WATER QUALITY ASSESSMENT

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WHAT IS WATER QUALITY?

Water Quality means the physiochemical characteristics of water that harbors diverse aquatic flora and fauna and various uses for human beings.

The Water (Prevention & Control of Pollution) Act, 1974

‘An Act to provide for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water’

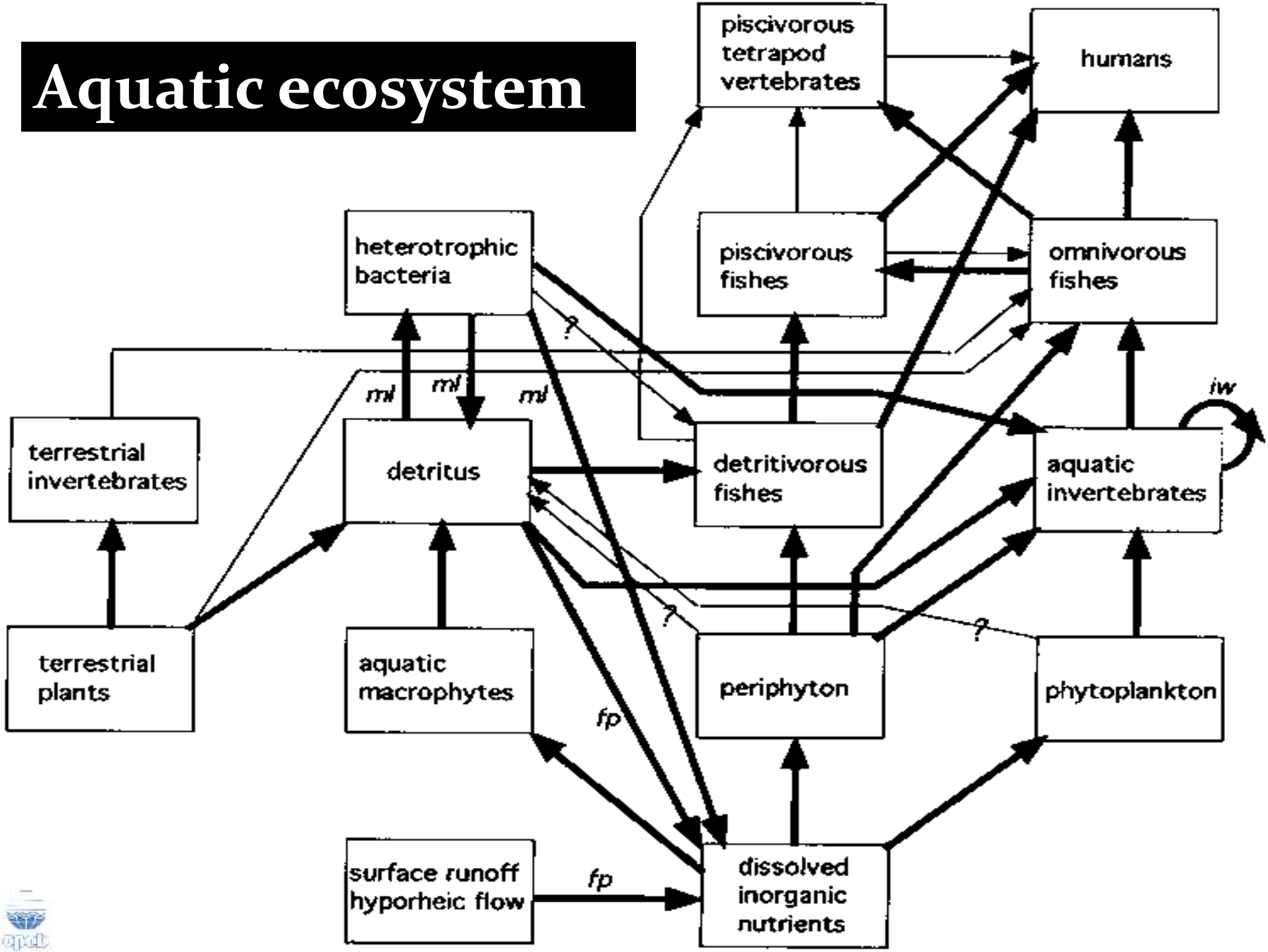
Wholesomeness of water

By wholesomeness of water means an aquatic ecosystem act as a dynamic biological machine that sustains a physicochemical characteristics that harbors diverse aquatic flora & fauna & various uses for human being

This biological machine also assimilates pollutants to a great extent

$$\text{Assimilative capacity} = \frac{\text{Re-aeration constant}}{\text{De-oxygenation rate}}$$

Aquatic ecosystem



Definition of Pollution under Section 2 (e) of Water Act, 1974.

- "Pollution" means such contamination of water or such alteration of the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or of any other liquid, gaseous or solid substance into water (whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plant or of aquatic organisms.

Water Quality Objective

- To asses the fitness of water for different uses.
- To evaluate water quality trend over a period of time.
- To assess nature and extent of pollution control needed at various stretches of water body.
- Determination of the extent and effects of specifies waste water discharge.

WATER QUALITY
-objective, criteria & standard-

Scheme for zoning & classification of Indian rivers

Designated best use concept

- Water quality objective: aimed at restoring &/or maintaining natural water bodies at various reaches to such qualities as are needed for their best use

- Water use map: Any stretch of river or lake or estuary or coastal water may be subjected to more than one organized used. The use list contains irrigation, drinking, industry, power generation, fisheries and wildlife propagation, navigation, recreation and aesthetics and even receptacle for treated wastes. In any stretch there would be one use which would be demanding the highest quality of water & the stretch is designated by that use & THAT USE IS TERMED AS THE DESIGNATED BEST USE. The designated best use of each stretch of river is marked on a map which is henceforth refered as the 'WATER USE MAP'

- A minimal water quality monitoring programme for those water quality stations using significant and essential water quality parameters is required. This would help to prepare 'Water Quality Map' on 'Water Use Map' stretches of natural water bodies warranting water pollution control are identifies for immediate, interim, and long-term followup action

SCHEMATION ZONING CLASSIFICATION (fresh water)

Criteria	A	B	C	D	E
Dissolved Oxygen (DO), mg/l, Min	6	5	4	4	-
Biochemical Oxygen Demand (BOD), mg/l Max	2	3	3	-	-
Total coliform oganisms, MPN/100 ml, Max.	50	500	5000	-	-
pH value	6.5 – 8.5	6.5 – 8.5	6 - 9	6.5 – 8.5	6 – 8.5
Free ammonia (as N), mg/l Max	-	-	-	1.2	-
Electrical conductivity, micromhos/cm, Max	-	-	-	-	2250
Sodium adsorption ration, Max.	-	-	-	-	26
Boron, mg/l Max	-	-	-	-	2

