CHAPTER-4

MORPHOMETRY

4.1. INTRODUCTION:

Morphometry refers to physical factors (shape, size, structure, etc) that determine the lake basin. Lake Morphometry deals with the quantification and measurement of these forms and form elements. Morphometric data are of fundamental importance in most Limnological and hydrological point of view. This is obvious to most scientific in the field, but it is just as evident that lake morphology and Lake Morphometry are comparatively neglected topics of scientific endeavour. The main purposes of this work are to present a thorough discussion concerning definitions and determinations of morphometrical parameters of Veeranam Lake.

Morphometric parameters are needed to evaluate erosion, nutrient loading rates, chemical mass, heat content, thermal stability, biological productivity and effectiveness of growth, and many other structural and functional components of the ecosystem. Management techniques such as loading capacity for effluents and selective removal of undesirable components of the biota are also dependent on detailed knowledge of the morphometry and flow characteristics.

The water in lakes is balanced by the basic hydrological relationship in which change in water storage is governed by inputs from all sources minus water losses. Water income from precipitation, surface influents and groundwater sources is balanced by outflows from surface effluents, seepage to groundwater and evapotranspiration. Each of these inflows and outflows vary seasonally and geographically and is governed by
the characteristics of particular lake basins, their groundwater, drainage basins and climate. The hydrological cycle, which can be altered extensively by human induced changes of surface water systems, determines the distribution of lakes in relation to the suitable catchment (watershed) area.

A limnological description of a lake is a necessary step in the research of an aquatic ecosystem and it includes the study of lake forms, their genesis and their role in a physical limnological perspective (Hakanson, 1981). In this sense, the morphology of a lake basin reflects processes closely related to its origin, which is a useful descriptor towards the classification of wetlands (Florin et al., 1993). In addition, morphometrical parameters exert a major control over a wide range of processes and features of a lacustrine ecosystem, and are fundamental in most limnological and hydrological studies.

4.2. DRAINAGE SYSTEM:
Drainage system is the pattern formed by the stream, rivers and lakes in a particular basin. They governed by the topography of the land, whether a particular region is dominated by hard (or) sedimentary rocks, and the gradient of the land. According to the configuration of the channels, drainage system can fall into one of several categories known as drainage patterns. Drainage pattern depends on the topography and geology of the land.

Veeranam tank is one of the important biggest lake in Tamilnadu. The name Veeranam is born from the name of Veera Narayanan. The Vadavar canal in the southern part of Lake is the main inlet for the Veeranam tank. The tank is of 16 km
The total capacity of the tank was 1446 million sq.ft. Due to the deposition of the sediments from the inlets of the tank for many years the total capacity of the tank has been reduced. In order to improve its capacity desiltation was done in three periods viz. 1966, 1978 and 1982; its capacity level varies as 1102 million sq.ft. 981 million sq.ft. and 931 million sq.ft. respectively. The tank has 28 outlets in broader side and 6 outlets in other opposite side. The water from these outlets is used for irrigate the total of 44,856 Acres of agricultural lands. The peak level of the tank is 44.50ft. (13.870m). Higher water level is 48.00 ft. (14.630 m). The higher level of the bank is 54.00 ft. (16.450 m).The water catchment of the tank is 427 sq.km (165 sq.miles). The Sengal odai, Vannanodai and Karuvaattu odai are the three major inlets with other 42 minor inlets supply water to this tank. Apart from this the continuous rainfall for 3 to 4 days in the Udayarpalayam taluk also gives 10,000 to 15,000 sq.ft. of water to the tank.
Fig. 4.1. Drainage pattern map of Veeranam Lake
In total 17845 sq.ft. of extra water during rainy season has been drained out through 14 canals from the Lalpet regulators and 5265 sq.ft. of water are drained by natural outlets. The 1500 sq.ft. of water is drained by one canal from the northern regulator, 875 sq.ft. drained by three canals from Veeranam Pudhuvarthu outlet and 680 sq.ft. of water is drained by one canal from the northern regulator, 875 sq.ft. drained by three canals from Veeranam Pudhuvarthu outlet and 680 sq.ft. of water is drained by one canal. The Vadavar canal which is one of the main inlet of the tank is of 22 km in length. With 24 sub canals and are been separated from the main canal. The total capacity of the canal is 2200 sq.ft. The water is released from the downstream of this canal to the Veeranam tank. The basement of the Vadavar major regulator is 44.28 ft. (13.460 m).

