This guide helps HYMOS software users from its installation to completion of a wide range of hydro-meteorological data validation & its analysis.

Application Guide for HYMOS Users

National Water Academy,
Central Water Academy

October, 2011 (Revised)

CONTENTS

FOREWORD

Planning, design and management of water resources projects in India for sustainable and optimal development of the country's water resources have to be essentially based on sound hydrological and hydraulic studies using appropriately validated hydro-meteorological data. Two softwares namely SWDES and HYMOS were developed under the Hydrology Project-I for the first time in India with the objective of systematic management of hydro-meteorological data, its proper validation and carrying out various studies such as water availability, dependability, intensity-duration frequency curves, rainfall-runoff relations, flood frequency analysis etc,

SWDES being the much simpler software of data entry only is quite user friendly and people using it do not encounter much difficulty in adopting it for regular use. HYMOS is, however much more complex and many users find difficulty in developing sufficient expertise for it in a "self teaching" mode. Consequently, use of HYMOS is still limited to a few officers only and, as a result, utilizing the full potential of the collected and duly validated hydrological data continues to be a major concern. It requires renewed attempts to train, educate and familiarize all those engaged in this activity about use of HYMOS which the Central Water Commission continues to do time to time through its National Water Academy (NWA) as well as other units.

In an effort to address these issues, NWA has brought out this publication "Application Guide for HYMOS Users". The guide illustrates several worked out examples ranging from software installation to tertiary level of data validation, i.e. rainfall-runoff validation etc. It is intended to guide users to attain their task without much difficulty as it is simple to understand due to the use of extensive screenshots and descriptions.

I would like to place on record my appreciation for the faculty of the National Water Academy, Central Water Commission in bringing out this document. Since this is the first edition of this publication, suggestions for improvement will emerge in the days ahead. I am sure NWA will incorporate those comments and make this compilation still better in future versions.

(A K Bajaj)
Chairman, CWC
& Ex-Officio Secretary to Govt of India

Instructions to Users

- A series of hand-outs illustrating validation of rainfall, water level data; fitting of rating curves; and rainfall runoff validation in the end have been incorporated in this booklet. These examples supplement the already published HYMOS user manual and a number of training modules brought out under Hydrology Project – I.

- A presumption that these hand-outs are enough in acquiring familiarity with HYMOS has no merit. It is only a step forward in that direction. Accordingly, users are strongly suggested not to follow instructions herein in isolation of user manual and training module.

- To guide the users accomplish their task smoothly, descriptive paragraphs have been linked with concerned figures. This aside, references at several places have been inserted in this document which users may refer to.

- The beginner in HYMOS may start with these examples without referring to these materials. However, gaining full familiarity with the various functionalities of HYMOS does need understanding of materials referenced.

Contributors

Chapter 2	**Dr R N Sankhua, Director, NWA**
Chapter 1, & 3 to 13	**A K Srivastava, Director, NWA**
Typing and Formatting	**Ms Uma G Sundaram, Steno Gr-II, NWA**

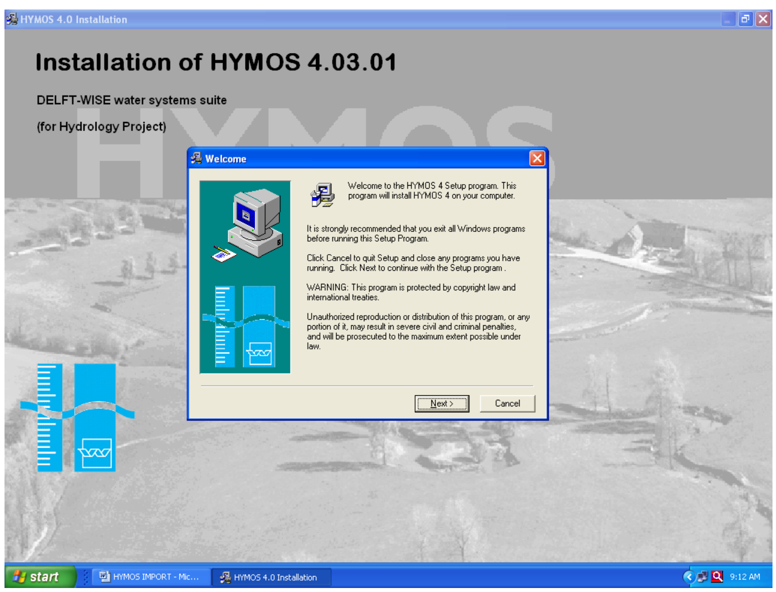
Chapter 1

HYMOS INSTALLATION & EXPORT OF DATA FROM SWDES TO HYMOS

The set-up file for HYMOS 4.03 version installs the HYMOS software in addition to creating a number of folders in c:\ drive. Of them, c:\HYMOS database and C:\Program Files\HYMOS 4\SYSTEM are important ones. Another file quite often used for report file generation is C:\Program Files\HYMOS 4\HTML Report Sample. The SYSTEM file needs one license file

with *.DAT extension. The file **Hymos.dat** matching with Hardware key/Dongle must be available in the SYSTEM folder. Additionally, a green dongle driver/set-up launcher is required to be run before HYMOS is ready for use.

Green Dongle Drivers (Sentinel v5.39.2) 95-98-ME-NT4-2000-XP.exe



This exercise aims to expose the user to export data from SWDES software to HYMOS followed by its import in HYMOS environment for its secondary validation and extracting a set of invaluable information for subsequent hydrological studies. Upon clicking on *SWDES icon*, an opening window of SWDES appears. A box in the middle needs username and password to start with **(Fig.1**). Default username and password is admin & admin respectively. This step lets the user to next interface having a series of options for data entry.

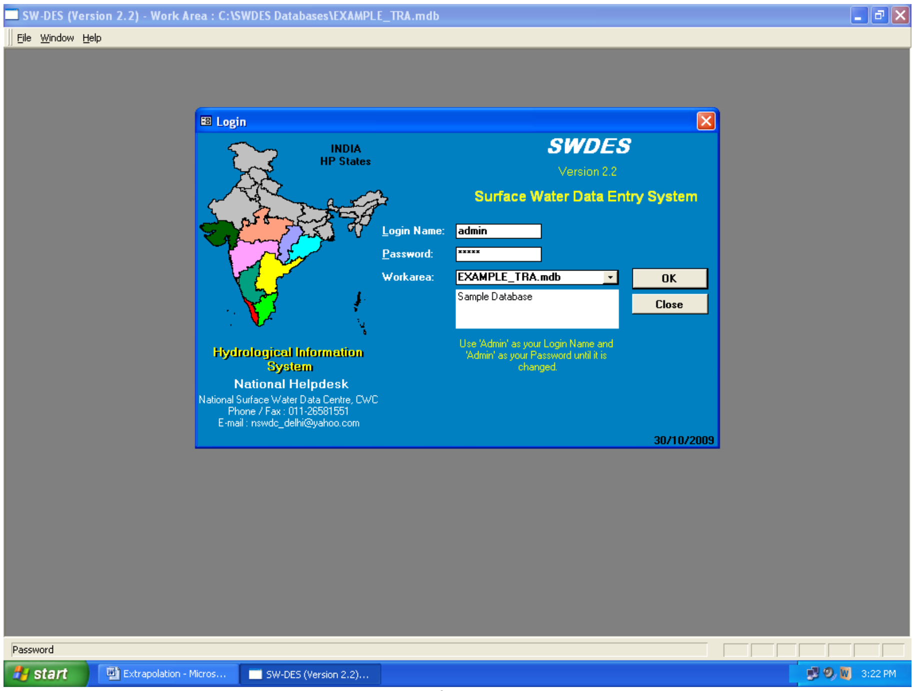


Fig. 1

Click on the *'Hydrological Data'* button followed by on *'Summary of stage-discharge data'* & from the dropdown menu of station name **(Fig.2),** select *'Mancherial'* station and check if data for a period starting from 01/01/1998 to 31/12/1998 is available (User may select a period of his/her choice). Change in period/months etc is accomplished by appropriate selection of year and month appearing at upper right part of the page **(Fig.3).** Close this page and return to Main Switchboard by pressing *'return to main switchboard'*.

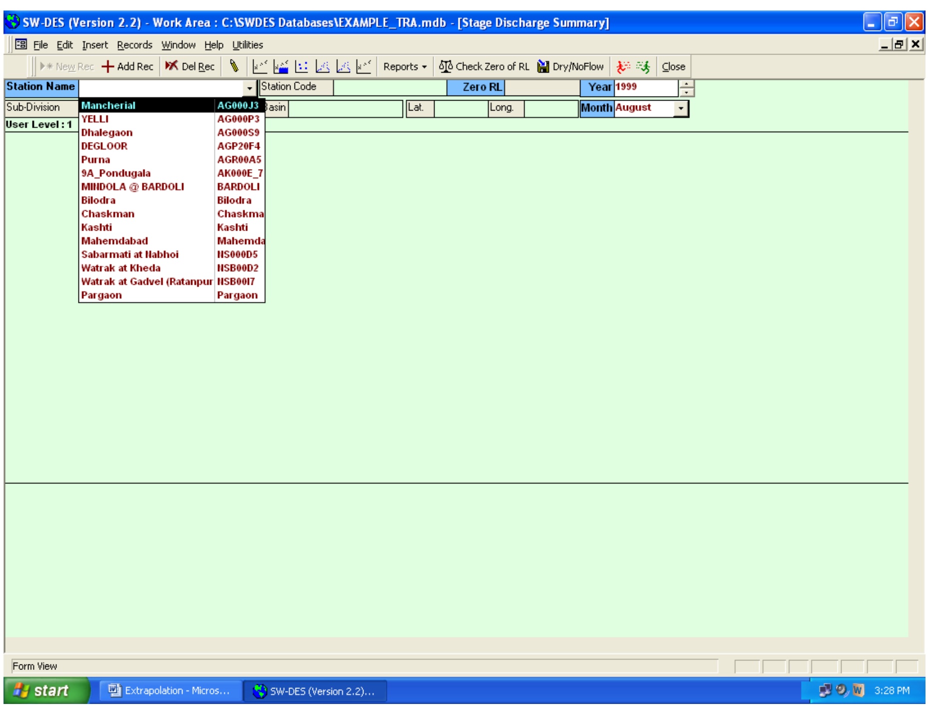


Fig. 2

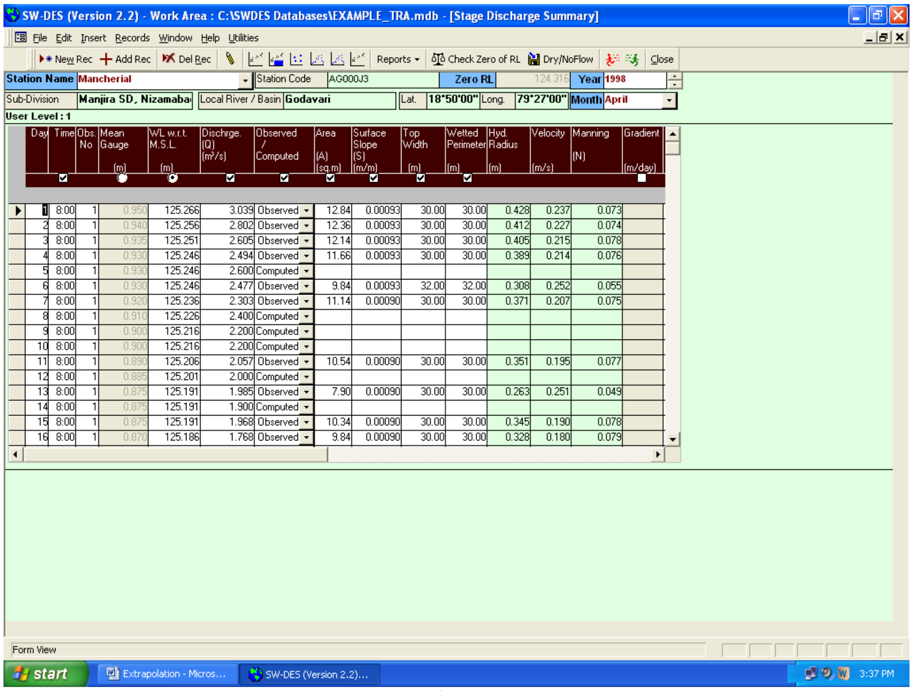


Fig. 3

Click on 'Utilities' > 'Export of Data' > 'Export for HYMOS (New Version)' to get a list of stations; data of which need to be exported to HYMOS. Select 'Mancherial' and click on 'ok' **(Fig.4).** This step opens up a dialog box prompting user to select the range as well as type of data to export **(Fig.5).** Backward/Forward buttons or spin buttons (if cursor is clicked next to year fig) help select the desired duration/period. Destination file path/name is defined as c:\SWDES databases\mancherial_export. Else, user may define the path using browse button appearing by it. Once done, press Transfer' button to let software generate a file at user defined location. Exit from SWDES now.

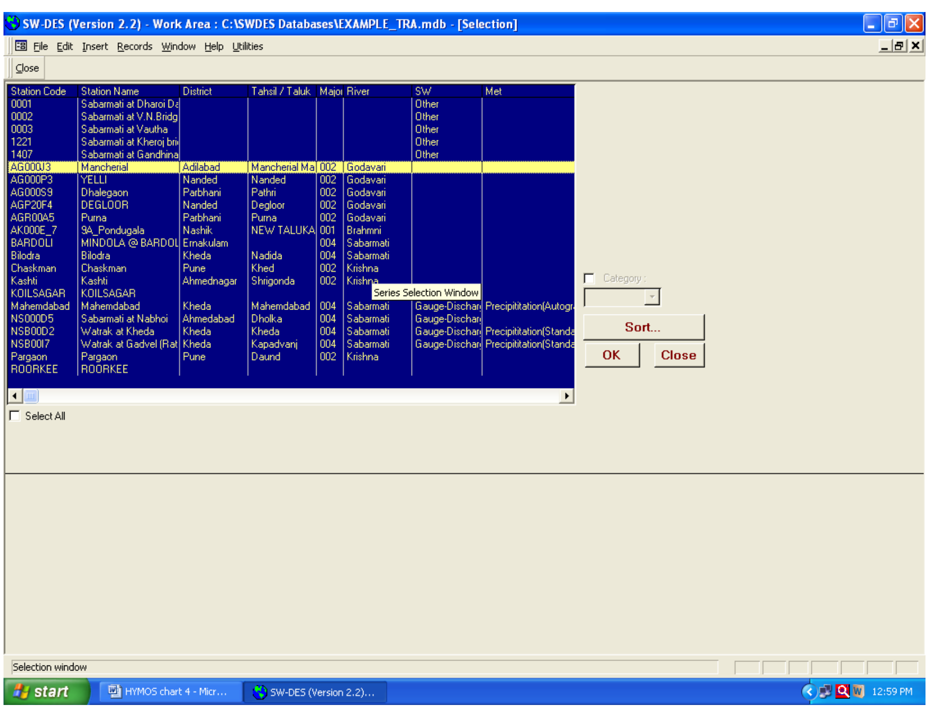


Fig.4

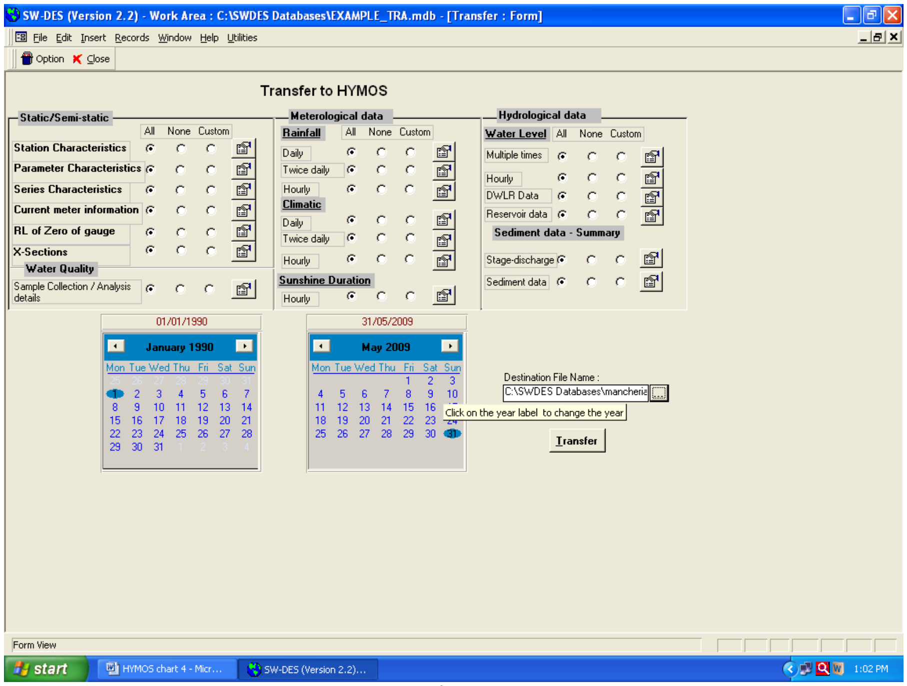


Fig.5

Preceding steps have created a file 'mancherialexport' in SWDES Database folder. This point forward, a number of steps involving HYMOS SOFTWARE guide the user to import this file in HYMOS (For HYMOS, default username and password are administrator & hello respectively). Open the *Database Manager* by clicking on *Database Manager* button on the tool bar and click on 'New' under Database menu (**Fig.6)**.