Sequential procedure

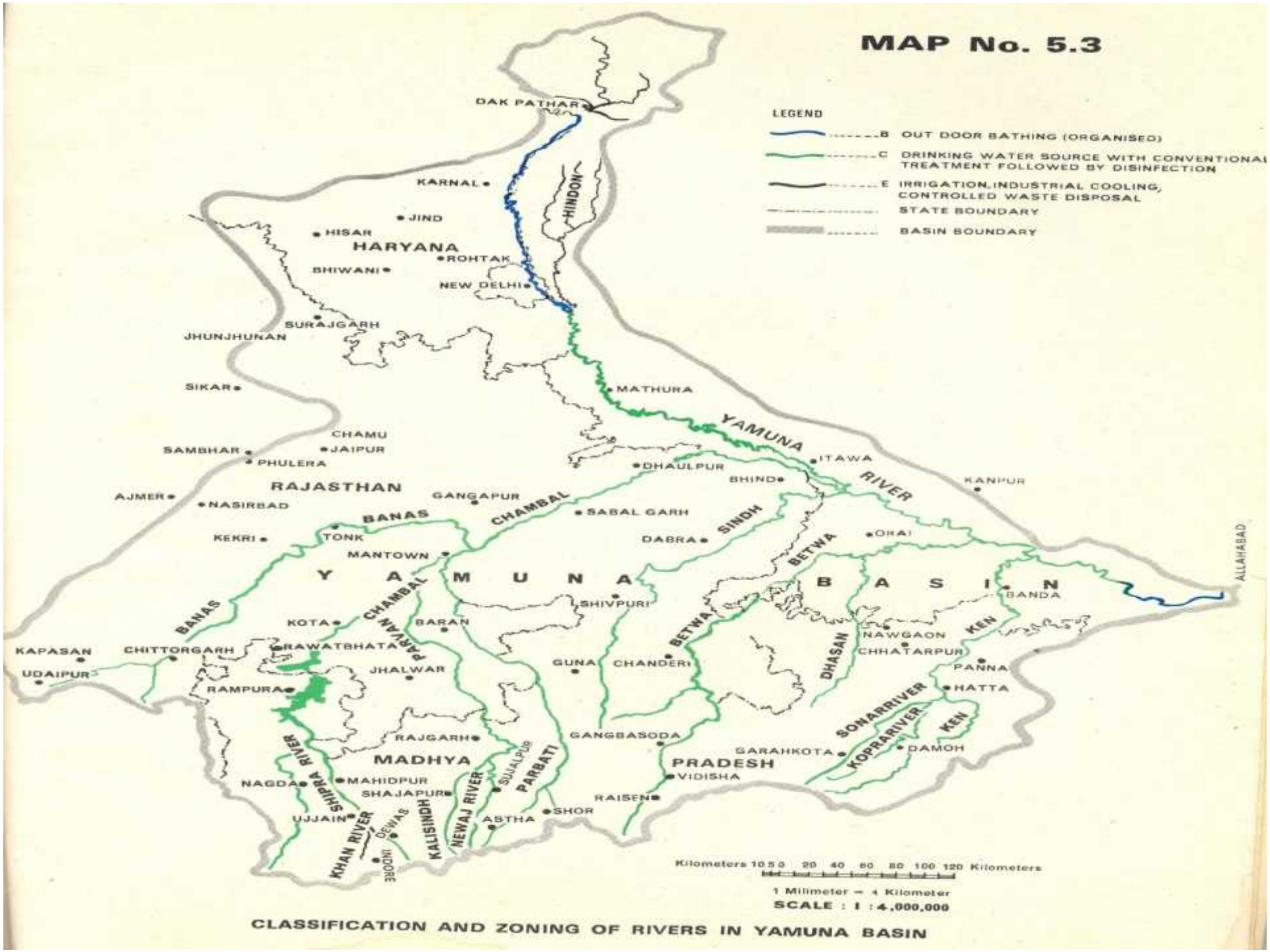
The zoning of water bodies consist of the following steps:

- Step 1: prepare an inventory of water bodies or portions thereof

- Step 2: identify the various uses of each of the water body or portions thereof

- Step 3: identify the designated best use of each of the water body or portions thereof

- Step 4: assign the class nomenclature based on the designated best use from the scheme of classification to each of the water body or portions thereof



CLASSIFICATION AND ZONING OF RIVERS IN YAMUNA BASIN

MONITORING PROGRAMME

Monitoring is a programme for a systematic observation in order to draw inference (prediction) about the experiment or the phenomena for which it is designed.

By systematic observation means a periodic observation with regular intervals.

➔When (how often) to observe ? → frequency of observation

By observation in science means measurement

➔ What to measure? → parameters to be defined

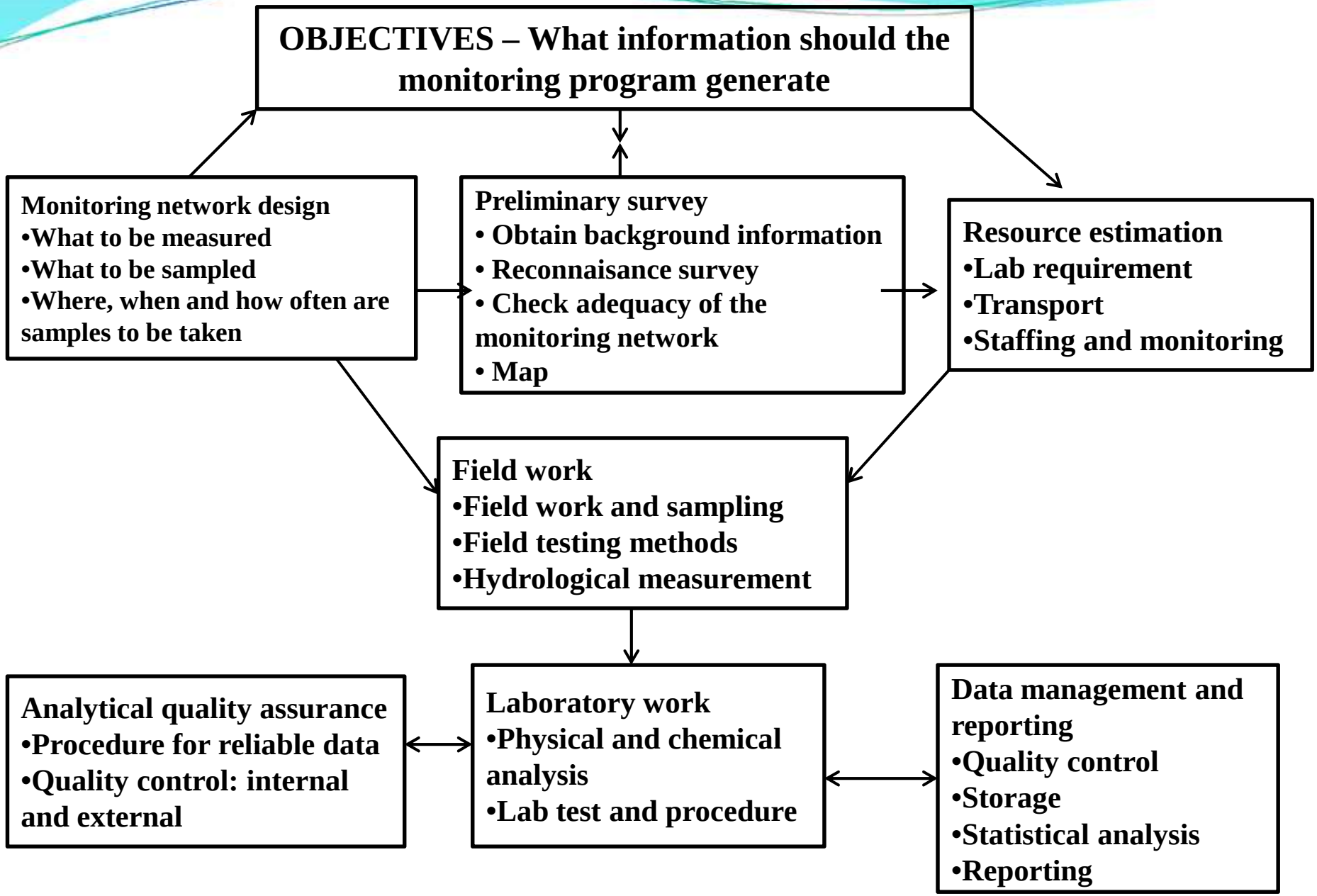
The third component of monitoring is the location

➡ Where to sample?

