ENVIRONMENT MONITORING IN THE NEIGHBOURHOOD [WORKBOOK]

	T V Ramachandra	
Asulabha K S	Bharath H. Aithal	Bharath Settur
Durga Madhab Mahapatra	Gouri Kulkarni	Harish R. Bhat
Sincy Varghese	Sudarshan P. Bhat	Vinay S.

The Ministry of Science and Technology, Government of India
The Ministry of Environment and Forest, Government of India
Indian Institute of Science, Bangalore 560012

ENVIS Technical Report: 77

February 2014

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Open Source GIS: http://ces.iisc.ernet.in/grass

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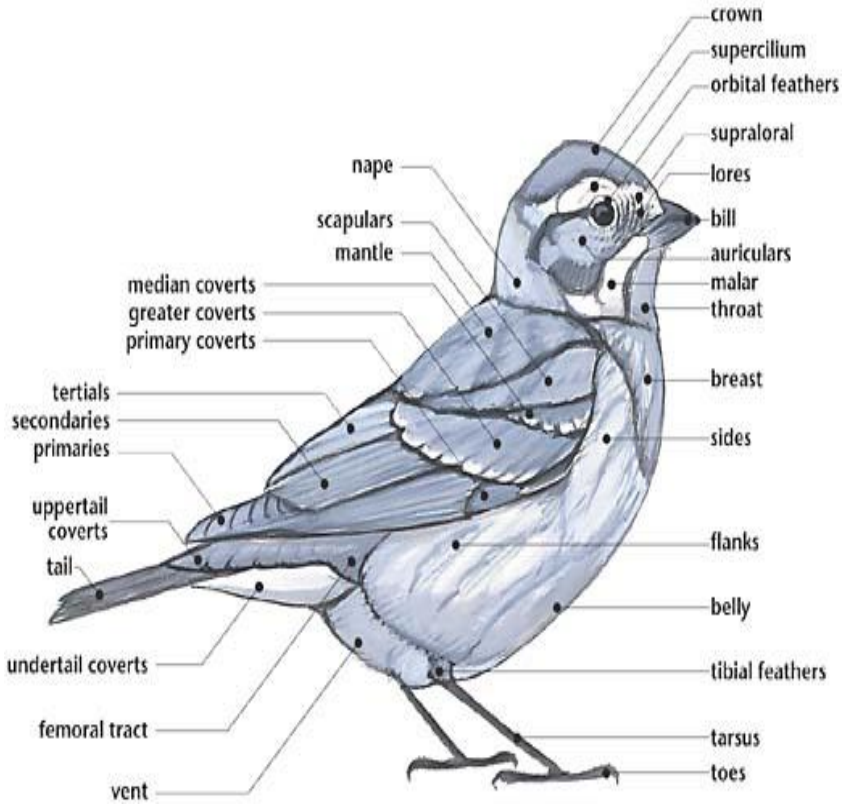
Centre for Ecological Sciences,
Indian Institute of Science,
Bangalore-560012

ENVIRONMENT MONITORING IN THE NEIGHBOURHOOD [WORKBOOK]



ENVIRONMENT MONITORING IN THE NEIGHBOURHOOD

Environment monitoring is essential for evaluating environmental planning and policy. Long term monitoring helps in evaluating the success of policy as well as helps in identifying areas for improvement. Environmental monitoring provides a vital scientific insights of long-term trends apart from new knowledge and understanding. For Example, monitoring of Bangalore wetlands during the last two decades, provided evidence of poor environmental status of wetlands in Bangalore affecting the land and groundwater sources in the vicinity. Due to its distinctive contributions to science and practice, monitoring is an integral aspect of ecological research, management, and policy.

Environment monitoring in the neighbourhood would help in the preservation of natural resources (lakes, parks, street trees). During 2011-12, we attempted the deployment of student community from high schools and colleges to document biodiversity under the banner 'My Village Biodiversity' in the Uttara Kannada district of Karnataka State. This helped in the compilation of biodiversity information of 300 villages within a year. Competitions were conducted for students and nominal rewards announced for the best reports and good presentations. No financing of the educational institutions has been done to carry out this model of work. The objectives of environment monitoring is to generate "Environment Sensitive Citizens" required for the sustainable management of natural resources. This approach includes:

a. ***Sensitisation of students:*** Pre tested data formats is aimed at sensitizing students to environment, biodiversity and ecology related issues.

b. ***Recording observations:*** Study and understand data formats necessary in the contemporary contexts of conservation and sustainable use. Regular monitoring would help in updating the environment information.

c. ***Vital information on goods and service:*** documentation of goods and services and their significance in meeting the people's livelihood.

d. ***Low cost methods:*** long term monitoring would provide information and technique would be cost effective

e. ***Creating ambassadors of goodwill:*** Students, with their unbiased minds were expected to merit greater acceptability in the neighbourhood, as the local people otherwise tend to be more reserved with outside agencies like NGOs engaged in such work.

f. ***Expertise in communication:*** Students were expected to gain good communication skills.

g. ***Capacity building:*** Students and teachers will have an opportunity to interact with the researchers from Indian Institute of Science, apart from taking active part in LAKE 2014 at Parisara Sabhangan, Sirsi, Uttara Kannada, Central Western Ghats during 13-15 November 2014 (details at the end of this report).

Workshop on Water and Environment- Interactive Session with School Teachers

Date: 15th February 2014, 10 am to 5 30 pm
Venue - Rustum Choksi Hall [near IISc Main Gate], Indian Institute of Science

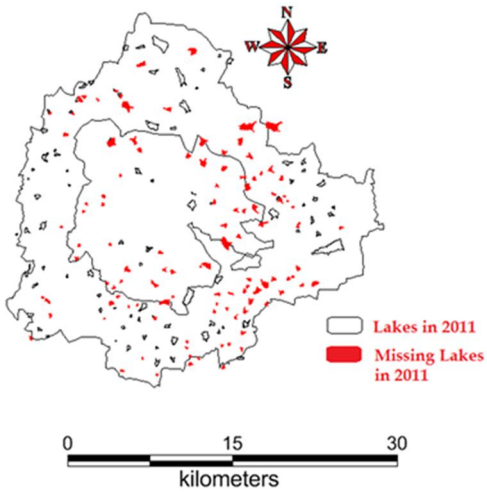
Energy & Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India
&
Bangalore South District High School Headmasters Association

Time	Topic	Resource Person
10.00 am- 10.30 am	Inaugural Session, Introduction and purpose of the workshop – M A Khan	
10.30 am- 11.00 am	Environment Literacy by T.V Ramachandra	
11.00 am- 11.30 am	**Tea**	
11.30 am- 1.00 pm	Mapping of Earth Features	Bharath Aithal, Bharath Settur, Vinay S, Gouri Kulkarni
1.00 pm -1.30 pm	Flying friends	Harish Bhat
1.30 pm-2.30 pm	**Lunch (at Prakruthi Cafétaria)**	
2.30 pm- 3.00 pm	**Water Quality Monitoring**	
	On site parameters	Sincy Varghese
3.00 pm-4.00 pm	Parameters - Lab analysis, Identification of Macrophytes	Asulabha K S Sudarshan P Bhat
4.00 pm-4.30 pm	Nutrient Analysis (C, N and P)	Durga Madhab Mahapatra
4.30 pm-5.00 pm	Concluding Session Invited talk on trees of Bangalore	
Tea		

Contact

M.A Khan Principal, K K English High School, Varthur- 560087, Bangalore. **Secretary, Bangalore South District High School Headmasters Association** Email- khanattaulla@gmail.com Phone – 9845224228/ 080-28538051	T.V. Ramachandra Energy & Wetlands Research Group Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India Phone- 080-22933503 extn 107 Email - cestvr@ces.iisc.ernet.in, energy@ces.iisc.ernet.in web: http://ces.iisc.ernet.in/energy

1.0 MAPPING AND MONITORING WATER BODIES



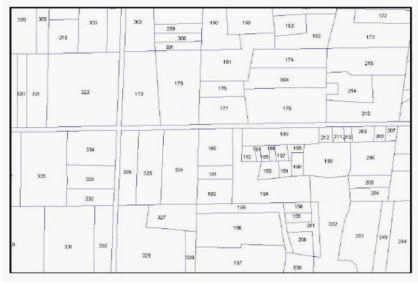
	Bangalore city	Greater Bangalore
1973	58	207
2010	10	93

Objective: Mapping water bodies (Spatial extent and location)

Knowledge required: We need to know (i) Map (ii) Mapping tools (iii)Details about a Map

MAP: Is a diagrammatic representation usually on a flat surface of the whole or a part of the Earth surface showing various features like road, water bodies etc.

Types of Maps: Maps are classified based on (a) scale- On the basis of scale (ex. *Cadastral Maps* or *Revenue Maps, Topographical Maps, Geographical Maps*, *Atlas Maps etc.,)* (b) Contents and purpose (ex: Road map, Railway map, cultural map)

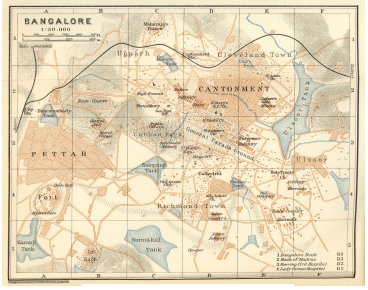


Cadastral Map

These maps are drawn on large scale ex: administration and collection of revenue

Topographical Maps

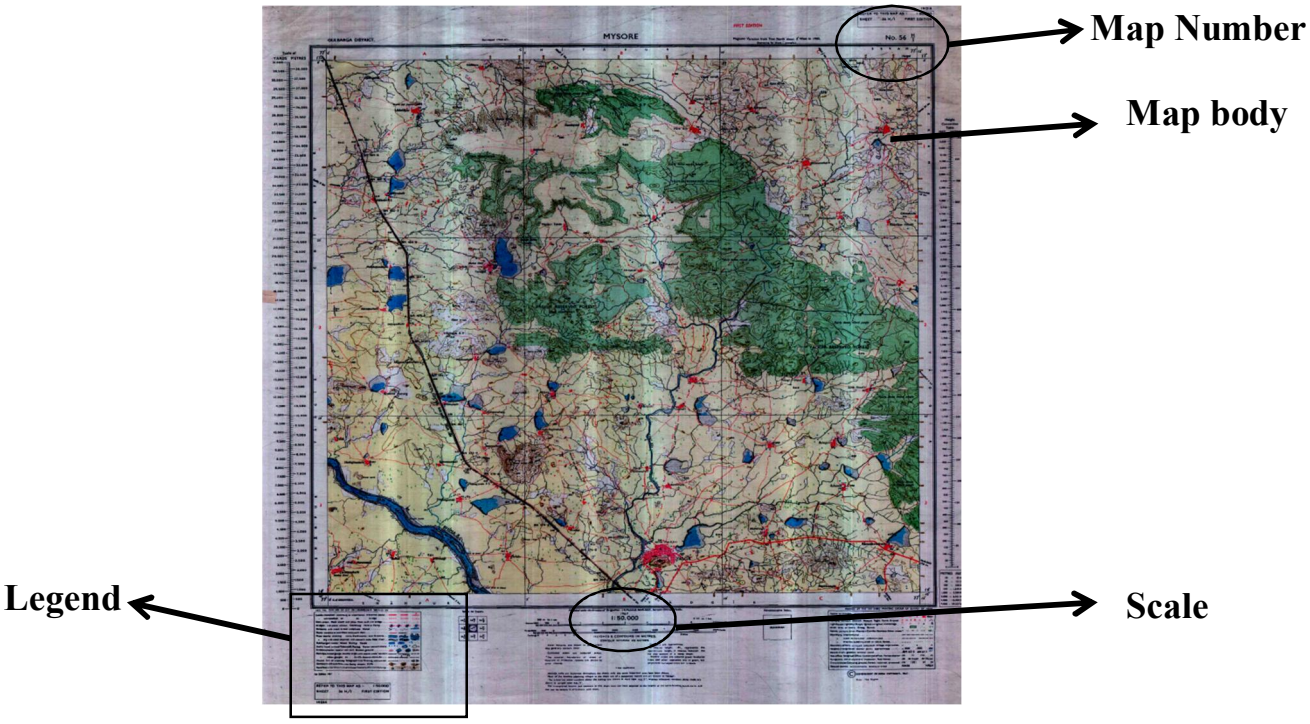
These maps show natural as well as man-made features of an area.



Geographical maps

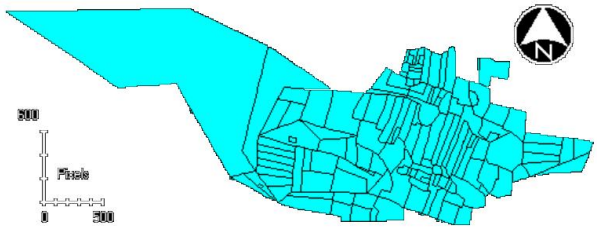
They are on small scales in which strict representation of the individual features.

How to read a MAP?



- **North arrow** represents North direction
- **Scale** is the ratio between distances on a map and the corresponding distances on the earth's surface.
- **Legend** provides details of the content of the map.

Scale represents map unit on the ground. For example, scale of 1:250,000 means that 1 unit on the map corresponds to 250,000 units on ground.



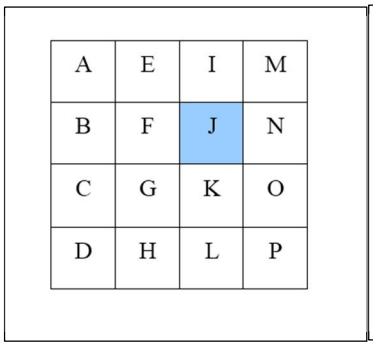
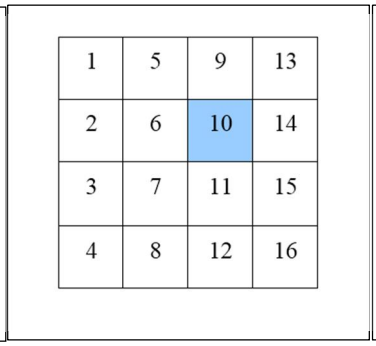
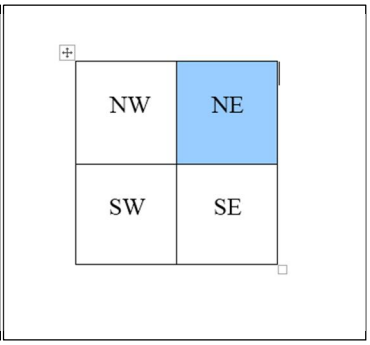
Large scale means maps shows a larger details smaller area coverage (1:10,000). Gives details of each parcels of land

Small scale maps means maps shows lesser details but large area covered

Examples of Scales: 57/H/9/NE – 1:25000 map of North east area of Bangalore, 57/H/9 – 1:50000 Map of Bangalore,

Map: 57 indicate 1:1 million, 57/H -1:250,000 shows the district, 57– 1:100000 covers Indian subcontinent.

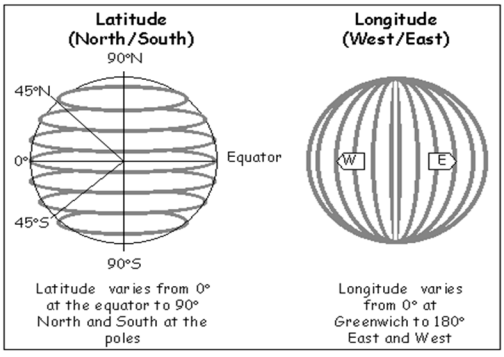
Map Numbering

		
57 - 4^0 x 4^0 on 1:1M scale Shaded cell shows 57 J of scale 1: 250000	57 - 1^0 x 1^0 on 1: 250000 scale Shaded cell shows 57 J/12 of scale 1:50000 scale	57 - 15' x 15' on 1: 50000 scale Shaded cell shows 57 J/12/NE of scale 1:25000 scale

MAP Coordinate system: A coordinate system is a standardized method for assigning codes to locations so that locations can be found easily. Good example is Latitude (LAT) Longitude (long) system.

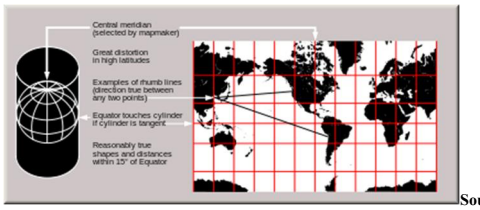
- **Latitude:** specifies the north-south position of a point on surface of Earth. Latitude is an angle which ranges from 0° at the Equator to 90° (North or South) at the poles. Reference being equator.

- **Longitude:** specifies the east-west position of a point on surface of Earth, measured as the angle east or west from the Greenwich Prime Meridian, ranging from 0° at the Prime Meridian to +180° eastward and −180° westward.



- **Datum:** A datum is a set of reference points on the earth's surface against which position measurements are made and an associated model of the shape of the earth to define a geographic coordinate system.

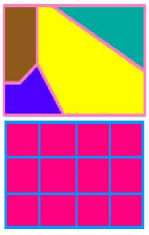
- **Projection:** A transformation of the spherical or ellipsoidal earth onto a flat map is called a map projection.ex: Projection: Cylindrical UTM projection as shown below, Datum:WGS84



Source: WIKI

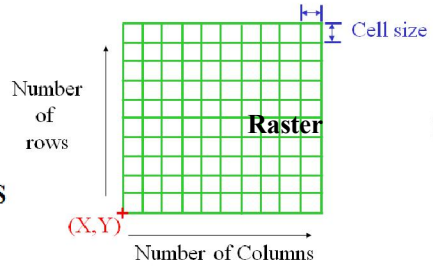
Spatial data: Data that represents the space is referred as spatial data. Two kinds of spatial data are (i) raster and (ii) vector. Both these are used in GIS (Geographic Information System) to store and retrieve geographical data.

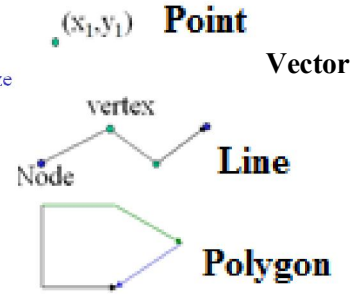
- **Raster data**: is a collection of **cells** which have a single value and are organized in arrays in number of rows and columns. Ex: Your own photograph is a raster data, when zoomed you can see pixels
- **Vector data:** are associated with **points, lines, or polygons**, Points are located by coordinates, Lines are described by a series of connecting line segments and polygons are described by a series of vectors enclosing the area.



Discrete Space: Vector GIS

Continuous Space: Raster GIS





Global Positioning System (GPS): GPS help in locating the co-ordnates of a location, which helps in the navigation. This works on the constellation of 24 communication satellites. Minimum of three satellite signals are necessary for correct measurements.

- Switch on the GPS (Soft switch normally at top or front)
- Navigate to the page showing lat-long and satellite signal strength
- Stand in the location to be marked and press mark
- Note the waypoint number and lat-long and proceed
- GPS can also be connected to pc using USB and software

Conversion from Degree Decimals to Degree, Minutes, Seconds

Consider the example 96.31°, the whole units of degrees will remain the same (i.e. in 96.31°, longitude, start with 96°).
Multiply the decimal by 60 (i.e. .31 * 60 = 18.6).
The whole number becomes the minutes (18').
Take the remaining decimal and multiply by 60. (i.e. .6 * 60 = 36).
The resulting number becomes the seconds (36"). Seconds can remain as a decimal.

GPS NAME: …… Area surveyed……..
Date: ……., Time: ……., Name: ……..

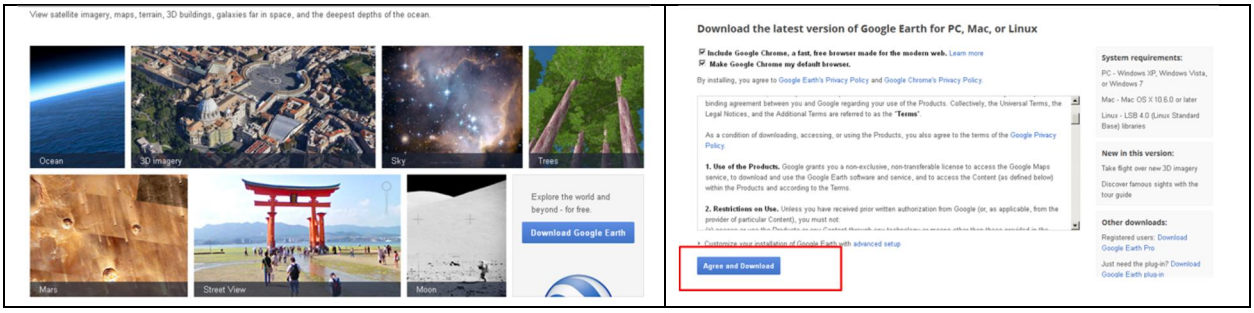
Location (inlet of lake, near place etc.)	Waypoint number	Latitude	Longitude

2.0 DIGITSING MAP FROM ONLINE DIGITAL DATABASE

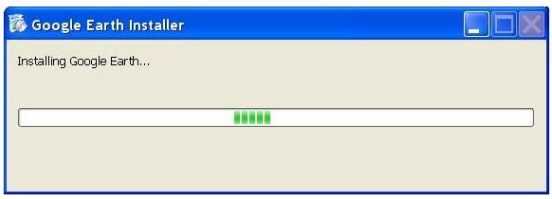
Google earth (http://earth.google.com) /Bhuvan (http://bhuvan.nrsc.gov.in)

Downloading Google earth

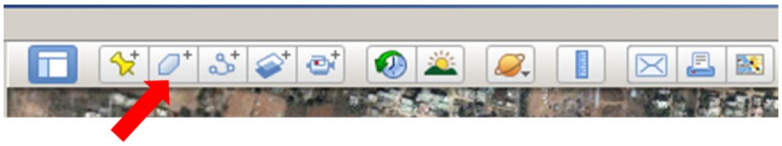
1. Go to http://www.google.com/earth/



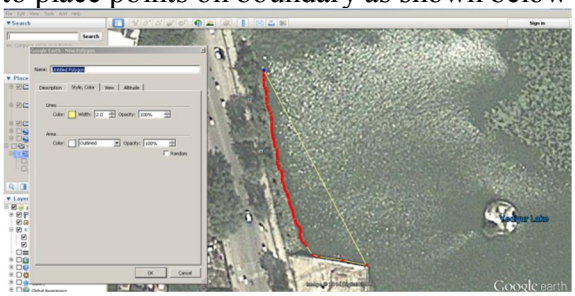
2. Installing google earth : Click on downloaded googleearthupdatesetup.exe file to install, you will be greeted with below message



3. Creating a vector Layer (Polygon, Point, Line)
   a. Adding a polygon – describes a area (ex boundary of a lake)

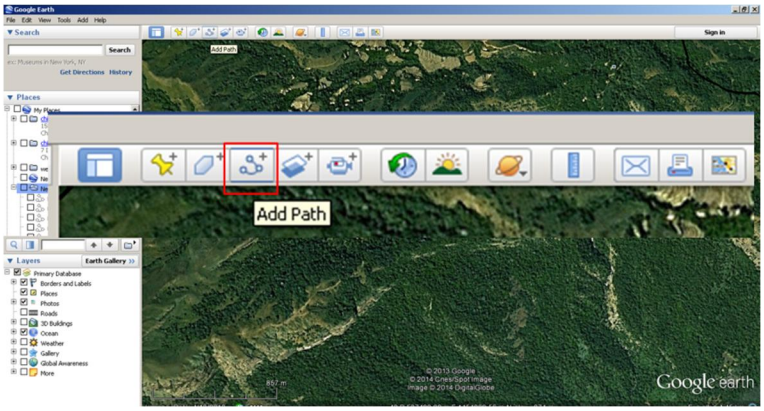


Use left mouse button to place points on boundary as shown below

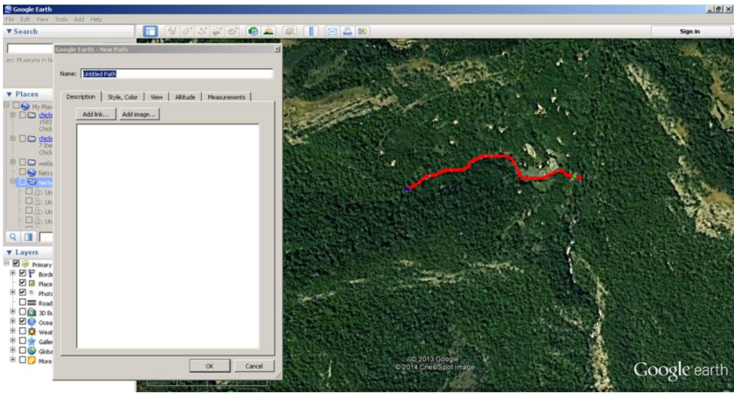


Once completed the entire waterbody click ok (example shown below)

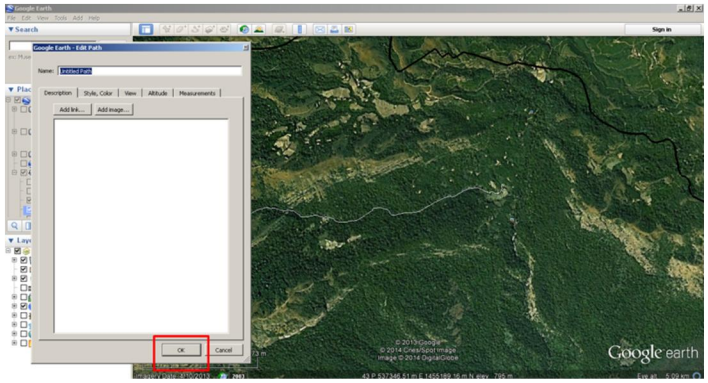
b. Creating a line feature to digitize a stream



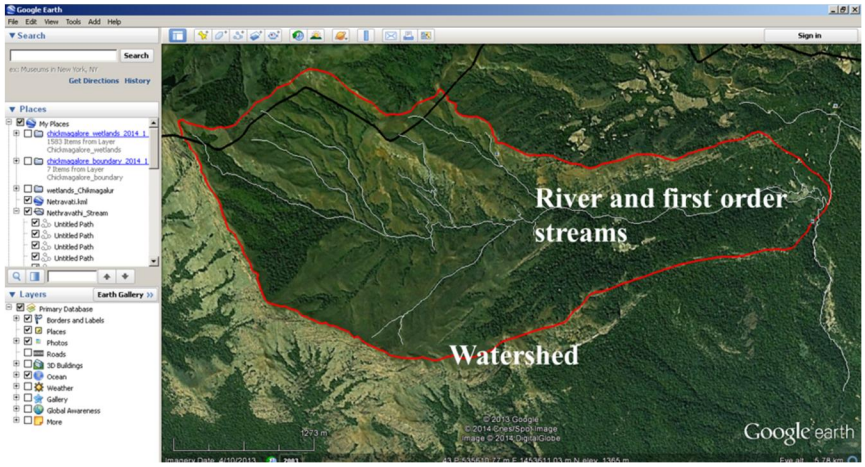
Digitise river using mouse by left clicking at each point



After entire stream is delineated click on ok



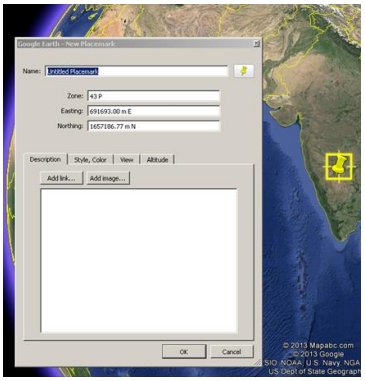
Example of first order streams and catchment delineated from Google earth



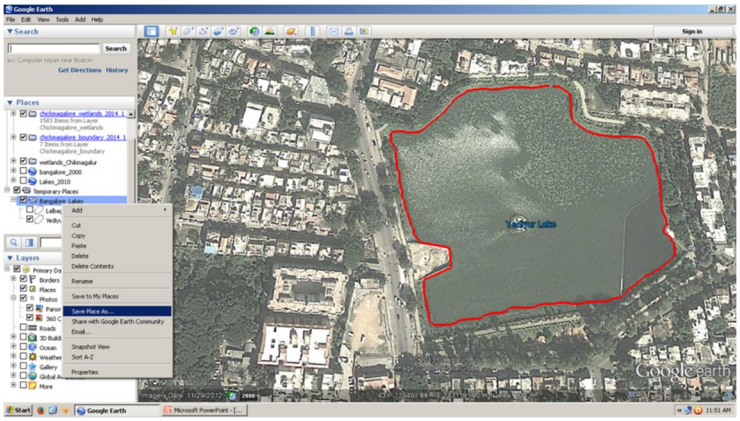
c. Creating a point feature to show a place of interest (Point may represent your school location)

Click on placemark as shown below

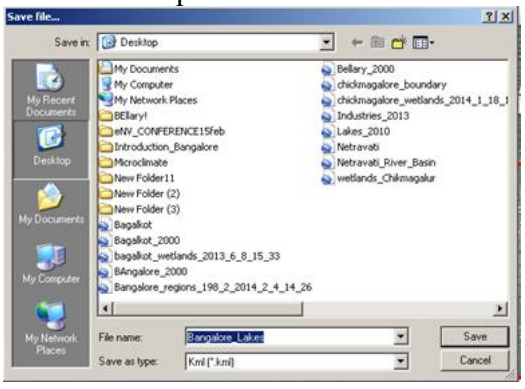
Click on ok, once you could locate your school



d. **Save digitized KML layers :** Right mouse click on the layer to be saved and select save place as



e. Select type as kml and press on button save as shown below

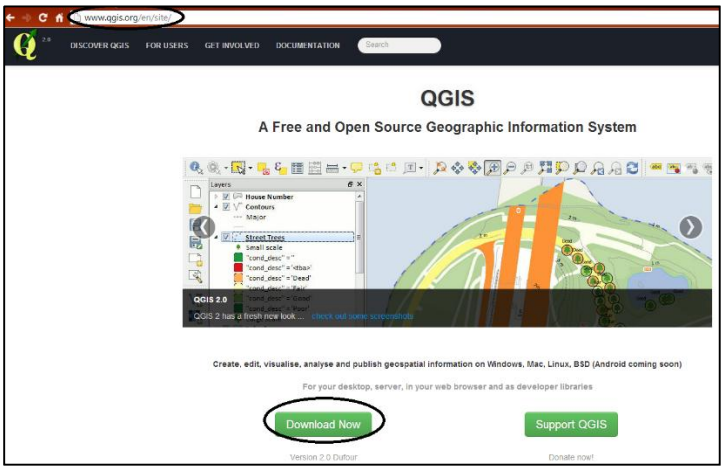


3.0 QUANTUM GIS (QGIS) – SPATIAL MAPPING TOOL

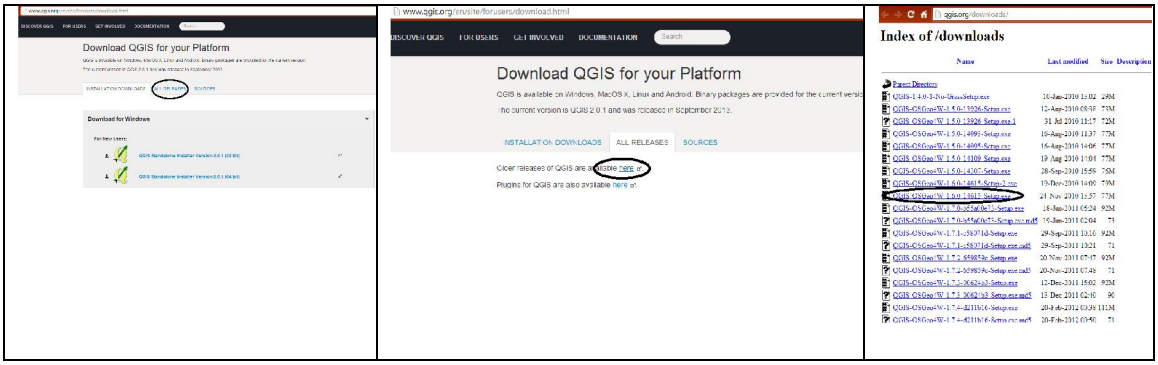
QGIS is a Free and Open Source GIS for manipulating geographical data (vector, raster), statistical analysis.

INSTALLATION:

- Download QGIS from http://www.qgis.org/en/site/
- QGIS main page will be opened as shown below.



- Click on download now you will find the list of versions available.
- Download the latest stable version.

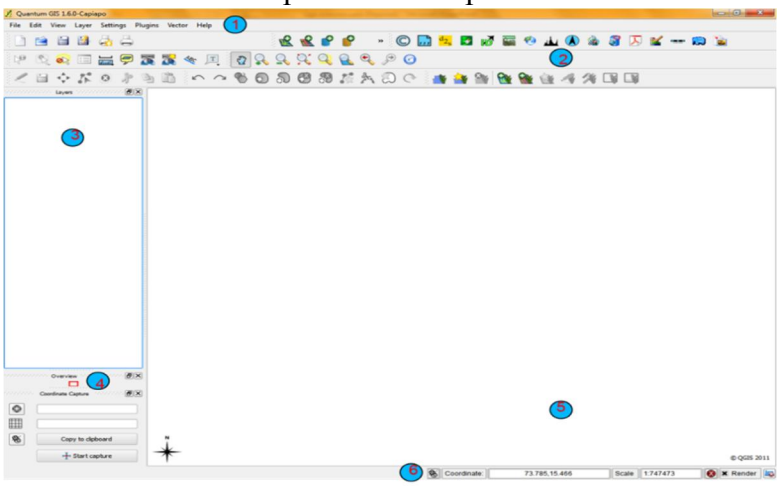


- Installation of Software: Double click on QGIS-OSGeo4W-1.6.0-3-Setup-x86_32.exe. After the installation click on QGIS icon on the desktop.