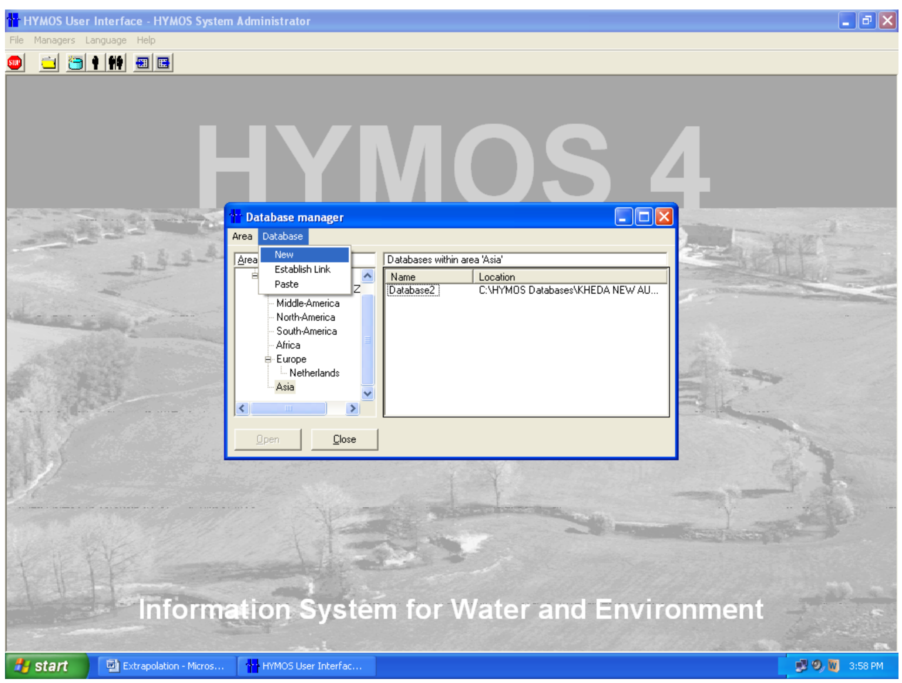


Fig.6

Define the location for database as C:\hymos database and click on '*Create*' button on the right. Type folder name as '**KHEDA_BASIN**' (**Fig.7)** and click on 'ok' on either window box to add this folder to HYMOS Database folder. User should preferably define folder name after concerned basin/sub-basin as this folder will contain every detail of this unit related to all pre & post data analysis.

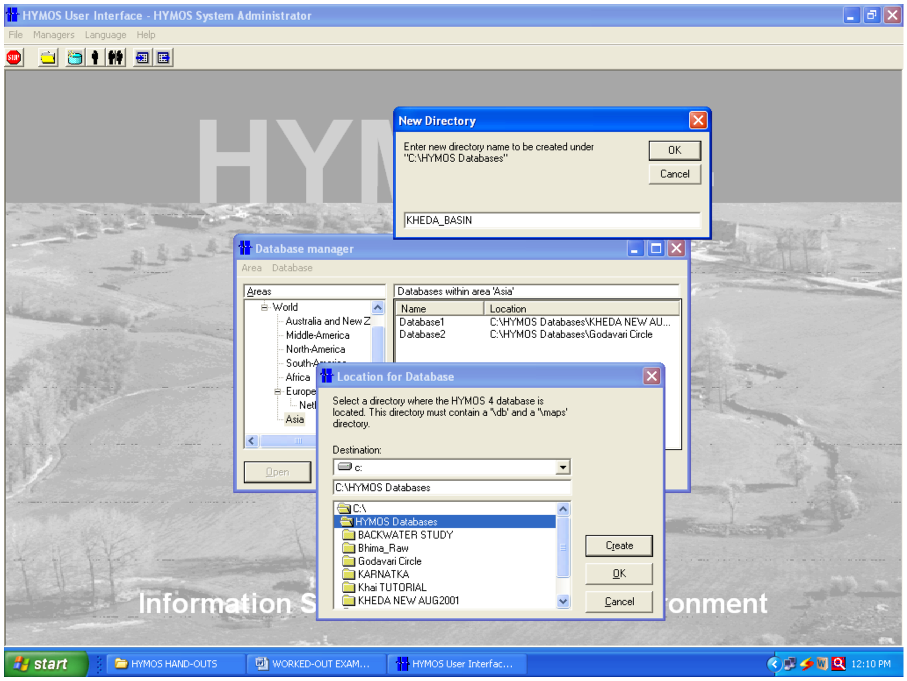


Fig.7

Once over, close the box and press *'import'* button second from right on button bar. This opens up import wizard (**Fig.8)**. Click on the 'Next button' and appropriately define the file to be imported using browse button. Move to next the step.

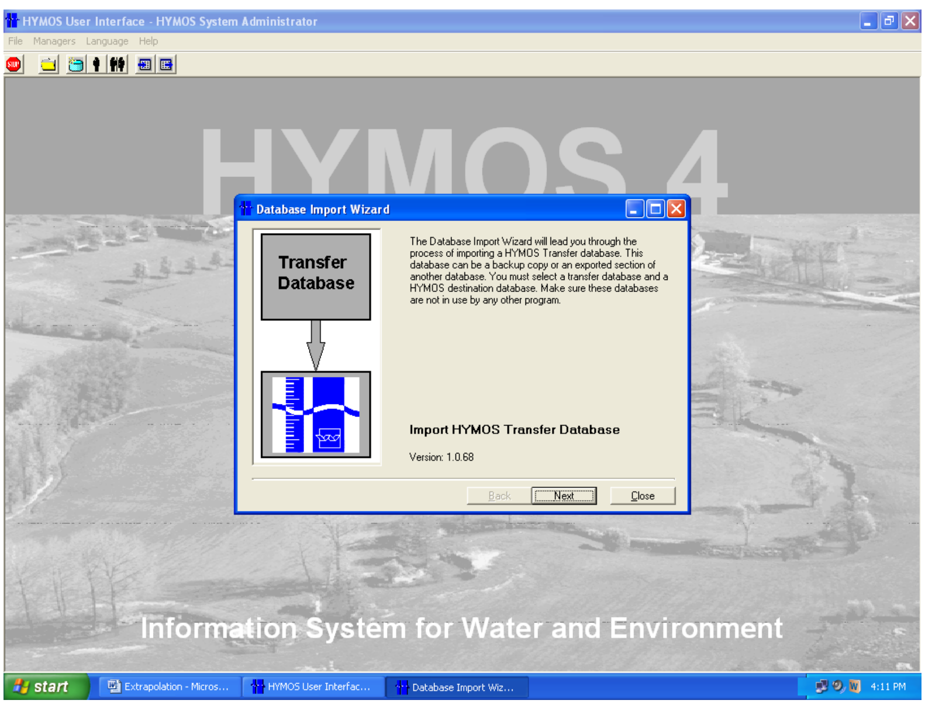


Fig.8

This step asks the user for defining the location and appropriate file name where he wishes to import data from and click on *‘next’* button. This pops up a window to define destination folder (**Fig.9**). Press *‘next’*.

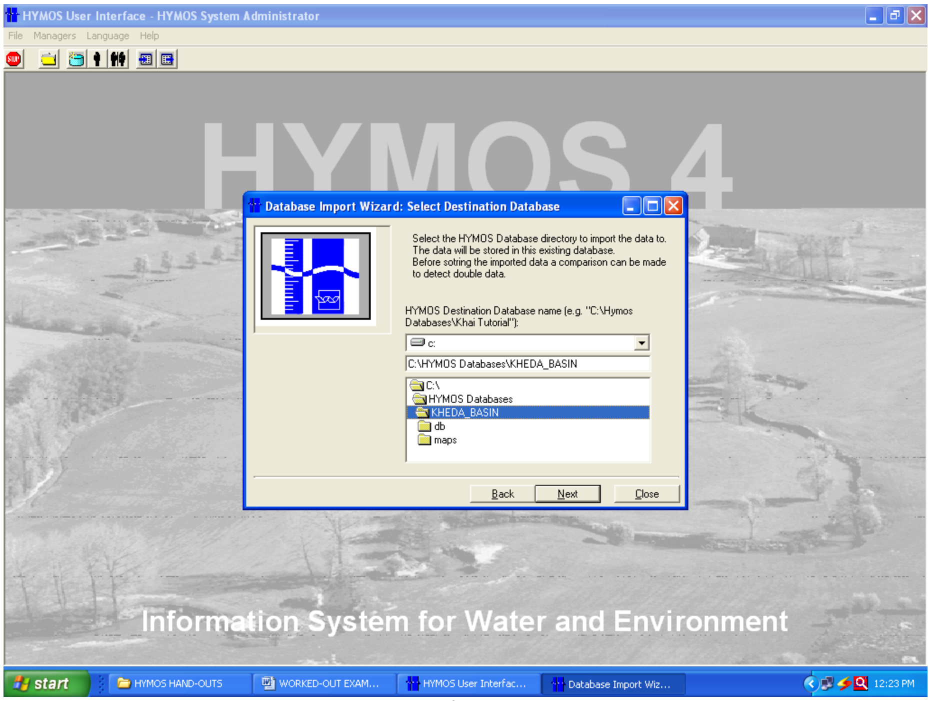


Fig.9

At this stage define location of ‘Import Template’ as shown in **Fig.10**. Press ‘next’ . Go on clicking on *‘compare database’* and *‘import database’* to complete import task (**Fig.11)**. On notice of action completed, close the box.

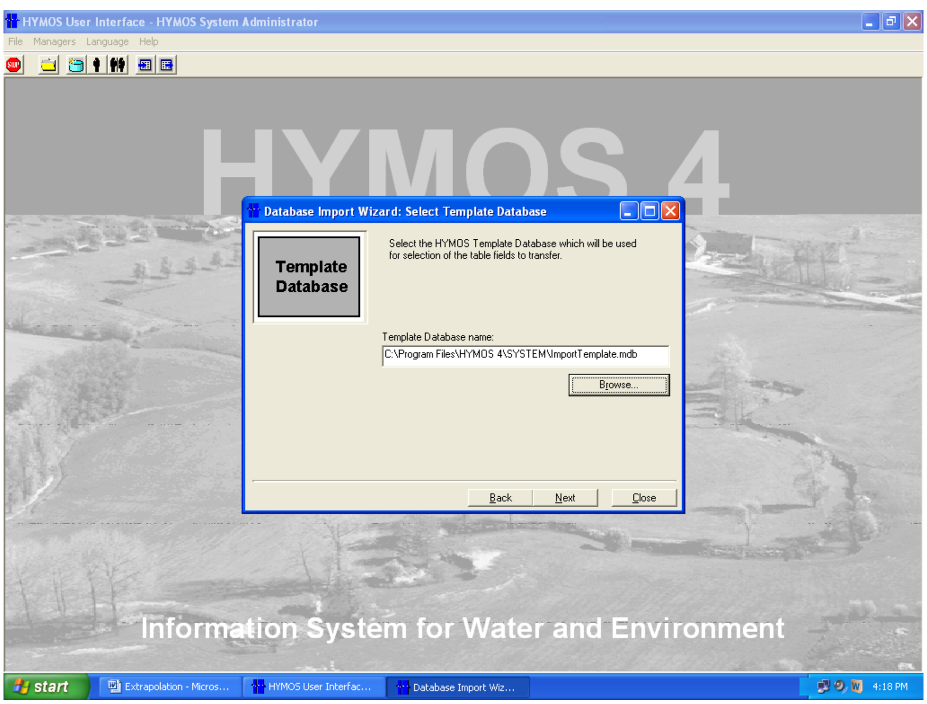


Fig.10

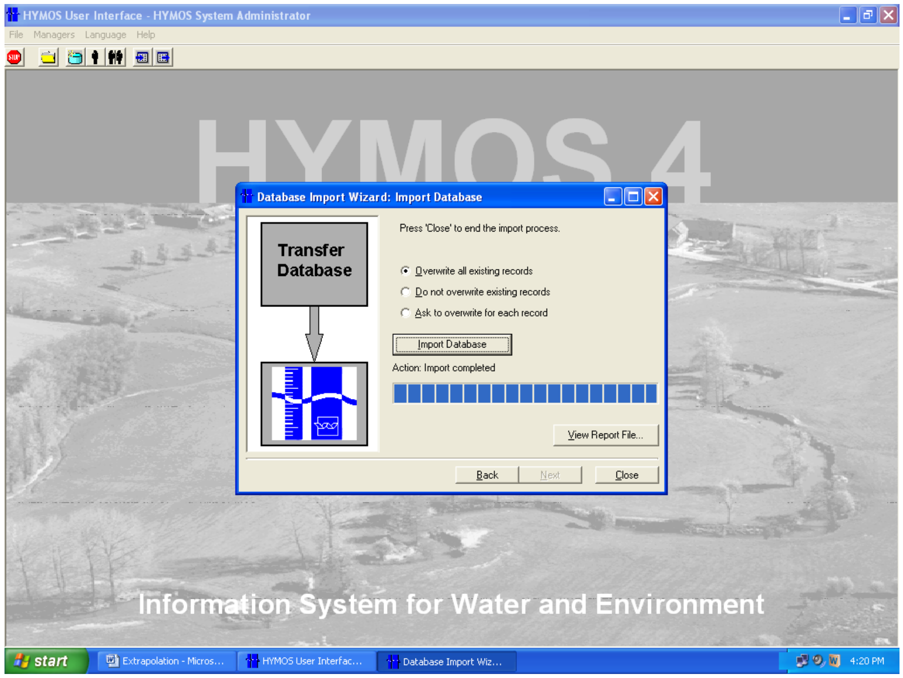


Fig.11

Go back to 'Database Manager' box and select appropriate database and *'double click'* on it to open up netter screen (**Fig.12**).

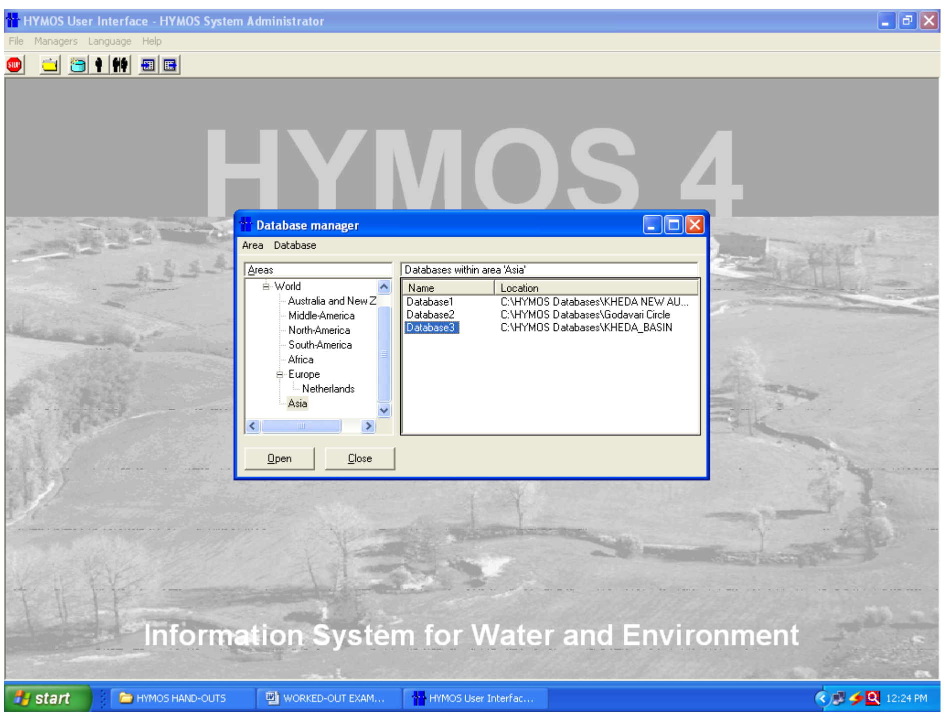


Fig.12

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Chapter 2

CREATION OF MAP LAYERS IN HYMOS

NETTER is the map component of HYMOS facilitating display of various geographic features for easy enabling of manipulation, viewing and printing of these layers. The GIS layers contain geographic data in the form of vector Geographic Information System (GIS) or raster files. In general, these layers are used as a background for the network layers, but they can also be approached as stand-alone layers. However, these map layers are required to be in **.MPL** format, which is native HYMOS format. The GIS layers which can be used in Netter have the following formats:

- .MAP, Mapper map file
- .MOS, Manual of Style (Us Defense layer)
- .MIF, Map Information , ER Mapper layer
- .MPL, Mapper map layer file
- .BNA, Boundary Atlas GIS layer file
- .SHP Files, Arc view files and also ***.e00** files (coverage) after conversion to ***.shp**

The map layers available in any of these formats can be converted into **.MPL**, format (for use in HYMOS) using the program MAPLINK from HYMOS as has been depicted in **Fig. 1& 1a**. The easiest way to input the map layers in HYMOS from feature files of GIS, **Shape** files *(.shp, .shx and dbf)*.