Monitoring is, therefore, a programme, or an experimental design composed of

- Location of sampling – Where to sample?
- Frequency of sampling – How often?
- What to sample – What are parameters?

MANAGEMENT ACTIONS



Water quality monitoring involves 8 steps as explained below:

Step-1Setting Water Quality Monitoring Objectives

Step-2

Assessment of Resources Availability

- Laboratory facilities and competence
- Transport
- Manpower –adequate number and competence

Step-3

Reconnaissance Survey

- Map of the area
- Background information
- Human activities
- Potential polluting sources
- Water abstractions and uses
- Hydrological information
- Water regulation

Step-4

Network Design

- Selection of sampling locations
- Optimum number of locations
- Parameters to be measured
- Frequency of sampling
- Component to be samples – water, sediment or biota

Step-5

Sampling

- Representative sampling
- Field testing
- Sample preservation and transport

Step-6

Laboratory Work

- Laboratory procedures
- Physical, chemical analysis
- Microbiological and biological analysis

Step-7

Data Management

- Storage
- Statistical analysis
- Presentation
- Interpretation
- Reporting

Step-8

Quality Assurance

- Production of reliable data
- Quality control
- Internal AQC
- External AQC

APPROACH TOWARDS WATER QUALITY MONITORING NETWORK

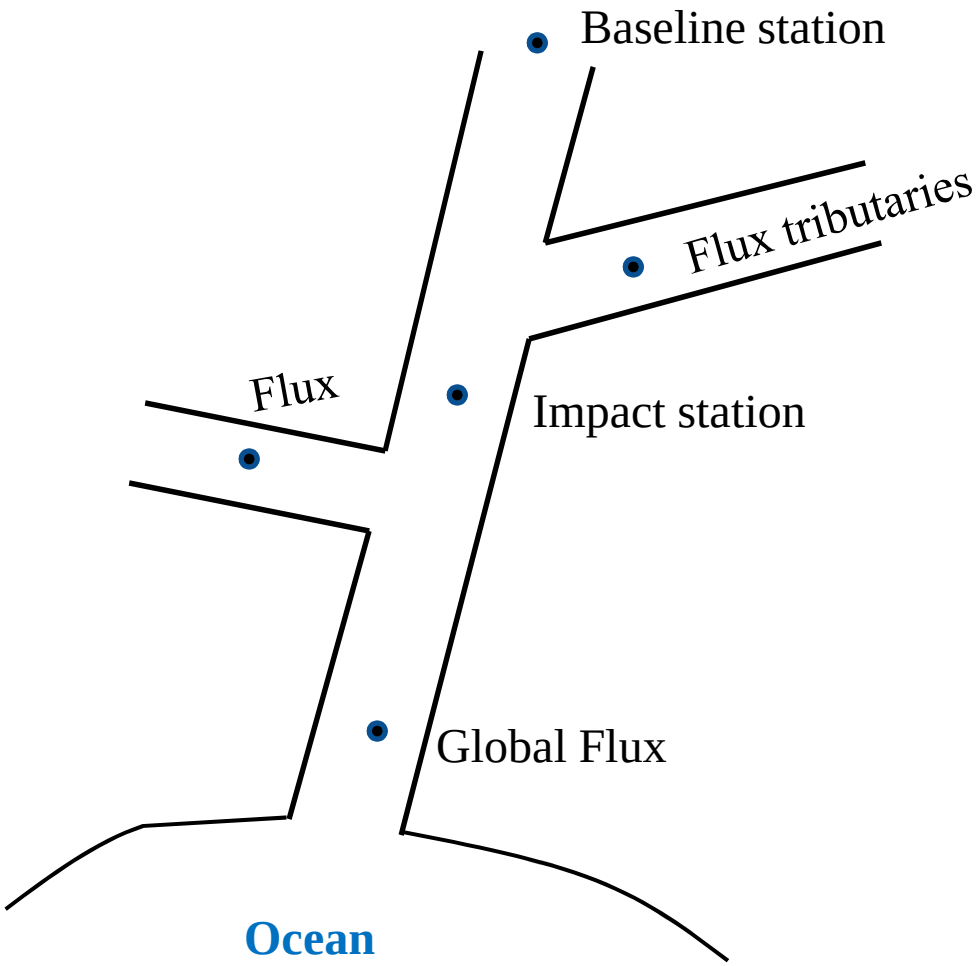
TYPE OF STATIONS

Baseline station means the monitoring location where there is no human activities on water quality.

Flux station means the monitoring location where pollution load discharges point by tributaries, irrigation drains, storm water drain etc. to mainstream discharge point to sea itself is a flux station. This station is also called a flux station.

Trend station means the monitoring location designed to show how a particular point on a water course varies overtime due, normally, to the influence of man’s activities.