Use of QGIS:

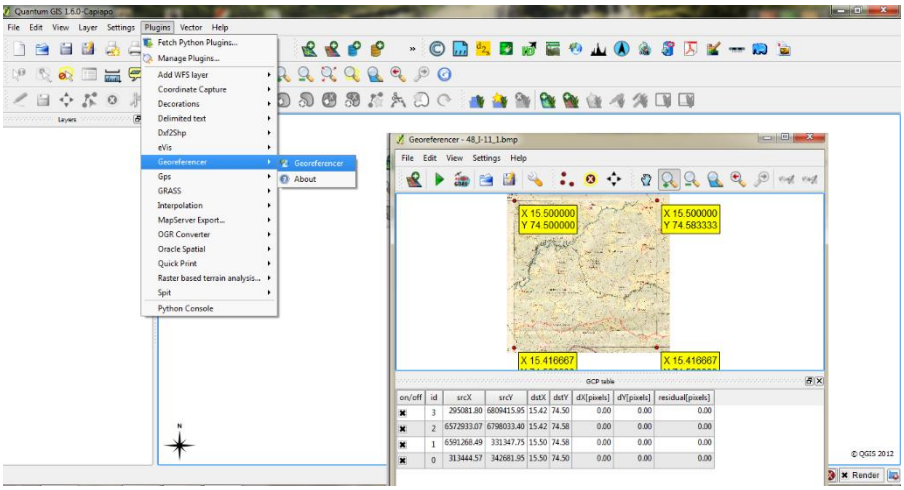
- **QGIS main** window will be opened and looks as shown
  1. The menu bar provides access to numerous QGIS features.
  2. The toolbars offers additional tools for interacting with the map. Hold the mouse over the particular icon, a short description of the tool's purpose will be displayed.
  3. The map legend area sets the visibility
  4. QGIS - maps are displayed in map canvas area

5. The map overview panel provides a full extent view of layers added
6. The status bar shows the current position in map coordinates



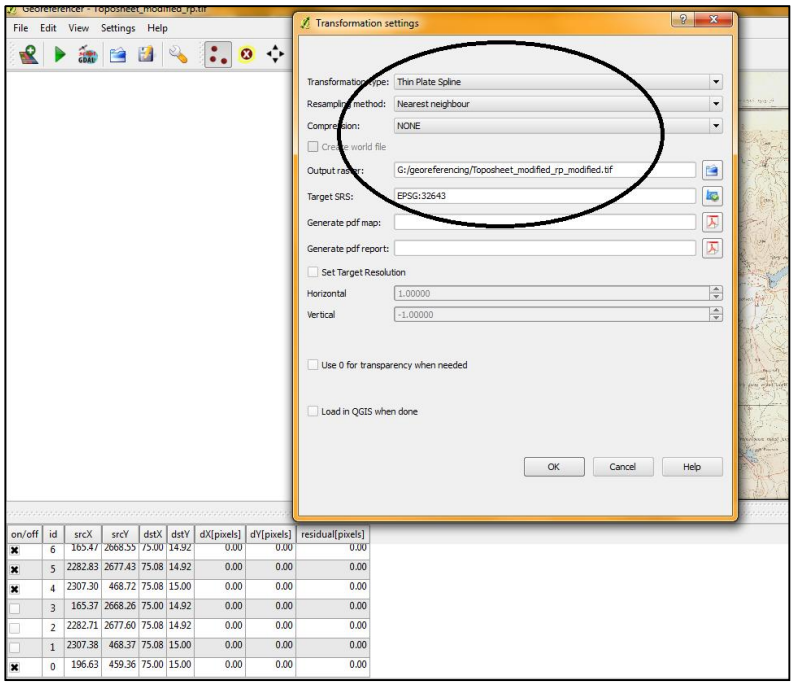
Geo referencing:

- Geo-referencing is the process of assigning real earth coordinates to the digitised maps, so it can be viewed, queried, and analysed with other geographic data.
- To start geo referencing an unreferenced raster, we must load it by clicking Plugins menu option in the menu bar and click on **Georeferencer** plugin. The Georeferencer window will be opened click on **File** menu and click Add raster layer. The raster will show up in the main working area of the dialog. Once the raster layer is loaded, we can start to enter reference points.
- Using the Add Point button (Edit→ Add points), you can add points to the main working area and enter their coordinates. Click on a point in the raster image which you want to assign co-ordinates and enter the X and Y coordinates manually. With the move button option you can move the GCPs (Ground control points) on map, if they are at the wrong place.



- Continue entering points. You should have at least 4 points and the more coordinates you can provide, the better the result will be. There are additional tools on the plugin dialog to zoom and pan the working area in order to locate a relevant set of GCP points.

- After entering GCP's click on Settings option in Georeferencing menu bar select Transformation Settings option. A drop box will be displayed and select options as shown in the below image. Specify output file name and transformation parameters and projection system then click OK.

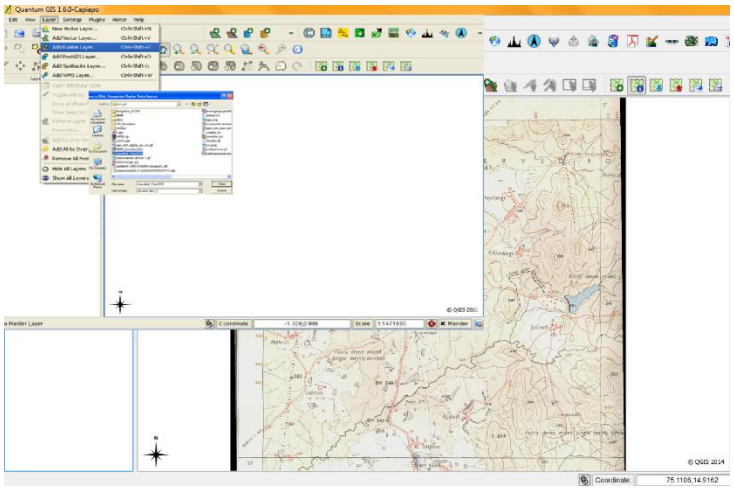


- Click on File menu and Select Start Georeferncing option. The Georefrencing will be started.

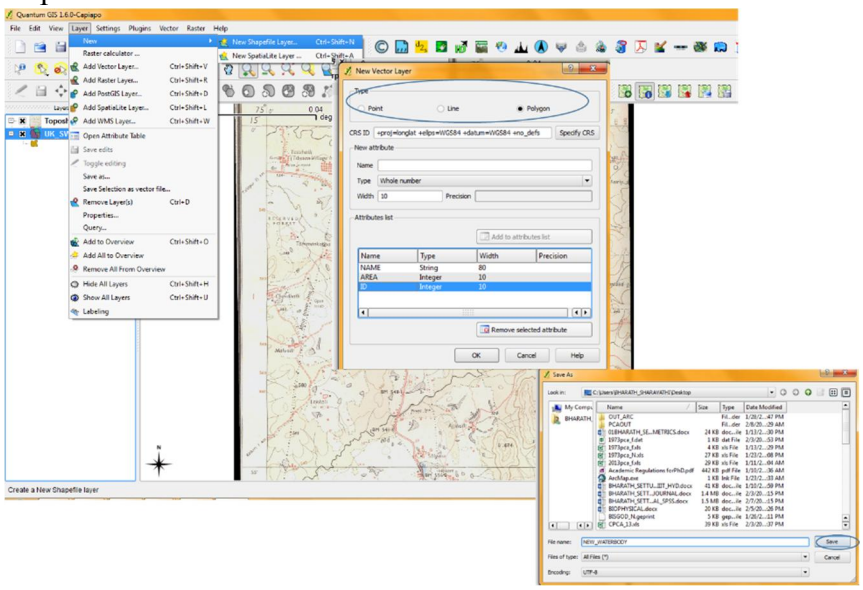
Digitising vector data

Digitising features (water bodies) of Topo map:

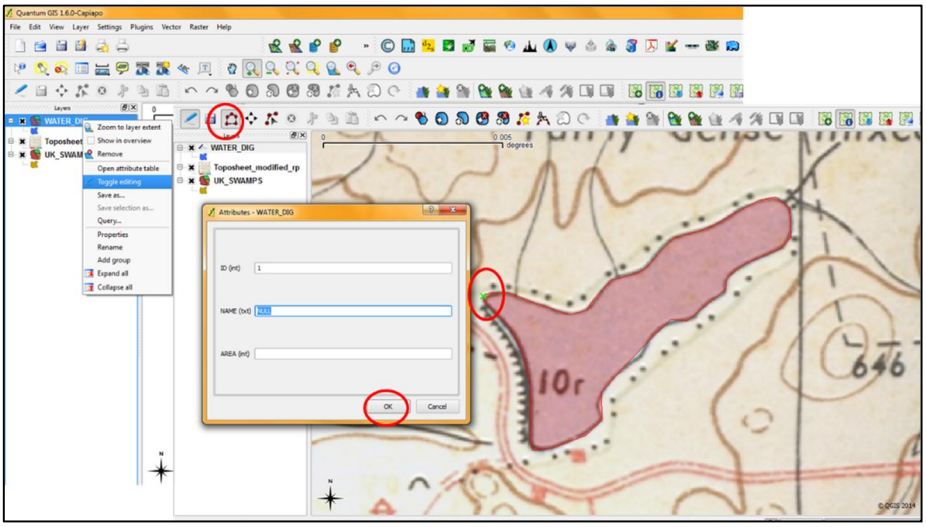
- Open the raster file you have geo referenced by clicking Layer→ Add raster layer option.
- The raster layer window will be open and load the saved layer. It will be displayed on Map canvas.



- To digitise the water bodies select Layer menu and click New→create new shape file layer option. Then new shape file layer drop box will open with options.
- Select polygon option and provide the attributes for it and save the file with a name. The saved new shape file will be loaded for creation of features.



- **Attributes** are entered as features to be created.
- Zoom to the feature you want to digitize by using zoom options. Right click on the vector layer you have created and select **Toggle editing** (pencil like symbol) option. Then tool bar will be highlighted. Click on **capture polygon icon** and start digitizing the water body.

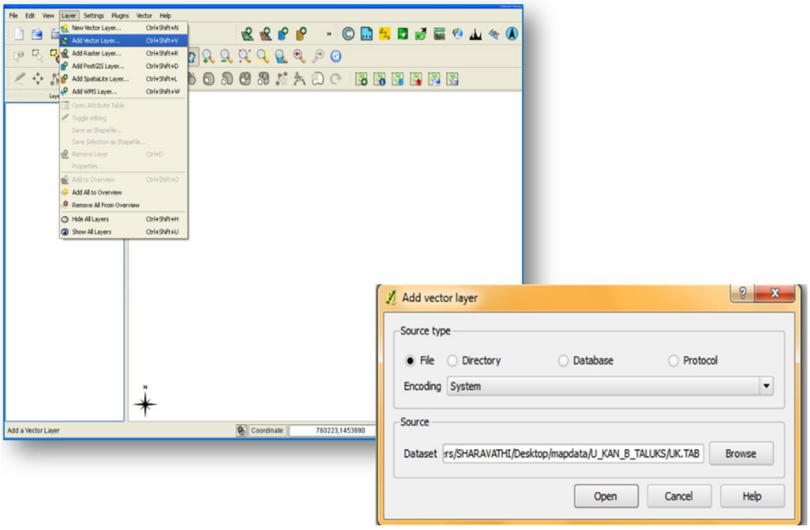


- Enter the attributes and press ok. After digitisation click save layer option to save the modifications you made.
- To compute area of the polygon right click on the layer you digitised and click open attribute table and select field calculator select area option to compute area.

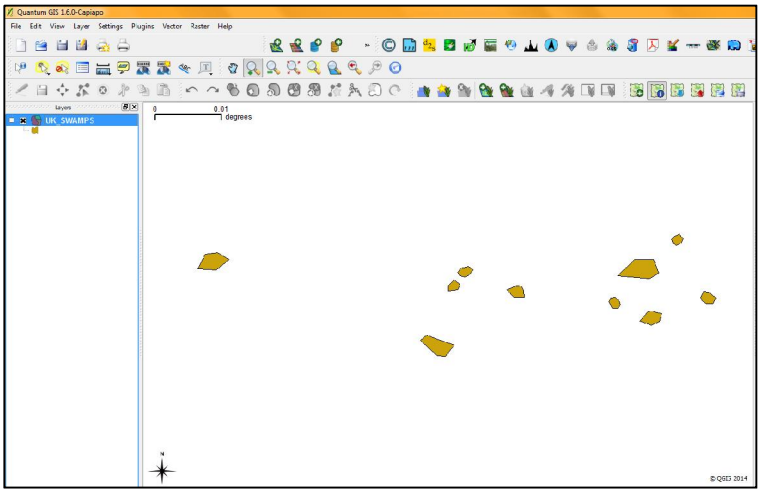
- The area will be shown in degrees. Convert it to Hectares by adding new column and provide the name for new column. Then select field calculator select the new column to be updated.
- Type the formula as AREA*110*110*100 for getting in terms of Ha.

Importing Google earth data:

- To load a vector file click on **Layer menu** in menu bar select add vector layer, a dialogue box will be displayed, which allows to traverse through the file system and load a kml file which you have created using Google earth or other formats of vector data.



- The layer will be displayed in the map canvas area.



- Right click on the layer and select properties to check the attributes, colors etc.
- QGIS supports a number of Symbology renderers to control how vector features are displayed
- Labels tab allows to enable labelling features and control a number of options related to fonts, placement, style, alignment and buffering.
- Attributes tab allows to manipulate the attributes of the selected dataset
- General tab permits to change the display name, view/change the projection of vector

- Metadata tab contains general information about the layer which is not yet editable.
- Diagram tab used to overlay a graphics to a vector layer. It allows overlying pie charts, bar charts.
- Right click on the layer click save as option to create a ***shape file***. Import the shape file and continue to work with it. So you can edit the features and compute the area etc.

Help from QGIS:

http://www.qgis.org/en/site/forusers/index.html#

http://www.qgis.org/en/docs/index.html

4.0 WATER YIELD IN THE CATCHMENT

Objective: To estimate the water yield in a catchment (of a lake, pond, stream or river).

Catchment (Drainage area, Drainage Basin or Watershed): The area of land draining water into a water body (fig1). Two neighboring catchments are separated by a ridge (highest land that separates two watersheds). The areal extent of a catchment is obtained by tracing the ridge on a Topographical Map (fig2). Based on the spatial extent, catchments are classified given in table 1.

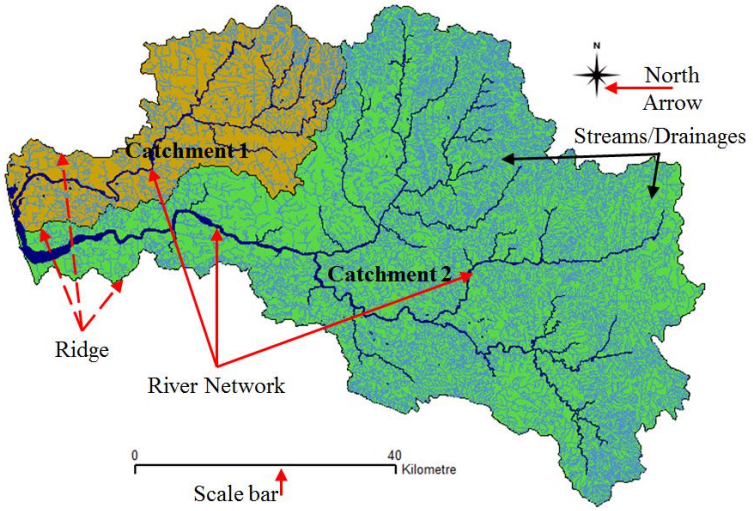


Fig1: Catchment Map

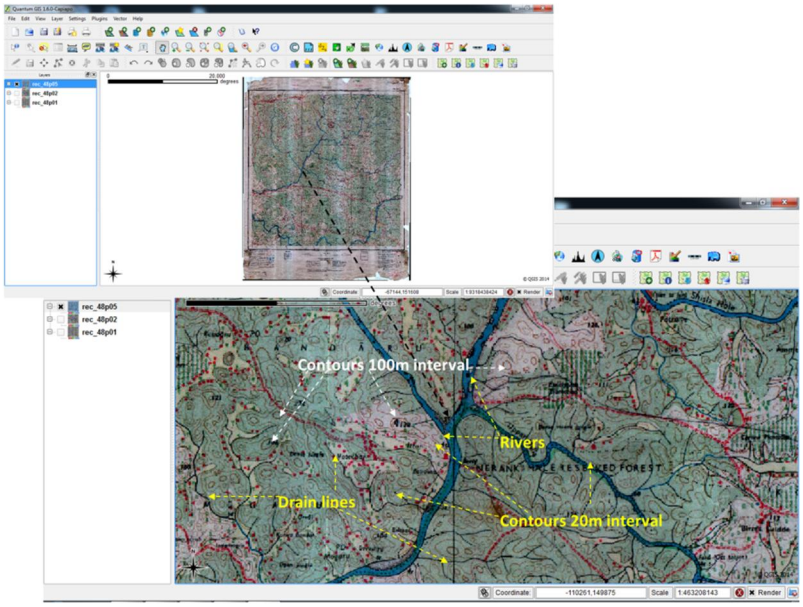


Fig2 : Topographic map indicating different features

Table1: Classification of Catchments in India

Sl.no	Type of Catchment	Area in 1000 Hectares
1	Micro-watershed	Less than1
2	Milli-Watershed	1 – 10
3	Sub-Watershed	10 – 50
4	Watersheds	50 – 200
5	Sub-Catchments	200 – 1000
6	Catchments	1000 – 3000
7	Basin	3000 – 25000
8	Region	Greater than 25000

Source: http://fes.org.in/source-book/SWC%20Source%20Book_final.pdf

Contours: Contours are the imaginary lines on the earth surface with equal elevation. In a topographic map of 1:50000 scale, contours are at every 20 metre interval. Contours with decreasing altitudes with respect to an higher altitude contour indicates hillock, on the contrary increasing contours along a low altitude contour indicates Valley.

Steps involved in Delineating a Catchment:

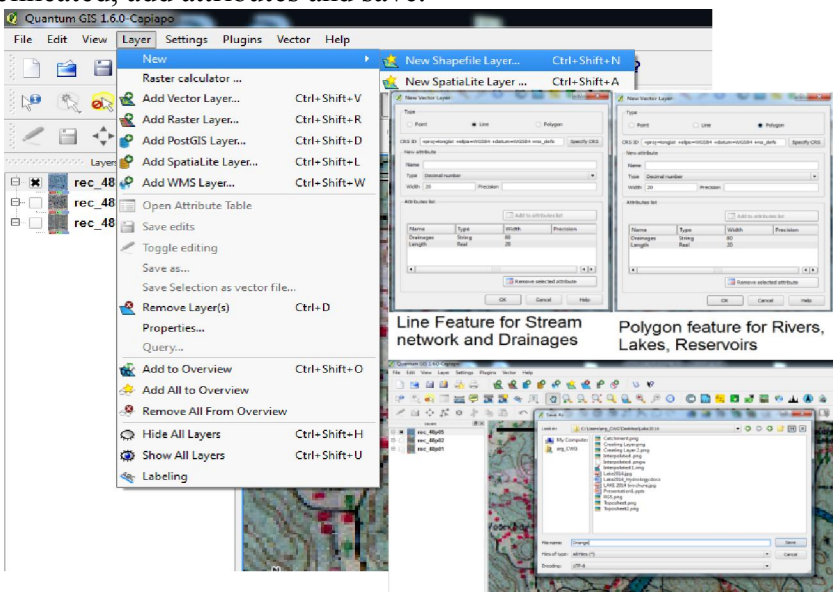
Step 1. Scan the respective topographic map

Step 2. Use QGIS, Geo-reference or assign the co-ordinates

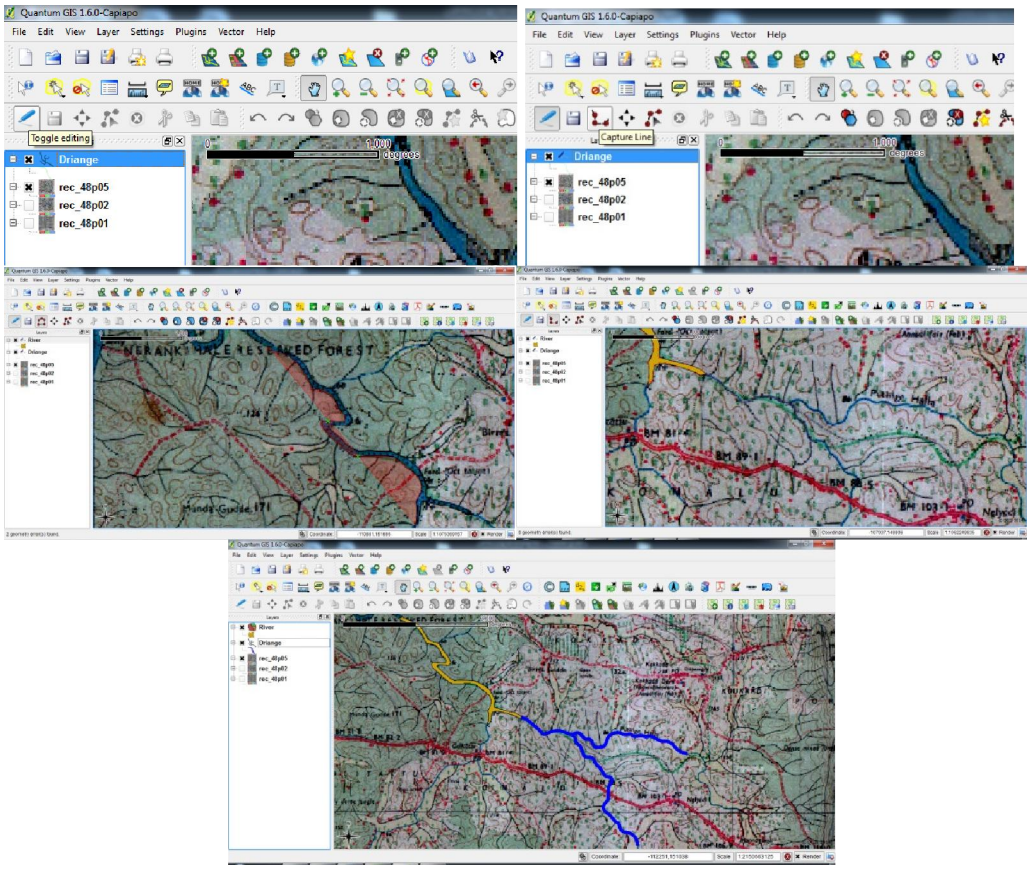
Step 3. Digitise waterbody as polygons and Stream network as line features.

a. Create New features as line or polygon

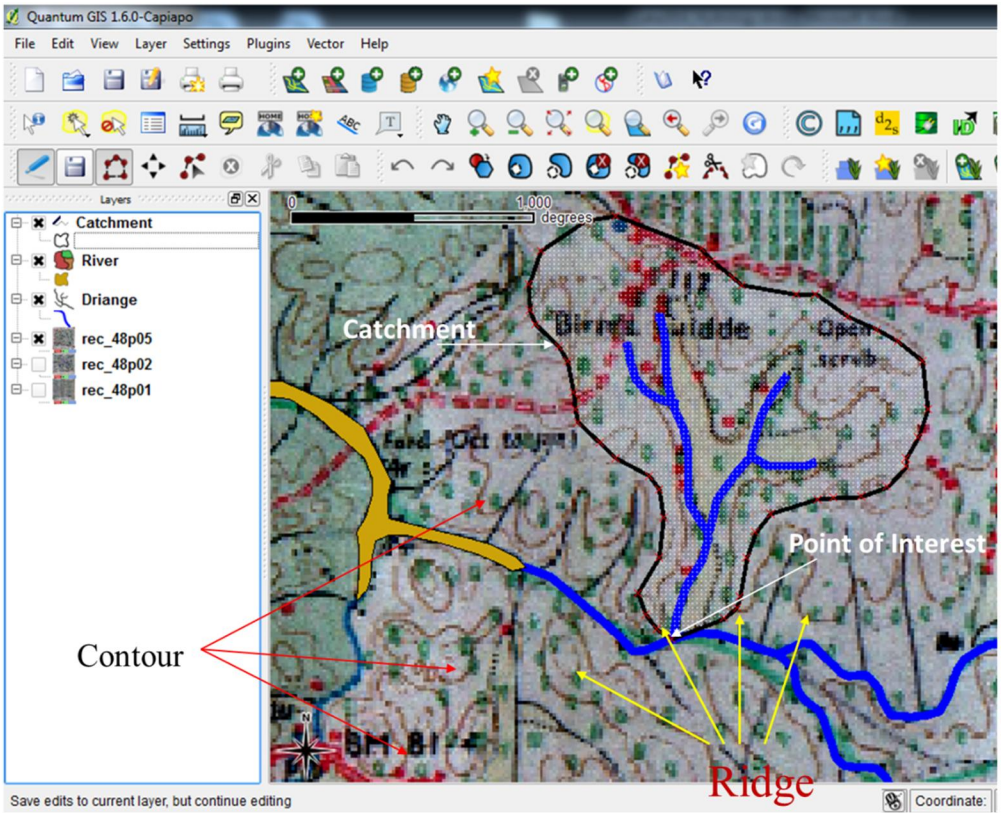
Go to Layers, New Shape file Select Line or Polygon feature based on the feature to be delineated, add attributes and save.



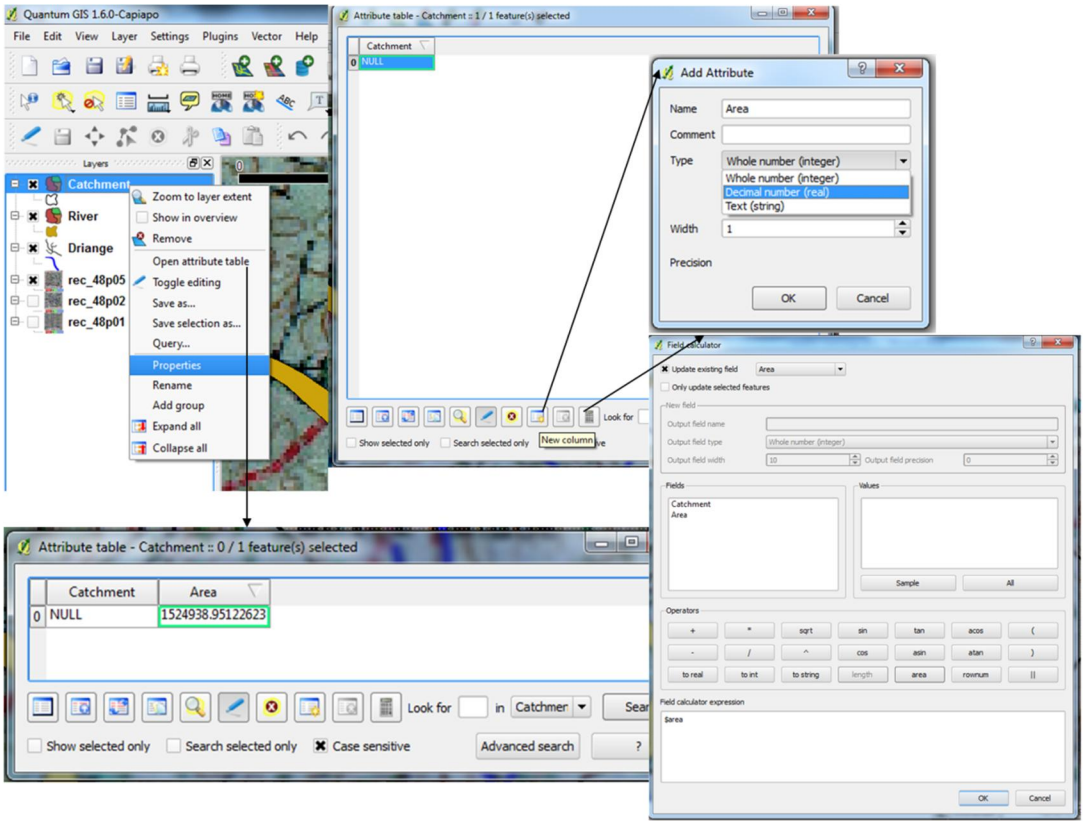
b. Load the new shape files created, click on toggle editing, click on add feature and start delineating the feature, save the edits. And stop toggle editing.



Step 4. With respect to the water body, digitize its catchment as polygon feature.



Step 5. Compute the spatial extent of the catchment. To measure the Area, right click on the catchment layer, click on properties, toggle editing, add column (the same procedure could be adopted to define the attribute), provide the details of the attribute such as attribute name, type such as text, integer or float and then ok. Click on the Field Calculator, click on update field and select the field to be updated (Area). Add the Area Operator to the field calculator expression to estimate the area of the polygon (Catchment). Save Edits and Stop Toggling.

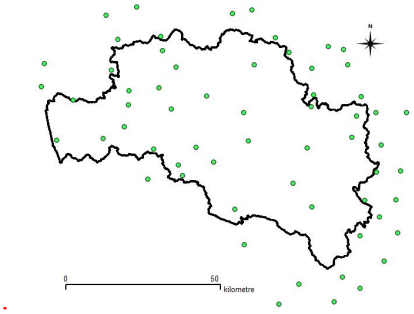


Step 6. Click on the Open Attribute to obtain the information about the area estimated. [**very important: if you have the coordinate system in latitude longitude degree decimal coordinate system, are would be in square degrees, if the coordinate system is UTM then the area would be as square metres. To convert square degrees to hectares multiply the area measured with 1100*1100, and to convert square metres to hectare divide area measured by 10000**]. In the above example demonstrated, area is 152.5 Hectares.

Similarly, other measurements such as distance, coordinates, centroids etc. along with other vector operations could be made using Calculator TOOL.

Rainfall: Daily Rainfall data at different locations are observed using rain gauges as millimeter and maintained by India Meteorological Department (IMD), Public Works Department (PWD), Water resources Development Organisation (WRDO), Agriculture Department, Revenue Department, Forest Department, etc, and is as depicted in fig.3. ***Each rain gauge represents rainfall over an area assuming rainfall is uniform in its vicinity***

Fig 3: Rain Gauge stations



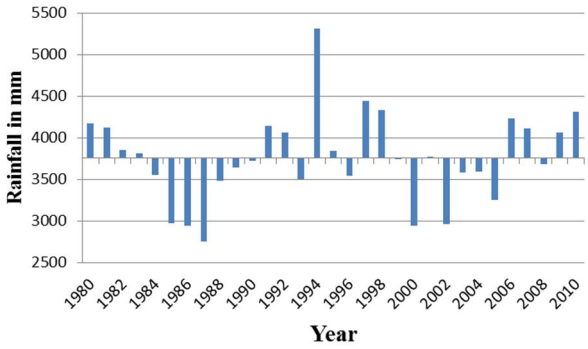
To analyze the rainfall trend and dynamics over a region, seasonal and annual rainfall data for atleast 10 to 20 year.

Steps involved in analyzing rainfall trend in the basin:

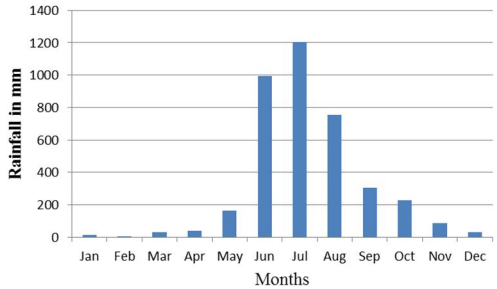
Step 1. Rainfall data for 15 to 20 years shall be acquired from the agencies such as IMD (Indian Meteorological Department), WRDO, Statistical department etc.

Step 2. Rain gauge stations inside and near to the basin are identified based on the location of the rain gauge stations.

Step 3. Annual data is plotted as a graph to understand the dynamics of rainfall over time.



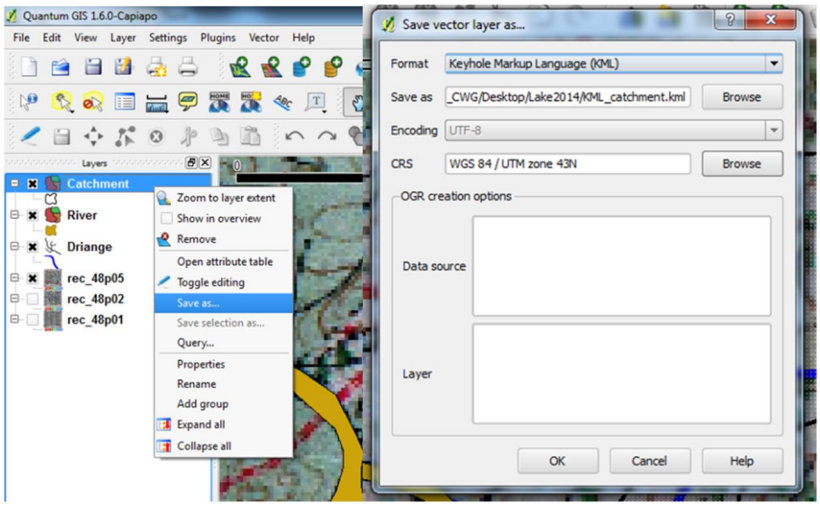
Step 4. Based on the annual rainfall trend, seasonal variation in the watershed is estimated



Extraction of Land use details from Google Earth: Google earth provides satellite images with high resolution, this could be used to identify different types of land uses in the basin.