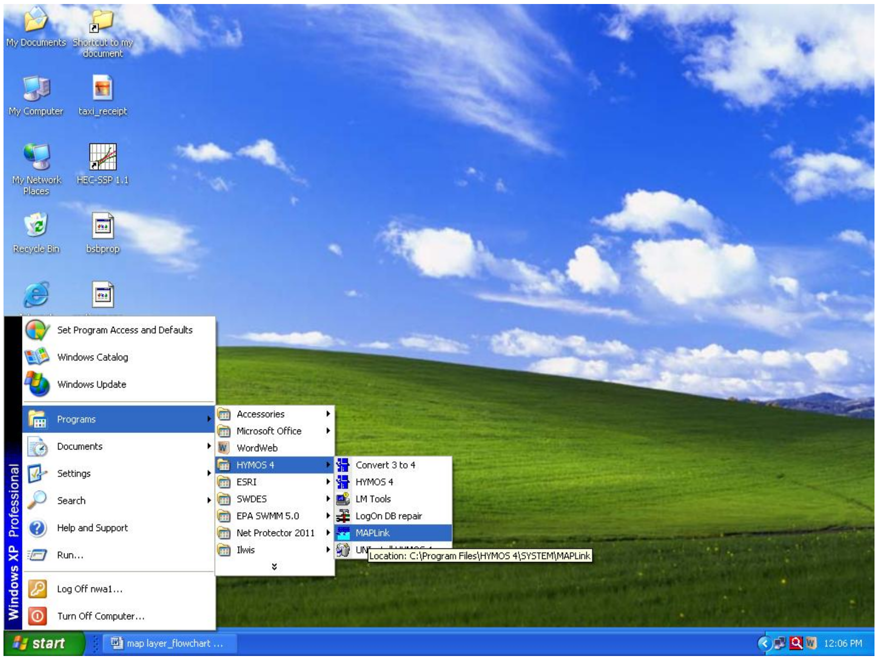

Fig.1

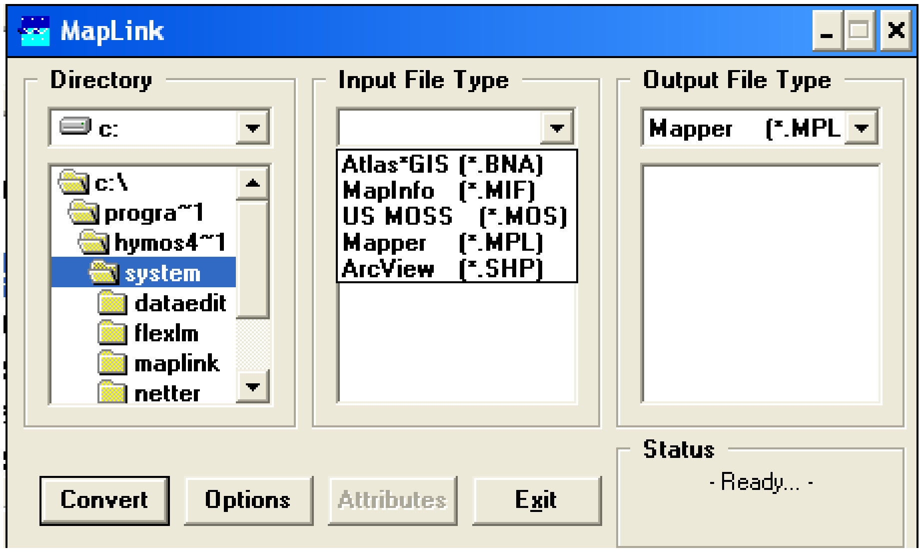

Fig. 1a

Within Netter you can use GIS layers to generate a network from scratch or add elements to your network. GIS layers should be provided in BNA format. The BNA format is a common ASCII format for GIS layers and was originally defined by Arc-Info. File extension of these files is ***.bna**. Care should be taken to place all the vector layers in the map folder of HYMOS, where the work is intended to be stored.

When a GIS layer file is selected, the following situations may occur:

1. No active windows are available: Netter opens a new window to show the GIS layer contained by the file.
2. The GIS layer is opened from a window which contains a network: Netter asks the user if the GIS layer has to be combined with the network or not.

❖ If the user wants to combine, Netter tries to combine the GIS layer with the network using the co-ordinates of both the GIS layer and the network. If the co-ordinates are overlapping, that part of the GIS layer will be visible which agrees with the current view of the network. If the co-ordinates of the network and the GIS layer are not overlapping, the full GIS layer is drawn on the current view of the network. The co-ordinates attached to the network are converted to GIS layer co-ordinates. ·If the user does not want to combine, Netter opens a new window to show the GIS layer contained by the file.

3. The GIS layer file is opened from a window which already contains GIS layers:

❖ If the opened file is a *.map (Mapper) file, Netter asks the user if he wants to replace the current map. If the user wants to replace the current map, Netter replaces the current map by the new GIS layers. When the co-ordinates of the new map overlap with the co-ordinates of the old map, Netter shows the new data with the same view. If the co-ordinates are not overlapping, Netter shows the map as specified in the GIS files. If the user does not want to replace the map, Netter opens a new window to show the GIS layers contained by the file.

❖ If the opened file is not a *.map file, the GIS layer is added to the GIS layers in the active window. From the file menu a network File can be opened selecting the open menu. Available network file formats are:

- AAD (*.abp)
- PDM (*.pdm)

- BBB model (*.bbb)
- Netter (*.ntw)
- OMIS (*.oms)
- Ribasim (*.ntr)
- Ribasim (*.rib)
- Siware (*.siw)

Changing visual appearance of Mapper layer

When you want to change the visual appearance of Mapper layer files, choose Option menu followed by Map option command (**Fig.2**). Map Properties dialogue pops up (**Fig.6**), in which you can change the appearance of each map layer.

Layers: in this frame it is possible to open a new layer, select a layer and make it visible and selectable, save a layer with its new settings and close a layer.

Layer name: change the name of the layer.

Map scale:

Zoom range:

Lines: change the appearance of the lines of the layer.

Fill: change the appearance of the filling of polygons.

Points: change the appearance of a point.

Map: change the background colour and fonts of the maps.

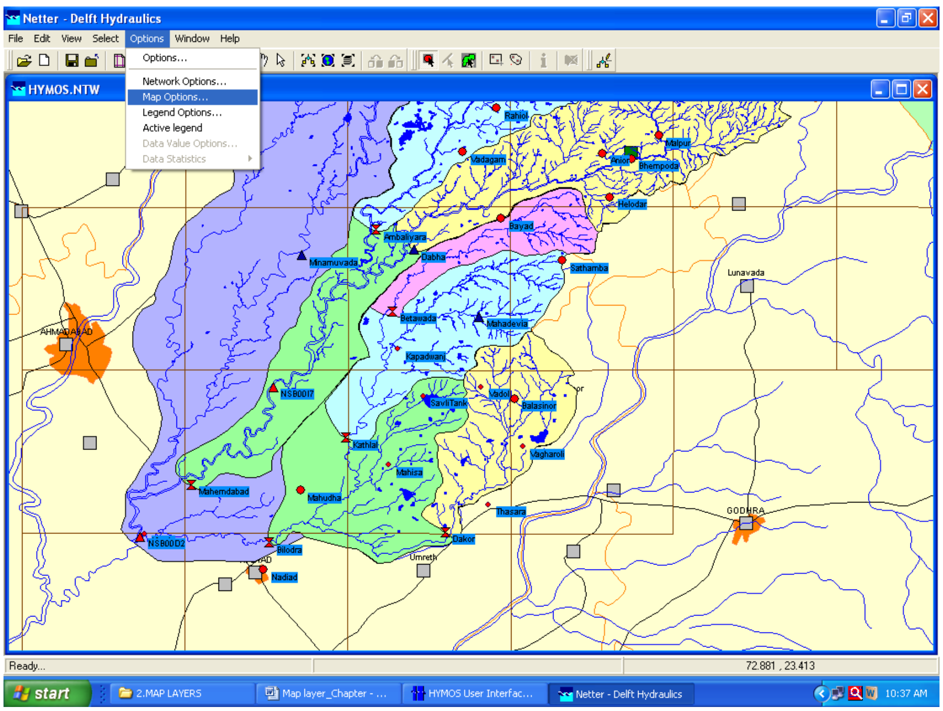

Fig.2

Map layer creation

a) Vector layers in **HYMOS** can be created using a digitizing tablet and using a pucker to catch the points.

b) It can be input by on screen digitization from ArcVIew/ArcGIS/ ERDAS/ EASIPACE/Geomatica/ENVI/ArcScan or any GIS/image processing software.

c) By manual input of coordinates to prepare the **.BNA** format, which can be imported to coordinates of the layer in **HYMOS** and also can be converted to native **.MPL** layer of HYMOS.

Preparing BNA files

Boundary Atlas GIS file .BNA is an **ASCII** file format (Text file), generally used by ATLAS GIS and related products for exchanging data with other software packages and hardware platforms. BNA files can contain a combination of Points, Lines and Polygons within a single file. And this can be created by notepad or also from MS excel (***.xls)** spreadsheet. The BNA format is a common ASCII format for GIS layers and was originally defined by Arc-Info. File extension of these files is *.**BNA**. The longer spreadsheet data can have the ID, coordinates of vertices of feature files and saved as Tab Delimited txt files and opened in **Notepad** or **WordPad** and saved again as .BNA format.

A. For Point Thematic Map Layer

1. Open notepad and enter the **points** as shown in **Figure- 3**. Point ID, Name of the point within **" "** should be put in without any space bar and the no of point i.e, 1. Tab may be used for separation of words. Save as **Towns.bna.** (name of your choice)

"ID1" , "NameID1" , 1
x1, y1
"ID2" , "NameID2" , 1
x2, y2

…..

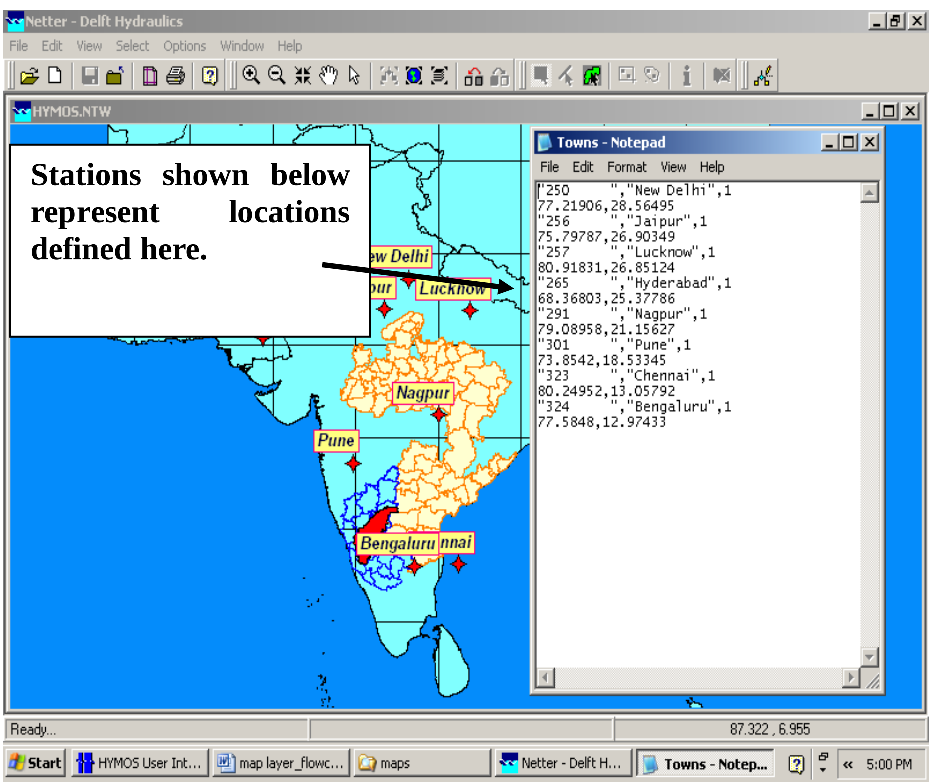

Fig. 3

B. For Line Thematic Map Layer

Enter the data in the following manner as shown at **Fig. 4**. Where, **-N** (negative sign) denotes the no of coordinate points. Save as **Brahma.bna**. (or any name of your choice)

"ID1" , "NameID1" , -N
x1, y1

x2, y2
x3, y3
….
xn, yn

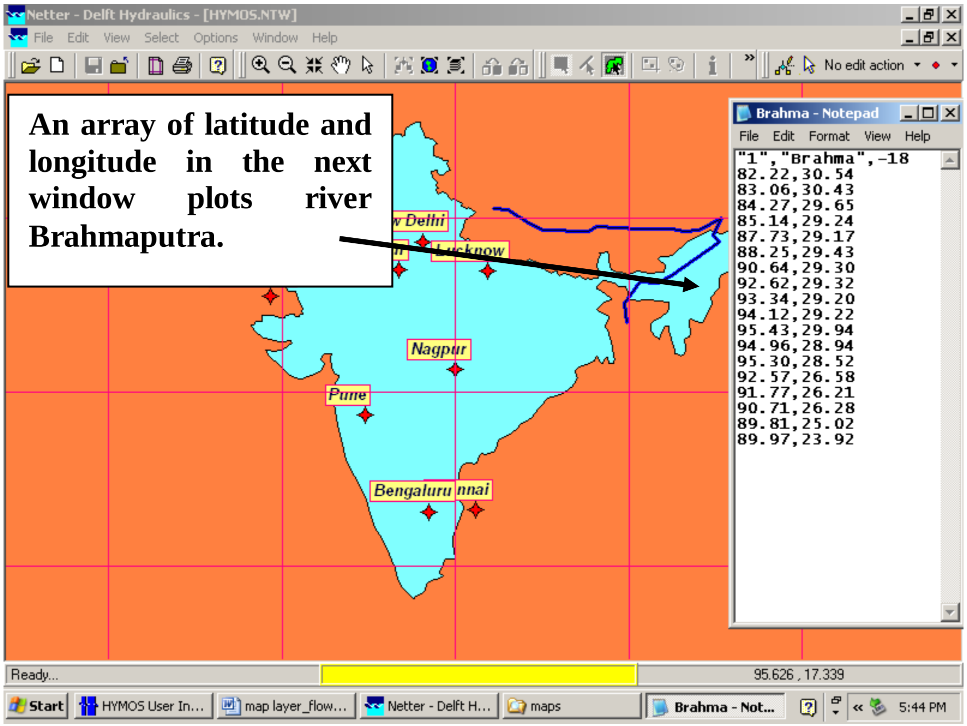

Fig.4

C. For Polygon Thematic Map Layer

For the polygon feature enter the data in the manner as illustrated below in **Fig. 5 & 6**. The **last** point coordinate (x_1,y_1) should be the **first** point coordinate (x_1,y_1) for closing the polygon). Do not add more blank lines after the last line. All features may be entered in one single file or in different files. Save the file with **State.bna** as file extension preferably in **Hymos_databases/ yourname_database/ maps** folder.

"ID1" , "NameID1" , N

X_1,Y_1
X_2,Y_2
X_3,Y_3
….
X_1,Y_1 *(This should be the same as the first coordinates)*

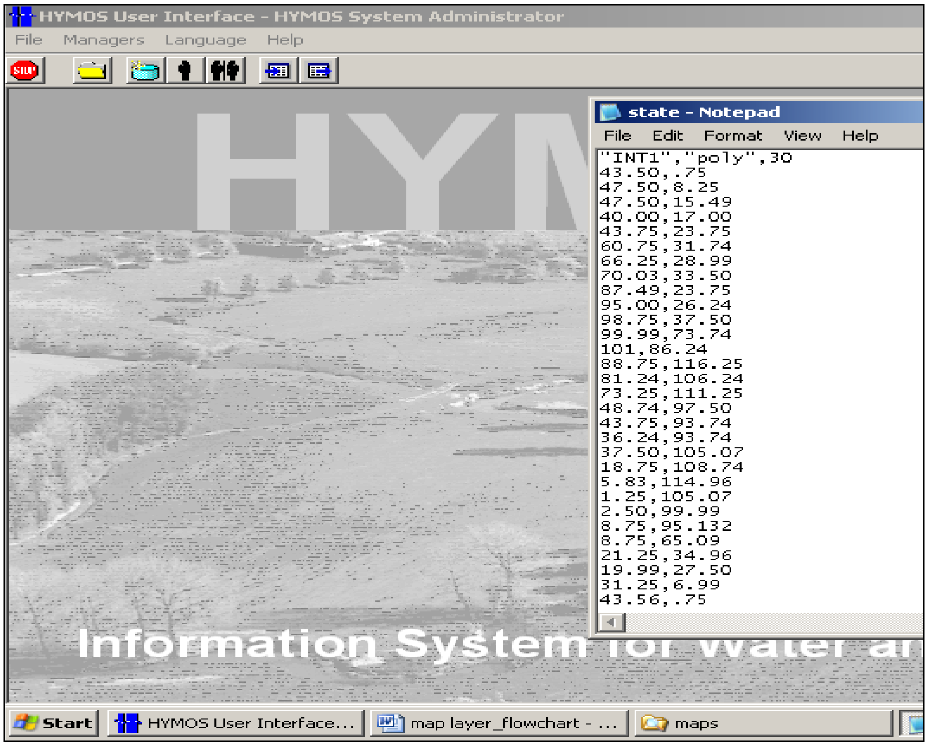

Fig. 5

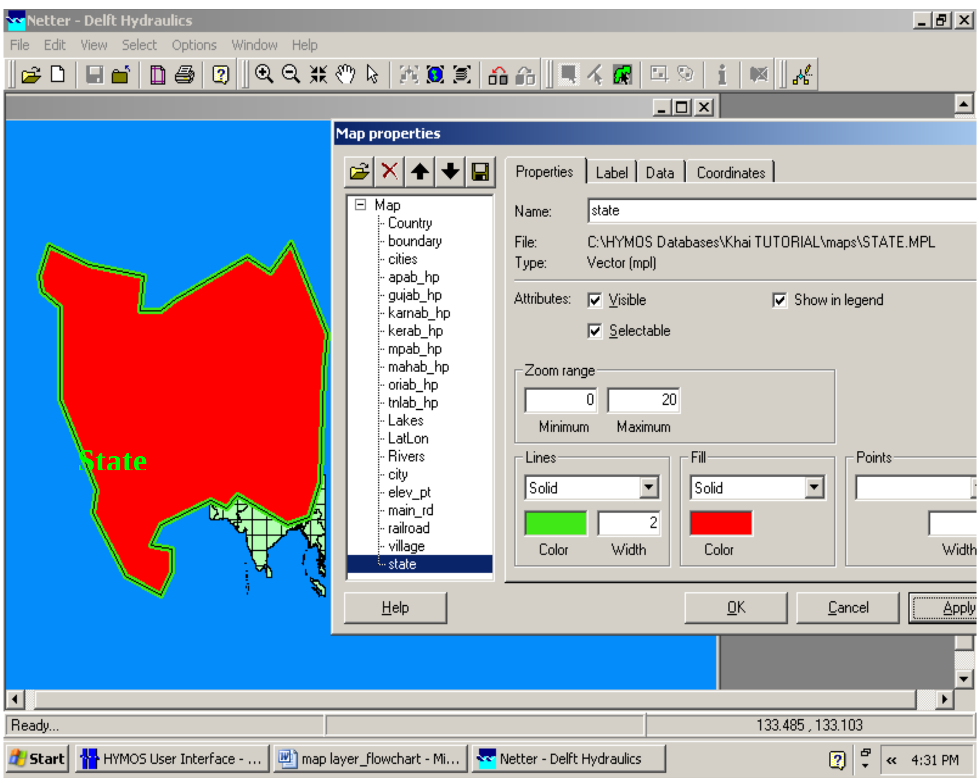

Fig. 6

Use MAPLINK program from the Start Menu and convert the **.BNA** files **.MPL** for compatibility in HYMOS**.** Select the State.bna as input file and select **.MPL** as output format and click ***convert*** button. A new file **State.mpl** will be created and added to the same folder in the similar manner as shown in **Fig. 8**. Open **Option**>**Map Option** and Click **Add** the layer button and add **State.mpl** from **Map Properties** window. From Properties Tab change the Fill color and line color and set **width** for better visibility (**Fig. 6**). Label the **Name** from the **Label** Tab and format the fonts etc.