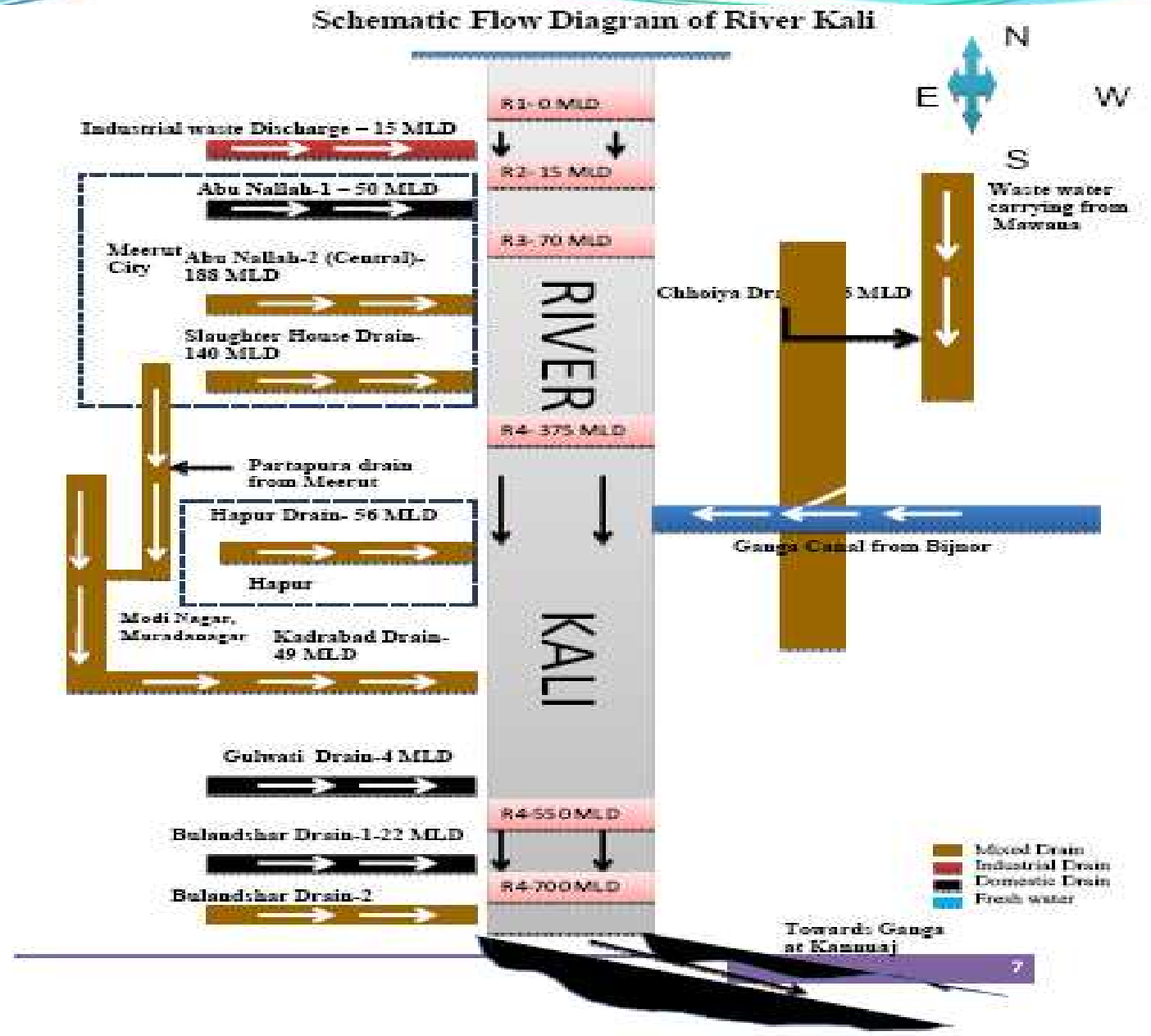
Impact station means the station where pollutant is well mixed with the mainstream water quality


Baseline station
Flux tributaries
Flux
Impact station
Global Flux
Ocean

How to select a monitoring station?

- Reconnaissance survey
- Mixing zone
- Depth
- Minimum distance

RECONNAISSANCE SURVEY OF POLLUTION LOAD OF RIVER KALI



MIXING ZONE/DEPTH

Estimated distance for complete mixing in streams and rivers

Average width (m)	Mean depth (m)	Estimated distance for complete mixing (km)
5	1	0.08-0.7
	2	0.05-0.3
	3	0.03-0.2
10	1	0.3-2.7
	2	0.2-1.4
	3	0.1-0.9
	4	0.08-0.7
	5	0.07-0.5
20	1	1.3-11.0
	3	0.4-4.0
	5	0.3-2.0
	7	0.2-1.5
50	1	8.0-70.0
	3	3.0-20.0
	5	2.0-14.0
	10	0.8-7.0
	20	0.4-3.0

MINIMUM STATION

Suggested sampling regimes for composite samples in flowing waters

Average discharge ($m^3 s^{-1}$)	Type of stream or river	Number of sampling points	Number of sampling depths
< 5	Small stream	2	1
5-140	Stream	4	2
150-1,000	River	6	3
≥ 1,000	Large river	≥ 6	4

Ground Water Quality Monitoring

- One base line station
- Three stations as impact stations.
- One at deep down stream (Trend Station)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WATER QUALITY PARAMETERS (SURFACE & GROUNDWATER)

#	Parameters	Surface	Groundwater	Impact
1	pH	+	+	General Health of the Water
2	DO	+	-	
3	Conductivity	+	+	
4	Temperature	+	-	
IONS				
5	Ca++ as CaCO3	+	+	Ionic behavior Salinity Hardness
6	Mg++ as CaCO3	+	+	
7	Na+ as CaCO3	+	+	
8	SO4--	+	+	
9	HCO3-	+	+	
10	Cl-	+	+	
11	F-	+	+	Flurosis

WATER QUALITY PARAMETERS (SURFACE & GROUNDWATER)

#	Parameters	Surface	Groundwater	Impact
12	Free Ammonia	+	-	Fish toxicity
12	BOD	+	+	Organic Matters
13	COD	+	+	
14	Faecal coliform	+	+	Pathogens
15	NO3-N	+	+	Eutrophication
16	PO4+++	+	-	
17	Heavy metals	+	+	Toxicity
18	Pesticides	+	+	

Frequencies and parameters for analysis of surface water samples

1	2	3
Type of Station	**Frequency**	**Parameters**
Baseline	**Perennial rivers and lakes: Four times a year (seasonal)** **Seasonal rivers: 3-4 times (at equal spacing) during flow period** **Lakes: 4 times a year (seasonal)**	**(A) Pre-monsoon: Once a year Analyse 25 parameters as listed below:** **a) General: Colour, Odour, Temperature, pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Turbidity, Total Dissolved Solid (TDS)** **b) Nutrients: Ammoniacal Nitrogen (NH4 -N), Nitrite & Nitrate Nitrogen (NO2 + NO3) Total Phosphate (Total P)** **c) Demand parameters: Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD)** **d) Major ions: Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Carbonate (CO3) Bicarbonate (HCO3), Chloride (Cl), Sulphate (SO4)** **e) Other inorganic: Fluoride (F), Boron (B) and other location specific parameter, if any f) Microbiological: Total coliform and Faecal Coliform** **(B) Rest of the year (after the pre-monsoon sampling) at every three months interval Analyse 10 parameters: Colour, Odour, Temperature, pH, EC, DO, NO2 + NO3 , BOD, Total coliform and Faecal Coliform**

Contd..

Trend or flux or impact	**Once every month starting April-May (pre-monsoon) i.e. 12 times a year**	**A. Pre-monsoon:** Analyze 25 parameters as listed for baseline monitoring **B. Other months:** Analyze 15 parameters as listed below : **a. General : Colour, Odour, Temp, pH, EC,** DO and Turbidity **b. Nutrients :** NH3 -N, NO2 + NO3 , Total P **c. Organic Matter :** BOD, COD **d. Major ions :** Cl **e. Microbiological:** Total and Faecal coliforms **C. Micro pollutant:** Once in a year/ premonsoon. **a. Pesticides –** Alpha Benzenehexachloride (BHC), Beta BHC, Gama BHC (Lindane), OP-Dichlorodiphenyltrichloroethane (OP-DDT), PP-DDT, Alpha Endosulphan, Beta Endosulphan, Aldrin, Dieldrin, Carbaryl (Carbamate), Malathian, Methyl Parathian, Anilophos,Chloropyriphos **b. Toxic Metals:-** Arsenic (As), Cadmium (Cd), Mercury (Hg), Zinc (Zn), Chromium (Cr), Lead (Pb) Nickel (Ni), Iron (Fe) (The parameters may be selected based on local need)

Frequencies and parameters for analysis of Ground Water samples

1	2	3
Type of Station	**Frequency**	**Parameters**
Baseline	**Twice a year** (Pre and post monsoon season)	**A. Pre and Post Monsoon Season**: Analyse 20 parameters as listed below: • General: Colour, Odour, Temperature, pH, EC, TDS • Nutrients: NO2 + NO3 , Orthophosphate • Demand Parameter: COD • Major Ions: Na+, K +, Ca++, Mg++, CO3 --, HCO3 -; CI, SO4, --%Na & SAR • Other inorganics: F, B and other location-specific parameters, if any

Contd..