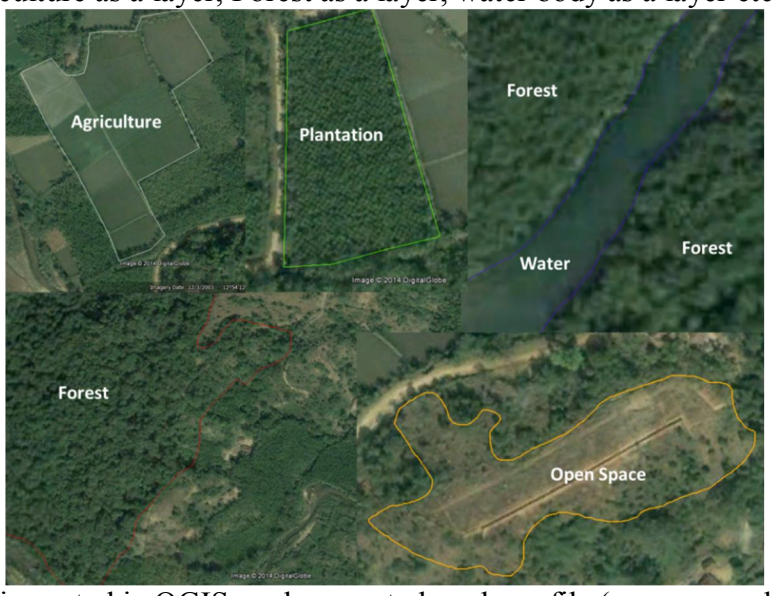
Steps involved in extraction of landuse features from Google earth:

Step 1. The delineated catchment would be in the form of **xxx**(filename)***.shp*** format i.e., as a shape file, first convert the same to kml. Right click on the shape file, click on save as, click on format and select KEYHOLE MARKUP LANGUAGE (KML) to convert the convert the file to kml, save the file



Step 2. Double click on the saved 'kml' to open the same in Google earth

Step 3. Within the watershed, start digitising layers as polygons and save as 'kml'.
Example: Agriculture as a layer, Forest as a layer, water body as a layer etc



Step 4. 'kml' files are imported in QGIS, and converted as shape file (same procedure as step1)

Step 5. Calculate the are under each landuse using Map calculator tool

Assessment of water yield: Water yield or Surface Runoff is the precipitated water that drains to a water body in a catchment. Surface runoff occurs during monsoon. Factors affecting Runoff are the Slope, Drainage, Land use, Soil Characteristics, Rainfall. The total quantity of water that can be expected in a stream in a given period of time such as monthly, annual etc… is referred to as Runoff Yield.

Runoff Yield (Q) as kilo.cubic metre (Million Litres) is estimated empirically (eq.1) as a function of Rainfall (P) in mm and Area under different land uses (A) in Hectares.

$$Q = (C*P*A)/100 \qquad 1$$

Where Q = Runoff Yield in Million litres
C = Runoff Coefficient of a particular land use
A = Area under land use in Ha
P = Mean Monthly rainfall in mm (average of 10 – 15 years)

Runoff Coefficient under different land use is as specified in table 2.

Land Use	**Runoff Coefficient**
Forests	0.1 – 0.2
Plantations	0.2 – 0.6
Agriculture	0.4 – 0.7
Open Spaces, Grasslands	0.5 – 0.8
Built-up	0.7 – 0.9
Rocky Areas	0.8 - 1.0

Water Yield Estimation

Location Description						
Catchment Extent		Latitude			Longitude	
		min			min	
		max			max	
Catchment Area in Ha						
Annual Rainfall in mm						
Land Use		Area in Ha **A**			Runoff Coefficient **C**	
Forests						
Plantations						
Agriculture						
Open Spaces, Grasslands						
Built-up						
Rocky Areas						
Monthly rainfall ***P*** in mm	January	February	March	April	May	June
	July	August	September	October	November	December
Seasonal Catchment Yield in Million Litres **Q = (C*A*P)/100**						
Land Use	January	February	March	April	May	June
Forests						
Plantations						
Agriculture						
Open Spaces, Grasslands						
Built-up						
Rocky Areas						
Gross Yield **Q**						
Land Use	July	August	September	October	November	December
Forests						
Plantations						
Agriculture						
Open Spaces, Grasslands						
Built-up						
Rocky Areas						
Gross Yield **Q**						
Annual Catchment Yield = (Σ Q)				Million Liters		

5.0 FLYING FRIENDS….

Introduction: Birds (class Aves or clade Avialae) are feathered, winged, two-legged warm-blooded, egg-laying vertebrates. Aves ranks as the tetrapod class with the most living species, approximately ten thousand. Extant birds belong to the subclass Neornithes, living worldwide and ranging in size from the 2 in Bee Hummingbird to the 9 ft Ostrich. The fossil record indicates that birds emerged within the theropod dinosaurs during the Jurassic period, around 150 million years ago. *Archaeopteryx* was the first fossil to display both clearly traditional reptilian characteristics: teeth, clawed fingers, and a long, lizard-like tail, as well as wings with flight feathers identical to those of modern birds. It is not considered a direct ancestor of modern birds, though it is possibly closely related to the real ancestor. Depending on the taxonomic viewpoint, the number of known living bird species varies anywhere from 9,800 to 10,050. In India, around 1314 species of birds are documented, of which 42 are endemic to India. In Karnataka state, 535 species of birds has been reported.

Evolution: Modern birds are characterized by feathers, a beak with no teeth, the laying of hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a lightweight but strong skeleton. Wings are evolved forelimbs, and most bird species can fly. Flightless birds include penguins, and diverse endemic island species. Some species of birds, particularly penguins and members of the Anatidae family, are adapted to swim. Birds also have digestive and respiratory systems that are uniquely adapted for flight. Some birds, especially corvids and parrots, are among the most intelligent animal species; several bird species make and use tools, and many social species culturally transmit knowledge across generations.

Behaviour: Many species annually migrate great distances, and many more perform shorter irregular movements. Birds are social, communicating with visual signals, calls, and songs, and participating in such social behaviours as cooperative breeding and hunting, flocking, and mobbing of predators.

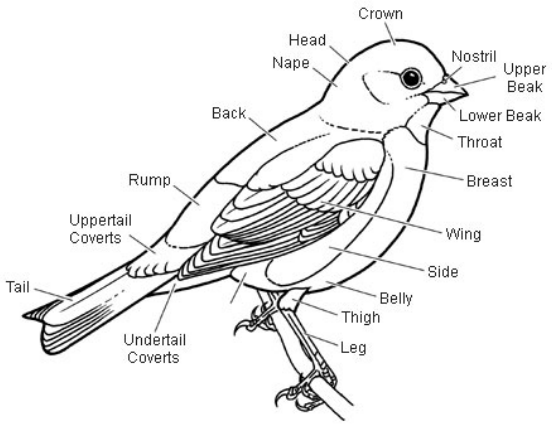
Usefulness: They eat a lot of harmful insects that may destroy crops. they are part of the food chain. They help disperse the seeds of many plants. The raptors keep rodent populations in check. The vultures help clean the land of animal carcasses, preventing the spread of infectious diseases. Another use of birds is harvesting guano (droppings) for use as a fertilizer. Birds prominently figure throughout human culture. About 120–130 species have become extinct due to human activity since the 17th century, and hundreds more before then.

Need to study: Birds are among the most fascinating creatures on Earth. Many are beautifully colored. Others are accomplished singers. Many of the most important discoveries about birds and how they live have been made by amateur birders. Ornithology is the scientific study of birds. The information ornithologists gather is used to better understand how birds function, inside and out, and to learn how birds relate to their natural environment.

- Birds provide a terrific doorway into nature and scientific study.
- They are easy to see and study.
- They engage in fascinating behaviors and play important roles in the ecosystems that sustain life
- Birds are excellent indicators of environmental health.
- Their changing populations often provide clues to the overall health of their habitat.

Requirements: A pair of binoculars, good pictorial field guide and note book to pen down observation.

Parts of a bird



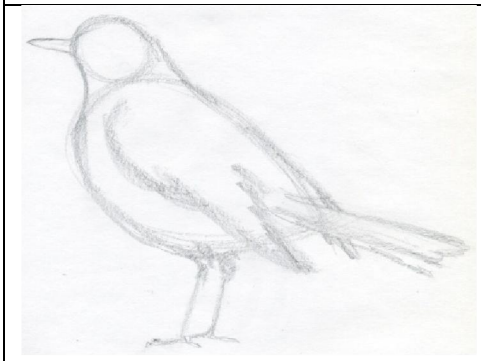
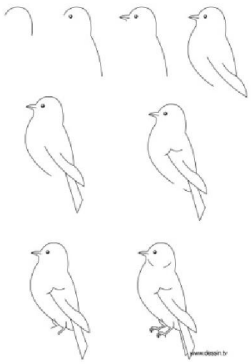
- **Head**: The bird's head is one of the best places to look for field marks such as eye colour, malar stripes, eyebrows, eye rings, eye lines and auricular patches. The crown (top) and nape (back) are also key parts of the head that can help identify a bird.
- **Bill**: The size, shape and colour of a bird's bill is critical for identification. Also check for any curvature in the bill or unique markings such as differently coloured tips or bands.
- **Chin**: The chin, directly below the bill, is often hard to see on many birds, but when it is a different colour it can be an exceptional body part to check for identification.
- **Throat**: A bird's throat may be a different colour from its surrounding plumage, or it may be marked with spots, streaks or lines. Malar stripes may frame the throat as well, helping set it off from the rest of a bird's body. For many birds, the chin and throat have similar colours and markings.
- **Neck**: The neck of a bird is hard to see on many species, since it can be relatively short and insignificant. On wading birds, however, the neck is much more prominent and can be a good place to look for field marks. The length of the neck can also help distinguish different bird species.
- **Back**: A bird's back is often broad and easy to see in the right posture. Different colours and markings along the back that distinguish it from the neck, rump and wings.
- **Chest**: The chest (also called the breast) is the upright part of the bird's body between the throat and the abdomen. A bird's chest may be differently coloured or marked with stripes, streaks or spots that can help with identification.
- **Abdomen**: The abdomen or belly of a bird extends from the bottom of the chest to the under-tail coverts. The colours and markings on the abdomen may vary from the chest and flanks, making it a good feature to check for identification.
- **Flanks**: The flanks (sides) of a bird are located between the underside of the wings and the abdomen. In many bird species, the flanks have unique colours or markings, though depending on how the birds carry their wings, the flanks may be difficult to see.

- **Wings**: Birds' wings are their upper limbs used for flight. Wing bars or patches are useful field marks, as are the lengths of the wings compared to the length of the tail when the bird is perched. In flight, wing shape is also a great field mark.
- **Rump**: A bird's rump is the patch above the tail and low on the back. For many birds, the rump does not stand out, but some species show unique rump colour patches that are useful for identification.
- **Tail**: The length, shape and colours of a bird's tail are important for proper identification. The tail can be held in different positions when the bird is perched or flying. Also, watching for different markings can help distinguish different birds.
- **Under-tail Coverts**: The short feathers beneath the tail are the under-tail coverts, and these feathers often show unique colours or markings that can distinguish bird species.
- **Legs**: Birds' legs vary in length and colour, both of which can be useful field marks for proper identification. The thickness of the leg, while difficult to see on many species, can also be a clue, as can any feathering. Some raptors, for example, have heavily feathered legs that can be used to identify the birds.
- **Feet**: Many birds' feet are the same colour as their legs, but not always. The orientation of the toes, the size of the talons and how a bird uses its feet are also useful identification characteristics.

Field Analysis:-

Method - Random Sampling
Equipment used - Binoculars, Digital SLR Camera
Duration – every month last Sunday
Weather Conditions: **Day light: Sunny/cloudy**
Temperature:

Date	Location	Habitat	Birds	comment

How to sketch a bird in field?	
	
Common Friends in Bangalore	
	
House Sparrow (*Passer domesticus*)	*Spotted Munia* (Lonchura punctulata)
	
House Crow (*Corvus splendens*)	*Jungle Crow* (*Corvus macrorhynchos*)
	
Common Myna (*Acridotheres tristis*)	*Jungle Myna* (*Acridotheres fuscus*)

	
Red-whiskered Bulbul (*Pycnonotus jocosus*)	*Red-vented Bulbul* (*Pycnonotus cafer*)
	
Black Kite (Milvus migrans)	*Brahminy Kite* (*Haliastur indus*)
	
Cattle Egret (*Bubulcus ibis*)	*Rose-ringed Parakeet* (Psittacula krameri)
	
Green Bee-eater (Merops orientalis)	*White-cheeked Barbet* (*Megalaima viridis*)

6.0 PROTOCOL FOR WATER QUALITY MONITORING (PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS)

WATER SAMPLING

Sampling:

The sample collected should be small in volume, enough to accurately represent the whole water body. The water sample tends to modify itself to the new environment. It is necessary to ensure that no significant changes occur in the sample and preserve its integrity till analysed (by retaining the same concentration of all the components as in the water body). The essential objectives of water quality assessment are to:

- Define the status and trends in water quality of a given water body.
- Analyse the causes for the observed conditions and trends.
- Identify the area specific problems of water quality and provide assessments in the form of management to evaluate alternatives that help in decision-making.

Site selection in a waterbody: Sampling sites for the water body/lake are selected to represent the water quality at different points and depths. Generally three sampling sites are selected for monitoring.

- ***Inlet*:** the point where the principal feeder opens into the lake.
- ***Center*:** the point that gives the general water quality of the lake.
- ***Outlet*:** the place where the overflow occurs.

Types of sampling: Generally three types of sampling are adopted for collecting water samples.

- ***Grab or Catch sampling:*** the sample is collected at a particular time and place that represents the composition of the source at that particular point and time.
- ***Composite sampling:*** a mixture of grab samples is collected at the same sampling point at different time intervals.
- ***Integrated sampling:*** a mixture of grab samples collected at different points simultaneously.

Sampling frequency

The quality of water varies with time in a water body due to various natural and human induced factors. The monitoring has to be done in a way that records all the changes in the quality. The sampling frequencies generally adopted in monitoring are:

- Monthly sampling covering all seasons (preferably for 24 months).
- Weekly sampling for one year.
- Consecutive day sampling during the study period.
- Hourly sampling for 24 hours (example: parameters such as dissolved oxygen, pH, etc.).

Variations in water quality are mainly due to changes in the concentrations of the components of the water flowing into the water body. These variations can be man-made or natural and can either be cyclic or random.

- *Random variations*: due to spasmodic, often unpredictable events such as accidental oil spills, sewage leaks, overflows, etc.
- *Cyclic variations:* may be a result of regular seasonal changes triggering certain natural processes such as rainfall, snowmelts and seasonal temperature changes, altering the ecosystem. Seasonal growth and decay of vegetation will also rise due to cyclic changes in the composition of water.

In lakes, the mass of water and good lateral mixing provide inertia against any rapid modifications due to inputs and outputs.

Sampling container: The sampling container should not react with the sample, be of adequate capacity to store the sample and be free from contamination.

Sampling method: Grab sampling can be performed at the inlet, center and outlet in most of the water bodies studied to assess their physical and chemical qualities. The samples can be collected in thoroughly cleaned 2.5-litre inert plastic containers, which is rinsed with distilled and lake/tank water before collection.

Note: Water samples were collected in a sampling bottle avoiding floating materials. The stoppers of the sample containers were closed properly to prevent outside contamination. The container was labelled describing the name of the water body, date, time, sampling-point, and conditions under which it was sampled.

Analyses of Physical, Chemical and Biological Parameters
The parameters analysed to assess the water quality are broadly divided into: • **Physical parameters:** Colour, Temperature, Transparency, Turbidity and Odour. • **Chemical parameters:** pH, Electrical Conductivity (E.C), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium Hardness, Magnesium Hardness, Nitrates, Phosphates, Chlorides, Dissolved Oxygen (D.O), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fluorides, Free Carbon-dioxide, Potassium and Sodium. • **Biological parameters:** The biological parameters involved the qualitative analyses of planktons
Field measurement: The field (on-spot) parameters measured include pH, conductivity, dissolved oxygen, temperature and transparency.
Sample Preservation: Between the time a sample is collected and analysed in the laboratory, physical, chemical and biochemical reactions may take place in the sample container leading to changes in the intrinsic quality of the sample, making it necessary to prevent or minimize these changes with suitable preservatives such as alcohol and mercuric chloride. Highly unstable parameters such as pH, temperature, transparency, free carbon-dioxide, dissolved oxygen, etc. is measured at the sampling site. The preservation procedure includes keeping the samples in the dark, adding chemical preservative, lowering the temperature to retard reactions, or combinations of these.

Experiment	Preservative	Max. holding time
BOD	Cool, 4°C	4 hours
Calcium	Cool, 4°C	7 days
Chloride	Cool, 4°C	7 days
COD	Cool, 4°C	24 hours
Dissolved Oxygen*	Fix on site	6 hours
Magnesium	Cool, 4°C	7 days
Nitrate + Nitrite	Cool, 4°C	24 hours
pH	None	6 hours
Phosphorus*		
Dissolved	Filter on site using 0.45µm filter	24 hours
Inorganic	Cool, 4°C	24 hours
Ortho	Cool, 4°C	24 hours
Total	Cool, 4°C	1 month
Potassium	Cool, 4°C	7 days
Specific Conductance	Cool, 4°C	24 hours
Sodium	Cool, 4°C	7 days

(Source: Analytical Methods Manual, Water quality branch, Environment Canada, 1981)

WATER TEMPERATURE	**1**

WATER TEMPERATURE: The water temperature is important for its effects on the chemistry, and biological reactions in the organisms in water. A rise in temperature of the water leads to the speeding up of the chemical reactions in water, reduces the solubility of gases, affects carbon dioxide-carbonate-bicarbonate equilibrium and amplifies the tastes and odours. Temperature influences water chemistry, e.g. DO, solubility, density, pH, alkalinity, salinity, conductivity etc. At elevated temperatures, metabolic activity of organism's increases, requiring more oxygen but at the same time the solubility of oxygen decreases. Water temperature is important in relation to fish life. The disease resistance in the fishes also decreases with rise in temperature. The aquatic organisms show varied sensitivities to temperature. The temperature of drinking water has an influence on its taste.

Procedure

Clean the pH-TDS-EC probe/thermometer (Hg bulb region) with distilled water and fill the container with water sample. Then check the water temperature of the sample by dipping the pH-TDS-EC probe into sample and record it in degrees Celsius (^{o}C).

Apparatus: pH-TDS-EC probe/ Laboratory thermometer, Beaker

Do's and Dont's:

- Clean the electrode (sensor parts) of the meter with distilled water and wipe properly using tissue paper, before and after usage.
- Calibrate the meters prior to each field trip. (Follow internal calibration solutions as per the Company instructions)
- Ensure: Company instructions for field use, maintenance and storage of the pH-TDS-EC probe have been followed properly.
- Note down the temperature readings of each sample.
- Don't expose the meter/laboratory thermometer directly to sunlight.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

pH	2

pH: pH is the measure of the acid-base balance of a solution and is defined as the negative logarithm to the base 10 of the hydrogen ion (H^+) concentration. The pH scale runs from 0 to 14 (i.e., very acidic to very alkaline) with pH 7 representing a neutral solution. When the pH is less than 7, it is said to be acidic; a pH greater than 7 is basic.

pH tends to increase during day largely due to the photosynthetic activity (consumption of carbondioxide) and decreases during night due to respiratory activity. pH is also governed by the equilibrium between carbon dioxide/bicarbonate/carbonate ions. The change in the intensity of acidity or alkalinity of an aquatic ecosystem can be due to inflow of industrial effluents, domestic sewage and atmospheric deposition of acid-forming substances. Diurnal variations in pH can take place due to photosynthesis and respiration cycles of algae in eutrophic waters. Acidity of water is controlled by strong mineral acids, weak acids (such as carbonic, humic and fulvic acids) and hydrolysing salts of metals such as iron and aluminium. Waste water and polluted natural waters have pH values lower or higher than 7 based on the nature of the pollutant. Changes in pH endanger the lives of the organisms in the water.

A lower pH value, below 4 will produce sour taste whereas pH above 8.5 produces an alkaline taste. If the pH is below 6.5, corrosion of pipes occur, thus toxic metals like Zinc, Lead, Cadmium and Copper etc. are released. Higher pH values induce scale formation in water heating apparatus, production of toxic trihalomethanes and also reduce the germicidal potential of chlorine.

Procedure

- **Colorimetric method:** About 10ml of the sample is taken in a wide mouth test tube, 0.2 ml of BDH indicator is added, and shaken gently. The colour developed is matched with the chart and the pH noted.
- **Electrometric method:** The pH is determined by measuring the Electro Motive Force (E.M.F) of a cell comprising an indicator electrode (an electrode responsive to hydrogen ions such as a glass electrode) immersed in the test solution and the reference electrode (usually a mercury/calomel electrode). Contact between the test solution and the reference electrode is usually got by means of a liquid junction, which forms a part of reference electrode. E.M.F of this cell is measured with pH meter that is a high impedance voltmeter calibrated in terms of pH. The electrode is allowed to stand for 2 minutes to stabilize before taking reading for reproducible results (at least ±0.1 pH units).

Apparatus:

- **pH indicator (BDH) method:** BDH Indicator (Universal Indicator) and test tubes.
- **Electrometric method:** Glass electrode, reference electrode (mercury/calomel or silver/silver chloride) and pH meter.

Do's and Dont's:

- Clean the meters with distilled water and wipe properly using tissue paper, before and after usage.
- Calibrate the meters prior to each field trip.
- Ensure that all the instructions on use, maintenance and storage of the pH-TDS-EC probe have been followed.
- Note down the pH readings of each sample.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 7-8.5 Excessive Not less than 6.5 or greater than 9.2
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

ELECTRICAL CONDUCTIVITY (EC)	3

ELECTRICAL CONDUCTIVITY: Conductivity denotes the ability of an aqueous solution to conduct an electrical current. It depends on the presence of ions, their total concentration, mobility, valence, relative concentration and on the temperature of measurement. Electrolytes in a solution dissociate into positive (cations) and negative (anions) ions and impart conductivity. Solution of most inorganic acids, bases and salts (chloride, nitrate, sulfate, phosphate anions, sodium, magnesium, calcium, iron, and aluminium cations) are relatively good conductors unlike organic compounds (oil, phenol, alcohol, and sugar). Conductivity increases with temperature.

Conductance is defined as the reciprocal of the resistance involved and expressed as mho or Siemen (s).

$G=1/R$ [where, G – Conductance (mho or Siemens) and R – Resistance]

The amount of current that can flow through a solution is proportional to the concentration of dissolved ionic species in the solution. Thus, higher the concentration of electrolytes in water, the more is its electrical conductivity. i.e. lesser the resistance.

Procedure

The electrode of the conductivity meter is dipped into the sample, and the readings are noted for stable value shown as mS/cm.

Apparatus: Conductivity meter, 100ml Beaker

Do's and Dont's:

- Clean the meters with distilled water and wipe properly using tissue paper, before and after usage.
- Calibrate the meters prior to each field trip.
- Ensure that all the instructions on use, maintenance and storage of the pH-TDS-EC probe has been followed.
- Note down the EC readings of each sample.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 750-2000 Excessive >2000
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

TOTAL DISSOLVED SOLIDS (TDS)	4

TDS : The substances that would pass through the filter paper but will remain as residue when the water evaporates which includes dissolved minerals and salts, humic, tannin and pyrogens. A constant level of minerals in the water is necessary for aquatic life. Changes in the amounts of dissolved solids can be harmful because the density of total dissolved solids determines the flow of water in and out of an organism's cells. Many of these dissolved solids contain chemicals, such as nitrogen, phosphorous, and sulfur, which are the building blocks of molecules for life. Concentration of total dissolved solids that are too high or too low may limit the growth and may lead to the death of many aquatic organisms. High concentrations of total dissolved solids may reduce water clarity, which contributes to a decrease in photosynthesis and lead to an increase in water temperature. Many aquatic organisms cannot survive in high temperatures. The conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. These particles contribute the dissolved solids of the water. Waters with high dissolved solids generally are of inferior palatability and may induce an unfavourable physiological reaction.

Procedure

Clean the pH-TDS-EC probe with distilled water and fill the container with water sample. Then the total dissolved solids is determined by dipping the pH-TDS-EC probe into sample and express in parts per million (ppm).

Apparatus: pH-TDS-EC probe, 100ml Beaker

Do's and Dont's:

- Clean the meters with distilled water and wipe properly using tissue paper, before and after usage.
- Calibrate the meters prior to each field trip.
- Ensure that all the instructions on use, maintenance and storage of the pH-TDS-EC probe has been followed.
- Note down the TDS readings of each sample.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 500 Excessive 1500
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

TRANSPARENCY (LIGHT PENETRATION)	5

TRANSPARENCY: Solar radiation is the major source of light energy in an aquatic system, governing the primary productivity. Transparency is a characteristic of water that varies with the combined effect of colour and turbidity. It measures the light penetrating through the water body and is determined using Secchi disc.

Procedure

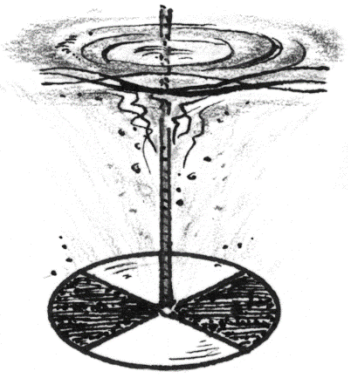
Transparency is measured by gradually lowering the Secchi disc at respective sampling points. The depth at which it disappears in the water (X_1) and reappears (X_2) is noted.

The transparency of the water body is computed as follows:

Transparency (Secchi Disc Transparency) = $(X_1 + X_2)/2$

Where, X_1 = Depth at which Secchi disc disappears

X_2 = Depth at which Secchi disc reappears



secchi disk

Apparatus: Secchi disc, a metallic disc of 20cm diameter with four quadrats of alternate black and white on the upper surface. The disc with centrally placed weight at the lower surface, is suspended with a graduated cord at the center.

Do's and Dont's:

- Clean the secchi disc before and after usage.
- Handle the secchi disc with care.
- Note down the readings of each sample.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible Excessive
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

TURBIDITY	**6**

TURBIDITY: Turbidity is an expression of optical property; wherein light is scattered by suspended particles present in water (Tyndall effect) and is measured using a nephelometer. Any substance having a particle size more than 10^{-9} will produce turbidity in water. Suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter; plankton and other microscopic organisms cause turbidity in water. Turbidity affects light scattering, absorption properties and appearance in a water body. Increase in the intensity of scattered light results in higher values of turbidity. Turbidity makes the water unfit for domestic purposes, food and beverage industries, and many other industrial purposes. In natural waters, turbidity restricts light penetration for photosynthesis.

Nephelometric measurement is based on comparison of the intensity of scattered light of the sample with the intensity of light scattered by a standard reference suspension (Formazin polymer) under similar conditions.

Procedure: The nephelometer is calibrated using distilled water (Zero NTU) and a standard turbidity suspension of 40 NTU. The thoroughly shaken sample is taken in the nephelometric tube and the value is recorded.

Turbidity (NTU) = (Nephelometer readings) (Dilution factor*)

* If the turbidity of the sample is more than 40 NTU, then the sample is diluted and the dilution factor is accounted in final calculations.

Apparatus: Nephelometer (It detects scattered light at 90^{o} to the incident beam of light. It consists of a light source for illuminating the sample. One or more photoelectric detectors with a display unit indicate the intensity of light scattered at 90^{o} to the path of incident light.), sample cells, lab-glass wares.

Do's and Dont's:

- Collect the sample directly into the sampling cuvet (cell).
- Do not leave the sample cell in the meter so as to avoid scratches.
- Empty the sample at each site and rinse properly.
- Note down the Turbidity readings of each sample.
- Wipe the cell properly with tissue paper and ensure that the outside of the cell is clean and dry before placing the cell in to the meter.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 5 NTU Excessive 25 NTU
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

DISSOLVED OXYGEN (DO)	**7**

DISSOLVED OXYGEN: Oxygen is essential to all forms of aquatic life. DO depend upon the physical, chemical and biochemical activities in the water body. The analysis of DO is a key test in water pollution and waste treatment control. The two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity. Low levels of DO frequently indicate a high concentration of decaying organic matter in the water. As bacteria digest organic matter, they use up oxygen, leaving little for the other aquatic creatures. The factors affecting the DO are (1) temperature: as temperature increases, the amount of oxygen (or any gas) dissolved in water decreases. (2) Partial pressure of O_2 in contact with water: at high altitudes, less oxygen is dissolved in water because the partial pressure of oxygen in the atmospheric is low (3) Salinity: the solubility of gases O_2 and CO_2 decreases with increasing salinity.

D.O (mg/L)	Water quality
Above 8.0	Good
6.5-8.0	Slightly polluted
4.5-6.5	Moderately polluted
4.0-4.5	Heavily polluted
Below 4.0	Severely polluted

Winkler's method

Principle: Oxygen present in the sample oxidizes the dispersed divalent manganous hydroxide to the higher valency to precipitate as a brown hydrated oxide after addition of potassium iodide and sodium hydroxide. Upon acidification, manganese reverts to its divalent state and liberates iodine from potassium iodide, equivalent to the original dissolved oxygen content of the sample. The liberated iodine is titrated against N/80 sodium thiosulphate using fresh iodine as an indicator.

Calculation: $N_1V_1 = N_2V_2$ (Molar equivalence formula)

$$\text{Dissolved oxygen, mg/L} = \frac{\text{(ml*N) of sodium thiosulphate * 8 * 1000}}{V_2\,[(V_1 - V)/V_1]}$$

Where, V_1 = Volume of sample bottle

V_2 = Volume of contents titrated

V = Volume of $MnSO_4$ and KI added (2ml)

Procedure

The samples are collected in BOD bottles, to which 1ml of manganous sulphate and 1ml of potassium iodide are added and sealed. This is mixed well and the precipitate is allowed to settle down. Then, 1ml of concentrated sulphuric acid is added, and mixed well until all the precipitate dissolves. 25 ml of the sample is measured into the conical flask and titrated against 0.025N sodium thiosulphate using starch as an indicator. The end point is the change of colour from blue to colourless.

Apparatus: BOD bottle-125ml, measuring cylinder, conical flask, 1ml glass pipette etc.

Reagents:

- **Manganous sulphate solution:** Dissolved 100 g of manganous sulphate in 200ml of distilled water and heated to dissolve salt and filtered after cooling.
- **Alkaline potassium iodide solution:** Dissolved 100 g of KOH and 50 g of KI in 200ml of pre-boiled distilled water.
- **Starch indicator:** 1g of starch is dissolved in 100 ml of warm distilled water and added few drops of formaldehyde solution.
- **Stock sodium thiosulphate (0.1 N):** 24.82g of sodium thiosulphate pentahydrate ($Na_2S_20_2.\ 5H_2O$) is dissolved in distilled water and made up to 1000ml.

- **Standard sodium thiosulphate (0.025N):** 250ml of the stock sodium thiosulphate pentahydrate is made up to 1000ml with distilled water to give 0.025N.

Do's and Dont's

- Label the BOD bottle with waterproof pen before collecting sample.
- Ensure that no air bubble enters the BOD bottle while filling it with water sample.
- Clean and different microtips should be used for each reagent.
- Handle the reagents and acids with extreme care. Wear disposable gloves if possible.
- Don't keep the BOD under direct sunlight while doing experiment as it will interfere with the results.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 3 Excessive 6
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

BIOLOGICAL OXYGEN DEMAND (BOD)	8

BIOLOGICAL OXYGEN DEMAND: BOD is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter (carbonaceous) in water under aerobic conditions. The test is used to determine the pollution load of wastewater, the degree of pollution and the efficiency of wastewater treatment methods. 5-Day BOD test being a bioassay procedure (involving measurement of oxygen consumed by bacteria for degrading the organic matter under aerobic conditions) requires the addition of nutrients and maintaining the standard conditions of pH and temperature and absence of microbial growth inhibiting substances.

The method consists of filling the samples in airtight bottles of specified size and incubating them at specified temperature (20 ^{o}C) for 5 days. The difference in the dissolved oxygen measured initially and after incubation gives the BOD of the sample.

Calculation:

$$\text{BOD, mg/L} = (D_0 - D_5) \times \text{Dilution factor}$$

Where,

D_0 = Initial DO in the sample

D_5 = DO of the sample after 5 days

Procedure

The sample having a pH of 7 is determined for first day DO. Various dilutions (at least 3) are prepared to obtain about 50% depletion of D.O. using sample and dilution water. The samples are incubated at 20 ^{o}C for 5 days and the 5th day D.O is noted using the Winkler's method. A reagent blank is also prepared in a similar manner.

Apparatus: BOD bottles - 125ml capacity, air incubator - to be controlled at 20 ^{o}C ± 1 ^{o}C, magnetic stirrer.

Reagents:

- **Manganous sulphate solution:** Dissolved 100 g of manganous sulphate in 200ml of distilled water and heated to dissolve salt and filtered after cooling.
- **Alkaline potassium iodide solution:** Dissolved 100 g of KOH and 50 g of KI in 200ml of pre-boiled distilled water.
- **Starch indicator:** 1g of starch is dissolved in 100 ml of warm distilled water.
- **Stock sodium thiosulphate (0.1 N)*:*** 24.82g of sodium thiosulphate pentahydrate ($N_{a2}S_2O_2$. $5H_2O$) is dissolved in distilled water and made up to 1000ml.
- **Standard sodium thiosulphate (0.025N):** 250ml of the stock sodium thiosulphate pentahydrate is made up to 1000ml with distilled water to give 0.025N.
- **Formaldehyde:** preservative for freshly prepared starch solution

Do's and Dont's

- Rinse the BOD bottles properly with distilled water before initiating the experiment.
- Label the BOD bottle with waterproof labels/pen before collecting sample.
- Ensure that no air bubble enters the BOD bottle while filling it with water sample.
- Handle the reagents and acids with extreme care. Wear disposable gloves if possible.
- Don't keep the BOD bottles under direct sunlight while doing experiment as it will interfere with the results.