In total 5 spillways are present in the regulator with the height of the door of the spillway is 10' to 0". Total of 2200 sq.ft. of water per second can be drained through this Vadavar major regulator. The peak water level height of the Vadavar canal is 2.56m, and the height between full water level to the total height of the canal is 1.00 m. The slope level of the canal is 1:1. The breadth of the basement of canal is 36.60 m (0.0 to 4.8 km), 30.00 m (4.8 to 21.80 km). The velocity of water in the canal is 0.8m/s. The modified level of water drain is 2300 sq.ft./second and the actual capacity of drain water is 2895 sq.ft./second.

4.3. MORPHOMETRIC PARAMETERS:

4.3.1. Bathymetry:

Bathymetry is the study of underwater depth of lake (or) ocean floor. In other words, bathymetry is the underwater equivalent to hypsometry or topography. The name comes from Greek (bathus-deep and metron-measure). Bathymetric maps are the source of most morphometric data used in Limnological, hydrological and sedimentological contexts. The reliability of the morphometric data will depend on
the accuracy of the hydrographic map, which in turn will depend on the intensity and accuracy of the hydrographic survey. The Bathymetric map of Veeranam Lake has been created based on the depth data collected using GPS with transducer and GNSS receiver at 120 locations. The depth data were interpolated using IDW method under GIS environment and bathymetric map was generated for Veeranam Lake and is shown in fig.4.2.

The bathymetry map of 0.5m interval show N-S oriented linear oval shaped lake is steeper at central part and flatter to gently sloping on the banks. The gentle slope in the eastern and western part is attributed to rapid accumulation of sediments.

The bathymetry map also reveals that the lake basin is having undulated bottom floor (fig.4.2.) with maximum depth of 9.72m recorded in the northern extremity part of the surveyed area of the water body. The central portion of the water body is also deeper depth compared to its other nearer parts. Similarly the bathymetric map of the water body reveals that compaitively series of very small deep basins along the eastern side. These series of small deep basins are aligned straight in the N-S directions, and these are the desiltation locations. The significant morphometric features of the Veeranam Lake are given in the table 4.1. The descriptive explanations of the morphometric parameters are given in the following heading.
Fig. 4.2. Bathymetry map of Veeranam Lake.
Table 4.1. Morphometrical parameters of Veeranam Lake, (according to Hakanson, 1981).

<table>
<thead>
<tr>
<th>Morphometric parameter</th>
<th>Formula</th>
<th>Symbol</th>
<th>Morph Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td></td>
<td>a</td>
<td>19.42 km²</td>
</tr>
<tr>
<td>Shoreline length</td>
<td></td>
<td>ℓ₀</td>
<td>43.64 km</td>
</tr>
<tr>
<td>Shore development</td>
<td>( F = \frac{ℓ₀}{2\pi\sqrt{a}} )</td>
<td>F</td>
<td>0.634</td>
</tr>
<tr>
<td>Maximum length</td>
<td>( L_{MAX} )</td>
<td>ℓₘₐₓ</td>
<td>14.63 km</td>
</tr>
<tr>
<td>Maximum width</td>
<td>( B_{MAX} )</td>
<td>Bₘₐₓ</td>
<td>3.67 km</td>
</tr>
<tr>
<td>Mean width</td>
<td></td>
<td>B⁻</td>
<td>1.32 km</td>
</tr>
<tr>
<td>Maximum depth</td>
<td>( D_{MAX} )</td>
<td>Dₘₐₓ</td>
<td>10.0 m</td>
</tr>
<tr>
<td>Volume</td>
<td>( V_p )</td>
<td></td>
<td>65639.6 m³</td>
</tr>
<tr>
<td>Mean depth</td>
<td>( D = \frac{1000V_p}{a} )</td>
<td>D⁻</td>
<td>3.38 m</td>
</tr>
<tr>
<td>Relative depth</td>
<td>( D_r = \frac{D_{MAX} \pi}{20\sqrt{a}} )</td>
<td>Dᵣ</td>
<td>0.53 m</td>
</tr>
<tr>
<td>Median depth</td>
<td>( D_{50} )</td>
<td></td>
<td>2.7 m</td>
</tr>
<tr>
<td>Mean slope</td>
<td>( \alpha )</td>
<td></td>
<td>1.86%</td>
</tr>
<tr>
<td>Dynamic Ratio</td>
<td>( DR = \sqrt{\left(10^{-6}\right) / D} )</td>
<td>DR</td>
<td>0.25</td>
</tr>
<tr>
<td>Direction of major axis</td>
<td></td>
<td></td>
<td>N-S</td>
</tr>
</tbody>
</table>
4.3.2. Areal Characteristics:
Generally, lakes that are small in surface area and larger in depth exhibit higher water quality than those that are larger in surface area and shallow in depth. This is referred to as surface to volume ratio (S/V). Maximum depth and median depth along with percentage of littoral area (part of the lake basin where enough light penetrates to allow growth of plants and algae) is important in the lake morphometry. If a lake has a very large watershed area compared to its surface area, it will receive larger surface runoff with substantial nutrient loads.