Trend	**Twice a year (Pre and post monsoon)**	**A. April-May**: Analyse 20 parameters as listed for Baseline monitoring **B. Other times**: Analyse 14 parameters as listed below:- • General: Colour, Odour, Temperature, EC, pH, TDS, %Na & SAR • Nutrients: NO2 + NO3, orthophosphate • Demand parameter: COD • Major ions: Cl • Other inorganics: F,B • Microbiological: Total coliform and Faecal coliform **C. Micro pollutant** (parameters may be selected based on local need): 2. **Pesticides**-Alpha BHC, Beta BHC, Gama BHC (Lindane), OP-DDT, PP-DDT, Alpha Endosulphan, Beta Endosulpham, Aldrin, Dieldrin, 2, 4-D, Carbaryl (Carbamate), Malathian, Methyl, Parathian, Anilphos, Chloropyriphos. 3. **Toxic Metals** – As, Cd, Hg, Zn, Cr, Pb, Ni, Fe (Pesticides and Toxic metals may be analysed once a year in pre monsoon on selected locations)

Measurement Methods, Units and Significant Figures for different parameters used in water quality monitoring

PARAMETERS	UNIT	MEASUREMENT METHODS	SIGNIFICANT FIGURES AFTER DECIMAL
Colour	-	Visual method	
Odour	-	Manual	
Temperature	°C	Thermameter	1
pH	-	pH meter	1
Electrical Conductivity	µS/cm	Conductivity meter	0
Dissolved Oxygen	mg/L	DO Meter or Winkler modified method	1
Turbidity	NTU	Nephelometer	1
Total Dissolved Solids	mg/L	Gravimetry	0
Ammonical Nitrogen (NH_4-N)	mgN/L	Colorimetry	1
Nitrite + Nitrate-N	mgN/L	Colorimetry	1
Total Phosphate	mg/L	Colorimery	4
Orthophosphate	mg/L	Colorimetry	4
Biochemical Oxygen Demand (BOD)	mg/L	DO consumption in 3 days at 27 °C	1
Chemical Oxygen Demand (COD)	mg/L	Potassium dichromate method	1
Sodium	mg/L	Flame photometry	1
Potassium	Mg/L	Flame photometry	1
Calcium	mg$CaCO_3$/L	EDTA Titrimetric	1
Magnesium	mg $CaCO_3$/L	EDTA Titrimetric	1

Contd.

Carbonate as CaCo3	**mg $CaCO_3$/L**	**Titrimetric**	**1**
Bicarbonate, as CaCo3	**mg $CaCO_3$/L**	**Titrimetric**	**1**
Chloride	**mg/L**	**Argentometric titration**	**1**
Sulphate	**mg/L**	**Turbidimetry**	**1**
Fluoride	**mg/L**	**Ion meter, Colorimetry**	**2**
Boron	**mg/L**	**Ion meter, curcumin method**	**2**
Total Coliform	**No./100mL**	**MPN or MF method**	**0**
Fecal Coliform	**No/100mL**	**MPN or MF method**	**0**
% Sodium	**-**	**Calculation**	**2**
SAR	**-**	**Calculation**	**2**
SPECIFIC PARAMETERS			
Arsenic	**µg/L**	**Cold vapour AAS**	**1**
Mercury	**µg/L**	**Cold Vapour AAS**	**1**
All other heavy metals	**µg/L**	**AAS**	**1**
Pesticides and other organics	**µg/L**	**GC, GCMS**	**1**

Container Types and Volumes Needed for Sampling

	Analysis	Container	Volume (mL)	Preservation
0	On-site analysis	PE bowl or container	±200	-
1	General (SS, TDS, major ions, chlorophyll-a)	Glass, PE	1000	-
2	COD, NH3, NO2-+NO3-	Glass, PE	500	H_2SO_4, pH <2
3	o-PO4	Glass	100	-
4	BOD	Glass, PE	1000	4°C, Dark
5	Coliforms	Glass, PE, Sterilised	300	4°C, Dark
6	Heavy metals (Cd, Zn)	Glass, PE	500	HNO_3, pH <2
7	Mercury	Glass	1000	HNO_3, pH <2
8	Pesticides	Glass, Teflon	1000	4°C, Dark

CHECKLIST FOR FIELD VISIT

• Itinerary for the trip (route, stations to be covered, start and return time)	• Personnel and sample transport arrangement
• Area map	• Sampling site location map
• Icebox filled with ice or icepacks or ice	• Weighted bottle sampler
• BOD bottles	• Rope
• Special sample containers: bacteriological, heavy metals, etc.	• Sample containers
• Sample preservatives (e.g. acid solutions)	• Thermometer
• Tissue paper	• Other field measurement kit, as required
• Sample identification forms	• Labels for sample containers
• Field notebook	• Pen / pencil / marker
• Soap and towel	• Match box
• Spirit lamp	• Torch
• Drinking water	• Knife
• First-aid box	• Gloves and eye protection
• Dump sampler to check well conditions	• Submersible pump and accessories

INSIDE VIEW OF A MOBILE LABORATORY VAN (SAMPLING VAN)

Sampling Van

Specifications:

- Seating For 6 Passengers.
- Length = 6065 MM,
- Width = 1975 MM,
- Height = 2550 MM (Model (17 + D) of Force Travellers)
- Fully Air conditioned

List of Equipments and Electronic Gadgets:

1. COD Digestion Apparatus
   Dimension: (310x310x310) mm, Top cover S.S, Powder coated box.

2. Spectro-fluorometer UV/VIS/IR
   Dimensions 500 x 400 x 230 mm

3. Multi-Parameter box that can measure pH , TDS,
   DO, Salinity, conductivity (can be placed in table drawer with provision of keeping it in fixed position)