*Alkaline KI – potential skin irritant

*Conc. H_2SO_4 – corrosive acid

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 10 Excessive 30

Inference	
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)

CHEMICAL OXYGEN DEMAND (COD)	**9**

CHEMICAL OXYGEN DEMAND: COD is the measure of oxygen equivalent to the organic content of the sample that is susceptible to oxidation by a strong chemical oxidant. The intrinsic limitation of the test lies in its ability to differentiate between the biologically oxidisable and inert material. It is measured by the open reflux method.

The organic matter in the sample gets oxidized completely by strong oxidizing agents such as potassium dichromate in the presence of conc. sulphuric acid to produce carbon-dioxide and water. The excess potassium dichromate remaining after the reaction is titrated with Ferrous Ammonium Sulphate (FAS) using ferroin indicator to determine the COD. The dichromate consumed gives the oxygen required for the oxidation of the organic matter.

Procedure

15ml of conc. sulphuric acid with 0.3g of mercuric sulphate and a pinch of silver sulphate along with 5ml of 0.025M potassium dichromate is taken into a Nessler's tube. 10ml of sample (thoroughly shaken) is pipetted out into this mixture and kept for about 90 minutes on the hot plate for digestion. 40ml of distilled water is added to the cooled mixture (to make up to 50ml) and titrated against 0.25M FAS using ferroin indicator, till the colour turns from blue green to wine red indicating the end point. A reagent blank is also carried out using 10ml of distilled water.

Calculation:

$$\text{COD, mg/L} = \frac{(b-a) \times N \text{ of FAS} \times 1000 \times 8}{\text{ml of sample}}$$

Where,

a = ml of titrant with sample.

b = ml of titrant with blank.

Apparatus: Reflux apparatus, Nessler's tube, Erlenmeyer flasks, hot plate and lab glassware.

Reagents:

- **Standard potassium dichromate solution (0.250M):** 12.25g of potassium dichromate dried at 103 ^{o}C for about 2 hours is dissolved in distilled water and made up to 1000ml.
- **Standard ferrous ammonium sulphate (FAS) 0.25N:** 98g of FAS is dissolved in minimum distilled water to which 20ml of conc. sulphuric acid is added and made up to 1000ml using distilled water to give 0.25N of ferrous ammonium sulphate.
- **Ferroin indicator:** 1.485g of 1,10-Phenanthroline monohydrate and 695mg of ferrous sulphate is dissolved in 100ml of distilled water.
- **Conc. sulphuric acid**
- **Silver sulphate crystal**
- **Mercuric sulphate crystals**

Do's and Dont's

- Label the cleaned Erlenmeyer flasks properly.
  .
- Handle the reagents and acids with extreme care.
- It is safe to wear gloves.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 30 Excessive 100
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

FREE CARBON-DIOXIDE	10

FREE CARBON-DIOXIDE: The important source of free carbon-dioxide in surface water bodies is mainly respiration and decomposition by aquatic organisms. It reacts with water partly to form calcium bicarbonate and in the absence of bicarbonates gets converted to carbonates releasing carbon-dioxide.

Procedure

A known volume (25ml) of the sample was measured into a conical flask. 2-3 drops of phenolphthalein indicator was added and titrated against 0.22N sodium hydroxide till the pink colour persisted indicating the end point.

If the pink colour appears on adding phenolphthalein it indicates the absence of free carbon-dioxide.

Apparatus: Lab glassware - measuring cylinder, pipette, conical flask, etc.

Reagents:

- **Sodium hydroxide solution (0.22N):** 1g of sodium hydroxide was dissolved in 100ml of distilled water and made up to 1000ml to give 0.22N.
- **Phenolpthalein indicator:** Dissolve 0.5 g of phenolphthalein in 50 ml of 95% ethanol and add 50 ml of distilled water. Add 0.05 N CO_2 free NaOH solution dropwise, until the solution turns faintly pink.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Handle the reagents and acids with extreme care.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible Excessive
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

ALKALINITY	11

ALKALINITY: In natural water, that are not highly polluted alkalinity is more commonly found than acidity. Alkalinity is the good indicator of presence of dissolved inorganic carbon (bicarbonates and carbonate anions). Some of the minor contributions to alkalinity come from ammonia, phosphates, borates, silicates and other basic substances.

Alkalinity is beneficial to aquatic animals and plants, because it buffers both the natural and human induced pH changes. Water with high alkalinity generally have a high concentration of dissolved inorganic carbon (in the form of HCO_3^- and CO_3^{2-}), which can be converted to biomass by photosynthesis.

Titrating a basic water sample with acid to pH 8.3 measures phenolphthalein alkalinity. Phenolphthalein alkalinity primarily measures the amount of carbonate ion (CO_3^{2-}) present in the sample. Titrating with acid to pH 3.7 measures methyl orange alkalinity or total alkalinity. Total alkalinity measures the neutralizing effects of all the bases present.

Calculate total phenolphthalein and methyl orange alkalinity as follows and express in mg/L as $CaCO_3$,

$$\text{P Alkalinity m mg/L as } CaCO_3 = \frac{A*1000}{\text{ml sample}}$$

$$\text{T Alkalinity m mg/L as } CaCO_3 = \frac{B*1000}{\text{ml sample}}$$

Where,

A= ml of H_2SO_4 required to raise pH up to 8.3

B= ml of H_2SO_4 required to raise pH up to 4.5

Procedure

Measure a suitable volume of sample in 250 ml conical flask. Add 2-3 drops of phenolphthalein indicator. If the pink colour develops titrate against 0.02 N H_2SO_4, till the colour disappears, which is the characteristic of pH 8.3.Note down the volume of H_2SO_4 consumed. Add 2-3 drops of methyl orange and continue titration with H_2SO_4 till the yellow colour changes to orange, which is the characteristic of pH 4.5. Note down the additional amount of H_2SO_4 required. In case pink colour does not appear after addition of phenolphthalein, continue with addition of methyl orange.

Apparatus: Lab glassware - measuring cylinder, pipette, conical flask, etc.

Reagents

1. **Standard sulphuric acid (0.02N):** Dilute 200 ml of 0.1N H_2SO_4 with distilled water to 1000ml to obtain standard 0.02N H_2SO_4.
2. **Phenolphthalein indicator:** Dissolve 0.5g phenolphthalein in 1:1 of 95 % ethanol and distilled water. Add 0.05 N CO_2 free NaOH solution drop wise until faint pink colour appears.
3. **Methyl orange indicator:** Dissolve 0.5 g of methyl orange in 1000ml CO_2 free distilled water.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Handle the reagents and acids with extreme care.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible Excessive 500
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

TOTAL HARDNESS	12

TOTAL HARDNESS: Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring a considerable amount of soap to lather.Hardness is predominantly caused by divalent cations such as calcium, magnesium and alkaline earth metals such as iron, manganese, strontium, etc. The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/L. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness.

In alkaline conditions EDTA (Ethylene-diamine tetra acetic acid) and its sodium salts react with cations forming a soluble chelated complex when added to a solution. If a small amount of dye such as Eriochrome black-T is added to aqueous solution containing calcium and magnesium ions at alkaline pH of 10.0 ± 0.1, it forms wine red colour. When EDTA is added as a titrant, all the calcium and magnesium ions in the solution get complexed resulting in a sharp colour change from wine red to blue, marking the end point of the titration. Hardness of water prevents lather formation with soap rendering the water unsuitable for bathing and washing. It forms scales in boilers, making it unsuitable for industrial usage. At higher pH >12, Mg^{++} ion precipitates with only Ca^{++} in solution. At this pH, murexide indicator forms a pink color with Ca^{++} ion. When EDTA is added Ca^{++} gets complexed resulting in a change from pink to purple indicating end point of the reaction.

METAL + INDICATOR ⟶ METAL-INDICATOR COMPLEX (WINE RED COLOUR)

METAL-INDICATOR COMPLEX + EDTA ⟶ METAL-EDTA COMPLEX + INDICATOR (BLUE COLOUR)

Calculation:

$$\text{Total hardness (mg/L)} = (T)\,(1000) / V$$

Where, T = Volume of titrant

V = Volume of sample

Hardness Chart *(for drinking water)*:

Soft	0 – 60 mg/L
Medium	60 –120 mg/L
Hard	120 - 180 mg/L
Very Hard	> 180 mg/L

Procedure

The complete titration should be completed within 5 minutes after addition of the buffer. Take 25 ml of the sample (dilute it with distilled water if required) and add 1-2 ml of the buffer solution and 1-2 g of EBT indicator. Then titrate against the EDTA, with continuous stirring; until the last reddish tinge disappears. At the end point the solution gives blue colour.

Apparatus: Lab glassware-burette, pipette, conical flask, beakers etc.

Reagents:

1. **Buffer solution**: (a) 16.9 g of ammonium chloride was dissolved in 143ml of concentrated ammonium hydroxide. (b) Dissolve 1.179 g of disodium EDTA and 0.780 g of $MgSO_4$. $7H_2O$ in 50 ml distilled water. Mix both (a) and (b) and dilute to 250ml with distilled water
2. **Standard EDTA indicator:** (0. 01 M) Weigh 3.723 g of EDTA and dissolve in 1000 ml of distilled water and standardize against standard calcium solution.
3. **EBT Indicator:** Mix 0.40 g of Eriochrome Black T with 100 g NaCl (AR) and grind.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids with extreme care.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 150 Excessive 500
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

CALCIUM HARDNESS	13

CALCIUM HARDNESS: The presence of calcium (fifth most abundant) in water results from passage through or over deposits of limestone, dolomite, gypsum and such other calcium bearing rocks. Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates. Calcium carbonate solubility is controlled by pH and dissolved CO_2. The salts of calcium, together with those of magnesium are responsible for hardness of water. Calcium is an important element for all organisms and is incorporated in to the shells of many aquatic invertebrates, as well as the bones of vertebrates. Calcium concentrations in natural waters are typically <15 mg/l. For water associated with carbonate rich rocks, concentrations may reach 30-100 mg/l. Salt waters have concentrations of several hundred milligrams per litre or more.

When EDTA (Ethylene-diamine tetra acetic acid) is added to the water containing calcium and magnesium, it combines first with calcium. Calcium can be determined directly with EDTA when pH is made sufficiently high such that the magnesium is largely precipitated as hydroxyl compound (by adding NaOH and iso-propyl alcohol). When murexide indicator is added to the solution containing calcium, all the calcium gets complexed by the EDTA at pH 12-13. The end point is indicated from a colour change from pink to purple.

Calculation

$$\text{Calcium hardness as } CaCO_3 = \frac{A*B*1000}{\text{ml of sample taken}} * \text{Dilution factor (If diluted)}$$

Where, A = ml titrant for sample and B = mg Caco3 equivalent to 1.0 ml EDTA titrant.

Procedure

A known volume (25ml) of the sample is pipetted into a clean conical flask, to which 1ml of sodium hydroxide is added. A pinch of murexide indicator is added to this mixture and titrated against EDTA until the pink color turns purple.

Apparatus: Burettes, pipette, conical flask, beakers and droppers

Reagents:

1. **Sodium hydroxide (8%):** 8g of sodium hydroxide is dissolved in 100ml of distilled water.
2. **Murexide indicator (ammonium purpurate):** 0.2 g of murexide is ground well with 100g of sodium chloride.
3. **Standard EDTA titrant, 0.01M:** 3.723 g of EDTA (disodium salt) is dissolved in distilled water and made up to 100ml with the same.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids with extreme care.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 75 Excessive 200 *Calcium (as Ca) mg/l
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

MAGNESIUM HARDNESS	**14**

MAGNESIUM HARDNESS: Magnesium is a relatively abundant element in the earth's crust, ranking eighth in abundance among the elements. It is found in all natural waters and its source lies in rocks, generally present in lower concentration than calcium. It is also an important element contributing to hardness and a necessary constituent of chlorophyll. Its concentration greater than 125 mg/L can influence cathartic and diuretic actions.

Magnesium hardness can be calculated from the determined total hardness and calcium hardness.

Magnesium = (T - C) x 0.243 (as mg/L)

where, T = Total hardness mg\L (as $CaCO_3$)

C = Calcium hardness mg\L (as $CaCO_3$)

High concentration of magnesium proves to be diuretic and laxative, and reduces the utility of water for domestic use while a concentration above 500 mg/L imparts an unpleasant taste to water and renders it unfit for drinking. Chemical softening, reverse osmosis and electro dialysis or ion exchange reduces the magnesium hardness to acceptable levels.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 50 Excessive 150 *Magnesium (as Mg) mg/l
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

CHLORIDES	**15**

CHLORIDES: Chloride (Cl^-) enters surface waters by the atmospheric deposition of oceanic aerosols with the weathering of some sedimentary rocks (mostly rock salt deposits), industrial effluents and agricultural run-off. High concentrations of chloride can make waters unpalatable and therefore unfit for drinking or livestock watering. Chloride is an abundant anion found in the wastewaters and is a good indicator of pollution sources. Chloride gives water a salty taste detectable at a level of 250 ppm with sodium as cation, but with Ca and Mg cations, the salty taste is not detectable until the chloride concentration reaches up to 1000 ppm. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants. They are calculated by Argentometric method.

In alkaline or neutral solution, potassium chromate indicates the endpoint of the silver nitrate titration of chlorides. Silver chloride is quantitatively precipitated before the red silver chromate is formed.

$$Ag^+ + Cl^- \longrightarrow AgCl \text{ (White precipitate)}$$

$$2Ag^+ + CrO^{-4} \longrightarrow Ag_2CrO_4 \text{ (Red precipitate)}$$

Calculation

$$\text{Chlorides mg/L} = \frac{(A-B)*N*35.45*1000}{\text{ml sample}}$$

Where, A = ml $AgNO_3$ required for sample.

B = ml $AgNO_3$ required for blank.

Procedure

A known volume of filtered sample (50ml) is taken in a conical flask, to which about 0.5ml of potassium chromate indicator is added and titrated against standard silver nitrate till silver chromate (Ag_2CrO_4) starts precipitating.

Apparatus: Lab glassware, pipette.

Reagents:

1. **Potassium chromate indicator solution:** 50g of potassium chromate is dissolved in minimum amount of distilled water and silver nitrate is added drop wise till a red precipitate is formed. The mixture is allowed to stand for about 12 hours and diluted to 1000ml with distilled water.
2. **Silver nitrate solution (0.014N):** 2.395g of silver nitrate is dissolved in distilled water and made up to 1000ml.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids with extreme care.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 250 Excessive 600
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

POTASSIUM	16

POTASSIUM: Potassium ranks seventh among the elements in order of abundance, behaves similar to sodium and remains low. Though found in small quantities (<20mg/L), it plays a vital role in the metabolism of fresh water environment.

Trace amounts of potassium can be determined by direct reading of flame photometer at a specific wavelength of 766.5nm by spraying the sample into the flame. The desired spectral lines are then isolated by the use of interference filters or suitable slit arrangements. The intensity of light is measured by the phototube.

Working principle of Flame photometer: The emission of characteristic radiations by alkali and alkaline earth metals and the correlation of the emission intensity with the concentration of the element form the basis of flame photometry. The principle of the flame photometer depends on the "Emission Spectroscopy" in which the electrons of the metals after absorbing energy get excited from ground state to higher energy level and return back to the ground state with emission of light. The sample under test is introduced into flame in solution by means of atomizer. The radiation from the flame enters a dispersing device and isolates it (radiation) from the flame to the desired region of the spectrum. The photo tube measures the intensity of isolated radiation, which is proportional to the concentration of the element present in the sample.

Calculation:

Potassium (K) or Sodium (Na), mg/L

= (mg/L of K/Na in diluted aliquot) x dilution factor

Procedure

The filter of the flame photometer is set at 766.5nm (marked for Potassium, K) and the flame is adjusted for blue colour. The scale is set to zero and maximum using the highest standard value. A standard curve of different concentration is prepared by feeding the standard solutions. The sample is filtered through the filter paper and fed into the flame photometer. The concentration is found from the standard curve or as direct reading.

Apparatus: Flame photometer, lab glassware and Whattman filter paper.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids with extreme care.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible Excessive
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

SODIUM	**17**

SODIUM: Sodium is one of the most abundant elements and is a common constituent of natural waters. The sodium concentration of water is of concern primarily when considering their solubility for agricultural uses or boiler feed water. The concentration ranges from very low in the surface waters and relatively high in deep ground waters and highest in the marine waters. It is calculated by flame photometric method.

Procedure

The filter of the flame photometer is set to 589nm (marked for Sodium, Na). By feeding distilled water the scale is set to zero and maximum using the standard of highest value. A standard curve between concentration and emission is prepared by feeding the standard solutions. The sample is filtered through filter paper and fed into the flame photometer and the concentration is found from graph or by direct readings.

Apparatus: Flame photometer, lab glassware and Whattman filter paper.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids and gas of flame photometer with extreme care.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible Excessive
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

NITRATES	18

NITRATES: Nitrate ion (NO_3^-) is the common form of combined nitrogen found in natural waters. It may be bio chemically reduced to nitrite (NO_2^-) by denitrification processes, usually under anaerobic conditions. The nitrite ion is rapidly oxidized to nitrate. Natural sources of nitrate to surface water include igneous rocks, domestic sewage, land drainage and plant growth and decay. The natural concentration of nitrate is 0.1mg/L; it may be enhanced by sewage, industrial effluents and nitrate fertilizers.

Ammonia and other nitrogenous material in natural waters tend to be oxidized by aerobic bacteria first to nitrite and then nitrates. So all organic compounds containing nitrogen are potential source of nitrates. It is first oxygenated to nitrite (NO_2^-) and is rapidly oxidized to nitrate (NO_3^-) so normally the amount of nitrite is very low. High concentrations (>1-2 mg/L) of nitrate or nitrite in surface or ground water generally indicate agricultural contamination from fertilizers and manure.

NITRIFICATION

$$\text{Ammonia} \xleftrightarrow[\text{ADB}]{(O)} \text{Nitrite} \xleftrightarrow[\text{FAB}]{(R)} \text{Nitrates}$$

ADB = Aerobic Denitrifying Bacteria. Ex: Nitrosomes

FAB = Facultative Anaerobic Denitrifying Bacteria. Eg: Pseudomonas

Estimation of nitrates by electrode screening method

The NO_3^- ions electrode is a selective sensor that develops a potential across a thin, porous, inert membrane that holds in a place a water-immiscible liquid ion exchanger. The electrode responds only to NO_3^- ion activity between about 10^{-5} and 10^{-1} M (0.14 to 1400 mg NO_3^- -N/L). The lower limit of detection is determined by the small but finite solubility of the liquid ion exchanger.

Procedure

A known volume (50ml) of the sample is pipetted into a porcelain dish and evaporated to dryness on a hot water bath. 2ml of phenol disulphonic acid is added to dissolve the residue by constant stirring with a glass rod. Concentrated solution of sodium hydroxide or conc. ammonium hydroxide and distilled water is added with stirring to make it alkaline. This is filtered into a Nessler's tube and made up to 50ml with distilled water. The absorbance is read at 410nm using a spectrophotometer after the development of colour. The standard graph is plotted by taking concentration along X-axis and the spectrophotometric readings (absorbance) along Y-axis. The value of nitrate is found by comparing absorbance of sample with the standard curve and expressed in mg/L.

Apparatus: Porcelain dishes, pipettes, standard flasks, beakers, spectrophotometer, cuvettes, measuring jar and hot water bath.

Reagents:

 Phenol disulphonic acid: 25 g of phenol is dissolved in 150 ml of concentrated sulphuric acid, to which 85ml of sulphuric acid is further added and heated for about 90 min on a water bath and stored in dark bottles upon cooling.

 Sodium hydroxide: About 50g of sodium hydroxide is dissolved in 150-200 ml of water and cooled.

 Conc. Ammonium hydroxide (Liquid ammonia)

Nitrate solution:

- **Stock nitrate solution:** 721.8 mg (0.722g) of AR potassium nitrate is dissolved in distilled water and made up to 100ml for stock solution.
- **Standard nitrate solution:** Standard nitrate solution is prepared by evaporating 50ml of the stock solution to dryness in the water bath. The obtained residue is dissolved in 2ml of phenol disulfonic acid and diluted to 500ml, to give 1ml = 10

μg. The solution of various strengths ranging from 0.0 (blank) to 1.0 mg/L at the intervals of 0.2 mg/L is prepared by diluting stock solution with distilled water.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids with extreme care.

Results

Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 45 Excessive
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

PHOSPHATES	**19**

PHOSPHATES: Phosphates are an essential nutrient for living organisms and exist in water bodies on both forms as dissolved and particulate species. Phosphorus concentration is limiting factor for algae growth. Artificial increase in phosphorous concentration in aquatic system results in eutrophication. In natural water and wastewater phosphorous occurs as orthophosphates, polyphosphates and organically bound phosphates.

Orthophosphates applied to agricultural land as a fertilizer, finds its way to the surface water by runoff. The condensed phosphate like pyrophosphates and polyphosphates comes to environment from the heavy-duty detergents (Sodium tri polyphosphate $Na_5P_3O_{10}$). Biological processes are the only source for organic phosphates, such as weathering of rock and decomposition of organic matter.

Estimation of phosphorous by stannous chloride Method

In the acidic condition, orthophosphates reacts with ammonium molybdate to form molybdophosphoric acid. It is further reduced to intensely coloured molybdenum blue colour by adding the reducing agent stannous chloride. The intensity of the coloured complex is measured at 690nm, which is directly proportional to the concentration of phosphates present in the sample.

$$PO_4 + 12(NH_4)_2MoO_4 + 24H^+ \longrightarrow (NH_4)PO_4.12MoO_3 + 21NH_4^+ + 12H_2O$$

$$(NH_4)_3PO_4.12\ MoO_3 + Sn^{2+} \longrightarrow \text{Molybdenum blue} + Sn^{4+}$$

Calculation

Mg/L of phosphates = Test absorbance * Slope * Dilution factor

$$\text{Where, Slope} = \frac{\text{Sum of concentration of Standards}}{\text{Sum of absorbance of Standards}}$$

Dilution ratio (D) = $\frac{\text{ml sample + ml distilled water}}{\text{ml sample}}$

Procedure

Take the appropriate aliquot of sample (as per the expected concentration of phosphates) in the Nessler tube. Add 2ml of ammonium molybdate and mix well. Add 0.5 ml of stannous chloride and make up to the mark with distilled water. Prepare the blank using the distilled water instead of sample. Measure the intensity of light path at 690 nm.

Apparatus: Spectrophotometer, lab glassware, hot plate and Nessler's tube.

Reagents

1) Standard phosphate solution: Dissolve 219.5 mg of anhydrous KH_2PO_4 in 1000ml of water (1 ml = 0.5 mg PO_4).
2) Ammonium molybdate solution:
    a) Dissolve 25 g ammonium molybdate in 175 ml distilled water.
    b) Add cautiously 280 ml concentrated sulphuric acid to 400ml water and cool.

    Mix two solutions (a) and (b) and make up to 1000ml.
3) Stannous Chloride: Dissolve 2.5 g $SnCl_2$. 2 H_2O in the 100ml glycerol. Heat in water bath to ensure complete dissolution. Prepare stannous chloride freshly.

Do's and Dont's

- Ensure that the Erlenmeyer flasks to be used are washed properly and labeled.
- Don't keep the reagent bottle open.
- Handle the reagents and acids with extreme care.

Results					
Date	**S1**	**S2**	**S3**		**Limits (Inland)**
					Permissible 2 Excessive 5
Inference					
References	APHA (1998); Trivedi R. K. and Goel P. K. (1986); Ramachandra T. V. and Ahalya N. (2001)				

Table: Surface Water Quality Standards (as per IS: 2296).

Class A – Drinking water without conventional treatment but after disinfection. Class B –Water for outdoor bathing. Class C – Drinking water with conventional treatment followed by disinfection. Class D – Water for fish culture and wild life propagation. Class E – Water for irrigation, industrial cooling and controlled waste disposal. (Unobj = Unobjectionable).

Sl	Parameter and Unit	A	B	C	D	E
1	Taste	None	--	--	--	--
2	Odour	Unobj	--	--	--	--
3	Colour (True) (Hazen unit)	10	300	300	--	--
4	pH (max) (min : 6.5)	8.5	8.5	8.5	8.5	8.5
5	Conductivity (25oC) uS/cm	--	--	--	1000	2250
6	DO (mg/L) (minimum)	6	5	4	4	--
7	BOD (3d, 27oC) (mg/L)	2	3	3	--	--
8	Total Coliforms (MPN/100 mL)	50	500	5000	--	--
9	TDS (mg/L)	500	--	1500	--	2100
10	Oil and Grease (mg/L)	--	--	0.1	0.1	--
11	Mineral oil (mg/L)	0.01	--	--	--	--
12	Total Hardness (mg/L as CaCO3)	300	--	--	--	--
13	Chlorides (mg/L as Cl)	250	--	600	--	600
14	Sulfates (mg/L as SO4)	400	--	400	--	1000
15	Nitrates (mg/L as NO3)	20	--	50	--	--
16	Free CO2 (mg/L)	--	--	--	6	--
17	Free NH3 (mg/L as N)	--	--	--	1.2	--
18	Fluorides (mg/L as F)	1.5	1.5	1.5	--	--
19	Calcium (mg/L)	80.10	--	--	--	--
20	Magnesium (mg/L)	24.28	--	--	--	--
21	Copper (mg/L)	1.5	--	1.5	--	--
22	Iron (mg/L)	0.3	--	50	--	--
23	Manganese (mg/L)	0.5	--	--	--	--

24	Zinc (mg/L)	15	--	15	--	--
25	Boron (mg/L as B)	--	--	--	--	2
26	Barium (mg/L)	1	--	--	--	--
27	Silver (mg/L)	0.05	--	--	--	--
28	Arsenic Total (mg/L)	0.05	0.2	0.2	--	--
29	Mercury (mg/L)	0.001	--	--	--	--
30	Lead (mg/L)	0.1	--	0.1	--	--
31	Cadmium (mg/L)	0.01	--	0.01	--	--
32	Chromium (VI) (mg/L)	0.05	0.05	0.05	--	--
33	Selenium (mg/L)	0.01	--	0.05	--	--
34	Cyanide (mg/L as CN)	0.05	0.05	0.05	--	--
35	Phenols (mg/L)	0.002	0.005	0.005	--	--
36	Anionic detergents (mg/L as MBAS)	0.2	1	1	--	--
37	PAH (mg/L)	0.2	--	--	--	--
38	Pesticides (ug/L)	0	--	--	--	--
39	Insecticides (ug/L)	--	--	0	--	--
40	Alpha emitters (10^{-6}uC/mL)	0.001	0.001	0.001	0.001	0.001
41	Beta emitters (10^{-6}uC/mL)	0.01	0.01	0.01	0.01	0.01
42	Percent Sodium (%)	--	--	--	--	60
43	Sodium Absorption Ratio	--	--	--	--	26

BIOLOGICAL PARAMETERS

PLANKTON ANALYSIS: The physical and chemical characteristics of water affect the abundance, species composition, stability and productivity of the indigenous populations of aquatic organisms. The biological methods used for assessing water quality includes collection, counting and identification of aquatic organisms; biomass measurements; measurements of metabolic activity rates; toxicity tests; bioaccumulation; biomagnifications of pollutants; and processing and interpretation of biological data. The work involving plankton analysis would help in:

1. Explaining the cause of colour and turbidity and the presence of objectionable odour, tastes and visible particles in waters.
2. The interpretation of chemical analyses.
3. Identifying the nature, extent and biological effects of pollution.
4. Providing data on the status of an aquatic system on a regular basis.

Plankton: A microscopic community of plants (phytoplankton) and animals (zooplankton), found usually free floating, swimming with little or no resistance to water currents, suspended in water, non-motile or insufficiently motile to overcome transport by currents, are called "Plankton".
Phytoplankton (microscopic algae) usually occurs as unicellular, colonial or filamentous forms and is mostly photosynthetic and is grazed upon by the zooplankton (microscopic protozoans, rotifers, cladocerans and copepods) and other organisms occurring in the same environment.

The structure of photosynthetic populations in the aquatic ecosystems is dynamic and constantly changing in species composition and biomass distribution. An understanding of the community structure is dependent on the ability to understand the temporal distribution of the different species. Changes in species composition and biomass may affect photosynthetic rates, assimilation efficiencies, rates of nutrient utilization, grazing, etc.
Plankton, particularly phytoplankton, has long been used as indicators of water quality. Because of their short life spans, planktons respond quickly to environmental changes. They flourish both

in highly eutrophic waters while a few others are very sensitive to organic and/or chemical wastes. Some species have also been associated with noxious blooms causing toxic conditions apart from the tastes and odour problems.
Plankton net: The plankton net is a field-equipment used to trap plankton. It has a polyethylene filter of a defined mesh size and a graduated measuring jar attached to the other end. A handle holds the net. The mesh size of the net determines the size range of the plankton trapped. The mesh number 30 of size 60 mm was used for collecting samples.
Sampling Procedure: The manner in which sampling is done should conform to the objectives of the study. The "surface samples" (samples collected from the surface) are collected as close to the water surface as possible, mostly towards the center of the lake at regular monthly intervals. A known volume of the sample, 5L to 50 L is filtered and planktons are filtered and preserved for further analysis.
Labels: The sample label has the date, time of sampling, study area-lake name and the volume measured and pasted on the containers of 50 ml capacity.
Preservation: The samples are collected into 100 ml polyethylene vials and are preserved by adding suitable amounts of 1ml chloroform to act as the narcotizing agent and 2 ml of 2% formalin for preservation and analyses.
Concentration technique: The plankton nets are used to collect samples for the qualitative and quantitative estimation of the plankton, by filtering a known volume of water (5-50 liters) through the net depending on the plankton density of the tanks.

Qualitative and quantitative evaluation of plankton: Detailed analyses of phytoplankton populations are done by estimating the numbers in each species. The phytoplankton consisting of individual cells, filaments and colonies are counted as individual cells. When colonies of species are counted, the average number of cells per colony is counted, and in filamentous algae, the average length of the filament has to be determined.

Sedimentation and enumeration by microscope: Preserved samples in bottles are mixed uniformly by gentle inversion and then exactly 1ml of the sample is pipetted out into the S-C cell for analysis.

Microscope

Compound microscope: A monocular compound microscope is used in the counting of plankton with different eyepieces such as 4X, 10X and 40X. The microscope is calibrated using plankton-counting squares.

Counting

Counting cell- Sedgwick-Rafter (S-R) cell: The Sedgwick-Rafter cell is a devise used for plankton counting and is about 50mm long by 20mm wide and 1mm deep. The cell is covered by a relatively thick cover slip and is calibrated to contain exactly 1.0 ml.

Method

Filling the cell: The cover slip is placed diagonally across the S-R cell and filled with the sample carefully without air bubbles with a large bore pipette. The sample is allowed to settle for about 5 minutes before the actual counting begins.

Note: Since the configuration of the S-R cell does not allow the use of high power microscope objectives, the identification of organisms smaller than 10 – 15 mm is difficult or impossible, limiting the usage to only larger forms of relatively dense populations.

Strip counting: A "strip" is the length of the cell that constitutes a volume approximately 50 mm long, 1-mm deep accounting to the volume of 25mm^3 or 1/40 (2.5%) of the total cell volume. By moving the mechanical stage from left to right, the organisms can be examined in a systematic manner. By knowing the surface area of the portion counted in relation to that of the total, a factor is determined to expand the average counts of the plankton to the total area of the counting surface. This total area represents the number of organisms present per given volume of the sample. This volume expanded to an appropriate factor yields the organisms per litre of water for the lake.

The total number of planktons in the S-R cell is obtained by multiplying actual count in the strip by the number (enumeration factor) representing the portion of the S-R cell counted. The number of the strips counted is a function of the precision desired and the number of units (cells, colonies) for the strips measured. In this study, 500 cells were counted for estimation.

The plankton count in the S-R cell is got from the following,

$$\text{Number/ml} = \frac{C \times 1000 \text{ mm}}{L \times D \times W \times S}$$

Where

C = Number of organisms counted
L = Length of each strip (S-R cell length) mm
D = Depth of a strip (S-R cell depth) mm
W = Width of a strip in mm
S = Number of strips counted

$V_1 = (50)(1)(W)$

$= \quad mm^3$

The plankton counts per strip are then determined by multiplying the actual count by the factor representing the counted portion of the whole S-R cell volume.

$$\text{Number/ml} = (C)\ (1000\ mm^3) / (L)\ (D)\ (W)\ (S)$$

Where

C = Number of organisms counted.
L = Length of each strip in mm (of S-R cell)
D = Depth of the strip in mm (S-R cell)
W = Width of the strip in mm (Whipple grid image width)
S = Number of strips counted.

Phytoplankton Counting Units: Some plankton are unicellular while others are multicellular (colonial), posing a problem for enumeration. For analysis, a colony of plankton is accounted as a single count. The large forms that cross two or more boundaries of the grid are counted separately at lower magnification and their number included in the total count.