A) Length:
In geometric measurements, length is the longest dimension of an object. In other context length is the measured dimension of an object.

(i) Maximum Length ($L_{max}$ in Km):
$L_{max}$ is defined by the line connecting the two most remote points on the shoreline (fig.4.3). In regular basins the line is generally straight and contours with the maximum effective Length ($L_e$). In regular lakes, $L_{max}$ is curved line. Consequently, the maximum length cannot always be given a definite value. It has limited limnological use, and is primarily to be considered as descriptive measure.

The maximum length ($L_{max}$) is **14.63 Km** in Veeranam Lake.

(ii) Maximum effective length ( $L_e$ in Km):
$L_e$ is defined by the straight line connecting the two most distant points on the shoreline over which wind and waves may act without interruptions from land or
islands. This is an important parameter in many Limnological and hydrological contexts, e.g., concerning internal seiches.

The maximum effective length \( (L_e) \) is 9.15 Km in Veeranam Lake.

(iii) Direction of major axis:

Direction of Major axis is defined by the general compass direction of the maximum length \( (L_{\text{max}}) \).

The direction of major axis \( (L_{\text{max}}) \) is N-S in Veeranam Lake.

B) Width:

In geometry, the minimum distance between two parallel lines, planes (or) hyperplanes that enclose a given shape is known as width.

(i) Maximum Width \( (B_{\text{max}} \text{ in Km}) \):

\( B_{\text{max}} \) defined by the straight line at a right angle to the maximum length \( (L_{\text{max}}) \), which connects the two most remote extremeties on the shoreline (fig.4.3). \( B_{\text{max}} \) like \( L_{\text{max}} \), primarily a descriptive value in limnological contexts.

The maximum width \( (B_{\text{max}}) \) is 3.67 Km in Veeranam Lake.

(ii) Maximum effective width \( (B_e \text{ in Km}) \):

\( B_e \) defined by the straight line on the lake surface, perpendicular to the maximum effective length \( (L_e) \), which connects the two most distant points on the shoreline.

The maximum effective width \( (B_e) \) is 2.48 Km in Veeranam Lake.
Fig. 4.3. Length and Breadth map of Veeranam Lake.

Legend

- $L_{\text{max}}$ – Maximum Length
- $B_{\text{max}}$ – Maximum Breadth
- $L_e$ – Effective Length
- $B_e$ – Effective Breadth
(iii) Mean width ($B^{-}$ in Km):

Mean width is defined by the ratio of lake area ($a$ in Km$^2$) to maximum length ($L_{\text{max}}$ in Km), i.e.

$$B^{-} = \frac{a}{L_{\text{max}}}$$

Where, $B^{-}$ = mean width

$a$ = lake area

$L_{\text{max}}$ = maximum length

The mean width ($B^{-}$) is **1.32 Km** in Veeranam Lake.

C) Depth:

Depth is a dimension taken through an object (or) body of a material, usually downward from an upper surface, horizontally inward from an outer surface, (or) from top to bottom of something regarded as one of several layers.

(i) Maximum Depth ($D_{\text{max}}$ in m):

$D_{\text{max}}$ is the greatest known depth.

The maximum depth ($D_{\text{max}}$) is **10m** in Veeranam Lake.

(ii) Mean Depth ($D^{-}$ in m):

Mean depth is defined by the quotient Lake volume ($V$ in Km$^3$) to lake area ($a$ in km$^2$). The Mean depth ($D^{-}$ in m) is determined by following the method of Hakanson (1981). Mean depth is important to infer the lakes potential for waves and mixing events to disrupt the bottom sediments. Shallow lake are generally more productive than the deep lakes and the mean depth is quick way of assessing overall depth.