4. Laptop

5. Printer

6. Portable Generator

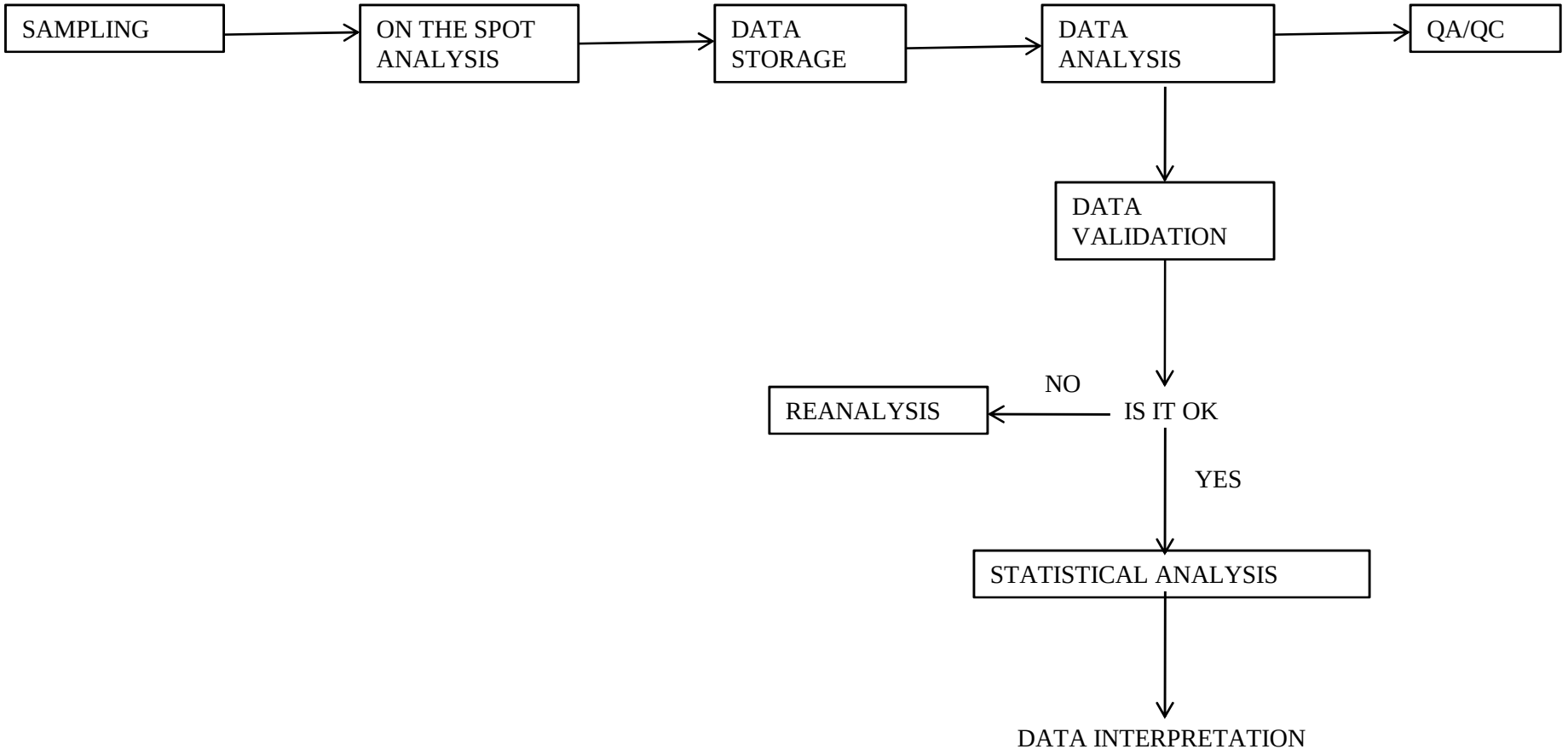
7. Deep Fridge: 4 ° (12 V), Ice Box, Bottle Cooler with separate compartments to store 3 sets of samples (Drain, Rivers, Industrial effluent)(1000*600*950 (L*W*H) in MM, Volume would be 300 lit, power would be required 200W).

Accessories

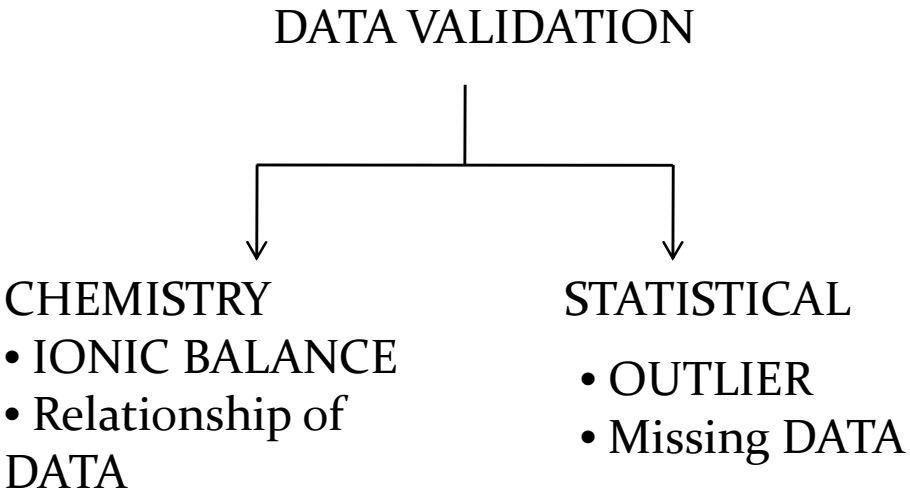
1. One rack to keep the sample bottles, reagent bottles, etc.
2. Reagents and chemical kits
3. Folding Table -1 and Chair -2
4. First Aid Kit - 1
5. Umbrella's - 2
6. Torches -3
7. Gum Boots - 2
8. Power sockets - 5-7
9. Steel buckets - 2
10. GPS Locater and Tracker

Data Validation and Management Technique

DATA MANAGEMENT FLOWCHART



DATA VALIDATION



DATA VALIDATION

- Absolute checking/Data entry
- Checking if data is within the detection limits of a particular method
- Checking if the data is within the expected ranges for a parameter
- Checking if there are too many (or too few) significant digits reported
- Checking if data are physically or scientifically possible (general checks)
- Checking correlation of parameters (Some conditional checks like BOD/COD relation, TC/FC relation)
- Checking the correlation between EC and TDS
- Checking cation/anion balance
- Total coliforms must be greater than faecal coliforms
- Total iron must be greater than dissolved iron
- Total phosphorus must be greater than dissolved (ortho-)phosphorus
- Total iron must be greater than dissolved iron

GENERAL CHECKS

Total solids	≥ Total dissolved solids
Total solids	≥ Total settleable solids
COD	> BOD
Total Coli	≥ Faecal Coli
Total Iron	≥ Fe+2, Fe+3
Total P	≥ PO4-3
EC (µS/cm)	≥ TDS (mg/l)
Total oxidized nitrogen	≥ Nitrate, nitrite
Total oxidized nitrogen	= Nitrate + nitrite
Total hardness	= Ca hardness + Mg hardness

Ionic Balance

IONIC BALANCE

Cation	Conc., mg/L	Anion	Conc., mg/L
Ca^{++}	82.2	HCO_3^-	220.0
Mg^{++}	17.9	SO_4^{--}	98.3
Na^+	46.4	Cl^-	78.0
K^+	15.5	NO_3^-	25.6

Solution 1. Prepare a cation-anion balance

Cation	Conc., mg/L	mg/ meq	meq/L	Anion	Conc., mg/L	mg/ meq	meq/L
Ca^{++}	82.2	20.04	4.10	HCO_3^-	220.0	61.02	3.61
Mg^{++}	17.9	12.15	1.47	SO_4^{--}	98.3	48.03	2.05
Na^+	46.4	23.00	2.02	Cl^-	78.0	35.45	2.20
K^+	15.5	39.10	0.40	NO_3^-	25.6	62.01	0.41

$\sum cations = 7.99$ $\sum anions = 8.7$

2. Check the accuracy of the cation anion balance using eqs (2-5)

$$\text{Percent difference} = 100 \text{ X } \frac{\left(\sum \text{cations} - \sum \text{anions}\right)}{\left(\sum \text{cations} + \sum \text{anions}\right)}$$

$$\text{Percent difference} = 100 \text{ X } \frac{(7.99 - 8.27)}{(7.99 + 8.27)} = -1.27\%$$

For a total anion concentration between 3 and 10 meq/L, the acceptable difference must be equal to or less than 2% (see table above); thus, the analysis is of sufficient accuracy.

