SESSION – 5

STUDIES ON CHENNAI DRAINAGE SYSTEM – RIVERS, CANALS, CREEKS, ESTUARIES, LAKES.

Session – V

Studies and Research related to Cooum

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Introduction

- The River Cooum, once a fresh water source is today a drainage course collecting surpluses of 75 small tanks of a minor basin. The length of the river is about 65 km, of which 18 km, fall within the Chennai city limits. This once fishing river & boat racing ground has borne the brunt of the city's population explosion.
- The water quality as we are all aware is bound to degrade progressively as the river takes the untreated sewage but unable to flush it into the sea.
- Even if the planners succeed in limiting the disposal of untreated sewage at some point in future, the water discharge in the river is insufficient to improve the water quality
- The purpose of this study is to explore means of enhancing the flushing capability through appropriate engineering intervention as there is little scope for natural flushing.

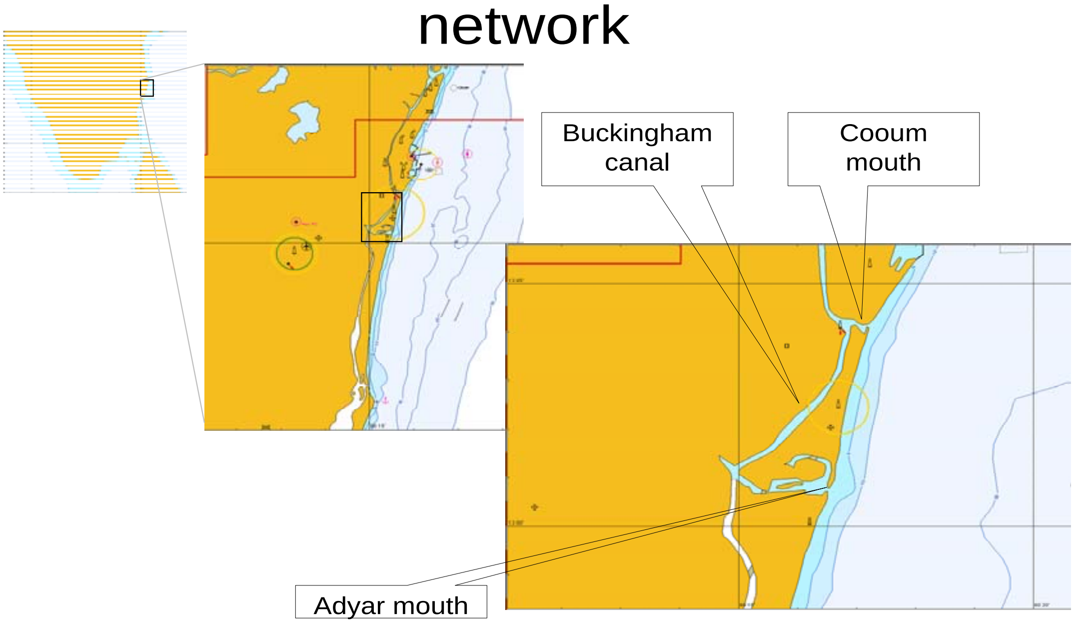
Reasons for degradation

- Littoral sediment transport along coast line results in the formation of sand bar at mouth.
- The little river discharge is not sufficient for preventing the bar formation.
- Tidal range is small at Chennai coast (1.2m) reducing the possibility of tidal prism induced flushing in the estuary
- The terrain is very gentle leading to stagnation

Suggestion for improvement

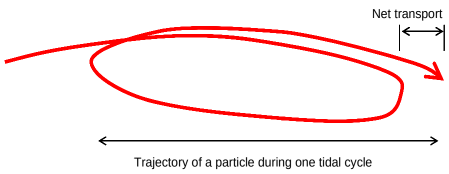
- Considering the other waterways of Chennai city viz. Adyar and Buckingham canal, it will be possible to create a network with sea and let the tidal flow do the flushing job.
- To enable tidal flow, the network needs to be designed for sufficient cross section and minor alterations may be required at mouths of Cooum and Adyar rivers.
- After achieving optimum channel dimensions, the flushing action would be a continuous process maintained by regular tidal movement and will have very little seasonal variation

Components of Channai waterway network

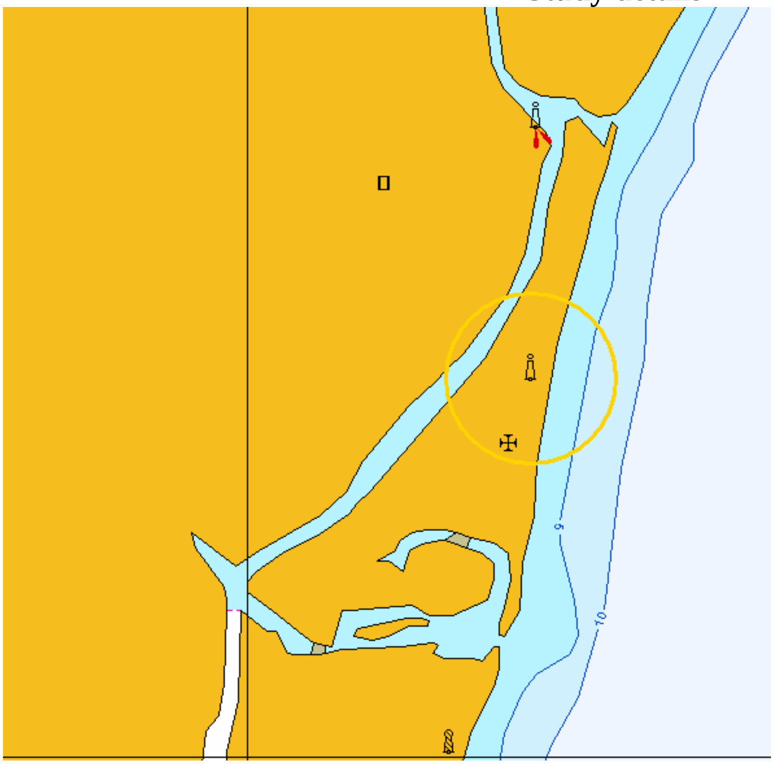


Asymmetric tidal flow

- The water elevation variation due to tidal forcing in open sea is accompanied by tidal currents.
- The currents when in a channel carry water mass to and fro repeatedly – but not equally always.
- This unequal (or asymmetric) flow results in net transport of water mass along the channel.
- The magnitude and direction of this net transport will be determined by various factors like tidal elevation asymmetry, channel configuration, channel bed friction, estuarine mouth configurations, etc



Study details



Qin $\neq$ Qout

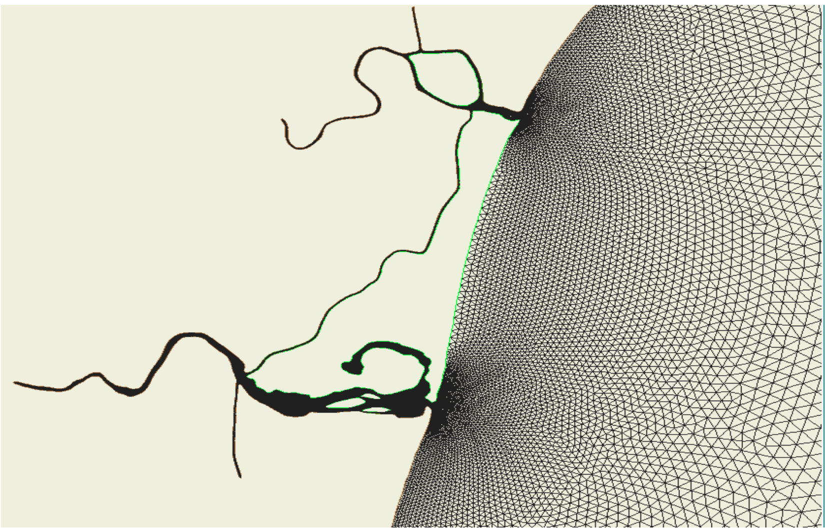
flow directed inward during flood and directed outward during ebb are not equal (within a tidal cycle).

This difference will cause a net flow of a small magnitude through the network as a second order effect.

A numerical simulation to study the hydrodynamics of network flow was carried out through ADCIRC model

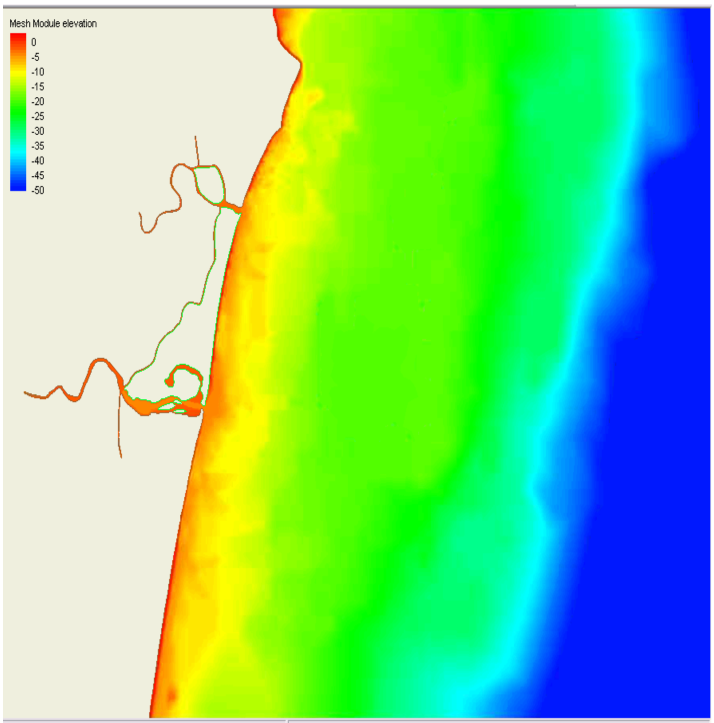
The depth in model domain has been altered so that the asymmetric effect reaches through out the network

Model simulation



- The model domain was extended to deep water as indicated in figure
- the boundary was forced with elevation variation using tidal constituents
- The continuity equation and momentum equation within the domain are solved using a finite element scheme.
- The output of velocity variation at each node of the FEM grid was used to generate the net or residual flow
- Minor modifications were introduced to arrive at an optimum channel configuration and the model was simulated to assess the results

Physical setting



The portion of model shown in figure has depth variation of about 50m in sea.

