during peak events but the absence of data makes analysing floods and designing improvements extremely challenging.

Figure 13.37 : Alignment of the Valavanar Drain

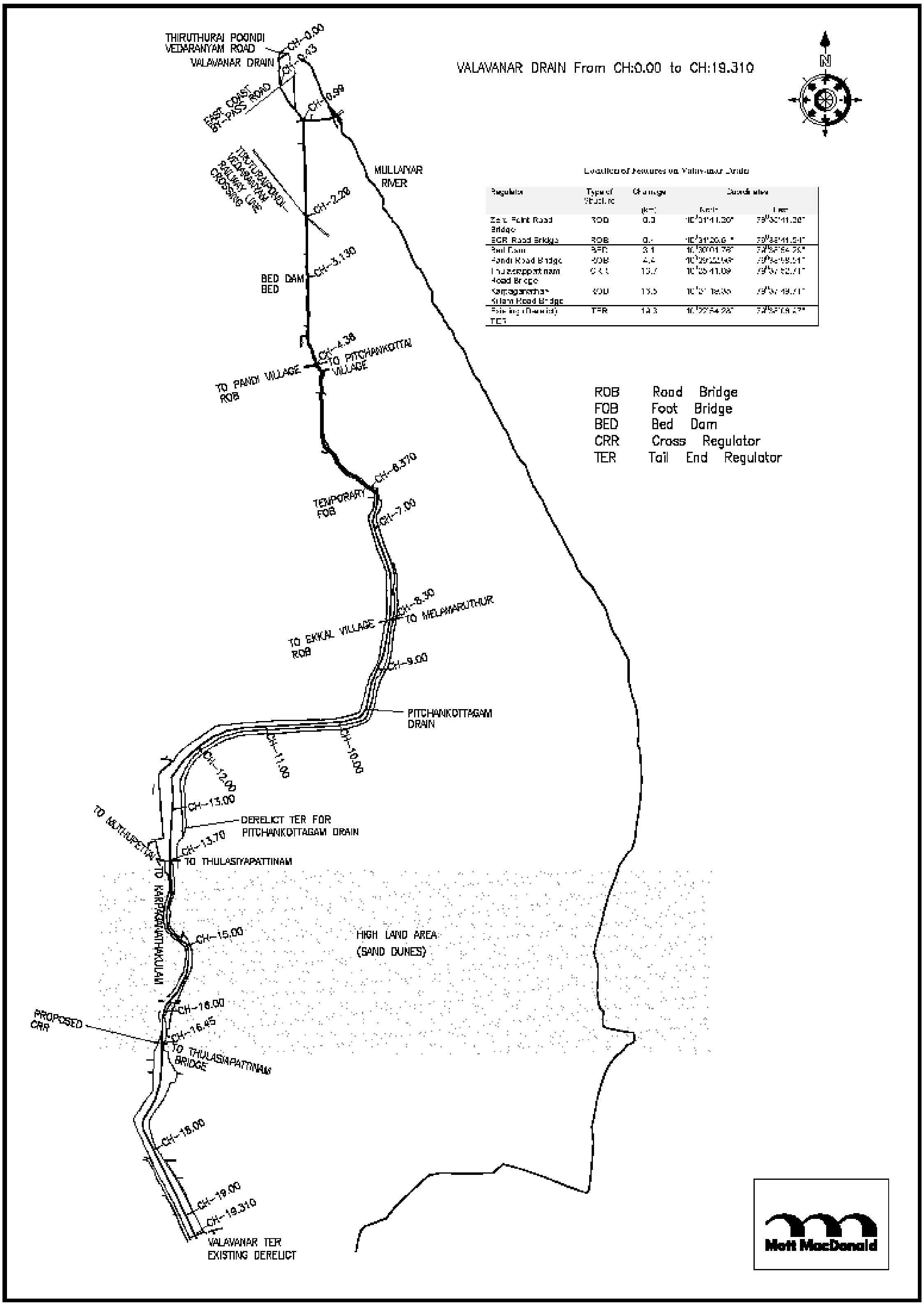


Table 13.21 : Comparison of PWD and PMSL Chainages and Adjustment made to Correct Chainage

Location	**PWD Chainage**	**Distance between points**	**PMSL Chainage (1)**	**Distance between adjacent points**	**Google Earth**	**Distance between adjacent points**	**Adjusted chainage for design and for Component Register (2)**
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
Thiruthuraipoondi-Vedharanyam Road Bridge	0 (Zero point)		See Note (1)		0		0
Ariyalur Drain infall	Not specified				80		
						350	
ECR Road Bridge	210				430		
Pamani Vadikal	480		480		1010		990
		1240		1300		1300	
Railway Bridge	1720		1780		2310		2290
		760				840	
Bed dam	2480		Not specified	2070	3150		3130
		1200				1240	
Pandi Bridge	3680		3850		4390		4380
		1950				1990	
Temporary Footbridge	5630		Not specified	3920	6380		6370
		1830				1890	
Ekkal Road bridge	7460		7770		8270		8300
				5400		5370	
Thulasiappattinam Road Bridge	Not specified		13170		13640		13700
		14540		2750		2764	
Voimedi Road Bridge	Not specified		15920		16404		16450
				2860		2880	
Existing (derelict) TER	22000		18780		19284		19310

(1) PMSL Chainage starts from bridge on Thiruthuraipoondi-Vedharanyam Road across Pamani Vadikal
(2) Component Register for Valavanar Drain is given in Annex 2

13.3.6.2 Channel Modelling

Model Domain

A HEC-RAS model has been developed for the Valavanar Drain. The model extends from the bridge on the Thiruthuraipoondi-Vedharanyam road to the derelict tail end regulator (TER). WRD take the road bridge as the zero point for the Valavanar Drain. The three channels that connect to the head reach of the Valavanar drain (Varambian, Thiruraipoondi and Ariyalur) were not surveyed by PMSL and have not been included in the HEC-RAS model. The drainage from surrounding land is derived from the results of SWAT modelling and is allocated to the appropriate reach of the river based on the SWAT rainfall catchments. The flows are assumed to be distributed uniformly along each reach. There are no flow data for any of the channels and no flow measurement at the head of the Valavanar Drain. There is anecdotal information on the water levels at the bridges and hence bridges are included in the model as well as the dilapidated tail end regulator, as listed in Table 13.22.

Table 13.22: Structures included in the Valavanar HEC-RAS model

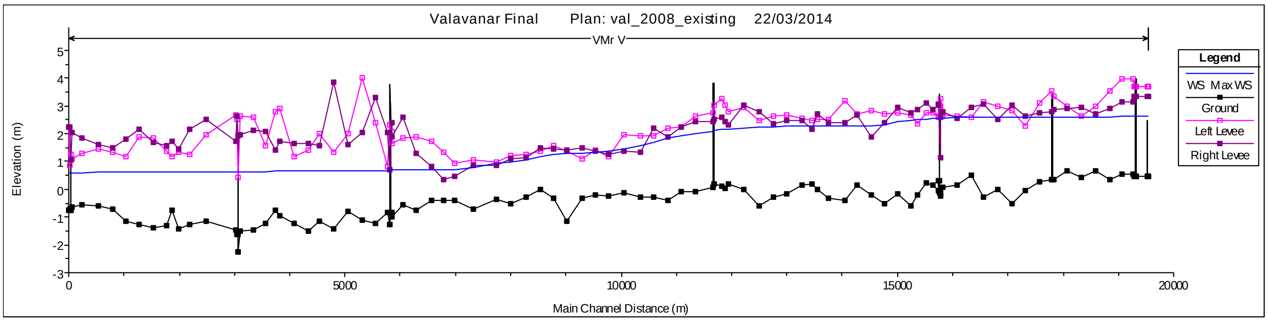
River	Structure
Valavanar	Thiruthuraipoondi-Vedharanyam Road Bridge
Valavanar	East Coastal Road Bridge
Valavanar	Thiritharapundi Railway Bridge
Valavanar	Pandi Bridge
Valavanar	Ekkal Road Bridge
Valavanar	Thulasiappattinam Road Bridge
Valavanar	Voimedi Road Bridge

The PMSL survey starts where the Thiruthuraipoondi-Vedharanyam road crosses the Pamini Voikkal drain. PMSL took the Pamini Voikkal drain to be the main Valavanar channel. In the absence of surveyed cross sections of the upper reach of the Valavanar drain, it was assumed that the cross section and bed slope of the initial 990 m reach of the Valavanar drain upstream of its junction with the Pamini Voikul drain can be approximated by using the PMSL cross sections of the Pamini Voikul drain as the two drains have similar bed widths.

Validation

There are no flow or water level records for the Valavanar drain. Anecdotal information from WRD indicates that the area around the drain was inundated in 2008 although the bridges were not surcharged. Furthermore the tail end regulator was overtopped with substantial flow by-passing the structure. The 2008 flood map shows that there was left and right bank flooding between Pandi Bridge and Ekkal Road Bridge.(see Figure 13.37) The carrying capacity of the tail end regulator with gates fully opened is of the order of $50m^3$/sec. But reportedly the water depth is more than the opening size and the regulator is outflanked almost every year). Thus the total flow may have been almost double of the calculated capacity. SWAT simulated flows were used to represent drainage that enters the river between the zero point bridge and the tail end regulator. Given the anecdotal evidence that areas draining to the river exceed the natural watershed, the SWAT inflows were increased by 20%. Roughness values (Manning's n) were set at 0.20 for out of channel flow and 0.08 for in channel flow. These high roughness values reflect the high degree of vegetation and relatively poor state of the channel. The simulated water levels for the 2008 event are shown in Figure 13.38. The results show that the water level does not exceed the bridge invert levels but does exceed the tail end regulator crest. Furthermore significant out-of bank flow is simulated upstream of the Thulasiappattinam Road Bridge.

Figure 13.38 : The 2008 simulated long profile for the Valavanar River



Results

The results are reasonably consistent with the 2008 flood map (see Figure 13.6) for the upper reach and indicate that the assumed inflows are acceptable given the lack of flow and level data. Furthermore the simulation confirms that the 2008 flow was greater than the channel capacity but that the bridges were not over-topped. However, the model does not represent flows in the middle reach downstream of about Chainage 12000 (on Figure 13.38) very well as the drain enters a low-lying depression to which there is considerable overbank flow. Local people report that during floods the whole low-lying area fills with water and takes several weeks to drain out via the downstream channel through the sand dunes (between Chainage 3000 to 6000), the maximum carrying capacity of which is about 40-50 m^3/s. Thus the low-lying area performs as a retention basin that reduces downstream flows. As the bed slope is almost flat, flood flow is driven slowly by the water level gradient which is very shallow due the extent of lateral spreading of water in the depression, even with high inflows from the upper catchment.

The model was run for the 25 and 50-year flood events and the results showed that there is almost no change in water level. This is because for all return periods the water level exceeds the bank level at several locations such that the main channel flow is the same for each scenario. The same results were noted when the model was run for the 25, 50 and 100 year events with allowance for climate change.

Feasibility Proposal

The options to mitigate floods are constrained by:

- The absence of flow or water level data for flood or normal events in the Valavanar Drain throughout its length or entering the head reaches.
- In the upper reach from the zero chainage point to about Chainage +6.370 km, contrary to initial information, WRD said that government land is available adjacent to the drain so standardisation of the banks was possible along the length of the drain..
- Bed slopes of the drain are almost flat (0.0013 % or less).

The design proposals considered were the standardisation of the banks and improvement of the hydraulic performance of the channel by smoothing the channel sides and bed and removing sand bars and vegetation that impeded flow. The impact of the proposals on water levels and flows are shown in Table 13.23 and Figure 13.39.

Discussion and Recommendations

The lack of flow and water level records for the Valavanar Drain has restricted validation to a comparison between the simulated water levels, anecdotal information from WRD and a comparison with the 2008 flood map. The model results are reasonably consistent with these sources of information for the upper reaches and the model could be used to assess the impact of alternative design scenarios. The bridges do have sufficient capacity to pass the design flows. .

Figure 13.39: Long Section of the Valavanar Drain

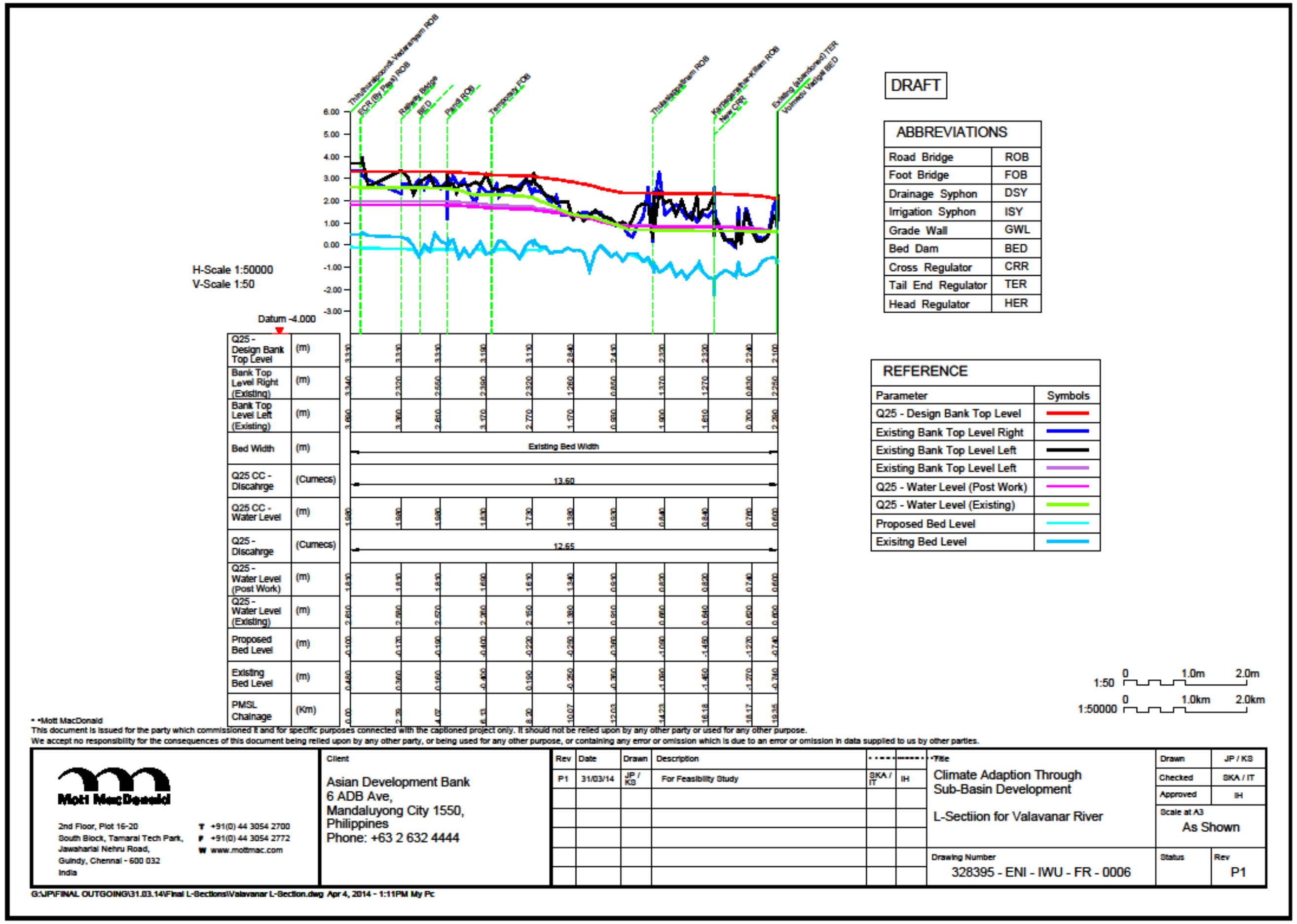


Table 13.23 : Design Discharges and Water Levels for Different Floods, Valavanar

Scenario	Name of Structures		Thiruthuraipoondi-Vedharanyam ROB (PWD Zero Point)	Railway Bridge-	Ekkal ROB	New CRR (see Note 1)
Q25	**Discharge**	**(m^3/s)**	1.43	1.42	70	
	WL existing	**(m)**	2.61	2.58	2.13	
	WL post Project	**(m)**	1.81	1.81	1.59	
Q25cc	**Discharge**	**(m^3/s)**	1.43	1.41	88.27	
	WL existing	**(m)**				
	WL post Project	**(m)**	1.98	1.98	1.71	
Q50	**Discharge**	**(m^3/s)**	1.43	1.42	80.95	
	WL existing	**(m)**	2.64	2.61	2.18	
	WL post Project	**(m)**	1.92	1.92	1.67	
Q50cc	**Discharge**	**(m^3/s)**	1.43	1.42	100.83	
	WL existing	**(m)**	2.67	2.65	2.26	
	WL post Project	**(m)**	2.09	2.09	1.78	

Note (1) the model worked well for the upper reaches of the drain. In the lower reaches there is considerable out of bank flow into the depression around the drain and the model results are less reliable.

13.3.6.3 Improving Structures

In the absence of a component register, the structures on the Valavanar Drain were surveyed to assess their current condition and assess the need for repair or reconstruction or new structures. The findings are summarized in Table 13.24 and full details are given in Annexure 2.

Table 13.24: Existing and Proposed Structures and Channel Features, Valavanar

Feature	Total	Remarks
Open Infalls	44	See discussion below - Box Culvert 2 Nos , Drainage Inlets 7 Nos & Infall Bridge 1 No Proposed
Bridges	7	No work proposed
Footbridges	1	No work proposed
Bed Dam	2	1 Needs reconstruction
Cross Regulator	1	New Structure at Chainage 16.45 Km Proposed in Project -2
Tail End Regulator	1	Derelict for over a decade. Design provided for replacement TER for construction

Several feasibility proposals were considered:

- **Access to the drain for maintenance**. The approach to improving the rivers taken up by CASDP is to provide access on both sides of channels to facilitate maintenance. At present, there is no road access along the Valavanar drain . The existing drain embankments are about 1 m wide and passage along the embankments is interrupted by the numerous drainage infalls shown in Table 13.24. As the embankment top is below flood level, a significant increase in the size of the embankment is required to provide the standard 5 m wide access road plus a freeboard of 1.5 m. In addition, up to 44 structures would be required at the drainage infalls. WRD report that government land is available either side of the drain to construct standardised embankments. Hence road access will be provided along the drain.

In the lower reach below Chainage 6.370 km, there is scope to provide road access along the Valavanar Drain by standardizing the embankment between the Pitchankottagam Drain and the Valavanar drain. The land within the drains is government land. The embankment could be formed with material taken from the channel smoothing. Structures would not be required except at the downstream end where the Pitchankottagam Drain infalls into the Valavanar (at the location of the existing derelict regulator) as Pitchankottagam Drain was constructed to serve as a collector drain for the left bank infalls. A road crossing would be provided at this location. At its head, the Pitchankottagam Drain is not connected to the Valavanar.

- **Bed Dam** - There is an existing bad dam located at Chainage 3.130 km and the structure should be re-constructed. In addition to storing water for irrigation, the structure should be designed and monitored to measure flows in the upper reach of the drain.

- **Tail End Regulator (TER)** - The existing Valavanar TER has been derelict for over a decade, but there is local demand to reconstruct it or provide a new TER close by in order to restore about 500 ha of lost irrigation area. The salient features of the replacement TER are given in Table 13.25.

Table 13.25 : Salient Features of Reconstruction of Tailend Regulator of Valavanar Drain

Name	Units	Replacement TER
Chainage (Adjusted Chainage)	(km)	19.284
Design Flood	(m3/s)	50
U/S River bed Level	(m)	-0.80
D/S River bed Level	(m)	-0.90
U/S FSL	(m)	0.69
D/S FSL	(m)	0.66
Channel Width	(m)	U/S 190 m D/S 320 m
Sill Level	(m)	-0.65
Clear Waterway	(m)	63.0
No. and Size of Vents		15 vents Width= 4.2 m Height = 1.94 m
Overall Waterway	(m)	79.8
Total Floor Length	(m)	12.69
U/S Floor Thickness	(m)	0.6
D/S Floor Thickness - Range	(m)	Variable from
Cutoff wall depth U/S	(m)	1.10
Cutoff wall depth D/S	(m)	1.38
U/s Protection (CC Blocks)		Thickness = 0.6 m Length = 4.0 m
U/s Protection (CC Blocks)		Thickness 0.9 m Length = 5.0 m

13.3.7 Vedharanyam Canal

13.3.7.1 Description of the Vedharanyam Canal

The Vedharanyam canal runs parallel to the coastline of the Bay of Bengal and is located about 3-8 km inland. Between the canal and the sea, there are sand ridges that are 2-3 m higher than the canal.

The canal was excavated between 1863 and 1867 for inland navigation and is connected to the sea at Nagapattinam in the north, Vailankanni in the middle and at Thopputharai in the south. The length of the canal is 57 km between Nagapattinam and Thopputhurai and 44 km between Vailankanni and Thopputhurai. The canal reach from between Vailankanni and Thopputhurai was considered under this Project.

The canal was constructed for inland water transport, specifically for carrying salt from Vedharanyam to Nagapattinam port. With the subsequent development of railways and roads, the importance of the canal declined until eventually it became redundant for navigation.

The canal now functions as a drainage carrier for eastward flowing rivers of the Vennar System, including four of this Project rivers, the Pandavayar, Vellaiyar, Harichandra and Adappar Rivers. The canal intersects these rivers and also connects a number of remnant sea lagoons. The canal was not designed as a drainage carrier, and in some reaches, particularly between the Vellaiyar and the Harichandra/Adappar rivers, the top width of the canal is 20-50 m as compared to top widths of 100-300 m in the reaches north of the Vellaiyar River and south of the Adappar straight cut.

In the 1960's, the following five straight cuts were constructed to facilitate the drainage of flood flows from the canal and lagoons to the sea:

- Harichandra (also known as the Lawford Straight Cut)
- Adappar
- Chakkliyan Voikal
- Vellaiyar
- Nallar

The straight cuts are now affected by siltation to varying degrees. They all have sand bars across their outfalls to the sea, caused by the deposition of coastal sediment by longshore drift. The channels of the Harichandra and Adappar straight cuts are open while the channels of the Nallar, Vellaiyar, and Chakkliyan Voikal straight cuts are heavily silted and carry no tidal flows.

The origin of the other two outlets from the Vedharanyam Canal to the sea, the Vellaiyar Old Course at Vailankanni in the north and the Uppanar Drain (or Vedharanyam River Old Course) close to Vedharanyam town in the south is less certain. Both are well established channels. The Vellaiyar Old Course may have been the natural outlet of the Vellaiyar River. The meandering alignment of the Vedharanyam Canal upstream of the Uppanar drain suggests that this reach was also natural channel with the Uppanar Drain being the sea outlet. There is a straight cut in the Uppanar Channel to the sea that shortens the length of the channel from about 2.9 km to 1.4 km. At the coastal outlet, a spit is growing on the northern bank and erosion is occurring on the southern bank indicating that the outlet is migrating southwards.

The coastal and riverine processes are in competition along the Vedharanyam Canal and its straight cuts and outlets. For most of the year, the tail end regulators are closed and there is no regular riverine flow in Vedharanyam canal and the canal acts as a tidal channel. However when there are fluvial floods, the TERs are opened and flood flows reach the canal, but flows from the canal to the sea are constrained by the diurnal tidal cycle and the low tide range (approximately +0.3 to -0.3 m).

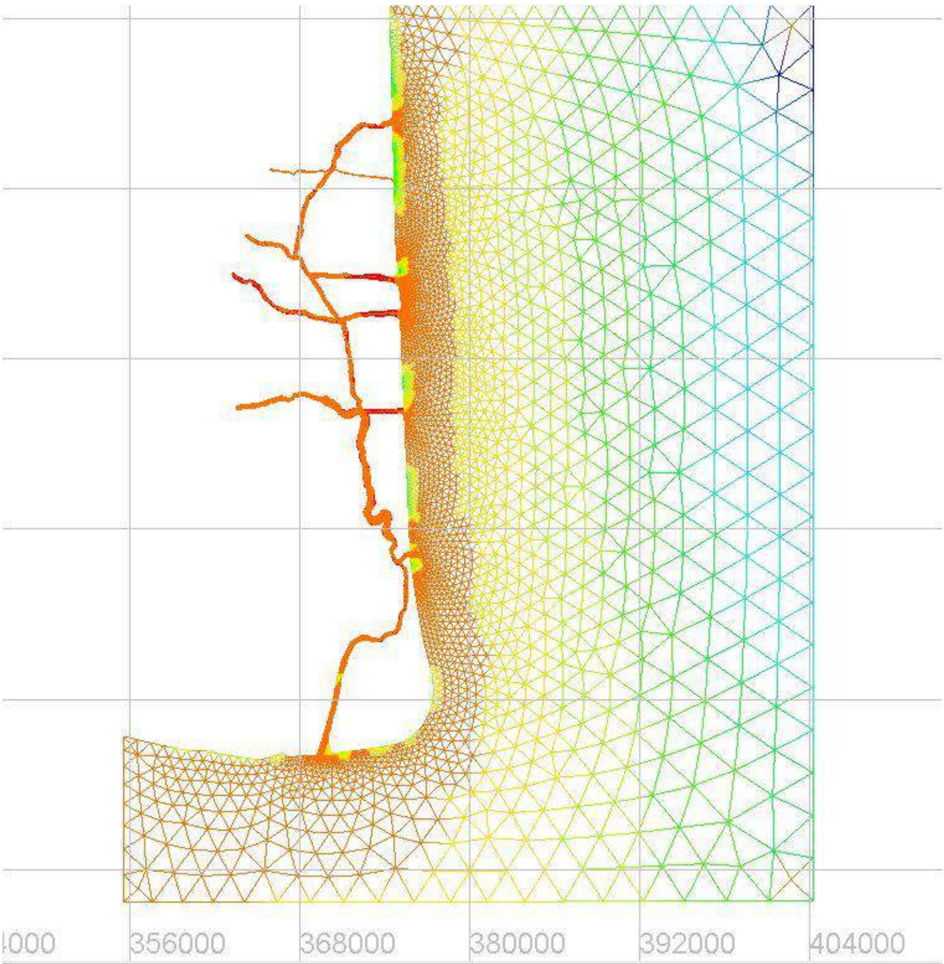
PWD take zero chainage point for the Vedharanyam Canal as the junction of the Vedharanyam Canal and the Kaduvayar River. The junction is about 4 km south-west of Nagapattinam Port. PMSL started their Chainage from the outfall of the Vellaiyar Old Course to the sea, adjacent to Vailankanni Town. Based on PWD chainages, the length of the canal is 55.7 km. After adjusting the PMSL Chainage to start at the PWD zero point, the length of the canal from the PMSL Survey is 52.7 km.

The alignment of the Vedharanyam Canal is shown in Figure 13.43.

13.3.7.2 Modelling to Assess Improvements in the Vedharanyam Canal

Flows and water levels in the Vedharanyam Canal were modelled using the TELEMAC2D model. The grid and length of rivers used for the model are shown in Figure 13.40.

Figure 13.40 : Network for Telemac 2D Model and layout of Vedharanyam Canal including Straight Cuts



The main flow outlets for the canal are the Vellaiyar Old Course in the north and Uppanar Drain in the south. The model was extended in the south to include the southern reach of the Vedharanyam Canal to the salt flats. The Vellaiyar, Chakklan Voikal, Harichandra and Adappar straight cuts were also included, along with the lower reaches of the Harichandra, Adappar, Chakklan Voikal and Vellaiyar rivers. Inflows to the model were taken as the flows from Harichandra, Adappar and Vellaiyar rivers as determined from the respective HECRAS models. There are no flow data for the Chakklan Voikal Drain and the river was not modeled so its flows were not included. The Chakklan Voikal Drain has a much smaller catchment than the other 3 rivers and hence its omission should not influence the results.

Validation

It was not possible to validate the model as there are no flow or water level data.