COMMONLY FOUND ALGAL GROUPS IN LAKES

Bacillariophytes: They occur in fresh water, salt water, and terrestrial ecosystems. They are single-celled algae with shells constructed of two overlapping valves composed of pectin and impregnated with silica. Amorphous silica is the form of silicon in diatom cell walls. The diatoms are single-celled or unicellular organisms, but some can form colonies and filaments. They may occur as plankton or periphyton, with most brownish-green films on substrates such as rocks or aquatic plants being composed of attached diatoms. The Bacillariophytes comprises two main types: centric and pennate. Centric diatoms are radially symmetrical and pennate diatoms that are bilaterally symmetrical. Many diatoms have conspicuous oil droplets within the cell, which is the photosynthetic food reserve, chrysolaminarin. The diatoms contain the pigments chlorophyll *a* and *b*, alpha and beta carotene, and several xanthophylls.

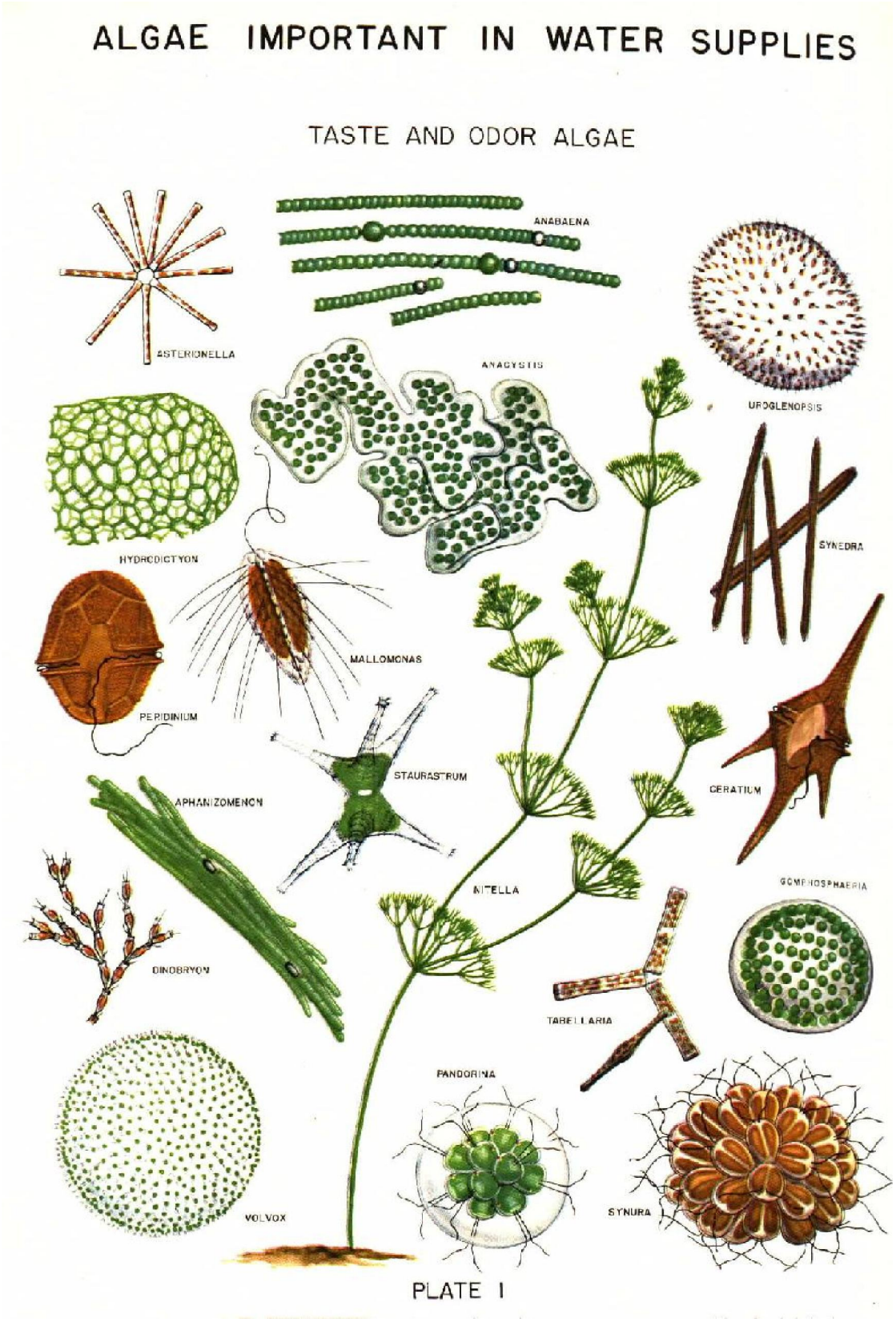
Example: *Nitzschia* sp., *Cymbella* sp., *Melosira* sp., *Navicula* sp., *Gomphonema* sp., *Cyclotella* sp., *Pinnularia* sp., *Gyrosigma* sp., etc.

Euglenoids: Typically green and unicellular, euglenoid flagellates occur in most freshwater habitats: puddles, ditches, ponds, streams, lakes, and rivers, particularly waters contaminated by animal pollution or decaying organic matter. Most are photosynthetic, but many, lacking chloroplasts are heterotrophs. Most do not reproduce sexually. Euglenoids lack a cellulose cell wall; instead, they have a proteinaceous pellicle just inside the plasmalemma. Euglenoids are characterized by chlorophylls *a*, *b*, beta carotene, and xanthophylls, one membrane of chloroplast endoplasmic reticulum, a mesokaryotic nucleus, two emergent flagella with fibrillar hairs in one row and paramylon or chrysolaminarin as the storage product in the cytoplasm. They have eyespot (stigma) which is a collection of orange-red lipid droplets. If placed in the dark over the course of several divisions, the chloroplasts of *Euglena gracilis* will become colorless. When returned to the light, the plastid structure is reformed and the green color returns. All euglenoid species with an eyespot and flagellar swelling exhibit phototaxis, usually swimming away from bright light (negative phototaxis) and away from darkness toward subdued light (positive photoaxis) to accumulate in a region of low light intensity.

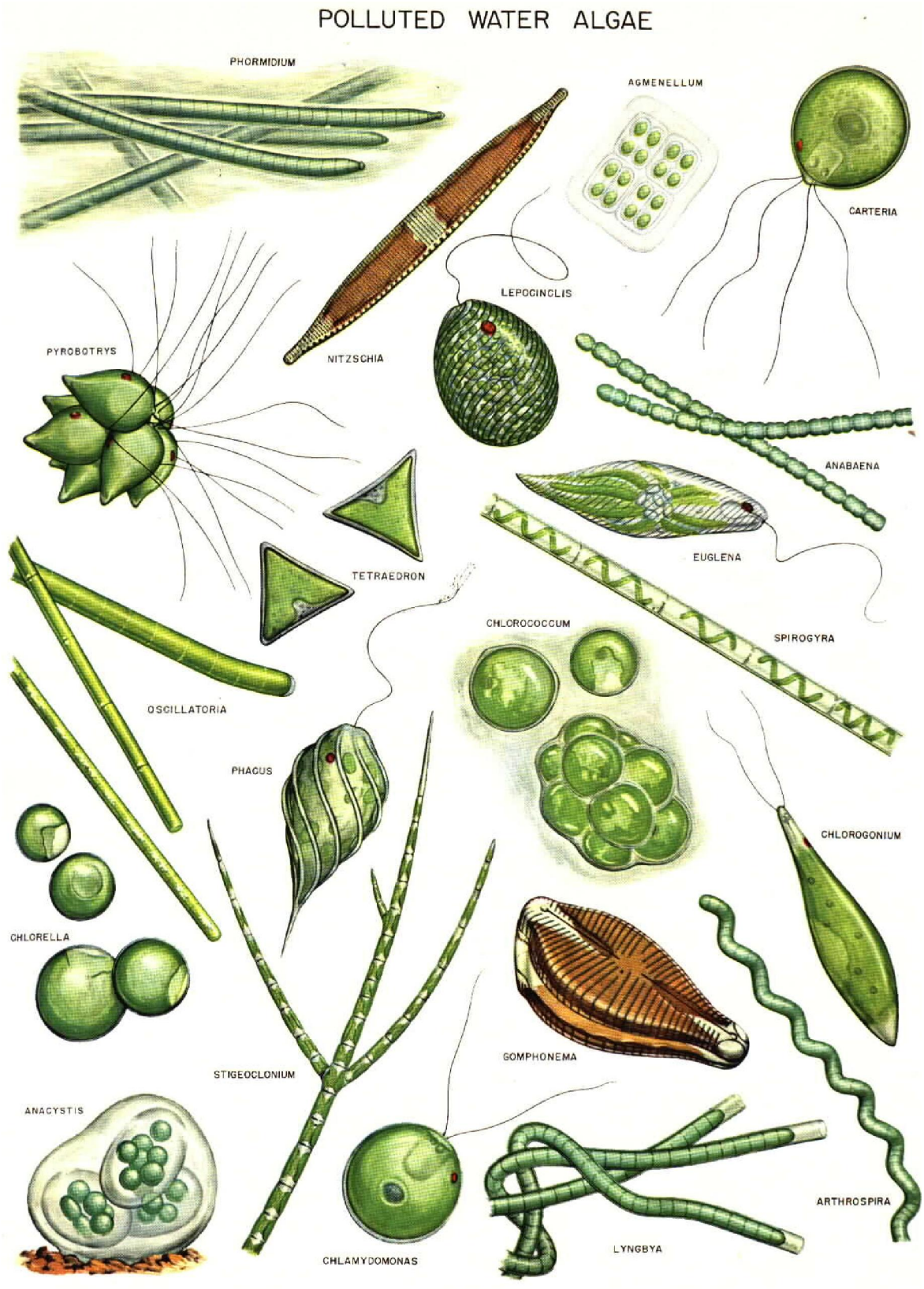
Example: *Euglena* sp., *Phacus* sp., *Trachelomonas* sp., etc.

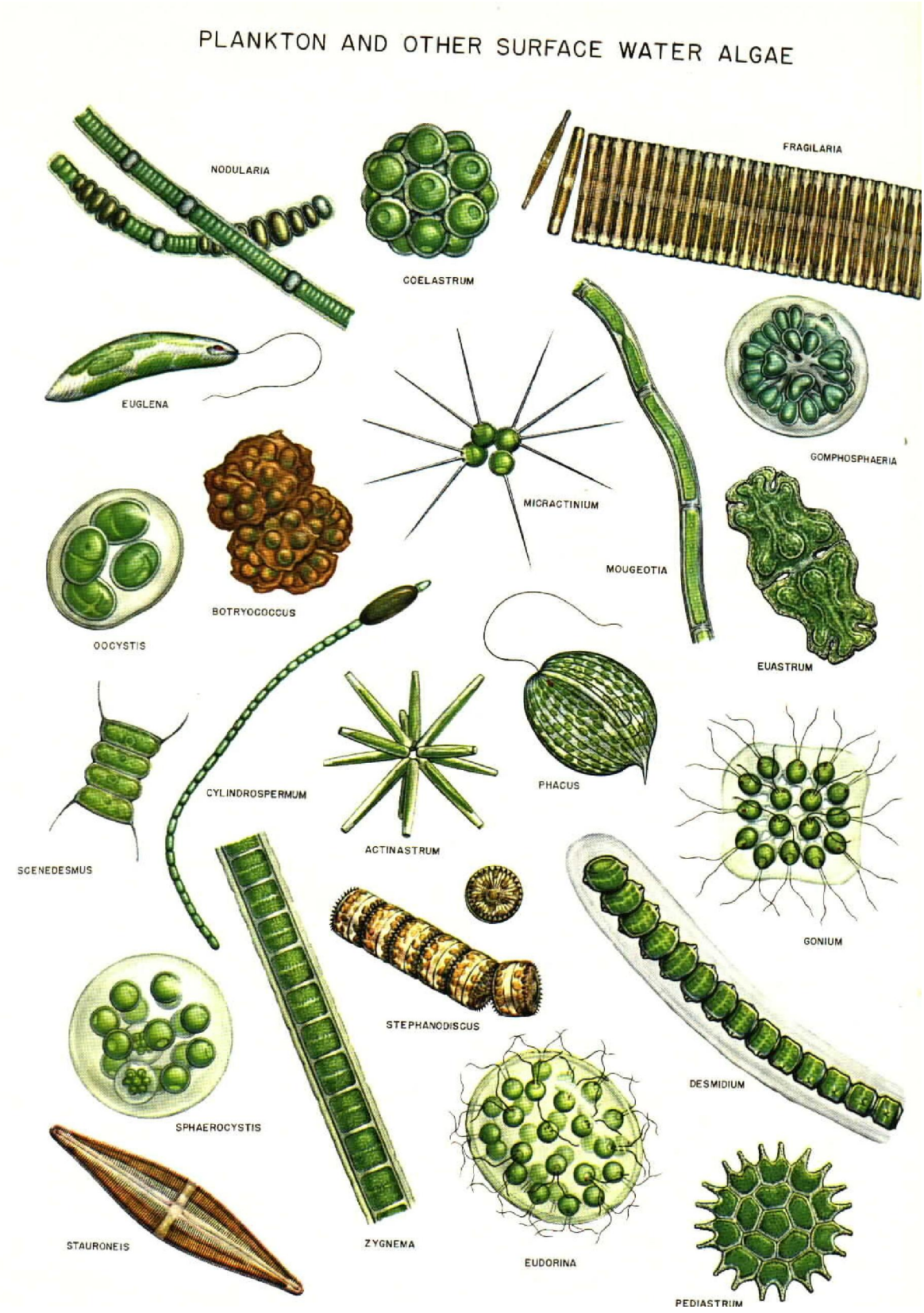
Blue-Green Algae (Cyanobacteria): The cyanophytes are the only prokaryotic algae and lack membrane bound organelles. Cyanobacteria are aerobic phototrophic organisms that can perform photosynthesis as they possess chlorophyll a and photosystem II. They are ubiquitous in nature and are found in every type of environment including terrestrial, freshwater, and marine habitats. Blue green algae are very common in waters of a great range of salinity and temperature, and they occur in and on the soil and also on rocks and in their fissures. However, the external structure can range from unicellular or colonial to branched or unbranched and filamentous. The cyanobacterial cells possess a number of cell inclusion bodies like include phycobilisomes, carboxysomes, glycogen granules, polyphosphate granules, poly-β –hydroxybutyrate granules, cyanophycin granules and gas vesicles. The cyanophytes possess no flagellated or cilliated cells at any stage of their lifecycle, although, simple movements such as bending and swaying are made possible by internal pressure changes exerted on the cell wall. They are heavily pigmented with chlorophyll *a*, beta carotene, and several xanthophylls. The presence of several phycobiliproteins gives the cyanophyta their unique blue-green coloration. Food is stored in the form of glycogen. Example: *Microcystis* sp., *Merismopedia* sp., *Phormidium* sp., *Anabaena* sp., etc.

Green Algae (Chlorophytes): Chlorophytes are a diverse group and are common in fresh water, salt water, and soil. The chlorophyta are primarily freshwater; only about 10% of the algae are marine, whereas 90% are freshwater. Green algae have unicellular or multicellular thalli. Some are flagellates, and others produce reproductive cells, the majority of which are biflagellate. Chlorophyte reproduction varies greatly, from asexual division to isogamy and heterogamy to oogamy. Cell walls are constructed of cellulose and pectin. The food storage product is true starch, the same as plants. Green algae possess true chloroplasts, which contain the same pigments found in higher plants: chlorophyll *a* and *b*, alpha and beta carotene, and many xanthophylls.
Example: *Chlorella* sp., *Ankistrodesmus* sp., *Chlamydomonas* sp., *Pandorina* sp., *Eudorina* sp., *Chlorogonium* sp., *Actinastrum* sp., *Pediastrum* sp., *Scenedesmus* sp., etc.


ALGAE IMPORTANT IN WATER SUPPLIES
TASTE AND ODOR ALGAE
ASTERIONELLA
ANABAENA
ANACYSTIS
UROGLENOPSIS
HYDRODICTYON
SYNEDRA
MALLOMONAS
PERIDINIUM
STAURASTRUM
APHANIZOMENON
CERATIUM
NITELLA
GOMPHOSPHAERIA
DINOBRYON
TABELLARIA
PANDORINA
VOLVOX
SYNURA
PLATE I


ALGAE GROWING ON RESERVOIR WALLS
PHORMIDIUM
ULOTHRIX
CLADOPHORA
GOMPHONEMA
ACHNANTHES
TETRASPORA
VAUCHERIA
STIGEOCLONIUM
AUDOUINELLA
TOLYPOTHRIX
CHARA
BULBOCHAETE
LYNGBYA
MICROSPORA
COMPSOPOGON
BATRACHOSPERMUM
CYMBELLA
PHYTOCONIS
DRAPARNALDIA
OEDOGONIUM
CHAETOPHORA


POLLUTED WATER ALGAE
PHORMIDIUM
AGMENELLUM
CARTERIA
LEPOCINCLIS
NITZSCHIA
PYROBOTRYS
ANABAENA
EUGLENA
TETRAEDRON
SPIROGYRA
CHLOROCOCCUM
OSCILLATORIA
PHACUS
CHLOROGONIUM
CHLORELLA
GOMPHONEMA
STIGEOCLONIUM
ANACYSTIS
ARTHROSPIRA
CHLAMYDOMONAS
LYNGBYA


PLANKTON AND OTHER SURFACE WATER ALGAE
NODULARIA
COELASTRUM
FRAGILARIA
EUGLENA
GOMPHOSPHAERIA
MICRACTINIUM
MOUGEOTIA
BOTRYOCOCCUS
OOCYSTIS
EUASTRUM
CYLINDROSPERMUM
PHACUS
SCENEDESMUS
ACTINASTRUM
GONIUM
STEPHANODISCUS
DESMIDIUM
SPHAEROCYSTIS
STAURONEIS
ZYGNEMA
EUDORINA
PEDIASTRUM

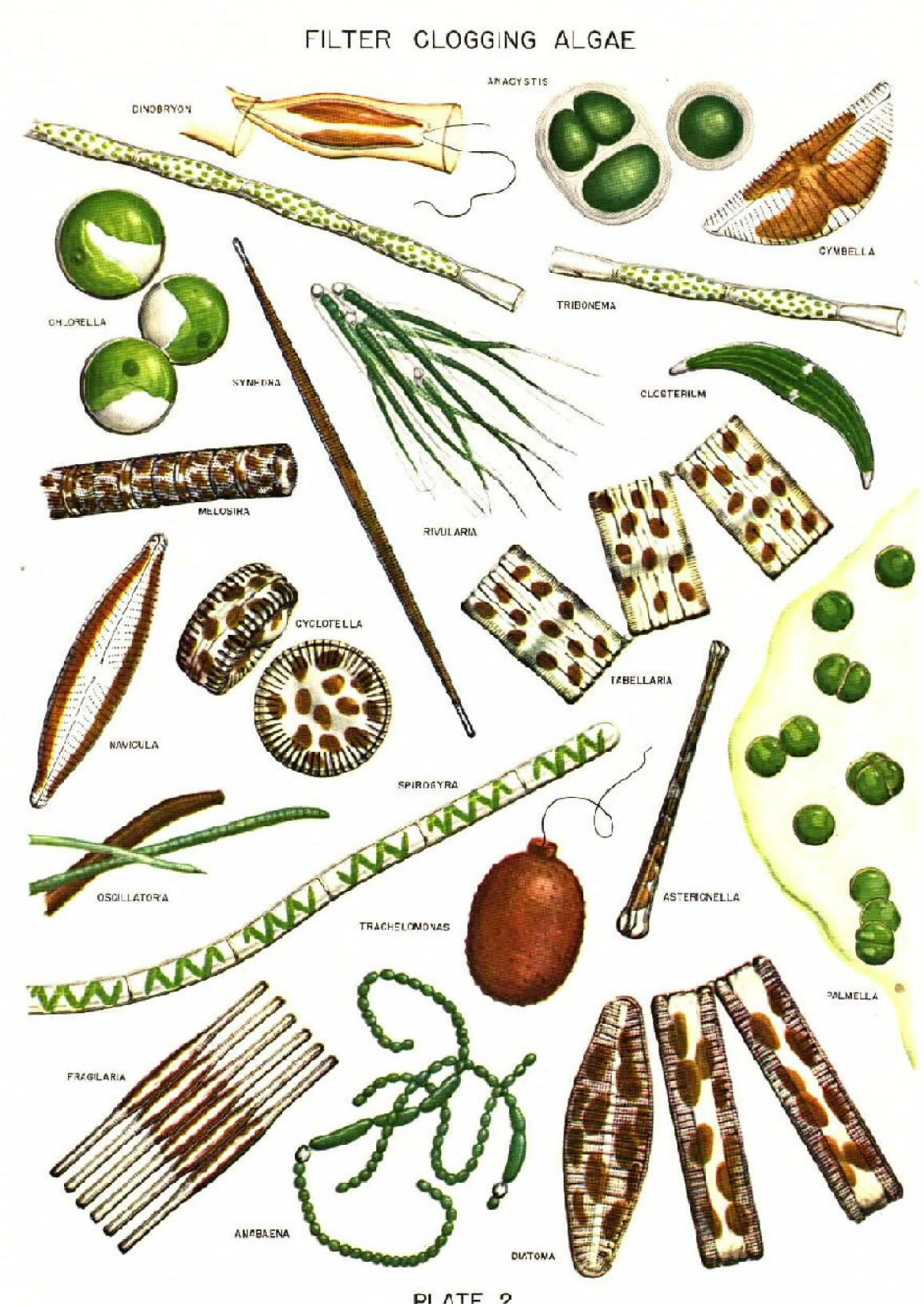

FILTER CLOGGING ALGAE
ANACYSTIS
DINOBRYON
CYMBELLA
TRIBONEMA
CHLORELLA
SYNEDRA
CLOSTERIUM
MELOSIRA
RIVULARIA
CYCLOTELLA
TABELLARIA
NAVICULA
SPIROGYRA
OSCILLATORIA
TRACHELOMONAS
ASTERIONELLA
PALMELLA
FRAGILARIA
ANABAENA
DIATOMA

PLATE 2

Macrophytes (Aquatic plants) commonly found in Bangalore

Name: *Eichhornia crassipes*

Common Name: Water hyacinth

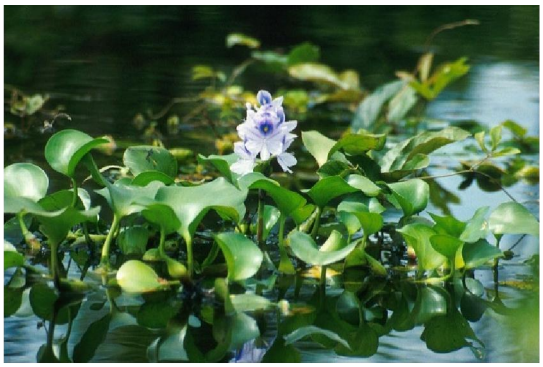
Description: Water hyacinth is a free-floating perennial aquatic plant with broad, thick, glossy, ovate leaves; leaves are 30-40 cm long with spongy petiole. Roots are fibrous and featherlike.

Flowering: March-July

Habitat: Water hyacinth grows in still or slow-flowing fresh water in tropical and temperate climates. Optimum growth occurs at temperatures of between 28°C and 30°C, and requires abundant nitrogen, phosphorus and potassium.

Impact: Its wide spread occurrence in the fresh water lakes and riverbeds is harmful to fishing (depleting DO), rowing, and depleting water content from the water bodies and interfering in water utilization and other activities. Water hyacinth by its abundance of leaves, dense vegetation and innumerable rootlets in tertiary manner obstruct water flow in irrigation channels and displaces many aquatic grasses, which were useful as fodder for cattle, and suppresses the phytoplankton growth. Water hyacinth provides suitable breeding places for mosquitoes and other disease-carrying insects by stagnating the water in ditches and shallow areas.

Uses: Phytoremediation, waste water treatment



Name*: Alternanthera philoxeroides* **Common name:** Alligator weed **Habitat:** grow in a variety of habitats, including dry land but usually found in water. **Stems** are pinkish, long, branched, and hollow. Fleshy, succulent stems can grow horizontally and float on the surface of the water, forming rafts, or form matted clumps which grow onto banks **Leaves** are simple, elliptic, and have smooth margins. They are opposite in pairs or whorls, with a distinctive midrib, and range in size from 5-10 cm. **Flowers:** whitish, papery ball-shaped flowers that grow on stalks. Fibrous roots arising at the stem nodes may hang free in water or penetrate into the sediment/soil. **Flowering:** December-April **Impact:** Alligator weed disrupts the aquatic environment by blanketing the surface and impeding the penetration of light. Such blanketing can also prevent gaseous exchange (sometimes leading to anaerobic conditions) which adversely affects aquatic flora and fauna. It also competes with and displaces native flora along river and in wetlands	 
Name: *Typha* **Common name:** Cattail **Description:** It is a common perennial marsh, aquatic or wetland plant in temperate, tropical, and subtropical climates. Plants are rhizomatous monoecious herb, grow upto 1.5-3m high, leaves radical, sheath white. Flowering stem length is	

typically equal to or somewhat longer than leaf length. Numerous tiny, dense, flowers occur in a terminal spike that is 0.7 to 2 inches, Male flowers make up the upper, narrower half of the spike and female flowers the lower, slightly wider half **Flowering:** June- August **Habitat:** It grows in shallow water of lakes, rivers, ponds, marshes, and ditches. **Significance:** Phytoremediation, wastewater treatment, used as medicine and fodder.	
Name: *Lemna* **Common name*:*** Common duckweed ***Lemna minor***: free-floating aquatic plants, with one, two or three leaves each with a single root hanging in the water; as more leaves grow, the plants divide and become separate individuals. The root is 1-2 cm long. The leaves are oval, 1-8 mm long and 0.6-5 mm broad, light green, with three (rarely five) veins, and small air spaces to assist flotation. It propagates mainly by division, and flowers rarely produced. **Habitat:** Grows in water with high nutrient levels and a pH of between 5 and 9, optimally between 6.5 and 7.5, and temperatures between 6 and 33 °C.	 *Lemna minor*

Significance: Important food resource for fish and birds(ducks)

Lemna gibba

Name: *Pistia stratiotes*

Common name: water cabbage, water lettuce

Description: Aquatic free-floating, odorous monoecious herb with thick, soft leaves that form a rosette. Roots hanging submersed beneath floating leaves. Leaves can be up to 14 cm long and have no stem. They are light green, with parallel veins, wavy margins and are covered in short hairs which form basket-like structures which trap air bubbles, increasing the plant's buoyancy.

Habitat: waters with high nutrient content, particularly those that have been contaminated with human loading of sewage or fertilizers

Impact: major weed of lakes, dams, ponds, irrigation channels and slow-moving waterways in tropical, subtropical and warmer temperate regions. It can completely cover water bodies(lowering DO), disrupting all life on the water.

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Influence of Catchment Land Cover Dynamics on the Physical, Chemical and Biological Integrity of Wetlands

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Abstract

Land use and land cover (LULC) changes in the wetland catchments are the direct and indirect consequence of human actions to secure essential resources. These changes encompass the greatest environmental concerns of human populations today, including loss of biodiversity, pollution of water and soil, and changes in the climate. Monitoring and mitigating the negative consequences of LULC while sustaining the production of essential resources has therefore become a major priority today. This communication investigates the effect of land-cover and water quality on distribution of diatoms in selected wetlands of Bangalore. In this respect, water quality (chemical and biological) was assessed along with LULC of respective wetland catchments. Spatial analysis has been done using remote sensing data and geographic information system (GIS). Diatoms, the major primary producers of aquatic ecosystem, respond quickly to environmental perturbations aid as bioindicators. The results showed gradients in physical, chemical and biological parameters across wetlands with different LULC. The diatom community results, when compared to chemical analyses, proved useful in providing an indication of the quality of waters. Pollution tolerant taxa such as *Nitzschia palea* dominated at sites with heavy inflow of sewage while, *Cymbella* sp. and *Gomphonema* sp. present abundantly at less pollution sites. Across the land-cover types, wetlands catchment comprising more of built-up area reflected higher nutrient and ionic levels, whereas wetlands with high vegetation cover showed oligotrophic water quality conditions. Species belonging to the genera *Gomphonema, Cyclotella, Nitzschia* and *Achnanthidium* expressed clear ecological preferences. This study emphasizes the need for conservation efforts at catchment level for conservation of wetlands biota.

Keywords: Land use land cover (LULC), landscape, landscape dynamics, wetlands. Diatoms, Water quality

Introduction

Wetlands being one of the productive ecosystems play a significant role in the ecological sustainability of the region, providing the link between land and water resources (Ramachandra, 2008). The quality and hydrologic regime of the water resource is directly dependent on the integrity of its watershed. In recent years, the rapid urbanization coupled with the unplanned anthropogenic activities has altered the wetland ecosystem severely across globe (Vitousek *et al.,* 1997; Grimmond, 2007). Changes in land use and land cover (LULC) in the wetland catchments influence the water yield in the catchment. Apart from LULC changes, the inflow of untreated domestic sewage, industrial effluents, dumping of solid wastes and rampant encroachments of catchment has threatened the sustenance of urban wetlands. This is evident from the nutrient enrichment and consequent profuse growth of macrophytes, impairing the functional abilities of the wetlands. Reduced treatment capabilities of the wetlands have led to the decline of native biodiversity affecting the livelihood of wetland dependent population. Decline in the services and goods of wetland ecosystems have influenced the social, cultural and ecological spaces as well as of water management. This necessitates regular monitoring of wetlands to mitigate the impacts through appropriate management strategies. LULC analysis is done using remote sensing data acquired through the space-borne sensors. Factors related to water quality are the most important pressure driving heterogeneity of biotic components at an intermediate spatial and temporal scale.

Algae, the primary producers are linked with the changes in various physical (landscape) and chemical (nutrients) variables and indeed have been used as bioindicators of water quality. Among several groups, diatom-based pollution monitoring has proved to be rapid, efficient and cost-effective technique has been implemented worldwide to monitor rivers, streams and lakes (Taylor *et al.,* 2007; Juttner *et al.,* 2010; Karthick *et al.,* 2011). Diatoms are the species-rich group of photosynthetic eukaryotes, with enormous ecological significance and great potential for environmental application. During the last two decades, diatoms have gained considerable popularity throughout the world as a tool to provide an integrated reflection of water quality (Atazadeh *et al.,* 2007). The sensitivity and tolerance of diatoms to specific physical and chemical variables such as pH, electrical conductivity, nitrates, phosphates and biological oxygen demand (BOD) and inherent ecological patterns has been investigated across countries (Sabater et al., 2007; Taylor et al., 2007; Jüttner et al., 2009; Alakananda et al., 2011).

Diatom community structure respond to the LULC changes in the catchment (Cooper, 1995), nutrient concentration (Potapova and Charles, 2002), riparian disturbance (Hill et al., 2000) and decreasing species richness, evenness and diversity from agriculture / forest areas to urban area (Bere and Tundisi, 2011). Walsh and Wepener (2009) report the dominance of *Nitzschia* sp. in the catchment with high intensity agriculture, while *Navicula* sp. was dominant at low intensity agriculture regions. However, studies on water chemistry of wetlands with the catchment LULC conditions and its impacts on diatom assemblages in urban scenario is scarce and needs to be investigated to evolve location specific catchment restoration measures and to mitigate the impact of anthropogenic activities in the fragile ecosystem's catchment.

Wetlands play a prominent role of meeting the domestic and irrigation needs of the region apart from being habitats for wide variety of flora and fauna. Bangalore, with a population of 9.5 million (as per 2011 census) has been rapidly urbanizing during the last three decades. Recent studies reveal that there has been 63.2% increase in built-up area with 78% loss of vegetation cover and 79% loss of wetlands (Ramachandra and Kumar, 2008). Wetlands have become vulnerable ecosystems evident from regular mass fish kill (Benjamin et al., 1996) reduction of migratory bird population (Kiran and Ramachandra, 1999) and ground water contamination (Shankar et al., 2008). Sustained inflow of the city's sewage and industrial effluents apart from conversion of wetlands for other activities have threatened the existence of these fragile ecosystems necessitating the interventions to restore and sustainable management with location specific appropriate conservation strategies. Failure to restore these ecosystems will result in extinction of species or ecosystem types and cause permanent ecological damage.

Wetlands function as kidneys of the landscape and help in treating the nutrients. However, the excess inflow of nutrients beyond the treatment capability results in the changes in the water quality impairing the ecological functions. Diatoms, the major primary producers of aquatic ecosystem, respond quickly to environmental perturbations, hence used as a bioindicator across continents. However, usage of diatoms as a part of environmental monitoring program in Southern Hemisphere is very limited due to inadequate knowledge on its taxonomy. Ecological optima of four dominant species were investigated for standardizing diatom indices for Indian conditions. Current study investigates the influence of LULC in the wetland catchment on diatom communities composition and distribution at spatial scale in an eco-region. LULC analysis was done using remote sensing data with Geographical Information System (GIS). Water quality was analyzed to investigate temporal variation in physicochemical parameters and their relationship with diatom community during pre-monsoon (August), monsoon (September and October) and post-monsoon (November) months.