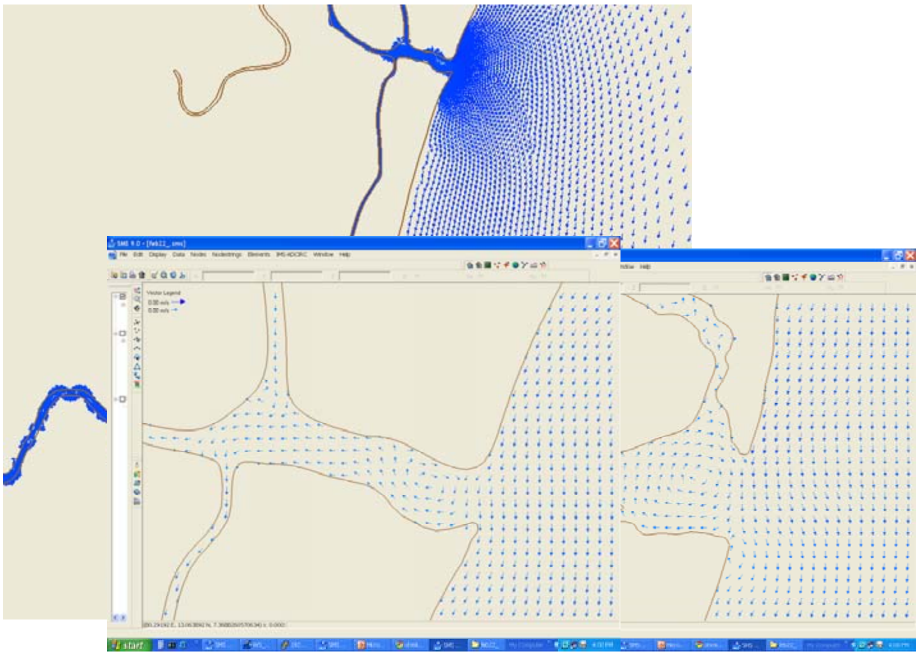
Within the water way network, the depth is artificially assigned to -3m (CD)

The mouths at Adyar and Cooum has been enlarged to transfer more tidal effect into the network

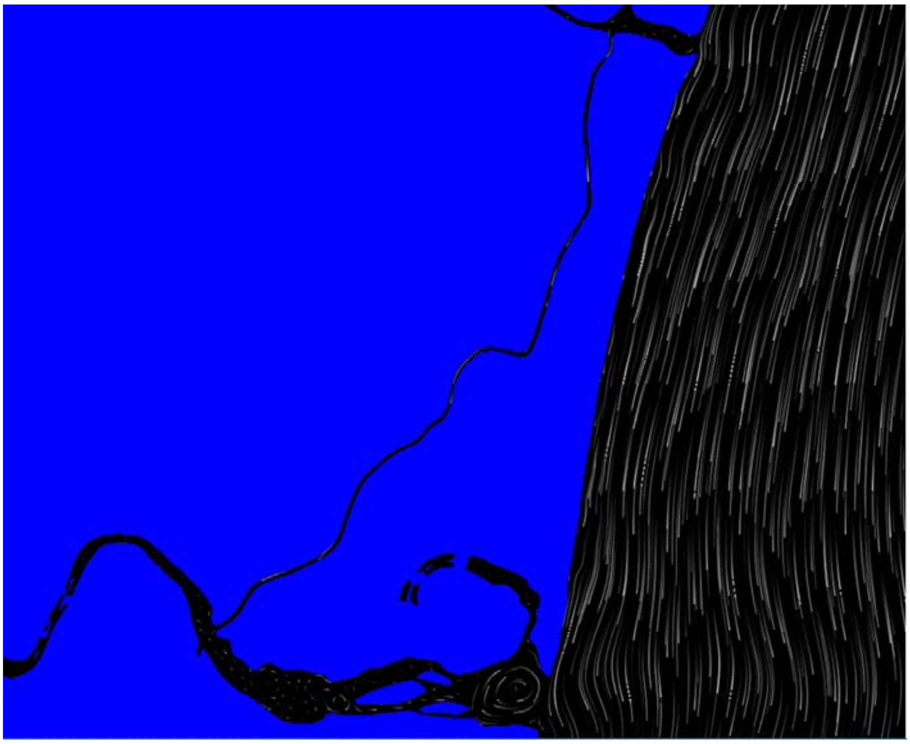
A uniform trapezoidal channel section is assumed for the network with top width of 30m

The bathymetry on sea side was adopted from NHO charts

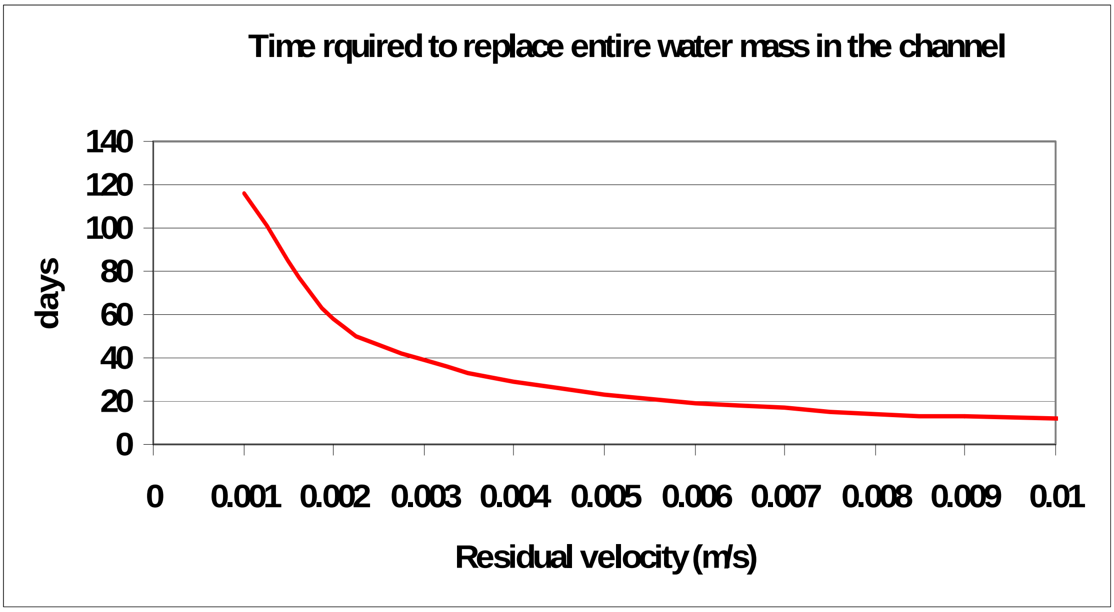
Simulation results : Residual Flow



Simulation results : Particle Tracking



Target residual flow



Summary & Conclusion

- Assuming 10 km length for waterway network, approximately 0.7 Mm3 material will be required to be removed
- With canal section lined with geosynthetic material, the cost of creating network will be of the order of Rs. 30 Cr. (based on assumed approximate quantities and rates)
- Based on model results an attempt is made to achieve on average a residual flow of 0.001m/s for entire network. At this rate of residual flow, a complete replacement of water mass within the network will take place in about 4 months time.
- The water quality improvement will be gradual and remain steady with fresh sea water entering continuously within the network.

Anticipated problems and means to minimize their effects

- It may be noted that even if the scheme is successful and we transfer the sewage from within the Cooum to open sea, it may end up polluting along the shoreline (Marina beach) due to open sea flow pattern.
- In long run, it is desirable to arrest the untreated sewage input to the river network as a permanent solution so that the problem is not merely shifted from river to sea.
- The river mouths will need continuous maintenance to avoid closure due to littoral drift.
- A combination of Groynes and dredging / sand by-passing will be needed to maintain the river mouth opening.
- Settlements and Elevated railway track along the network may deter the smooth implementation.

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Session – V

Pollution Status of the Adyar & Cooum Rivers

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Introduction

- Water – essential for Socio-economic development & healthy ecosystem maintenance
- Freshwater resource stress – demand increment, increasing population-extravagant use, pollution load
- Water quality – important factor – influence aquatic organisms growth & development, its use (drinking, domestic, industrial and agricultural purposes)

About Chennai Waterways

- Three Waterways – Kosathaliyar, Cooum and Adyar and manmade Buckingham canal
- The *Cooum River* almost divides the city into half
- The *Adyar River* divides the southern half of the city into two.
- The historic *Buckingham canal* runs nearly parallel to the coast almost through the entire length of the city.
- There are a number of other smaller canals and nullahs (*Otteri Nullah, Captain Cotton Canal and Mambalam Drain*) draining into these main waterways.

Present status of Chennai City Waterways

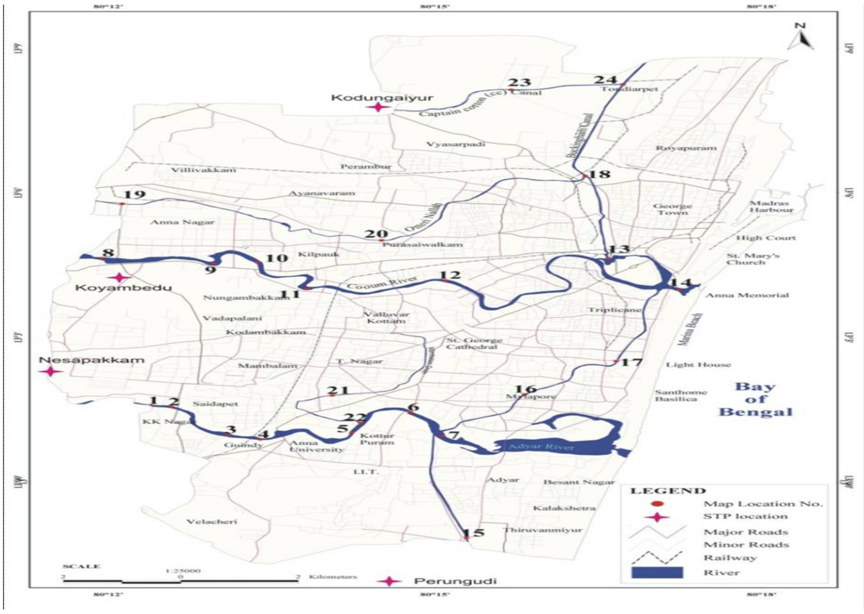
Factors for pollution load in the Waterways:

All these waterways are polluted due

- to outfalls from industries,
- commercial institutions,
- sewage treatment plants,
- pumping stations, sewers, storm water drains and slums.

This wastewater discharge contributes contaminated or polluted water to the waterways and leads to unsanitary condition.