Feasibility Options

Feasibility options were analysed as follows:

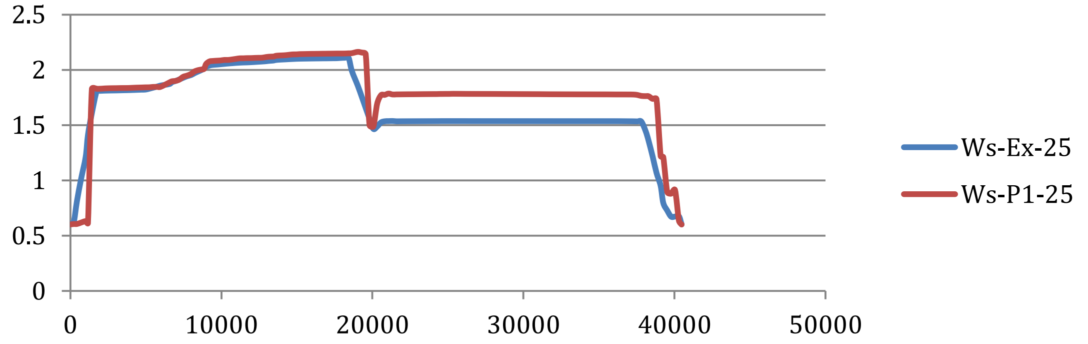
- Existing condition
- Dredging of the Vedharanyam Canal and three straight cuts

The dredging was limited to a channel width of 20 m and a minimum bed level of 0.0 m (sea level) on the basis that deepening the canal below sea level would lead to additional ingress of seawater and hence should be avoided. There is a clear partition of flow towards the north and towards the south at about Chainage 20 km just south of the junction of the Vedharanyam Canal and the Harichandra/ Lawford Straight Cut. The results of the modelling are discussed for each component below:

Vedharanyam Canal

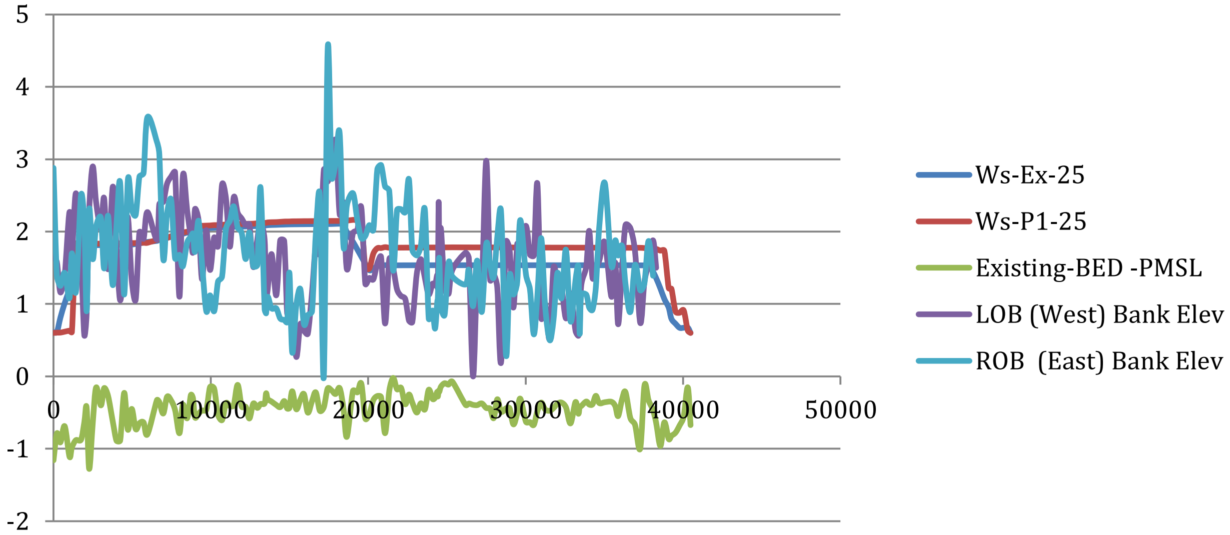
The impact of dredging on the Vedharanyam Canal is shown in Figure 13.41 (Water Surface only) and Figure 13.42 (Water Surface plus Right and Left Bank Levels and bed levels).

Figure 13.41: Impact of Dredging to 0.0 m (sea level) and 20 m bed width along the Vedharanyam Canal



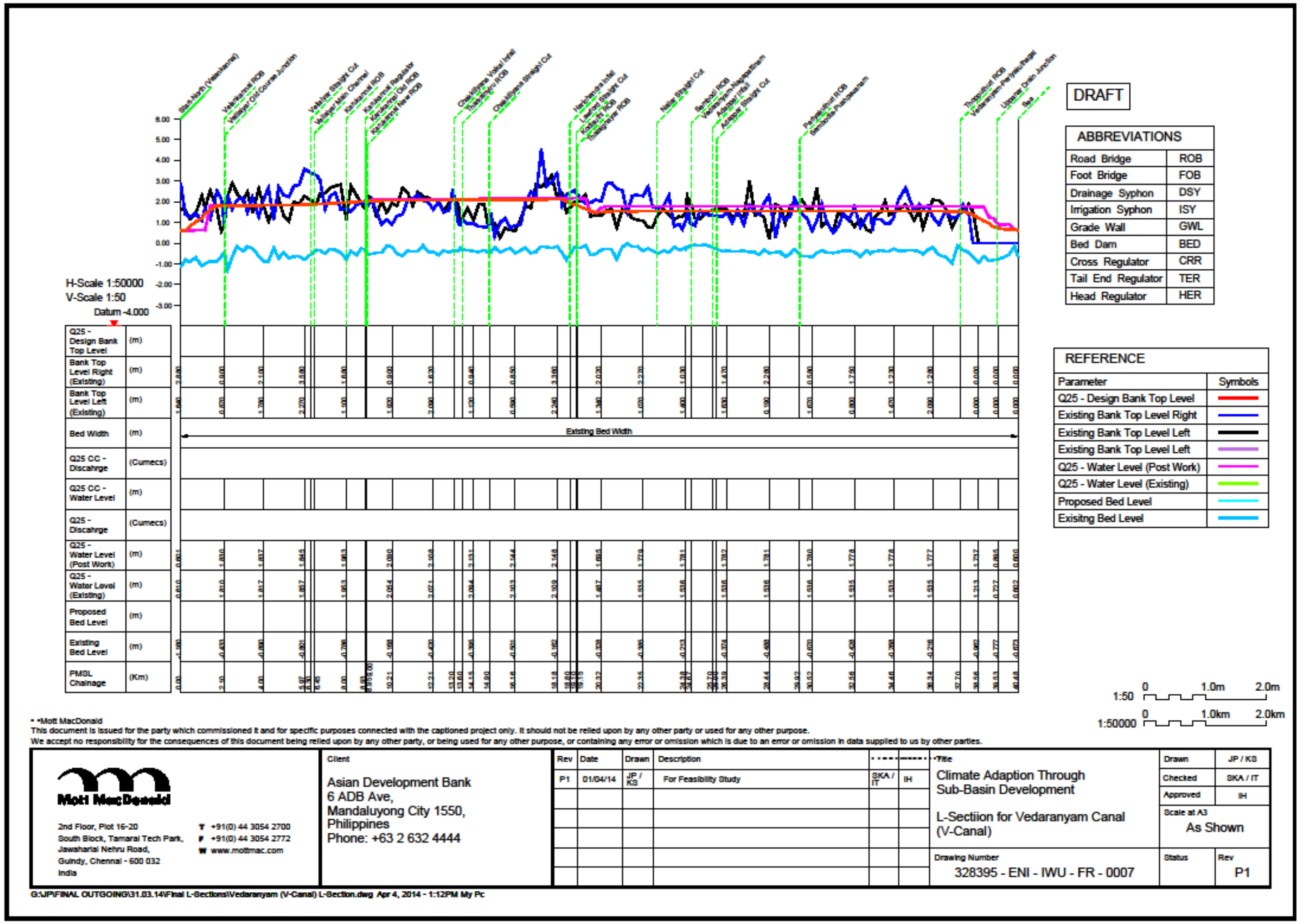
Note: WS-Ex-25 shows water surface for Q25 under existing conditions (blue colour) and WS-P1-25 shows water surface for Q25 under proposed conditions (dredging) (red colour)

Figure 13.42: Impact of Dredging to 0.0 m (sea level) and 20 m bed width along the Vedharanyam Canal



The results show the dredging has no impact north (upstream) of Model Chainage 20000 (approximately the junction of the Vedharanyam Canal and the Harichandra) and increases the flood levels downstream. The latter is caused by increased ingress of seawater into the canal during the tidal cycle resulting from lowering the bed levels of the canal. Flood flows are higher towards the north as the Harichandra and Vellaiyar enter the northern reach. As dredging has no impact on the northern reach and a negative impact in the southern reach and dredging of the Vedharanyam Canal provide no technical benefits. The long-section of the Vedharanyam Canal is shown in Figure 13.43.

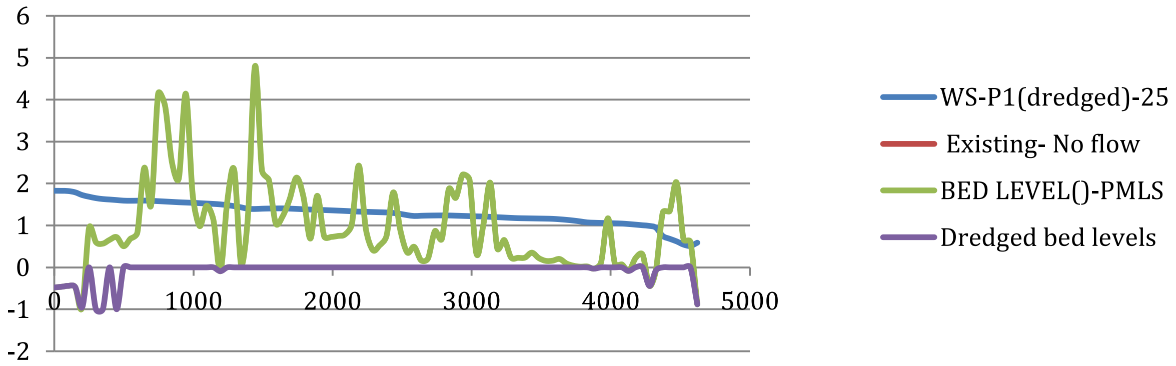
Figure 13.43: Long Section of the Vedharanyam Canal



Vellaiyar Straight Cut

The impact of dredging on the Vellaiyar Straight Cut is shown in Figure 13.44.

Figure 13.44: Impact of Dredging to 0.0 m (sea level) and 20 m bed width along the Vellaiyar Straight Cut



There is no flow under existing conditions as the straight cut is heavily silted, to the extent that the existing bed level (green line on Figure 13.44) is above peak flood water level in the Vedharanyam Canal.

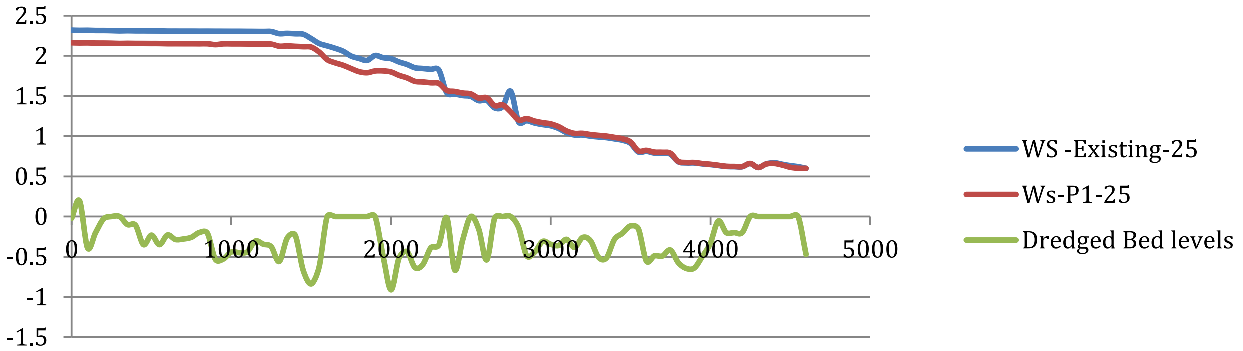
The dredged straight cut allows flows to pass from the canal to the sea,. As with the Vedharanyam Canal, dredging has been limited to 0.0 m (sea level) as below this level, seawater ingress will be greater especially under normal conditions.

Conclusion: Dredging opens up the Vellaiyar straight cut to carry flood flows and reduces peak flood water levels in the Vedharanyam Canal and hence dredging of the Vellaiyar Straight Cut has technical benefits.

Harichandra/Lawford Straight Cut

The impact of dredging on the Lawford Straight Cut is shown in Figure 13.45.

Figure 13.45: Impact of Dredging to 0.0 m (sea level) along the Lawford Straight Cut



Note: WS-Existing-25 shows water surface for Q25 under existing conditions (blue colour) and WS-P1-25 shows water surface for Q25 under proposed conditions (dredging) (red colour)

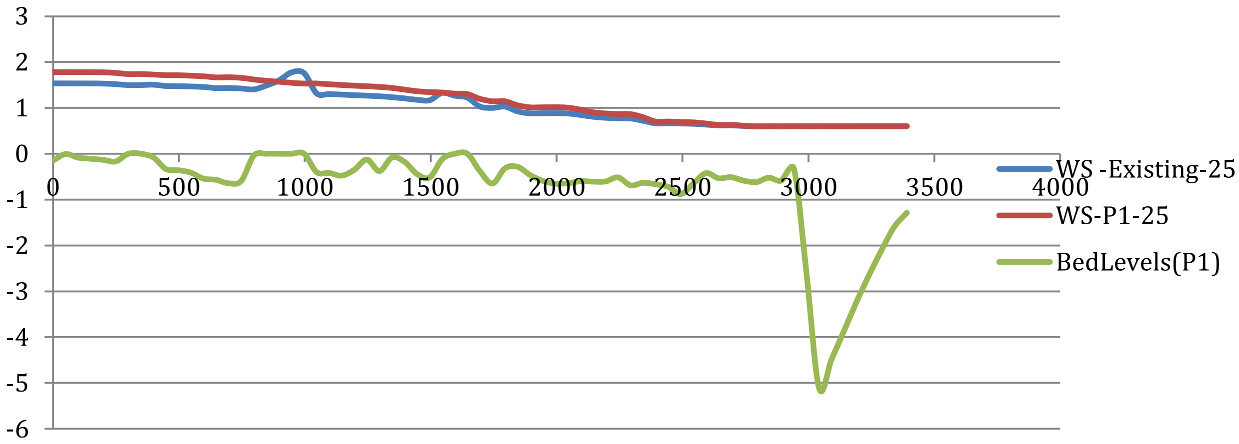
Dredging has no impact on water levels in the lower reach of the straight cut (from about Chainage 2500 to 5000) as the existing bed level is about sea level (0.0 m). From Chainage 0 to 2500, dredging reduces water levels by about 0.25m.

Conclusion: Dredging of the Lawford Straight Cut reduces peak flood water levels in the Vedharanyam Canal.

Adappar Straight Cut

The impact of dredging on the Adappar Straight Cut is shown in Figure 13.46.

Figure 13.46 : Impact of Dredging to 0.0 m (sea level) along the Adappar Straight Cut



Dredging has minimal impact on water levels in the lower reach of the straight cut (from about Chainage 1500 to 3400) as the existing bed level is below sea level (0.0 m). From Chainage 0 to 1500, dredging slightly increases water levels during floods. The increase in water levels may arise from tidal flows in the southern Vedharanyam Canal having greater influence. At higher flows the influence of tidal flows will be reduced and, water levels will fall with dredging.

Conclusion**:** Dredging of the Adappar Straight Cut has a small impact on peak flood water levels in the Vedharanyam Canal that may increase positively with higher flows or different tidal conditions. The recommendation is for dredging of the Adappar Straight Cut.

Uppanar Drain (Old Vedharanyam Course)

The channel width of the Uppanar Drain is generally at least 50-70m wide. The impact of the dredging is shown on the right side of Figures 13.41 and 13.42, for Chainages in excess of 40000.

Conclusion: Dredging of the Uppanar Drain will reduce peak flood water levels in the Vedharanyam Canal, Ingress of sea water into the canal may be affected slightly as the bed levels in the drain are already at +0.0 or lower. The recommendation is for dredging of the Uppanar Drain and the reach of the Canal from the Uppanar Drain to the Thopputharai Road Bridge (Vedharanayam-Periyakuthagai) at PWD Chainage 44.335 km.

Southern Reach of the Vedharanyam Canal

The Vedharanyam Canal south from the Uppanar Drain (PWD Chainage 46.60 km) to the Salt Pans (PWD Chainage 57.70 km) has no outlet to the southern sea lagoons as the channel is completely silted and embankments have been constructed across the channel in several locations to prevent the ingress of seawater. Hence there is no southern flow exit for the Vedharanyam Canal and hence dredging the southern reach would not contribute to reducing peak flood water levels in the Vedharanyam Canal.

Standardized Canal Embankments : The initial proposal was for right embankment (on the western or inland side) of the canal to be standardized to allow road access from PWD Chainage 18.5 km to the PWD Chainage 31.200 km. The top of the embankment was to be designed for the design water level (Q25) plus 1.5 m freeboard. The benefits of the standardized embankment include:

- Providing protection to the land on the west side from tidal surges and high tides,
- Providing access along the Canal for operation and maintenance.

13.3.7.3 Improving Structures on the Vedharanyam Canal

There is no component register for the Vedharanyam Canal. Based on the PMSL survey and PWD’s flow schematic and field visits, the structures were surveyed and assessed to determine if the requirements were for reconstruction, repair or new structures. A summary of the structures and their requirements is shown in Table 13.26 and the full list of structures is given in Annexure 2.

Table 13.26 : Summary of Structures on the Vedharanyam Drain

Summary	Total	Reconstruction	Repair	New	No Work
Drainage Sluice (DRS)	13	7	0	0	6
Drainage Open infalls	10	0	0	1	9
Irrigation Syphons (IRS)	2	1	0	0	1
Bridges road ROB)	21	0	0	0	21
Footbridges (FOB)	3	0	0	0	3
Other structures	2	0	0	0	2
Total	**51**	**8**	**0**	**1**	**42**

There are 21 bridges across the Vedharanyam Canal and only one regulating structure, the lock at Karunkannai (PMSL Chainage 8.930 km). The lock is derelict and has not functioned for many years. Reportedly the lock was used to collect tolls from boats using the canal and may also have been used to regulate north-south flows in the canal as the lock can hold up to 2.4 m of water on one side during the north east monsoon (CMP 2008).

Several of the road bridges have been constructed with very little headroom above the high tide water level in the canal, and, where this is the case, the bridge decks would need to be raised before navigation was again possible.

Six drainage sluices and one irrigation syphon will be reconstructed in the middle reach. One new drainage infall will be provided.

13.4 Surface Water Pumping Schemes

13.4.1 Description of Pumping Schemes

Within the Vennar System, there are 26 functioning pumping schemes that irrigate elevated land that cannot be irrigated by gravity directly from the canal system. Most of the pumping schemes take water from the tail end of drains, although a few take irrigation water from rivers. The schemes provided irrigation to 8,805 hectares (21,757 acres) and resulted in an estimated additional production of 16,544 tonnes of food grains. Presently the schemes irrigate 4,973 hectares (12,289 acres) only, or 56% of the total design command area.

A typical scheme comprises of an intake channel leading to the sump of the pump house, electrically operated pumps, and a main distribution channel and canal network downstream to supply water to the fields. In addition, there is an electrical sub-station and staff quarters. The pumping schemes are listed in Table 13.27 and their location shown in Figure 13.47.

Table 13.27 : List of Pumping Schemes in the Vennar System

Map Number	Name of Pumping Scheme	Serial No.	Name of Pumping Scheme
1	Velankanni	16	Vilangadu
2	Vilunthamavady	17	Melathondiakkadu
3	Aymoor-I	18	Thillaivilagam
4	Aymoor-II	19	Mangal
5	Oradiyambalam	20	Pamanimullur
6	Umbalachery	21	Sekal
7	Mulliar (Thagattur)	22	Korukaithalaikadu
8	Ayakkarampulam	23	Thenpathy Thalaiyamangalam
9	Manangondanar	24	Moovanallur**
10	Thennadar	25	Kollukadu*
11	Vanduvanchery	26	Poyyundar Kudikadu*/**
12	Valavanar	27	Okkanadukeelaiyur
13	Karpaganatharkulam**	28	Chinnaparuthikkottai*
14	Keelathondiakkadu	29	Arasapattu*
15	Karaiyankadu		

The pumping schemes have deteriorated over the 40-50 years that they have been operational. In addition to the normal wear and tear of the electrical and mechanical equipment, there has been significant damage to civil works mainly due to deterioration of construction materials in the saline coastal environment plus penetration by roots and other vegetation, and the swelling nature of the local soils. Maintenance has been meagre, and many pumps are beyond repair. In addition, the efficiency of the pumps which are still in operation has been greatly reduced.

13.4.2 Pumping Schemes of this Project

There are 13 pumping schemes located on the six Rivers of this Project or related channels, as shown in Figure 13.47. The 13 schemes are:

Table 13.28: Pumping Schemes of this Project

Sl.No	Name	River/Drain	Ayacut (Design) (ha)	Year of Construction
1	Velankanni	Maravanar	60*	1965
2	Vilunthamavady	Chandira North	652	1957
3	Aymoor-I	Mallianar	290	1957
4	Aymoor-II	Mallianar	202	1957
5	Oradiyambalam	Nallar	231	1977
6	Umbalachery	Adappar	121	1974
7	Vanduvanchery	Valavanar	180	1957
8	Valavanar	Valavanar	931	1962
9	Keelathondiakkadu	Vettar	283	1977
10	Karaiyankadu	Valavanar	153	1957
11	Pamanimullur	Adappar	300	1962
12	Sekal	Adappar	161	1962
13	Korukaithalaikadu	Adappar	236	1974

Note: *Original design area was 511 ha but this has reduced to 60 ha due to urbanization of command area.

The technical details of the pumping schemes are shown in Table 13.29.

Figure 13.47 : Location of Pumping Schemes

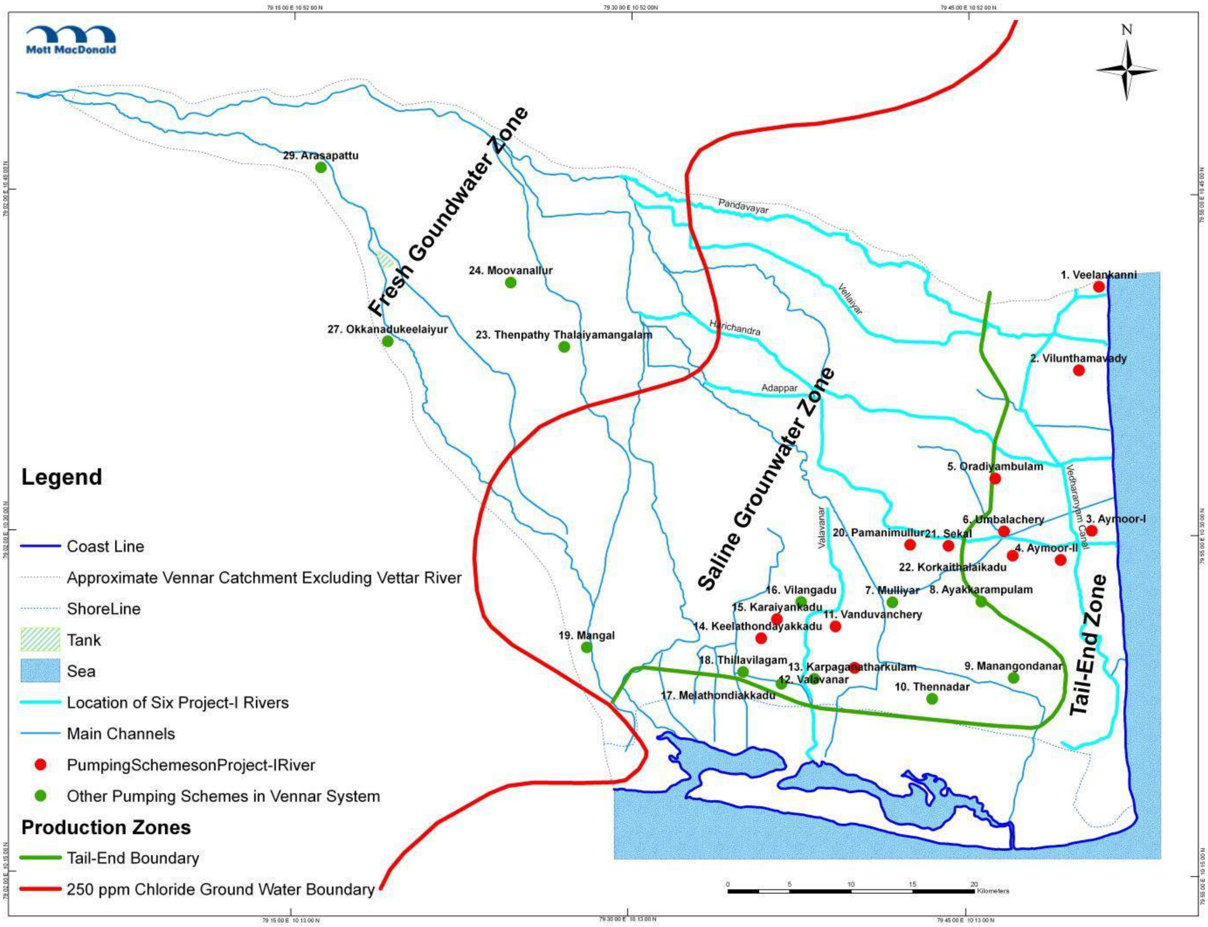


Table 13.29 : Technical Details of the 13 Pumping Schemes

Name	Con-junctive use (Y/N)	Tail-end (Y/N)	Ayacut (Command area) Present (ac)	Ayacut (Command area) Present (ha)	Ayacut (Command area) Renovation (ac)	Ayacut (Command area) Renovation (ha)	Static lift (m)	Water Requirement Present (m3/y)	Water Requirement Renovation (m3/y)	Pumping rate Present (l/s)	Pumping rate Renovation (l/s)	Canal capacity (cusec)	Pumping time Present (h/y)	Pumping time Present (h/d)	Pumping time Renovation (h/y)	Pumping time Renovation (h/d)	Minimum power rating Present (HP)	Minimum power rating Renovation (HP)
Pamanimullur	N	Y	651	260	740	296	4.5	2,955,583	3,361,714	456	519	19	1,550	10	1,763	12	54	46
Sekal	N	Y	360	144	397	159	3.5	1,635,429	1,802,151	252	278	11	1,407	9	1,551	10	23	22
Korukkai Thalaikk.	Y	N	499	200	584	234	4.5	2,266,431	2,652,529	350	409	15	1,482	10	1,735	12	41	37
Umbalacheri	N	Y	271	108	300	120	3.1	1,230,433	1,362,857	190	210	16	754	5	836	6	15	27
Oradiyambalam	N	Y	441	176	554	221	2.6	2,002,946	2,514,926	309	388	16	1,228	8	1,542	10	21	23
Aymoor-I	N	Y	641	256	717	287	2.9	2,909,927	3,257,229	449	503	16	1,784	12	1,997	13	34	25
Aymoor-II	N	Y	491	196	500	200	2.9	2,229,634	2,271,429	344	351	16	1,367	9	1,393	9	26	25
Velankanni	N	Y	0	0	60	24	5.3	454	272,571	0	42	2	2	0	1,337	9	0	6
Vilunthamavadi	N	Y	981	392	1,611	644	5.8	4,454,953	7,318,543	687	1,129	27	1,619	11	2,659	18	104	85
Karayankadu	N	Y	361	144	379	152	5.6	1,637,700	1,721,743	253	266	10	1,691	11	1,778	12	37	29
Kela Thondiyakkadu	N	Y	549	219	700	280	5.6	2,492,529	3,180,000	385	491	18	1,358	9	1,733	12	56	55
Vanduvanchery	N	Y	300	120	445	178	3.1	1,363,766	2,021,571	210	312	11	1,176	8	1,743	12	17	19
Valavanar	N	Y	1,791	716	2,300	920	7.3	8,134,440	10,446,981	1,255	1,612	40	1,995	13	2,562	17	241	160
Total			**7,333**	**2,933**	**9,286**	**3,714**		**33,314,225**	**42,184,245**				**17,414**		**22,627**		**670**	**557**

13.4.3 Findings of Survey and Recommendations for the Project Pumping Schemes

The 13 pumping schemes of this project were surveyed to determine the present condition of their electrical, mechanical and civil works and identify the specific requirements for rehabilitating the schemes to restore the irrigated area to their potential design command area. The main findings and recommendations are summarized in Table 13.30.

The overall efficiency of the outdated and worn out pumping equipment being used is likely to be about 40-50%. With new up-to-date, energy efficient equipment, the overall efficiency of the pumping schemes could almost double.

The refurbishment of the pumping schemes also provides an opportunity to train staff in the operation and maintenance of electrical and mechanical equipment and provide adequate personal protection equipment (PPE) at each pumping scheme. The recommended PPE is listed in Table 13.31. Rather than rehabilitating the staff quarters, all of which are now derelict, a single room with toilet facilities should be provided as an office and rest place for operators. The room should be within the pump house or attached to the pump house if space is not available elsewhere.