Navigate **Upward Arrow/ Downward Arrow** for proper sequencing. Click **Apply** to make the new setting effective. Click **OK** to close the box. The map layer will be visible now.

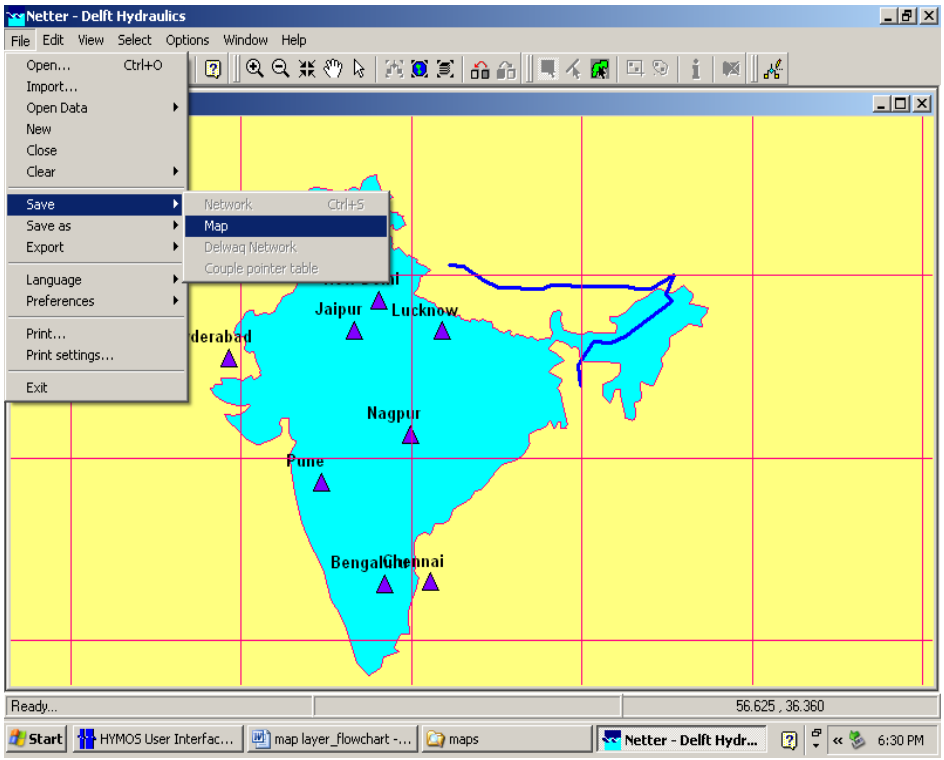

Fig. 7

Save the map file from menu **File → Save → Map**. The map layer and its properties setting will be saved in the map file.

Adding a GIS map layer as a network file

Within Netter you can add GIS layers elements to your network. Add the ***.shp** file to the Map folder and convert it to ***.MPL** layer in MAPLINK. Click **Option**>**Map Option** and Click **Add** the layer button and add ***.MPL** from **Map Properties** window as shown in **Fig.8 & 8a.** Also**,** AUTOCAD files **dxf, dwg,** and ***.e00** files (through **Import71** utility) can be converted to ***.shp** files and then can be used in HYMOS**.**

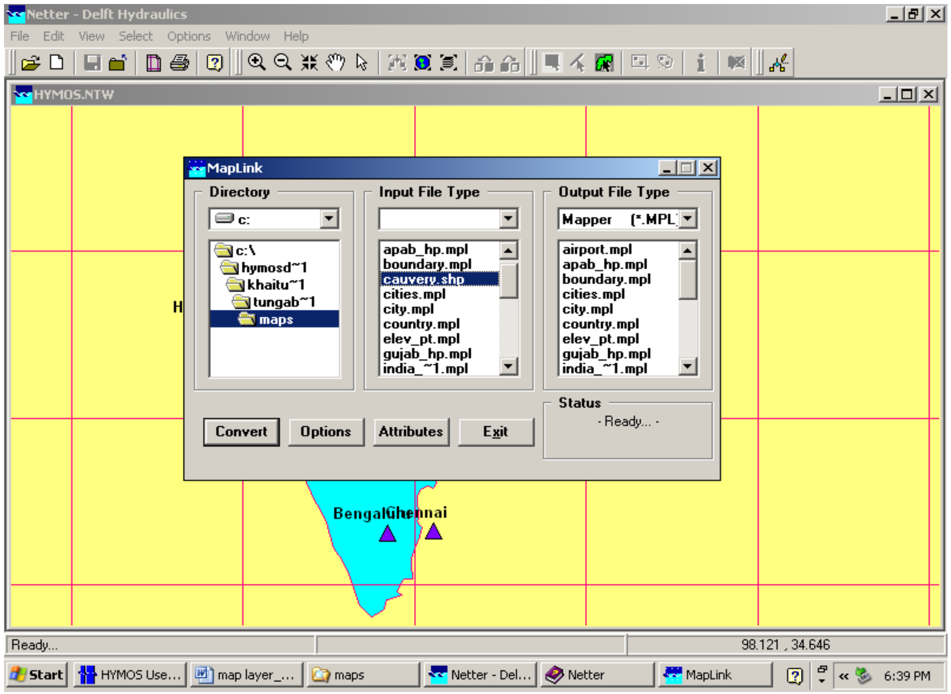

Fig. 8

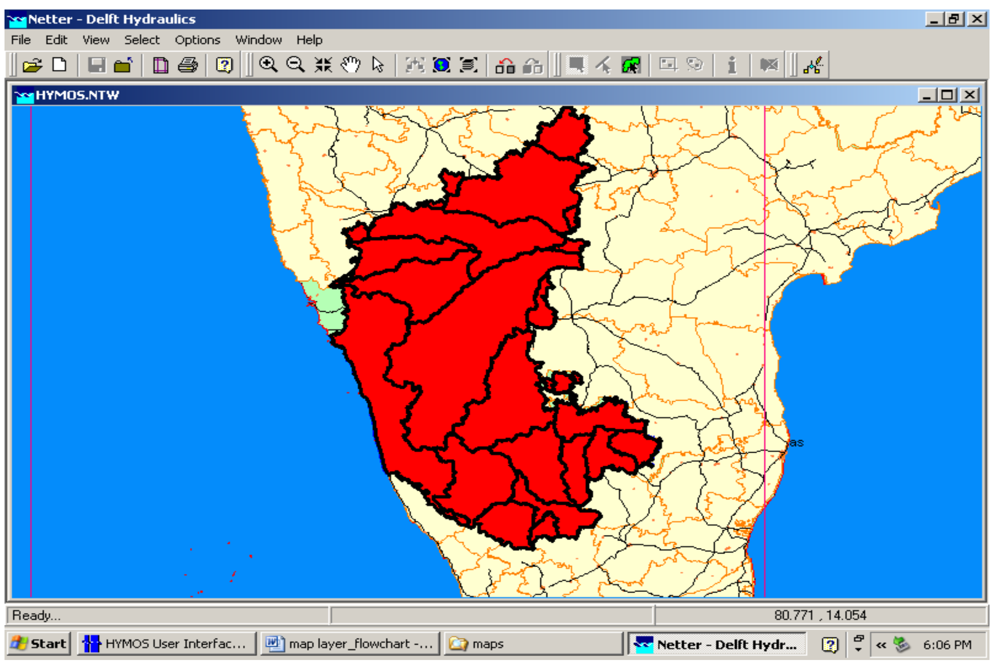

Fig. 8a

Adding Catchment's Coordinates to NETTER

Transfer the data from SWDES as done in the first chapter, so that the stations are visible in the netter. Add the ***.MPL** layer after converting ***.shp** files, as has been done in the **Fig. 8** above for the Karnataka state. R-Click the station → Process **HYMOS.** Expand **Entry and Edit → Relations → Catchment Characteristics → Add New** and fill up the required information about the catchment as shown in the **Fig. 9.**

Then click the **Coordinate Tab → File→ Import Catchment Coordinates→ Latitude Longitude→ *.BNA** file**.** Click **Ok.** The Coordinates are automatically taken into the Hymos database as depicted in the **Fig. 9**.

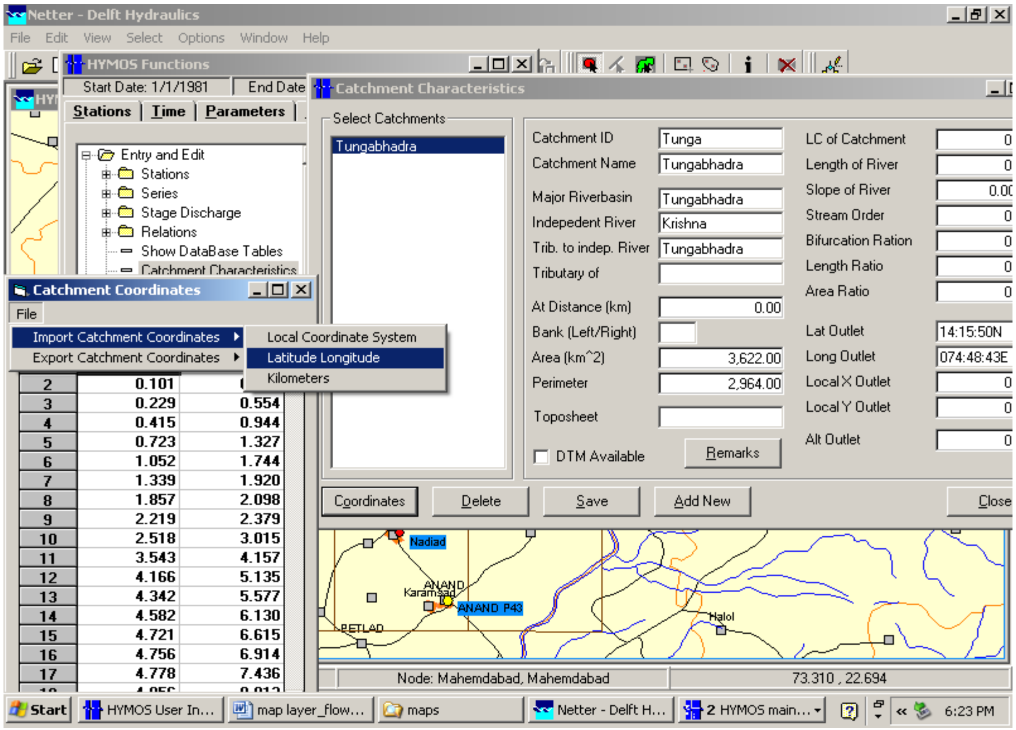

Fig. 9

Generate a New Network

Select **Open**... from the File menu.
Select a ***.bna** file in the File **Open** dialogue, and press **OK**.
Select <**network**> in the **Use as. frame** of the open GIS network layer dialogue when adding line elements or <**add locations**> when adding points only.
Make a choice between **Full vector** and **Split vector** in the **Vector-Link options**, see **Set calculation grid** for more information on this option.
Choose a **reach type** for the line elements and a **node type** for the point elements, and press **OK**.
Now enjoy making a map layer.

To be turned on:

Prepare a *.BNA file from set of points and add to Netter.
Convert one catchment ***.DXF** file from AutoCAD to ***.SHP** file.
Then change the format to***.BNA** and ***.MPL** and Input its coordinates automatically to HYMOS and find its area.
Note: While inputting the ***.SHP** files, care must be taken to project the same to Geographic Coordinate System (GCS)/Universal Transverse Mercator (UTM) projection, so that the file superposes the real world co-ordinate.

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Chapter 3

UNDERSTANDING STATISTICS & its APPLICATION in DATA VALIDATION & ANALYSIS

Introduction

Detection and removal of manual and systematic errors are two essential requirements for hydro-meteorological data validation to check for data continuity and consistency. Subsequent task is its analysis to distil useful information for use in hydrology and hydraulics. Randomness in observation procedure induces scattering in plot and demands its understanding by determining several statistical parameters. This helps us know the behaviour of samples/population. A multitude of data validation and its analysis functions available in HYMOS extensively employ statistical tools to generate final results; and therefore, it is expected that a user must have a grasp of rudimentary knowledge of statistics.

This chapter presents fundamentals of statistics in brief. For more details, readers are encouraged to refer to Training Module No. 43' and any other good book on statistics.

Statistics

Statistics is concerned with the collection, ordering and analysis of data. Data consists of sets of recorded observations or values. It also provides criteria for judging the reliability of the correlation between variables; means for deriving the best relationship for predicting the one variable from known values of other variable (S). Any quantity that can have a number of values is a *variable*. A value that a variable takes is called **Variate'** . A variable may be one of two kinds:

- *Discrete* – a variable, whose possible values can be counted, e.g. number of rainfall days in a month or year. Number would take only integer values within zero and infinity,

- *Continuous* – a variable; which can take on any value within specified interval. Annual maximum discharge, for example, is a continuous variable as it could be any value between zero and infinity.

Sample and Population

Any time set of recorded or observed data does not constitute the entire population. It is simply a fraction of entire population and is called a 'sample' . By deducing the characteristics exhibited by sample, inferences are drawn about the nature of entire population. In other words, collected samples help us predict the likely magnitude and occurrence of future events. It is obvious here that quality and length of sample used in analysis hugely impact the quality of forecast of ensuing events.

Types of Errors

Errors reduce the reliability of observed records by severely altering its distribution. Some of them appear in the plot as 'outlier' and some may not. Their detection followed by their deletion/removal, retention or modification need good understanding of 'Statistics' .

Manual error

Errors on manuscript in various form such as incorrect data entry, wrong water level assigned to observed discharge value leave unidirectional (either + or -) impact on the observed variable and are serious in nature. These are identifiable and causes can be assigned. Careful inspection of record is a measure to detect and modify the errors. It is important not to let them travel beyond primary validation stage.

Systematic error

Faulty graduation on gauge post/wading rod/sounding rod, pivot line markings, c/m under or over recording the velocity, faulty/defective tape to measure water edge every day are a few source that can induce errors in the measurement. The result is either under estimation or over estimation of the variables implying unidirectional characteristics of this error. This kind of errors needs removal/modification before analysis of data. In this case too, causes are assignable. Periodical inspection of instrument, gauge post, pivot line method and several others could minimize/obviate its occurrence. Like manual errors, a sample affected by systematic errors distort the properties of sample; and therefore, their treatment is crucial to reliable data analysis

Random error

Once set of data become free from above two kinds of errors, their distribution usually follows law of probability/chance & can be analyzed statistically. Errors of this kind will be either + or – (bidirectional) and on averaging cancels its effect. Factors introducing randomness in data include uncertainty in several operations such as lowering of c/m exactly at 0.6D (not possible because of rocking of boat), at what point, time of exposure, wind direction and its speed, positioning of boat at defined RD, number of verticals/RDs, movement of sandy bed, temperature of river water, sediment concentration, depth measurement by eco-sounder or by wading or sounding rod, water level measurement in windy condition etc. In the event of likelihood of more factors such as these prevailing/working at site, wider scattering of plotted data is normally noticed. No matter what measure one takes, randomness in variable can’ t be avoided. In other words, it is impossible to exercise control over its occurrence and need statistical analyses to deduce characteristics of samples/population.

Dispersion is also introduced by variable backwater/drawdown condition or by unsteady flow condition. A site frequented by such conditions needs a different approach for data handling as explained in one of the succeeding chapters.

Measure of central tendency

The arithmetic mean of a set of *n* observations is their average:

$$\text{mean} = \frac{\text{sum of observations}}{\text{number of observations}} \quad \text{that is} \quad \bar{x} = \frac{\sum x}{n}$$

When calculating from a frequency distribution, this becomes:

$$\bar{x} = \frac{\sum xf}{n} = \frac{\sum xf}{\sum f}$$

Mean for any variable is not a firm/fixed value and fluctuates on either side with increased length of samples. This fluctuation is better addressed by St Error of Mean; as defined later.

Dispersion

- ***Range***

The mean, mode and median give important information about the central tendency of data but they do not tell anything about the spread or dispersion about the centre.