Problems

S.No.	Cation	Sample	Anion	Sample
1.	Ca^{2+}	121.3	HCO_3^-	280
2.	Mg^{2+}	36.2	SO_4^{2-}	116
3.	Na^+	8.1	Cl^-	61
4.	K^+	12	NO_3^-	15.6

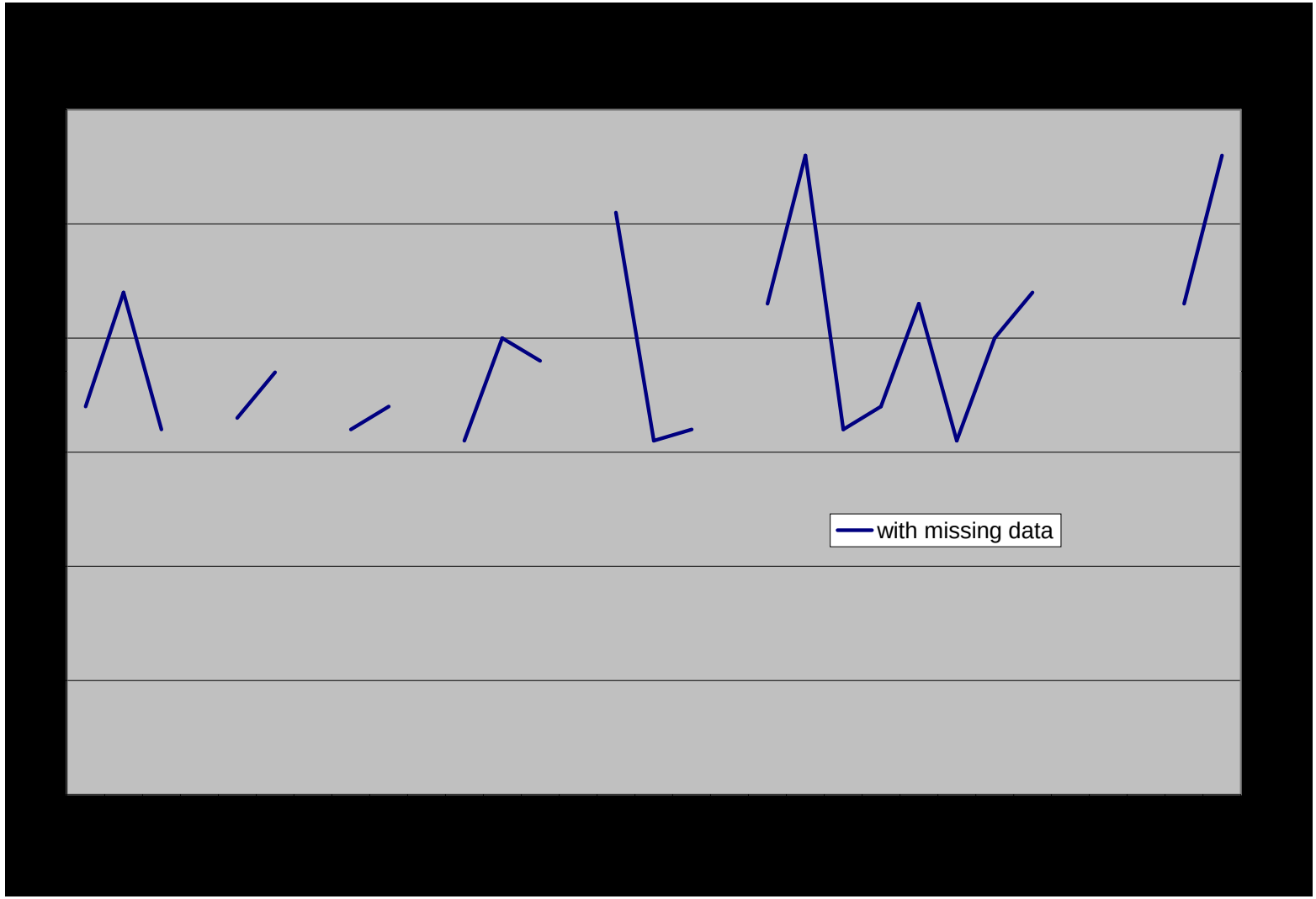
Statistical Technique

- Missing Value
- Outlier
- Conditional Check

Missing Value Estimation:

- Missing values are gaps in continuous data. This happens due to lack of personnel, problem in machinery etc. at the monitoring station.
- Missing values result in incorrect data analysis
- Missing values of upto 20% are common in environmental data
- Missing values can at best be estimated by the following statistical methods, they cannot be recovered:
  - Replacing by series mean
  - Replacing by neighboring values' mean
  - Linear interpolation
  - Using a single site single parameter time series model
  - Using a multi-parameter multi-site time series model