Table 13.30 : Main Findings and Recommendations of Survey of 13 Pumping Schemes of this project

Finding	Recommendations
The floor levels at 7 pump house are below natural ground level or below paek flood level resulting in continuous seepage through the pump house. walls and flooding of equipment during peak floods or intense rain storms	The floor level of all pump houses should be above peak flood level or submersible pumps used . All electrical control equipment should be located above peak flood level
Pump house do not have either dedicated overhead distribution line (OHDL) or transformer	Provide dedicated transformers and new dedicated OHDL to minimize disruption to supply
The oil circuit breakers are difficult to maintain and are completely outdated technology	Provide Moulded Case Circuit Breakers (MCCB)
Fuses inside pump house are unsafe	Provide MCCBs with thermo magnetic protection
No optimization of energy consumption	Provide heavy duty self healing All Polypropolene (APP) capacitor for reactive power compensation
Motor starting mechanism outdated	Provide fully automatic star delta starter or digital soft starter with motor protection relay
Energy meters with 0.5% accuracy are installed but there is no recording of power consumption as WRD/farmers not charged for electricity	Power consumption should be recorded daily to determine usage, volume of water pumped etc.
Prime movers are usually slip ring induction motors that are quite old.	Provide Energy efficient, continuous duty, class F' insulation, Squirrel cage induction motor (SCIM)
Internal wiring is in poor condition	Provide energy efficient lamps and heavy duty uPVC conduits
Pumping equipment used for only six months a year	Provide motor Driving End (DE) and Non-driving end (NDE), sealed for life bearings, lubricated for their entire life
Fluctuating voltage	Install Servo Voltage Stabiliser
No mechanism to prime pumps	Provision made in the electrical panel to feed the priming /dewatering pump motor set.
Outlived power and control cables	Replace with latest cross link polyethylene (XLPE) insulated cables
No earth provided	Provide specialised pipe in pipe technology with earth enhancing material to maintain the desired earth resistance in different seasons of the year
Training	Provide hands-on training for operation and maintenance of electrical and mechanical equipment
No personal protective equipment (PPE) provided	Provide PPE to meet current standards (as listed in Table 13.33)
Lack of basic amenities (urinal, toilet, washroom) near pump house	Provide toilet facilities plus office/rest area for operators

Table 13.31 : List of Personal Protective Equipment (PPE)

Item	Specification
Fire Extinguisher	CO2 type- portable Fire extinguisher, of size 5kg each ,manufactured from CRCA sheets in all welded construction, body coated with glossy corrosion resistant epoxy powder coating ,with inbuilt water proof pressure gauge ,with wall bracket ,as per IS 2190 and IS 13849 with latest amendments-1 Number.
Synthetic Insulation Mat	415 V ,A' class, non-skid ,high voltage insulation synthetic mat made from electrometric polymer material ,1000 mm wide , 2.0 mm thick, Dielectric strength 3300V for 1 minute ,fire retardant ,no adverse effect of transformer oil ,diesel, acid ,alkali, High Tensile & Elongation properties, good mechanical strength to withstand load and movement of breaker trolley ,as per IS 15652 with latest amendments -2 m2
Shock Treatment Chart	Laminated Shock treatment chart, duly laminated in Tamil (Local) and English languages.
First aid box	First aid box with all essential medicines including wall mounted bracket
Danger Caution Plate (11000 V)	11000 V, Aluminium, anodised Danger caution plate in Tamil (local) and English languages with the sign of skull and bones in signal red colour on front side, as per IS 2551 with latest amendments
Danger Caution Plate (415 V)	415 V, Aluminium, anodised Danger caution plate in Tamil (local) and English languages with the sign of skull and bones in signal red colour on front side, as per IS 2551 with latest amendments-2 numbers each.
Fire Bucket	Galvanised mild steel sand Fire bucket with lid and handle, 9 Litres capacity. Buckets number to be provided with suitable strand with 4 numbers. hooks to hang sand filled buckets, as per IS 2546 with latest amendments-4 numbers.(1 Set)
Fire Safety:	Fire Safety: The requirement of portable fire extinguisher and fire bucket with sand in electrical equipment room and transformer yard shall be provided as per guidelines by Tamil Nadu Fire Service Rules 1990 and Tamil Nadu Generation and Distribution Corporation Ltd. (TANGEDCO).

14 Power

There are two existing power plants in the Vennar system (one in Nagapattinam district and the other in Thanjavur district). However, at least seventeen more plants are being set up at various locations in the two districts, as shown in Table 14-1. The capacities of the proposed power plants vary from a minimum of 300 MW to a maximum of 1820 MW and all of them are likely to be commissioned by 2020. The total output capacity of the plants is expected to be 9955 MW. All these plants are coal based and it is proposed that seawater will be used for cooling, with the exception of one in Karuppur in Thanjavur district where cooling water will come from Coleroon river.

Table 14-1: Proposed Thermal Power Plants in the Vennar System

District	Location	Capacity (MW)	Source of Cooling Water
Thanjavur	Karuppur	120 MW (existing)	Coleroon river
Nagapattinam	Srikali	NA	Sea water
	Perunthottam	1,980	Sea water
	Neidavasal	1,320	Sea water
	Vanagiri, Keezhaperumpallam, Maruthampallam	1,000	Sea water
	Thalachankadu	1,320	Sea water
	Thirukadaiyur	325 (existing)	Sea water
	Erukkattanchery, Kazhiappanallur, Manickapangu	1320	Sea water
	Neikuppai, Velangudi	300	Sea water
	Vetaikkarannirru, Vizhuthamavadi	NA	Sea water
	Keezhapidagai	1,820 MW	Sea water
	Karappidagai	150 MW	Sea water
	Nagai	300 MW (expansion up to 1320 MW)	Sea water
Total		9,955 MW	

Source : http://www.solidaritaetsfods.de/http://www/industrialmarinepower.com

15 Navigation

Five of the six rivers of this project are not used for navigation except in their lower reaches close to the coastline and even there, boats tend to be designed for the sea and use the river mouths for shelter from the seas rather than for travel very far inland.

The sixth channel of this project the Vedharanyam Canal was designed for navigation, as discussed in Section 13.3.7, but the canal is no longer used for this purpose. As with the other rivers, sea-faring boats use the outfalls at the Vellaiyar Old Course and Uppanar Drain to shelter from the sea.

The central government plans to re-open the Vedharanyam Canal for inland navigation.

16 Groundwater

16.1 Introduction

The rivers of the Cauvery Delta have supplied water for irrigation for centuries whereas groundwater use has intensified over the last twenty years to supplement surface water supplies plus provide water for domestic and other uses.

Groundwater use for irrigation is important because:

- Surface water flows are not available throughout the year, and coincidentally when surface water is not available there is little rainfall
- Surface water irrigation supplies are inadequate to meet areas planted for paddy and other crops, and groundwater is an immediately available additional source of water
- Some areas are not particularly well supplied with surface water, and so in those areas farmers rely on groundwater to meet their crop water needs.

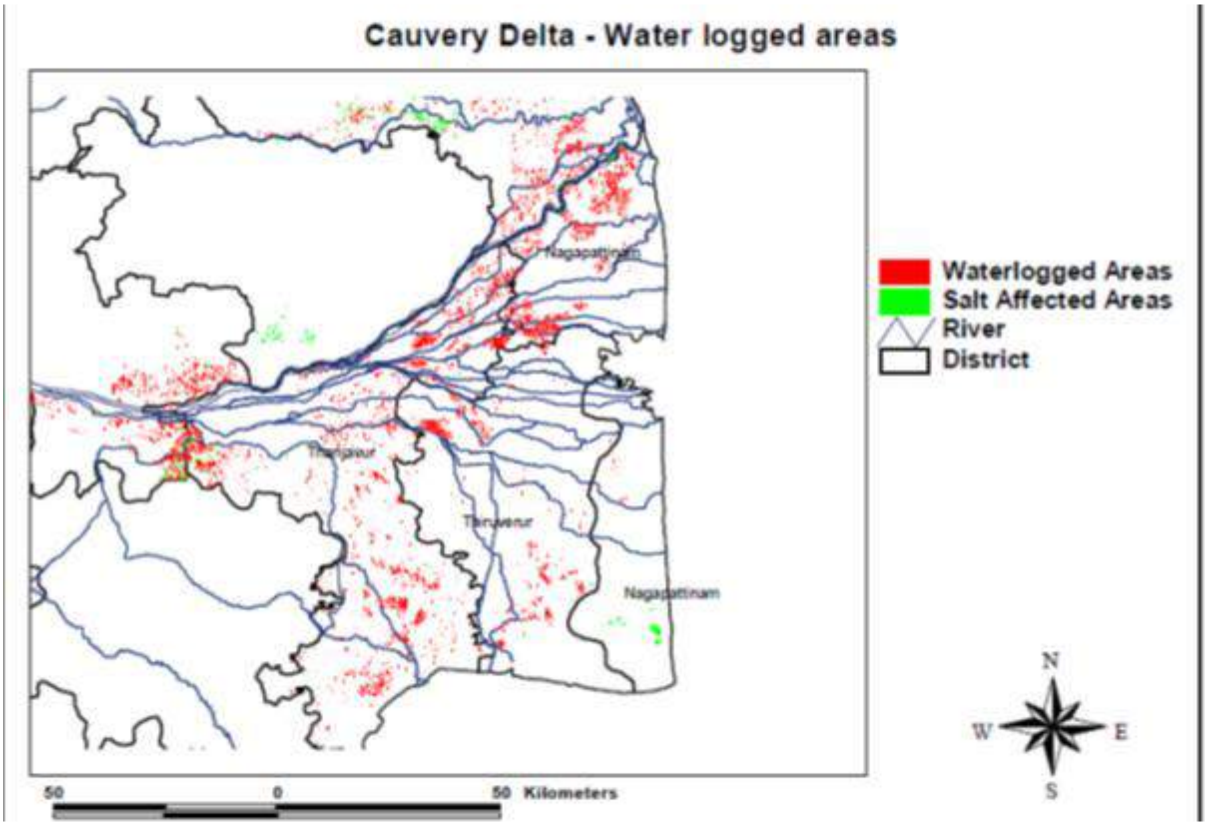
It is estimated that there are about 135,000 hand dug wells and 90,000 tubewells constructed in the CASDP project area (CGWB, 2008a, 2008b, 2009). Hand dug wells are predominantly for household water supply, while the tubewells (also called borewells) are used for irrigation. Groundwater quality is general good inland but close to the coast, the groundwater is more saline.

In this chapter, key issues related to groundwater are discussed and recommendations are made to ensure the sustainability of the resource and improve the availability of good quality groundwater at specific locations. Background details of the hydrogeology and the other aspects of groundwater development are discussed in Annexure 6.

16.2 Depth to Groundwater

Water table levels throughout the Cauvery Delta are high, but not restrictively so. Information on waterlogging in the region is provided by ADB (2011) and the areas with an identified "waterlogging" problem are shown in the Figure 16.1

Figure 16.1: Waterlogged Areas

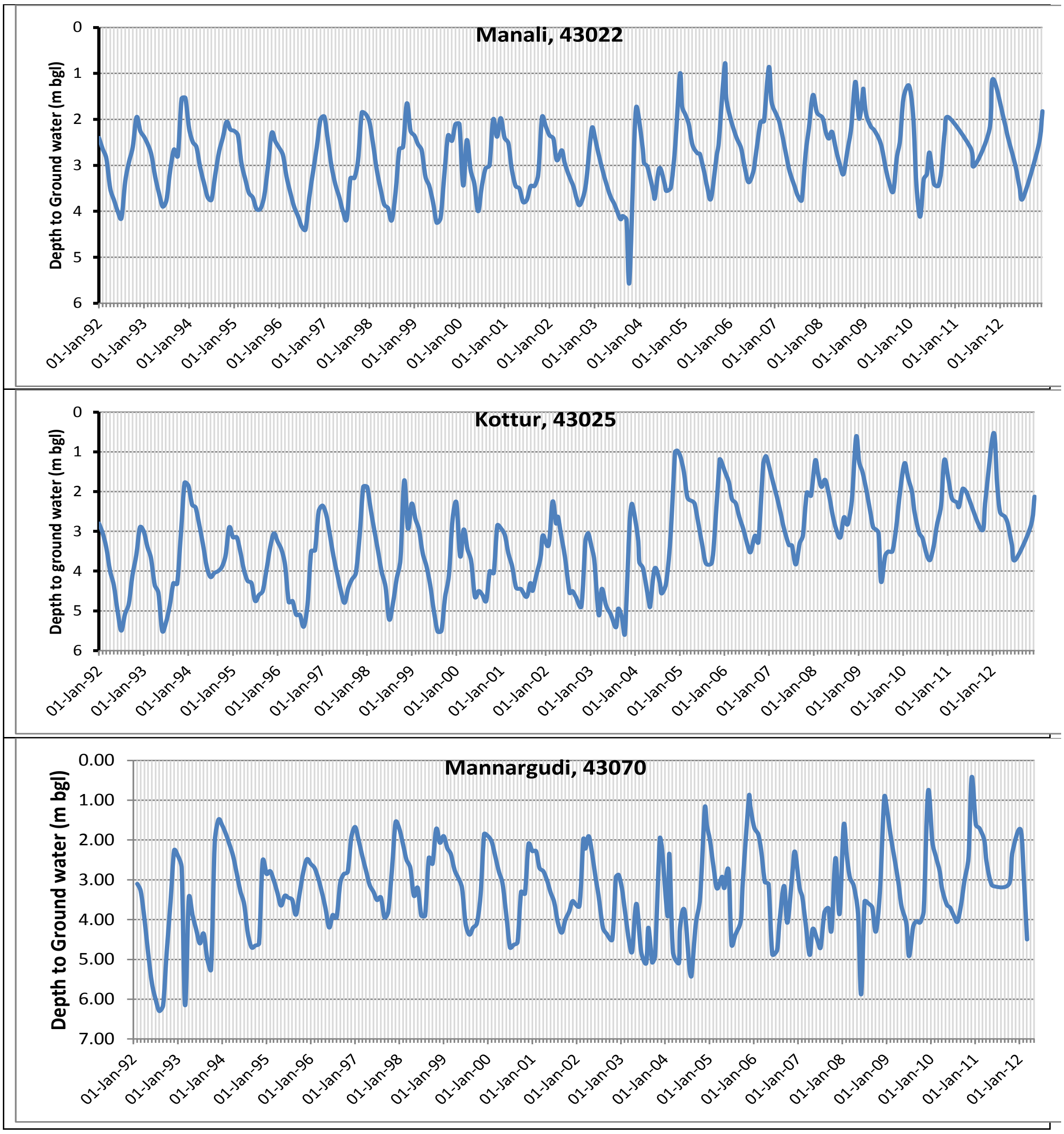


Source: ADB 2011

Most identified areas are located close to head regulators and appear to be related to local ponded water and leakage.

In general, water levels in the upper unconfined aquifer are as illustrated in the following typical groundwater hydrographs in Figure 16.2

Figure 16.2: Historical trend of ground water in shallow aquifer



These show:

- pre-monsoon water tables 4 to 5 m below ground level
- post-monsoon water tables 1-2 m below ground level.
- No long-term trend in water table levels.

Depth to water table below ground surface in the Vennar system, during pre-monsoon and post-monsoon seasons, is shown in Figures 16.3 and 16.4.

Figure 16.3 Depth to ground water table (m below ground surface), pre-monsoon 2008

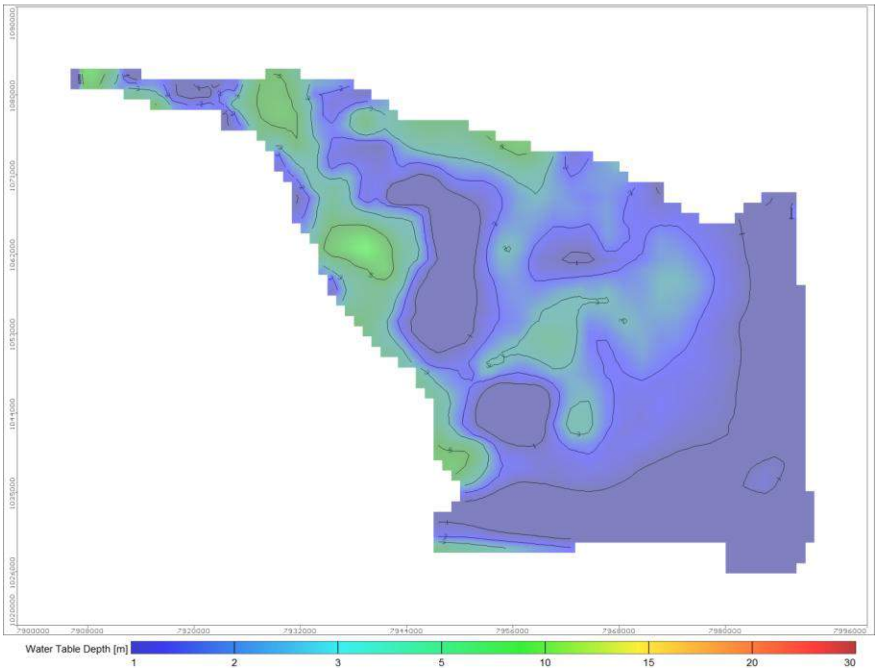
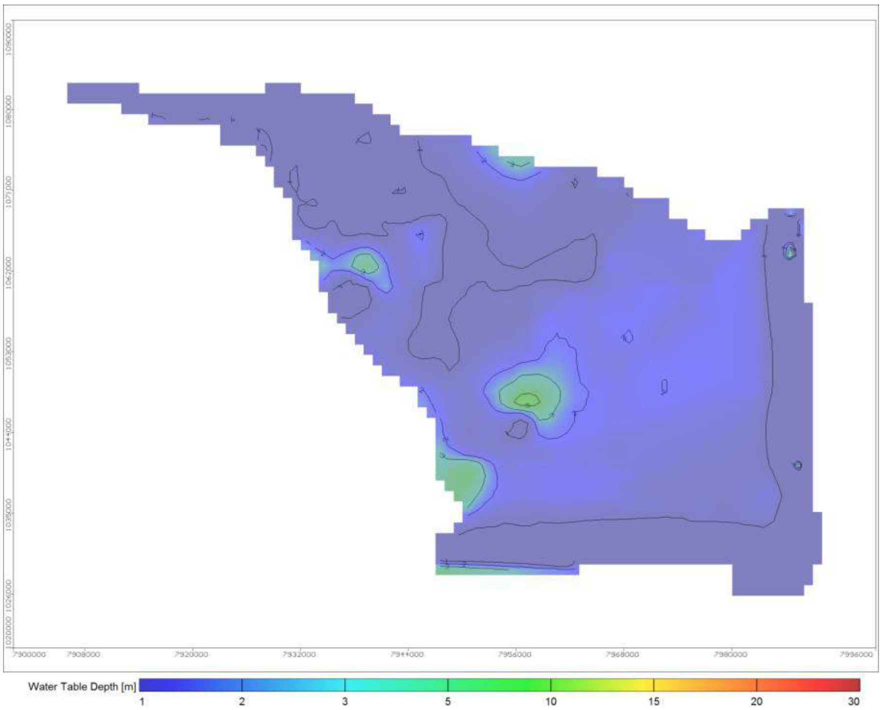


Figure 16.4 Depth to ground water table (m below ground surface), post-monsoon 2008



16.3 Assessment of the Groundwater Potential in the Command Area

The water balance for the three districts in the Vennar System is shown in Table 16.1

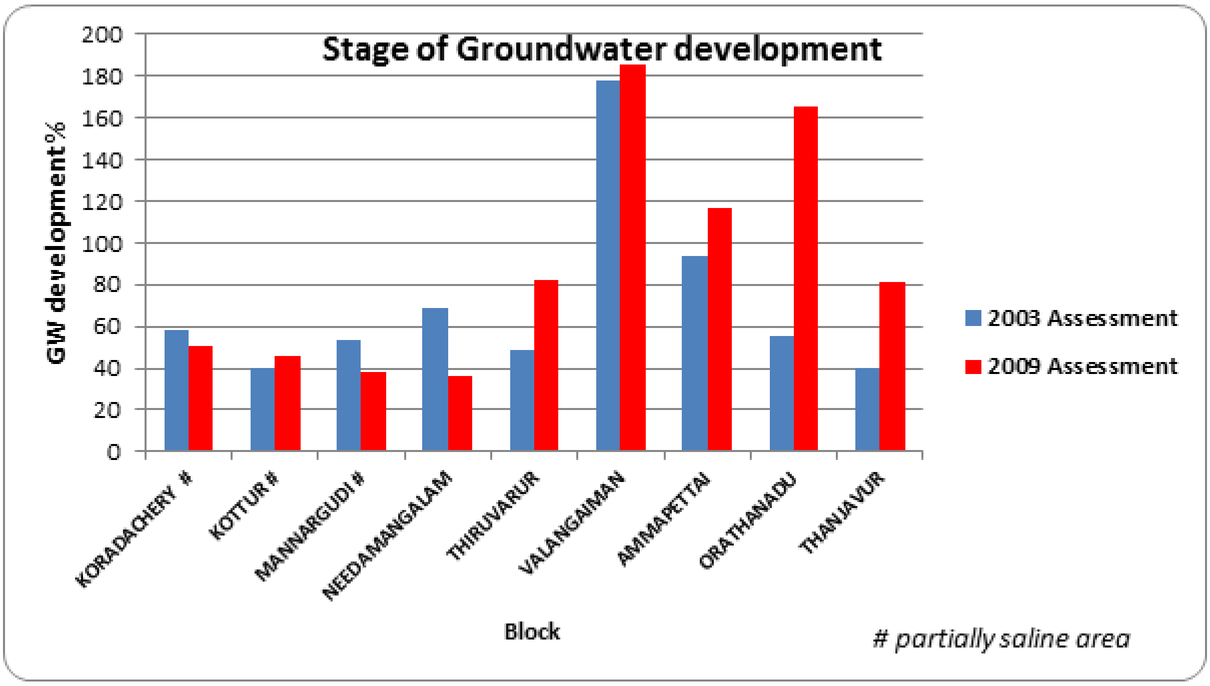
Table 16.1: Annual Groundwater Balance by Block as Water Depth (2009)

District	Block	Net Annual GW availability Mm	Annual Groundwater Draft			Groundwater Balance Mm
			Irrigation Mm	Domestic & Industrial Use Mm	Total mm	
Thanjavur	Ammapet	215.4	246.6	6.4	253.07	-37.67
	Madukkur #	213.9	78.2	9.3	87.53	126.32
	Orathanadu	160.3	257.1	7.0	264.02	-103.69
	Thanjavur	222.8	174.2	5.7	179.85	42.99
Thiruvarur	Koradachery #	237.3	120.0	0.1	120.09	117.23
	Kottur #	119.8	52.8	2.7	55.49	64.28
	Mannargudi #	192.2	66.2	6.6	72.82	119.37
	Muthupet*	Saline Area	Saline Area	Saline Area	Saline Area	Saline Area
	Needamanagalam	225.7	75.6	6.7	82.33	143.32
	Thiruthuraipoondi *	Saline Area	Saline Area	Saline Area	Saline Area	Saline Area
	Thiruvarur	109.3	88.5	1.6	90.07	19.22
Nagapattinam	Keeliyur*	Saline Area	Saline Area	Saline Area	Saline Area	Saline Area
	Nagapattinam*	Saline Area	Saline Area	Saline Area	Saline Area	Saline Area
	Thalainayar*	Saline Area	Saline Area	Saline Area	Saline Area	Saline Area
	Vedranyam*	Saline Area	Saline Area	Saline Area	Saline Area	Saline Area
# Part saline area * Saline area – resource not estimated Source The 2009 Groundwater Assessment (GEC data)						

The most recent estimates by the CGWB (2009) indicate that there is an annual replenishable ground water resource of about 1,187 MCM in the three districts of

Thanjavur, Thiruvarur and Nagapattinam. Out of this resource, 80% is presently used for irrigation and water supply. This resource is reported, in the CGWB assessment, to be over-exploited to the tune of 122 % (1,450 MCM). The block-wise increase, within Vennar system, in ground water development is shown in Figure 16.5.

Figure 16.5: Stage of Groundwater Development



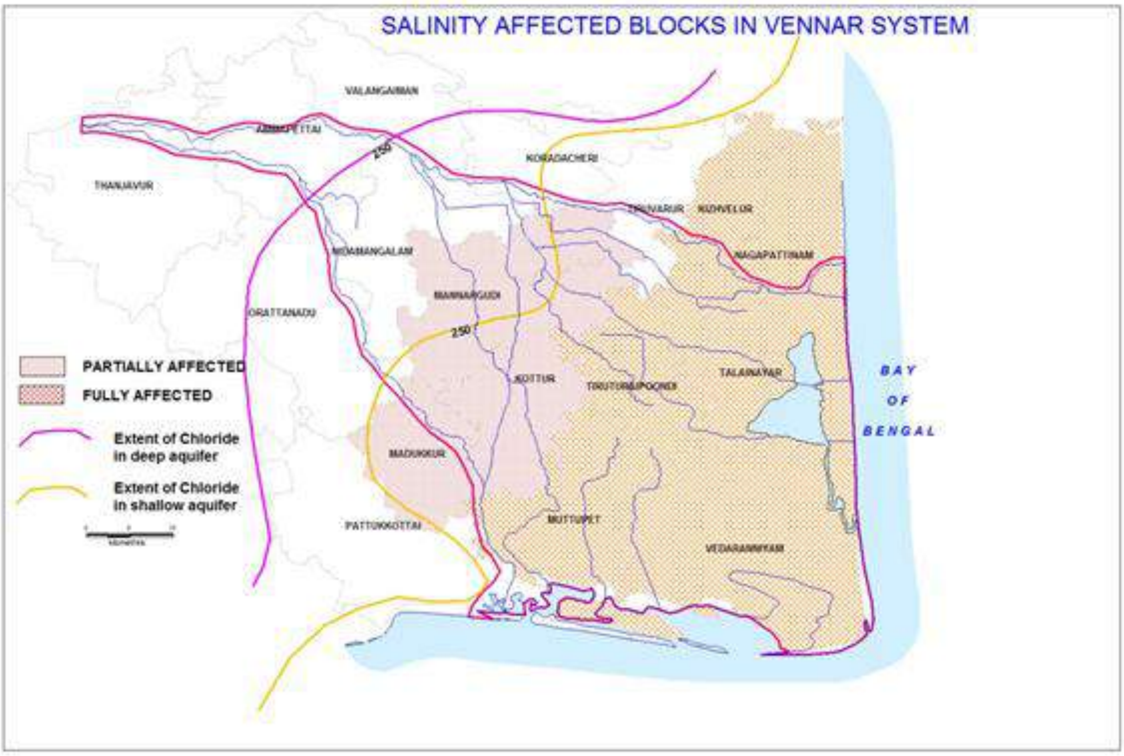
Source: PWD

16.4 Quality of Groundwater

Inland, the quality of groundwater is generally suitable for irrigation and groundwater is used for this purpose without any identified long-term complications. However, towards the coast, much of the area is underlain by saline water. Figure 16.6 indicates the salinity-affected blocks in the region, and the extent of saline water in the upper unconfined aquifer and in the deeper artesian aquifer. Information on salinity within the lower aquifer system is sparse, so the indication in Figure 16.6 of the extent of saline water within this aquifer is approximate only.

The origins and dynamics of the poor quality groundwater in the basin are uncertain, and yet to be scientifically established. Some reports - such as the Cauvery Modernisation Report, (WRO, 2008) and the ADB report (ADB, 2011) refer to sea water intrusion. The Central Groundwater Board report (CGWB, undated) concludes that the saline water is from the time of deposition of the formation in a marine delta environment, with incomplete flushing of the salts from fresh water through-flow. There is an on-going PWD monitoring programme for the groundwater in the coastal area to monitor changes.

Figure 16.6 : Saline Affected Blocks



The salinity in both aquifers is likely to be connate, that is, existing from the time of deposition of marine sediments. The connate salinity has been flushed out by recharge waters of lower salinity to a certain degree which is why the upper aquifer has a greater extent of fresh groundwater than the lower aquifer as the through flow of recharge water has been greater. Historically the recharged water has emerged within the delta as seepage into the river distributaries and flushing is less as the coast is approached.

Since the location of the interface between the fresh and saline groundwater was first identified in UNDP studies in the 1960's, there has been no significant movement of the interface. Some analysis has suggested that the interface is moving inland, and that further development of groundwater in the delta could accelerate this movement and result in salinization of groundwater in areas where the groundwater is fresh. While this is an acknowledged risk, our analysis of the available data shows little sign of such processes, which suggests that this risk has been overstated in the past. Nevertheless, it is prudent to invest in a more complex monitoring system to provide regular updates of the situation and early warning of any undesirable movement.

16.5 Assessment of Possible Impact on Groundwater Recharge due to Canal Lining

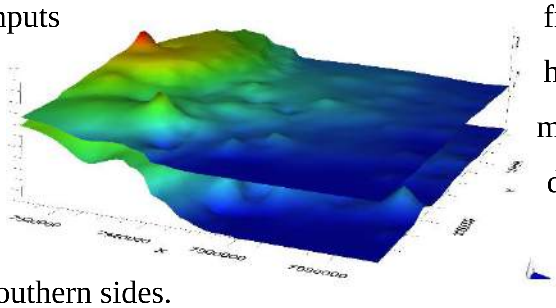
Works to improve the performance of river channels in this Project do not include canal lining. Therefore they are unlikely to impact on recharge to groundwater system. Construction of new Tail End Regulators (TER) will help to recharge aquifers in the coastal area.

Under this Project ground water modelling is proposed to improve the understanding of the availability and movement of groundwater and to determine the feasibility of different options for managing groundwater:

Enhancement of recharge of the deeper aquifer using recharge shafts is being prioritised by the local government in Thiruvarur District so that the groundwater resource is sustainable and can continue to support irrigation and increasing water demand in other sectors on a long term basis. At present, the deeper aquifer (> 100 m bgl) only benefits through vertical leakage from the upper aquifer because the current recharge shafts are shallow. With deeper shafts, the deeper aquifer would receive direct recharge. Also the recharge structures should be maintained on an annual basis to maintain their efficiency since there is a tendency for clogging after one recharge cycle.

16.6.1 Groundwater Modelling

Ground water modelling of the Vennar system has been carried out to simulate the ground flow system for a broad two aquifer system of alluvium and sandstone. Available data inputs from existing databases of WRD and CGWB have been taken into consideration to run the model. Simulation for ground water quality distribution is also included due to the presence of sea water on the eastern and southern sides.



The modelling study revealed large gaps in the data available for the simulation of the complex ground water flow and solute transport system in the delta region. These data gaps in water levels of different layers of aquifers, aquifer parameters, level of resource utilisation, spatial distribution of resource recharge and utilisation are required to be filled up for meaningful simulation and understanding of the aquifer system that is being used in the delta region in conjunction with the surface water supply and rainfall.