Study area

Bangalore is located at 12^{o} 39' N and 13^{o} 18' N and longitude of 77^{o} 22' E and 77^{o}, almost equidistant from both eastern and western coast of the South Indian peninsula, and is situated at an altitude of 920 m above mean sea level. Major soil types are red loamy and laterite soil and physiography variations ranges from rocky upland, plateau and flat-topped hills forming slope at south and south east, and pedi-plains along western parts (http://cgwb.gov.in). The mean annual total rainfall is about 880 mm with about 60 rainy days a year over the last 10 years. The summer temperature ranges from 24 to 38 °C, while the winter temperature ranges from 12 to 28 °C. Bangalore is located over ridges delineating four watersheds, viz. Hebbal, Koramangala, Challaghatta and Vrishabhavathi watersheds. The undulating terrain in the region has facilitated creation of a large number of tanks providing for the traditional uses of irrigation, drinking, fishing and washing (Figure 1). Their creation is mainly attributed to the vision of Kempe Gowda and of the Wodeyar dynasty. This led to Bangalore having hundreds of such water bodies through the centuries. Recent studies reveal that there has been 63.2% increase in built-up area with 78% loss of vegetation cover and 79% loss of wetlands (Ramachandra and Kumar, 2008).

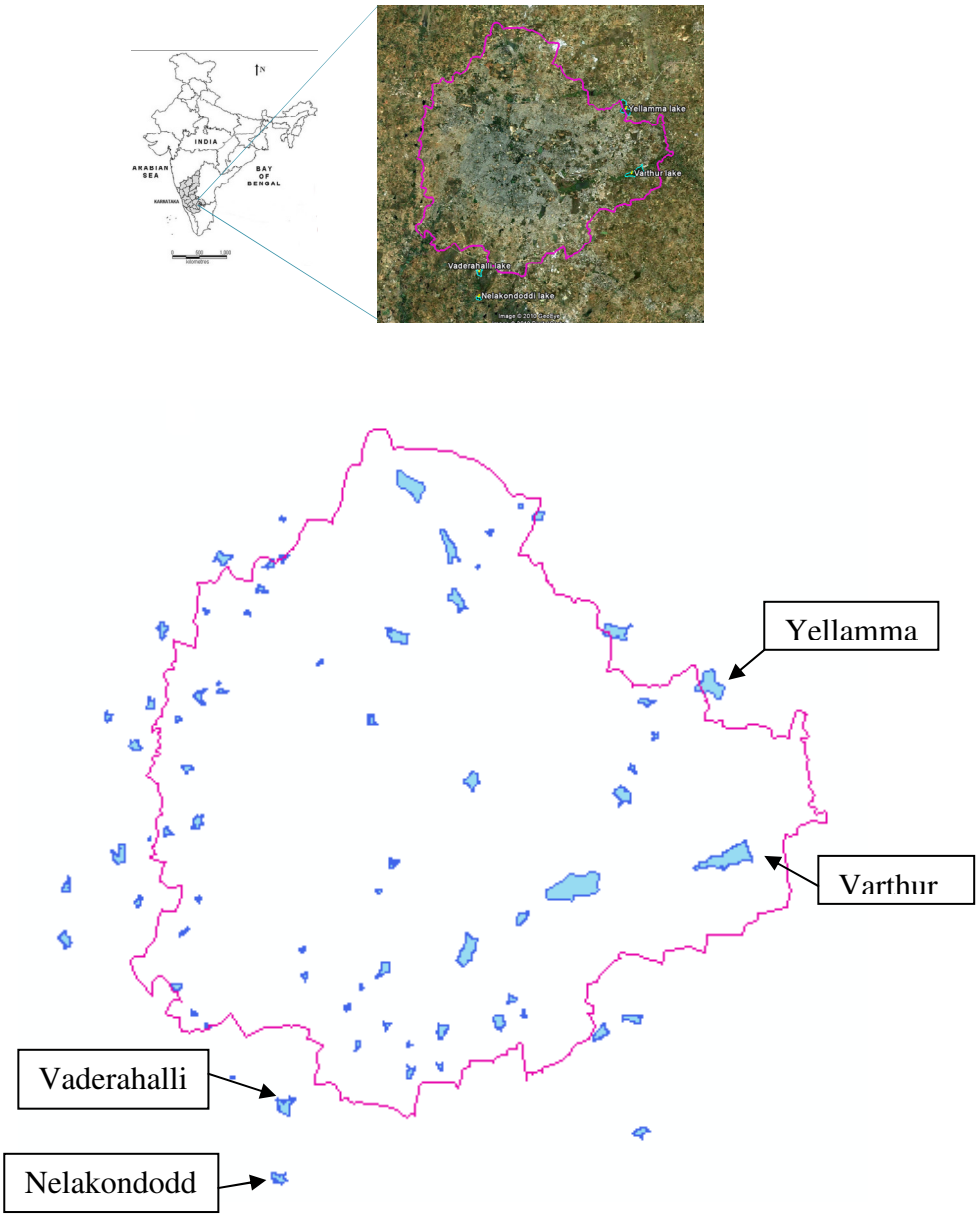

Figure 1: Study area with India Map and Bangalore map with 4 lakes marked on the digitized vector layer of Bangalore

Four wetlands were selected for the current study. Among these Yellamallappa chetty (110 ha) and Varthur (166.87 ha) are located in Bangalore urban district and drained from densely populated area of Bangalore metropolitan (Mahadevapura zone, Population of 5,19,663). Industrial waste and agricultural runoff (Usha et al., 2008) contaminated Yellamappa chetty and Varthur together with macrophyte growth and severe sludge deposition (Ramachandra, 2008). Two other wetlands Vaderahalli (55ha) and Nelakondoddi (36 ha) are located in Bangalore Rural district with less human population and more of plantation and forested land in catchment area.

Table 1: Variation in physical and chemical parameters across months at Varthur and Yellamma Wetland

Sampling site	VARTHUR INLET (Vri VTI)				VARTHUR OUTLET (VroVTO)				YALLAMMA INLET (YMI)			YALLAMMA OUTLET (YMO)			
Sampling months	**Aug**	**Sep**	**Oct**	**Nov**	**Aug**	**Sep**	**Oct**	**Nov**	**Aug**	**Sep**		**Nov**	**Aug**	**Sep**	**Oct**	**Nov**
pH	7.46	7.25	7.10	8.50	7.84	7.58	8.00	8	7.49	8.90		7.5	7.5	8.00	7.20	8
Water temperature (^{0}C)	25	27.00	26.00	24.00	29.5	27.50	26.50	26	25.3	29.00		-	26.2	28.60	-	-
Electric conductivity (µScm^{-1})	823	948.00	-	-	798	890.00	-	-	1083	1120.00		-	1092	863.00	-	-
Total dissolved solids (ppm)	654	730.00	-	-	636	700.00	-	-	865	850.0		-	870	654.00	-	-
Salinity (ppm)	403	550.00	-	-	385	563.00	-	-	538	620.0		-	537	490.00	-	-
Turbidity (NTU)	92.5	110.00	82.20	-	83.5	81.30	62.20	-	42.7	44.00		70.8	42.8	60.50	-	38.5
Dissolved Oxygen (mgL^{-1})	0.813	0.00	1.22	0	4.065	7.15	1.63	4.06	4.227	0.00		-	5.04	1.95	0.00	-
Biological oxygen Demand (mgL^{-1})	49.95	71.54	56	95	46.28	55.28	44.7	-	33.74	117.07		35	24.29	104.07	87.9	30
Chemical oxygen demand (mgL^{-1})	293.33	197.73	133.00	314.67	192.00	298.67	-	234.66	581.33	213.33		85.33	570.66	218.67	186.70	74.67
Nitrates (mgL^{-1})	0.05	0.27	0.157	0.299	0.03	0.28	0.162	0.24	2.57	0.85		-	0.394	0.57	0.179	-
Phosphates (mgL^{-1})	0.21	1.94	3.217	1.637	0.05	1.73	4.175	0.718	0.51	0.61		1.94	2.98	0.44	3.3	1.813
Total Hardness (mgL^{-1})	268	256.00	240.00	336	264	236.00	292.00	420	276	320.00		360	300	284.00	296.00	288
Calcium Hardness (mgL^{-1})	120	120.00	144.00	88.17	132	112.00	200.00	188.17	372	132.00		68.93	280	124.00	196.00	57.71
Magnesium Hardness (mgL^{-1})	189.92	136.00	96.00	28.261	85.392	124.00	92.00	48.757	185.232	188.00		45.838	231.68	160.00	100.00	35.107
Alkalinity (mgL^{-1})	520	55.00	440.00	140	260	56.00	-	120	420	90.00	**	1700	560	65.00	400.00	1580
Chlorides (mgL^{-1})	136.32	153.36	147.68	150.52	119.28	142.00	-	142	107.92	193.12		227.2	167.56	190.28	221.52	213
Sodium (ppm)	33.6	34.30	3.1	20.05	34.6	31.50	-	18.93	40.6	40.30		22.83	49.5	39.70	3.9	23.39
Potassium (ppm)	6.8	7.00	4.4	0	6.7	6.30	0	0	7.7	7.80		0	8.5	8.20	5	0

** No sampling was carried out due to the Ganesha immersion.

Table 2: Variation in physical and chemical parameters across months at Nelakondoddi and Vaderahalli Wetland

Sampling site	NELAKONDODDI INLET (NiNKI)				NELAKONDODDI OUTLET (NoNKO)				VADERAHALLI INLET (VdiVHI)				VADERAHALLI OUTLET (VdoVHO)			
Sampling months	**Aug**	**Sep**	**Oct**	**Nov**	**Aug**	**Sep**	**Oct**	**Nov**	**Aug**	**Sep**	**Oct**	**Nov**	**Aug**	**Sep**	**Oct**	**Nov**
pH	8.05	8.36	8.20	8.60	7.95	7.94	8.10	8.60	9.4	9.11	8.30	8.20	8.5	9.00	8.20	8.20
Water temperature (^{0}C)	28.4	26.30	26	26.00	26	29.50	24.5	25.00	29	27.10	24	26.00	29.5	26.10	24	25.00
Electric conductivity (μScm^{-1})	711	541.00	-	-	661	582.00	-	-	550	687.00	-	-	480	608.00	-	-
Total dissolved solids (ppm)	564	390.00	-	-	496	441.00	-	-	300	433.00	-	-	295	468.00	-	-
Salinity (ppm)	351	218.00	-	-	301	256.00	-	-	255	265.00	-	-	220	278.00	-	-
Turbidity (NTU)	22.9	24.00	17.7	14.60	24.4	22.50	-	8.06	17.5	57.10	7.05	12.40	12.2	24.40	8.77	9.85
Dissolved Oxygen (mgL^{-1})	10.98	6.50	8.29	10.4	7.2	7.80	6.50	11.05	5.854	9.88	1.22	-	6.667	10.73	2.76	-
Biological oxygen demand (mgL^{-1})	5.42	6.50	5.42	18.44	14.92	16.26	3.25	13	20.34	15.00	2.03	13.7	16.00	14.00	3.9	14
Chemical oxygen demand (mgL^{-1})	32.00	20.00	13.33	17	23.00	26.67	17.60	18	32.00	26.00	8.00	16	23.00	19.50	16.00	14.4
Nitrates (mgL^{-1})	0.08	0.18	0.085	0.254	0.06	0.11	0.084	0.153	0.06	0.14	0.634	0.149	0.08	0.06	0.161	0.327
Phosphates (mgL^{-1})	0.017	0.16	0.046	0.052	0.004	0.02	0.225	0.11	0.025	0.13	0.008	0.046	0.1	0.04	0.098	0.028
Total Hardness (mgL^{-1})	300	232.00	160.00	160	364	240.00	204.00	180	284	148.00	148.00	172	144	148.00	160.00	500
Calcium Hardness (mgL^{-1})	16	88.00	80.00	24.04	36	68.00	88.00	32.06	160	36.00	60.00	32.06	76	44.00	44.00	32.06
Magnesium Hardness (mgL^{-1})	296.096	144.00	80.00	24.388	355.216	172.00	116.00	24.384	244.96	112.00	88.00	22.432	125.456	104.00	116.00	4.86
Alkalinity (mgL^{-1})	400	87.50	240.00	666.66	420	70.00	300.00	700	340	77.50	100.00	733.33	360	67.50	260.00	566.66
Chlorides (mgL^{-1})	31.24	187.44	130.64	113.6	39.76	184.60	136.32	122.12	31.24	139.16	127.80	136.32	34.08	130.64	110.76	127.8
Sodium (ppm)	60.9	44.20	3.4	19.49	71.5	44.10	3.4	18.38	32.1	35.20	2.8	18.381	31	34.70	2.6	18.93
Potassium (ppm)	3.1	2.40	1.7	0	3.7	2.60	1.6	0	3	3.20	2.5	0	2.8	3.30	2.1	0

Materials and Methods

Water quality analysis: Water samples from all four wetlands were collected during 4 months viz., August, September, October and November 2010. Samples collected from 10 to 30 cm below the surface of water during the morning hours and stored in disinfected plastic bottles. On-site water analysis included water temperature, pH, turbidity, salinity, electrical conductivity, total dissolved solids and dissolved Oxygen. No preservatives were added as the samples were transported to laboratory and refrigerated for subsequent analysis. Laboratory analysis includes total alkalinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness, calcium hardness, Magnesium hardness, Potassium, Sodium, nitrates (NO^{3-}), inorganic phosphates (PO_4^{3-}) and chlorides (Cl^-). These water analyses were followed as per standard procedures published by the American Public Health Association (APHA, 1998) and Chemical and Biological methods for water pollution studies, (Trivedy and Goel, 1986).

Diatom analysis: Diatoms have been collected from habitats such as epilithic, (found in stones) epiphytic (found in plants) and episammic (found in sediments) of four wetlands were collected during the month of September 2010. Cleaning and identification of samples is done following Laboratory procedure as per Taylor *et al.,* 2005 and Karthick *et al.,* 2010. Samples are cleaned following Hot HCl and $KMnO_4$ method and slides were prepared using Pluerax as the mounting medium. Relative abundance of each taxon was determined after counting at least 400 valves in each sample using light microscope. Identification of diatoms has been done following key characters mentioned by Krammer and Lang-Bertalot (1986-1991), Round *et al.,* (1990) and Gandhi (1957a-1959d).

LULC analysis: Shuttle Radar Topography Mission (SRTM) data is downloaded from CGIAR Consortium for Spatial Information (CGIAR-CSI). Digital Elevation Model (DEM) was generated using ENVI 4.7 version. The digitized Wetlands were overlayed on the DEM. The drainages were digitized using toposheet of Bangalore, 1972. Catchment of these four Wetlands was delineated using the topographic maps of 1:50000 and referring the digitized drainages. LULC for each catchment was assessed using IRS 1D data (October 2006). IRS data was geo-referenced using image-to-image registration. Training data is collected from field using pre-calibrated handheld Global Positioning System (GPS). IRS data were classified using supervised classification techniques with the Gaussian maximum likelihood classifier into three classes – vegetation, water body and built up. Accuracy assessment was done to validate the classified data.

Statistical analysis: Variation in water quality and diatom species distribution across sites is analysed using PAST software, version 2.11. Canonical correspondence analysis (CCA) included data of 8 abundant diatom taxa (RA >10% at least in 1 sampling site), 17 environmental across 8 sampling sites during 4 month period to evaluate role of environmental variables (water quality and land cover type) in structuring diatom communities.

Results and Discussion

Water Quality Analysis

Varthur Wetland: The overall water quality parameters measured are listed in Table 1. pH was recorded as neutral to slightly alkaline with lowest and highest at VTI (7.1) in October and VTI (8.5) in November respectively. Electric conductivity and total dissolved solids values were consistent with a narrow range of 823 to 948 mgL^{-1} and 636 to 730 mgL^{-1} respectively. Hypoxic and even anoxic condition due to low dissolved oxygen was observed at VTI site (1.22 mgL^{-1}) and at VTO site as well with a range of 1.63 -7.15 mgL^{-1}. This attributed to the presence of water hyacinth covering the water surface with heavy domestic organic load and decomposition of organic matter. This condition is also reflected in elevated concentrations of BOD and COD with exceeding permissible limits at all sampling sites across months (Table 1). Total hardness (236-420 mgL^{-1}), alkalinity (55-440 mgL-1) and chlorides (119.28-153.36 mgL^{-1}) were recorded very high due to sewage inflow.

Yellamma Wetland: pH was recorded as neutral to slightly alkaline with lowest at YMO (7.20) in the month of October and highest at YMI (8.90) in the month of September. Electric conductivity and total dissolved solid values show a significant range. In September, YMO showed a less EC value of 863 μScm^{-1} and Yellamma inlet showed high value of 1120 μScm^{-1} owing to high ionic concentrations inflow from industrial wastes. Dissolved oxygen content varied in both inlet and outlet ranging from 0 to 5.04 mgL^{-1}. DO was less than measurable amount in the month of October in YMO and September in YMI reasoning to high organic load. In the month of August DO of 4.22 mgL^{-1} in YMI and 5.04 mgL^{-1} in YMO was observed. The discharge of sewage containing organic material from the nearby factories contributed to this situation. This condition was also reflected in elevated concentrations of BOD and COD with exceeding permissible limits at all sampling sites across months (Table 1). In the month of October no sampling could be done in Yellamma inlet due to blockage on account of immersion of idols (Ganesha).

Nelakondoddi Wetland: pH ranged from 7.94 at NKO site (Sep) to 8.60 at both the sites (Nov) indicating slightly neutral to alkaline nature of water and within the permissible limits (Table 2). EC, TDS and salinity ranged from 480 to 687 μScm^{-1}, 295 to 468 ppm and 220 to 278 ppm respectively indicating low mineralization in this Wetland. However, slight gradation was observed in September due to monsoon climate. DO at all sampling sites was within the permissible limit and ranged from 6.5 mgL^{-1} at NKI to 11.05 mgL^{-1} at NKO. The higher DO recorded during monsoon and post monsoon seasons (i.e., Oct and Nov) may be due to the impact of rain water resulting in aeration (Ayoade et al., 2006). A huge variation in BOD (5.42 to 16.26 mgL^{-1}) and COD (13.33 to 32 mgL^{-1}) was studied across months, the highest value of BOD being in the November month (18.44 mgL^{-1} at NKI) and COD being highest at both sites in August month (Table 2).

Vaderahalli Wetland: The pH in both sites indicates slightly alkaline ranged from 8.20 to 9.11 (Table 2). Water temperature varied depending on the time of sampling with a range of 24 to 29.5 ^{0}C. EC, TDS and salinity ranged from 541 to 711 μScm^{-1}, 390 to 564 ppm and 218 to 351 ppm respectively indicating low mineralization in this Wetland. However, slight gradation was also observed in September due to monsoon climate. DO at all sampling sites was within the permissible limit and ranged from 5.854 mgL^{-1} at VHI to 10.73 mgL^{-1} at VHO except in October where the DO was observed to be very low. A huge variation in BOD (2.03mgL^{-1} to 20.34 mgL^{-1}) and COD (8 mgL^{-1} to 32 mgL^{-1}) was studied across months being

within the permissible limits, the highest value of BOD and COD being in the August month. (Refer Table 2).

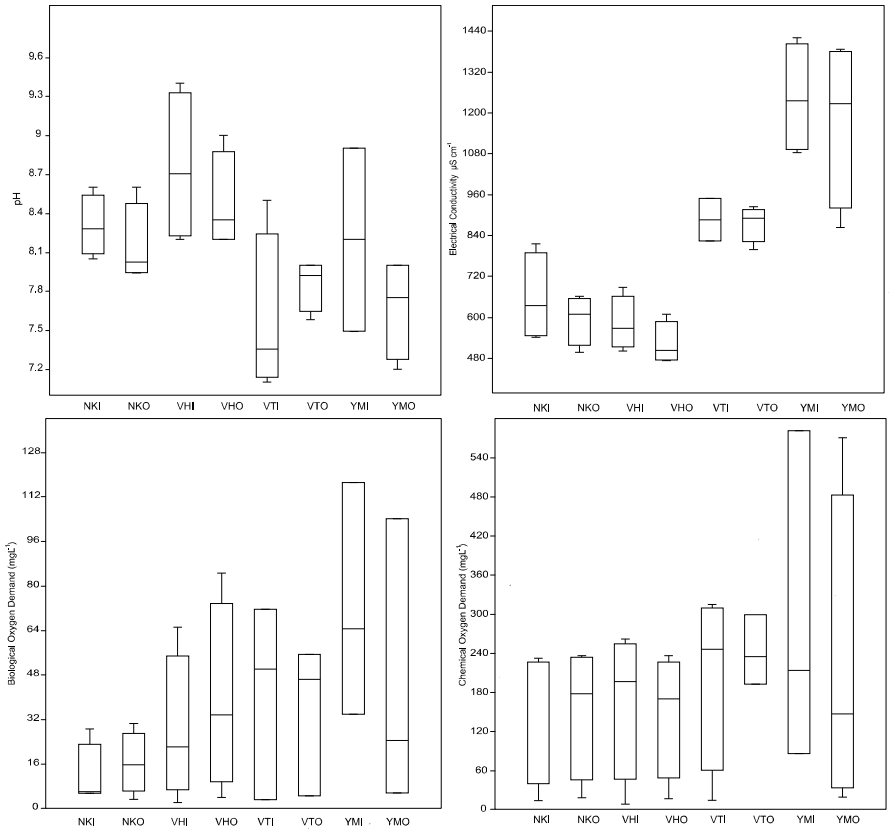

Figure 2: Variation in water quality across sampling sites [For sampling sites and its codes refer annexure I](a) pH (b) Electric conductivity (c) Biological oxygen demand (d) Chemical oxygen demand

Water Quality across Wetlands

The level of pollution status and spatial distribution of Wetlands from urbanized area is well reflected by water quality. Across Wetlands, pH was recorded as slightly alkaline with minimum of 7.6 at Varthur inlet and maximum of 8.75 at Vaderahalli inlet. EC, turbidity and TDS at Varthur and Yellamallappa chetty was in extremely high concentrations due to high cation concentrations. EC was more than the permissible limit at Yellamallappa chetty inlet (1101.50µScm^{-1}) and high turbidity of 94.9mgL^{-1} in Varthur inlet and high TDS of 857.5 was observed in Yellamallappa chetty inlet. These parameters were low in Vaderahalli inlet with 6.18µScm^{-1}of EC, turbidity of 13.81 NTU and total dissolved solids of 366.50 mgL^{-1}. These parameters show marked seasonal variations (Awasthi and Tiwari, 2004). As in figure 2and 3, BOD and COD values reflected high pollution at Varthur, Yellamallappa chetty and Nelakondoddi sampling sites but contradictory values were observed in Nelakondoddi and Vaderahalli with a range of 8.959 to 12.97 mgL^{-1}. The study by Atobatele et al., 2008 shows pH, conductivity, temperature and dissolved oxygen as important parameters contributing to the annual variability of Wetland water. Dissolved oxygen concentration was found very less in all sampling sites of Varthur Wetland and Yellamallappa chetty Wetlands compared to

other two Wetlands, which is quite evident by heavy organic load and macrophyte cover and hence reduces redox potential of the system.

Diatom Distribution

Fifty eight species belonging to 29 genera has been recorded and are listed in annexure 1. The dominant taxa were *Achnanthidium* sp., *Gomphonema*. *parvulum* (Kutzing var. *parvulum* f. *parvulum*) *Gomphonema* sp., *Nitzschia palea* (Kutzing) W.Smith, *Nitzschia umbonata* (Ehrenberg) Lange-Bertalot, *C. meneghiniana* Kutzing, *Cymbella* sp. and *Fragilaria* sp. Most of the species occurred in polluted regions are recorded as cosmopolitan (Taylor *et al.,* 2007). The diatom community structure shows a strong correlation with various environmental variables (Soininen *et al.,* 2004). The species such as *G. parvulum, C. meneghiniana, N. palea* and *N. umbonata* are tolerant to high electrolyte and organic rich condition (Karthick *et al.,* 2009) which inhabited Varthur and Yellamallappa chetty Wetlands. This clearly signifies that both these Wetlands are polluted and eutrophic in condition. Nelakondoddi and Vaderahalli show low electric conductivity, BOD and COD values and were dominated by *Achnanthidium* sp., *Gomphonema* sp. and *Cymbella* sp. These species were recorded as inhabiting in moderate pollution.

Temporal variation and diatom distribution across Wetlands

The monthly variation in water quality was reflected by diatom community composition. *G. parvulum* and *N. palea* were dominated in all months at Varthur outlet while *N. linearis* was recorded as abundant in October at Varthur inlet notifying the pollution level. *C. meneghiniana* and *N. palea* was dominant across months at both sampling sites in Yellamallappa chetty followed by *G. parvulum* in October at Yellamallappa chetty outlet. Diatom species such as *Achnanthidium sp, Gomphonema sp* and *C. kappi* (Cholnoky) Cholnoky being dominant at Vaderahallli Wetland resembled a different community structure than former Wetlands. Ecological significance of *Achnanthidium* sp. needs to be studied as it shows a wide range of occurrence, from oilgotrophic to slightly mesotrophic condition.

Temporal variation is a significant factor responsible for changes in diatom distribution and its abundance (Sivaci *et al.,* 2008). In Nelakondoddi outlet (NKO), *N.palea*, which was dominant in the month of August, was replaced by *C. kappi* and *Mastogloia smithi* Thwaites in September. However, *Achnanthidium* sp. dominated in October followed by *Achnanthidium* sp. together with *Navicula* sp. in November. *C.kappi* was dominant in September which was followed by *N. amphibia* Grunow *f.amphibia* and *Achnanthidium* sp. reflecting moderate trophic status. The eutrophic status and electrolyte rich was significant in November with the dominance of *Fragillaria. biceps* (Kutzing) Lange-Bertalot and *N. linearis* (Agardh) W Smith.

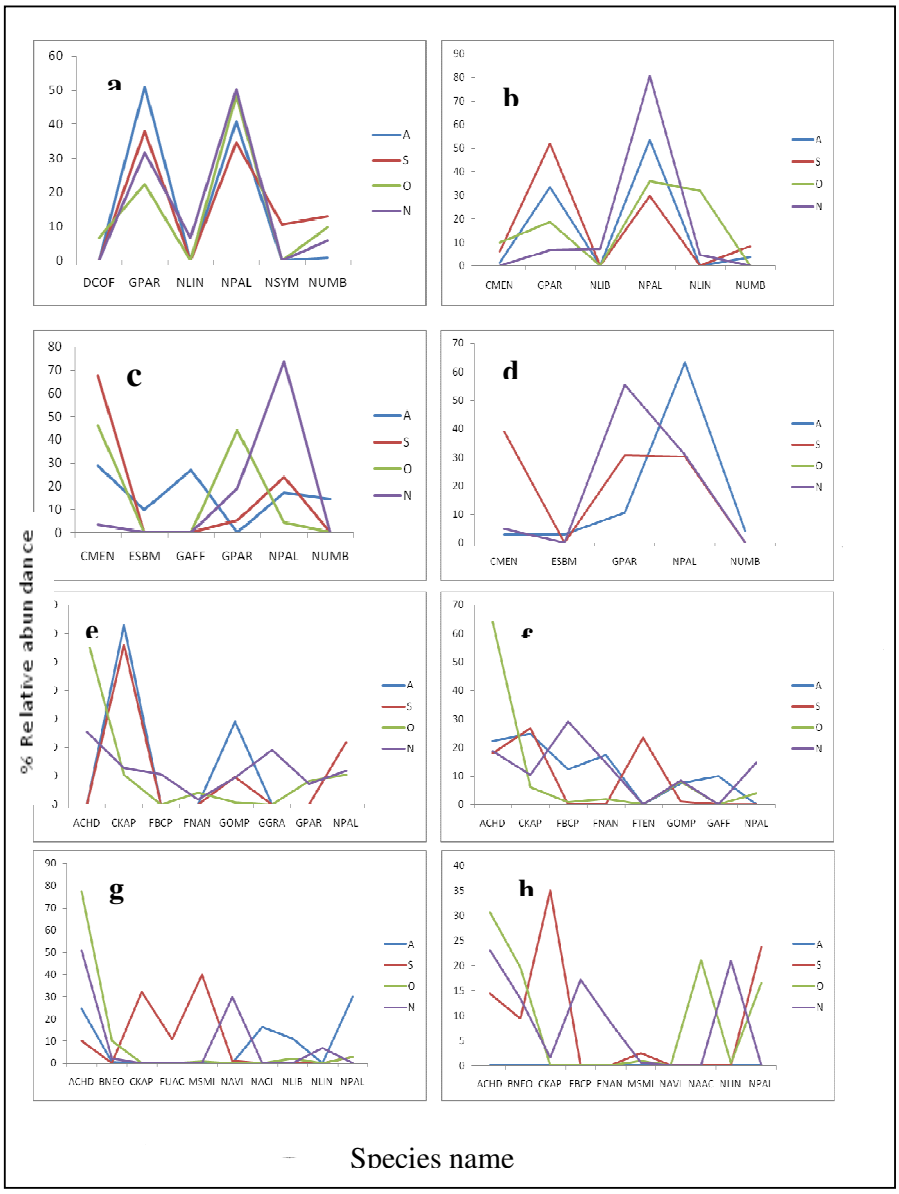

Figure 3: Percentage relative abundance of species across months [A-August, S-September, O-October, N-November] (a) Varthur Siddapura (b) Varthur Fishing (c) Yallamma Outlet (d) Yallamma Inlet (e) Vaderahalli Outlet (f) Vaderahalli Inlet (g) Nelakondoddi Outlet.

Relationship between dominant taxa and Water Quality

CCA triplot explained 65.43% of the variability in the diatom and environmental data with 45.92% in axis 1 and 19.51% in axis 2 (Figure 4; Table 3). Monte Carlo permutation test (n=1000) showed that both axes were statistically significant ($p<0.01$). The ordination of sampling sites was based on the species composition and their relationship with environmental and land-cover variables. The axis 1 represented an urban to rural gradient, where rural sampling sites were ordinated towards the right side and urban sites were on the

left side. The sampling sites on the right side were Vaderahalli and Nelakondoddi sites while clustered on the left side were Varthur sampling sites. Axis 2 represented Nelakondoddi and Vaderahalli sites and dominance of ACHD on the right side of the axis. Axis 1 was significantly negatively correlated with variables such as EC, TDS, Turbidity, P, K and % built up and taxa such as NUMB, GPAR and NPAL Likewise, a significant positive correlation of axis 1 was observed with DO, pH and % vegetation along with dominance of CKAP and GGRA. There was no significant correlation of BOD, COD, sodium and chlorides with both axes.

Table 3 Correlation coefficients between selected environmental variables and the first two CCA axes (Significant correlation $p<0.01$).

CCA axes		
Variables	**1**	**2**
Eigen value	**0.725**	**0.308**
pH	0.621	0.25
Conductivity	-0.8588	-0.137
TDS	-0.876	-0.155
Turbidity	-0.77	-0.006
P	-0.6566	-0.095
N	-0.367	0.256
K	-0.909	-0.021
Sodium	-0.211	0.365
BOD	-0.380	0.227
COD	-0.36	0.257
DO	0.663	0.170
Chlorides	-0.414	0.14
% Built up	-0.920	-0.084
% Vegetation	0.928	0.075

Ecological preference of dominant taxa

Figure 5 illustrates the occurrence of dominant taxa at differing water quality. The dominant taxa *G. parvulum* (GPAR), *C. meneghiniana* (CMEN), *Achnanthidium* sp. (ACHD) and *N. palea* (NPAL) at varying pH and EC show the dominance of particular taxa at respective pH and EC optima . *G. parvulum* was persistent across months and abundant at pH ranging from 7.6 to 8 and was less towards alkaline pH. The electric conductivity more than 850 μScm^{-1} attributed to *G.parvulum* optima while sampling sites less than 700 μScm^{-1} comprised a different composition with *G parvulum* as less in abundance. *C. meneghiniana*

was recorded to be more dominant at pH of 7.7 to 7.9 and as the EC increases (>900 µScm^{-1}). This range of pH and EC limits the distribution of *G.parvulum* and *C. meneghiniana* to extremely eutrophic water condition. The sensitivity and tolerance of diatoms to such specific environmental factors attributed towards the species- specific ecological characterization (Sabater *et al.,* 2007).

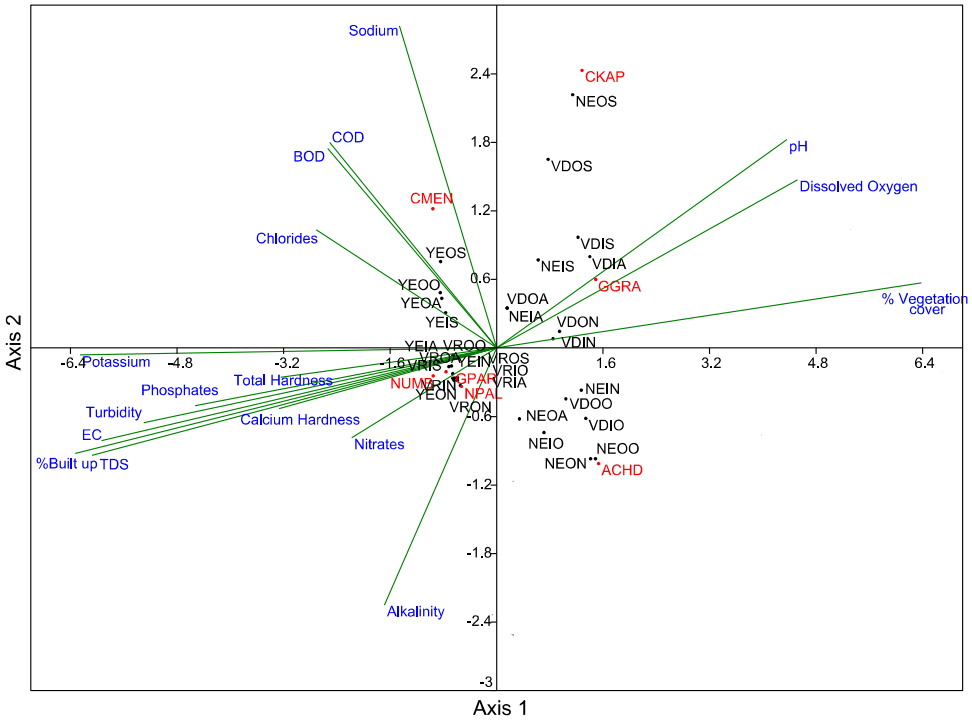

Figure 4 Canonical correspondence analysis (CCA) plot explaining impact of land use/ land cover on species distribution.