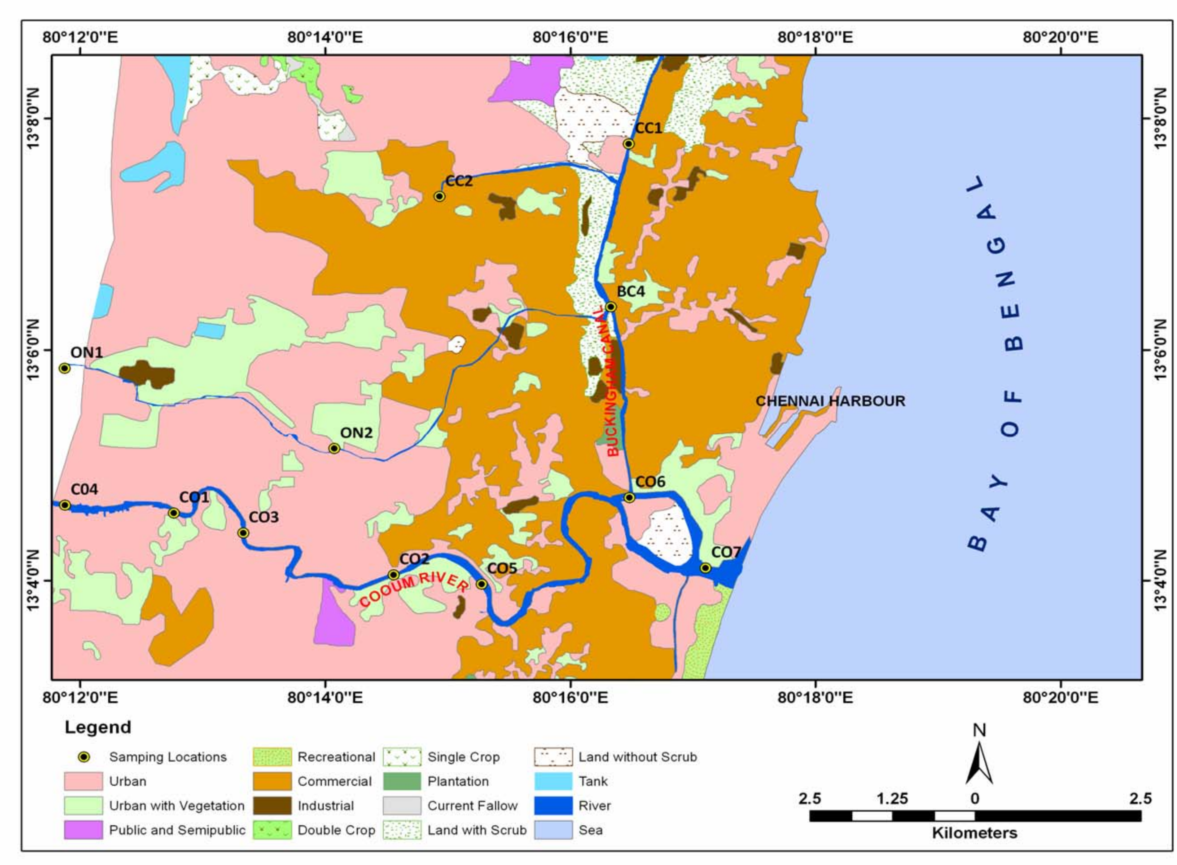
Sampling Stations



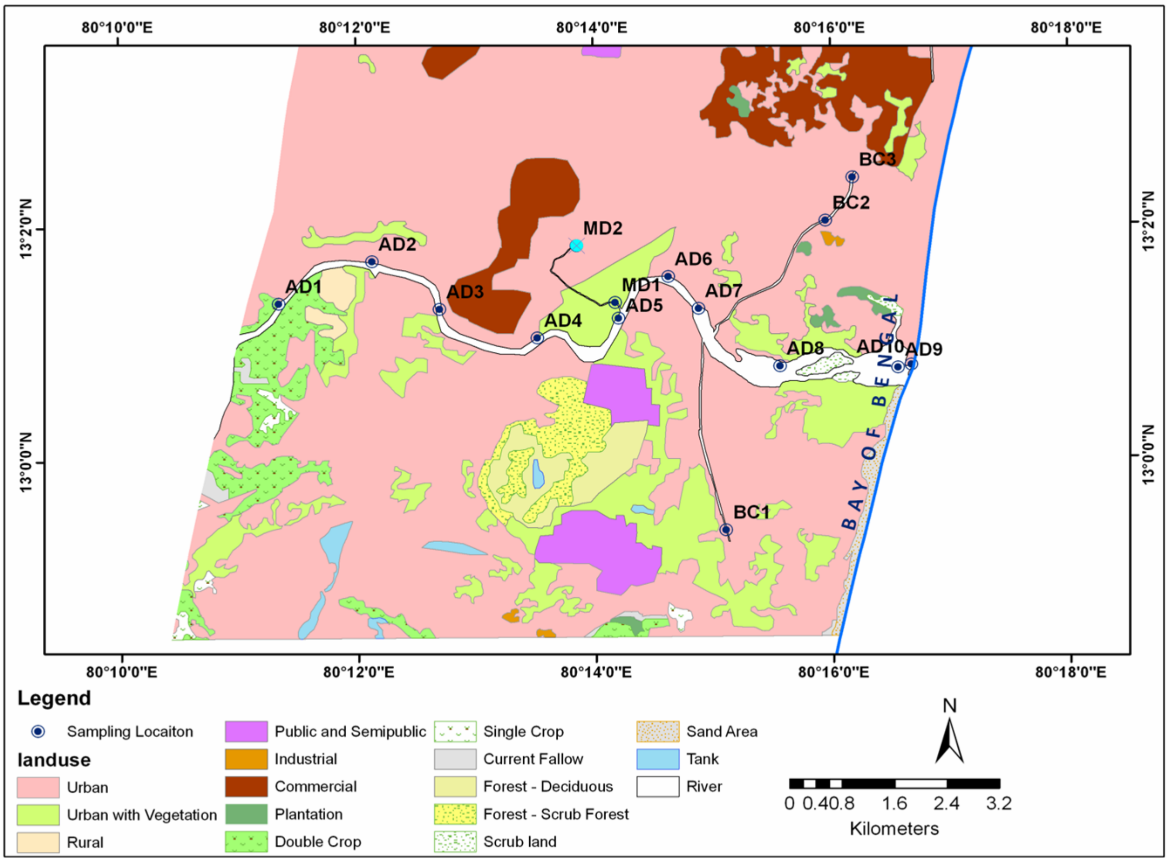
Sampling Stations

Sl. No	Sampling Sites	Sample ID	Location	UTM Zone 44	No. of Samples
1	Adyar	AD-1/W	Nandambakkam	1439323 N 0411615 E	7
2		AD-2/W	Ekkattuthangal	1440268 N 0414095 E	
3		AD-3/W	Jaferkhanpet	1439123 N 0415093 E	
4		AD-4/W	Maraimalai Bridge	1439255 N 0415943 E	
5		AD-5/W	Before Golf Course	1439725 N 0417200 E	
6		AD-6/W	Kotturpuram	1438340 N 0418633 E	
7		AD-7/W	Near Boat Club	1440152 N 0418013 E	
8	Cooum	CO-1/W	Anna Nagar	1445721 N 0414652 E	7
9		CO-2/W	Arumbakkam	1444725 N 0417893 E	
10		CO-3/W	Amanjikarai	1445399 N 0415675 E	
11		CO-4/W	Poonamalle	1445852 N 0413050 E	
12		CO-5/W	College Road	1444574 N 0419190 E	
13		CO-6/W	Near Central Jail	1445947 N 0421375 E	
14		CO-7/W	Nappier Bridge	1444822 N 0422492 E	
15	Buckingham canal	BC-1/W	Tidal Park	1435786 N 0422054 E	4
16		BC-2/W	Mylapore	1441154 N 0420680 E	
17		BC-3/W	Ice House	1442778 N 0421802 E	
18		BC-4/W	GMR Vasavi Industries	1448995 N 0421109 E	
19	Mambalam Drain	MD-1/W	Usman Road	1440631 N 0416580 E	2
20		MD-2/W	Golf Course	1439725 N 0417200 E	
21	Otteri Nullah	ON-1/W	Otteri Nullah Origin	1448042 N 0413048 E	2
22		ON-2/W	Kilpauk garden	1446743 N 0417025 E	
23	Captain cotton canal	CC-1/W	Erukanjeri	1450766 N 0418585 E	2
24		CC-2/W	Kodungaiyur	1451599 N 0421382 E	