Addressing the issue of optimal use of ground water potential of the shallow and multiple layers of the deeper aquifer should be given priority due to the increasing dependency on ground water for irrigation and domestic use. Unless the ground water resource is managed with a more realistic approach based on the study of entire framework of aquifer system, an irreparable impact on the ground water environment may creep in. Understanding the realistic availability of ground water resources in space and time is relevant to address the water demand and management issues in a canal command area. Three dimensional modelling of the aquifer system shall provide solutions in the estimation of aquifer wise ground water conditions in its quantity and quality. Availability of ground water resource in space and time, from the model, helps in the management of canal water supplies and meet the demand of needy areas.

Data Inputs. The modelling studies are intended to develop a three dimensional aquifer model for evaluating ground water potential in the major aquifers of the area. Delineation of these aquifers should be based on their geometry, hydraulic characteristics, their response to external stresses, etc. Due to the non-availability of such data for developing a 3D model, the data has to be collected through new observations and monitoring in the area.

Model Requirements. For utilising the modelling tool in understanding the process of ground water in the multi-layer aquifer system and variation in chemical quality and develop strategies for the management of available resources, equipment (hardware and software) required is attached in Annexure-1. The software with graphical user interface is more convenient for pre-processing of data inputs in the form of tables, maps in GIS format, satellite images and also for testing the model for several scenarios. The software should also have capability for processing data outputs and managing the outputs to produce in various presentation formats, graphs, charts and maps.

Staffing. One full-time experienced person in ground water from WRD supported by an external modelling specialist with good experience in aquifer modelling studies exposed to similar hydrogeological conditions as that of Cauvery delta region are required to carry out and develop an aquifer model for ground water flow and solute transport conditions.

Cost Estimate. The cost estimate for implementing the detailed groundwater modelling study is about INR. 35 lakhs (US$ 60,000), excluding data collection and consulting services. Details of the cost estimate are given in Table 16.3.

Table 16.3 Cost Estimate for Modelling

s.no	Item	Unit	INR	Unit cost INR (Lakhs)	Total cost INR (Lakhs)
1	HARDWARE (Computer, printer)	No.	2	2.5	5
2	SOFTWARE (Modflow based GUI software)	No.	2	10	20
3	International consultancy services for groundwater modelling	Month	2	Cost included in implementation support consultancy	
4	National consultancy services for groundwater modelling	Month	6		
5	Training in groundwater modelling	No.	1	10	10
	Total cost in INR. Lakhs				35
	Total cost in US $				60,000

17. Drainage and Land Reclamation

Four of this six Project channels, namely the Pandavayar, Vellaiyar, Harichandra and Adappar rivers, are used as delivery channels for irrigation water as well as drainage channels to remove drain water and flood water. The other two of this Project channels, namely the Valavanar drain and the Vedharanyam canal, carry flood and drainage flows only.

Chapter 13 gives a description of the rivers, drains and canal systems. As an integrated system, irrigation and drainage requirements are discussed together. The river/canal system is analysed and proposed interventions are identified to alleviate problems of flooding and drainage congestion.

The proposed interventions aim at reducing the extent, depth and frequency of flooding and drainage congestion. However, these measures are limited to main channels. The non-availability of an accurate DEM, system layout and longitudinal and cross sectional details of other canals and drainage channels, limited the option of analysing the problem of field drainage in detail and evolving appropriate interventions for alleviation.

Land reclamation is not included in this Project.

18. Land Acquisition, Rehabilitation and Resettlement

18.1 Introduction

The Resettlement Framework (RF) guides the resettlement implementation and management phase of CASDP Project. The document explains the number of families impacted by the project and specifies implementation procedures including budget and monitoring and reporting requirements. Finally, all works undertaken are to strictly adhere to all ADB SPS, 2009 and operational procedures and government policies. The document provides a framework for assessment of any involuntary resettlement impacts in the identified subprojects and those of other subprojects for funding in future CASDP projects.

This Project aims to improve the performance of six rivers in the Vennar System. The proposed activities do not involve any need for land acquisition. The PPTA field survey of encroachment estimated that approximately 203 squatters will be affected who may need to be relocated. The possible impacts can be categorized in three broad groups:

- Loss of immovable assets, i.e. agricultural land, homestead, cattle sheds, wells, ponds, trees, commercial establishments, community infrastructure, etc.
- Loss of livelihood or income opportunity on account of loss of agricultural land.
- Impact on the community in terms of loss of common property resources, such as grazing land, other common land, village commons or forests or access to them.

The impacts could be either temporary (for the duration of construction activities) or permanent. The WRD will ensure that no physical or economic displacement will occur without providing the entitlements listed in the resettlement plan.

18.2 Scope of Resettlement

There is no land acquisition anticipated in this Project and resettlement impacts are not significant.

The RF describes the details of entitlements and type of assistance to be extended to the affected persons, which will become the basis for preparing a resettlement plan (RP) for each CASDP project. All sub projects shall be screened for their likely adverse impacts in the planning stage. Where land acquisition cannot be avoided, a census of the potentially affected persons will be carried out. If the issues related to resettlement are triggered, an RP will be prepared for the concerned tranches of the MFF.

18.3 Policies of the Government and ADB

The principles for this Resettlement Framework are derived from ADB's Safeguard Policy Statement (2009) and the Government of India's Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 20I3.

18.4 Screening and Categorization

ADB's Involuntary Resettlement Impact Screening Checklist will be adopted for the each of the six rivers of this projects. The following criteria for screening and categorization of subprojects will be followed:

- Category A: as a result of the subproject, 200 or more people will experience major impacts, that is, being physically displaced from housing, or losing 10% or more of their productive (income-generating) assets;
- Category B: as a result of the subproject, fewer than 200 people will be physically displaced from housing or lose less than 10% of their productive (income-generating) assets;
- Category C: the subproject does not require temporary or permanent land acquisition, and there are no impacts involving the loss of land, structures, crops and trees, businesses or income.

18.5 Eligibility and Entitlements

18.5.1 Eligibility

All Project Affected Persons (PAP) identified in the project-impacted areas on the cut-off date will be entitled to compensation for their assets. The cut-off date for the encroachers will be the date of census survey and cut-off date for the title holders to be defined by the Land Acquisition Act 2013. The rehabilitation measures will be sufficient to assist them to improve or at least maintain their pre-project living standards, income-earning capacity and production levels. The resettlement framework identifies or categorizes project affected persons under these three broad categories as follows:

- Type 1: Legal titleholders of the land that is acquired
- Type 2: Those without formal titles, whose claims are recognized/recognizable under national laws, e.g., communities with traditional land tenure systems having collective usufruct, tenants and leaseholders; and
- Type 3: Squatters, encroachers, sharecroppers and wage labour who have no recognizable claims but are entitled to assistance if land requirement affects their livelihoods

18.5.2 Entitlement

The entitlement matrix summarizes the main types of losses envisioned by the works and the corresponding nature and scope of entitlements in accordance with the Government of India and ADB policies.

18.6 Monitoring

Resettlement plan implementation will be closely monitored by PMU for identifying potential difficulties and problems in resettlement plan implementation. Such monitoring for resettlement plan implementation will be carried out during the entire Project period with monitoring commencing after three months of project initiation.

18.7 Cost Estimate and Budget

The WRD will make the fund available as required to cover all compensation and Resettlement and Rehabilitation (R&R) costs from the ADB loan. The budget rates, as well as the costs, are based on field-level information and past experience in resettlement management. The cost estimates included in this plan also make adequate provision for 20% contingencies as indicated in the Table 18.2. The total cost for this Project will be Rs.3,03,31,123 (USD $ 505518.72)/-.

Table 18.2: Resettlement Costs

S No	Description	Unit	Unit Rate/(Rs)	Quantity	Total/(Rs)
1	Cost of Houses to Residential squatters requiring relocation	No	100,000	106	10,600,000
2	Cost of Land for resettlement site	sq.m	945	2,275	2,149,748
3	Shifting assistance to Residential squatters requiring relocation	No	25,000	106	2,650,000
4	Subsistence allowance to Residential squatters requiring relocation @ Rs.3,000 p.m for 6 months	No	18,000	106	1,908,000
5	Replacement cost for cattle shed / shed for storage	No	15,000	97	1,455,000
6	Transitional allowance to commercial squatters requiring relocation @ Rs.3,000 p.m for 6 months	No	18,000	17	306,000
7	Shifting assistance to Commercial squatters requiring relocation	No	25,000	17	425,000
8	Replacement cost for commercial structures	sq.m		17	2,380,000
	Sub Total -A				21,873,748
9	NGO Support for RP implementation	LS			2,500,000
10	External Monitoring	LS			2,000,000
11	Disclosure / Consultations / Administrative Expenses	LS			1,200,000
	Sub Total-B				5,700,000
12	Contingency @ 10% of Sub Total A+B				2,757,375
	Total				**30,331,123**

19. Water Management and Maintenance

19.1 Current Management of Project-1 Rivers

The current method of management of the Project-1 Rivers is rudimentary and mainly based on manual methods. The method responds to requests from farmers for water. Often farmers' lobbies raise their demands directly to the WRD or indirectly through the Agriculture Department, agriculture associations and also through regular farmer grievance meetings with their District Collectors.

WRD's management of this Project Rivers involves three main activities:

(i) Management of irrigation flows through the rivers and canals to meet irrigation requirements. Irrigation water is usually provided over a period of about nine months from June through to the end of January,

(ii) Management of flood flows through the rivers and drains to minimise flood damage. Flood flows normally occur during the north-east monsoon (October-December) but can also occur during the south -west monsoon ,

(iii) Maintenance of irrigation rivers, canals, drains and structures.

19.1.1 Management of Irrigation flows

The current normal operating procedure in the Vennar system is to respond directly to farmers' demands for irrigation water. In practice it is sometimes difficult to satisfy the demands because the inflow into the system are variable, depending on the volume of water stored in the Stanley Reservoir and releases from Mettur dam, and because the water distribution system is in poor condition. Consequently, it is difficult for WRD to achieve equity of supply across the system. Moreover many tail end areas have saline groundwater and therefore farmers in those areas cannot supplement surface water supplies with groundwater and are therefore are disadvantaged.

The normal irrigation water distribution procedures are as follows :

(i) Evaluating the volume of water available in Stanley Reservoir, with allowances for possible further inflows to the reservoir,

(ii) Evaluating the volume of additional inflows into the Cauvery River below Mettur,

(iii) Estimating the total flows that might be available at the Grand Anicut,

(iv) Estimate water availability in the upcoming season and estimate potential deficits using information on cropped areas, crop water requirements in normal and dry years and water supply efficiencies,

(v) Sharing any deficits evenly over the entire command area and over the entire irrigation season,

(vi) Assessing actual water stress by location so that if possible irrigation water can be supplied to areas suffering more than others

(vii) Determining the optimum scheduling of flows in each canal and what the gate settings should be.

19.1.2 Management of flood flows

The current operating procedure for flood management in the Vennar irrigation system is to fully open selected head regulators and all tail end regulators in order to minimise damage to infrastructure and flooding of the flood plains, as shown in Figure 13.5. Nevertheless owing to the limited capacity of many of the rivers and drains flood damage is unfortunately endemic in the system.

Major floods in the Vennar system are usually caused by intense local cyclonic rainfall during the north-east monsoon, lasting several days. The largest floods in recent times were in September 2005, November 2005, November 2008 and again in November 2010. Very occasionally floods are caused in the Cauvery delta by distant storms in Karnataka, Kerala and highland Tamil Nadu during the south-west monsoon, the runoff from which exceeds the capacity of the Grand Anicut. This occurred in September 2005 and possibly once in the preceding 20 years.

19.1.3 Maintenance of irrigation canals

Generally, the maintenance of irrigation systems in the Cauvery sub-basin is carried out by WRD according to urgency and fund availability. Periodic inspection is done by WRD Engineers to assess the condition of the irrigation structures and other assets and the need for maintenance work. Cost estimates are then prepared for maintenance. Funds for maintenance are allocated annually according to the cost estimates and the availability of funds. The funds are released quarterly. The average annual allocation of maintenance funds per division in the Vennar system is roughly about INR 60 million/year. Maintenance work is normally carried out during the dry season (February to June), except for emergency works.

Downstream of the main rivers, irrigation channels are categorized into six different classes, namely A, B, C, D, E, and F. In the absence of formal Water User Associations (WUAs) in the Cauvery sub-basin, the maintenance of all classes of channels is taken up directly by the WRD. The number of channels in each class and their length is shown in Table 19.1.

Table 19.1 Length of Different Classes of Channel, Vennar System

Channel type in Vennar System	Number	Length (km)
A Class	583	2316.21
B Class	3932	3992.11
C Class	5191	3060.89
D Class	2566	1349.43
E Class	837	312.20
F Class	178	48.11
Total	**13287**	**11079.04**

This Project works will facilitate maintenance by making six channels more accessible through provision of standardised embankments. The dredging of the straight cuts will require a commitment to an annual maintenance expenditure on dredging to keep the straight cuts open.

19.2 Analysis of Current Decision Making

- Surface water supply to the Cauvery Delta during June to October is determined largely by the flows in the Cauvery River and amount of water stored in the Stanley Reservoir at Mettur Dam. Estimates of irrigation demand are prepared by the WRD sub-divisional engineers according to irrigated farm areas and standard water duties. The sub-divisional estimates are aggregated by the Executive Engineers and Superintending Engineer and used to decide the necessary releases of water from Mettur Dam.
- Operation of head regulators in the Cauvery Delta determines the distribution of surface water. In the Vennar system the gate operators at the VVR head regulator release the necessary discharges to maintain normal supply levels in the Vettar, Vennar and Vadavadar Rivers simultaneously, if sufficient water is available. If sufficient water is not available then a 6-day rotation system is adopted, based on the normal travel time of 6 days between Mettur Dam and the tail end of the rivers.

- Formal control rules and structure ratings, published in 1937, are still referred to by local WRD staff. These instruct the operators how to determine appropriate gate settings to maintain normal supply levels.
- WRD review gate settings on a six-day cycle using information on irrigation demands and recent rainfall to decide appropriate discharges and gate settings for the next 6 days. This procedure is based on the experience and judgment of WRD Engineers.
- Actual discharges through the head regulators are considered by WRD to be less than those indicated by the 1937 structure ratings because of the influence of vegetation and sediment on flow characteristics in the vicinity of the regulators. Therefore the gate operators decide to adjust gate openings based on their judgment in order to maintain normal supply levels in the system.
- During flood conditions inflows into the delta from the Cauvery River are stopped at the Grand Anicut. In order to discharge storm runoff generated within the delta to the sea as quickly as possible, specific regulators are opened fully. During widespread flooding, flood waters are directed preferentially down the Vettar River, then the Vennar River.

The conclusion is that (i) there is a need for greater accuracy of discharge measurements at all regulators through updated calibrations of the gates, (ii) linking gate operation with rainfall forecasts could improve the management of the irrigation systems by reducing irrigation requirements increasing water use efficiency and securing crop production, (iii) some irrigation head sluices are unregulated because they are blocked or stuck partially open, or fully open, due to lack of maintenance and therefore some farmers probably receive too much water, others too little, (iv) the use of groundwater by farmers is not taken into account in channel operations.

19.3 Proposed Decision Support System

19.3.1 Management of Irrigation Flows

To improve the management of irrigation flows in the Project 1 area it is recommended that operational and planning decision making by WRD is supported by an appropriate decision making tool.

The architecture of this DSS will comprise a host computer server located in WRD offices, locally in the Cauvery Delta area or remotely in the PWD Surface Water and Groundwater Data Centre in Chennai, linked to workstations in the offices of the divisional Executive Engineers and/or the sub-divisional Assistant Executive Engineers. The databases will be linked through mobile phone networks or other suitable means to selected rainfall, groundwater and river monitoring stations distributed at key locations in the delta. The monitoring stations will deliver data into the databases automatically on a daily basis and will be immediately available for quality control and archiving by specially trained WRD technicians and also for operational decision making by key WRD engineers.

Key decisions that could be supported include:

- Facilitate irrigation planning and efficient water distribution for the systems (on seasonal and 10-day time scales) based on actual needs, both for surface water and groundwater.
- Fine tuning water supply to actual needs in individual command areas.
- Integrated operation of dams, head regulators, cross regulators and tail regulators to maintain appropriate flows and water levels during normal supply periods and during floods.
- Detect and respond to distribution system problems and breakdowns.

19.3.2 Management of Flood Flows

For the management of flood flows it is essential to have real time data. Therefore a network of telemetered rain gauges, weather stations and flow gauges and a data acquisition system is required including:

- Water levels and flows within the canal system to inform decisions on the timely operation of control structures
- Expected inflows to the system – both at the head of the system (main river) and the drainage from land within the irrigated area
- Sea water levels or downstream water levels as appropriate
- The state of groundwater and surface water storage in the catchment

These could then be used in a set of forecasting models (rainfall-runoff, hydraulic and water balance models) to forecast water levels and flows within the system (forecasts would be updated as real time data is updated). The flood management element of the DSS would:

(i) Provide links to rainfall estimates from appropriate web-sites for best estimate forecast rainfall over next (say) 6 days

(ii) Calculate current flows within the canal / drainage system (with facility to improve prediction using adjustment from present reported water levels and flows within the system)

(iii) Calculate likely flows in the Cauvery River at Grand Anicut over next (say) 6 days – implying that a routing model is required (either a hydrodynamic model or a routing model)

(iv) Estimate runoff hydrographs within the irrigated area over next 6 days for forecast rainfall using rainfall runoff modelling such as SWAT, HEC-HMS or NAM (models such as HEC-HMS or NAM become more appropriate at short time intervals)

(v) For assumed flood management flow distribution for this 6 day period, and assumed operation of tail sluices, estimated water levels within the canal / drainage system at key locations and for the three day forecast

(vi) Identify areas where water levels are expected to collect in the drainage area and to exceed bank top levels together with the predicted depth and duration of flooding

(vii) Allow operators to alter operation of main controls at key distribution points so that flows are re-directed manually to minimise overall impact of flooding

(viii) Once preferred operation of flow distribution has been selected, the RTDSS would identify areas in danger of flooding and providing warnings to those likely to be affected and mobilising contingency plans and actions.

19.3.3 Initial Simple DSS

Recognising the challenges and constraints facing WRD, a simple DSS comprising surface water and groundwater databases containing hydrometeorological, hydrological and hydrogeological data and irrigation command area (ayacut) information is proposed initially. This simple DSS will be accessible to WRD decision makers through a user-friendly computer interface allowing them to inspect up-to-date river levels, flows, water demands throughout each irrigation and drainage system and to adjust surface water deliveries to actual needs considering groundwater availability and recent rainfall.

While it is recommended that a simple DSS will improve operational decision making for water distribution, it is also recommended that, after a sufficient period of familiarisation and confidence building, which will establish the usefulness of the DSS, consideration should be given to the development of the simple DSS into a more sophisticated tool that will support the maximisation of water use efficiency and fully reap the benefits of integrated water resources management within the Cauvery Delta. This more sophisticated DSS could include hydrologic and hydraulic models that would guide the operators of the irrigation and drainage systems on a daily basis and provide comprehensive assessments of water resources management options on a seasonal basis. Further development of the DSS could include flood forecasting (using links to the India Meteorological Department and the CWC) and flood warning.

19.3.4 Training of WRD Staff

WRD staff will receive regular and intensive training on monitoring the parameters used as input to the DSS, updating and maintaining the databases, using the information generated, and communicating this information to farmers and other stakeholders. The training program would also include intensive training for key WRD staff on the hydrologic and hydraulic models, operation and maintenance of the field equipment and the database software and hardware.

Beyond this, an overall capacity building program in climate-resilient integrated water resources management would be provided for WRD staff. In addition to training on the DSS tools, WRD staff would gain knowledge and additional skills in using climate change projections, using the new criteria for engineering designs prepared through the PPTA, setting up and using hydraulic and hydrologic modelling for design and planning, flood forecasting and warning, and working with farmers to manage their surface water and groundwater resources.

19.4 Costs of the DSS

19.4.1 Initial Simplified DSS

Four main inputs into the simplified DSS are proposed (i) field monitoring equipment, (ii) computer hardware and database software, (iii) programme of flow measurements to calibrate discharges through regulators and (iv) a watering schedule calendar in the form of a simple spreadsheet. In consultation with WRD it is agreed to pilot the simplified DSS for one channel of Vennar system (the Harichandra River) during the first phase and, based on its performance, it may be extended to cover other rivers.

19.4.2 Monitoring Equipment and Hardware and Database Software

Table 19.2 lists the hydrometric field equipment and office based hardware and software that would be needed to link the monitoring stations to the DSS and implement the DSS under this Project.

Table 19.2: Equipment and Indicative Costs of DSS

Equipment	**Phase I (Harichandra River)**	
	Nr	**Estimated Cost $**
Field Equipment		
Recording raingauges	5	$5,000
Check raingauges	5	$1,500
Surface water level recorders	10	$10,000
Groundwater level recorders	5	$5,000
Gate openings recorders	5	$5,000
Ultrasonic Flow meter	1	$25,000
SIM cards and cell phone contracts	20	$6,000
Training of WRD field engineers		$5000
Sub-Total		**$62,500**
Office Equipment		
Database + User Interface	1	$10,000
Server + Back-Up Facility	1	$2500
Workstations + UPSs	5	$5000
Sub-Total		**$17,500**
TOTAL		**$80,000**

19.4.3 Calibration of Regulator Discharges

To make decisions on releasing precise flows through the irrigation network it is important to calibrate the regulators accurately. The calibration of the regulator gates involves measuring the actual discharge directly at a river cross-section close to the regulator over the widest possible range of flows. For the matrix of flow measurements and gate openings, coefficients of discharge Cd (the ratio of actual discharge to theoretical discharge) are calculated.

A calibration programme could be developed by a national expert working alongside WRD staff. A tentative cost for expert support for recalibration of regulators for the Harichandra River under this Project, including training of WRD staff, is $10,000.

19.4.4 Water Schedule Calendar

This is a spreadsheet-based approach that will assist in a practical way the management of irrigation systems in the Vennar system using a projected crop water requirement calendar to forecast irrigation scheduling well in advance.

The spreadsheet is a calendar of irrigation requirements for the crops under consideration which can be used to estimate future water requirements at any particular point in irrigation season to come. From inputs of planned areas of Kuruvai, Samba and Thalladi paddy and their respective sowing dates, the spreadsheet would output irrigation requirements according to the growth stage of the crop using the standard Penman-Monteith equation for evapotranspiration, making allowances for rainfall and alternative water sources such as tanks, ponds and groundwater. This output from the spreadsheet would assist facilitate decision making with reasonable confidence about the release of water without risking future water scarcity.

Tentative cost for expert support for development of spread sheet based approach under this project including training of WRD staff of Cauvery basin would be about $25,000 and for the software would be about $50,000.

19.5 Summary of DSS Costs

The estimated cost for developing and implementing the simplified DSS for the first phase is about $80,000 the major portion of which would be towards field and office equipment.

20 On-Farm Works

On-farm works are not included in this Project.

21 Construction Programme

21.1 Project Area

The six rivers in this Project area are the worst affected by flooding and the most in need of improvement as per water resources management. The six rivers are representative of the water problems of the Cauvery Delta and have been selected with the intention of scaling up and applying this Project interventions throughout the Delta.

The six rivers of this Project are:

- Adappar
- Harichandra
- Vellaiyar
- Pandavayar
- Valavanar Drain
- Vedharanyam Canal

21.2 Major Works

21.2.1 Nature of Works

The following works are included in Project:

- **Re-sectioning** of the river which includes increasing the width and depth of the river.
- **Desilting** of the river which includes excavation of the channel bed to remove sand bars and other impediments to restore the channel to its design section.
- **Standardisation** of banks which includes raising and strengthening of the embankments, restoring the bank side slopes, top width, construction of road etc. to bring the embankment bank to BIS standards.
- **Repairs** of Head Regulators, Cross or Intermediate Regulators, Tail End Regulators, Irrigation Sluices, Drainage Sluices, Drainage Infalls, Irrigation Syphons, Drainage Syphons, Bed Dams and Grade Walls. Repairs are defined as the restoration of the components of the structures to function as designed.
- **Reconstruction** of existing and construction of new Head Regulators, Cross or Intermediate Regulators, Tail End Regulators, Irrigation Sluices, Drainage Sluices, Drainage Infalls, Irrigation Syphons and Drainage Syphons, Bed Dams, Grade Walls. Reconstruction is defined as the demolition and removal of all components of the existing structure and construction of new structure including foundations on the same site.
- Fluming and River Training. Bank revetment/pitching and masonry walls depending upon severity of the problem of bank failure and non availability of land

The works to be constructed on each river may include one or more of these works.

The total length of the six Project river channels to be re-sectioned or re-graded is 234.5 km. The number of new structures and the existing structures to be reconstructed and repaired/rehabilitated is given in Table 21-1.

Table 21-1: New Structures and Structures to be Reconstructed and Repaired

Type of Structure	New	Reconstruction	Repair
Regulators (Head, Cross and Tail)	5	8	13
Irrigation Head Sluice	2	86	47
Drainage Sluice / Drainage Infall	33	42	26
Drainage Syphon / Irrigation Syphon	0	11	3
Bed Dam/Grade wall	4	1	15
Total	44	148	104

21.3 Estimated Costs

Total estimated cost of works only is INR 9120 million (US $ 152.00 million). The estimated cost for each river is shown in Table 21-2

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Table 21-2: Cost of Works for Each of the Six Rivers of this project

River	Estimated Cost (1) (INR Millions)	Estimated Cost (US $ Millions)	No of packages (see Table 21-3)
Harichandra	2218.30	36.97	1
Adappar	1498.00	24.97	1
Vellaiyar	1656.80	27.61	1
Pandavayar	917.00	15.28	1
Valavanar	367.60	6.13	1
Vedharanyam Canal	268.20	4.47	1
Pumping Schemes (2)	127.85	2.13	1
Others	2066.25	34.44	
Total (3)	**9120.00**	152.00	**7**

Note (1) Costs includes all physical works plus environmental and social costs
(2) Pumping schemes includes civil, mechanical and electrical costs.
(3) Other provisions for example physical contingencies including advertisement charges, escalation,,, price adjustments etc. are not included

21.4 Project Duration

The primary source of water supply to the six Project rivers is the Mettur dam. A secondary source is local drainage water (in the case of the Valavanar Drain, local drainage is the only source). The main crop is paddy. Depending upon availability of water in the dam, irrigation supply starts in June and continues through to January. After the irrigation water supply stops, the rivers dry up until the next irrigation season. Floods on the six rivers occur from October until December depending upon whether the intense rainfall comes from the northeast monsoon.

Therefore works on the river channels and structures can be undertaken for the dry five months period from February to June without interrupting irrigation deliveries or be affected by flooding. Most of the construction can take place in dry conditions as the rivers have no water, except for reaches close to the coast where there may be tidal flows in which case dredging (for channel re-sectioning) and coffer dams (for construction of structures) would be required.

Most of the structures except the tail end regulators are small and can be completed within a period of three months. At the new tail end regulators, the bed levels of the rivers are below sea level. As there is tidal flow into these reaches, arrangements are required to stop the backflow from the sea.

The total duration of this Project is 36 months.

21.5 Procurement of Works

Based on the type of construction, the layout of the rivers and the availability of the sites, it is proposed to have 7 tender packages. Details of the seven tender packages are given in Table 21.3.

Table 21-3:

APPENDIX C: PROCUREMENT PLAN

Basic Data

Project Name: Climate Adaptation through Sub-Basin Development – Project 1	
Project Number:	**Approval Number**:
Country: India	**Executing Agency**: Water Resources Department, Government of Tamil Nadu
Project Procurement Classification: B	**Implementing Agency:**
Procurement Risk: Substantial	
Project Financing Amount: $150 million **ADB Financing:**$105 million **Cofinancing (ADB Administered):** N/A **Non-ADB Financing:** $45 million	**Project Closing Date:**[month/day] 2020
Date of First Procurement Plan: 19/12/2014	**Date of this Procurement Plan**: 19/12`/2014

A. Methods, Thresholds, Review and 18-Month Procurement Plan

1. Procurement and Consulting Methods and Thresholds

Except as the Asian Development Bank (ADB) may otherwise agree, the following process thresholds shall apply to procurement of goods and works.

Procurement of Goods and Works		
Method	**Threshold**	**Comments**
International Competitive Bidding (ICB) for Works	$40,000,000	
International Competitive Bidding for Goods	$3,000,000	
National Competitive Bidding (NCB) for Works	Beneath that stated for ICB, Works	
National Competitive Bidding for Goods	Beneath that stated for ICB, Goods	
Shopping for Works	Below $100,000	
Shopping for Goods	Below $100,000	

Consulting Services	
Method	**Comments**
Quality and Cost Based Selection (QCBS)	90:10 quality-cost ratio will be used
Quality Based Selection	
Consultants' Qualifications Selection	
Least-Cost Selection	
Fixed Budget Selection	
Individual Consultant Recruitment	

2. Goods and Works Contracts Estimated to Cost $1 Million or More

The following table lists goods and works contracts for which the procurement activity is either ongoing or expected to commence within the next 18 months.