The mean depth ($D^{-}$) is **3.38m** in Lake Veeranam.
(iii) Median depth ($D_{50}$ in m):
According to the definition, 50% of the lake area should lie below the $D_{50}$ value and 50% above.
The median depth ($D_{50}$) is **2.7m** in Lake Veeranam.
The median depth may be used, e.g., to determine the lake bottom roughness (R), which is a useful parameter in Sedimentological contexts and in the optimizational model for lake hydrographic surveys.

(iv) Relative Depth (Dr in %):
Dr is defined by the ratio of maximum depth ($D_{max}$ in m) to mean diameter of the lake i.e.

$$Dr = \frac{D_{max} \sqrt{\pi}}{\text{Mean dia} \sqrt{a}}$$

Where $a$ is the lake area in km$^2$
The relative depth (Dr) is **0.53%** in lake Veeranam, which is a normal figure for large basins. Small and deep lakes have high Dr-values. The relative depth may be used to describe stability of stratification of lakes.

(v) Depth Ratio:
Neumann (1959) concluded that the depth ratio provides a useful approximation to lake form.

Depth Ratio = ($D$/$D_{max}$)
The depth ratio is **0.34** in Veeranam Lake.
4.3.2. Volumetric Characteristics:

A) Shoreline length (Io in km):
Shoreline length has been determined with the help of ArcGIS software,
The shore line length (Io) is 43.64 Km in Veeranam Lake.

B) Total Lake area (a in km$^2$):
The lake area within the limits of the shoreline. This area value is determined with the help of ArcGIS Software.
The total area (a) of Veeranam Lake is 19.42 km$^2$.
The ‘a’ value is used to determine the shore development (F), which is an important parameter in the optimization model for hydrographic surveys.

C) Volume (Vp):
Total lake volume can influence a lake capacity. It allows the sedimentation of mixed layer (epilimnion) volume (or) hypolimnion. The volume is called as the linear approximation of the volume with the lake having concave relative hypsographic curve, which is determined based on depth and area.

\[ V = \frac{1}{3} H (a_1 + a_2) \sqrt{a_1 * a_2} \]

Where, $H$ is contour interval,
$a_1$ is area with outer depth,
$a_2$ is area with inner depth,
The volume (Vp) of the Veeranam lake is 65639.6 m$^3$. 
D) Mean Slope ($\alpha$):

The slope for an arbitrary station in lake may be determined with the help of contour difference expressed in the form of height in a particular transect of direction as the major slope axis, which can be determined from the bathymetric map and Slope map. The Mean Slope ($\alpha$) is 1.86% in Veeranam Lake.

E) Slope Analysis:

Wentworth's method of slope determination is a general and easier method and is easier to follow,

$$\tan \theta = \frac{N \times I}{3361}$$

Where, $N$ is no. of contours

$I$ is the contour interval.

The nature and slope of the Veeranam lake is shown in fig.4.4. The slope map of the water body comparatively steep slope towards middle zone and flatter in the bank. The slope angle of the Veeranam Lake roughly follows steepness towards bull- eye pattern with the deepest part in the lake centre.

F) Dynamic ratio (DR):

Dynamic ratio is a morphometrical parameter designed to represent bottom dynamic conditions (Lindström et al., 1999). The influence of this parameter over processes such as lake desiccation and other processes related to the water-sediment interface denoted its importance.
Fig. 4.4. Slope Diagram of Veeranam Lake
The dynamic ratio value of Veeranam Lake is 0.25.

G) Shore Development (F dimensionless):
A measure of the degree of irregularity of the shoreline. It provides a measurement of the amount of interface between the lake and surrounding lands. Shore development is a measure of the degree of irregularity of the shoreline. Shoreline development is a measure of how much the lakes surface shape deviates from being a perfect circle. The $F$-value is defined by the formula,

$$F = \frac{lo}{2 x \sqrt{\pi} A}$$

Where, $lo$ the normalized shoreline length in km,

$A$ is the total lake area in km$^2$,

The shore development ($F$) is 0.634 for Lake Veeranam.

The value of $F$ is 0.634 in Veeranam Lake implies that the lake is having dendritic and devoid of semicircular nature.

H) Lake Bottom roughness (R):
Lake bottom roughness (R) is a measure of the degree of irregularity of the bottom. R value is only defined for whole Lakes, accordingly.

$$R = \frac{0.165 x (Ic + 2) x (Lo + 1)}{D_{50} x \sqrt{a}}$$

Where, $R$ is the normalised lake bottom roughness,
Ic is the contour line interval in m,

$D_{50}$ is the median depth in m,

a is the lake area in Km$^2$ and

Lo is the shoreline length in Km.