Achnanthidium sp. was present at all sampling sites whilst, the abundance was optimum at pH 8.1 to 8.2 and at EC 600 to 650 µScm^{-1} and later decreased at elevated EC concentration. *N. palea* was present at all sampling sites and revealed a wide range of optima though was less abundant at alkaline pH. *N. palea* was also abundant at its optima of EC i.e., more than 850 µScm . Low EC concentration (<800 µScm^{-1}) was limiting the distribution of *N. palea*. Thus, in consideration with observed species autecological values the sampling sites with profuse *Achnanthidium* sp. can be classified as oligo to slightly eutrophic at the same time as, the sampling sites with *N.palea* can be classified as in eutrophic status and extremely polluted. However, many studies have investigated autecological status of indicator species (Taylor *et al.,* 2007; Álvarez-Blanco *et al.,* 2010), very less study contributes to species optima of *Nitzschia* sp., *Gomphonema* sp., and *Achnanthidium* sp. and further none of the study come from Asia region. However, ecological optima of *N. palea* can be classified as eutrophic status. Performing the ecological optima for few more taxa that commonly occur in wetlands of Bangalore can lead to developing specific diatom indices for bioassessment practices.

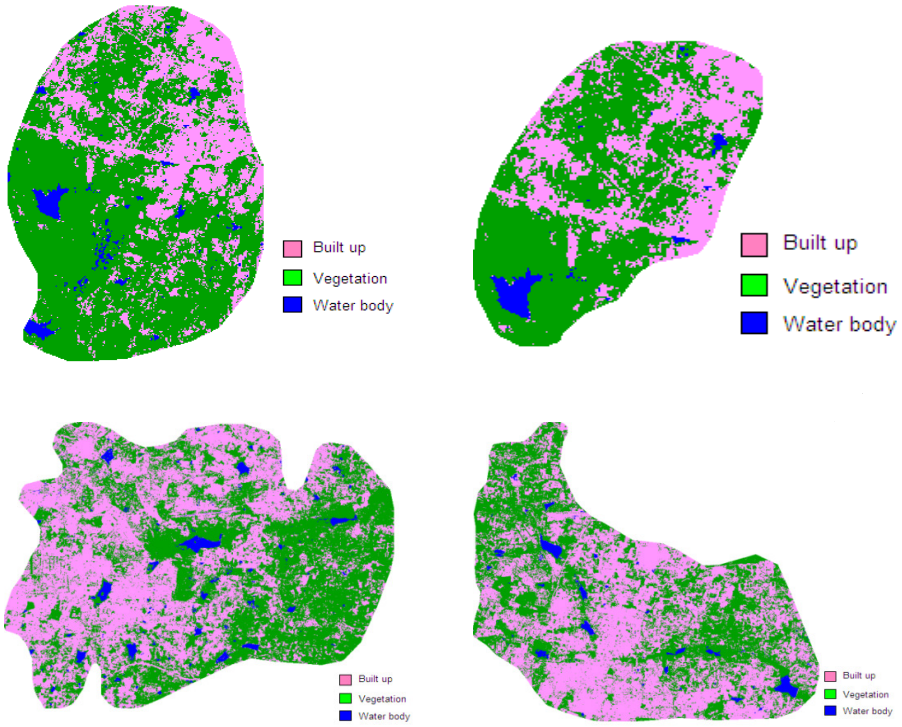

Figure 6: Land use in the catchments of . (a) Nelakondoddi, (b) Vaderahalli, (c) Varthur and (d) Yellamma wetlands.

Chattopadyay et al., (2005) also report of the similar scenario of urban landuse with poor water quality throughout the year. The increased amount of organic concentration and degradation in water quality is mainly due to increasing urbanization (built up) at Yellamma and Varthur regions (Chandrasekhar et al., 2003). In contrast to this situation, vegetation in Vaderahalli catchment (61.21%) and Nelakondoddi catchment (65.98%) is higher compared to the built up land (35.96% and 31.48% respectively). This analysis also shows that the influence of anthropogenic activity was less in these two wetlands. Majority of the area is under vegetation (with less human interventions) and thus less chances of contamination of water compared to the wetlands situated in urban region. LULC changes influence varying diatom community composition (Soininen et al., 2004, Weijter et al., 2009). Yallamallappa chetty and Varthur Wetlands are having high percent of built-up with high sewage and industrial inflow into the Wetland. Diatom community comprised of pollution tolerant species reflecting trophic status. The high percent of vegetation (including forest) cover at Nelakondoddi and Vaderahalli Wetland comprised species, which inhabit oligo to slightly mesotrophic conditions.

Pandey and Verma, (2008) study illustrates that the catchment integrity is significant in determining ecosystem properties of freshwater Wetlands. Li et al., (2010) focused on rapid landscape change and regional environmental dynamics in the Lianyungang bay area from 2000 to 2006 based on remote sensing data indicating that the area has a widespread urban–rural interface with rapid land-use changes, urban expansion and wetland degradation. Rapid increase in urban built-up land has led to large-scale salt wetlands degradation. Allan et al., (1997) highlight that in streams, habitat structure and organic matter inputs are determined primarily by local conditions such as vegetative cover at a site, whereas nutrient

supply, sediment delivery, hydrology and channel characteristics are influenced by regional conditions, including landscape features and land use/cover at some distance upstream and lateral to stream sites. Understanding the effects of changes in land use and land cover (LULC) is important for maintaining a desired level of water quality and also for restoring water quality in affected areas (Gove et al., 2001).

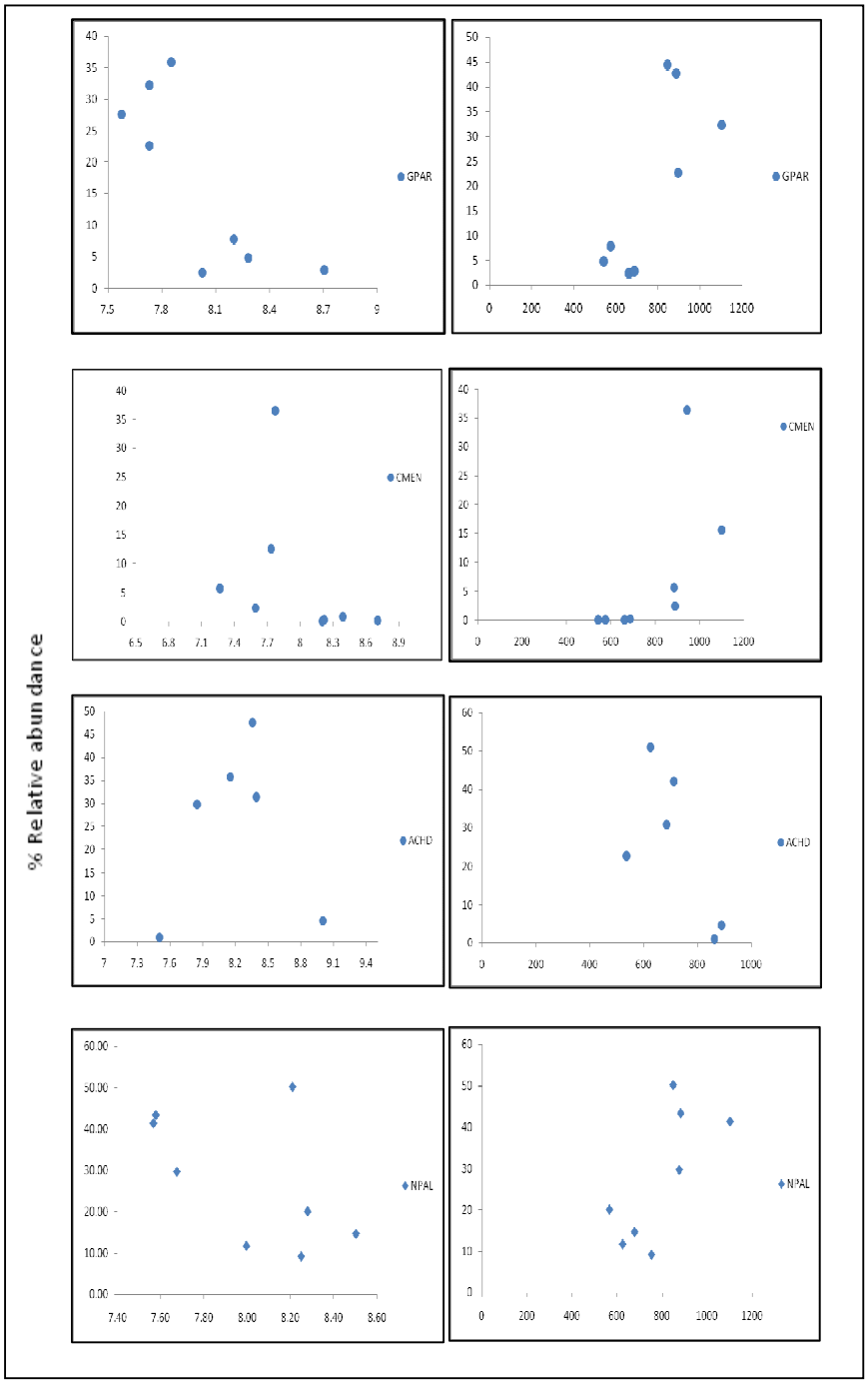

Figure 5 Distribution and autecology of dominant taxa across pH and Electric conductivity

Table 4 Land use/ Land cover classification of selected 4 Wetlands of Bangalore

Class (%)	Nelakondoddi	Vaderahalli	Varthur	Yellamma
Vegetation*	65.98	61.21	45.85	42.90
Built up**	31.48	35.96	55.16	51.68
Water body	2.61	2.82	2.46	1.92

*Vegetation includes cropland, plantation, forest and algal cover.
**Built up include open space also.

Conclusion

LULC changes in the wetland catchment alter the physical and chemical integrity of the system, which influences the diatom community structure. Wetlands with eutrophic water quality conditions were dominated by pollution tolerant diatoms, whereas less polluted wetlands were characterized with diatoms corresponds to oligotrophic – mesotrophic class. Water quality is a decisive parameter in diatom community structure in the respective wetland, even though rainfall seems to have certain influence on diatom succession.

More area of built up in the catchment of Varthur and Yellamallappa chetty increase stress on these wetlands which in turn result in high pollution. Vaderahalli and Nelakondoddi wetlands which is having more vegetation than built up is comparatively facing less disturbance and thus less polluted. Varthur and Yellamallappa chetty wetlands are located in densely populated region with tolerant species whereas wetlands such as Vaderahalli and Nelakondoddi are situated in sparsely populated area and have sensitive species. These results signify that urban wetlands are under severe stress. Thus, catchment characteristics are critical in determining biota of freshwater bodies, thus plans for conservation of wetlands should also be seen at catchment scale, rather than looking wetlands as isolated ecosystem. Ecological preference observed in this study will also lead to development of diatom indices, which can be applicable to monitoring of tropical Asian wetlands.

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Ecological and Socio-Economic Assessment of Varthur Wetland, Bengaluru (India)

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Wetlands are the most productive ecosystems, recognized globally for their vital role in sustaining a wide array of biodiversity and provide goods and services But presently increased anthropogenic activities such as intense agriculture practices, indiscriminate disposal of industrial effluents and sewage wastes have altered the physical, chemical as well as biological processes of wetlands, which is evident from the present study carried out to assessVarthur wetland in India Coastal wetland ecosystem in the world has 14,785/ha US$ annual economic value An earlier study of relatively pristine wetland in Bengaluru revealed the value of ₹ 10,435/ha/day while the polluted wetland showed the value of ₹ 20/ha/day On the contrary Varthur, a sewage fed wetland has a value of ₹ 118 9/ha/day The pollutants and subsequent contamination of the wetland-Varthur has telling effects such as disappearance of native species, dominance of invasive exotic species (such as African catfish), in addition to profuse breeding of disease vectors and pathogens Water quality analysis revealed high phosphate (4 22-5 76 ppm) level in addition to the enhanced BOD (119-140 ppm) and decreased DO (0-1 06 ppm) The amplified decline of ecosystem goods and services with degradation of water quality necessitates the implementation of sustainable management strategies to recover the lost wetland benefits of Varthur

Key words : *Urban wetlands, ecosystem services, water quality, urbanization, conservation strategies*

Introduction

Wetlands represent a combination of aquatic and terrestrial environment, in which the soil is seasonally or permanently covered by shallow water and the water table is close to or near the surface[1 2] Wetland covers thousands of square kilometers; at spatial scale ranging from a crack in the rock to rain forest or ocean Being highly productive, in terms of biodiversity and as well ecosystem's benefits; human community derive, directly or indirectly from ecosystem functions Ecosystem functions refer varyingly to the habitat, physical and biological benefits/processes of the ecosystem[3]. On a larger scale, anthropogenic activities impact physical, chemical and biological processes, which impair the ecosystem functioning[4] causing decline and degradation of ecosystem services and also economic value of the wetland[5]. Wetlands predominantly endure change in wetland hydrology and habitat, loss of catchment area adjacent to urban growth, increasing runoff of nutrients and pollution, introduced species replacing indigenous species, land clearance and over-use of resources by losing its subsistence economies of that region mainly due to urbanization The benefits which may be lost are not effectively quantified in viable markets and also in terms comparable with economic services, are often specified with too little weight in policy decisions Hence, quantifying economic values of ecosystem are essential to respite human activities apart from accounting their services in the regional planning

Valuation entails assigning an economic value in direct market for all the benefits (such as food, fodder, remediation, clean water, biodiversity, groundwater recharge, etc) of wetlands. Nevertheless, the possible way of addressing the economic value is to estimate the value which is exactly the price payable to replicate the natural ecosystem[3] or the price estimated/ paid for the same in direct market by means of economic valuation.

Economic valuation

Economic valuation is an attempt to assign values in terms of market price for the goods and services offered by the ecosystem In Economic terms, the goods and services are broadly grouped as use and non-use values[6] as indicated in **Table 1**. Valuation technique includes "willingness to pay" reflecting individual's choice for the ecological commodities (aesthetic value, recreational opportunities), wood products and intrinsic values[7,8] and also captures its values in an economic value framework[9]. The commonly used technique for the valuation is the contingent valuation technique based on personal interactions with the local people using questionnaires; information on willing to pay for something they value or willing to receive in compensation for tolerating a cost

The zero ecosystem benefits imply zero human welfare[3], thus economic value of a wetland varies from a pristine

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Table 1: Classification of total economic value for wetland

Use Values			Non - Use Values
Direct use values	**Indirect use values**	**Option value & Benefits**	**Existence value**
Fish, Agriculture, Fuel wood, Fodder, Recreation,(Boating, Fauna, Walking) Transport, Wildlife, harvesting, Peat/ Energy Education	Nutrient retention, Flood control,Storm protection,Ground water recharge,External ecosystem support, Filtration,Micro-climate, Shoreline stabilization	Potential future use (as per direct and indirect use). Future value of information, e g., pharmaceuticals, education.	Biodiversity,Culture, Heritage,Bequest

Source [14]

(natural benefits) to polluted (degraded ecosystem's benefits) wetland; influenced by a defined set of environmental conditions. Wetland value increases with quality of goods and services derived and vice versa.

Numerous studies on economic valuation of wetlands have been carried out around the world; however, most of these studies have focused on wetlands in developed countries[11]. Economic studies for Indian wetland are meager addressing serious threats due to agricultural conversion, hydrological alteration followed by urbanization in recent years owing to 60 % loss

Several studies across countries in the past few decades support the estimation of economic value of a wide variety of goods and services. The annual value of wetland was estimated to be second highest, US$ 14 785/ha based on the assessment of 17 ecosystem services in 16 biomes which emphasize that ecosystem functions provide an important portion to the total contribution to human welfare[3]. Other studies include wetlands of Africa[11], China[12], Bangladesh[13] and the European water framework directive of European Union (EU) (2000/60/EC). Assessment of the health of wetlands in China highlights that among all factors, water quality, ecosystem function and structure of waterfront area as the main factors that limit the wetlands value. Study of Mississippi Alluvial Valley focuses on the restoration of wetland ecosystem services in the floodplain area which has profound consequences due to habitat loss, fragmentation, flood storage loss and water quality degradation due to non point source runoff[14]

Many wetlands in India including those in Bengaluru are being degraded due to the apathy of the decision makers and planners. These wetlands, urban as well as rural, paved way to residential layouts, industrial complexes and indiscriminate disposal of urban wastes which has led to the deteriorating water quality and significant changes in local climate. Number of wetlands has dwindled from 250 to 81 (1985) and 33 in 2006[15]. Population of Bengaluru reached 7 million in 2007[16] due to the spurt in unplanned urbanization and consequent land use activities. Effect of sustained inflow mainly of sewage, industrial effluents and agricultural runoff is evident from the results of regular monitoring of water quality at Hebbal, Varthur, Madiwala, Rachenahalli and Amruthalli wetlands[17]. A comparative evaluation of Amruthhalli lake with the relatively unpolluted Rachenahalli lake[2] brings out the impact of degrading ecological integrity of wetlands evident from the drastic decline of values from ₹ 10, 435/ha/day (Rachenahalli lake) to ₹ 20/ha/day (Amruthalli lake). Lower value is mainly due to eutrophication and water being unavailable for any use with an excessive nutrient inflow (sewage and industrial effluents) and storm water. Discharge and dumping of waste into catchment area lead to high levels of phosphates, Total Suspended Solids (TSS), Alkalinity, Hardness, Odour, weed infestation and low dissolved oxygen (DO). Study of Hebbal lake also reflects decreased water quality due to excessive sewage and industrial effluents inflow from surrounding area. The Contingency valuation technique employed for preliminary socio-economic survey reveal high level of dependency on wetlands for groundwater, food, fodder, fuel and so on. The lake supports irrigation, provides food (fish, etc.) and fodder to the livestock in the surrounding areas. The investigation of causes of mass fish mortality in Sankey Lake[18] revealed that the death was due to a sudden and considerable fall in dissolved oxygen (DO) levels in some locations caused by sewage let into the lake resulting in asphyxiation. An incidence of mass-scale fish mortality in Bengaluru reported from Ulsoor Lake[19] supported the above study. These studies highlight the significance of maintaining wetland's quality to ensure sustained ecological functions contributing to economic values.

Bengaluru was known for its lush greenery with numerous wetlands, Varthur wetland being one of the largest amongst all. Rapid unplanned urbanization coupled with the increase in population has affected both Bengaluru and its surrounding towns and villages, including Varthur[15]. Varthur lake constructed 1000 years ago by Ganga rulers, today

receives almost 40% of Bengaluru sewage to the extent of 450-500 minimum lethal dose per day (MLD/day). Part of city's untreated sewage passes through the network of interconnected lakes such as Bellandur and Ulsoor apart from many households directly in the immediate vicinity in a span of 220 hectares. The quantum of sewage exceeds the wetlands ability to assimilate contaminants and hence water quality has declined and has become unfit for human consumption. The contaminated water from Varthur ultimately flow downstream connecting Dakshina Pinakini River. Considering the dependence and impaired livelihood due to decline in ecological functional ability and capability consequent to sustained inflow of sewage and effluents, necessitates the ecological restoration of the lake. This entails understanding of the physico-chemical aspects with the wetland dynamics and the valuation of ecosystem services and goods. The study was carried out with a hypothesis that accumulation of contaminants has been responsible for degradation of water quality and consequent erosion of ecosystem services and goods. In this backdrop, Varthur wetland was investigated for water quality and valuation of the benefits to understand the drivers responsible for wetland degradation and impairment of economic benefits

The study objectives were to: 1. assess physicochemical water quality variables and 2. economic valuation of wetlands through contingent valuation technique, focusing on the causes for wetland degradation and appropriate allocation of wetland use.

The study region

The study was carried out in Varthur wetland, one of the largest wetland located to the south of Bengaluru with 12.940699°N and 77.746596°E geographic position and a surface area of 220 sq. km. The wetland water accounts to irrigate 625 hectares of agricultural fields in the command area, for growing crops like rice, ragee, coconut, flowers and a variety of fruits and vegetables. It provides habitat for a wide variety of flora and fauna, including resident and migratory waterfowl. The inlet receives sewage and industrial wastes, contaminating not only wetland water quality but also Pinakini river at the downstream. Decreased water quality in recent years has influenced the economical significance of wetlands. **Fig.1** represents the study area and sampling points.

Methods

Water quality analysis

Water samples (triplicates) were collected from three sites viz. inlet (12°56'35.99"N lat. and 77°44'5.32"E long.), south-outlet (12°56'43.91"N lat. and 77°44'48.21"E long.) and

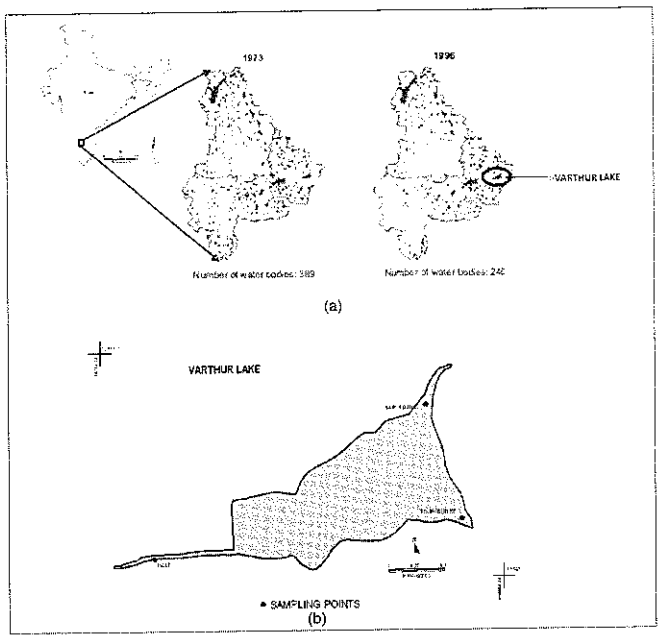

Fig. 1: (a) No. of water bodies in Bengaluru in 1973 and 1996 and (b) Varthur Lake with samplig points (inlet, north outlet and south outlet)

north outlet (12°57'22.86"N lat. and 77°44'40.56"E long.) in Varthur wetland during February 2009. Samples were stored in polythene bottles and were carried to laboratory for further analysis. Dissolved Oxygen was analyzed on-site using 125mL BOD bottles. Physical variables like pH, temperature (°C); total dissolved solids (mgL^{-1}); salinity (mgL^{-1}) and electric conductivity (μScm^{-1}) were measured using EXTECH EC500 Probe immediately after collection. Other water chemistry variables like chloride, hardness, magnesium, calcium, sodium, potassium, nitrates and phosphates were analyzed in laboratory and analyses were carried out as per the standard methods for the examination of water quality as mentioned[20]

Socio-economic survey

A contingency valuation technique was applied for the economic survey of wetland through a participatory approach involving local school students. 235 people from 43 randomly selected households from Varthur and nearby villages were interrogated using a standard questionnaire by KK High School students (VIII to X grade), Bengaluru. The questionnaire was made to quantify use-values of the lake including demographic information, domestic water usage, irrigation, fishing and aquaculture, water usage for livestock, livestock fodder, groundwater recharge, health effects and family history. Valuation of resources through the survey was aimed to evaluate the economic status and dependency of residents. Demographic information included total number of persons/houses, occupation and income per annum which

relate to the dependency of residents on lake domestic water usage, irrigation, fishing and aquaculture, water usage for livestock and livestock fodder in turn the dependency of residents on lake water, aquatic plants and organisms The use of groundwater resources highlights the indirect association with the Varthur lake, responsible for recharging local aquifers

Results

Water quality analysis

Characteristics of water collected from various sampling sites are mentioned in **Table 2**. pH ranged from 7.5-7 7 across sampling sites Conductivity was found to be high in inlet (1420 µS) compared to outlet sampling sites (South outlet, 1075 and North outlet, 1224 µS) Higher conductivity value at inlet was mainly due to the sustained sewage inflow and dissociation of minerals from soil Total Dissolved Solids which account for the amount of sedimentation did not show much variation (749-994 ppm) in lake Dissolved Oxygen (DO) was 0 ppm and 1.06 ppm as observed in inlet and north outlet respectively while at south outlet 8 16 ppm was recorded. Biological Oxygen Demand (BOD) was higher (119-140 ppm) at the inlet which confirms the inflow of higher amount of nutrients into the lake Chemical Oxygen Demand (COD) range (124-188 ppm) indicated the presence of increased oxidizable load. This highlights the anoxic conditions prevailing at inlets. Total hardness and alkalinity were found in the range of 236-288 ppm and 400-420 ppm respectively. The sodium and potassium values were174-180 ppm and 19-21 ppm respectively. Nitrates and phosphates varied from 0.31-0 55 ppm and 4.22-5 76 ppm respectively Phosphate concentrations were found above the permissible limits.

Socio-economic survey

235 people from 43 houses were surveyed for evaluating the level of dependence for goods and services of Varthur Lake, which are listed in **Table 3**.

Domestic use: Few residents in the catchment area depend on lake for domestic usage due to its poor quality. Among all, 15 houses rely on bore wells Groundwater or bore well water usages are categorized as indirect use value as wetlands play significant role in recharging the groundwater sources in and around catchment area. On an average 5 individuals in a house utilize 200 liters of water per day. The dependency value is ₹ 25, 000 per house per year. For drinking water the amount spend on bottled water accounts to ₹ 30,000 per house per year.

Agriculture: Among 43 households surveyed, 35 houses depend on agriculture for livelihood. Wetland water is utilized for irrigating a total land area of 24 28 ha for growing mainly paddy, radish, carrot, tomato, chilly, coconut, beetle leaf and floriculture and the area under each crop is listed in **Table 3**. Apart from this, many paddy, coconut and beetle fields are cultivated nearby which are not included in this survey. The dependency for water for agriculture amounts to ₹ 12, 24,000 every year.

Table 2: Water quality analysis

Variables	Inlet	South outlet	North outlet	Surface Water Standards (permissible limit)
pH	7.70	7.50	7 50	6.5-8.5
Water Temperature (^{0}C)	29.00	30.00	26.00	—
Air Temperature (^{0}C)	28.00	31.00	29 00	
Salinity (ppm)	710.00	532.00	605 00	<400
TDS (ppm)	994.00	749 00	849.00	<500 ppm
Electric Conductivity (µS)	1420 00	1075 00	1224.00	<1200 µS
Total Alkalinity (ppm)	420.00	400.00	420.00	<600 mgL^{-1}
Dissolved Oxygen (mgL^{-1})	1.06	8.16	0.00	> 5 mgL^{-1}
Chlorides (ppm)	167.56	173 24	191 70	< 200 mgL^{-1}
Total Hardness (ppm)	252.00	236.00	288.00	< 300 mgL^{-1}
Calcium Hardness (ppm)	108.00	128.00	135.00	<80 mgL^{-1}
Biological Oxygen Demand (mgL^{-1})	122.40	119.50	140.80	< 3 mgL^{-1}
Chemical Oxygen Demand (mgL^{-1})	128.00	124.00	188.00	< 250 mgL^{-1}
Nitrates (ppm)	0 31	0.47	0.55	20 mgL^{-1}
Phosphates (ppm)	5.76	4.22	5.00	—
Sodium (ppm)	177 00	174.00	180.00	—
Potassium (ppm)	21.00	19.00	19 00	—

Table 3: List of resources and their economic values

Use values	Quantity of Resource	Wetland Value in Rupees (₹)
Domestic use (bathing, cooking)	25-50 litres/person/day	25,00,000/year
Agriculture (income)	4,080/house/month	12,24,000/year
Household	2,500/month	30,000/house/year
Fisheries	5 kg fish/person/yr	25,00,000 /year
Domestic animals	6 animals/house	10,000/year
Fodder for Domestic animals	720 kg/year	57,60,000/year
Fire wood	10,000/month	12,24,000/year
Total		Rs. 95,54,000/220 ha/year

Livestock : On an average 5 animals viz cows, buffaloes, sheep and goats were reared in each house. Water hyacinth and other aquatic weeds (*Eichornia crassipes*., *Typha* sp , *Alternanthera* sp etc) are utilized as feed for cattles. Farms rely on the sale of dairy products for part of their income. The dependency for livestock (fodder) and for washing purposes amounts to ₹ 57, 60,000 and ₹ 10,000 per 6 cows every year respectively.

Fisheries : 5 residents depend on aquaculture for occupation. Fishing is the major source for people nearby. As per the survey consumption of fish is 5 kg/person/year and the value from fisheries amounts to ₹ 25,00,000/year.

Fire wood (Energy): The dependency of people for the fire wood on the wetland amounts to ₹ 10,000 per year.

Discussion

Residents are residing in the catchment of Varthur lake for nearly 30 years to more than 200 years and at least 60% of the families persist for over 100 years[2]. It plays a significant role in providing daily requirements for the local inhabitants such as for domestic use of water, irrigation, fuel and fodder for livestock; while undergoing the stress sequentially due to anthropogenic activities. Higher values of BOD, COD, Nitrates and Phosphates reveal that lake water is severely contaminated. DO of lake was quite low (1.06 ppm) in inlet mainly due to increased inflow of organic material through untreated sewage. DO decreases due to presence of inorganic reducing agents such as Hydrogen Sulphide (H_2S), ammonia, nitrites and certain oxidizable substances[21] Profuse growth of macrophytes mainly water hyacinth, limits air water interface, light penetration and consequently there is a drop in the penetration of atmospheric oxygen as well as algal photosynthetic activities. This maximizes the probability of hypoxic and anoxic conditions in the lake making difficult for survival of aquatic organisms in the water. Higher values of alkalinity show the presence of more carbonates, bicarbonates and hydroxyl ions. Water quality analysis of Varthur during 2002 also reported similar conditions of low dissolved oxygen, alkaline pH and high nutrient inputs (Nitrates, Phosphates and Ammonia). Varthur contains significant amounts of the macronutrients in large quantities in order to grow and survive aquatic plants under higher concentrations of nitrates and phosphate. Elevated amount of nutrients mainly fortify the contamination of water with sewage and non-point sources - fertilizers[2]. Amplified water quality degradation observed when current status was compared with that of past study (**Table 5**), explaining due to the sustained and enhanced inflow of contaminants over time.

Table 4: Livelihood details

Livelihood	Hectares
Floriculture	11.74
Vegetables	10.32
Paddy	2.02

Calculation : ₹ 9554000/220 ha /year

= ₹ 43427.28/ha/year

= ₹ 118.978/ha/day

Water pollution

Varthur Wetland receives 450-500 MLD of sewage from households and industrial wastewater directly into wetland from Bellandur and surrounding localities. These contribute enriched nutrients and increased amount of toxic substances (heavy metals). Enhanced land cover changes have contributed to siltation and consequent sedimentation decreasing lake's depth. The degree of soil saturation of the wetland depends on the consistency of its freshwater flow. Effluents loading has gone beyond the ability to assimilate contaminants, further degrading the water quality. Along with effluents from households and industrial waste, household garbage, plastics and solid waste from commercial places are being dumped in lake bed.

Valuation of ecosystem highlights that due to the severe contamination of water the wetland's goods and services have declined impinging livelihood of dependent population and also local economy. Even though residing

Table 5: Comparison of major water quality parameters of Varthur (2003 and 2009)

General parameters	2003 (Outlet)			2009	
	October	November	January	Inlet	Outlet
pH	7.61	7.55	7.68	7.7	7.50
Temperature (^{0}C)	27	27	23	29	26
Electric conductivity (µS)	460	474	1420	1420	1224
Dissolved oxygen (mgL^{-1})	2	3	2.9	1.06	0
Chlorides (ppm)	-	100	170	167.56	191.7
Total hardness(ppm)	213.6	209.3	232.5	252.0	288
Calcium hardness(ppm)	132	124	158.1	108	135
Biological oxygen demand(ppm)	-	-	74.2	122.4	140.8
Chemical oxygen demand(ppm)	-	-	82.2	128.00	188
Phosphates(ppm)	-	>1	15.54	5.76	5.00

(Source: Ramachandra *et al* 2003 and current survey)

community is dependent on lake for manifold use as mentioned in **Table 3** many problems are faced by the wetland for being beneficial. The total economic value of Varthur resources accounts to ₹ 95, 54,000/220 ha/year (ie ₹ 118.98/ha/day), which is much lower compared to a relatively unpolluted lake (₹10,450/ha/day)[3]. The dependency value on wetland water for domestic and agricultural use is maximum compared to other use-values

Causes of depreciation in lake values

Dumping of garbage and other non-degradable waste materials, inflow of untreated sewage from the residential areas and open defecation are the problems accountable for water quality. Such substances liberate toxic in to the water body; remains suspended; gets dissolved in water or set down on the water bed contributing to groundwater pollution. This majorly deteriorates water quality impinging on aquatic ecosystems. Few effects of these environments are :

- Utilization of contaminated lake water for irrigation purposes has a negative effect on the quality as well as the quantity of crops and this has influenced the major source of income for farmers reliant on agriculture.
- Possibility of contaminants especially heavy metals getting to food chain through fish (which accumulates higher concentrations of heavy metals- bioaccumulation[22]).
- Dumping of municipal solid waste in the lake catchment and letting untreated sewage and effluents into lake has affected the health of the local population due to increase of disease vectors and pathogens (mosquito -*Plasmodium* sp. causing Malaria) and flies population around Varthur region. Current survey also reports health problems like fever, dysentery and skin diseases (dermatitis) in most of the houses. Due to mosquito problem and health hazards, residents spend more than ₹ 30,000 per year in purchase of mosquito repellants (according to survey). Presence of *Eschericia coli* in water sample indicates the fecal matter contamination[3]. Fecal contamination is often associated with other types of pathogenic bacteria and viruses found in untreated sewage and survives for a prolonged period in turbid, warm temperature, mildly alkaline pH, and low oxygen levels in lake water
- Profuse growth of exotic plant species such as water hyacinth (*Eichornia crassipes*) and exotic fish culture have also contributed to extinction of native species of fauna. Prolific macrophytes growth has roofed water surface completely lessening dissolved oxygen level and hindering photosynthesis process. Algal communities depending on photosynthetic activity have declined together with mortality of sensitive life stages inside water. Disturbance in food chain may also lead to changes in algal community and its metabolism.
- Poaching of waterfowl such as Purple Moorhen (*Gallinula chloropus*), Spot Billed Pelican (*Pelecanus philippensis*), Common Coot (*Fulica atra*) and White Breasted Waterhen (*Amaurornis phoenicurus*) by poachers were observed, resulting in its decline.