Package Number[6]	General Description	Estimated Value	Procurement Method	Review [Prior / Post/Post (Sample)]	Bidding Procedure[7]	Advertisement Date (quarter/year)	Comments[8]
CW 1 - CASDP/TN /HRN/ /2014	Infrastructure Improvements and Reconstruction Works on Harichandranathi from LS 121.142 Km to 160.200 Km &Lawford Straight Cut from LS 0 to 3.900 Km.	Rs.2218.30M, $36.97M	NCB	Prior	1S2E	Q1/2015	Small Works SBD
CW 2 - CASDP/TN /ADP/ /2014	Infrastructure Improvements and Reconstruction Works on Adappar River from LS 130.236 Km to 169.025 Km &Adappar Straight Cut from LS 0 to 2.40 Km.	Rs 1498.00M, $24.97M	NCB	Prior	1S2E	Q1/2015	Small Works SBD
CW 3 - CASDP/TN /VLR/ 2014	Infrastructure Improvements and Reconstruction Works on Vellaiyar River from LS 111.650 Km to 153.650 Km.	Rs.1656.80M, $27.61M	NCB	Prior	1S2E	Q1/2015	Small Works SBD
CW 4 - CASDP/TN /PDR /2014	Infrastructure Improvements and Reconstruction Works on Pandavaiyar River from LS 109.270 Km to 148.020 Km.	Rs.917.00M. $15.28M	NCB	Prior	1S2E	Q1/2015	Small Works SBD
CW 5 - CASDP/TN	Infrastructure Improvements and Reconstruction	Rs.367.60M, $6.13M	NCB	Prior	1S2E	Q1/2015	Small Works SBD

/VNR /2014	Works on Valavanr Drain from LS 0 Km to 16.450 Km.						
CW 6 - CASDP/TN /VRM /2014	Infrastructure Improvements and Reconstruction Works on V.Canal and Uppanar.	Rs.268.20M, $4.47M	NCB	Prior	1S2E	Q1/2015	Small Works SBD
Pump 1 - CASDP/TN /PS /2014	Design, Supply, Installation, Testing and Commissioning of Various pumping machinery including associated electrical, Mechanical and civil works.	Rs.127.85M, $2.13M	NCB	Prior	1S2E	Q1/2015	Plant SBD

3. **Consulting Services Contracts Estimated to Cost $100,000 or More**

The following table lists consulting services contracts for which the recruitment activity is either ongoing or expected to commence within the next 18 months.

Package Number	**General Description**	**Estimated Value**	**Recruitment Method**	**Review** (Prior / Post)	**Advertisement Date** (quarter/year)	**Type of Proposal**	**Comments**
TBD	Project Implementation Consultants (PIC)	$632,000	**ICS**	Prior	Q1/2015	N/A	National individuals (8)
TBD	Project Technical Assistance Consultants (PTAC)	$1.1 million	**QCBS**	Prior	Q2/2015	Full technical	For feasibility study, detailed design, and loan preparation for subsequent MFF tranches, conducting groundwater pilot, flood mapping, and DSS set-up. International. 90:10 quality-cost ratio.
TBD	Environmental consultants to undertake EIA to obtain CRZ clearance	$220,000	**CQS**	Prior	Q1/2015	Bio-data	National Lump sum contract
TBD	MIS Development and Maintenance	$300,000	**QCBS**	Prior	Q3/2015	Bio-data	National. Lump sum contract
TBD	Topography Survey- Vennar	$400,000	**QCBS**	Prior	Q3/2015	Bio-data	National. Lump sum contract
TBD	Topography Survey- Cauvery	$475,000	**QCBS**	Prior	Q3/2015	Bio-data	National. Lump sum contract

4. Goods and Works Contracts Estimated to Cost Less than $1 Million and Consulting Services Contracts Less than $100,000 (Smaller Value Contracts)

The following table groups smaller-value goods, works and consulting services contracts for which the activity is either ongoing or expected to commence within the next 18 months.

Goods and Works

Package Number	General Description	Estimated Value	Number of Contracts	Procurement Method	Review [Prior / Post/Post (Sample)]	Bidding Procedure	Advertisement Date (quarter/ year)	Comments
Vehicles 1	Vehicles (19)	$260,000	1	NCB	Prior	1S1E	Q1/2015	Multiple lots for different types of vehicles
Equipment 1	Field hydro-meteoro-logical equipment	$137,500	1	NCB	Prior	1S1E	Q1/2015	Provider will provide training on equipment use
Equipment 2	DSS Office equipment	$22,500	1	Shopping	Post	N/A	Q1/2015	
Equipment 3	PMU Office Equipment	$240,000	Multiple	Shopping	Post	N/A	Q1/2015	

Consulting Services

Package Number	General Description	Estimated Value	Number of Contracts	Recruitment Method	Review (Prior / Post)	Advertisement Date (quarter/ year)	Type of Proposal	Comments
TBD	NGO for resettlement plan implementation	$42,000	1	**CQS**	Prior	Q1/2015	Bio-data	National

D. Non-ADB Financing

The following table lists goods, works and consulting services contracts over the life of the project, financed by Non-ADB sources.

Goods and Works				
General Description	**Estimated Value (cumulative)**	**Estimated Number of Contracts**	**Procurement Method**	**Comments**
WRD Program Management Unit Building Construction	TBD	1	Government procedure	To be financed solely from state counterpart funds

Procurement packages have been planned in such a manner that works in each package will be constructed over two working seasons, with one working season being 6 months from February to July.

21.6 Implementation Schedule

Based on the above procurement plan for 7 works packages, the preparation of the procurement documents is proposed to be done one team. Preparation of bidding documents will be done by

- Correcting mistakes from previous bidding process.
- Absorbing the workload and in getting acquainted with bidding procedures in a systematic manner.
- Streamlining contract management and payments to the contractors based on the experience of the World Bank project.

The time for bidding and tender award will be 4 to 6 months. The activities involved from preparation of bidding documents to award of bid are as follows:

- Preparation of documents
- Invitation and Submission of bids (8 weeks)
- Receipt of bids and Technical Evaluation (2 weeks)
- Submission Technical Bid Evaluation to ADB for approval (1 week)
- Open financial offers and their Evaluation (1 week)
- Submission Financial Bid Evaluation to ADB for approval (1 week)
- Approval of Government of Tamil Nadu and ADB (1 week)
- Submission to State Level Award Committee (2 weeks)
- Letter of Acceptance (1 week)
- Contract Agreement and Submission of Performance Security (4 weeks).
- Issue of Notice to Proceed (Date of Commencement)

The Implementation plan is shown in Table 21-4 and the responsibilities for implementing the plan are shown in Table 21.5.

Table 21.4 Implementation Plan

Sl.No	Packages No.	Start of bidding	End of bidding	Start of construction of works	End of construction of works	Remarks
I	Package 1,	Q1/2015	Q2/2015	Q3/2015	Q3/2018	In the working season of February to July in a year, Q1 will have 2 months (Feb to March), Q2 will have 3 months (April to June) and Q3 will have 1 month (July) for construction activity.
II	Package 2	Q1/2015	Q2/2015	Q3/2015	Q3/2018	
III	Package 3	Q1/2015	Q2/2015	Q3/2015	Q3/2018	
IV.	Package 4	Q1/2015	Q2/2015	Q3/2015	Q3/2018	
V.	Package 5	Q1/2015	Q2/2015	Q3/2015	Q3/2018	
VI.	Package 6	Q1/2015	Q2/2015	Q3/2015	Q3/2018	
VII.	Package 7	Q1/2015	Q2/2015	Q3/2015	Q3/2018	

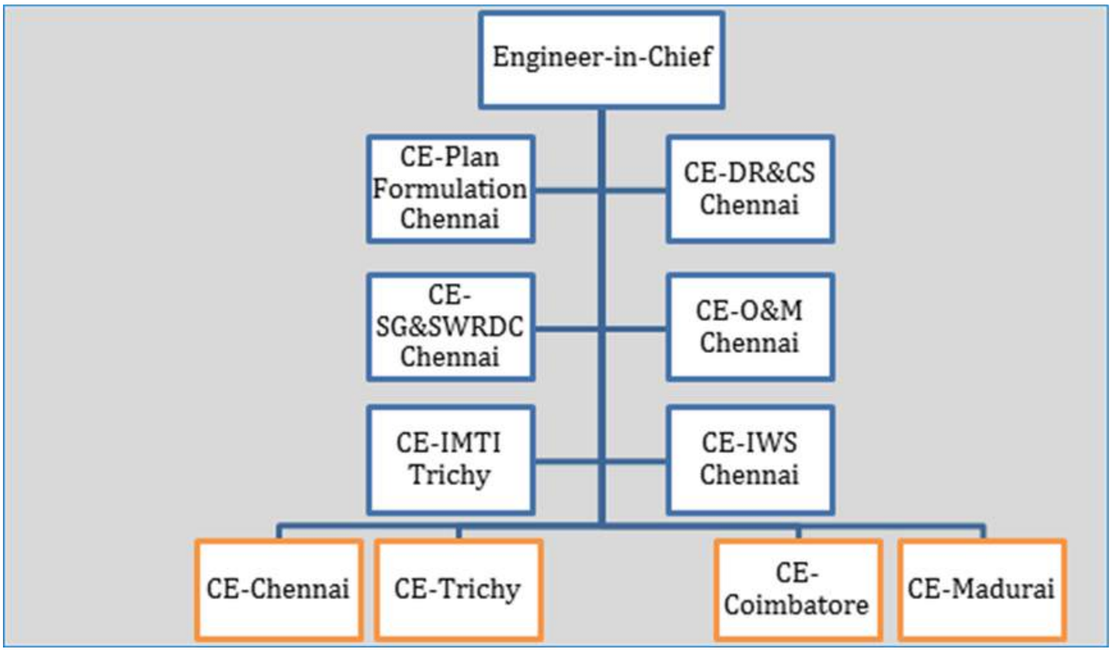
22 Construction Organisation

22.1 Background

The current organisational arrangement within the WRD is hierarchical with its head office located in Chennai, headed by an Engineer-in-Chief, who in turn reports to the Secretary (see Figure 22.1). The Engineer-in-Chief is the custodian of all technical responsibilities related to irrigation. The office of the Engineer-in-Chief in Chennai has five specialist wings each headed by a Chief Engineer. The sixth wing, the ~~Irrigation Management Training Institute (IMTI) in Trichy, is also headed by a Chief Engineer and is entirely dedicated to training. Four Regional Chief Engineers based in Chennai~~, Trichy, Coimbatore and Madurai report to the Engineer-in-Chief. The Regional Chief Engineer in Trichy is the in-charge of the CASDP project area and is also the Project Director.

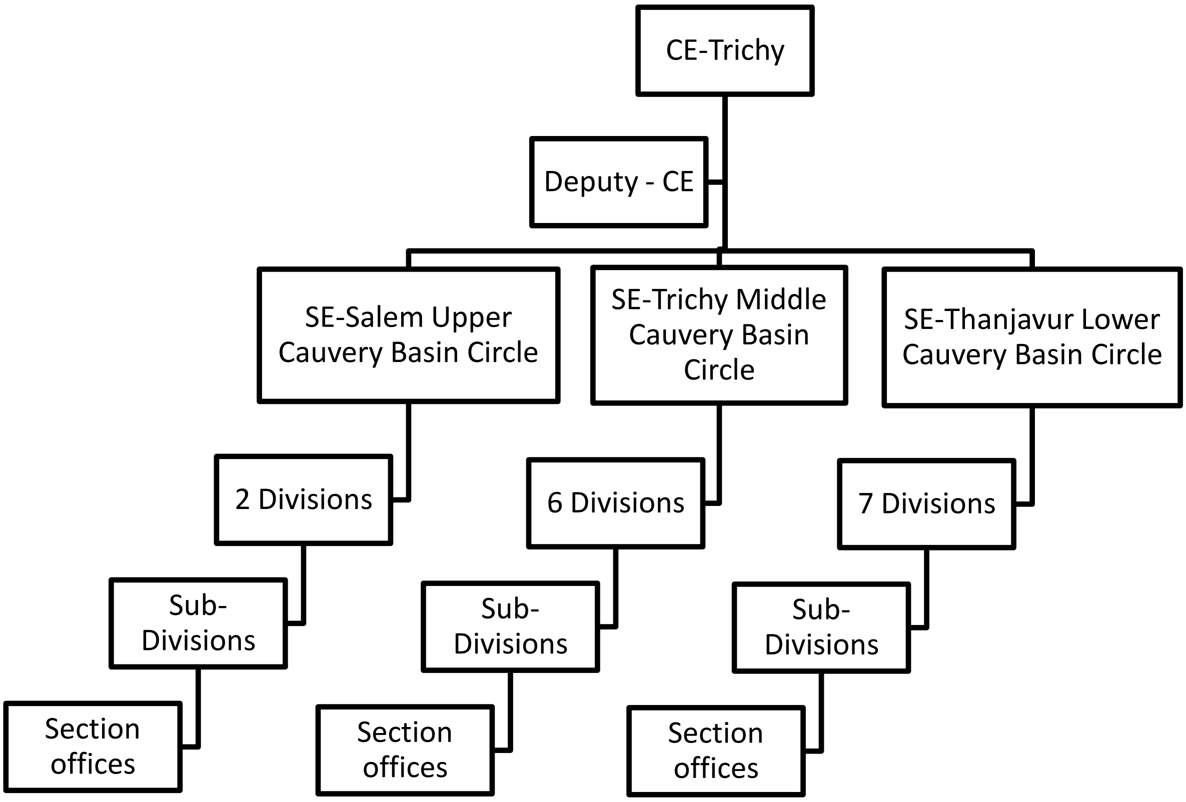
Typically the Regional Chief Engineer's office is organized into Circles, Divisions, Sub-divisions and Section Offices. Under the control of Trichy region there are three circles (see Figure 22.2). The Lower Cauvery Basin Circle, Thanjavur, will be involved in the implementation of CASDP Project.

Figure 22.1 Organisation of WRD at the state level



Note: Blue boxes show functional divisions; Orange boxes show Operational Divisions

Figure 0.1: Organisation structure of CE Office, Trichy



The existing staffing numbers at the Circle Office in Thanjavur and at seven divisional offices are shown Table 22.1. The staffing numbers at the two Vennar divisional offices (Thiruvarur and Thanjav~~u~~r) reflect the actual staff strength on March 2014. These two divisions are expected to be the implementing divisions for CASDP Project.

It is evident from Table 22.1 that across the circle, the ratio between technical and non-technical is skewed towards non-technical staff. The gaps in technical and non-technical staff numbers are particularly wide in Thanjavur division where only about 48% of the non-technical cadre are in post. This is a usual feature of a public sector organization, but it is pertinent to note that efforts to build the WRD staff skills have been limited. A more detailed assessment of the WRD staff should be made during this Project.

Table 22.1 Current Staff Strength of Thanjavur Lower Cauvery Circle

Designation	Circle Office, Thanjavur	Vennar Division Thiruvarur	Vennar Division Thanjavur	Other Five Divisions (see Note 1)	Total
Superintending Engineer (SE)	1	0	0	0	1
Deputy Superintending Engineer (SE)	1	0	0	0	1
Executive Engineer	0	1	0	5	6
Assistant Executive Engineer (AEE)	1	4	1	20	26
Assistant Engineer (AE) /Junior Engineer (JE)	1	10	4	66	81
Irrigation Inspector	0	1	18	89	108
Drafting Section	16	2	4	20	42
Technical staff Sub-total	20 (35%)	18 (35%)	27 (47%)	200 (33%)	265 (34%)
Accounts/Admin	3	4	0	18	25
Office Support Staff	34	21	22	262	339
Other Support Staff	0	8	8	124	140
Non-technical staff sub-total	37 (65%)	33 (65%)	30 (53%)	404 (67%)	504 (66%)
Total	57 (100%)	51 (100%)	57 (100%)	604 (100%)	769 (100%)

Note (1) An additional division has recently been added to Thanjavur Lower Cauvery Circle but has yet to become operational.

22.2 Project Management Unit

This Project will result in a significant increase in the funds being handled by WRD's divisional offices and the offices will need support to implement this Project efficiently. There is also a need to set up steering and technical committees and working groups for this Project (and other CASDP projects) at i) state level ii) regional level and iii) project level. Given the current vertical organization structure, layered decision making processes, and locations of the divisional offices, setting up committees at two levels and a Project Management Unit (PMU) at the project level will be a necessity. The recommended organisational structure of this Project, committee membership and mandates are presented in Figure 22-3.

Figure 22.3 Project-1 Organisation

Project implementation organizations	**Management Roles and Responsibilities**
Water Resources Department (Executing Agency)	• Establish the Project Management Unit in Trichy and Project Implementation units at three locations • Overall responsibility for executing the program/project and ensuring achievement of project objectives • Prepare annual work plan and budget and ensure counter part fund availability • Monitor and ensure compliance of loan covenants and environmental and social safeguards and facilitate implementation of corrective action • Manage project finances and accounts, arrange for financial audits and implement recommended financial management improvement actions. • Ensure all stakeholders are effectively consulted and information disseminated as required during project implementation.
Program Steering Committee	• The PSC will be established in the State with Principal Secretary, Public Works Department as chair. The committee members will include PD CASDP, Engineer in Chief WRD, Chief Engineer Plan Formulation, WRD, CE Groundwater WRD, CE Trichy, heads of key stakeholder departments (Department of Finance, Revenue Department, Department of Agriculture, Department of Fisheries, Department of Highways and Rural Works, Department of Environment and Forest), State Disaster Management Authority, and Director SWARMA. Functions of the PSC will be to: • Provide policy guidance and support • Facilitate inter-departmental co-ordination for implementation at the state level • Facilitate co-ordination with central government ministries and departments • Oversee compliance to covenants of loan agreements and central government requirements • Approve annual project plans • Monitor program progress including achieving development objectives and safeguard compliance • Meet every quarter
Field Implementation Coordination Committee	• The FICC will be established at the division level. The committee will be chaired by the Program director and will include Project Managers (3 EEs), Heads of relevant stakeholder departments (district), and District Collector. Mandate of the committee includes: • Monitor progress at field level • Ensure coordination at field level among various departments • Take up any unresolved issues to PSC • Meet once every two months
Technical Advisory Committee	• The TAC will provide overall technical oversight to the program

	—To persue the Sub-Basin development plans prepared by the Chief Engineer, WRD., Trichy Region and to examine the necessity and technical viability of the Detailed Project Report and various packages proposed with reference with reference to objectives of this project. • Review the Detailed Project Report • To examine the correctness of the designs of infrastructure proposed by the Chief Engineer, WRD., Trichy Region. • Approve any deviations to project scope, costs and design • To fix realistic completion periods for the various packages and evolve correct construction specification for the proposed works. • To devise measures to evict encroachments in the water bodies and water courses with suitable compensation for the project affected persons, if any • To settle any inter departmental issues that arise during implementation of the project • To finalize the cost estimates prepared by the Chief Engineer, WRD., Trichy Region for the various packages proposed in the project. • It will be chaired by the Engineer in chief, WRD and include–Chief Engineer, WRD, PWD, Plan Formulation, Chief Engineer, WRD, PWD, Design Research & Construction Support, Chief Engineer, WRD, PWD, State Ground and Surface Water Resources Data centre, Chief Engineer & Director, WRD, PWD, Institute for Water Studies and Chief Engineer, WRD, PWD, Operation & Maintenance as members and Chief Engineer, WRD, PWD, Trichy Region as member-secretary. • The committee will meet as and when required
CASDP Program Management Unit (PMU)	• The PMU will be located in the WRD Regional Office in Trichy under a full time Project Director with overall responsibility for execution of the program. • The PD will liaise directly with ADB. • The core functions of the PMU include: (i) design and planning, (ii) procurement of goods, works and services, (iii) contract supervision and quality assurance control, (iv) program finance management, (v) implementation of environmental and social safeguards, and (vi) program monitoring and evaluation. The specific functions of the PMU include: • (i) preparation of overall implementation plan and annual work programs and budgets, (ii) procure all goods, works and services , (iii) review and monitor overall progress include contractors performance and ensure timely implementation of program activities, (iv) ensure all necessary requisite government approvals are in place, (v) ensure timely implementation of safeguard implementation plans, (vi) supervise and guide the PIUs, (vii) maintain program financial records and accounts and ensure timely submission of documents to ADB, (viii)

	ensure compliance of loan covenants, (ix) establish and maintain a program management information system, (x) submit quarterly progress reports, annual progress reports, semin annual resettlement monitoring reports, and annual environmental monitoring reports to ADB and government and (xi) oversee the preparation and timely submission of PFRs to ADB.
CASDP Project Implementation Units (PIU) at the executive engineers offices	Three PIUs will be established in Thiruvarur, Nagapattinam, and Thiruthuraipoondi. Day to day management of the PIUs will be undertaken by the Executive Engineers/Project Managers of the three divisions. The core functions of the PIU will include: (i) construction supervision, (ii) contract management, (iii) quality assurance control, (iv) monitoring of implementation of resettlement and environmental management plans, (v) conducting stakeholder consultations and (vi) addressing any project related grievances.

The operational costs for the PMU/PIU are shown in Table 22.3 and the equipment costs are shown in Table 22.4.

To assist the PMU and PIU in project management, reporting and monitoring, a few individual national consultants will be recruited. The PMU will be set up as soon as the project is approved.

Table 22.2 Staffing of PMU and PIU

Task	PMU-Trichy	Project Implementation Units
Overall project management	Project Director	
Design and Planning	Design and planning wing of CE's office	
Procurement	1 EE and 2 AE's technical staff	
Finance and Administration	1 head of Finance (of Chief Account officer rank) supported by 2 deputy accountants	1 Divisional accountant from AG's office for each EE's office. 3 divisional accountants in total
Quality Assurance	Quality assurance wing within the WRD	
Construction Supervision	EE and 2 AE's responsible for procurement will also supervise construction	1 EE, 3 AEEs, 9 AEs per EE's office. Total 3 EE, 9AEE, and 27 AEs
Resettlement monitoring		2 AEE Nagapatinam and Thiruvarur
Environmental Monitoring		AE from Project formulation wing trained as an environment officer
MIS/DSS manager	1 AEE , 2 AE	
Public relations/Liaison officer	1 AEE, 2 AE	

Table 22.4 PMU/PIU Equipment List

PMU/PIU Set up Cost				
Item	**UOM**	**Quantity**	**Rate**	**Value**
PMU				
Building for PMU at Trichy(land not valued ; in kind contibution)	sft	10,000	6,000	60,000,000
No of Workstations	No	18	40,000	704,000
Desktops/Laptops	No	13	50,000	660,000
Airconditioners	No	5	45,000	225,000
Vehicles- PD	No	1	1,900,000	1,900,000
Vehicle- Corrdinator	No	1	1,100,000	1,100,000
Vehicle- EE,Environment, Social Development officer	No	2	800,000	1,600,000
Printers	No	1	15,000	15,000
Telephones/Mobiles	No	2	5,000	10,000
Printer	No	2	15,000	30,000
Photocopier	No	1	150,000	150,000
				66,394,000
Office of Deputy Project Director at Tanjavur				
Existing Building	sft			-
No of Workstations	No	39	40,000	1,558,000
Desktops/Laptops	No	12	50,000	615,000
Airconditioners	No	3	45,000	135,000
Vehicles- SE- Multi Utility Vehicle	No	1	1,100,000	1,100,000
Vehicle- EE- Multi Utility Vehicle	No	1	800,000	800,000
Printers	No	1	15,000	15,000
Telephones/Mobiles	No	2	5,000	10,000
Printer	No	2	15,000	30,000

Photocopier	No	1	150,000	150,000
Total				**4,413,000**
PIU- Thirvaroor, Nagapattinam and Thirutharaipundi				
Building(4000 sft per PIU)	No	12,000	5,000	60,000,000
Workstations	No	174	40,000	6,954,000
Desktops/Laptops	No	43	50,000	2,173,125
Airconditioners	No	6	45,000	270,000
Vehicles- Multi Utility Vehicle - 1	No	3	800,000	2,400,000
Vehicles- Multi Utility Vehicle 2		10	800,000	8,000,000
Printers	No	3	15,000	45,000
Telephones/Mobiles		15	5,000	75,000
Large Format Scanner		3	641,000	1,923,000
Large format Plotter		3	300,000	900,000
Photocopier		3	150,000	450,000
Fax		3	20000	60,000
Total				**83,250,125**
Grand Total				**154,057,125**
INR in Mln				**154.06**
Building value in Mln				**120.00**

PMU /PIU Addiitonal Adminstration Expenses

2. Building rentals, Utilities, Maintenance and Overheads				
Item	**No of Months**	**Cost/month**	**Total Cost**	**Total cost including taxes**
Utilities and overheads	48	75,000	3,600,000	4,044,960
Vehicle running & maintenance	48	1,000,000	48,000,000	53,932,800
Miscellaneous	48	200,000	9,600,000	10,786,560
Total			**61,200,000**	**68,764,320**

Staffing	Nos
PIUs office at Thirvarur, Nagapattinam and Thiruthuraipundi	
EE	1
Officer Technical	1
Drawing Section	
Senior Drafting Officer	1
Junior Drafting Officer	3
Asst Draughtsman	1
Supporing Staff	
Divisional Accountant	1
Bill Processing	5
Administration and Establishment	6
Office Assistant	4
Driver	1
AEE(R&R)	1
AEEs office	
AEE	3
Admninstration Staff	9
Driver	3
Office asst	3
Aes office	
AE	9
Work Inspector	9
Total per Division	61
No of Divisions	3
Total Number of Desks required	183

PMU	Nos
Project Director	1
Coordinator-CE	1
EE	1
AEE	2
AE	4
Support Staff	
Accountant/Finance Management Specialist	1
Dy Accountant/Sr Accounts Officer	2
Jr Officer	1
Personal Assistant	1
Office Assistants	5
Watchmen	1
Driver	2
Total	22

Office of Deputy Project Director- Tanjavur	**Nos**
SE	1
EE	1
AEE	1
AE	1
Procurement Team	
Chief Head Draughtsman	1
Sr Drafting Officer	1
Draughting Officer	3
Jr Drafting Officer	3
Asst Drafting Officer	3
Support Staff	
A&E	1
Supdt	2
Assistants	8
Jr Assistants	4
Office Assistants	6
Driver	2
Watchmen	1
Data Entry Operator	1
Telephone operator	1
	41
Total Staff Strength of project	**246**

22.3 Project Consultants

To assist the PMU and PIU in project management, reporting, monitoring and implementation of specific components of the Project and to help design a follow on project for the remainder of the Vennar and Cauvery System the following consultancy services are required: : (i) project implementation consultants (comprising seven individual national consultants for a total of 96 person months), (ii) project advisory consultants (consultancy firm comprising of 24 international person months, and 96 national person months) to help support implementation of the soft components under the project and support the design of the follow on project, (iii) environmental consultants to undertake the environmental impact assessment required to obtain clearances under the Coastal Zone Regulatory act (a government accredited firm comprising of national consultants for a total of 11 person months), (iv) a firm to undertake a topographic survey for design of follow on project and (iv) a NGO to support the implementation of the resettlement plan comprising 50 person months (the costs of these have been included in the resettlement budget).

The cost of the Project-Implementation Consultants are shown in Table 22.6.