For example, the two sets of data:

26, 27, 28, 29 30 and 5, 19, 20, 36, 60

Both samples have a mean of 28 but one is clearly more tightly arranged about the mean than the other. The simplest measure of dispersion is the *range* – the difference between the highest and the lowest values.

- ***Standard deviation***

The standard deviation, Sd is the most widely used measure of dispersion around Mean.

The *variance* of a set of data is the average of the square of the difference in value of a variable, i.e. $x_1, x_2, \cdots x_n$ from the mean, $\bar{x}$:

$$\text{variance} = \frac{(x_1-\bar{x})^2+(x_2-\bar{x})^2+\ldots+(x_n-\bar{x})^2}{n}$$

If, cov(X,Y) > 0 X and Y are positively correlated
cov(X,Y) < 0 X and Y are inversely correlated
cov(X,Y) = 0 X and Y are independent

This has the disadvantage of being measured in the square of the units of the data. *The standard deviation is the square root of the variance*:

$$\text{standard deviation} = \sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n}}$$

This formula with denominator as 'n' indicates St deviation of entire population. However, for all practical purposes, we deal with 'samples' only; and in such case, denominator 'n' is replaced by (n-1) to account for limited length of data.

If samples are normally/evenly distributed about its mean (when sample distribution is not skewed), a pair of lines drawn at sample mean ± 1.96.Sd contains about 95% observations; and only 5% lie outside. This introduces a concept of 95% confidence band or limit.

Standard Error of Mean

The Standard error of mean quantifies the precision of the mean. In other words, it is a measure of how far the sample mean is likely to be from TRUE MEAN. It has application in optimization of rain gauge network in a catchment area and finding out the length of data to keep variation in averaged value within an acceptable range.

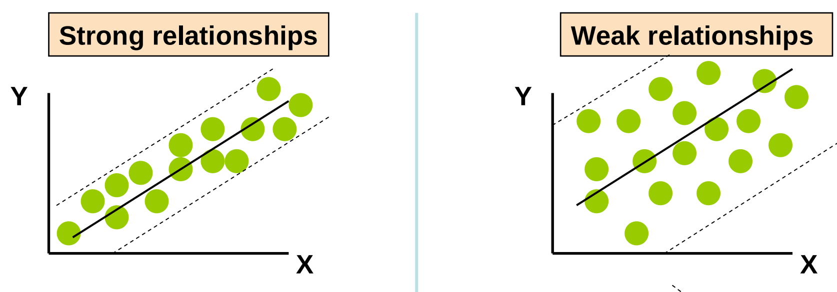
$$\sigma_M = \frac{\sigma}{\sqrt{N}}$$

For instance, if we are desirous of keeping percent deviation of estimated values determined after fitting a rating curve from observed discharge within 2% with 95% confidence level; $2*\sigma_m$ should be less than 2%. In other words, number of observations/values should be more than %age standard deviation.

Standard Error of Estimate

The Standard error of Estimate is precision of the best-fit line defined by using least–square method. In other words, it indicates how wide the dispersion/scattering of data around best fit line is. A narrow band/plot has lower Sest than the wider one. Here too, a pair of lines drawn at estimated/computed value ± 1.96.Sest contains about 95% plotted points; and help engineers monitor changes, if any, in the behaviour of river regime/basin characteristics with subsequent arrival of measured values and their comparison with already plotted points. Here, in the formula, Y represents observed/measured value, & Y' an estimated one. $\sum$ indicates addition of all such values in the series.

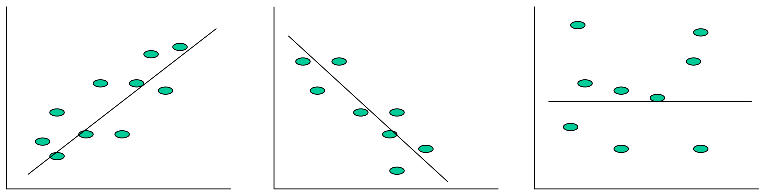
$$s_{est} = \sqrt{\frac{\sum (Y - Y')^2}{N - 2}}$$



Denominator of this parameter is normally defined by {N – (n+1)}; where, N is number of observations and n represents number of independent variables used in analysis. Parameter as above is valid for n= 1. This implies that independent variable is one.

Correlation Coefficient

The correlation coefficient, r, quantifies the direction and magnitude/strength of correlation. It tells you how much one variable tends to change when the other one does. It ranges between -1 and 1 where, 1 denotes perfect correlation.



Positive Correlation — $0 < R < 1$

Negative Correlation — $-1 < R < 0$

No Correlation — $R = 0$

It is estimated by dividing the **Covariance** with product of Standard Deviation of two variables.

Covariance, Cxy IS GIVEN BY Cxy = Σ((Xi – Xav)*(Yi – Yav))/ (N-1).

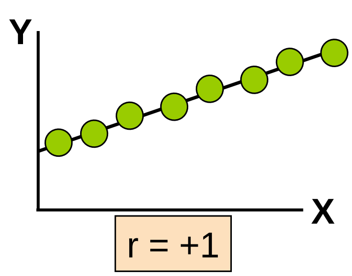
For **Variance**, X=Y, and so formula turns to = Σ (Xi – Xav)^2/(N-1)

Now, Correlation Coefficient, **r** is = Cxy / (St Dev of x * St Dev of y)

There exists a relationship between Standard error of estimate, standard deviation and correlation coefficient and this appears as below

Sest = Sd (or σ) √ (1- r^2)

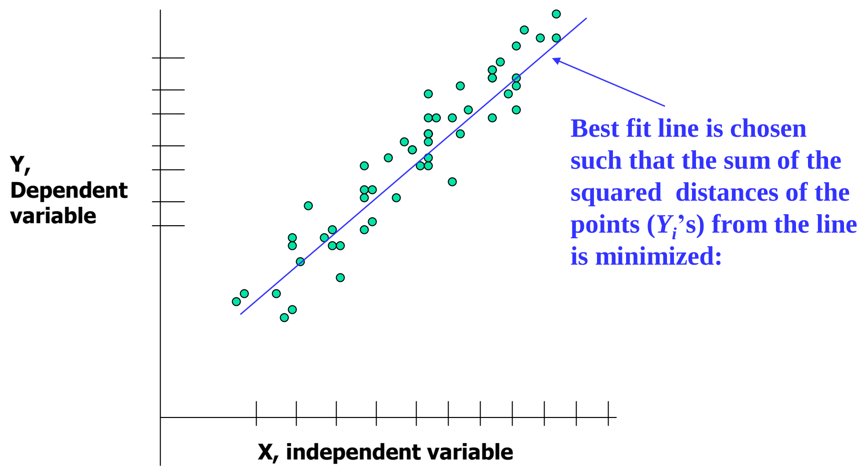
Reader may notice here that if r is 1, Sest turns zero. It implies that there is no scattering of plotted points around best fit line and all points lie on the best line itself. See chart below.



Best-Fit Line/Method of Least Square

A description to this sub-title is intentionally omitted here because of availability of wide range of functions readily offered by excel and many other software to plot a best fit line of different forms. Use of excel in plotting a best fit line of power equation type is demonstrated in subsequent part of this chapter.

Y depends on X



Standard Error of Mean Relationship

Just as Mean of a single variables is subject to vary on either side, position of an estimated/fitted curves is also not fixed and does fluctuate on either side. Fluctuation limit with certain confidence is determined by Standard Error of Mean Relationship, Smr.

$$S_{mr} = \pm t^*Se\ (1/n + (Pi - Pav)^\wedge 2/\Sigma(Pi - Pav)^\wedge 2)^\wedge 0.5$$

where, Pi = Ln (G-Go) & Se is st error of estimate.

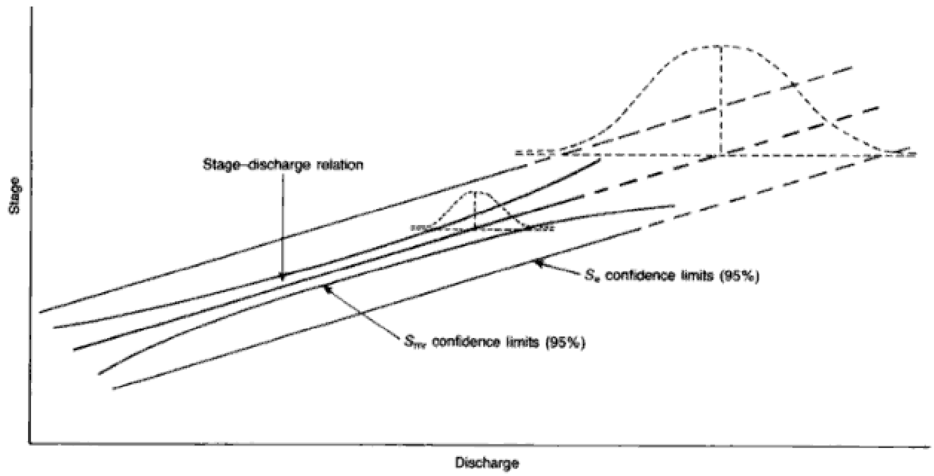
G = Water level

G_0 = Scale effect

t = student t value, 1.96

Se = Standard error of estimate

Pav = Average of all Pi



Outer pair of lines are estimated values ± 1.96* Se away and holds around 95% of observed records. Inner pair of lines is estimated values ± Smr away and signifies fluctuation in best fit line; which is likely to remain within this band with 95% confidence level.

A pair of lines so developed help detect outliers because of manual and/or systematic errors; alteration in river geometry or its regime etc.

Case Study

In the remainder of this chapter, a study involving water level and corresponding observed discharge data demonstrates through steps the fitting of a rating curve; estimation of series of statistical parameters and bands using functions of MS excel sheet.

Table 1

Water Level in m, G (1)	Discharge in cumec, Q (2)	$(G - G_0), G_0 = 75$ (3)
81.00	23418	6.00
81.07	23845	6.07
81.13	25974	6.13
81.35	26069	6.35
81.40	25704	6.40
81.40	26844	6.40
81.47	26306	6.47
81.64	29028	6.64
81.67	24751	6.67
81.69	29148	6.69
81.77	27829	6.77
81.80	29317	6.80
81.87	29562	6.87
81.89	30053	6.89
82.02	26479	7.02
82.03	32181	7.03
82.11	31292	7.11
82.21	32811	7.21
82.27	30500	7.27
82.30	33727	7.30
82.65	35306	7.65
82.75	33697	7.75
83.48	43695	8.48
84.03	51496	9.03

1. At the very beginning, water level is arranged in ascending order ensuring discharge data against the same water level in post arrangement scenario. Highlighting water level series followed by discharge and electing ascending order function in excel accomplish this without disturbing the pair.

2. A relationship between two variables, i.e. water level and discharge is commonly expressed by power equation of following type:

$$Q = c(G - G_0)^b$$

Where, Q = discharge,
G = water level

C & b are constants; and G_0 is scale effect determined by Johnson formula

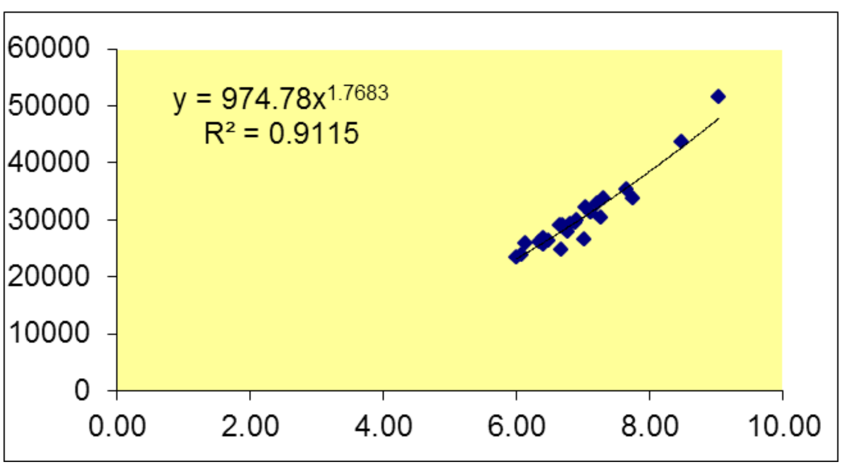
$$G_0=(G_2\char`^2-G_1*G_3)/(2*G_2-G_1-G_3)$$

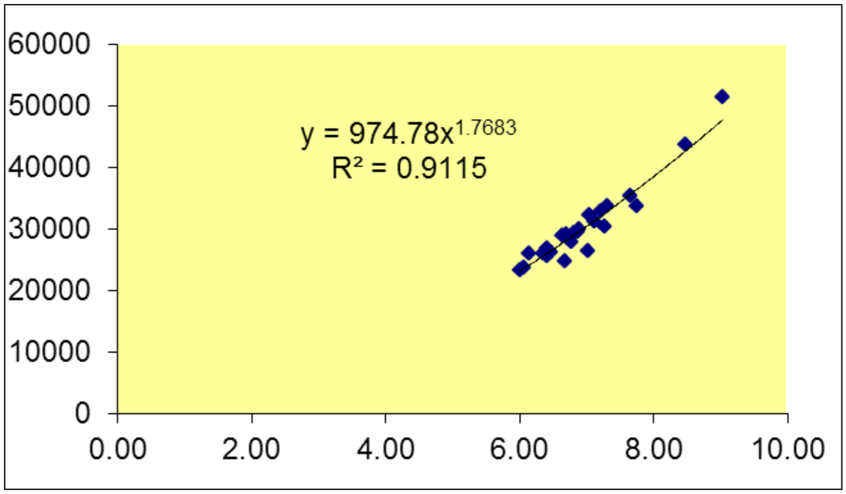
G_1 & G_3 are corresponding water level of Q_1, picked up from lower and Q_3 from higher ranges of data series, and G_2 is read from series against Q_2 which is obtained by square root of Q_1*Q_3. Having known three water levels, G_0 is calculated and an additional series is created that contains $(G - G_0)$. An estimation of G_0 based on data compiled in **Table 1** is shown below:

Q		G
Q1 =	23418	81
Q2 =	31988.27	82
Q3 =	43695	83.48
Go =	78.91667	
Go taken =		**75**

Selection of Q_1 & Q_3 is subjective; and therefore, it differs in each case. For instance, in the current selection, it is 78.91667 while value considered for fitting a rating curve is 75. This departure form estimated figure is explained a bit later.

3. Having got a G_0 as above, a best fit curve is plotted in excel keeping discharge on Y-axis and $(G - G_0)$ on abscissa. Additionally, a rating equation with power equation type and r^2, i.e. correlation coefficient is also opted to distill this information. A plot on these lines is depicted below for two G_0, the first with 79 and second with 75. We may notice here an appreciable increase in r^2 with change in G_0. As our understanding of correlation coefficient suggests, we go by second chart at it exhibits a higher degree of correlation between two variables. In an attempt to reach better r^2, various data handlers will converge to a single value of G_0. In doing so, one has also to be watchful about realistic nature of G_0, where river is expected to run dry. *While fitting a curve in HYMOS software, user intervention in obtaining G_0 is not needed.*





4. Steps till now generate a best fit equation of following type and is used in determining Q_{est} (discharge estimated) value for each and every water level values in the series.

$$\mathbf{Q = 974.78(G - G_0)^{1.7683}}$$

Table 2

Water Level in m, G (1)	**(G – G_0),G_0 = 75 (2)**	**Discharge in cumec, Q_{obs} (3)**	**Estimated Discharge, Q_{est} (4)**
81.00	6.00	23418	23169
81.07	6.07	23845	23649
81.13	6.13	25974	24064
81.35	6.35	26069	25612
81.40	6.40	25704	25970
81.40	6.40	26844	25970
81.47	6.47	26306	26475
81.64	6.64	29028	27717
81.67	6.67	24751	27939
81.69	6.69	29148	28087
81.77	6.77	27829	28684
81.80	6.80	29317	28909
81.87	6.87	29562	29437
81.89	6.89	30053	29589
82.02	7.02	26479	30583
82.03	7.03	32181	30660
82.11	7.11	31292	31280
82.21	7.21	32811	32062
82.27	7.27	30500	32536
82.30	7.30	33727	32773
82.65	7.65	35306	35603
82.75	7.75	33697	36430

83.48	8.48	43695	42716
84.03	9.03	51496	47736

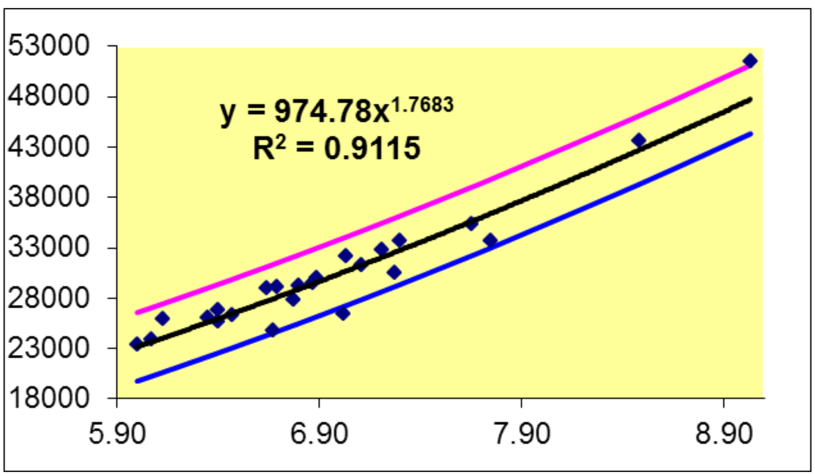
5. At this stage, reader may revisit descriptions under SD, Standard Deviation and Se, Standard Error of Estimate in order to calculate these statistical parameters based on data in **Table 2**. Estimated values are as under:

SD = 6316, Sest = 1737

6. Having determined Sest, two additional series to contain estimated/computed value ± 1.96 * Sest can be created and drawn to appear on either side of the best fit line or rating equation plotted on graph. For first row in Table 2, calculation is as below:

$$Q_{upper,} Q_{lower} = 23169 \pm 1.96 * 1737 = 26574, 19765$$

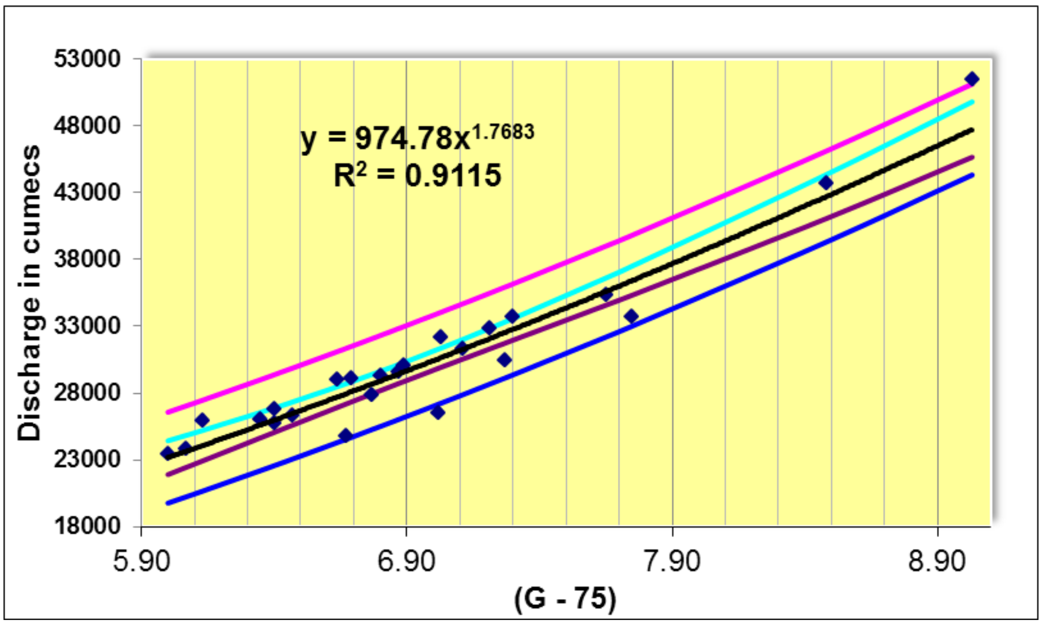
This process is repeated for remainder of cells; and series thus developed are used in plotting of confidence band which is likely to cover 95% of observed within its bounds. A plot showing these bands along with best fit line is produced next.