The lake bottom roughness (R) of the Veeranam Lake is 4.33.

I ) Form roughness ($R_f$, dimensionless):

Form roughness ($R_f$) is a preferable measure to compare the degree of bottom irregularity in Veeranam Lake.

$$R_f = \frac{0.165 \times (Ic + 2) \times Lo + 1}{A}$$

Fig.4.5 illustrates quantitative terms of the areal distribution of form roughness in Lake Veeranam. The fig shows the relative differences in bottom irregularity within the area.

4.4. RESULTS AND DISCUSSION:

The bathymetry and geometry of Veeranam Lake play a key role in the processes occurring within the lake. As fig.4.2 illustrates, the lake is elongated shaped and the long axis lying in the N-S orientation. Overall, the lake is shallow, with a mean depth of -3.38m and maximum depth of -10.0m. Veeranam Lake’s assymetrical bottom bathymetry is roughly bowl shaped; with broad shallow lake margins has a gentle slope than the northern and central part (fig 4.3). There is a nearly circular shaped deep area in the lake center.
Fig. 4.5 Form Roughness diagram of Veeranam Lake.
A Bathymetric map is the standard way of recording the morphometry of lakes. The lake Veeranam bathymetric map (Fig.4.1.) shows an elongated outline form, with one single basin. Among the morphometrical parameters, mean depth (D–) is probably the most useful morphometric feature available, because it could be related to the productivity and trophic status of lakes (Håkanson, 1981). It serves as a surrogate for most morphometric attributes and a host of biological processes, but no correlate can provide unambiguous information on underlying causes (Kalff, 2002). However, a high value of mean depth both in freshwater and in saline lakes, normally tends to show low levels of nutrients in water and consequently of productivity indicators (Chow- Fraser, 1991; Sakamoto, 1966). Even though this parameter was developed to compare different lakes, we used it to evaluate changes in the same lake (Veeranam Lake) across two different hydrological seasons. Therefore we can see a very different ecosystem performance. In this way, during the SUM Lake Veeranam shows a D– < 0.3. On the other hand, in the NEM the lake mean depth value was higher (D– = 1.4).

Mean depth is greater than median depth (D_{50}), as it is characteristic of a slightly convex basin. The median depth may be used to determine the lake bottom roughness, which is a useful parameter in sedimentological contexts and in the optimization models for lake hydrographical surveys (Hakanson 1981). Neumann (1959) concluded that the depth ratio (D–/D_{max}) provides a useful approximation to lake form. Veeranam Lake showed a value of 0.34, similar to an elongated ellipsoid form and it is characteristic of shallow lakes with flat bottoms (Carpenter, 1983). Veeranam Lake shows also a relative depth (Dr), a parameter that may be used to describe stability of stratification of lakes, typical of small and shallow basins. Shore
Development (F) is 0.64 and it represents a measure of the irregularity of the shoreline (Hakanson 1981), which is one of the morphological parameters that reflects processes related with lake origin.

Dynamic ratio (DR) is a morphometrical parameter designed to represent bottom dynamic conditions (Lindström et al., 1999). The influence of this parameter over processes such as Lake Desiccation and other processes related to the water-sediment interface denoted its importance. The dynamic ratio value (DR) of 0.25 in Veeranam Lake indicates that it has lower bottom areas exposed to wind/wave energy which is an useful tool to know the amount of sediment available for re-suspension on the erosion and transport areas, the fraction that goes to deep waters, and the fraction that goes to surface waters (Hakanson et al., 2000). The values obtained mean that 65.3% of the matter available can be assumed to be transported to deep waters and 34.7% to surface waters. Veeranam Lake has slight shore slopes, although there is some dissimilarity between the two shorelines. Ortega and Guerrero (2003) observed that the slight slope nature in lakes allows for colonization of the sediment by submerged macrophytes and helophytes.

The most important human impact affecting this Veeranam Lake ecosystem is mainly due to an inadequate vegetative matter on its shorelines. This implies changes in morphometry parameters and destruction and substitution of littoral plant communities around the lake. Hence in the present attempt it is emphasized the importance of morphological study in terms of possible future changes in morphometrical parameters as a consequence of human impact.