Table 22.6 Cost of Project Implementation Consultants

Summary of Consultants for PIC	Man months	Cost per month(USD)	Value excluding taxes	Value including taxes	Value in Mln in INR
Implentation Individual consultants(details below)			631,368	709,405	42.56
NGO for resettlement(details below)			42,525	47,781	2.87
CRZ Clearance(lumpsum)			190,559	214,112	12.85
Audit firm	48	5,000	240,000	269,664	16.18
MIS Implemntation firm(lumpsum)			300,000	337,080	20.22
Total Consultants Cost			**1,404,451**	**1,578,041**	**94.68**

Program Technical Assistance – Individual

									Travelling Cost Calculations			Travel						
	Man months	Cost per month(USD)	Travel and Subsistence	Total	Travel for team	Admn costs	Contingencies	Total	No of days	Rate per day	Total	Travel	Grand total	No of trips	Cost per trip	Total	Cost & per diem	Travelling
Project management specialist	36	5,000	53,100	233,100	38,400	2,500	11,655	285,655	1080	45	48,600	4500	53100	18	250	4500	228,600	4500
Procurement Specialist	6	4,000	8,850	32,850			1,643	34,493	180	45	8,100	750	8850	3	250	750	32,100	750
Social Development Specialist	12	4,000	17,700	65,700			3,285	68,985	360	45	16,200	1500	17700	6	250	1500	64,200	1500
Environment Specalist	6	4,000	8,850	32,850			1,643	34,493	180	45	8,100	750	8850	3	250	750	32,100	750
Construction quality assurance	18	4,000	26,550	98,550			4,928	103,478	540	45	24,300	2250	26550	9	250	2250	96,300	2250
Financial Management Specialist	6	4,000	8,850	32,850			1,643	34,493	180	45	8,100	750	8850	3	250	750	32,100	750
Construction Engineer	12	4,000	18,450	66,450			3,323	69,773	360	45	16,200	2250	18450	9	250	2250	64,200	2250
Total				**562,350**	**38,400**	**2,500**	**28,118**	**631,368**									**549,600**	**12,750**

NGO for Resettlement

	Number of Persons	Monthly Rate per person	Input in Months per person	Total (Number of persons x Rate x input months
Team Leader cum Community Development Specialist	1	50,000	6	300,000
Field Coordinator	2	45,000	12	1,080,000
Field Staff	2	25,000	10	500,000
				-
Local Travel	LS	30,000	10	300,000
Survey Cost	LS			200,000
Reporting and Documentation	LS			50,000
Sub Total				**2,430,000**
Contingency @5%				121,500
Grand Total				**2,551,500**
Grand Total in US$				**42,525**

Summary- PTAC- follow on Project

Consultants	PTAC	Survey	EIA by authorised agency	Total Costs	Total Costs including taxes	Total Costs including taxes in Mln INR
Remuneration and Per Diem						
International Consultants	504,000					
National Consultants	406,600					
International and Local Travel	63,750					
Reports and Communication	10,000					
Provisional sums - survey and data collection	59,100					
Miscellaenous and Administration support costs	10,000					
Contingencies	52,673					
Total Cost(excluding local taxes)	**1,106,123**	875,000	334,000	2,315,123	2,601,271.64	156.08

Environmental survey for CRZ Clearance

S.No.		INR	
Remuneration of the Experts		2,093,520	
Travel Cost including Air / Rail / Road		879,000	
Survey Cost (Terrestial, Aquatic, Air, water, soil and Social)		3,968,000	
HTL / LTL demarcation survey		4,030,000	
Purchase of Sattelite Imageries and documents		100,000	
Reports and Communication		350,000	
Misc		13,000	
Total Cost(excluding local taxes)		**11,433,520**	
Summary of Consultants for PIC	**Man months**	**Cost per Month (USD)**	**USD**
Implentation Individual consultants(details above)			631,368
NGO for resettlement(details above)			42,525
CRZ Clearance(lumpsum)			190559
Audit firm	48	5000	240000
Total Consultants Cost			1,104,452

Program Technical Assistance – Firm

Program Technical Assistance - Firm					Travelling Cost Calculations			Travel							Total (rem, travel and perdiem) same as column E
	Man months	Cost per month(USD)	Travel and Subsistence	Total	No of days	Rate per day	Total	Travel	Grand total	No of trips	Cost per trip	Total	Cost & per diem	Travelling	
Consultants- International															
Team Leader(Int)	12	18000	46,000	262,000	360	100	36,000	10000	46,000	5	2000	10000	252,000	10000	262,000
Hydraulic and coastal Modeler(International)	4	18000	20,000	92,000	120	100	12,000	8000	20000	4	2000	8000	84,000	8000	92,000
Hydrologist (international)	2	18000	10,000	46,000	60	100	6,000	4000	10000	2	2000	4000	42,000	4000	46,000
DSS specialist (international)	2	18000	8,000	44,000	60	100	6,000	2000	8000	1	2000	2000	42,000	2000	44,000
Groundwater Specailist(International)	2	18000	12,000	48,000	60	100	6,000	6000	12000	3	2000	6000	42,000	6000	48,000
Economist (International)	2	18000	10,000	46,000	60	100	6,000	4000	10000	2	2000	4000	42,000	4000	46,000
National Consultants															
GIS Expert(National)	12	4,000	17,450	65,450	360	45	16,200	1250	17450	5	250	1250	64,200	1250	65,450
Survey Supervisoon(national)	2	4,000	3,200	11,200	60	45	2,700	500	3200	2	250	500	10,700	500	11,200
Hydrologist	8	4,000	11,800	43,800	240	45	10,800	1000	11800	4	250	1000	42,800	1000	43,800
Hydraulic and coastal Modeller(national)	12	4,000	17,200	65,200	360	45	16,200	1000	17200	4	250	1000	64,200	1000	65,200
DSS developer	8	4,000	11,800	43,800	240	45	10,800	1000	11800	4	250	1000	42,800	1000	43,800
Groundwater Modelling(National)	6	4,000	10,100	34,100	180	45	8,100	2000	10100	8	250	2000	32,100	2000	34,100
Civil Engineer	6	4,000	9,100	33,100	180	45	8,100	1000	9100	4	250	1000	32,100	1000	33,100
Economist(National)	4	4,000	6,150	22,150	120	45	5,400	750	6150	3	250	750	21,400	750	22,150
Financial Management Specialist(National)	4	4,000	6,150	22,150	120	45	5,400	750	6150	3	250	750	21,400	750	22,150

Agriculture Specialist(national)	2	4,000	3,200	11,200	60	45	2,700	500	3200	2	250	500	10,700	500	11,200
Envrironmentalist(national)	6	4,000	9,100	33,100	180	45	8,100	1000	9100	4	250	1000	32,100	1000	33,100
Social development specialists (national)	6	4,000	9,100	33,100	180	45	8,100	1000	9100	4	250	1000	32,100	1000	33,100
Local Conveyance for the above group	24	750		18,000										18,000	18,000
Total				**974,350**									**910,600**	**63,750**	**974,350**
Project preperation work															
Asset Survey equipment and logistics	Lump sum			1,000											
Environmental Baseline survey	Time			6,000											
Socio Economic Survey				20,000											
Total				**59,100**											
Preparation of EIA by authorised agency	Time			334,000											
Topo Survey (separate from PTAC consultants two packages for Vennar and Cauvery- total of both packages)															
Topographic Survey	Lump sum			400,000											
Topgraphic Surey(flood Plains)	Lump sum			100,000											
Additional Topogrpahic Surveys for ground control	Lump sum			300,000											
Stereo image purchase and processing	Lump sum			75,000											
				875,000											

22.4 Preparation of follow on project

As stated above this project will help design a follow on project for the remainder of the Vennar and Cauvery system. This Project for six rivers / drains in Lower Vennar System has been prepared and is the subject of this DPR. DPRs for follow on ~~Project~~ will be prepared during the ongoing project and submitted for approval during implementation of this project.

22.4.2 Approach to the Preparation of follow on project

This project will include financing to prepare a follow on project. The approach will be to build on the experience gained from the preparation ~~of~~ this project and take a similar approach for preparation of the DPRs for subsequent project including the use of hydrological (rainfall-runoff) and hydraulic (channel flows and water levels) modelling. The rationale for following this approach is:

The Need for Modelling

- An integrated model provides the framework for collating and assessing data essential for the assessment of flooding and engineering design. Key gaps in data and the primary source of uncertainty are identified.
- The model represents the current knowledge of the hydrology, hydraulics and river network. It makes clear any lack of knowledge in the network of drains and rivers. It can be improved upon as further information becomes available.
- All approaches depend on calibration whether a modelling approach or a more traditional manual approach. Calibration not only provides a check on the model parameters it is also a valuable way of testing the quality of observed data for identifying the need for further observations.
- The calculation of drainage flows is the most uncertain component when estimating flows in the river network. It is therefore important to use a tried and tested approach that is based on available rainfall and climate data and can reflect the hydrologic response of a catchment.

SWAT Catchment Modelling

- The hydrological model (SWAT) is well tested model in India and has been accepted by CWC for the Hydrology Design Aids (HDA) being developed under Hydrology Project II. It objectively simulates runoff based on observed meteorological inputs (primarily rainfall) and the catchment characteristics. It can be calibrated to available flow records. The model is the only objective way to estimate the runoff from the catchments that contribute to a river. There is no easy alternative to calculating drainage flows.

- The model relies on the derivation of sub-catchment boundaries. These are derived using the best available DEM and can be adjusted to reflect the actual drainage areas when they differ from the topographic catchment.

- SWAT once set-up enables the quick generation of alternative scenarios such as the impact of climate change or a change in land use or cover.

Hydraulic Modelling

- The use of a one-dimensional hydraulic model (HECRAS in this case) ensures that hydraulic analysis reflects variations in the channel form, over-topping during high flows, structures and variable boundary conditions.

- HECRAS was set up using cross sections at 250m and the dimensions of the cross regulators as surveyed by PMSL. The downstream boundary condition was a variable sea level and out of bank flow was based on the embankment levels at 250m centres. The level of detail built into the model far exceeds the detail that can be used for alternative methods such as Manning's "n" calculations or simple backwater analysis.

- Once set up HECRAS can be used to rapidly assess numerous scenarios including dredging, bank raising and the re-design of structures. Numerous alternative scenarios can be run using the batch facility.

- The model allows steady and unsteady state analysis and provides the user with a full set of results including velocity, depth, flow and Froude number. Critical sections are identifiable and instabilities are evident. The modelling can determine peak flows more accurately than analysis based on the recorded daily average flows.

- HECRAS is easy to set up and easy to run. It is open-access software and supported by USGS manuals, on-line training material and examples.

Integrated Modelling

- The integration of SWAT and HECRAS gave a powerful tool for assessing the impact of alternative design hydrographs on the water level and flow in the river system. In addition, the generation of time series at any HECRAS cross section would allow the validation of the model at any location where flow or level data is available (now or in the future).
- The integrated model also gives a tool for quantifying the impact of changes in the location or timing of drainage flows and the interaction with river flows.
- The model together with a DEM allows flood maps to be easily generated for any number of scenarios.

Traditional Design not using Models

- The hydrological analysis relies on simple assumptions (e.g. runoff coefficients) and simple average rainfall. This results in less accurate estimates of runoff and a cumbersome method not well suited to the assessment of multiple scenarios. It is also reliant on the derivation of sub-catchments.
- The hydraulic analysis cannot account for the small scale (250m) variations in channel form and therefore may not identify critical sections (e.g. with a sudden reduction in flow area or rise in bed level). The analysis cannot easily combine the analysis of open channel sections with flow control structures, bridges, in-falls, off-takes and variable boundary conditions.
- Traditional design methods are cumbersome for evaluation of multiple options. It is likely that HECRAS would be quicker and easier to set up than a non-modelling approach.
- In summary, without modelling the approach may not be objective, is not suited to the assessment of numerous scenarios and cannot easily be interfaced with a DEM for flood mapping.

There are some differences with the approach used for the preparation of this project and that proposed for the preparation of follow on project namely,

(i) A separate feasibility study would not be prepared, only DPRs;

(ii) WRD staff would be fully responsible for engineering designs;

(iii)The additional survey being done under this Project to inform the flood mapping would not be needed because a DEM would be procured; and

(iv) Consultants would be used wherever the expertise does not currently exist within WRD, and would be engaged by and report to Project Director.

The preparation tasks and the resources needed are shown in Table 22.7. this Project will include approximately USD 1.6 million to prepare follow on project.

As the topographical survey and initial model covers the entire Vennar system, this approach allows WRD to build on the work of the PPTA. This project will also support overall Program management and detailed design of follow project.

Consultancy services required to support the preparation of the follow on Project are included under the Project Advisory Consultants ToRs (cost of consultancy service described above). In addition the topography survey contracts described in the earlier section are also to support the project preparation of the follow on project.

In addition WRD has committed the following staff resources to support the preparation of the follow on project.

Activity	WRD staffing resources
Topographic survey of channels and establishment of ground control points for flood plains	Supervision of Topographic Surveys in remainder of vennar and Cauvery- 2 AEE
Asset survey Collect data on all flow regulators and structures including: - Location - Type - State and maintenance issues - Dimensions - Operation - Performance Includes a review of existing registers and a site survey	2 Assistant engineers leading 2 teams for three months
Design Includes:Assessment of structures - Channel alignment - Additional surveys - Geotechnical survey and analysis	4 engineers for 48 months
Prepare detailed cost estimates	16 engineers for 4 months each
DPR preparation	2 EEs supported by 4 AEEs
Preparation of bid documents	Procurement team of the PMU

23. Environment, Ecology and Forest Aspects

23.1 Anticipated Environmental Impacts and Mitigation Measures

The Initial Environmental Examination is based on baseline environmental attributes and the interactions of the project components with the attributes. The environmental attributes relevant to the assessment of the impacts are air quality, noise level, soil, water resources, water quality, vegetation cover, land use, local infrastructures etc. The construction and operation of the project may have positive and negative impacts on the said environmental attributes. The assessment of impacts defines whether they are significant, irreversible, or reversible.

Mitigation measures are incorporated into the design phase and the construction and operation phases of the project. The design phase incorporates important considerations like selection of location of Regulators, whether reconstruction or rehabilitation of the structure is to be executed. The construction impacts are mainly limited to the locality of the construction works and last for short period. The operation stage impacts are expected to be positive and extend to the catchment area of the river channel concerned.

23.1.1 Methodology

The methodology followed was:

i. Review of Documents

An extensive literature search was carried out, with the following documents being reviewed:

- Environmental Protection Act, 1986
- EIA notification, 2006 and amendments
- CRZ Notification, 2011 and 1996 and amendments
- Forest Conservation Act, 1980 and amendments and Tamil Nadu Forest Conservation Rules.
- Consolidated data of Full Climatic Stations in Tamil Nadu, Government of Tamil Nadu,

- EIA Report of Reconstruction and Modernisation of PAZHAYAR Fishing Harbour (World Bank Aided), Fisheries Department, Government of Tamil Nadu, 2010
- Environmental Impact Assessment Study for Bar Mouth Opening at Tirumullaivasal in Nagapattinam District, WAPCOS, Govt of India
- Report of EIA and EMP of 2.96 MLD sewage treatment plant in Nagapattinam Municipality.

ii. Surveys and Site investigation

Site investigations were conducted during following schedule by PPTA team

- December 4-11, 2013
- February 10-21, 2014,
- March 24-31, 2014
- The following surveys were also carried out:
- Enumeration of trees along the rivers
- Investigation of river bed silt, Water and ground water for availability of pesticides.

iii. Public Consultation and Stakeholders' consultation by PPTA team

Consultation with local people was conducted to determine the impacts and mitigation measures. The stakeholder consultation was also held with the Fisheries Department, Agricultural Department, Water Resources Department, Forest Department and district level Pollution Control Board.

23.1.2 Mitigation Hierarchy

The mitigation hierarchy implemented in this project are given below

Minimisation – The minimisation of impacts such disturbance to the soil and water turbidity.

Restoration - The restoration of impacts which cannot be avoided like felling of trees on embankments or opening up of borrow areas. The restoration of borrow areas will be done according to the prevailing guidelines and compensatory trees will be planted in lieu of felling of trees.

23.2 Impacts and Mitigation Measures

23.2.1 Ambient Air Environment

23.2.1.1 Construction Stage Impacts and Mitigation Measures.

Air emissions during the construction stage arise from the operation of construction vehicles, equipment, haulage of material and earth, and dust generation from earthwork. The re-sectioning of channels and construction of embankments are included in the works on all 6 rivers of this project. The cumulative lengths of all six rivers are 234 km. The construction of embankments will generate dust locally which may impact nearby residential, commercial and sensitive locations like schools adjacent to the boundary of the rivers. However these impacts will not be significant, being less than the impact of dust created from agricultural land during ploughing.

Mitigation measures for suppression of dust near the residential, commercial and area of socially important places like temples and churches are required through sprinkling of water on the construction site. The transportation of silt will be done in covered trucks through residential and commercial areas. The wheels of truck will be washed at the construction site so that they do not carry dust to the residential areas. Regular checking of pollution emission from the construction vehicles exhaust will be done by the relevant authorised agency and a Pollution under Control (PUC) certificate will be obtained.

23.2.1.2 Operation Stage Impact and Mitigation Measures

Operation stage emissions and air pollution are not anticipated in this project.

23.2.2 Noise Level

23.2.2.1. Construction Stage Impacts and Mitigation Measures

Noise generation during construction may arise from operation of construction vehicles, equipment, haulage of material and earth. The impacts are not significant and are limited to construction hours in day time only. There are two schools identified at chainage 129.00 km on the Harichandra River and chainage 13.2 km on the Vellaiyar River. The main source of noise is de-silting and re-sectioning from the operation of construction vehicles, and drivers will be instructed to avoid using pressure horns. 'No horn' signage will be provided near schools.

Mitigation measures also include the proper maintenance of construction vehicles to minimise the amount of noise during operation.

23.2.3 Soil Environment

23.2.3.1. Construction Stage Impacts and Mitigation Measures

The construction stage impacts on soil are mainly due to re-sectioning, desilting of channels and construction of embankments. The re-section and de-silting involve the removal of silt from the river bed. Testing of silt has been conducted for rivers near head regulators and tail end regulators. The results show that pesticides are below detectable limits. Excavated soil and silt will be taken to specified locations for re-use wherever possible.

The other impact on the soil environment will be from the construction of borrow areas. Borrow areas will be identified by the contractor and will be operated and closed as per the contract. Soil quality will not be affected.

There is a risk of water borne soil erosion due to disturbance of soil during de-silting, re-sectioning of rivers and construction of embankments will be avoided as the construction work will be done when there are no flows in the channels. Air borne soil erosion will be prevented by applying water during placement and compaction.

Soil suitable for constructing embankments will be identified by laboratory tests. The excess silt and soil not suitable for construction will be used for gardening or landscaping. Areas suitable for disposal of excess silt and soil will be identified by the contractor.

The dredged material from the Vellaiyar, Lawford, Adappar and Uppanar Straight cuts will be saline and will not be suitable for disposal on agricultural land but will be disposed of in old meanders or stored near the embankment of the straight cuts.

Arrangements for locating the source of supply of material for embankment as well as compliance to environmental requirements, as applicable, shall be the sole responsibility of the contractor. The environmental personnel shall be required to inspect every borrow area location prior to approval. The operation and rehabilitation of borrow areas shall be according to the Madras Detailed Standard Specification (MDSS) and Environmental Code of Practices. The borrow areas shall be located at least 500 m away or suitably sufficient distances from schools and village access roads. The Contractor shall not borrow earth from the selected borrow area until a formal agreement is signed between the landowner and contractor and a copy of this agreement is submitted to the PIU. Planning of haul roads for accessing borrows materials shall be undertaken during this stage. The haul roads shall be routed to avoid agricultural areas. In case agricultural land is disturbed, the contractor shall rehabilitate it to its original condition. Haul roads shall be maintained throughout the operation period of the borrow areas by undertaking required maintenance and repair works, which may include strengthening, pot hole repairing and diversions. Improvements shall be done to reduce inconvenience to users of these roads, residents living along the haul roads and minimize air and water pollution. All borrow areas whether in private, community or government land shall be restored either to the original condition or as per the approved rehabilitation plan.

23.2.4 Water Resources and Quality

23.2.4.1. Construction stage Impacts and Mitigation Measures

As construction will take place when the river beds are dry, there will be no impact on water quality of de-silting and re-sectioning of the rivers. The overall quality of the river water will not change.

Water pollution may be caused due to spill of grease and oil from heavy machinery being used for the construction.

Embankment construction will take place during the dry season and stabilisation of embankments immediately after construction will avoid soil erosion if there is rain.

23.2.4.2. Operation Stage Impacts and Mitigation Measures

The flow of fresh water will be improved after de-silting and re-sectioning of the river channels which will have positive impact on the agricultural land and aquaculture upstream of the new and reconstructed tail end regulators.

23.2.5 Wildlife, Biodiversity and Reserved Forest

The project does not fall within or near any reserved forest, bio-diversity or wildlife area. Mangrove plantations exist downstream of the proposed Tail End Regulator on left bank of the Harichandra River but are not impacted by the project. Mangrove plantations on the Adappar river are remote from the river channel where re-sectioning is proposed.

There are no globally or nationally threatened species in the rivers.

23.2.6 Tree Plantation

23.2.6.1. Construction Stage Impacts and Mitigation Measures

There are 5468 trees on the banks of Vellaiyar, Harichandra, Adappar, Valavanar and Pandavayar Rivers. They are mainly teak, neem, coconut, tamarind and karuve trees planted by either the Forest Department or the Water Resource Department. Since these plantations are not natural ecosystem of woodland or forest and have agricultural land on both sides, the impact of felling of trees will not be significant.

The existing trees on the bank of the river are of two types:

- Type – 1 – Trees planted by the Forest Department
- Type – 2 – Remaining trees planted by the Water Resource Department or naturally grown.

The cutting, removal and compensatory plantation for felling of type-1 trees will be done by the Forest Department. The cutting, removal and compensatory plantation for felling of type-2 trees will be done by the Water Resource Department through contractors on permission of the Revenue Department.

Right of salvage of the felled trees are with the owner agency. The removal of felled trees planted by the Forest Department will be done by the Forest Department. The removal of felled trees which are not planted by the Forest Department, will be done by the WRD through the contractor. The wooden part of the trees will be sold. Other shrubs and grass will be disposed of along with the waste of clearance and grubbing of the site.

The compensatory plantation will be 3:1 i.e. plantation of three trees in lieu of cutting of one tree. The species of trees for compensatory plantation should be native or the same as previously planted and also should be determined in consultation with the local office of Forest Department. These plantations can be placed on the outer side toe of the constructed embankments.

A consultation has been done with the Forest Department for the permission of felling of trees. Forest Department will conduct its survey on receipt of proposal of felling of trees and then the valuation of compensatory afforestation will be done. On payment of the compensation amount the Forest Department will give permission of felling.

23.2.7 Land use

23.2.7.1. Construction Stage Impacts and Mitigation Measures

The land use of the project area will not change.

23.2.7.2. Operation stage Impacts and Mitigation Measures

The proposed project will positively influence the agricultural productivity due to increased supply of fresh water especially throughout the area and near the proposed new tail end regulators.

23.2.8 Archaeological Remains

There are no archaeological sites within or near the proposed project site. Any chance finding will be taken care according to Archaeological Survey of India guidelines. These chance finds can be ruined structures buried underground. This is not expected because there are no deep excavations.

23.2.9 Environmental Management Plan

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
Design and Pre-Construction Stage							
	Approval and NoC	Regulatory and Statutory Requirement	Obtain CRZ Clearance Obtain Approval from Forest Department and Revenue Department for Felling of Trees		PMU/WRD	PMU/ WRD	WRD to bear the cost
	Selection of Construction Camp for site office and storage of material, parking of	Conflict with local community, Additional load on water supply, sewerage, solid waste management	Since establishment of construction camp and labour camp are the decision of contractor. Selection of Construction camp and workers' camp away from the habitation area,	Location of Construction Camp and Labour camp. The number of these camps depends on the	Contractor	PMU/ WRD	Contractor's cost.

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
	vehicles and Workers' Camp for labour to stay during non-working hours.		Contractor to provide safe drinking water as per IS 10500 standards for drinking water. Provide sanitation for male and female workers. Collection and disposal of solid waste of the worker's camp	contract. 17 construction camp and 17 workers' camp depending on number of construction packages are expected.			
	Identification of borrow pits and quarry area	Impact from haulage and degraded surface during construction Unsafe condition near the borrow area	Selection of Borrow pits for earth should be away from residential area, sensitive location, and local roads. Before selection of borrow area, the contractor will take written consent from the	Borrow pits, and quarry area	Contractor	PMU/WRD	Contractor's cost.

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			environmental officer of PMU. Selection of sand, stone and other quarry material will be only government approved sites only.				
	Intervention with Utility	Utility like water supply, electricity, access to other side of the river	The contractor will identify water supply pipes, electrical poles, cables and access roads and bridges	All project location	Contractor	PMU/WRD	Incorporated in the contractor cost
Construction Stage							
Ambient Air Quality and Noise							
1	De-silting and resection of	Generation of dust having impact on	Dust suppression by	Habitation area, schools, temples,	Contractor	PMU/WRD	EMP

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
	river	habitation and agricultural land	sprinkling of water Provide dust curtain or geotextile membrane to cover soil.	churches as given in table D-1 to D-6, Agricultural field throughout the project area			Budget
2	Transportation of construction material, earth	Generation of dust	Provide covered transportation of material and earth, Avoid haulage rout in residential area and sensitive locations	Habitation area as given in table D-1 to D-6, Village roads	Contractor	PMU/WRD	Contractor cost
3	Operation of construction equipment's and	Emission of pollutants like NOx, SO2, HC ets	Maintenance of vehicles and equipment as per manufacturers guidelines and monitor emissions of	Construction camp	Contractor	PMU/WRD	Contractor cost

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
	vehicles		the vehicles and equipment				
4	Quarrying and borrowing of earth for construction of embankment and road	Extraction of clay, soils, stones, aggregates, and loose materials other than stones can cause disruption of natural land contours and vegetation resulting in accelerated erosion, disturbance in natural drainage patterns, and sedimentation/siltation of surface waters. Harichandranadi river Total conveyance of Earth is 17,18,600	Quarrying of sand, stone and aggregates will only be from the government approved and WRD identified location in bill of quantity. Operation and Rehabilitation of borrow area as per the Madras Detailed Standard Specification and Environmental Code of Practices given in **Annexure – 8** Arrangement for locating	Sand from Devankudi, Stone from Thuvakudi and Rattamdai, Gravel from Vallam, The Locations of borrow pits will be identified by the contractor as per the conditions of contract and ensuring the mitigation	Contractor	PMU/WRD	Contractor Cost

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
		cubic meter, Desilting 7,19,000 cubic meter by quantity, Desilting in Low Ford Straight cut is 1,61,100 cubic meter by quantity, Adappar river has conveyance of earth is 7,54,699 cubic meter, de-silting 8,50,400 cubic meter by quantity, Desilting in Adappar straight cut is 2,20,000 cubic meter	the source of supply of material for embankment and sub-grade as well as compliance to environmental requirements, as applicable, shall be the sole responsibility of the contractor. The environmental personnel shall be required to inspect every borrow area location prior to approval. The borrow areas shall be atleast 500m from schools and village access roads The Contractor shall not borrow earth from the	measures suggested herein.			

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
		by quantity	selected borrow area until a formal agreement is signed between land owner and Contractor and a copy of this agreement is submitted to the concerned officer of WRD/Supervision Consultant. Planning of haul roads for accessing borrow materials shall be undertaken during this stage. The haul roads shall be routed to avoid agricultural areas. In case agricultural land is disturbed, the Contractor shall rehabilitate as				

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			approved by the WRD/ Supervision Consultant Haul roads shall be maintained throughout the operation period of the borrow areas by undertaking the required maintenance and repair works, which may include strengthening, pothole repairing and diversions. Improvements shall be done to reduce inconvenience to users of these roads, residents living along the haul roads and minimize air and water pollution.				

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			Such measures shall include, but not limited to, frequent sprinkling of water, repairing of the road, road safety provisions (warning and informatory signage, flagmen etc.), and ensuring covering of loaded vehicles by waterproof tarpaulin; consultation with public and special precautions are required when measures are implemented near schools, health centers and settlement areas. All borrow areas whether in private, community or govt.				

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			land shall be restored either to the original condition or as per the approved by WRD/ Supervision Consultant				
Soil Environment							
6	Standardisation of embankment and delisting of river and construction of road on one side embankment. Operation of borrow pits and transportation of	Water and air born soil erosion,	After cutting and filling embankment will be immediately stabilized Avoid de-silting within the flow of water. Encourage utilisation of river silt in gardening and other agricultural purpose identified in consultation	All location of resectioning of Vellaiyar, Pandavayar, Harichandranadi, Adappar and Valavanar rivers. Vellaiyar, Lawford, Adappar and	Contractor	PMU/WRD	Contractor Cost

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
	material		with farmers. Disposal of silt and sand from the Vellaiyar, Lawford, Adappar and Uppanar straight cut will be disposed or stored near the embankment of the straight cut	Uppanar straight cut			
7	Disposal of construction debris	Improper disposal of construction debris in agricultural land and resulting loss of agricultural and reduced productivity and landscape and loss of aesthetic	Prohibition of throwing of construction debris in any sites other then the designated disposal sites identified at the detailed design stage	Construction zone	Contractor	PMU/WRD	Contractor Cost

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
		beauty					
Water Resource and Quality							
	Resection and de-silting of river Construction of Tail end regulators, Irrigation head sluices, drainage infalls, syphons, Bed dam, Grade dam, Chance spillage	Increased turbidity in downstream of river, Spillage on construction site, construction camp.	Since the most of the construction work will take place in the lean season so mitigation measure of avoidance of de-silting within the flow of water will minimise soil erosion and increase in turbidity in the downstream.	Construction zone and construction camp	Contractor	PMU/WRD	Contractor cost

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
	of oil, grease from heavy machinaries, construction vehicles and equipments						
Biological Environment							
	Clearance and grubbing of site for construction of embankment	There are 5468 trees available on the river banks of Vellaiyar, Harichandranadi, Adappar, Valuvanar and Pandavayar rivers. Removal of the trees planted by Forest Department will require	Cut trees will be removed by the Forest Department and stored. The Forest Department can later sell the trees according to their rules. The trees which are not planted by the Forest Department will be cut and removed by the contractor on permission of district	River banks of Vellaiyar, Harichandranadi, Adappar, Valuvanar and Pandavayar rivers. Adjacent and foot of the	Contractor	PMU/WRD	EMP budget

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
		permission from the Forest Department.	revenue officer. Compensatory Plantation of 3:1 ratio meaning plantation of 3 trees in lieu of felling of 1 tree.	embankment			
Occupation Health and Safety							
	Occupational Health and Safety of labours at construction site and Labour camps		Provide personal protective equipment to the labours. Ensure the labours are trained to work on the specific project. For untrained labour – training should be provided before permission to work on the site.	• Construction site; • Labour Camp; Construction Camp.			

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			The contractor shall provide, if required, erect and maintain necessary (temporary) living accommodation and ancillary facilities during the progress of work for labour to standards and scales approved by the Engineer-In charge. Contractor shall follow all relevant provisions of the Factories Act, 1948 and the Building & other Construction Workers (Regulation of Employment and Conditions of Service)				

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			Act, 1996 for construction & maintenance of labor camp. Construction camps shall not be proposed within 1000m or sufficiently away from nearest habitation to avoid conflicts and stress over the infrastructure facilities, with the local community. The location, layout and basic facility provision of each labour camp shall be submitted to Engineer prior to their construction. Safety and sanitation facility				

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			should be provided in the labour camp. Uncontaminated water shall be supplied to the construction workers at labour camps. The contractor shall arrange for - a readily available first aid unit including an adequate supply of sterilized dressing materials and appliances as per the Factories Rules in every work zone, Availability of suitable transport at all times to take injured or sick person(s) to the nearest				

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility		Cost
			hospital Equipment and trained nursing staff at construction camp.				
Community Health and Safety							
	Construction activity of excavation and closure of road	Risk of accident on or near construction site and inconvenience to the local commuters	Provide information about the construction schedule and construction activity Barricading construction site Display signage of diversion at construction road on embankment	Location of earthwork near habitation given in table number D-1 to D-6.	Contractor	PMU/WRD	Contractor cost
Operation Stage							

Sl No	Project Activity	Resource Impact	Mitigation Measures	Location	Responsibility	Cost
No operation stage negative impacts are envisaged. The construction of water flow control structure, standardisation of river embankment will bring positive impacts with the supply of fresh water to the farmers. This will also bring benefit to the aquaculture farming for shrimps by reducing salinity. This is also envisaged the salinity of ground water will also reduce.						