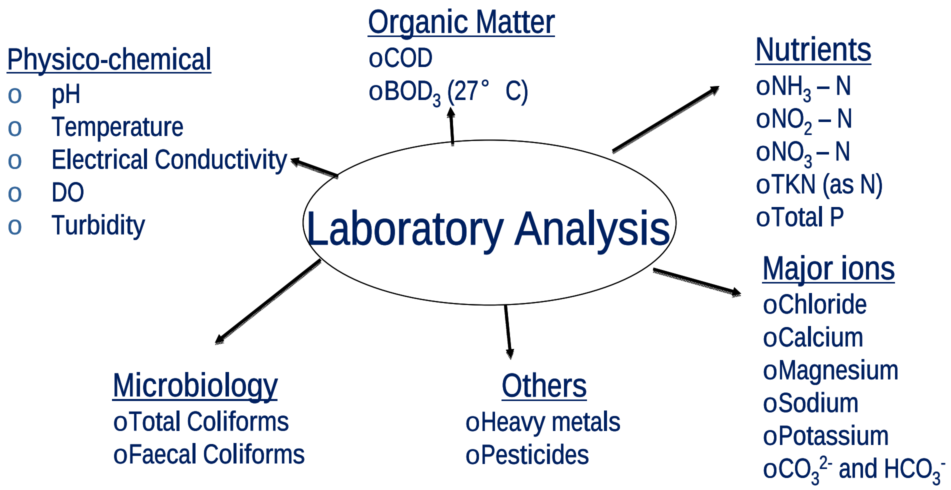
Sampling Locations – Cooum River



Sampling Locations – Adyar River



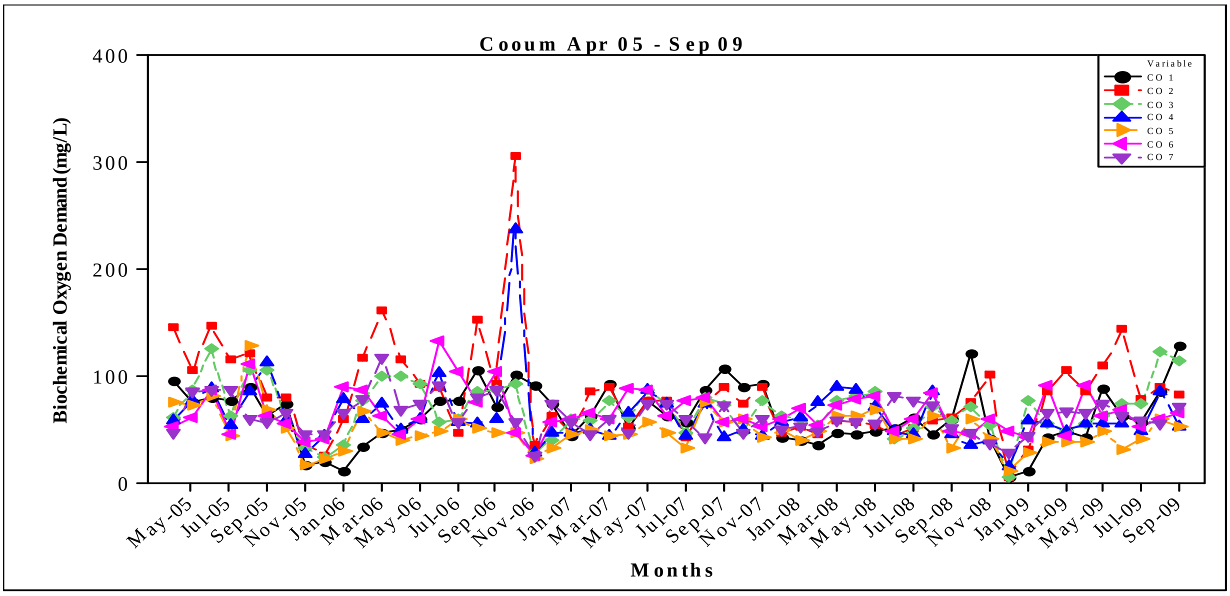
Parameters



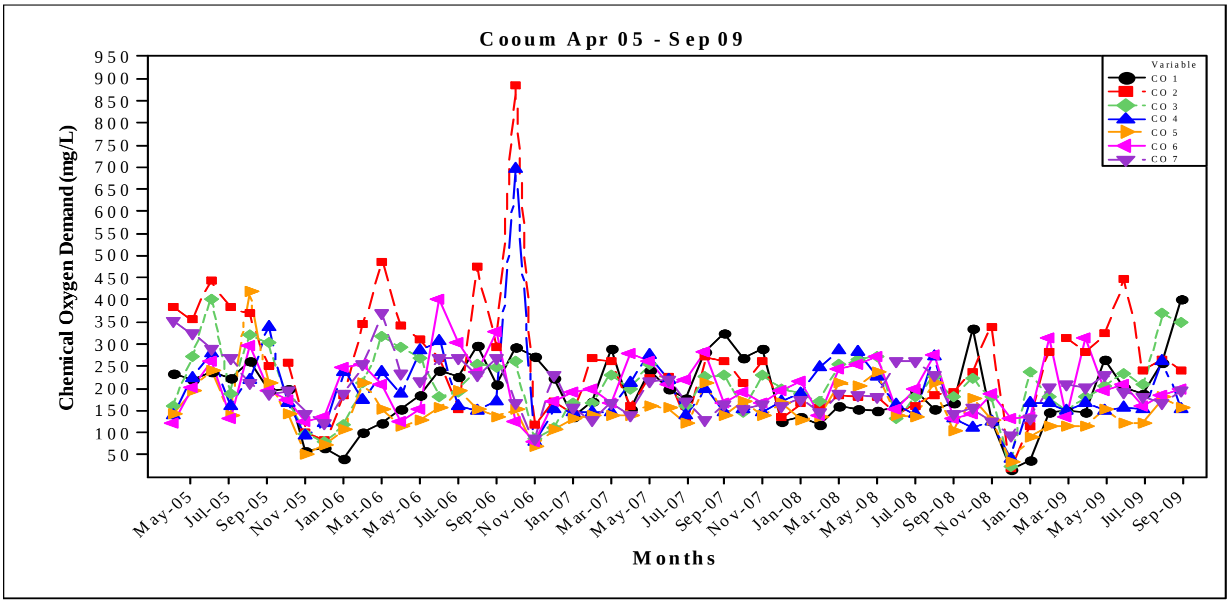
Methodology

ANALYSIS	METHOD	EQUIPMENT
General :		
pH (in-situ)	4500-H+	WQC-24 Water Quality Meter
Temperature	2120	WQC-24 Water Quality Meter
Electrical Conductivity	2510	WQC-24 Water Quality Meter
DO (in-situ)	4500-O	WQC-24 Water Quality Meter
Turbidity	2130	WQC-24 Water Quality Meter
Nutrients :		
NH3 – N	4500-NH3	Titrimetric Method
NO2 – N	4500- NO2	Spectrophotometry
NO3 – N	4500-NO3	Copper - Cadmium Reduction Method, Spectrophotometry
TKN (as N)	4500-Norg	Macro Kjeldahl Method
Total P	4500-P	Stannous Chloride Method
Organic Matter :		
COD	5220	Open Reflux Method
BOD3(27°C)	5210	3 -day BOD Test
Major ions :		
Chloride	4500-Cl	Argentometric Method
Microbiology :		
Total Coliforms	9221	MPN Technique
Faecal Coliforms	9221	MPN Technique
Others:		
Heavy metals	3030	ICP - OES
Pesticides	6630 B	Solvent Extraction, Gas Chromatography ECD