Dominant fish species reported in 1962, 1998 and 2009 are listed in **Table 6**. *Clarias batrachus, Heteropneustes fosslis, Mystus dittatus* and so on which once contributed substantially to fish community in earlier years has dwindled in their representation in the catches now. The invasive species currently harboring water body are *Catla catla* (Catla), *Labeo rohita* (Rohu), *Cirrhinus mrigala* (Mrigal), *Clarias gariepinus* (African catfish), *Oreochromis mossambica* (Tilapia) and medium sized carps. Enhanced sewage and effluents inflow coupled with the overexploitation of wetland goods are prime reasons for the decline in indigenous fish species and consequent prevalence of invasive species during the last two decades.

Table 6: List of major fish species in Varthur wetland during 1962, 1998 and 2009

Species name	1962	1998	2009
Catla catla (Catla)	-	+	-
Labeo rohita (Rohu)	-	+	-
Cirrhinus mrigala (Mrigal)	-	+	-
Clarias gariepinus (African catfish)	-	+	+
Oreochromis mossambica (Tilapia)	-	+	-
Clarias batrachus	+	-	-
Heteropneustes fosslis	+	-	-
Mystus dittatus	+	-	-
Minor carps	-	+	-

(Source: current survey + indicates presence and - indicates absence of fish species.)

Comparative analysis of polluted and unpolluted wetlands reveals difference in fish composition and associated economic value. Varthur lake harbors only *Clarias gariepinus* (African catfish), whereas *Catla catla* (Catla), *Labeo rohita* (Rohu), *Cirrhinus mrigala* (Mrigal) and *Oreochromis mossambica* (Tilapia) were found in Rachenahalli while another eutrophic lake at Amruthahalli did not have any species. Varthur and Amruthahalli being eutrophicated with heavy sewage contamination and Rachenahalli is relatively unpolluted. Invasive exotic species, African catfish in Varthur water body has predated native fish and survives under eutrophic condition with the macrophytes covering the entire lake. Subsequently, huge amount of waste along with metals and ions (toxic substances) are accumulated inside fish gut due to bioaccumulation[23]. Consumption of fish rich in heavy metals has carcinogenic influence on humans. According to fishermen, Varthur provides 200-300 kg/day of catfish costing ₹ 50-60 /kg/day due to absence of fish variety while Rachenahalli accounts for ₹ 75 /kg/day specified by varieties of fishes mentioned above[9]. Economic value of fish in Varthur is less than in Rachenahhali mainly because of exotic species and decline of native species, water accomplished with sewage and prolific macrophytes growth in Varthur.

The socio-economic studies on Rachenahalli and Amruthalli lakes showed that the economic dependency in the case of Rachenahalli lake (₹ 10,435/ha/day) is more than that of polluted Amruthalli lake (₹ 20/ha/day). This is mainly because of better water quality in former lake while water quality with severe pollution by phosphates, weed infestations and oxygen deficiency in later case. Although in Varthur, Sorahumase and Valepura village, the land irrigated by utilizing the wetland water amounts to 4211 6/day with water quality indicating eutrophic lake containing high concentrations of organic wastes and phosphorus[2].

Management of wetlands to sustain goods and services

This study highlights the need to manage the wetlands to enhance the use-value of an ecosystem. The strategies include : 1. Restoration of wetlands – removal of contaminants; 2. Letting only treated sewage to the wetlands; 3. Letting the treated water through series of wetlands further improves the water quality; 4. Maintaining food chain in the ecosystem – involves removal of excess growth of macrophytes (if any) and exotic fish species, African cat fish, etc ; and 5. Regular water quality monitoring involving local schools. This would also help in functioning as watchdog to prevent any contamination (solid waste dump, direct inflow of sewage, etc.)

Conclusion

The socio-economic survey and water quality analysis show a decline of ecosystem goods and services with the decline of water quality. This has influenced the livelihood of the local population who are dependent on the goods and services provided by the wetland. The persistent hyper eutrophic condition is due to the sewage from Bellandur lake and also from the surrounding residential apartments. Water treatment plant for Varthur wetland benefits the local environment with better water and impassive sludge that can be utilized for agricultural fields as fertilizer instead of commercial inorganic fertilizers. With the improved water quality, introduction of indigenous and herbivorous fish species into water body along with the removal of African catfish will enhance the food availability. To retain existing reserve and bring back the lost resource, efforts such as restoration process should include wastewater treatment system, removal of over growth of invasive macrophytes and awareness among community and enhanced co-operation among government agencies to manage wetland. Management priorities should mainly include evolving sustainable managing strategies for maintaining water quality, control of invasive species, encroachment, drastic land cover changes in the catchment and identification of buffer zone, providing aquatic resources with adequate water quality and limiting the spread of exotic biota in a sustainable manner evolving managing strategies

Acknowledgement

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LAKE 2014: Conference on Conservation and Sustainable Management of Wetland Ecosystems in Western Ghats

Dates: 13th -15th November 2014

Venue: Parisara Auditorium, Sirsi

Symposium Web: http://ces.iisc.ernet.in/energy

E Mail: lake2014@ces.iisc.ernet.in; lake2014symposium@gmail.com; cestvr@ces.iisc.ernet.in; energy@ces.iisc.ernet.in

Organised by	
Energy and Wetlands Research Group [http://ces.iisc.ernet.in/energy], Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560012	
Gramabhyudaya unit, Sri Swarnavalli Mahasamsthana, Sonda, Sirsi	*Vriksh Laksha Andolana, Karnataka*
School of Life Sciences, Assam University, Silchar	School of Environmental Sciences, M G University, Kottayam
Karnataka State Council for Science and Technology, Bangalore.	K.K. High School, Varthur, Bangalore
Vidyaniketan Public School, Ullal, Bangalore	Vagdevi Vilas Instituition, Bangalore

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Village Forest Committee, Shigehalli, Sirsi	Snehakunja, Honnavar
Karnataka Environment Research Foundation	Lions English High School, Sirsi

Introduction: Symposium focusing on lakes popularly known as "**Lake Symposium**" was initiated by the Energy & Wetlands Research Group at Centre for Ecological Sciences, Indian Institute of Science, Bangalore in the year 1998. The theme was broadened in 2000 (Lake 2000) with a wider participation of education institutions, Governmental and non-governmental organisations, etc. The basic idea of the symposium was to bring out the trends in ecosystem conservation, restoration and management including the hydrological, bio-physical, people's participation and the role of non-governmental, educational and the governmental organizations and the future research needs. **Lake 2014** will be the 9th Biennial Lake Conference focussing on "**Conference on Conservation and Sustainable Management of Wetland Ecosystems in Western Ghats"**. The theme of world wetlands day 2014 is "*Wetlands and Agriculture:*

Placing a focus on the need for the wetland and agricultural sectors (and the water sector too of course) to work together for the best shared outcomes" and this conference provides a unique opportunity to increase understanding of the role of wetlands in sustaining the food production and challenges faced by these fragile ecosystems.

Wetland ecosystems are cradles of biological diversity, providing water and primary productivity upon which countless species of plants and animals depend for survival. The degradation of these vital ecosystems is linked to continuing problems of land cover changes, deforestation, habitat fragmentation, pollution, indiscriminate disposal of liquid and solid wastes, and issues related to economic productivity and ecological security. The structural changes in the ecosystem due to land cover changes, will influence the functional aspects namely hydrology, bio-geo chemical and nutrient cycle, which are evident in many regions in the form of conversion of perennial streams to seasonal and disappearance of water bodies leading to a serious water crisis. There is growing evidence that biological diversity will be severely threatened by rapid climate change. Also, hydrological changes could be the dominant effect of climate change, as snowmelt increases, as evaporation rates increase and as droughts, storms and floods intensify. Much of the hydrological changes will be reflected in changes in freshwater ecosystems including most of the wetland areas. The biological impacts include dwindling of the biodiversity, habitat damage and loss of spawning grounds of aquatic organisms, reduction in inland fisheries resources and loss of vegetation. Conservation of natural resources through sustainable ecosystem management and development is the key to our secured future. Formulation and implementation of action plans that best conserve wetland resources require an understanding of issues, concerns and threats to water resources. Approaches towards this direction include:

- Fostering participation of all stakeholders to ensure that individuals and organizations are provided an opportunity to participate in the development of aquatic resources conservation activities;
- Encouraging intergovernmental initiatives through partnerships between communities and non-profit organizations;
- Identifying significant natural, recreational, economic, cultural, scenic resources and aquatic ecosystem values;
- Identifying potential threats to aquatic resources and values;
- Recommending policies and actions that can be undertaken to restore, maintain or enhance aquatic and terrestrial resources.

Scope:

Lake 2014 - "*Wetlands and Agriculture:* Placing a focus on the need for the wetland and agricultural sectors (and the water sector) to work together for the best shared outcomes". Lake 2014 would focus not only on updating of the current knowledge of the scientific community and also would bring in awareness among students, teachers and public. This would provide a platform for interaction among researchers, policy makers, academics and NGOs and address the issues related to wetlands and biodiversity in an era of climate change. This would help in developing a stronger network among experts and institutions in order to develop efficient strategies for the conservation and management of fragile ecosystems. As a part of the conference it has been decided to have theme based lead lectures by the eminent scholars, paper and poster presentations by researchers, school and college students.

Lake 2014 – Objectives:

Focus of Lake 2014 would be (i) assessment of the present status and conservation aspects of wetlands, lakes, tanks, ponds, swamps, streams and rivers in the Western Ghats, (ii) presentation by researchers, practitioners, students of case studies focusing on biodiversity, ecology, present status, threats, conservation measures required, (iii) discussion of current programmes on restoration, conservation oand management of wetlands, (iv) role of education institutions, non-governmental organisations, religious organisations, (v) discussion of people's livelihood and fundamental right towards equitable resource allocation through scientific assessment of ecosystem goods and services, (vi) presentation by students (schools and colleges) based on documentation foussing on wetlands – biodiversity, present status, ecology, conservation and protection needs, (vii) allocation of financial and human resources to conserve and protect ecologically fragile ecosystems, (viii) proposals by students and non-governmental organisations for conservation, protection, restoration and sustainable management of aquatic ecosystems, (ix) discussion on research gaps and activities to be initiated by researchers to evolve appropriate strategies towards conservation of ecosystems in Western Ghats.

Themes:

Papers are invited on the following themes from researchers, planners, development managers, economists and social scientists, school (VIII – XII students) and college students, school and college teachers.

Topics for Paper Presentation/ Poster in Lake 2014:

1. Biodiversity: Western Ghats, Rivers and Wetlands;
2. Wetlands and swamps: Restoration, Conservation and Management;
3. Land use, Land cover dynamics in Western Ghats
4. Climate Change and Western Ghats;
5. Carrying Capacity of Western Ghats;
6. Carrying capacity of river basins in Western Ghats;
7. Valuation of Ecosystem Goods and services;
8. Sacred Groves (kans, devara kadu) and Myristica Swamps;
9. Eco-Tourism in Western Ghats and Carbon sequestration;
10. Need for conservation - Food and water security of India;
11. Application of Geoinformatics in Wetland Management;
12. Natural and Anthropogenic disasters;
13. Limnology, aquatic ecology, biodiversity and prospects of biomonitoring;
14. Pollution –terrestrial and aquatic - Monitoring and Management, bioremediation;
15. Sustainable Agriculture and organic farming;
16. Coastal ecosystems – Biodiversity, Ecology, Productivity and livelihood aspects;
17. Wetland Resources and Livelihood;
18. Prospects of Renewable Energy (solar, biofuel, bioenergy) and Energy Conservation;
19. Environmental Education and Sustainable Development;
20. Environment Ethics and Green Technology.

There are **three awards in students and teachers category**— High School (VIII, IX, X); College (XI, XII and UG) and Teachers (school and college). Awards for the best paper presentation would include a Certificate and a Memento. The best posters would be similarly, awarded.

Venue: Parisara Auditorium (Swarnavalli Mutt Sabhagana, Sonda & Parallel Sessions at Lions English High School, Yellapur Road, Sirsi), Sirsi, Uttara Kannada, Karnataka

- Sirsi is located at an altitude of around five hundred and ninety meters (590m) and is located close to the Arabian Sea. Details are available at http://www.sirsicity.gov.in/

- **Location and Connectivity**: Sirsi town is in the central Western Ghats (Uttara Kannada district, Karnataka) is well connected with other parts of the country by road, rail and air. Nearest airports are Hubli, Goa and Bangalore which are 105, 210 and 440 km away from Sirsi.

- **Climate**: Sirsi has a moderate climate that is basically tropical. Weather during November month is very pleasant and are hospitable. The maximum temperature during these winter months is thirty two degrees (32°C) and the minimum temperature is nineteen degrees (19°C).

Registration Fee

Delegates: INR 2500/- and Accompanying person: INR 1500/-
Research scholars and University faculty: INR 2000/- (mandatory to attend all three days)
Masters students: INR 1000/- (mandatory to attend all three days)
UG students: INR 500/- (mandatory to attend all three days)
No spot registration
School and College (PU) teachers and students: Free (paper accepted for presentation in the technical session**)**

The organising committee has decided to waive registration fee to students and teachers (school/ PU) **whose papers/posters are accepted for presentation in the technical session**. The registration fee for individuals from industry, government and those who wish to participate in the symposium are required to pay INR 2500 (and for accompanying person: INR 1500) and Research scholars and University faculty: INR 2000/- (Research Scholars and university faculty need to attend all three days). Registration fee to be paid by demand draft, drawn in favor of **"Lake 2014, Indian Institute of Science"** payable at Bangalore. The registration fee would include registration kit, working lunch and tea during the symposium. Accompanying person will have access to all technical sessions and hospitality as per delegates except registration kit.

Exhibition: An exhibition of software and hardware related to Restoration and Monitoring technologies, Water quality analysis, Geographic Information System (GIS), Global Positioning System (GPS), Remote sensing, Image processing and Cartography, as well as products and services of other organizations and agencies working in the area related to the theme of the conference, will be organised. Organisations / Agencies can participate in the exhibition on payment of fee of INR 20,000. Registered agencies would be allowed to make 10 minutes presentation. Interested agencies may contact **Dr. T.V. Ramachandra** (cestvr@ces.iisc.ernet.in) and remit the fee through DD drawn in favor of ***"Lake 2014, Indian Institute of Science"*** payable at Bangalore.

Programme Details:

Date	Morning Session (9 am to 1 noon)	Afternoon Session (2 pm to 6 pm)
13th November 2014	Inaugural Session, Presidential Address, Keynote Talk, Felicitation of Senior Researchers	Session on "Integrated Ecological Carrying Capacity of Uttara Kannada" – 35 themes
14th November 2014	*Technical Sessions:* Biodiversity, land use dynamics, Aquatic Ecology, Forest Ecology, Sacred Groves, water, Wetlands and agriculture, pollution, green technology, environment ethics, limnology, Presentations by school and college students (parallel sessions)	*Technical sessions:* Myristica Swamps, wetlands, climate change, global warming, valuation of ecosystems, carbon sequestration, environmental education, ecotourism, sustainable livelihood. Presentations by school and college students (parallel sessions)
15th November 2014	Key note talk, presentation by school and college students (finalists)	Panel Discussion, Cultural programme, valedictory programme, distribution of prizes, certificates (prize and participation)
16th November 2014	*Field Visit*	

Dates to Remember:

Early Bird Registration (for participation), registration form is in page 9.	**18th May 2014**
Submission of scientific papers (full length / extended abstract), posters with the Registration Form (with the registration fee, depending on the category) **– delegates presenting papers/posters.**	**18th June 2014**
Review of Papers and posters by the committee	**June and July 2014**
Final submission of the revised manuscript (based on review comments)	**25th August 2014**
Notification of Acceptance of Papers (on web)	**30th September2014**
Lake 2014 Conference	13-15 November 2014
Field work	16 November 2014

Call for papers:

Call for Scientific Papers: Delegates interested in presenting papers as oral or poster need to submit the scientific paper as per the guidelines given below.

Guidelines for Paper Preparation: The full text paper (e-version preferably in a CD and one hard copy) formatted to A4 (210 mm x 297 mm) size, after having been scrutinized and accepted, will be printed as received, by offset process. Therefore, the text of the paper in English must confirm strictly to the following requirements and be free from errors.

Top/bottom margin	25mm (on first page 35mm)
Left/right margin	25mm (all pages)
Typing area	160 mm x 247 mm (including folio), single space single column
Total pages	8-10 pages including figures, tables, photographs, references etc., if any.
Font type	Times New Roman/Arial
Title	14 point BOLD CAPITALS
Author's Name	**12 point Bold** Upper-Lower (Do not prefix name with/Ms./Dr./Prof.)
Affiliation (designation, organisation and place)	*11 point italics*
E Mail ID, Telephone number and Mobile	11 point
Organisation web URL	11 point
Main headings	10 point **BOLD CAPITALS**
Subheadings	10 point **Bold Upper-Lower**
Text	10 point normal
Print	Laser Print or letter quality

The paper title, name(s) of author(s), affiliation and address, center justified, should be typed in a space of 50 mm from the top margin on the first page. The paper should begin with a synopsis of not more than 200 words describing the aim(s) of the work, methods, results obtained and conclusions. Type the headings, subheadings and paragraphs aligned with the left-hand margin (Align Left). Text justified on both sides is preferred. Use double space between paragraphs, and between section headings/subheadings and paragraphs. Do not number paragraphs, but number section and sub-sectional headings except synopsis, in conformity with established convention. The manuscript should be prepared by using MS Word (suitable for Windows). Figures should be drawn in black Indian Ink on translucent paper or acetate material (Gateway Tissue) with lettering of appropriate size using stencils. The figures should be placed nearest to the first reference

in the text. Photographs on glossy paper may be included, if absolutely necessary. The authors must send brief bio-data (100 words) and the recommendations that they would like to be considered as a part of the conference based on their presentations.

Accommodation: Key speakers and invited delegates would be accommodated at Guest houses, Sonda. Delegates whose paper is accepted for technical session will be accommodated at hotel on first come first serve basis. Delegates requiring accommodation need to mention the requirement in the registration form. Room rent is required to be paid by the delegates as per the tariff in the respective hotel. All delegates will have to make their own travel arrangements.

Accommodation will be arranged on payment basis upon the request from the delegates.

Hotel	**Room type (Bed room)**	**Tariff per day (INR)**	**Available Rooms (Nos.)**	**Other**
Saamrat	Single (Non AC)	260	25	Extra bed- INR 100
	Double (Non AC)	450	20	
	Double (AC)	700	10	
	Suit (Family)	940	5	
	Double Suite	450	2	
Madhuvan	Double (Non AC)	624	21	
	Double (AC)	1296	8	
	Suit (Family)	2500	1	
	Three Bedroom (Non AC)	830	1	
	Three Bedroom (AC)	1620	1	
Panchavati	Double	450	9	
	Double (With TV)	572	11	
	Delux	676	3	
	Delux (AC)	1030	4	
	Three Bedroom (Non AC)	624	1	
	Suit (Couple)	1620	2	
Yatri Nivas Homestay (BAKULA)	AC room	1500	4	Extra bed- INR 200
	Non AC room	1200	2	
Yatri Nivas (Swarnavalli)	Single (Non AC)	250	1	
	Double (Non AC)	250	5	
Netravati Hotel (Opp. Marikamba Temple)	About 20 rooms are available			

Symposium Organising committee:

Honorary President: Shri Shri Gangadharendra Saraswati Samiji,
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LAKE 2014: Conference on Conservation and Sustainable Management of Wetland Ecosystems in Western Ghats

Dates: 13th -15th November 2014, Venue: Parisara Auditorium, Sirsi

REGISTRATION FORM

1	Name	
2	Designation	
3	Official address	
4	Communication Address	
5	E Mail	
6	Telephone Number with Code	
7	Mobile	
8	Presenting Paper / Poster	Paper / Poster
9	If Yes, Title of the paper /Poster	
10	Enclosed: Abstract / Paper (e – version and hard copy): (Please ensure CD is virus free)	
	e-version of the Abstract and paper may also be sent to	lake2014@ces.iisc.ernet.in; lake2014symposium@gmail.com
11	Accommodation Required:	Yes / No:
12	If yes: Hotel Name	
13	Arrival at Sirsi	Date _____ and Time _____
14	Details of Registration Fee*	Amount: DD No: Bank: Date:
15	Accommodation required	From: To:
16	Details of accommodation charges*	Amount: DD No: Bank: Date:
17	Travel details	Arrival Train / Flight/Bus: Place and Date:
18	Travel details	Departure Train / Flight/Bus: Place and Date:

(All fields must be filled) *DD in favour of Lake 2014, Indian Institute of Science, Bangalore

Place:

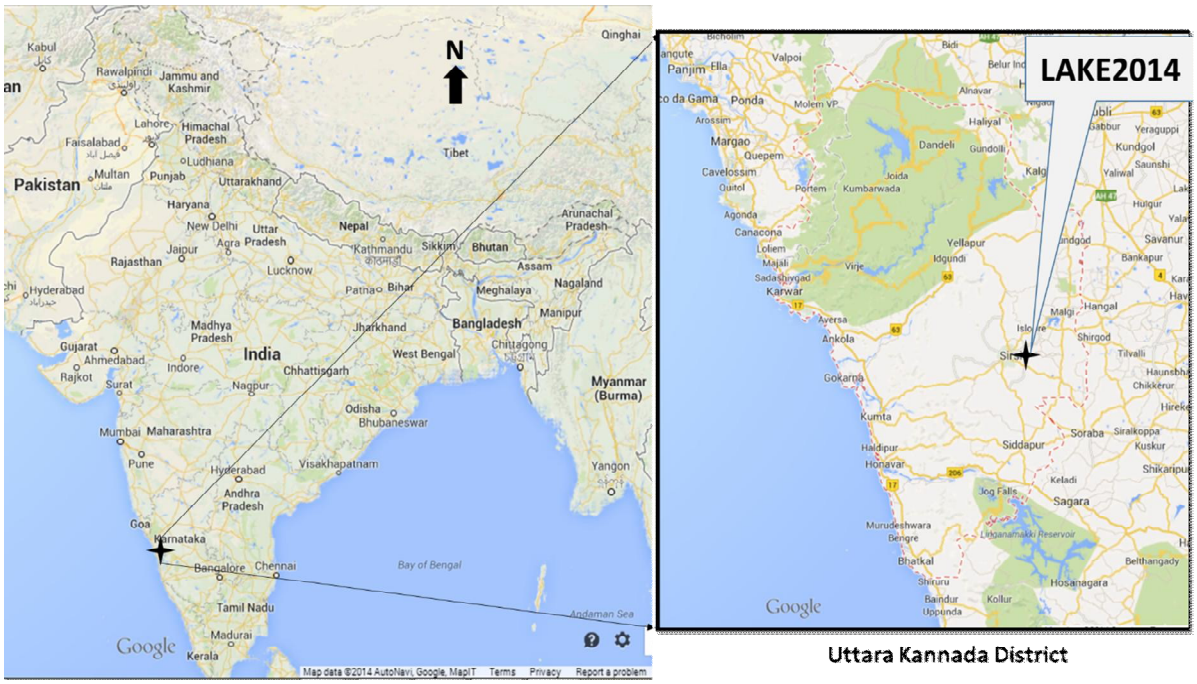
Date: Signature

How to reach Sirsi, Uttara Kannada (Karwar) district, Karnataka:

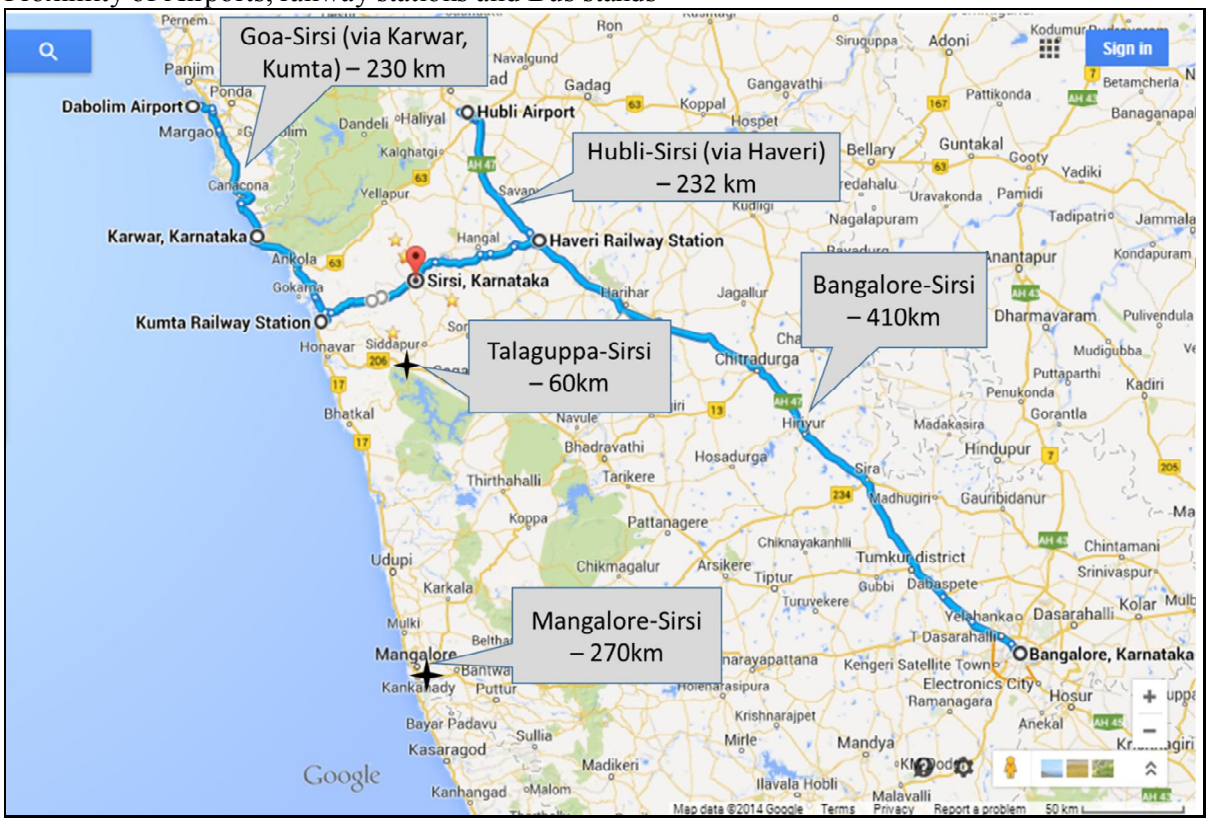
From	Distance (km)	Mode	Best option
Bangalore (International Airport, Railway station, Bus stand)	~ 450	Bus transport (Private and KSRTC) – Volvo, sleeper, semi sleeper Flight – Either Hubli or to Goa, then by road Railway – Haveri, Kumta or Talaguppa	Bus transport
Hubli (Airport, Railway station, Bus stand)	~110	Road transport (KSRTC buses and Taxi are available)	
Haveri (Railway station, Bus stand)	~ 80	Road transport (KSRTC buses and Taxi are available)	
Goa (Airport, Railway station, Bus stand)	~205	Road transport – Reach Ankola or Kumta by KSRTC/Kadamba (Goa transport). From there KSRTC buses and Taxi are available	
Talaguppa (Railway station, Bus stand)	~ 60	Reach Siddapaur (town) by KSRTC/Private buses. KSRTC buses/Taxi are available from Siddapur to Sirsi	
Kumta (Railway station (Konkan Railaway), Bus stand)	~ 65	Road- KSRTC Buses/ Taxi	
Karwar (Railway station, Bus stand)	~ 120	Road – Direct KSRTC buses are available (less frequent), Reach Ankola/Kutmta for more frequent buses	
Mangalore (Bajpe International Airport, Railway station, Bus stand)	~ 270	Road – Reach Kumta by KSRTC bus/Taxi and then Kumta to Sirsi via road Railway – Mangalore to Kumta, and then Kumta to Sirsi via road (KSRTC)	

Route Maps:

Location of the conference LAKE-2014

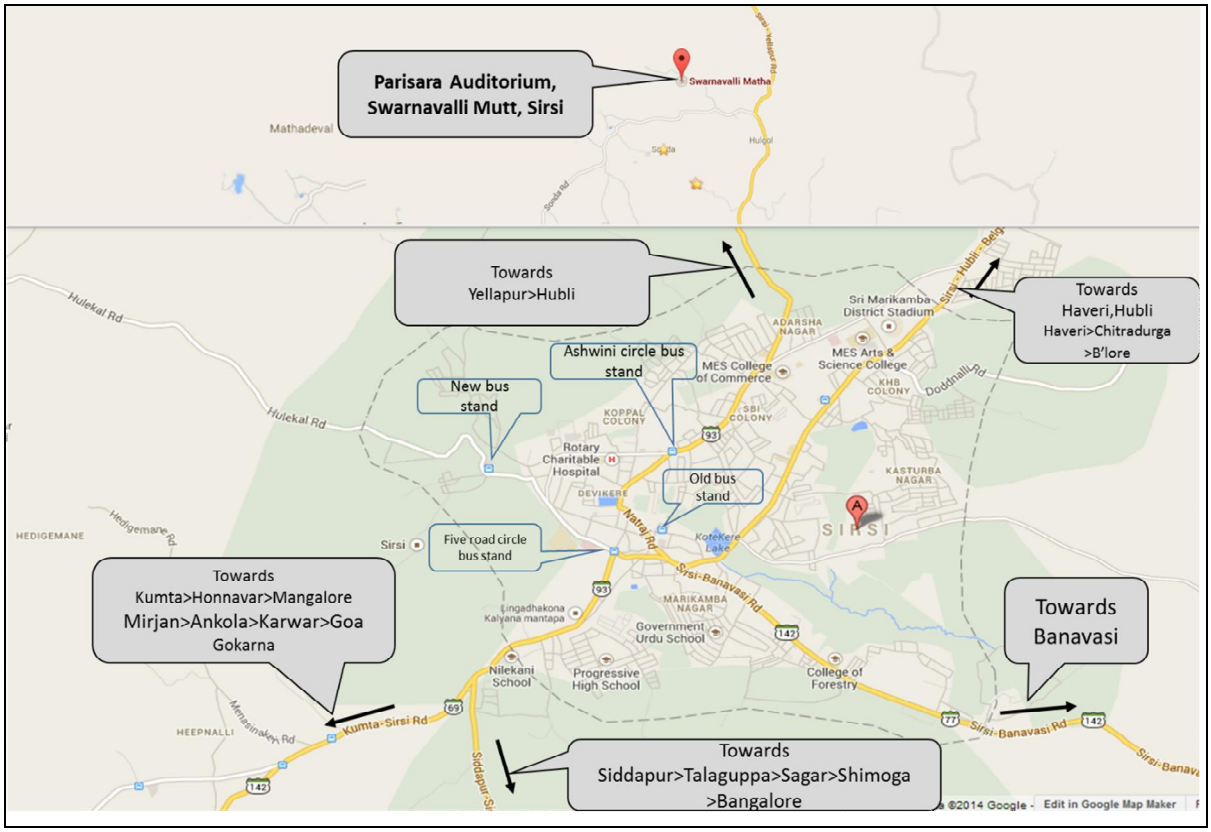


Proximity of Airports, railway stations and Bus stands



Useful Landmarks and road network in Sirsi

m


Parisara Auditorium,
Swarnavalli Mutt, Sirsi
Towards
Yellapur>Hubli
Towards
Haveri,Hubli
Haveri>Chitradurga
>B'lore
Towards
Kumta>Honnavar>Mangalore
Mirjan>Ankola>Karwar>Goa
Gokarna
Towards
Banavasi
Towards
Siddapur>Talaguppa>Sagar>Shimoga
>Bangalore
Ashwini circle bus
stand
New bus
stand
Old bus
stand
Five road circle
bus stand
Swarnavalli Matha
Mathadevai
Sri Marikamba
District Stadium
MES College
of Commerce
MES Arts &
Science College
Rotary
Charitable
Hospital
SIRSI
Sirsi
HEDIGEMANE
HEEPNALLI
Nilekani
School
Progressive
High School
Government
Urdu School
College of
Forestry
Lingadhakona
Kalyana mantapa
Hulekal Rd
Doddnalli Rd
Kumta-Sirsi Rd
Sirsi-Banavasi Rd
Sirsi-Hubli-Belgi
Natral Rd
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