7. Function to develop this band is unfortunately not available in HYMOS and only recourse available is to plot it using excel. This visual aid offers the engineer to infer a range of significant information such as

- Change in river regime, if all or most of the fresh observed data plot in one side of the band;
- is there any data beyond the bounds. If yes, that data is suspicious and needs to be handles for any manual or systematic errors;
- width of the band signifies the degree of randomness influencing the discharge observation. A quiet and less windy river site is expected to generate a narrow band than a turbulent river in hostile weather conditions;
- an altogether varying pattern of plot warrants a fresh fitting of rating curve with new set of gauge and observed discharge data.

8. Yet another question that confronts an engineer is to pick up a discharge value against a given gauge/water level for variety of analyses. He, often times, wobbles between observed discharge vs. computed discharge; and even if a computed discharge is chosen, he suspects its firmness. Previously, we have defined St error of mean as a parameter which defines the likely variation of mean for a single variable. Similarly, a best fit line drawn based on certain length of data has likelihood of fluctuation on either side with arrival of more data or with consideration of increased length of data. St error of mean relationship defined earlier draws this bound with 95% confidence level. A plot with this pair of lines determined from equation of S_{mr} given earlier, apart from dispersion band drawn previously, is shown next. Reader may notice the pattern of these lines with what is appended below St Error of Mean relationship, S_{mr}.



9. An excel sheet containing column-wise calculations of steps elaborated in preceding paras is given in **Table 3.** At the end of this analysis, we may conclude from this table an estimated discharge value against a desired water level. For instance, for water level of **81.80m**, discharge with degree of uncertainty involved is **28909 ± 722 cumecs.**

Table 3

Stage obs	(G-Go)	Discharge Qobs	Qc	(Qo-Qc)^2	Qc plus t*Se	Qc minus t*Se	pi=ln (G-go)	(pi-pav)^2	t*Smr	Qc plus t*Smr	Qc minus t*Smr
81.00	6.00	23418	23169	61890	26574	19765	1.79	0.021	1268	24437	21902
81.07	6.07	23845	23649	38280	27054	20245	1.80	0.017	1198	24848	22451
81.13	6.13	25974	24064	3647010	27469	20660	1.81	0.015	1141	25205	22923
81.35	6.35	26069	25612	208424	29017	22208	1.85	0.008	952	26565	24660
81.40	6.40	25704	25970	70842	29375	22566	1.86	0.006	915	26885	25055
81.40	6.40	26844	25970	763593	29375	22566	1.86	0.006	915	26885	25055
81.47	6.47	26306	26475	28410	29879	23070	1.87	0.005	867	27341	25608
81.64	6.64	29028	27717	1718687	31121	24313	1.89	0.002	773	28490	26944
81.67	6.67	24751	27939	10162304	31343	24534	1.90	0.001	761	28699	27178
81.69	6.69	29148	28087	1125411	31492	24683	1.90	0.001	753	28840	27334
81.77	6.77	27829	28684	730668	32088	25279	1.91	0.001	728	29412	27956
81.80	6.80	29317	28909	166516	32313	25504	1.92	0.000	722	29630	28187
81.87	6.87	29562	29437	15563	32842	26033	1.93	0.000	712	30149	28726
81.89	6.89	30053	29589	215336	32993	26185	1.93	0.000	710	30299	28879
82.02	7.02	26479	30583	16845383	33988	27179	1.95	0.000	716	31299	29867
82.03	7.03	32181	30660	2312247	34065	27256	1.95	0.000	718	31378	29943
82.11	7.11	31292	31280	142	34685	27876	1.96	0.001	735	32015	30545
82.21	7.21	32811	32062	560677	35467	28658	1.98	0.002	768	32831	31294
82.27	7.27	30500	32536	4143389	35940	29131	1.98	0.002	794	33329	31742
82.30	7.30	33727	32773	909508	36178	29369	1.99	0.003	808	33581	31966
82.65	7.65	35306	35603	88138	39007	32198	2.03	0.010	1018	36621	34585
82.75	7.75	33697	36430	7469124	39834	33026	2.05	0.013	1088	37518	35342
83.48	8.48	43695	42716	958746	46120	39311	2.14	0.041	1646	44362	41070
84.03	9.03	51496	47736	14134927	51141	44332	2.20	0.070	2071	49807	45665
	Sd =	**6319.212**		**66375214**		**pav =**	**1.94**				
			Se =	**1736.9672**			**∑(pi-pav)^2**	**0.2246**			

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VALIDATION OF WATER LEVEL DATA

The validation of recorded water level data of a site is primarily essential to rid it of manual and instrumental errors, if any by (i) defining a few bounds based on physical conditions and statistical parameters; (ii) & comparing it with the patterns recorded at adjacent station (s). A poorly validated water level series will gravely impact the computed discharge series- a vital input for subsequent hydrological analyses. The succeeding screenshots demonstrate the functionality of HYMOS in achieving the intended objective one after another. To logon to HYMOS, use default entry:

USER NAME – administrator
PASSWORD – hello (it appears on screen in the form of 'ASTERISK' sign) **(Fig1**).

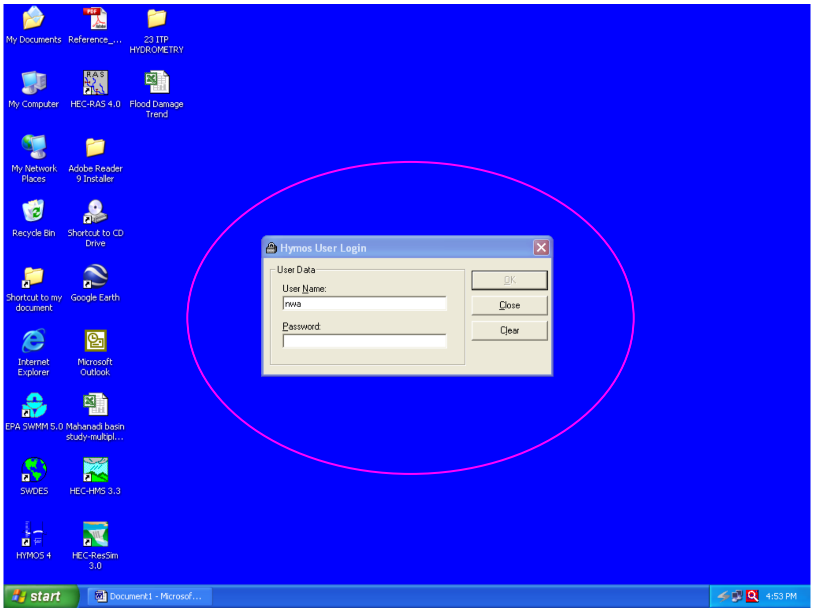


Fig.1

The first step brings you to the opening screen of this software **(Fig.2**). On tool bar, use *open database* or *database manager* to search for your desired work area. Here, **we choose 'KHEDA BASIN, by *double-clicking*** on it to carry out elementary exercise subsequently. Alternatively, you may select the desired work area and press *open* button.

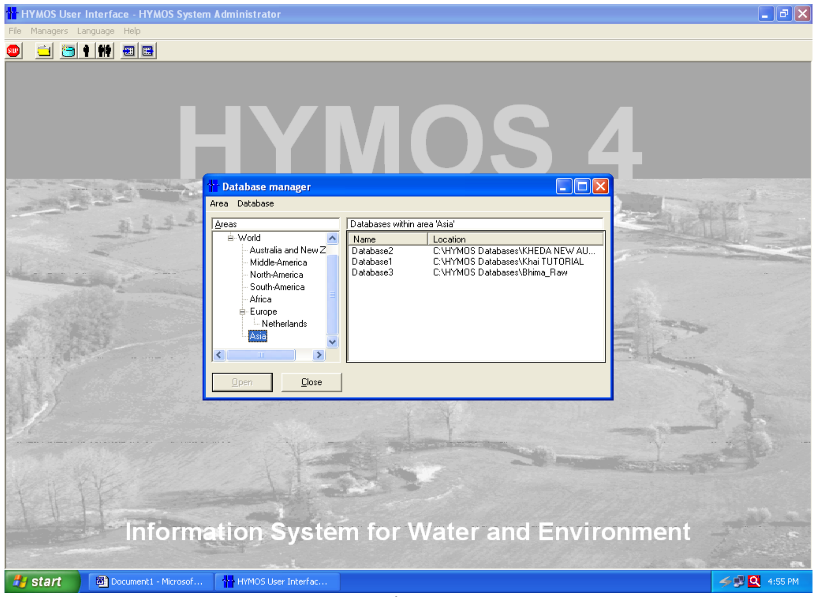


Fig.2

This leads you to *NETTER SCREEN* **(Fig.3).**

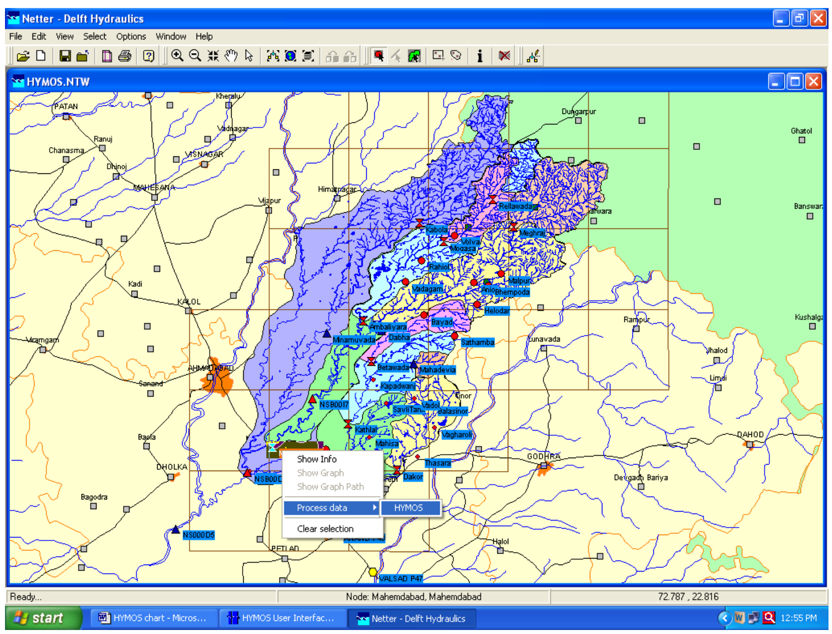


Fig.3

The netter screen contains a host of hydro-meteorological sites' name and provides links to database files of these stations to work with. To select a particular or a group of stations, do the following:

1. Hold down *Shift/Ctrl* key and click the desired *station(s) in turn*.
2. Press right mouse button and select *process data+HYMOS.*

For the current exercise, select *MAHEMADABAD* site and *press HYMOS*.

Pressing HYMOS, a HYMOS function box pops up containing a group of ***five tabs*** on menu bar **(Fig.4**). Most frequently used tabs are *time* and *function* tabs. *Time tab* allows the user to select the period and time base of the station/s according to the purpose. Function tab holds multiple folders each having numerous functions within. These *keys; selected upon+go to function button* open different boxes/windows; each performing specific functions.

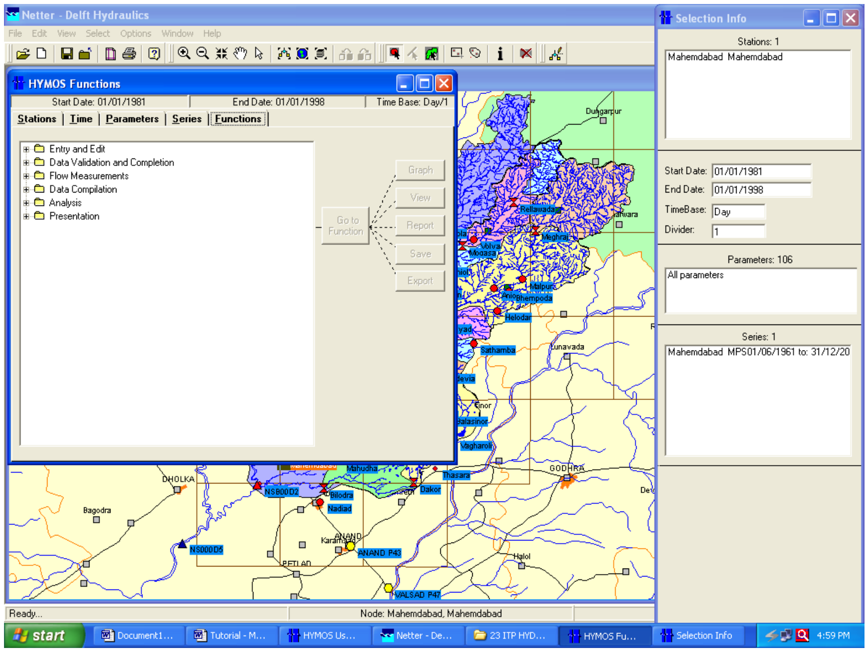


Fig.4

Press time tab and enter Start time: 01/07/1997;   End time: 01/01/1998; Time base: hr

Once it is over, press *Function tab* again *and click on + sign a*gainst Data compilation folder once or double click on folder itself to obtain a series of function within **(Fig.5**).

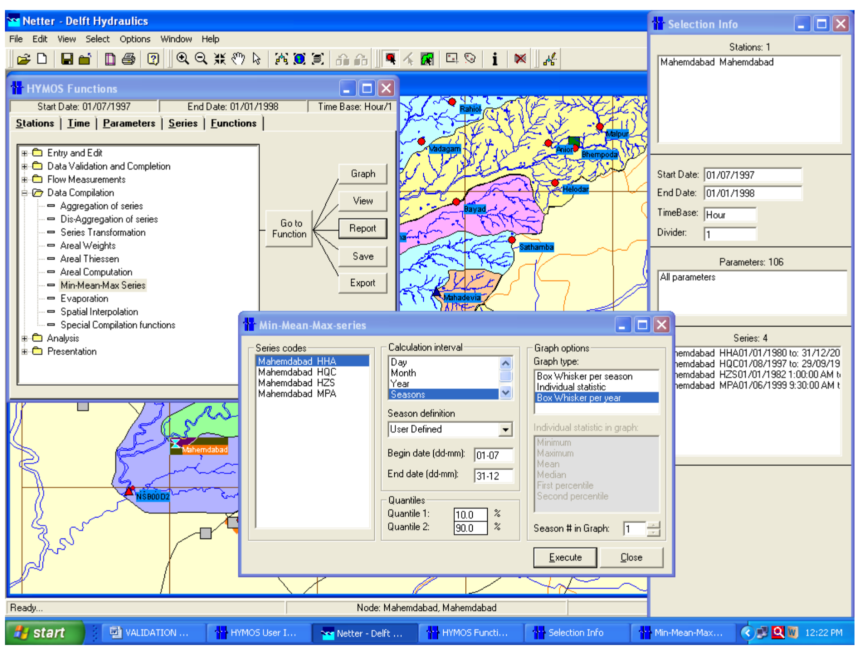


Fig.5

One such function is Min-Mean-Max Series. Select this choice followed by pressing the 'go to function' tab. This pops up another window prompting the user to make appropriate selections.