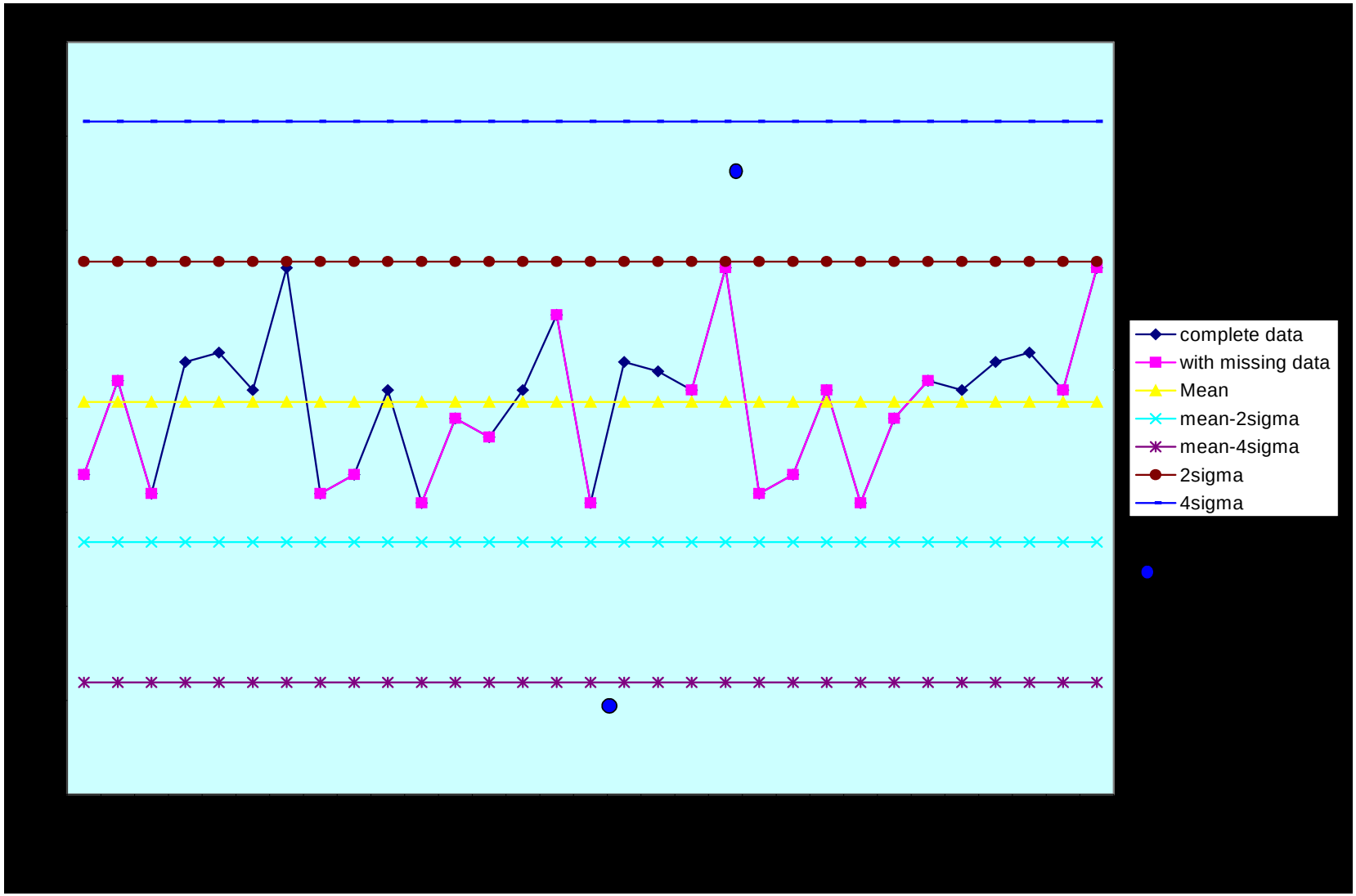
A Visual on Missing Data



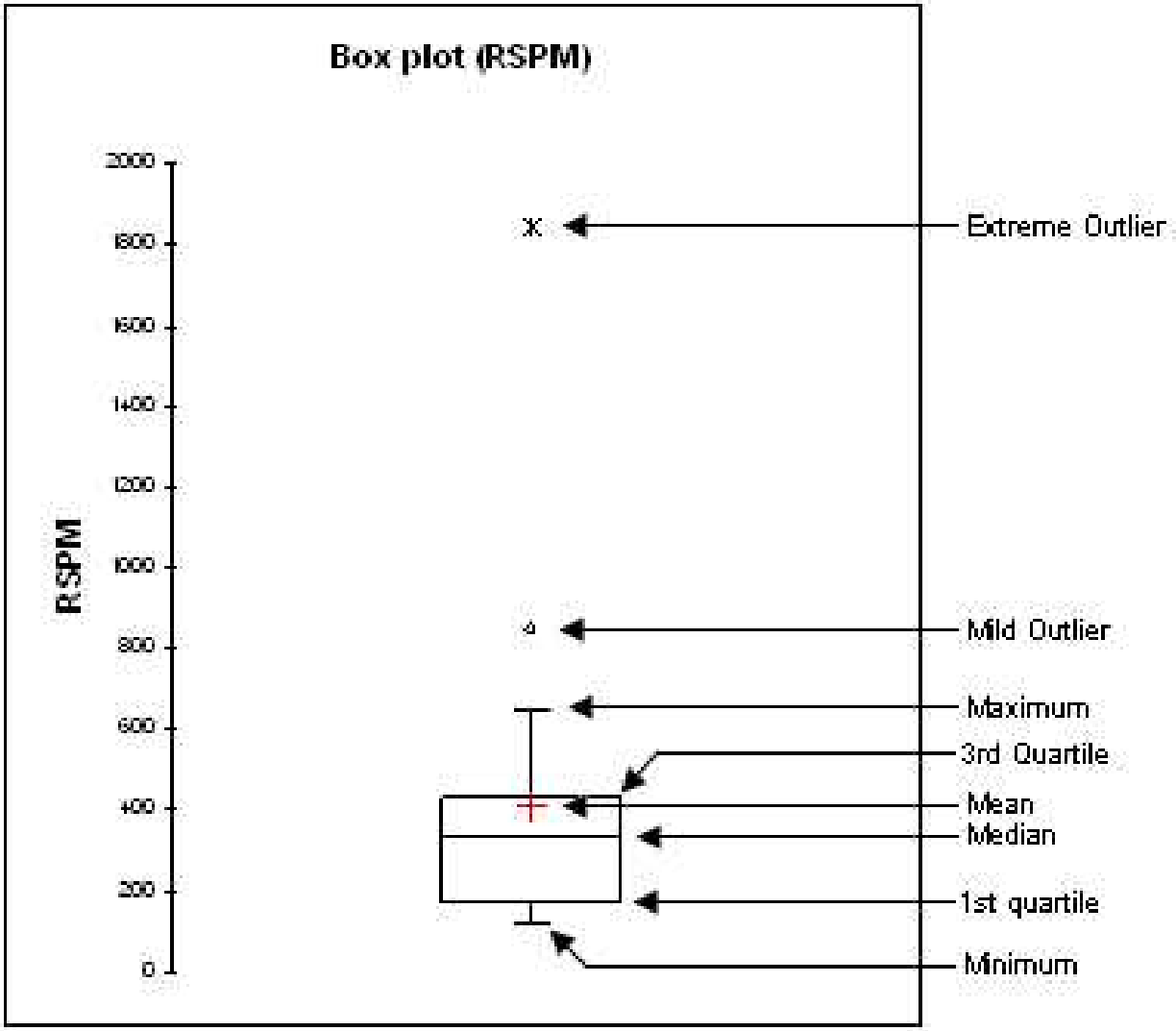
Outlier tests:

- Outliers are values in the data which lie at an abnormal distance from the other value in a sample.
- They can possibly be attributed to various kinds of errors or they could be true values caused by some drastic change in conditions, like a water quality data may show abnormally large values if there has been a spill upstream of the measuring station.
- Outliers change the statistics of the data, hence they must be looked into.
- Outliers can be detected using the ‘Mean ± 4σ’ test

Graphical example of Outlier detection



Box and Whisker plots:



A box whisker plot showing summary statistics for RSPM data

DATA INTERPRETATION

Interpretation

- Central Tendencies of data – Arithmetic mean, Geometric mean, Median
- Dispersion of data- Range, Standard deviation, variance
- Percentile value- 25^{th}, 50^{th}, 75^{th} , 100^{th}
- Exceedance factor in percentage
- Trend $\longrightarrow$ Temporal Spatial trend $\Big\}$ Analysis of variance & Non parametric analysis

Thank You