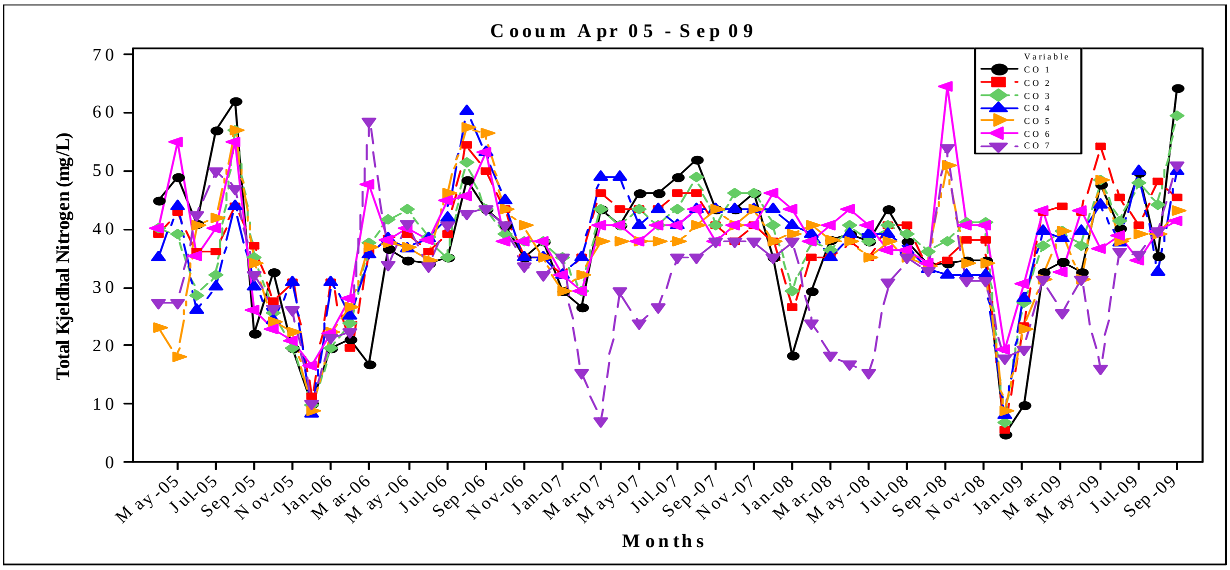
Cooum River – BOD



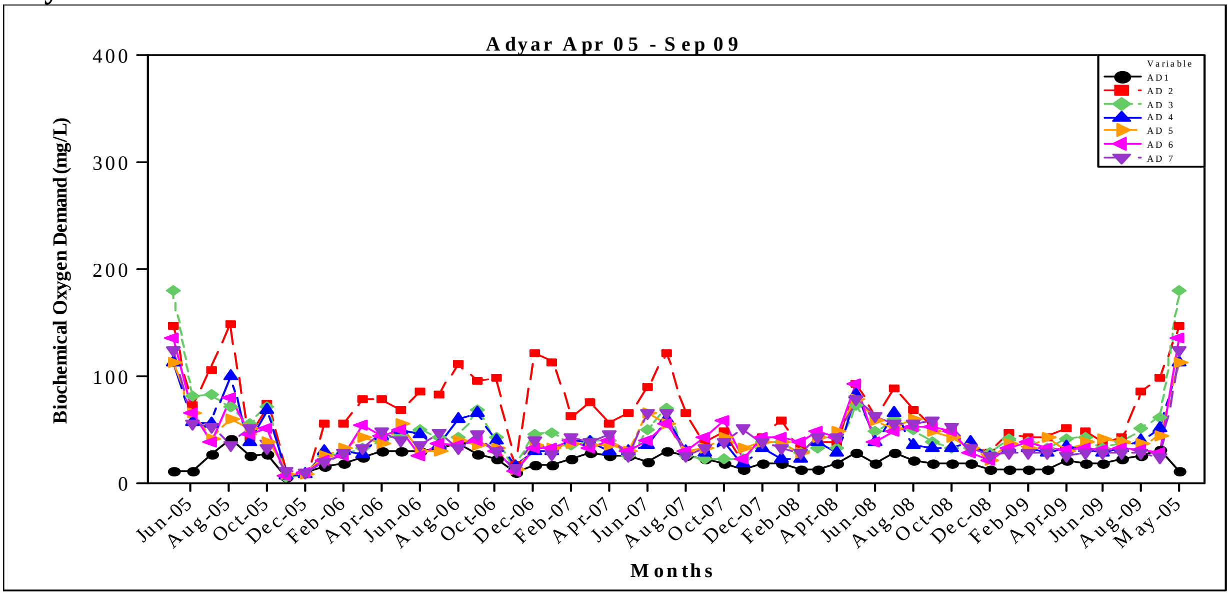
Cooum River – COD



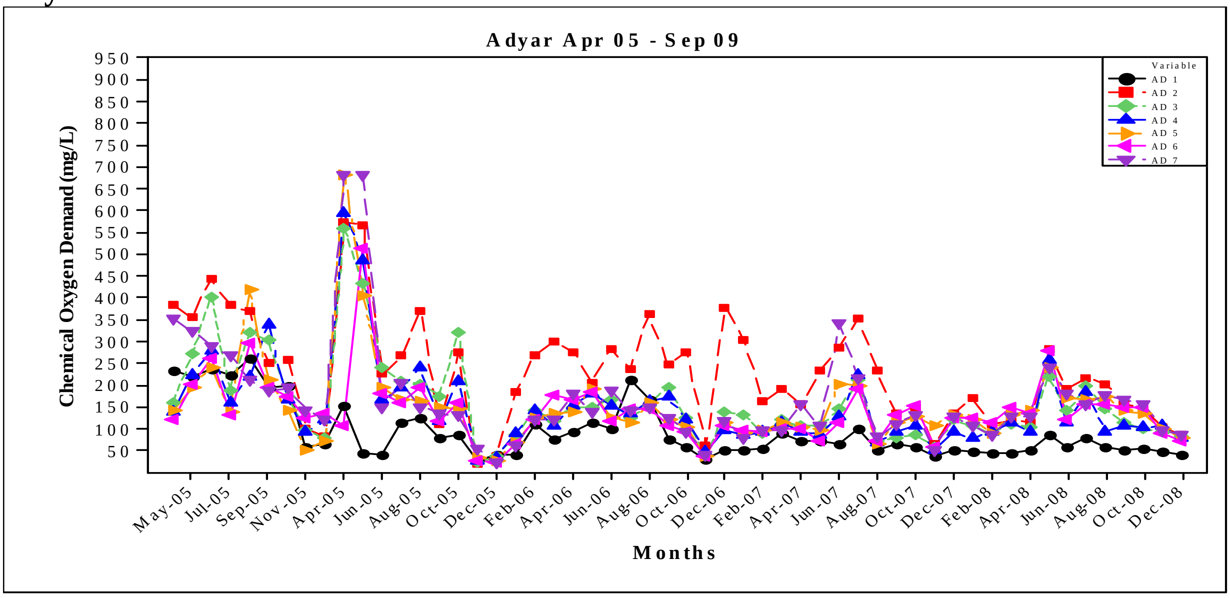
Cooum River – TKN



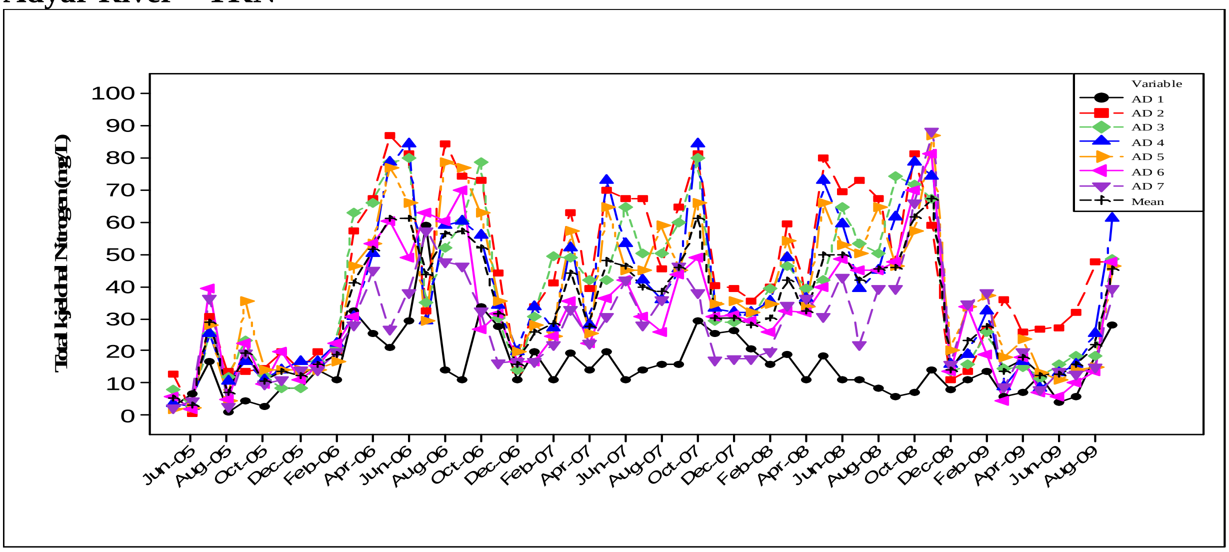
Adyar River – BOD



Adyar River – COD

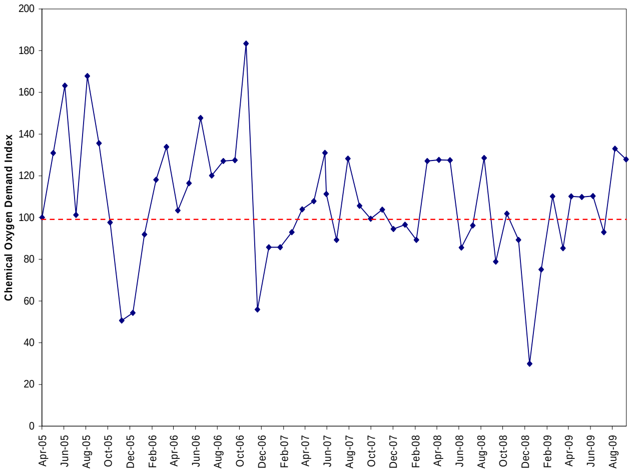


Adyar River – TKN

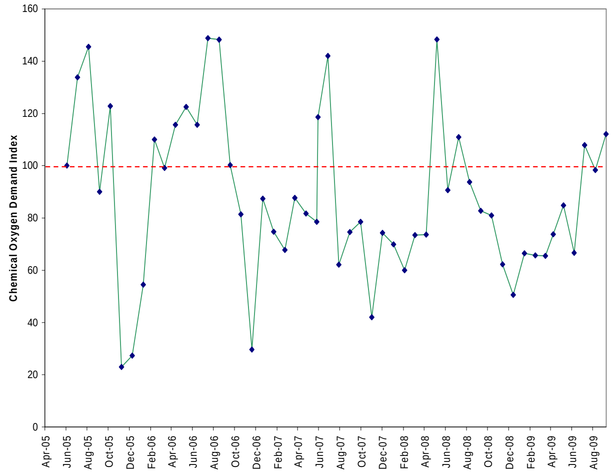


Index Graph – COD

The baseline value is the percentage of initially monitored status of the Chennai City Waterways April 2005, based on this the overall flux is calculated.

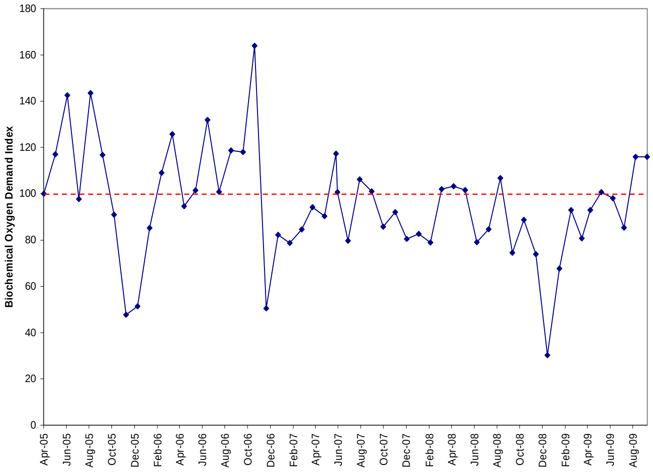


Cooum River

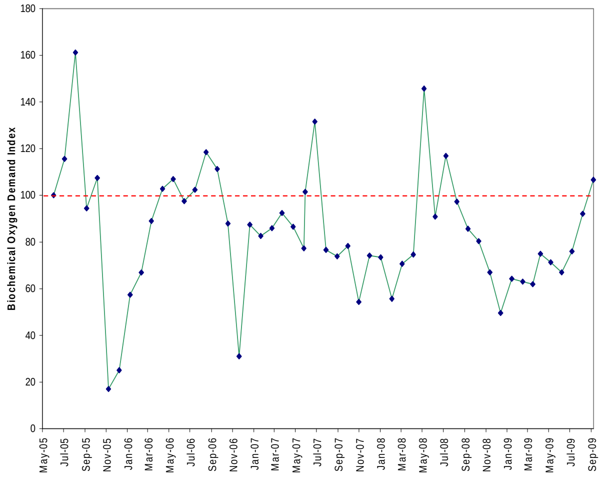


Adyar River

Index Graph - BOD

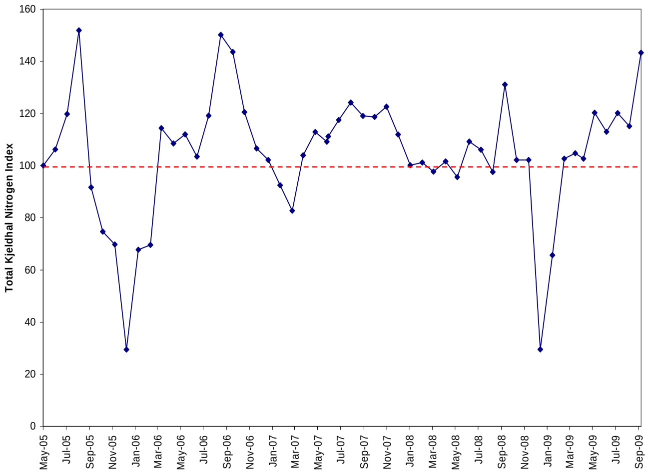


Cooum River

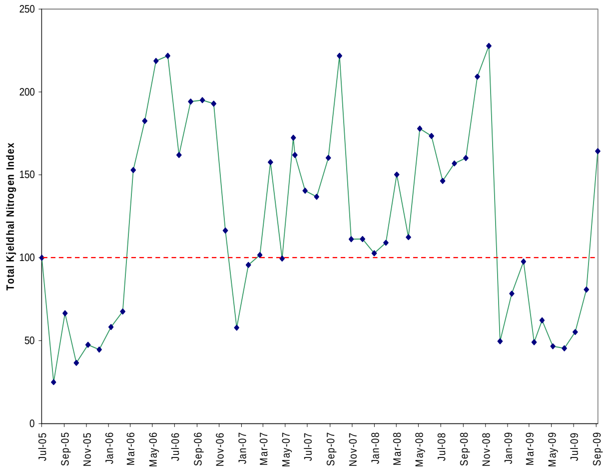


Adyar River

Index Graph - TKN



Cooum River



Adyar River

BOD : COD Ratio in Cooum and Adyar River

- BOD and COD are most widely used as parameters for calculating pollution load applied to both wastewater and surface water.
- The biodegradability of the organic compound depends on the BOD :COD ratio in the wastewater.
- For typical untreated domestic wastewater with high organic content has the BOD5 /COD ratio above 0.7.
- The average BOD:COD ratio obtained in Cooum and Adyar River is in the range of 0.28 to 0.38, which indicates poor biodegradability and also extensive industrial pollution.

BOD : COD Ratio in Cooum River

Cooum River Apr 05-Sep 09							
Annual Average	CO-1/W	CO-2/W	CO-3/W	CO-4/W	CO-5/W	CO-6/W	CO-7/W
2005	0.34	0.33	0.34	0.35	0.36	0.34	0.29
2006	0.34	0.33	0.34	0.33	0.32	0.34	0.32
2007	0.33	0.34	0.33	0.33	0.34	0.32	0.35
2008	0.33	0.32	0.31	0.32	0.32	0.33	0.31
2009	0.32	0.32	0.33	0.34	0.33	0.32	0.33
Total Avg	0.33	0.33	0.33	0.33	0.33	0.33	0.32

BOD : COD Ratio in Adyar River

Adyar River Apr 05-Sep 09							
Annual Average	AD1/W	AD2/W	AD3/W	AD4/W	AD5/W	AD6/W	AD7/W
2005	0.28	0.33	0.33	0.32	0.31	0.34	0.30
2006	0.30	0.31	0.31	0.31	0.30	0.29	0.30
2007	0.37	0.33	0.34	0.35	0.34	0.38	0.37
2008	0.35	0.34	0.34	0.33	0.33	0.33	0.34
2009	0.29	0.31	0.32	0.32	0.33	0.32	0.29
Total Avg	0.32	0.33	0.33	0.32	0.32	0.33	0.32

Water Quality Criteria by CPCB, Govt. of India

Best-Designated-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coliforms OrganismMPN/100ml shall be 50 or less 2.pH between 6.5 and 8.5 3.Dissolved Oxygen 6mg/l or more 4.Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organized)	B	1.Total Coliforms Organism MPN/100ml shall be 500 or less 2.pH between 6.5 and 8.5 3.Dissolved Oxygen 5mg/l or more 4.Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1.Total Coliforms Organism MPN/100ml shall be 5000 or less 2.pH between 6 to 9 3.Dissolved Oxygen 4mg/l or more 4.Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	D	1.pH between 6.5 to 8.5 2.Dissolved Oxygen 4mg/l or more 3.Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1.pH between 6.0 to 8.5 2.Electrical Conductivity at 25°C µS/cm max.2250 3.Sodium absorption Ratio Max. 26 4.Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Conclusion

- High BOD, COD and nutrients have been/ are being recorded at Near Central Jail in the Cooum river Anna Nagar and Ekkatuthangal and Jafferkhanpet (within city limits) in the Adyar river, indicating that these locations are "*typical hotspots of urban pollution*"
- The Buckingham Canal (Mylapore), Caption canal and Mambalam Drain waterways are more severely polluted than the Adyar and Cooum River, due to insufficient freshwater flow and continuous discharge of domestic wastes
- Creation of maintenance and sewerage infrastructure is the State's primary requirement

- Normally, river cleanup programs involve a long time period and large resources for effective action. But a successful program is bound to yield the desired water quality of the rivers for best utilization of this scarce resource.