24 Economic and Financial Analysis

24.1 Cost Estimates for River Improvements

The river channels of Project have been used to convey irrigation and floodwaters for centuries and many of the existing water management structures were constructed more than 100 years ago. Detailed field surveys were carried to assess the condition of the structures (See Annexure 2) and to identify the need for reconstruction or repair of existing structures or providing new structures. Extensive hydrologic and hydraulic modelling of the channels identified the need for re-sectioning or re-grading or dredging and standardising the banks to improve their hydraulic performance, reduce the risk of flooding and improve access along the channels. After surveying the river channels and structures, designs were prepared for the reconstruction or repair of structures or construction of new structures. In addition, designs were prepared for re-sectioning, re-grading and dredging the channels and standardising the banks of the river channels. WRD then prepared costs estimates for the proposed works. For the estimates, PWD used the Schedule of Rates published by the Public Works Department Tamil Nadu (2014-2015). The cost estimates are given in Annexure 8.

24.2 Cost Estimates for Pumping Schemes

Each pumping scheme in this Project area was inspected to assess the condition of the electrical and mechanical equipment and identify the need for their replacement. In addition, the condition of pump houses and other civil works was also assessed and the need for repairs identified. The inspection found that all of the electrical and mechanical equipment needed to be replaced, as it was generally about 30-50 years old.

Concerning the civil works, the inspection found that the pump houses were in reasonable condition and could be repaired but that the residential quarters of pumping scheme operators were derelict. A provision of INR 60,000 has been made to provide for a room with a toilet attached to the pump house for the use of operators during their shift.

The capacity of the pumps was calculated with following assumptions:

1. Crop water requirement of samba paddy (m^3/ha): 12,500 (1,250 mm)
2. Effective rainfall (m^3/ha): 4550 (455 mm, 80% exceedance)
3. Irrigation efficiency (%): 70
4. Pump efficiency after Renovation (%): 75
5. Dynamic head factor: 1.1
6. Irrigation season (days): 150
7. The cost of the electrical components and the pumps were determined from current quotations from reputed suppliers. To arrive at the financial costs 12.5% Service Tax/VAT has been added for the electrical and mechanical components. For the pumps, 5% transport & installation charges have also been added.
8. For Civil Works the cost estimates have been made as for works of river improvements.

24.3 Estimates of Costs

This Project Costs used for the Cost/Benefit analysis are summarised in Table 24.1.

CASDP Assisted by ADB

TOTAL ABSTRACT

Sl. No	Description	Amount in Crores
1	Civil Works	678.22
2	Mechanical and Equipment Work	6.24
3	Establishment and setup of PMU	15.41
4	Decision support System (DSS)	1.92
5	Consultancy for Project Implementation & Monitoring	9.47
6	Consultancy for follow on Project feasbility studies and survey works including environmental clearances	15.61
7	Capacity Development - Training	0.94
8	Enviornmental and Resettlement	5.48
9	Program Management Costs	6.88
10	Physical Contingencies	15.44
11	Price Contingencies	130.10
12	Interest	26.30
	TOTAL	**912.00**

The general abstract of costs for this Project is shown in Table 24.1. Detailed cost estimates of each river are given in Annexure 8. The costs for the pumping schemes are shown in Table 24.2.

Table A9.4

Cost Abstract for this Project Works

No.	Description of Work	Project Components							Other Costs	Total
		Harichandra	Adappar	Pandavayar	Vellaiyar	Valavanar	V. Canal	Pumping schemes		
A	**Direct Charges**	***(INR lakhs)***								
I	*Works*									
	A Preliminaries (See Note 1)	0	0	0	0	0	0	0	817.6	817.6
	B Lands (Resettlement) (See Note 2)	0	0	0	0	0	0	0		0
	C Works	2,181.69	6594.94	5,491.55	9,606.25	355.72	959.1	599.82		25789.07
	D Regulators & Measuring Device (For Canal Only)	2,041.44	2898.62	319.11	957.91	672.67	0	0		6889.75
	E Falls (For Canal Only)	0	0	0	0	0	0	0		0
	F Cross Drainage Works (For Canal Only)	613.78	200.84	0.0	0.0	50	83.67	0.0		948.29
	G Bridges (For Canal Only)	652.84	0	0	0	141	0	0		793.84
	H Escapes (For Canal Only)		0	0	0	0	0	0		0
	I Navigation Works (Dredging Works)	330.05	495	0.0	158	707.63	759.22	0.0		2449.9
	J Power Plant	0	0	0	0	0	0	0		0
	K Buildings	0	0	0	0	0	0	0		0
	L Earthwork, Lining and Service Road	15,280.40	4061.82	2,911.70	5,053.37	1,570.48	749.93	0		29627.7
	M Plantation	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0
	N Tanks	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0
	O Miscellaneous (See Note 3)	1005.7	676.59	415.5	735.07	164.81	120.9	51.73	192	3362.30

	P Maintenance	0	0	0	0	0	0	0		0
	Q Special Tools & Plants	0	0	0	0	0	0	0		0
	R Communications	0	0	0	0	0	0	0		0
	S Power Plant/ Electrical /Mechanical	0	0	0	0	0	0	623.75		623.75
	T Water Supplying Works	0	0	0	0	0	0	0		0
	U Distributies	0	0	0	0	0	0	0		0
	V Water Course	0	0	0	0	0	0	0		0
	W Drainage (included in X)	0	0	0	0	0	0	0		0
	X Environment and Ecology	76.7	52.19	32.34	56.4	12.79	9.78	4.7		244.9
	Y Losses on Stock	0.0	0	0	0	0	0	0		0
	Total I Works (including physical contingencies) (See Note 4)	**22,182.60**	**14,980.00**	**9,170.20**	**16,567.00**	**3,675.10**	**2,682.60**	**1,280.00**	**1,009.60**	**71,547.10**
	Total cost (excluding physical contingencies)	**21,176.90**	**14,303.41**	**8,754.70**	**15,831.93**	**3,510.29**	**2,561.70**	**1,228.27**	**817.60**	**68,184.80**
II	*Establishment*									
	i) Establishment Charges including leave and Pensionary Charges etc., @ 12 % of Project- I Works less B - Land.								8,585.65	
III	*Tools and Plants @ 1 % on I - Works*								681.85	
IV	*Suspense*									
V	*Receipts & Recoveries on Capital Account (75% of Q)*									
B	**Indirect Charges**									
	I) Audit & Account Charges @ 1 % on I - Works								681.85	
	Total	**22,182.60**	**14,980.00**	**9,170.20**	**16,567.00**	**3,675.10**	**2,682.60**	**1,280.00**	**11,776.55**	**82,314.05**

Table 24.2 Cost of Pumping Stations (INR lakhs)

Name	**Civil works**	**Electricals**	**Pumps**	Total
Pamanimullur	31.47	3.69	37.13	72.29
Sekal	40.57	3.32	33.84	77.73
Korukkai Thalaikkadu	42.28	4.26	40.91	87.45
Umbalacheri	44.37	3.84	28.51	76.72
Oradiyambalam	110.04	4.39	40.91	155.34
Aymoor-I	34.61	3.86	35.33	73.80
Aymoor-II	29.70	3.44	38.12	71.26
Velankanni	34.94	4.28	50.47	89.69
Vilunthamavadi	50.78	3.49	27.81	82.08
Karayankadu	34.49	3.52	25.07	63.08
Kela Thondiyakkadu	38.82	3.69	28.53	71.04
Vanduvanchery	39.78	5.13	56.34	101.25
Valavanar	67.97	20.24	113.63	201.84
Total	599.82	67.15	556.60	1223.57

For this Project, no land acquisition is required as the structures for reconstruction or repair are all located on land owned by WRD. The new structures are located in the river beds, which is uninhabited Government land. The re-sectioning of river chanels and the standardisation of banks has been designed in such a way that no land acquisition is required as the works are all located on land already owned by WRD. At some locations, where re-sectioning or standardisation of embankments is affected by encroachment, fluming is provided. If fluming is not possible, resettlement is required and a resettlement survey was carried out to identify the persons to be resettled and their entitlement (See Chapter 18). The resulting resettlement costs have been included in the project costs. Costs for environmental management and monitoring identified in the IEE have also been included (See Chapter 23).

24.4 Project Benefits 24.4.1 Benefits from Project Improvement Works

Benefits result from (i) repairs/reconstruction of irrigation structures maintaining the present levels of agricultural productivity, (ii) construction of new (Tail End) Regulators and other structures enabling a higher agricultural productivity in the benefitting areas, (iii) rehabilitation of pumping schemes by restoring original command areas (ayacuts) and maintaining agricultural productivity, and (iv) re-sectioning of channels, standardisation of embankments and repair or reconstruction of drainage sluices, infalls and siphons reducing loss of life, damages to houses, loss of livestock, loss of crops and infrastructure due to flooding in the drainage catchment areas of the rivers.

24.4.2 Agricultural Benefits

24.4.2.1 Agricultural Benefits of Improvements to Irrigation and Drainage Structures and River Sections

The without-project situation would be that the productivity of command areas of this Project rivers would decline as the already poor condition of the water management structures would continue to deteriorate, thereby reducing their effectiveness to manage flows. Ayacuts would gradually lose their water supply and would become more dependent on rainfall. In the project area rainfall is unpredictable and insufficient for crop water requirements.

The effect of the repairs and reconstruction of structures or the provision of new structures will be that the present productivity level will be maintained for another 50 years assuming the condition of the irrigation canals remains the same. Cross Regulators and Tail end Regulators do not have command areas of their own, but enable the more efficient operation of irrigation head sluices upstream.

Data on crop area coverage, crop yields, requirement of inputs (seeds and other inputs such as fertilisers, labour, machine hire etc., and current prices was collected from District Agriculture Offices of Thiruvarur and Nagapattinam districts. The agricultural data are given in Annexure 1 and analysed in Annexure 9. The data is not complete as, for example, the productivity or production costs were not provided for all crops.

Based on this data, average cropping pattern, average crop yield per hectare, average price of crop per kg and average requirement of seeds and other inputs per ha for these districts have been calculated for the two districts and applied to the Project area. Net value of produce after deducting cost of inputs from value of output was estimated. Wherever data was not available, appropriate assumptions were made. The net value of agricultural produce from the total area in these two districts was reduced by the ratio of the culturable cropped area (CCA) in this Project area to the total geographical area of the districts (See Table A9.3).

It has further been assumed that, in case proposed improvements in this Project area are not undertaken, agricultural productivity would gradually reduce by 15% due to reduced delivery of irrigation water. This reduction also takes into account the missing agricultural data.

Agricultural benefits are discussed further in Section 24. 7.

24.4.3 Flood Protection Benefits

Flood protection benefits consist of avoided flood damages. These damages happen at irregular intervals and at different levels, depending on the severity, timing and duration of the flood. Flood damage data for the period 2004-2013 was collected from the District Collectors of Nagipattinam and Thiruivarur and the data provided is shown in Annexure 9.1 for Thiruvarur and Annexure 9.2 for Nagapattinam. The data included the loss of life, loss of livestock, and damages to crops, irrigation infrastructure, houses and roads.

Based on anecdotal and field information, the flood damage data appears to be incomplete and the extent of flood damage under-reported (See Annexure 9 Tables A9.9 to A9.11). For example, there were two major floods in 2005 and yet no flood damages have been reported for road reconstruction, crop losses or repair of irrigation and municipal structures in Nagapattinam or Thiruvarur. Similarly, in 2008, when there was significant flooding in the lower reaches of this Project rivers in Nagipattinam (See Figure 13.6) there are no reported road damages or crop loses .

The total flood damages for the combined Nagipattinum and Thiruvarur districts over the 10 year period from 2004 to 2012 was INR 74932 lakh, as shown in Table 24.3. The average annual flood damage over the ten year period was INR7493.3 lakh. . The annual average flood damamge equivalent to the annual reduction in direct flood damages due to this Project works was calculated to be INR1498.6 lakh after taking into account the relative size of this Project area.

Table 24.3 Average Annual Flood Protection Benefits

Description	Total Flood Damages over 10 years				Annual Average over ten year period	
	Source	Nagapattinam	Thiruvarur	Combined Thiruvarur and Nagapattinam Districts		
			(INR)	(INR)	(INR)	(INR lakh)
Human Lives	*From Tables A9.9 and A9.10*	26,908,306	28,281,178	55,189,484.10	5,518,948.41	55.19
Houses	*From Tables A9.9 and A9.10*	489,041,847	3,431,997,402	3,921,039,248.70	392,103,924.87	3921.04
Crops	*From Tables A9.9 and A9.10*	1,281,942,759	1,389,442,153	2,671,384,912.68	267,138,491.27	2671.38
Livestock	*From Tables A9.9 and A9.10*	29,024,500	13,018,000	42,042,500.00	4,204,250.00	42.04
Roads and Bridges	*From Tables A9.9 and A9.10*	437,442,635	74,338,195	511,780,830.32	51,178,083.03	511.78
Water Supply	*From Tables A9.9 and A9.10*	0	30,652,683	30,652,683.20	3,065,268.32	30.65
Irrigation Infrastructure	*From Tables A9.9 and A9.10*	21,074,433	240,122,818	261,197,250.51	26,119,725.05	261.20
Total Direct Damages		2,285,434,480	5,207,852,430	7,493,286,909.51	749,328,690.95	7493.29
Adjustment for the relative size of this Project area						1498.66

24.5 Operation and Maintenance Charges

24.5.1 Water Rates for Irrigation

The Tamil Nadu Government policy is that farmers are not charged for surface irrigation water.

24.5.2 Betterment Levy

In Tamil Nadu, government policy is that farmers are not charged a betterment levy when they receive a new or modernised irrigation scheme. Therefore it is expected that this policy will be applied to the improvements made to this Project rivers and farmers will not be charged a betterment levy.

24.5.3 O & M Costs of Pumping Schemes

In Tamil Nadu, all operation and maintenance costs including power costs are paid for by the Government. The power utility is reimbursed by the Government for the power consumed.

24.5.4 O & M Costs of Groundwater Irrigation

For groundwater irrigation, farmers use their own funds to construct the well and for the connection to the power distribution system, and the Government pay for the power consumed.

24.5. 5 Flood Protection Costs

Households located on flood plains in Tamil Nadu, including those located on this six Project rivers, are not charged for flood defences or flood mitigation measures.

24.5.6 Annual Cost of Project

The annual cost for this Project works was worked out according to guidelines laid down by the Central Water Commission (CWC 2010). The following norms have been adopted:

1. Interest charges @ 10% of the Cost
2. O & M cost @ INR 180/ha of culturable command area (CCA)
3. Depreciation @ 2% of estimated project costs excluding cost of electrical and mechanical equipment for pumping schemes. This is based on the assumption that life of the civil works is 50 years.
4. Maintenance of Headworks (Regulators and Tail end Regulators) @ 1% of estimated costs.
5. Electrical and Mechanical equipment for pumping systems along with rising mains @ 8.33% of estimated costs. This is based on the assumption that these require replacement every 12 years.
6. Power consumption charges have not been considered as per policy of the government of Tamil Nadu.

The average annual cost of the Project was calculated to be 11245.83 Lakhs).

24.6 Cropping Patterns and Annual Crop Net Benefits

The seasons and possible crops per season in the project area are (i) Kuruvai (May-August) with paddy, (ii) Thaladi (September/October-March) with paddy, (iii) Samba (July/August-January) with paddy, followed by (iv) Summer (February-July) with black gram/green gram/gingelly (sesame), using residual moisture or groundwater irrigation, depending on availability, and (v) Annual with sugarcane (one year). The area covered by different crops is shown in Tables 24.4 for Nagapattinam and 24.5 for Thiruvarur.

Based on the areas under different crops, the production costs and the parameters discussed in Section 24.4.2.1, the average annual agricultural benefits for this Project were calculated to be $ 12.71 million (INR 7268 lakh) as shown in Table 24.6.

Table 24.4 Area with Different Crops, Nagapattinam

Crop	Area (ha)						
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Average Annual
Kuruvai	35197	27950	27313	42848	17115	22682	28851
Samba - Thaladi	136034	130774	132793	135829	131246	135767	133741
Kodai	1161	927	1840	2445	69	977	1237
Blackgram	61858	52007	53215	65930	31391	49900	52384
Greengram	35186	29476	28020	38000	23999	42000	32780
Sugarcane	0	0	0	3200	3298	3200	1616
Gingilly	0	0	0	132	740	400	212
Groundnut	0	0	0	1650	2598	1900	1025
Cotton	0	0	0	110	262	287	110

Source: Department of Agriculture, Nagapattinam (See Annexure 1 and 9)

Table 24.5 Area with Diffreent Crops, Thiruvarur.

Crop	Area (ha)												
	2001-02	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**Average**
Paddy - Total	177159	174187	131008	114308	148744	158543	182145	181562	166757	162569	188226	161285	167590.5	162622
Blackgram	62493	47529	18447	15126	38664	52385	51336	41676	44181	56004	44502	13170	5997	37808
Greengram	26160	20911	7559	9060	37	2325	33615	30788	34819	37662	35931	11747	53495	23393
Cotton	2373	2854	1347	2026	220	1403	323	912	563	874	1254	2100	3089	1488
Sugarcane	2303	1606	1152	1222	1417	4062	3137	1980	1370	835	546	615	486	1595
Gingelly	2002	6806	1406	2751	247	2474	1865	1602	1414	477	871	996	511	1802
Groundnut	870	1330	1041	1325	122	2040	2293	1509	2285	2032	4093	3744	1246	1841
Soyabean	5	0	0	23	40	17	2					1		7
Oil Palm	57	14	33	28	42	283	561	682	785	712	648	484	483	370
Maize	0	0	0	0			16	1				19	53	7
Coconut	0	0	0	0				4878	4918	4954	4107	4224	3151	2018
Other crops	0	0	0	546	694	792	51	893	1048.5		125			319

Source: Department of Agriculture, Thiruvarur (See Anexures 1 and 9)

Table 24.6 Agricultural Annual Net benefits

Crop	**Thiruvarur** Average Annual Area	**Nagapattinam** Average Annual Area (ha)	**Combined Annual Average Area T +N** (ha)	**Average Yield** (tonnes/ ha)	**Average Price** (INR/kg)	**Value of produce** (INR Lakh)	**Inputs Seeds** *Cost per hectare* *(INR lakh /ha)*	*Total cost* *(INR lakh*	**Inputs except seeds** Cost per hactare (INR lakh/ha)	**Area** (ha)	**Total Cost** (INR lakh)	**Total Inputs** (INR/ lakh)	**Annual Net Benefit** (INR lakh)	**Annual Net benefit of Project (See Note 1)** (INR Lakh)
Paddy - Total	162622	162592	325214	6.4	13.99	291184	0.02	6052.9						
Blackgram	37808	52384	90192	0.94	49	41542.4	0.02	1423.7						
Greengram	23393	32780	56173	0.86	52.5	25362.1	0.02	886.69						
Cotton	1488	110	1598			0	0.00	0						
Sugarcane	1595	1616	3211	97.5	2.75	8609.49	0.19	621.33						
Gingelly	1802	212	2014	0.45	81.5	738.63	0.00	7.05						
Groundnut	1841	1025	2866			0								
Soyabean	7		7			0								
Oil Palm	370		370			0								
Maize	7		7			0								
Coconut	2018		2018			0								
Other crops	319	1237	1556			0								
Straw and Stalk	162622	162592	325214	10	5.38	174965								
All crops									0.6	485226	291136			
Total			**485226**			**542401**		**8991.6**			**291136**	**300127**	**242274**	**16959**

1. Project-covers 20% of the area of Thiruvarur and Nagapattinam districts and Project works will prevent productivity reducing by 35%

Table 24.7

Annual Costs

Sl.No.	Description	Basis	Base	Re lakh
1	Interest charges (% of estimated costs)	10%	82,314.05	8,231.41
2	O & M cost for 87532 ha (@Re/ha)	180	87532	157.56
3	Depreciation (% of estimated costs)	2%	82,314.05	1,646.28
4	Maintenance of Head works (% of estimated costs)	1%	82,314.05	823.14
5	Pumping system along with rising mains (% of estimated costs)	8.33%	1,223.57	101.92
6	Power consumption charges @ per KWH			-
	Total			**10,960.31**

24.7 Benefit Cost Ratio

The cost-benefit ratio was calculated for this Project works as shown in Table 24.7.

All existing irrigation and drainage infrastructure that is not included in the project, such as irrigation and drainage canals, were considered to be in operational condition and have been treated as 'sunk costs'.

The benefit cost ratio for the works on this Project including pumping schemes is 1.69. The analysis shows that overall financial feasibility of this Project rivers/drainage works, including flood protection works, and the pumping schemes are satisfactory.

Table 24.7 Cost Benefit Ratios

Benefits	River Works (1) (INR Lakhs)	Remarks
Average Annual Flood Damage Prevention	1499	Refer Table 24.6
Average Annual Net Agriculture Benefit	16959	Refer Table 24.6
Total Annual Benifit	18458	
Costs		
Benefits		Remarks
Annual Costs of Project - 1 including cost of environment and Rehabilitation & Resettlement	10960	Refer Table 24.1 & 24.7
Benefit - Cost Ratio	**1.68**	

Note
(1) Costs Include of environment and resettlement costs

24.9 Baseline Survey

Environmental and re-settlement field surveys were carried out during the preparation of this Project. Flood damage and agricultural data was collected from District Collectors and District Agriculture Officers in Nagapattinam and Thiruvarur districts respectively.

The CASDP PMU will undertake a baseline survey and develop parameters for evaluation of the performance of this Project during implementation of this Project and then at regular intervals of 5 years after commencement of the project.

25. Administrative and Legislative Provisions

The Government of India has drafted a legal frame work titled "National Water Framework Law", which is governed by some key principles including IWRM. It empowers the states to develop, regulate and manage basins of inter-state rivers using a legislative route. It is expected that the National Water Framework Law will be enacted within the period of this CASDP Project and, if Tamil Nadu complies, the Law will provide an enabling environment for this Project to introduce appropriate IWRM practices in the Vennar system.

Currently water regulation in Tamil Nadu is characterized by a divergent set of state acts and rules adopted over many years. In terms of statutory development, irrigation laws constitute historically the most developed part of state water law. For example, Tamil Nadu has legislation to regulate water supplies, irrigation and canals, rainwater harvesting, protection of riverbanks etc. The key features of some of the legislative provisions in Tamil Nadu and their significance to CASDP are described in Table 25.1.

Table 25.1: Legislative provisions

Regulations	Key features	Significance to CASDP and IWRM in the Vennar system
National Water Framework Law (proposed)	Provides a framework for IWRM and for management of droughts and floods, provides a framework for urban water management and industrial water supply, provides for statutory powers to WUAs (collect and retain water charges)	Yet to be enacted. Once enacted, will provide a legal framework to transform IWRM concepts into practices at the basin level
The Tamil Nadu Panchayats Act, 1994	Food and agriculture standing committee at the District Panchayats , Maintenance of irrigation works, execution of kudimaramat, District Planning Committees, Minor irrigation, water management and watershed development Agriculture and agriculture extension, Animal husbandry and fisheries, Drinking water	Since provision for drinking water supply is the constitutional mandate of local governments, this Act has significance in terms of water supply for domestic purpose

The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013	Both land acquisition and rehabilitation and resettlement rights will apply when government acquires land for its own purposes and/or for other projects. Irrigated, multi-crop land will not be acquired, except for linear projects. Land for each family to be given if the acquisition is for irrigation purpose. Fishing rights in the reservoirs to be given to Project Affected Families. Compensation to cover share croppers and tenants	In the course of implementation of CASDP, land acquisition is likely be a minor component, although a clear picture will emerge only after sub-projects are formulated. Therefore, the relevance of this Act can be determined only after the site-specific surveys are completed
Coastal Regulation Zone Act	A central act enacted in 2011, with Coastal Zone Management Authority (CZMA) as the custodian	Coastal Zone Regulation Act classifies coastal area into four zones and prohibits any development activity in Zone I. Some parts of Nagapattinam coastal belt falls under this restricted zone. Therefore, its significance to CASDP is ranked very high
Tamil Nadu Groundwater (Development and Management) Act, 2003 (repealed in 2013)	Regulates drilling of new deep bore wells for extraction of groundwater	Enacted in 2003, but repealed in 2013. Therefore, not applicable until a new act is put in place. A new act is likely to be in place before the construction of sub-project activities commence
Eviction of Encroachment in Water Bodies, 2007	Enacted in 2007 to protect tanks against encroachments gives power to the authorities to identify original boundaries with a view to restore them	Tank encroachment is widespread in at least two districts in the project area. In the context IWRM, this act has high relevance to tank management.
The Tamil Nadu Farmers' Management of Irrigation Systems Act, 2000	Salient features of the Act include a basket of activities i.e. i) promoting farmers participation ii) geographical area delineation lies with the district collector iii) scope for forming distributary committees at the mid-level and a project committee at the apex level.	Defined functions of Farmers' Organization are: i) Rotational water supply ii) prepare plan for maintenance of irrigation systems iii) regulate the use of water iv) assist the revenue department to collect water tariff v) conduct social audits vi) promote plantation along canal and tanks and viii) remove encroachments. Once

		activated, CASDP is bound to have an organic relationship with the authorities of the Act
The Tamil Nadu Irrigation Cess Act, 1865	Enables the government to collect irrigation water cess	In the current institutional environment not particularly relevant
The Tamil Nadu Aqua Culture Act, 1995	Provides for the regulation and control of coastal aquaculture, with the exception of fresh water aquaculture	Licencing of prawn farming is vested with TNPCB and District Collector, restrictions can be placed on the withdrawal of groundwater for aquaculture and "zoning" of aquaculture area is in the authority domain of the Collector. Therefore, extremely relevant at least in some specific areas of Nagapattinam district
The Tamil Nadu Marine Fisheries Regulation Act	Provides for regulation, restriction and prohibition of fishing by vessels in the sea	Relevant only to coast facing areas of Nagapattinam and Thiruvarur districts

Separating the function of water regulation and irrigation supplies is near impossible, making it difficult to improve service delivery and provide equitable distribution of the water available.

26. Training

To maximize the returns from this CASDP Project investments, it is necessary to manage water and land in a systematic and scientific way. This requires capacity building of government staff as well as other stakeholders including water users. To identify the capacity building required, a training needs assessment will be carried out by the PMU during this Project.

Fortunately this Project will be located close to WRD's Irrigation Management Training Institute in Tiruchirappalli. The Institute was established 30 years ago and provides training courses on various aspects of irrigation and water resources management for professionals, government staff, and water users including farmers.

One training need that has been identified during the preparation of this Project is to address WRD's limited capacity for hydrologic and hydraulic modelling and for use of a DSS. Therefore basic training on the development and use of models of the Vennar system created during the preparation of this Project and on the further development of the DSS will be provided in a series of tutorials at the end of this Project preparation period. The training will be reinforced during the implementation of this Project. The total cost of this training during this Project is approximately **US million $ 9.44**

Training Program- Details of Costs				
Indicative Training	**Cost per participant**	**No of participants**	**No of courses**	**Total Cost**
Project Management & Monitoring	15000	10	2	300,000
IWRM concepts and practices	15000	15	3	675,000
DSS concept design and implementation	20000	5	1	100,000
Flood forecast and flood modelling	15000	4	2	120,000
Flood rescue, relief and rehabilitation, including estimating losses to assets	10000	15	2	300,000
ADB procurement procedures	10000	5	2	100,000
FIDIC style contract management	15000	20	1	300,000
Community engagement in resettlement	2000	100	2	400,000
Channel level stakeholder participation	500	200	6	600,000
Financial Management Systems and reporting	20000	6	1	120,000
Overseas training and exposure visits to best practice locations	300000	10	1	3,000,000
GIS applications and remote sensing	10000	5	1	50,000
IEE/EIA/Environment management related training	10000	5	2	100,000
Unallocated				2,235,000
Total				**8,400,000**

Cost includint taxes	9,438,240.00
Cost in Miln	9.4382

27. Conclusion

The Asian Development Bank (ADB) has provided development assistance to Tamil Nadu under various sectors that ranged from Tourism, Tsunami Rehabilitation to Urban Development. The proposed Climate Adaptation through Sub-basin Development is the first of its kind ADB investment in the water resources sector in the State. The World Bank through several urban and rural sector projects has invested in projects in the State in water resources and irrigation.

The Government of TamilNadu implementing the programs like accelerated Irrigation Benefit Program (AIBP), the Command Area Development program (CADP), Flood Management Program (FMP), and National Water Mission (NWM) etc. In 2012, the Government of Tamil Nadu released a policy document called Vision 2023, in which assurance of timely irrigation is an important component. The document estimates that between 2012 and 2023 an investment of INR 40,000 crore in the water resources sector will be needed. The launching of the Climate Adaptation for Sub basin Development Program (CASDP), with 30% contribution from the state budget is timed well to make a significant contribution to this new initiative.