Here, user is requested to follow selections as they are and press 'Execute' button. HYMOS does the rest and offers results in different forms. The result summary is obtained by pressing buttons such as Graph; View; & Report on Hymos Function box one by one.

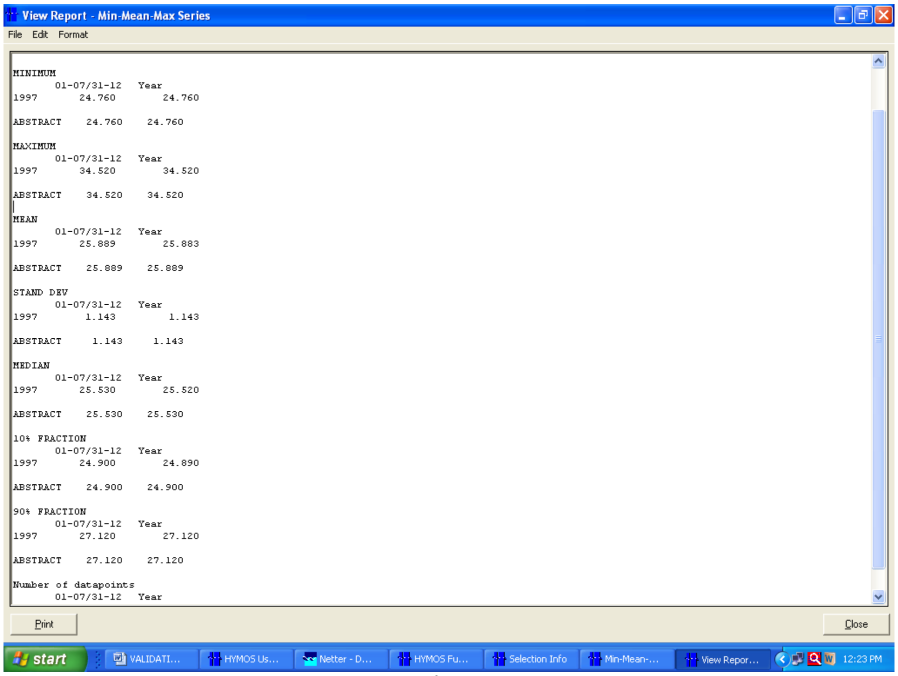


Fig.6

Pressing Report button, HYMOS returns a report file containing statistical parameters extracted based on the length of data under analysis **(Fig.6)**.

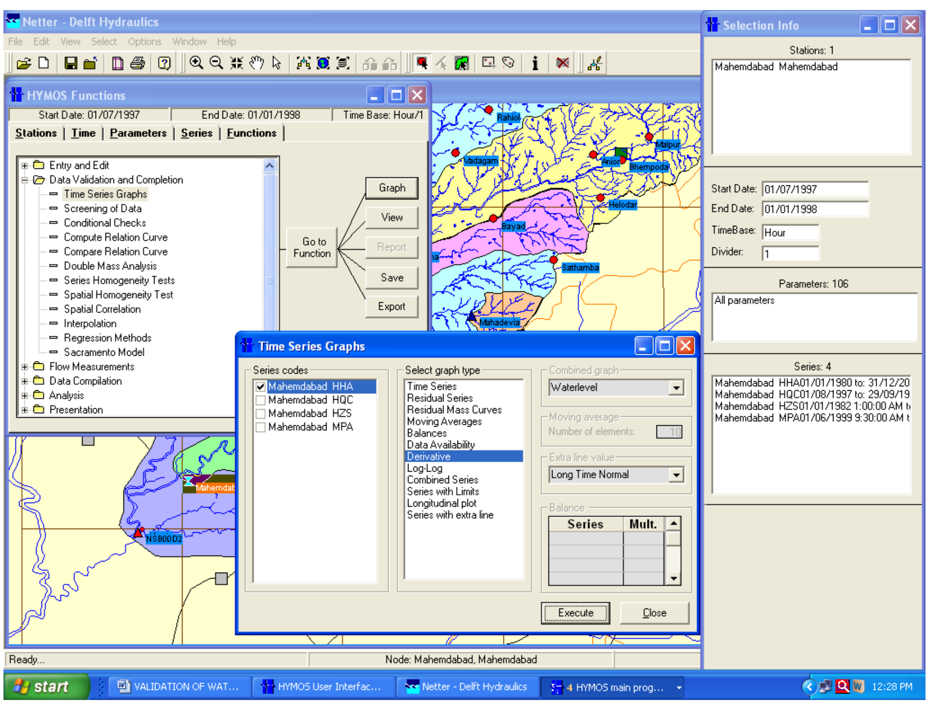


Fig.7

Of them, 10% and 90% fraction or percentile are important to grasp. The value against these parameters indicates the number of occasions/times that value was not exceeded in the time period. Data lying outside these parameters need closure scrutiny for detecting/obviating possible entry of erroneous data. User is also advised to follow steps/selection appearing in **Fig.7** and pressing Execute button to determine rate of rise and rate of fall of water level in m/hr.

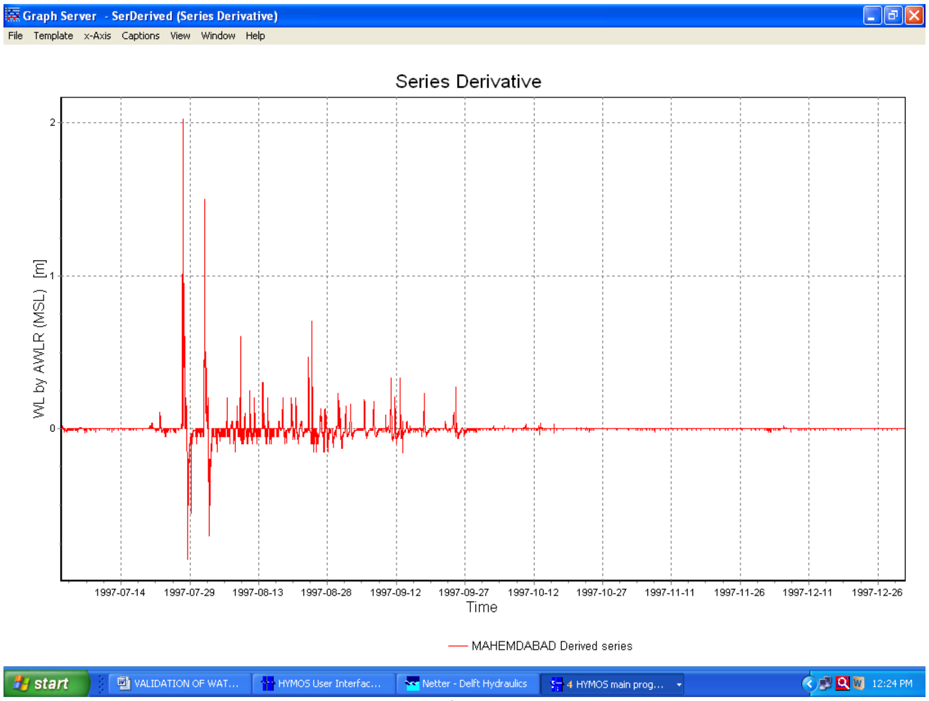


Fig.8

Clicking on Graph button on Hymos Function box returns the graph **(Fig.8)** indicating rate of rise around 2m/hr and rate of fall around 1m/hr.

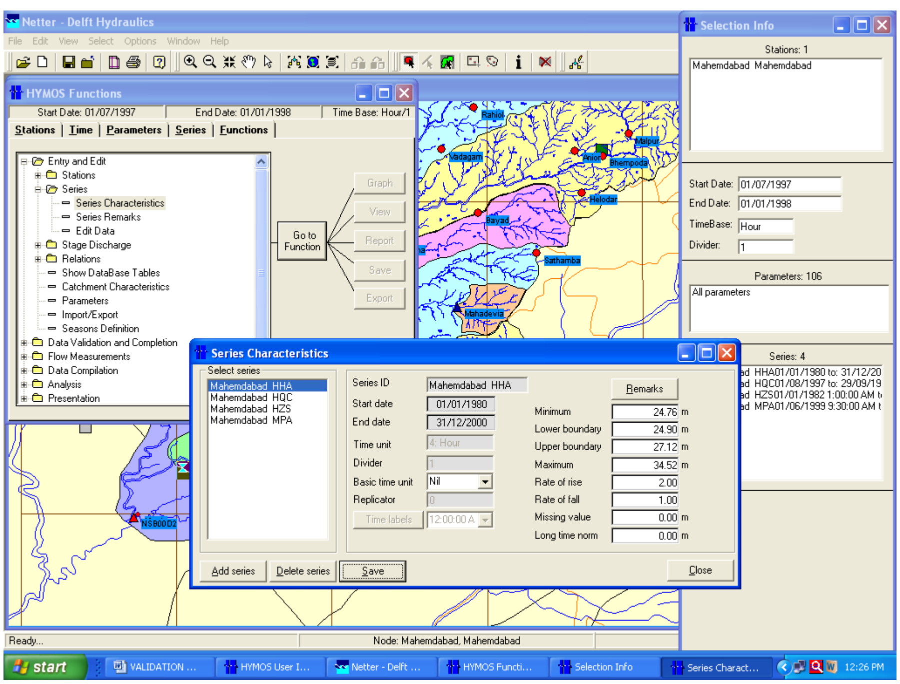
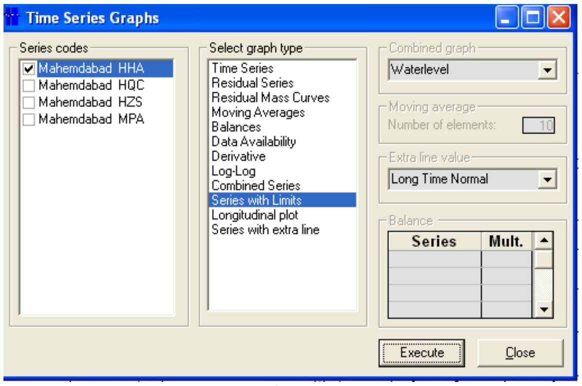


Fig.9

Information distilled from Fig.6 & Fig.8 is inputted in Series Characteristics box **(Fig.9)** by choosing appropriate series. Currently, it is Mahemadabad HHA series. Once keyed in, press save.

At this stage, user is advised to refer to **Fig.7** and select *Series with limits* as Graph type in place of Derivative **(Fig.10)**.



(Fig.10

Press Execute followed by clicking on Graph on Hymos function box opens up a graph with all limits but rate of rise and fall (**Fig.11).** Graphical presentation of time series data along with different bounds help user detect possible errors; & occurrences of extreme events on higher and lower sides. Any value that deviates from real event on the ground can be deleted or modified by opening up Edit data box. User may refer to **Fig.9/Fig.15** to get Edit data values box. This box presents an array of all values against time in addition to its plot. Having finished with edition, press save to record the changes permanently **(Fig.15**).

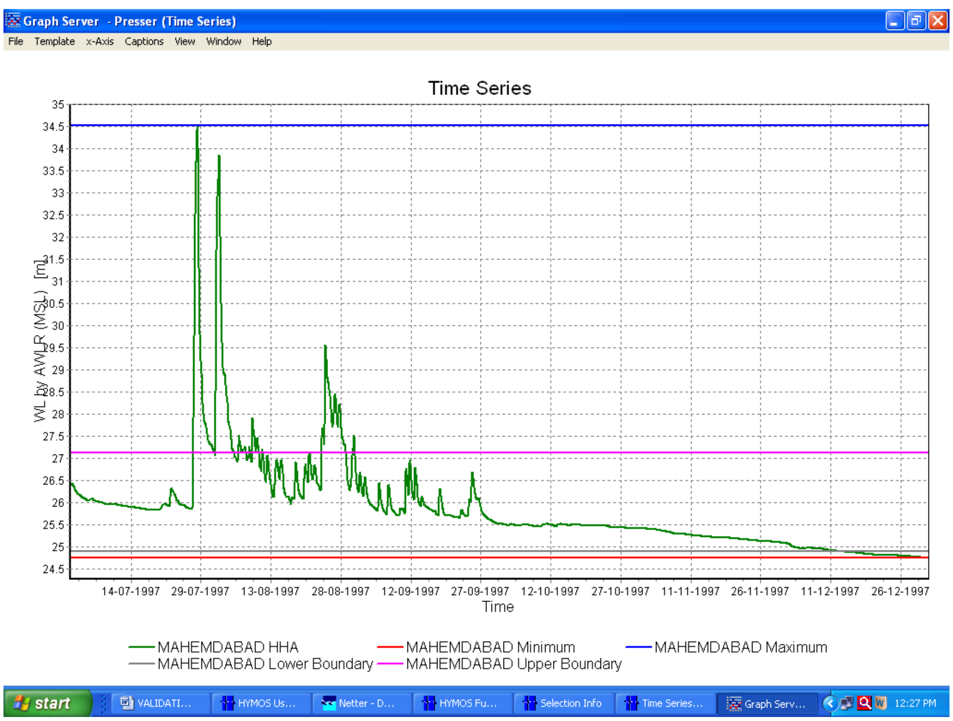


Fig.11

A similar selection of **Fig.7** once again offers a graph of derivatives aside from extreme rates of rise and fall ever noticed at site under analysis **(Fig.12**). This is an additional tool available in the software to prompt user against inclusion of wrong set of data.

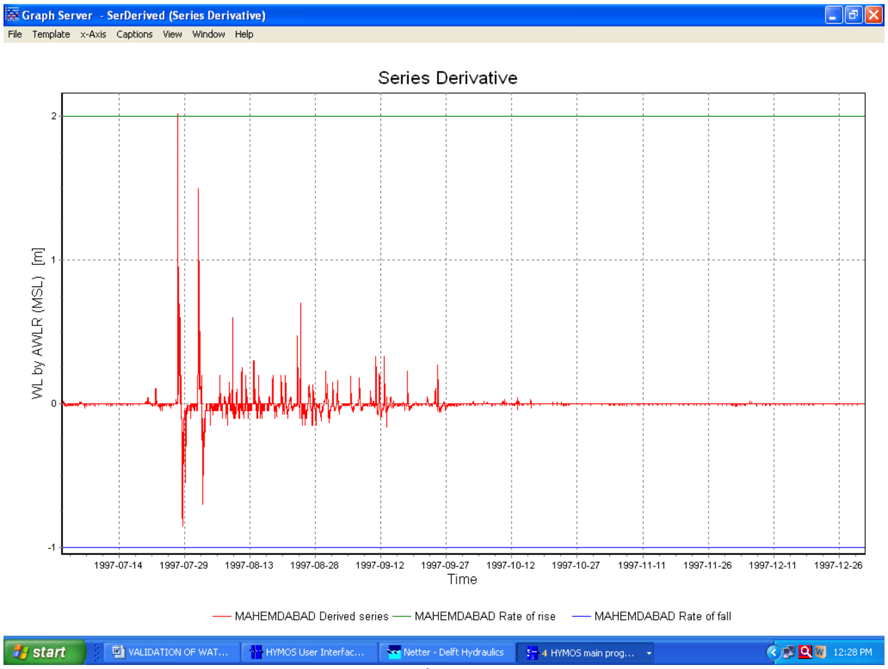


Fig12

Preceding illustration is limited to validation of water level data observed at a particular station. Two stations sited on the same stream normally exhibit identical pattern of water level if plotted against time.

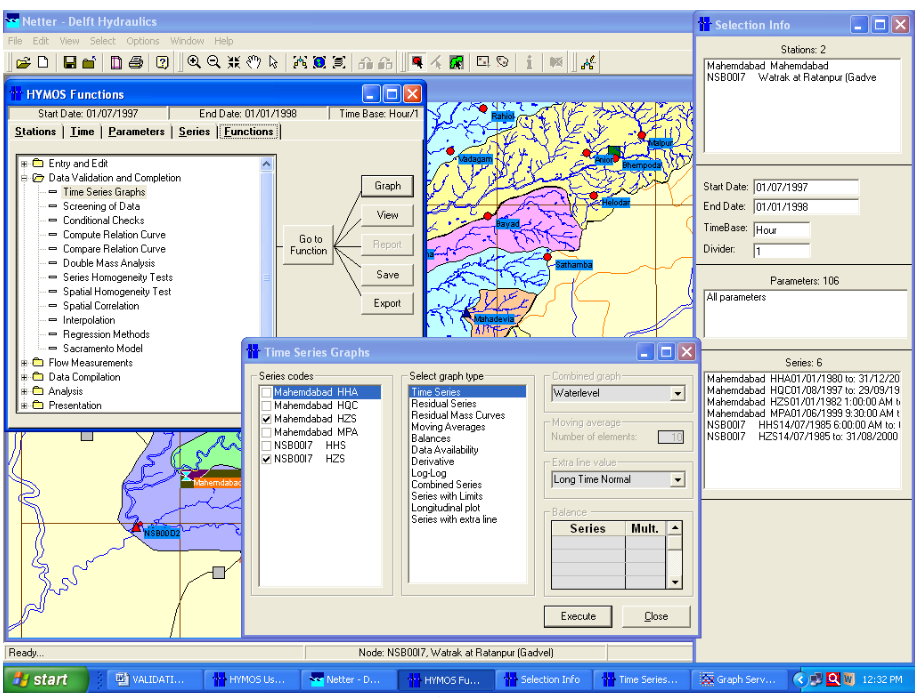


Fig.13

A graphical representation of such plot is yet another tool to notice anomalies in the record. **Fig.13** displays the relevant selections with check box 'on' for two neighbouring stations namely **Mahemadabad** and **NSB00I7 (Use Netter screen to choose additional station)**. Press 'Execute'. Pressing Graph button returns **Fig.14** as resultant plot.