References

1. A Uniform protocol on water quality by MoEF (Govt. of India) September 2005 (unpublished)
2. Report on Outfalls in the Waterways of Chennai Metropolitan Area, EMAT (2007)
3. Standard Method for the Examination of Water and Wastewater (APHA 2005)

Pollution Status of the Rivers Adyar & Cooum:

What Next ?

- *Grey water Harvesting?*
- *GREEN Technology Vs Efficient Technology??*
- *CSR???*

Acknowledgement:

- Institute of Ocean Management (IOM), Anna University, Chennai
- Ministry of Environment and Forest (MoEF), Government of India

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Session – V

Sustainability Measures for Water Resources Management

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- Water Issues to be addressed
  - Water management for urban and rural areas (water use, sewerage, pollution)
  - Water as a habitat / ecohydrology
  - Water quality
  - De-centralized water treatment
  - Creation of infrastructures in slums
  - Virtual water cycles
  - Ground water storage and rehabilitation of aquifers
  - Restoration of Water Bodies

Sustainable Water Resources Management of Chennai Basin

- Issues being addressed
  - Source assessment
    - Surface and Ground water
  - Sustainable yield
  - Demand estimation
    - Municipal & Industrial, Irrigation and Environmental
  - Sustainability of existing urban water supply systems and plans for improvements
  - Integrated flood management

What is Sustainable Development??

Ability to meet the needs of the present, without compromising the needs of the Future Generations - (WCED, 1987)

Sustainable Development

- Natural resources of the Earth are limited
- Intra-generational inequity
- Inter-generational inequity

restraining the present rate of use of material (resources) and non-renewable energy so as to keep enough for many future generations

Water Resources Decision Making

- ***Planning, Design and Management of Water Resources decision-making involves:***
  - ❖ participation of multiple stakeholders
  - ❖ dynamic interactions between human population and natural resources, processes, species
  - ❖ conflicting interests
  - ❖ complex circumstances of multiple objectives

Water Resources Decision Making -Sustainability Paradigm

- Complicated inter-relationships between ecological, economic and social factors

  environmental integrity
  economic efficiency
  equity
- Challenge of Time!!
- Change in Policies, Implementation

Three Legs of Sustainability

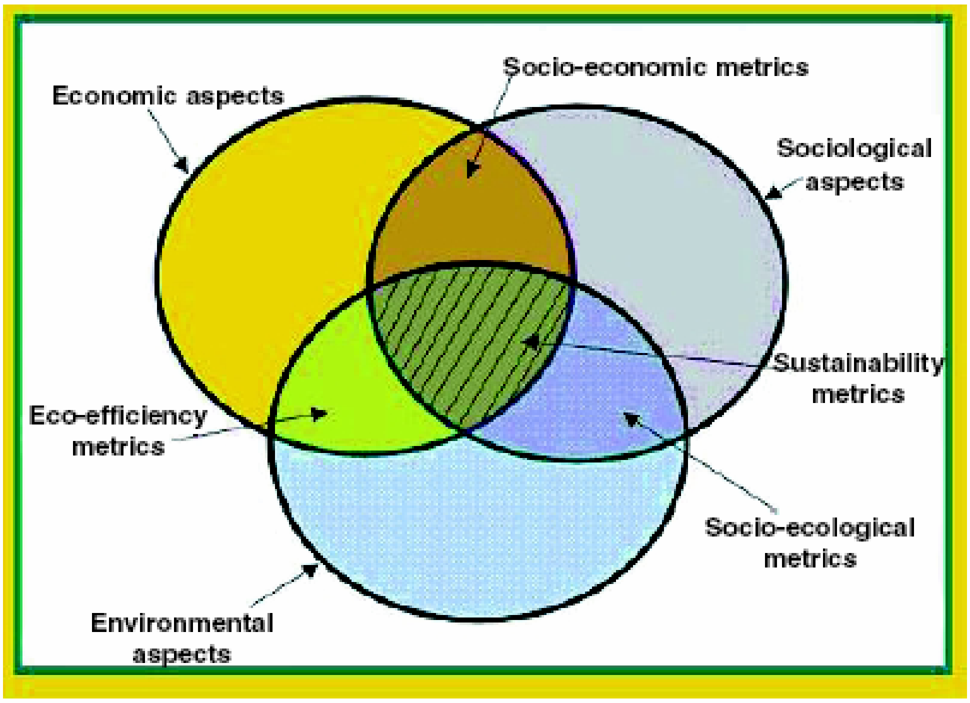


Figure 2. Three intersecting circles to illustrate sustainability.

Only by improving all three aspects of sustainability ***simultaneously*** can we claim to have progressed towards sustainability!!

Sustainability Indicators

Group 1 (1-D): economic, ecological, and sociological indicators

Group 2 (2-D): socio-economic, eco-efficiency, and socio-ecological Indicators

Group 3 (3-D): sustainability indicators: nonrenewable energy use, material use, pollutant dispersion.

Measures of Sustainability

- Sustainability Measures for WRM Decision-making
  - Fairness : assessment of benefits
  - Risk : consequence due to failure
  - Reversibility : degree to which the impacts due to developmental projects can be mitigated
  - Consensus : level of satisfaction of stake-holders with regard to a suggested solution

Urban Water System

Main components of an Urban Water System:

- Water supply
- Waste water disposal and
- Storm water drainage
  - traditional approach has been to consider the infrastructure that delivers potable water, separately from the infrastructure that disposes off wastewater and separately to the provision of drainage for storm water.

Growing need to reevaluate the traditional approach

- Minimize the environmental impact of urban areas on supply sources and receiving waters
- This necessitates the investigation of possible interactions between the three main components of urban water
- increasingly being seen as resources that need to be utilized rather than consider them as unavoidable by-products of urbanization.

Integrated Modeling Framework Needed

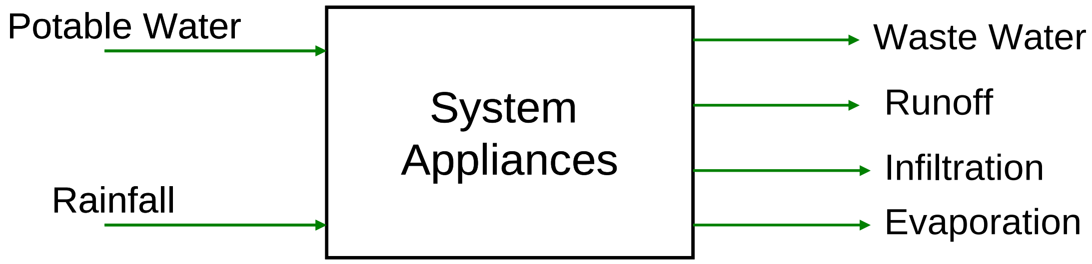
An integrated modelling framework is required

- to investigate and quantify the interactions and transformations of the three water flows
- to identify the future possibilities and the limitations of different systems

within the context of sustainable water management for new developments.

Decision Support for Sustainable option selection in Integrated Urban Water anagement

(Source : Urban Water Optioneering Tool (UWOT) U.K.



Urban Water Balance

Knowledge Base of Existing Water Management Technologies –

(in-house scale, house hold scale, development scale)

- Washing Machine - technology specifications
- Toilet Fittings, Technologies - flushing water consumption
- Showers - water consumption, user satisfaction
- Bath tubs - tub capacity
- Wash basin - water flow delivery type
- Dish washer – technology specifications
- Kitchen sink - water flow delivery type
- Garden watering - techniques and devices
- Outside use (swimming pools, pumps, foundations)
- Sustainable urban drainage system (SUDS) local - functionality
- Sustainable urban drainage system (SUDS) centralized - functionality
- Grey water treatment (local)
  - Decentralized RWH and grey water reuse
  - Design specifications
- Grey water treatment (centralized) - Treatment plants, potential recycling and level
- Rainwater treatment (centralized) - Treatment technology potential recycling & level

SUSTAINABILITY Indicators in decision making for water service providers

(Source : Urban Water Optioneering Tool (UWOT) U.K)

Capital	Indicators
ENVIRONMENTAL	Water use Water loss Energy use Chemical use Service Provision Environmental impact
ECONOMIC	Life cycle cost Willingness to pay Affordability Financial risk exposure Capital cost Operational cost
SOCIAL	Risk to health Acceptability Participation / responsibility Public awareness Social Inclusion
TECHNICAL	Performance Reliability Durability Flexibility / Adaptability

Optimal Development Plan

- The optimal development plan can be obtained using the UWOT Tool
  - with regard to the objective/s (indicator/s) specified by the user
  - ranking of solutions can be made
  - computations of performance indicators are done over the specified number of future generations

Life Cycle Assessment

For Urban Water Systems :

- Concept of Life cycle Assessment (LCA) could be extended and adapted after refinements to include water – specific impacts ??