Tamil Nadu aims to achieve the goal of “Doubling Food Production” by 2015. To achieve this goal, the State Government has formulated an agricultural policy, which has three specific components i.e. i) developing a scientific approach to support the development of the rural economy and preservation of ecological balance based on the requirements of agro climatic zones; ii) to increase productivity, production and profitability; and iii) implement of farmers welfare schemes such as integrated watershed development, land management, development of water resources, organic farming, value addition to agricultural produce, promotion of crops with export potential etc. It is the third component that has direct relevance to CASDP.

Summary and Recommendations

It is amply evident through specific agriculture policy and water resource funding initiatives that the Government of Tamil Nadu is committed to develop climate resilient irrigation infrastructure, thereby achieving higher water efficiency and improved agriculture productivity.

ADB COST ABSTRACTS

CASDP Assisted by ADB

TOTAL ABSTRACT

Sl. No	Description	Amount in Crores
1	Civil Works	678.22
2	Mechanical and Equipment Work	6.24
3	Establishment and setup of PMU	15.41
4	Decision support System (DSS)	1.92
5	Consultancy for Project Implementation & Monitoring	9.47
6	Consultancy for follow on Project feasbility studies and survey works including environmental clearances	15.61
7	Capacity Development - Training	0.94
8	Enviornmental and Resettlement	5.48
9	Program Management Costs	6.88
10	Physical Contingencies	15.44
11	Price Contingencies	130.10
12	Interest	26.30
	TOTAL	**912.00**

CASDP Assisted by ADB

BREAK UP DETAILS FOR

CIVIL, MECHANICAL & EQUIPMENT WORKS

Sl. No.	Description	Amount in Rs.Cr.
I.	Civil Worls	678.22
II.	Mechanical & Equipment Works	6.24
	Total	**684.46**

BREAK UP

1	**Work Value / Contract Value (Civil & Mechanical)**	**671.22**
2	**Contract related Costs**	
a	Payment of Contribution to TN labour welfare board	6.52
b	Advertisement Charges	0.33
c	Photographic, Video graphic & Name board charges	0.65
d	Environmental & CRZ Clearance	1.50
e	Shifting of Power post & transformer	0.98
f	Documentation Charges	0.33
g	Materials Testing Charges	0.33
h	Temporary building charges	1.30
i	Dewatering and diversion works	0.65
j	Procurement of Tools & Plants	0.65
	Sub Total	**13.24**
	Grand Total	**684.46**

CASDP Assisted by ADB

TOTAL ABSTRACT

Amount in Rs.Lakhs

Sl. No	Name of River / Drain	Work Value / Contract Value	Payment of Contribution to TN labour welfare board @ 0.93% on works	Advertisement Charges (0.05 %)	Photographic, Video graphic & Name board charges (0.09 %)	Environmental Clearance (0.21 %)	Shifting of Power post & transformer (0.14 %)	Documentation Charges (0.05 %)	Materials Testing Charges (0.05 %)	Temporary building charges (0.18 %)	Dewatering and diversion works (0.09 %)	Procurement of Tools & Plants (0.09%)	Total
1	Harichandranathi	21100.20	206.38	10.30	20.60	47.50	30.87	10.30	10.30	41.15	20.60	20.60	21518.80
2	Adappar	14251.22	139.24	7.00	13.90	32.00	20.85	7.00	7.00	27.80	13.90	13.90	14533.81
3	Pandavayar	8722.36	85.20	4.20	8.50	19.58	12.76	4.20	4.20	17.02	8.50	8.50	8895.02
4	Vellaiyar	15775.53	151.00	7.50	15.06	34.63	22.62	7.50	7.50	30.15	15.06	15.06	16081.61
5	Valavanar Drain	3497.50	34.00	1.73	3.40	7.83	5.12	1.73	1.73	6.82	3.40	3.40	3566.66
6	Vedaranyam Canal	2551.92	24.50	1.25	2.50	5.72	3.73	1.25	1.25	5.00	2.50	2.50	2602.12
7	Pumping Schemes - 13 Nos	1223.57	11.40	0.60	1.20	2.74	1.79	0.60	0.60	2.38	1.20	1.20	1247.28
	Total	**67122.30**	**651.72**	**32.58**	**65.16**	**150.00**	**97.74**	**32.58**	**32.58**	**130.32**	**65.16**	**65.16**	**68445.30**

or 684.46 Cr.

3.Establishment and Setup of PMU

Table 22.4 PMU/PIU Equipment List

PMU/PIU Set up Cost				
Item	**UOM**	**Quantity**	**Rate**	**Value**
PMU				
Building for PMU at Trichy(land not valued ; in kind contibution)	sft	10,000	6,000	60,000,000
No of Workstations	No	18	40,000	704,000
Desktops/Laptops	No	13	50,000	660,000
Airconditioners	No	5	45,000	225,000
Vehicles- PD	No	1	1,900,000	1,900,000
Vehicle- Corrdinator	No	1	1,100,000	1,100,000
Vehicle- EE,Environment, Social Development officer	No	2	800,000	1,600,000
Printers	No	1	15,000	15,000
Telephones/Mobiles	No	2	5,000	10,000
Printer	No	2	15,000	30,000
Photocopier	No	1	150,000	150,000
				66,394,000
Office of Deputy Project Director at Tanjavur				
Existing Building	sft			-
No of Workstations	No	39	40,000	1,558,000
Desktops/Laptops	No	12	50,000	615,000
Airconditioners	No	3	45,000	135,000
Vehicles- SE- Multi Utulity Vehicle	No	1	1,100,000	1,100,000
Vehicle- EE- Multi Utility Vehicle	No	1	800,000	800,000
Printers	No	1	15,000	15,000
Telephones/Mobiles	No	2	5,000	10,000
Printer	No	2	15,000	30,000

Photocopier	No	1	150,000	150,000
Total				**4,413,000**
PIU- Thirvaroor, Nagapattinam and Thirutharaipundi				
Building(4000 sft per PIU)	No	12,000	5,000	60,000,000
Workstations	No	174	40,000	6,954,000
Desktops/Laptops	No	43	50,000	2,173,125
Airconditioners	No	6	45,000	270,000
Vehicles- Multi Utility Vehicle - 1	No	3	800,000	2,400,000
Vehicles- Multi Utility Vehicle 2		10	800,000	8,000,000
Printers	No	3	15,000	45,000
Telephones/Mobiles		15	5,000	75,000
Large Format Scanner		3	641,000	1,923,000
Large format Plotter		3	300,000	900,000
Photocopier		3	150,000	450,000
Fax		3	20000	60,000
Total				**83,250,125**
Grand Total				**154,057,125**
				or
				15.41 Crore

Staffing	Nos
PIUs office at Thirvarur, Nagapattinam and Thiruthuraipundi	
EE	1
Officer Technical	1
Drawing Section	
Senior Drafting Officer	1
Junior Drafting Officer	3
Asst Draughtsman	1
Supporing Staff	
Divisional Accountant	1
Bill Processing	5
Administration and Establishment	6
Office Assistant	4
Driver	1
AEE(R&R)	1
AEEs office	
AEE	3
Admninstration Staff	9
Driver	3
Office asst	3
Aes office	
AE	9
Work Inspector	9
Total per Division	61
No of Divisions	3
Total Number of Desks required	183

PMU	Nos
Project Director	1
Coordinator-CE	1
EE	1
AEE	2
AE	4
Support Staff	
Accountant/Finance Management Specialist	1
Dy Accountant/Sr Accounts Officer	2
Jr Officer	1
Personal Assistant	1
Office Assistants	5
Watchmen	1
Driver	2
Total	22

Office of Deputy Project Director- Tanjavur	**Nos**
SE	1
EE	1
AEE	1
AE	1
Procurement Team	
Chief Head Draughtsman	1
Sr Drafting Officer	1
Draughting Officer	3
Jr Drafting Officer	3
Asst Drafting Officer	3
Support Staff	
A&E	1
Supdt	2
Assistants	8
Jr Assistants	4
Office Assistants	6
Driver	2
Watchmen	1
Data Entry Operator	1
Telephone operator	1
	41
Total Staff Strength of project	**246**

4.Decision Support System (DSS)

Table 19.2: Equipment and Indicative Costs of DSS

Equipment	For One River)	
	Nr	**Estimated Cost $**
Field Equipment		
Recording raingauges	5	$5,000
Check raingauges	5	$1,500
Surface water level recorders	10	$10,000
Groundwater level recorders	5	$5,000
Gate openings recorders	5	$5,000
Ultrasonic Flow meter	1	$25,000
SIM cards and cell phone contracts	20	$6,000
Training of WRD field engineers		$5000
Sub-Total		**$62,500**
Office Equipment		
Database + User Interface	1	$10,000
Server + Back-Up Facility	1	$2500
Workstations + UPSs	5	$5000
Sub-Total		**$17,500**
TOTAL		**$80,000**

For four rivers - $80,000 X 4 = $ 3,20,000 X 60 = Rs.1,92,00,000

(or) 1.92 Crore

5. Consultancy for Project Implementation & Monitoring

Table 22.6 Cost of Project Implementation Consultants

Summary of Consultants for PIC	Man months	Cost per month(USD)	Value excluding taxes	Value including taxes	Value in Mln in INR
Implentation Individual consultants(details below)			631,368	709,405	42.56
NGO for resettlement(details below)			42,525	47,781	2.87
CRZ Clearance(lumpsum)			190,559	214,112	12.85
Audit firm	48	5,000	240,000	269,664	16.18
MIS Implemntation firm(lumpsum)			300,000	337,080	20.22
Total Consultants Cost			**1,404,451**	**1,578,041**	**94.68**
					or
					9.47 Crore

Program Technical Assistance – Individual

									Travelling Cost Calculations			Travel						
	Man months	Cost per month(USD)	Travel and Subsistence	Total	Travel for team	Admn costs	Contingencies	Total	No of days	Rate per day	Total	Travel	Grand total	No of trips	Cost per trip	Total	Cost & per diem	Travelling
Project management specialist	36	5,000	53,100	233,100	38,400	2,500	11,655	285,655	1080	45	48,600	4500	53100	18	250	4500	228,600	4500
Procurement Specialist	6	4,000	8,850	32,850			1,643	34,493	180	45	8,100	750	8850	3	250	750	32,100	750
Social Development Specialist	12	4,000	17,700	65,700			3,285	68,985	360	45	16,200	1500	17700	6	250	1500	64,200	1500
Environment Specalist	6	4,000	8,850	32,850			1,643	34,493	180	45	8,100	750	8850	3	250	750	32,100	750
Construction quality assurance	18	4,000	26,550	98,550			4,928	103,478	540	45	24,300	2250	26550	9	250	2250	96,300	2250
Financial Management Specialist	6	4,000	8,850	32,850			1,643	34,493	180	45	8,100	750	8850	3	250	750	32,100	750
Construction Engineer	12	4,000	18,450	66,450			3,323	69,773	360	45	16,200	2250	18450	9	250	2250	64,200	2250
Total				**562,350**	**38,400**	**2,500**	**28,118**	**631,368**									**549,600**	**12,750**

NGO for Resettlement

	Number of Persons	Monthly Rate per person	Input in Months per person	Total (Number of persons x Rate x input months
Team Leader cum Community Development Specialist	1	50,000	6	300,000
Field Coordinator	2	45,000	12	1,080,000
Field Staff	2	25,000	10	500,000
				-
Local Travel	LS	30,000	10	300,000
Survey Cost	LS			200,000
Reporting and Documentation	LS			50,000
Sub Total				**2,430,000**
Contingency @5%				121,500
Grand Total				**2,551,500**
Grand Total in US$				**42,525**

6. Consultancy for follow on Project feasibility studies and survey works

Summary- PTAC- follow on Project

Consultants	PTAC US $	Survey US $	EIA by authorised agency US $	Total Costs US $	Total Costs including taxes US $	Total Costs including taxes in Mln INR
Remuneration and Per Diem						
International Consultants	504,000					
National Consultants	406,600					
International and Local Travel	63,750					
Reports and Communication	10,000					
Provisional sums - survey and data collection	59,100					
Miscellaenous and Administration support costs	10,000					
Contingencies	52,673					
Total Cost(excluding local taxes)	**1,106,123**	875,000	334,000	2,315,123	2,601,271.64	156.08

(OR) 15.61 Crores

Program Technical Assistance – Firm

Program Technical Assistance - Firm					Travelling Cost Calculations			Travel							Total (rem, travel and perdiem) same as column E
	Man months	Cost per month(USD)	Travel and Subsistence	Total	No of days	Rate per day	Total	Travel	Grand total	No of trips	Cost per trip	Total	Cost & per diem	Travelling	
Consultants- International															
Team Leader(Int)	12	18000	46,000	262,000	360	100	36,000	10000	46,000	5	2000	10000	252,000	10000	262,000
Hydraulic and coastal Modeler(International)	4	18000	20,000	92,000	120	100	12,000	8000	20000	4	2000	8000	84,000	8000	92,000
Hydrologist (international)	2	18000	10,000	46,000	60	100	6,000	4000	10000	2	2000	4000	42,000	4000	46,000
DSS specialist (international)	2	18000	8,000	44,000	60	100	6,000	2000	8000	1	2000	2000	42,000	2000	44,000
Groundwater Specailist(International)	2	18000	12,000	48,000	60	100	6,000	6000	12000	3	2000	6000	42,000	6000	48,000
Economist (International)	2	18000	10,000	46,000	60	100	6,000	4000	10000	2	2000	4000	42,000	4000	46,000
National Consultants															
GIS Expert(National)	12	4,000	17,450	65,450	360	45	16,200	1250	17450	5	250	1250	64,200	1250	65,450
Survey Supervisoon(national)	2	4,000	3,200	11,200	60	45	2,700	500	3200	2	250	500	10,700	500	11,200
Hydrologist	8	4,000	11,800	43,800	240	45	10,800	1000	11800	4	250	1000	42,800	1000	43,800
Hydraulic and coastal Modeller(national)	12	4,000	17,200	65,200	360	45	16,200	1000	17200	4	250	1000	64,200	1000	65,200
DSS developer	8	4,000	11,800	43,800	240	45	10,800	1000	11800	4	250	1000	42,800	1000	43,800
Groundwater Modelling(National)	6	4,000	10,100	34,100	180	45	8,100	2000	10100	8	250	2000	32,100	2000	34,100
Civil Engineer	6	4,000	9,100	33,100	180	45	8,100	1000	9100	4	250	1000	32,100	1000	33,100
Economist(National)	4	4,000	6,150	22,150	120	45	5,400	750	6150	3	250	750	21,400	750	22,150
Financial Management Specialist(National)	4	4,000	6,150	22,150	120	45	5,400	750	6150	3	250	750	21,400	750	22,150

Agriculture Specialist(national)	2	4,000	3,200	11,200	60	45	2,700	500	3200	2	250	500	10,700	500	11,200
Envrironmentalist(national)	6	4,000	9,100	33,100	180	45	8,100	1000	9100	4	250	1000	32,100	1000	33,100
Social development specialists (national)	6	4,000	9,100	33,100	180	45	8,100	1000	9100	4	250	1000	32,100	1000	33,100
Local Conveyance for the above group	24	750		18,000										18,000	18,000
Total				**974,350**									**910,600**	**63,750**	**974,350**
Project preperation work															
Asset Survey equipment and logistics	Lump sum			1,000											
Environmental Baseline survey	Time			6,000											
Socio Economic Survey				20,000											
Total				**59,100**											
Preparation of EIA by authorised agency	Time			334,000											
Topo Survey (separate from PTAC consultants two packages for Vennar and Cauvery- total of both packages)															
Topographic Survey	Lump sum			400,000											
Topgraphic Surey(flood Plains)	Lump sum			100,000											
Additional Topogrpahic Surveys for ground control	Lump sum			300,000											
Stereo image purchase and processing	Lump sum			75,000											
				875,000											

7. Capacity Development – Training

Training Program- Details of Costs				
Indicative Training	**Cost per participant**	**No of participants**	**No of courses**	**Total Cost**
Project Management & Monitoring	15000	10	2	300,000
IWRM concepts and practices	15000	15	3	675,000
DSS concept design and implementation	20000	5	1	100,000
Flood forecast and flood modelling	15000	4	2	120,000
Flood rescue, relief and rehabilitation, including estimating losses to assets	10000	15	2	300,000
ADB procurement procedures	10000	5	2	100,000
FIDIC style contract management	15000	20	1	300,000
Community engagement in resettlement	2000	100	2	400,000
Channel level stakeholder participation	500	200	6	600,000
Financial Management Systems and reporting	20000	6	1	120,000
Overseas training and exposure visits to best practice locations	300000	10	1	3,000,000
GIS applications and remote sensing	10000	5	1	50,000
IEE/EIA/Environment management related training	10000	5	2	100,000
Unallocated				2,235,000
Total				**8,400,000**

Cost includint taxes	9,438,240.00
Cost in Miln	9.4382 Or 0.94 Crore

8. Environmental Improvements and ResettlementCost

1. Resettlement Cost (Table enclosed)	–	Rs. 3.03 Crore
2. Environmental Management and Monitoring Cost (Table enclosed)	–	Rs. 2.45 Crore
Total	**-**	**Rs.5.48 Crore**

Resettlement Costs

S No	Description	Unit	Unit Rate/(Rs)	Quantity	Total/(Rs)
1	Cost of Houses to Residential squatters requiring relocation	No	100,000	106	10,600,000
2	Cost of Land for resettlement site	sq.m	945	2,275	2,149,748
3	Shifting assistance to Residential squatters requiring relocation	No	25,000	106	2,650,000
4	Subsistence allowance to Residential squatters requiring relocation @ Rs.3,000 p.m for 6 months	No	18,000	106	1,908,000
5	Replacement cost for cattle shed / shed for storage	No	15,000	97	1,455,000
6	Transitional allowance to commercial squatters requiring relocation @ Rs.3,000 p.m for 6 months	No	18,000	17	306,000
7	Shifting assistance to Commercial squatters requiring relocation	No	25,000	17	425,000
8	Replacement cost for commercial structures	sq.m		17	2,380,000
	Sub Total -A				21,873,748
9	NGO Support for RP implementation	LS			2,500,000
10	External Monitoring	LS			2,000,000
11	Disclosure / Consultations / Administrative Expenses	LS			1,200,000
	Sub Total-B				5,700,000
12	Contingency @ 10% of Sub Total A+B				2,757,375
	Total				**30,331,123**
					or
					3.03 Crore

Environmental management and monitoring costs

Item	Quantity	Unit Cost in INR	Total Cost in INR
Generation of Baseline Environmental parameters			
Ambient Air Quality	10 location X 1 season X 3 samples each = 30 samples	15,000	450,000
Noise level	10 location X 1 season X 3 samples each = 30 samples	8,000	240,000
Surface Water	18 location X1 season	10,000	180,000
Ground Water	4 locations X 1 season	10,000	40,000
Trees marking and inventory	Sum		500,000
Sub-Total			**1,370,000**
Implementation of EMP			
Ambient air quality during construction	10 location X 3 season X 3 years X 3 sampls each = 180 samples	15,000	4,050,000
Noise quality during construction	10 location X 3 season X 3 years X 3sampls each = 180 samples	8,000	2,160,000
Surface Water	18 location X3 season X 3 Years	10,000	1,620,000
Ground Water	4 Locations X 3 Season X 3 Years	10,000	360,000
Dust Suppression by sprinking of water	2 years	5,000	3,600,000
Physical fencing of stock piles of earth and silt at disposal site	lumpsum		1,000,000
Tree Plantation	Compensatory Plantation of 16404 trees in ratio of 1:3 for felling of 5468 trees	350	5,741,400
Training (For WRD/PMU)	Sum	-	1,000,000
Sub Total			**19,171,400**
Operation Stage			
Ambient Air Qaulity during Operation Stage	10 location X 3 season X 1 years X 3 sampls each = 180 samples	15,000	1,350,000
Ambient Noise Level	10 location X 3 season X 1 years X 3sampls each = 180 samples	8,000	720,000
Surface Water	18 location X3 season X 1 Years	10,000	540,000
Sub Total			**2,610,000**
Total			**23,151,400**
Grand Total			**24,521,400**

9. Program Management Costs

PMU /PIU Addiitonal Adminstration Expenses

2. Building rentals, Utilities, Maintenance and Overheads				
Item	**No of Months**	**Cost/month**	**Total Cost**	**Total cost including taxes**
Utilities and overheads	48	75,000	3,600,000	4,044,960
Vehicle running & maintenance	48	1,000,000	48,000,000	53,932,800
Miscellaneous	48	200,000	9,600,000	10,786,560
Total			**61,200,000**	**68,764,320**
				or
				6.88 Crore

10. Physical Contingencies

ABSTRACT FOR PHYSICAL CONTINGENCIES

Sl. No	Name of River / Drain	Work Value / Contract Value	Unforeseen items (1.04 %)	Petty supervision charges & contingencies (1.16 %)	Remarks
1	Harichandranathi	21100.20	230.79	257.81	
2	Adappar	14251.22	155.50	173.84	
3	Pandavayar	8722.36	95.25	105.97	
4	Vellaiyar	15775.53	169.04	188.75	
5	Valavanar Drain	3497.50	37.99	42.70	
6	Vedaranyam Canal	2551.92	28.02	30.62	
7	Pumping Schemes - 13 Nos	1223.57	13.24	14.78	
	Sub-Total	**67122.30**	**729.83**	**814.47**	

1	**Unforcing Item**	**=**	**729.83 Lakhs**
2	**PS Charges & Contingencies**	**=**	**814.47 Lakhs**
	Total	**=**	**1544.30 Lakhs**

or

15.44 Crore

11. Price Contingencies
&
12. Interest

Project Cost for the Project by Expenditure Category

Description		INR					USD Million			
	Total	2015	2016	2017	2018	Total	2015	2016	2017	2018
I. Investment Costs										
A) Civil Works	6,782.15	684.45	2,053.36	2,053.36	2,053.36	113.04	11.41	34.22	34.22	34.22
B) Mechanical and Equipment	62.38	6.24	28.20	34.44		1.04	0.10	0.47	0.57	-
C)Establishment and set up of PMU	154.06	106.06	48.00			2.57	1.77	0.80	-	-
D) Consulting Services						-	-	-	-	-
a) Project Impementation and Monitoring	94.68	9.47	28.40	28.40	28.40	1.58	0.16	0.47	0.47	0.47
b) Follow on Project feasbility studies and survey works including environmental clearances	156.08	9.47	28.40	28.40		2.60	0.16	0.47	0.47	-
Sub- Total	**250.76**	**18.94**	**56.81**	**56.81**	**28.40**	**4.18**	**0.32**	**0.95**	**0.95**	**0.47**
E.DSS	19.20	-	9.60	9.60	-	0.32	-	0.16	0.16	-
F.Capacity Development- Training	9.44	0.94	4.72	3.78	-	0.16	0.02	0.08	0.06	-
G. Environment and Resettlement	54.79	54.79	-	-	-	0.91	0.91	-	-	-
H. Program Management Costs	68.76	6.88	20.63	20.63	20.63	1.15	0.11	0.34	0.34	0.34
Total Investment Costs	**7,401.54**	**878.29**	**2,211.72**	**2,169.01**	**2,102.39**	**123.36**	**14.64**	**36.86**	**36.15**	**35.04**
Total Base Line Costs	**7,401.54**	**878.29**	**2,211.72**	**2,169.01**	**2,102.39**	**123.36**	**14.64**	**36.86**	**36.15**	**35.04**
Physical Contingencies	154.43	15.44	46.33	46.33	46.33	2.57	0.26	0.77	0.77	0.77

Price Contingencies	1,301.03	64.35	300.79	415.48	521.20	21.68	1.07	5.01	6.92	8.69
Sub Total	1,455.46	79.79	347.12	461.81	567.53	24.26	1.33	5.79	7.70	9.46
Total Project Costs	**8,857.00**	**958.09**	**2,558.84**	**2,630.82**	**2,669.92**	**147.62**	**15.97**	**42.65**	**43.85**	**44.50**
Interest and Commitment charges during implementation										
a) Interest	263.00	8.23	38.57	83.79	130.75	4.38	0.14	0.64	1.40	2.18
b)Commitment Charges	-						-	-	-	-
Sub- Total	263.00	8.23	38.57	83.79	130.75	4.38	0.14	0.64	1.40	2.18
Total Project Cost to be financed	9,120.00	966.31	2,597.40	2,714.61	2,800.67	152.00	16.11	43.29	45.24	46.68
Funding required										
ADB	70%	676.42	1,818.18	1,900.23	1,960.47	106.40	11.27	30.30	31.67	32.67
Government of Tamilnadu	30%	289.89	779.22	814.38	840.20	45.60	4.83	12.99	13.57	14.00
Total	100%	966.31	2,597.40	2,714.61	2,800.67	152.00	16.11	43.29	45.24	46.68
Interest during Construction period										
Opening Balance			676.42	2,494.60	4,394.83			11.27	41.58	73.25
Disbursement during the year		676.42	1,818.18	1,900.23	1,960.47	106.40	11.27	30.30	31.67	32.67
Closing Balance		676.42	2,494.60	4,394.83	6,355.30	106.40	11.27	41.58	73.25	105.92
Average Balance		338.21	1,585.51	3,444.72	5,375.07	53.20	5.64	26.43	57.41	89.58
Interest		8.23	38.57	83.79	130.75	1.29	0.14	0.64	1.40	2.18

Interest Rate										
Commitment Charges										
Committed amount(INR)	6383.9988	6,384.00	6,384.00	6,384.00	6,384.00		106.40	106.40	106.40	106.40
Closing Balance of loan		676.42	2,494.60	4,394.83	6,355.30		11.27	41.58	73.25	105.92
Commiment amount		5,707.58	3,889.40	1,989.17	28.70		95.13	64.82	33.15	0.48
Commitment Charges		8.56	5.83	2.98	0.04		0.14	0.10	0.05	0.00
Amount outstanding in USD										

Assmptions						
Base Year	2014					
Inflation and Exchange rates						
Item	**2014**	**2015**	**2016**	**2017**	**2018**	
Domestic Inflation*		7.50%	7.00%	6.50%	6.50%	
Cumulative Inflation		7.50%	15.03 %	21.98%	28.90%	
International Inflation*		0.30%	1.40%	1.50%	1.40%	
Cumulative Inflation International		0.30%	1.70%	3.23%	4.65%	
Differential inflation		7.20%	13.32 %	18.75%	24.26%	
Exchange Rate**	**60**	**64.32**	**67.99**	**71.25**	**74.55**	
* Source: ADB estimates						
** Source: Economic Analysis						
Intrest rate on Loan						
Libor 5 year swap(***)	1.78%					
Margin	0.50%					
Maturity Premium	0.1525%					
Total	2.4325%					
Commitment charges	0.15%					
Financing Plan						
ADB	70.00%					
GOTN	30.00%					
Tax Rates Services	12.36%					
Physical Contingency(only on Civil Works)	2.75%					
Million	1,000,000					
source: https://ycharts.com/indicators/5_year_swap_rate						
*****5 Year Swap Rate:**						
1.78% for Dec 30 2014						

CASDP Assisted by ADB
TOTAL ABSTRACT

Sl. No	Name of River / Drain	Work Value / Contract Value	Resettlement Charges (0.50%)	Environmental Improvements (0.23 %)	Payment of Contribution to TN labour welfare board @ 0.93% on works	Advertisement Charges (0.05 %)	Photographic, Video graphic & Name board charges (0.09 %)	Environmental Clearance (0.21 %)	Shifting of Power post & transformer (0.14 %)	Documentation Charges (0.05 %)	Materials Testing Charges (0.05 %)	Temporary building charges (0.18 %)	Dewatering and diversion works (0.09 %)	Procurement of Tools & Plants (0.09%)	Unforeseen items (1.04 %)	Petty supervision charges & contingencies (1.16 %)	Estimate Value in Lakhs
1	Harichandranathi	21100.2	98.50	76.70	206.38	10.3	20.60	47.50	30.87	10.30	10.30	41.15	20.60	20.60	230.79	257.81	22182.60
2	Adappar	14251.22	64.66	52.19	139.24	7.00	13.90	32.00	20.85	7.00	7.00	27.8	13.90	13.90	155.50	173.84	14980.00
3	Pandavayar	8722.36	41.62	32.34	85.2	4.20	8.50	19.58	12.76	4.20	4.20	17.02	8.50	8.50	95.25	105.97	9170.20
4	Vellaiyar	15775.53	71.20	56.4	151	7.50	15.06	34.63	22.62	7.50	7.50	30.15	15.06	15.06	169.04	188.75	16567.00
5	Valavanar Drain	3497.5	14.96	12.79	34	1.73	3.40	7.83	5.12	1.73	1.73	6.82	3.40	3.40	37.99	42.70	3675.10
6	Vedaranyam Canal	2551.92	12.06	9.78	24.5	1.25	2.50	5.72	3.73	1.25	1.25	5.00	2.50	2.50	28.02	30.62	2682.60
7	Pumping Schemes - 13 Nos	1223.57		4.7	11.4	0.60	1.20	2.74	1.79	0.60	0.60	2.38	1.20	1.20	13.24	14.78	1280.00
	Sub-Total	**67122.30**	**303.00**	**244.90**	**651.72**	**32.58**	**65.16**	**150.00**	**97.74**	**32.58**	**32.58**	**130.32**	**65.16**	**65.16**	**729.83**	**814.47**	**70537.50**
8	Others																**20662.50**
	Total	**67122.30**	**303.00**	**244.90**	**651.72**	**32.58**	**65.16**	**150.00**	**97.74**	**32.58**	**32.58**	**130.32**	**65.16**	**65.16**	**729.83**	**814.47**	**91200.00**