- For example, we want to compare alternative development plans like transporting drinking water from a long distance and desalination

Comparison of 3 Plans

Energy consumption (MJ)	191218.0	641331.0	213384.0
Global warming potential (kg CO2 equiv.) Eutrophication potential (kg O2 equiv.)	14964.0	50177.0	16645.0
Eutrophication potential (kg O2 equiv.)	181.0	601.0	198.0
Photochemical oxidant formation potential (kg ethene equiv.)	0.97	2.6	1.1
Human toxicity potential (kg DCB equiv.)	8.8	27.0	11.0
Marine ecotoxicity potential (kg DCB equiv.)	52503.0	166844.0	58264.0
Terrestrial ecotoxicity potential (kg DCB equiv.)	72.0	239.0	80.0

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Session – V

Integrated Flood Management of Adyar Basin

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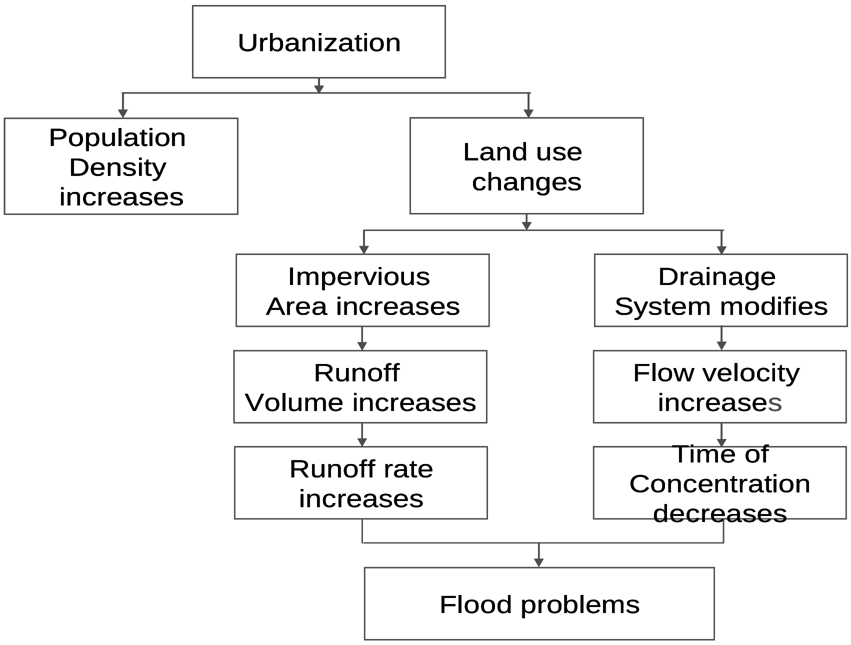
Introduction

- Flooding is a *growing problem* that is of great concern to engineers worldwide to design and implement mitigation measures. Floods can not only damage the natural resources and environment, but also causes the loss of lives, economy and health.
- Floods in the majority of areas of the world are caused *by rains of different duration and intensity*. Cyclonic storms are the major cause for flood in Chennai.
- Although flood hazard is natural, *human modification and alteration of nature's right of way* can accentuate the problem, while the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas

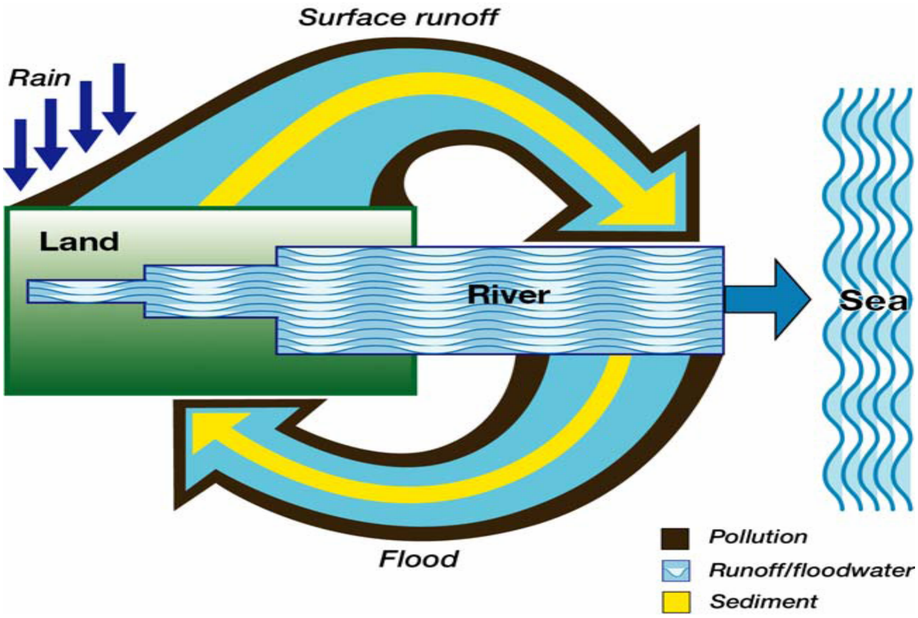
Impacts of Urbanization



Impacts on landuse change

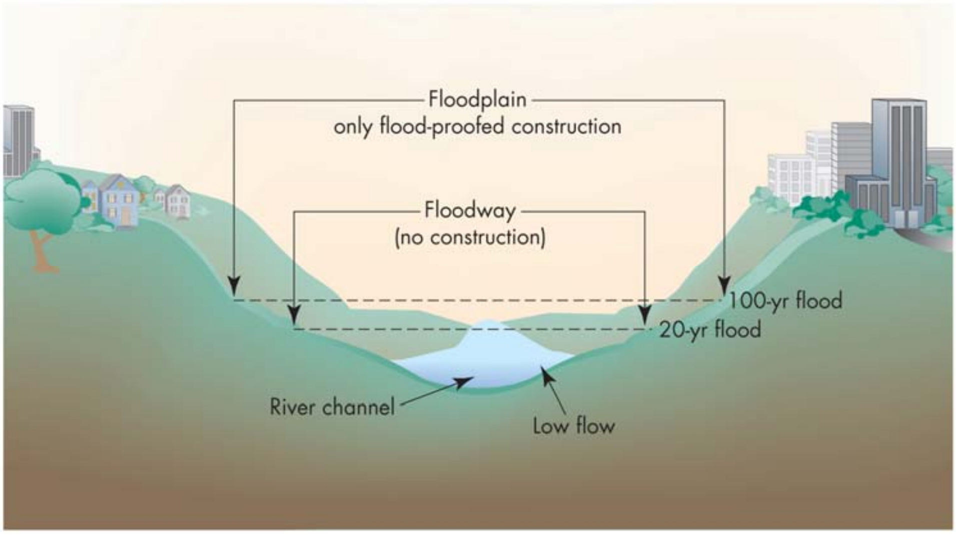
- Short term impacts
  - Flooding
  - Property damage
  - Economic impacts
- Long term impacts
  - Increase in surface water quantity
  - Decrease in surface water quality
  - Increased downstream flooding

Interactions between land and water environment



Source: 'The role of land use planning in flood management' WMO report

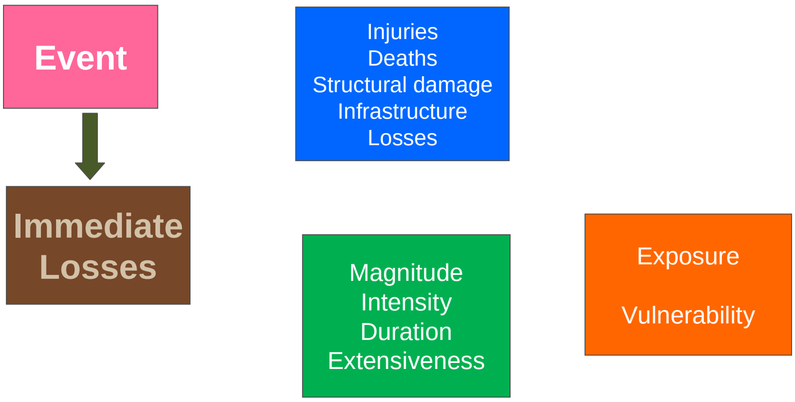
Floodplain and floodway



Perception of flooding

- Individual level: Variable
- Local and state level: Mitigation plans
- Federal government level
    - Mapping of flood-prone areas
    - Floodplain management plans

Consequences of flooding

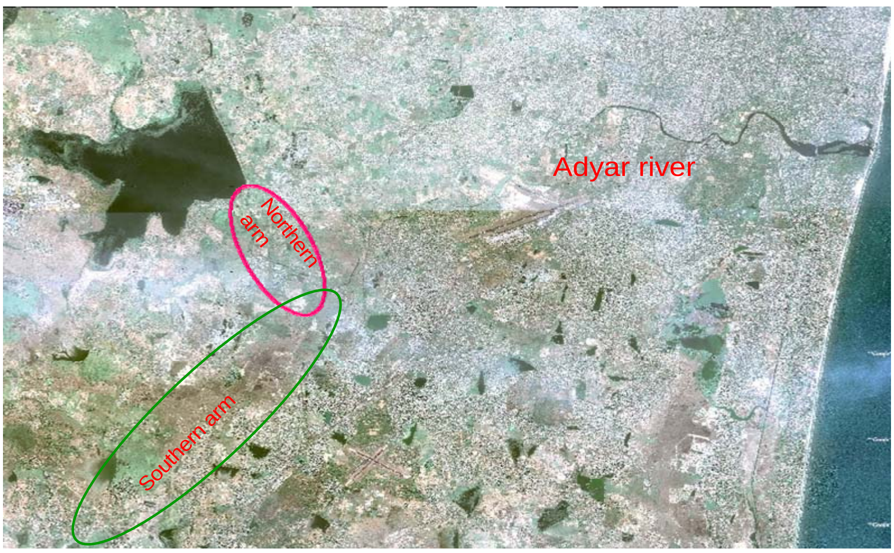


TRACKING THE ADVERSE CONSEQUENCES OF FLOODING

Adyar River

- Adyar river is a short river of 42 km long.It has two arms. The northern arm comes from Chembarambakkam minor basin and joins with the southern arm coming from Guduvancheri, at Tiruneermalai
- The river enters the city at Nandambakkam bridge and flows through the city and finally falls into Bay of Bengal
- The southern arm has no storage structure and the flat topography does not permit any storage structure as any structure having a moderate height would cause large scale inundation
- Raingauges present in the basin
  - Meenambakkam
  - Padappai
  - Sriperumpudur
  - Chembarambakkam
  - Tambaram

Map of Adyar river



Flood experiences during last three decades in Adyar river

- 1976 Heavy Flood Submergence in Adayar-Kotturpuram TNHB Qtrs. Flood could not enter into sea due to High tide. Chembarambakkam Tank surplused into Adayar – 28,000 C/s
- 1985 Floods in Adayar - 63,000 c/s submergence of encroached flood plains
- 1996 Floods in Adayar, Cooum and Kosasthalaiyar Rivers Poondi Dam surplused around - 80,000 c/s Karanodai Bridge collapsed Chembarambakkam Tank surplused into Adayar – 20,000 C/s
- 1998 3 persons Marooned in Thanikachalam Nagar - a residential colony in the flood plains of Kodungaiyur drain
- 2005 100 year RF 40 cm in a day, Flood in Cooum 19,000 C/S, Adayar 40,000 C/S, Otteri Nullah, Cooum, Adayar, B'Canal, Virugambakkam- Arumbakkam Drain over flown, 50,000 people evacuated.
- 2008 Chembarambakkam tank surplused into Adyar - 15,000 cusecs

Flood in 2008


Field visit

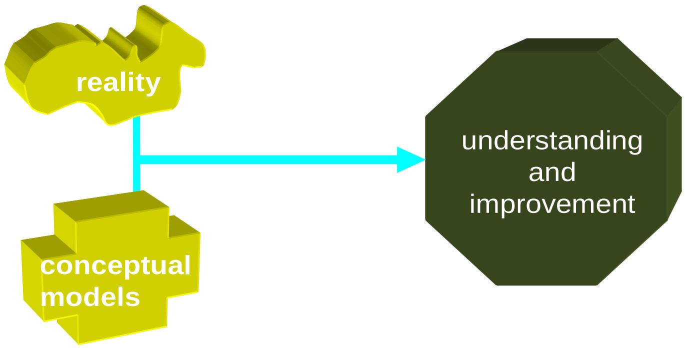

 

Soft System Methodology

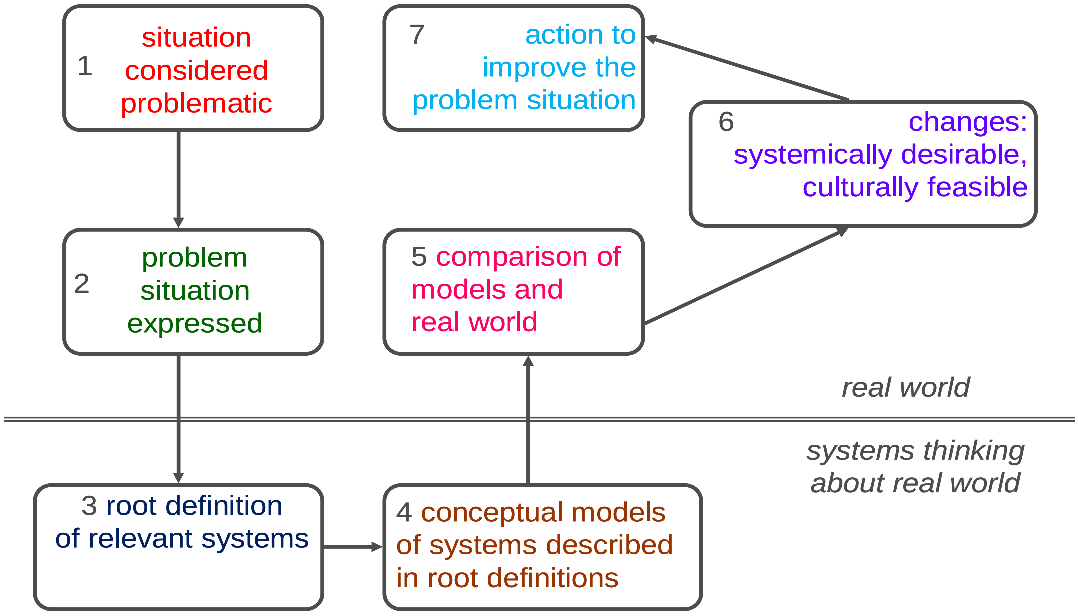
- *a methodology that aims to bring about improvements in areas of social concern by activating in the people involved in the situation a learning cycle which is ideally never – ending'* (Von Bulow, 1989)
- Use of SSM has involved four elements.
  - A perceived real world problem situation
  - A process for tackling that situation in order to bring about some kind of improvement
  - A group of people involved in this process
  - The combination of these three (intervention in the problem situation) as a whole with emergent properties. (Checkland,2000)

SSM for problem solving



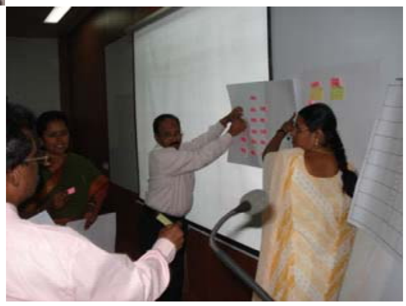
- Differences between models and reality become the basis for planning and policy making process.

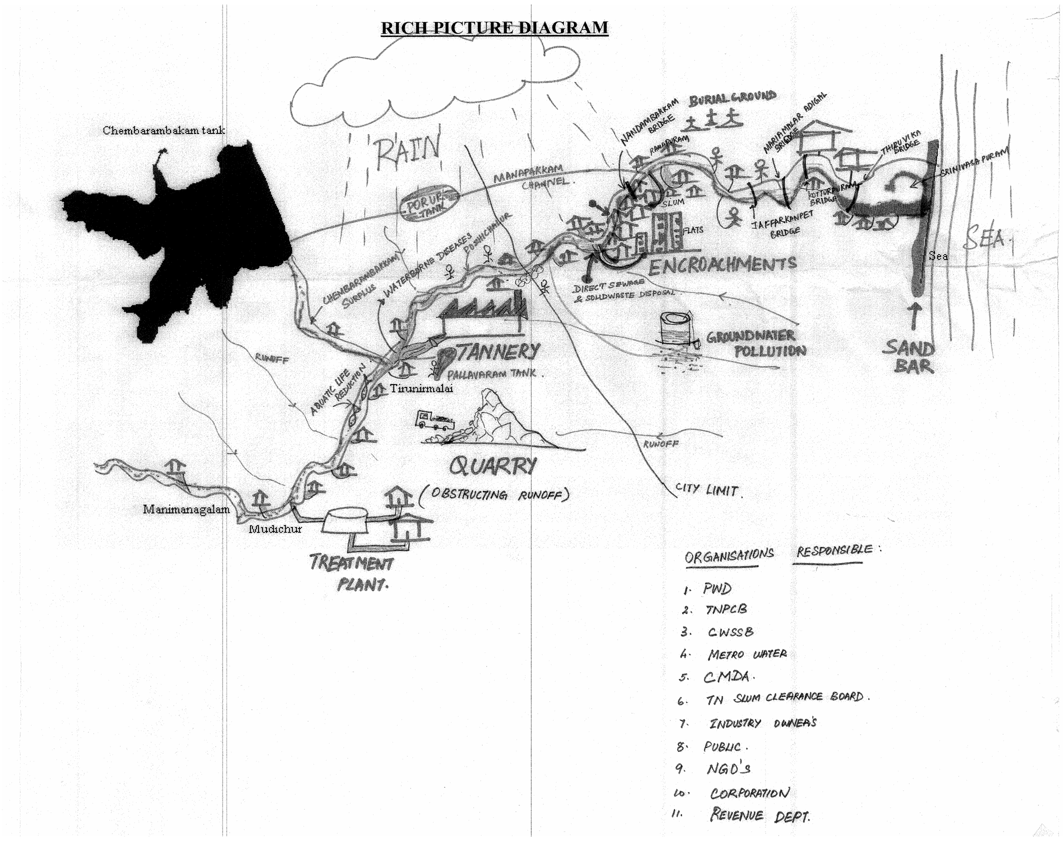
Seven stages of SSM



Source: Checkland: Systems Thinking, Systems Practice

Workshop conducted on 29.1.2010





CATWOE

- the storm water drainage system as flood protection

  C citizens of Chennai

  A Corporation of Chennai, Tamil Nadu Public Works Department

  T1 un-routed rainfall runoff –> runoff routed to waterways and the ocean

  T2 flood-prone areas –> flood protected areas

  W flooding should be averted

  O Corporation of Chennai, Tamil Nadu Public Works Department

  E topography of the Chennai region (flat, low-lying)

- Rich pictures and their accompanying root definitions and CATWOE analysis provide a mechanism for
  - mapping out a problem situation,
  - identifying conflicts, issues, risks and opportunities
  - clarifying the central focus of the system and
  - providing some clear structured way of expressing the elements within the system (CATWOE analysis).

A tool to rank a set of decision-making criteria and rate the criteria on a relative scale of importance

Pair wise comparison matrix

Criteria		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Encroachment	**A**	-	A	AC	D	E	AF	G	H
Uncontrolled Development	**B**	-	-	C	D	E	BF	G	H
Solid waste dumping	**C**	-	-	-	D	CE	CF	C	H
Waterways	**D**	-	-	-	-	D	D	D	D
Sand bar formation	**E**	-	-	-	-	-	E	E	E
Pollution	**F**	-	-	-	-	-	-	G	H
Inadequate & improper maintenance of micro drains	**G**	-	-	-	-	-	-	-	G
Lack of public awareness	**H**	-	-	-	-	-	-	-	-

Pair wise ranking

Criteria	No of responses	Rank
Waterways	7	1
Sand bar formation	6	2
Solid waste dumping	5	3
Inadequate & improper maintenance of micro drains	4	4
Lack of public awareness	4	4
Pollution	3	6
Encroachment	3	6
Uncontrolled development	1	8

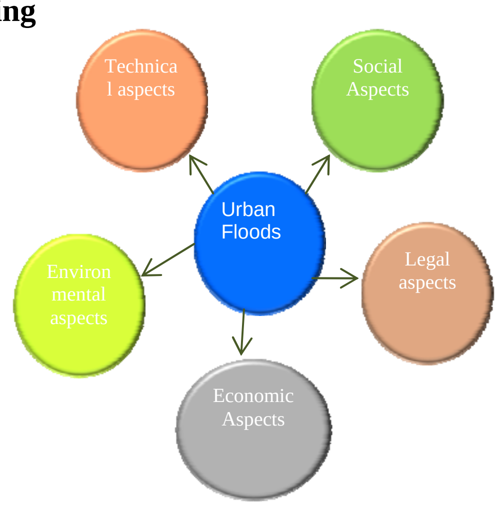
Integrated flood management

Integrated flood management (Integrates land and water resources development within the context of Integrated water resources management (IWRM) with a view to maximize the efficient use of flood plains and minimize loss to life)

The essential elements of IFM are:

- Adopting a basin approach to flood management;
- Bringing a multidisciplinary approach in flood management
- Reducing vulnerability and risks due to flooding;
- Enabling community involvement; and
- Preserving ecosystems

Different aspects of flooding



Technical aspects

- Technical aspects concentrates on studying
  - the relationship between rainfall and runoff
  - flood mapping and
  - land use changes etc.

Social aspects

- Social Aspects and Stakeholders Involvement identifies various social issues that need to be addressed while dealing with flood issues and explores means of stakeholder participation at various levels of decision-making in the context of flood management

Economic aspects

- Economic aspects states that the decision maker has to allocate limited and scarce resources and he must predict future physical and related economic consequences of a policy or plan and he should make choices based on physical and economic processes involved

Environmental aspects

- Environmental aspects states that the flood management policies and practices have to be viewed within the overall matrix of drivers of environmental degradation and in order to mitigate the adverse environmental impacts caused by structural measures of flood management, non structural flood management measures such as land use regulations, flood forecasting and warning, disaster prevention, preparedness and response mechanisms should be considered actively, channelization should be avoided as far as possible for flood mitigation

Legal aspects

- Key roles that the legal framework plays in the implementation process of flood management policies, namely:
  - To define institutional roles and responsibilities;
  - To determine and protect rights and obligations; and
  - To provide mechanisms for dispute management

Conclusion

- Floods are naturally caused by rainfall, but in urban areas it was characterized by inadequate adherence to planning regulations, even a short duration shower can be a critical initiator of flooding
- Floods cannot be prevented out rightly, but good planning and observance of the rules can reduce the level of vulnerability and facilitate coping. This calls for an integrated approach to urban flood management, since several element and dimension of urban planning can be identified. The unified urban flood management planning model must be developed for policy implementation. This implies that in considering options for flood mitigation or adaptation, all stakeholders, elements in flood management and dimensions of the society must be involved in flood management
- The starting point is comprehensive spatial planning, while sectoral and institutional aspects must be integrated for the purpose of providing efficient management plan

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