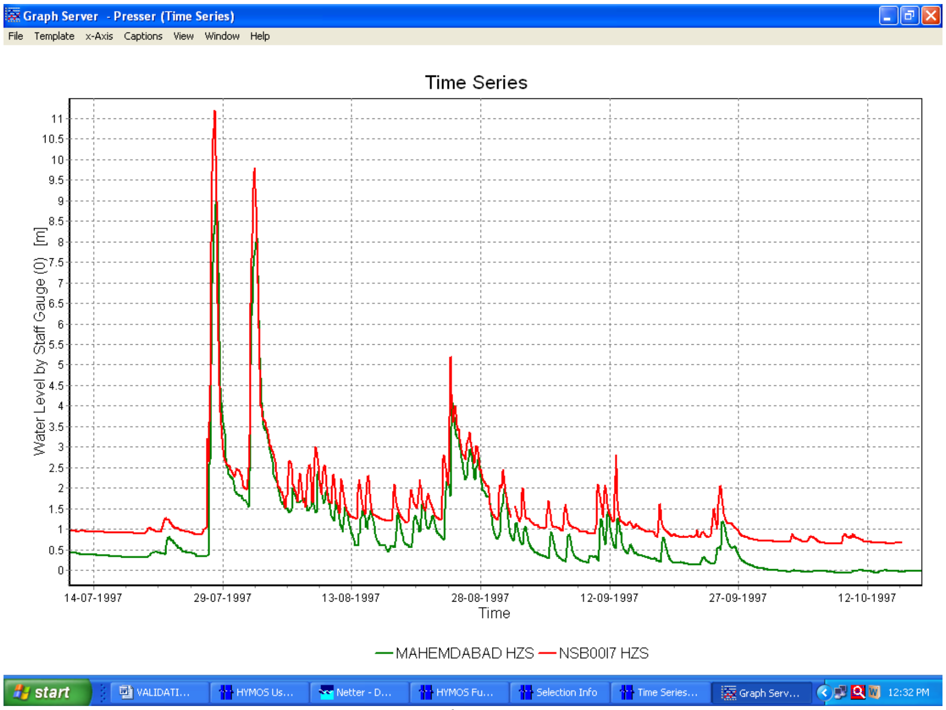


Fig.14

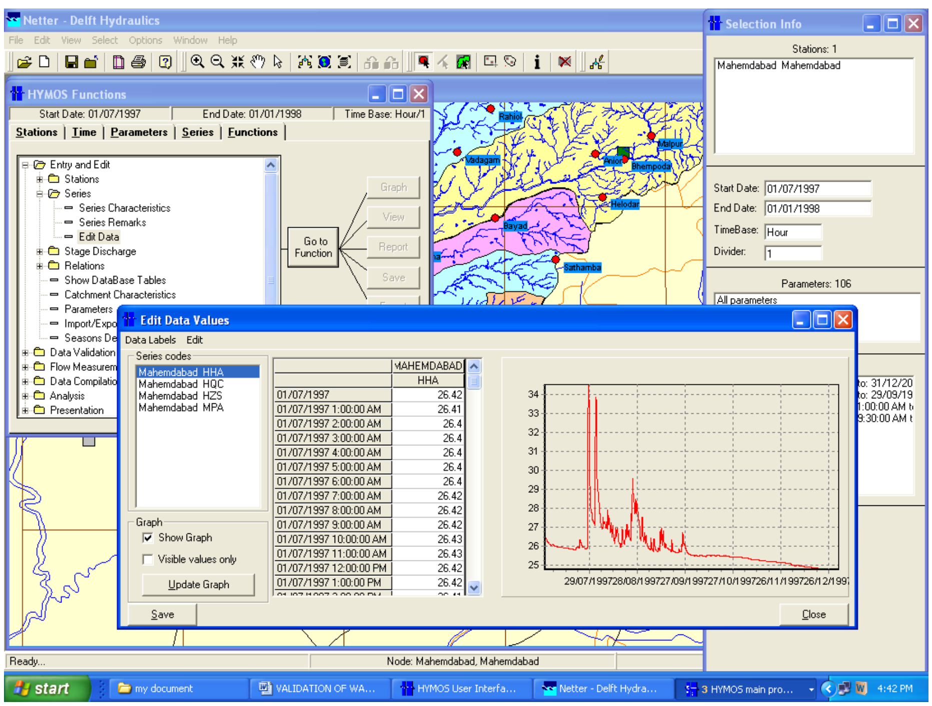


Fig.15

Occurrence of several peaks and lows at upstream site must precede the downstream' s peaks and lows. This simple premise can be used to validate record.

Often times, water level series are left with breaks of different lengths in between for reasons such as uprooting of gauge post; hostile site conditions particularly during flood; malfunctioning of recording instrument etc.

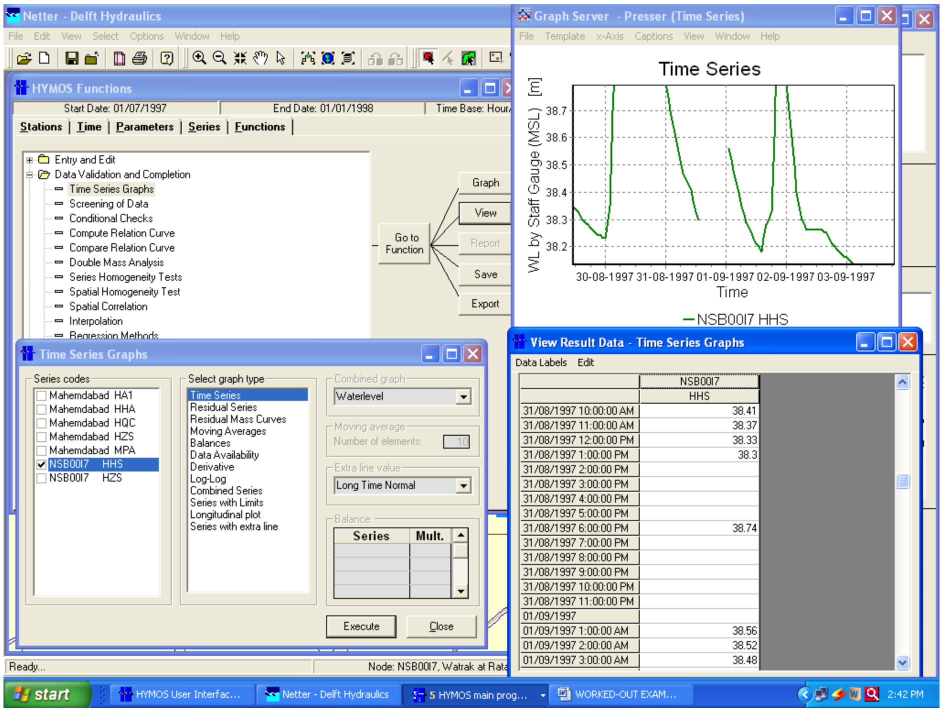


Fig.16

Short gaps, with no change in trend involved, at a site can very well be bridged by linear interpolation; large gaps with multiple peaks and troughs in between demand application of a relationship; the site data exhibits with data recorded at neighbouring station. HYMOS offers both options to fill in gaps in water level series; which is an essential step before stage discharge transformation exercise. One such gap extending upto six days appears in NSB00I7 site between 31.08.1997 and 01.09.1997 in **Fig.16**. Detection and viewing of any such gaps could be attained by choosing 'data availability' and 'time series' option on Time Series Graphs window.

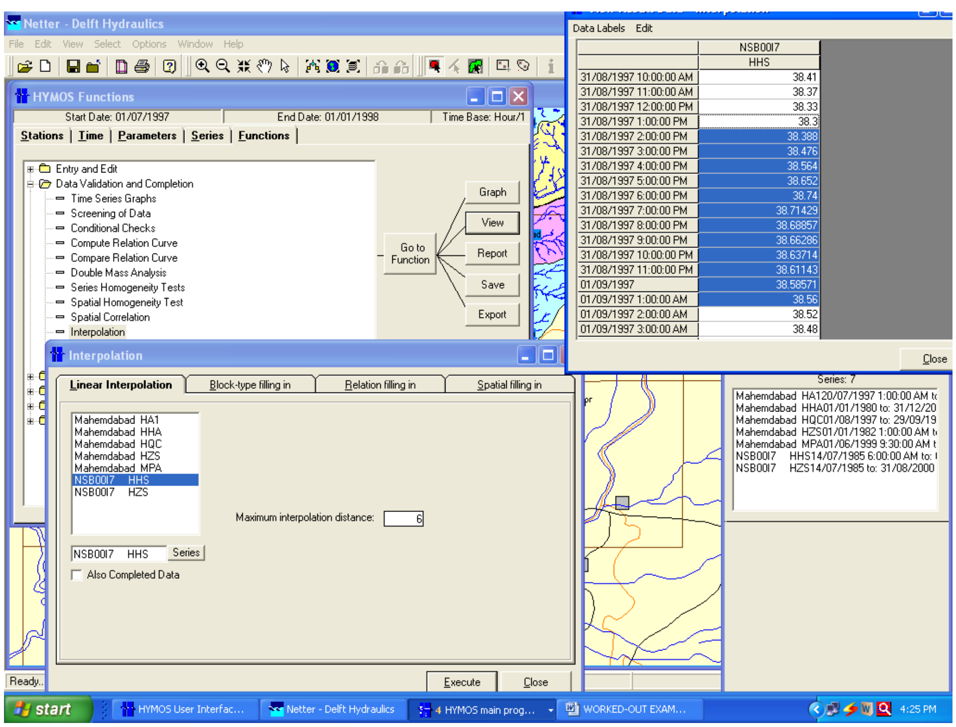


Fig.17

To fill in this gap, 'Interpolation' option under 'Data Validation and Completion' folder is double clicked on to get 'Interpolation' window with first tab meant for linear interpolation (**Fig.17**). User may choose appropriate series where gap is identified followed by pressing 'Series' tab to get the empty cell by it populated. Another cell on the right requires number in time unit. Here, a value as '6' implies that all gaps upto six hours in length would be identified and replaced with interpolated values. Press 'Execute' and click on 'View' tab on Hymos function box to ensure gaps filled in. User must save the series at this stage by selecting 'Save' on function box. Another window listing the series under consideration pops up; where user can check the box close to series name 'on' followed by pressing 'ok' button at lower right part on same window (**Fig.18).**

Gaps larger in size and missing peaks or lows are best infilled by determining relation curve between site having breaks in water level record and its adjoining site; where continuous record is available. To illustrate the steps involved in the process, one NSB00I7 HA1 series is created/saved by deleting water level from 01.08.1997 to 04.08.1997 and keeping other records as it is. Mahemadabad site is next station located in the downstream. Two series with break in first one is shown next (**Fig.19**).

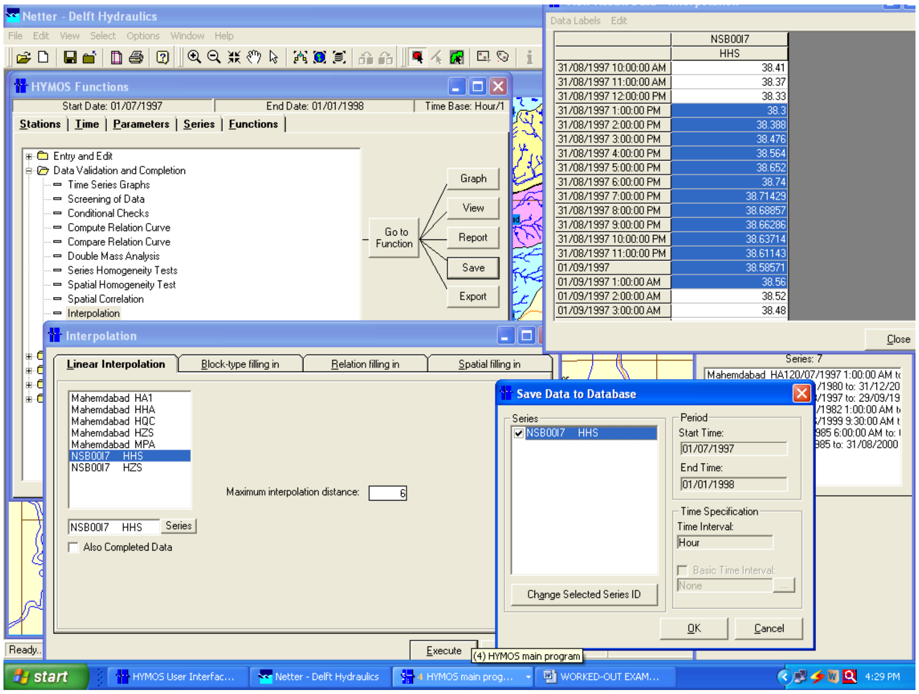


Fig.18

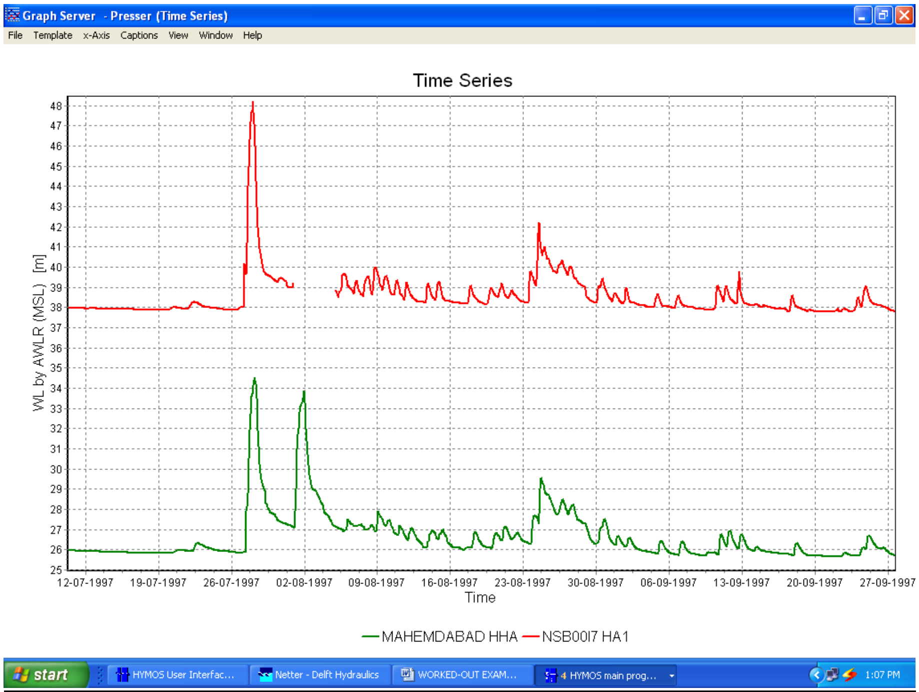


Fig.19

To compute a relation between records at these two stations, 'compute Relation curve' menu under Data Validation and Completion folder on HYMOS Function window is pressed twice (**Fig.20**). This brings up a window for Computation of Relation curve.

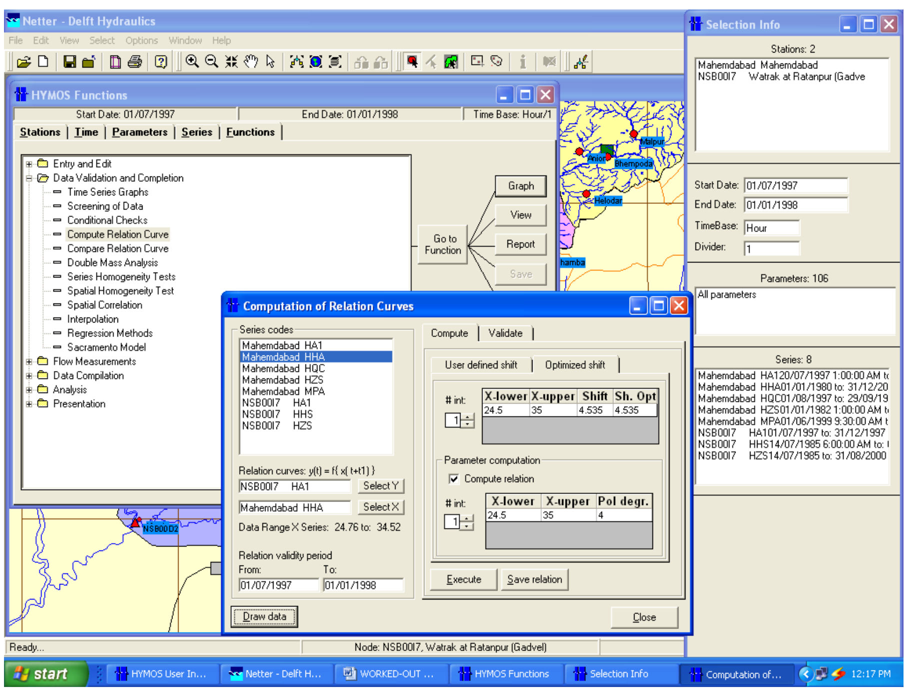


Fig.20

As gap needed to be bridged in NSB00I7 HA1 series, this series is first selected in Series Codes pan followed by clicking on 'Select Y' tab. This step defines this series as an independent variable appears in the adjacent empty cell. Dependent variable is Mahemadabad water level; so it is placed against 'Select Ā' tab by similar steps. Right part on this window displays a number of empty cells in two rows required to be filled in by users. First two cells in either row defines the range of X variable. User has the option to have polynomial equation of desired order and is picked up in a manner so as to obtain minimum standard error of estimate. A selection of '4' returns Sest as 0.14%. Click the check box on appearing next to 'compute relation' . Press 'Draw Data' tab in lower left corner presents scattering of data (also a loop) (**Fig.21).**

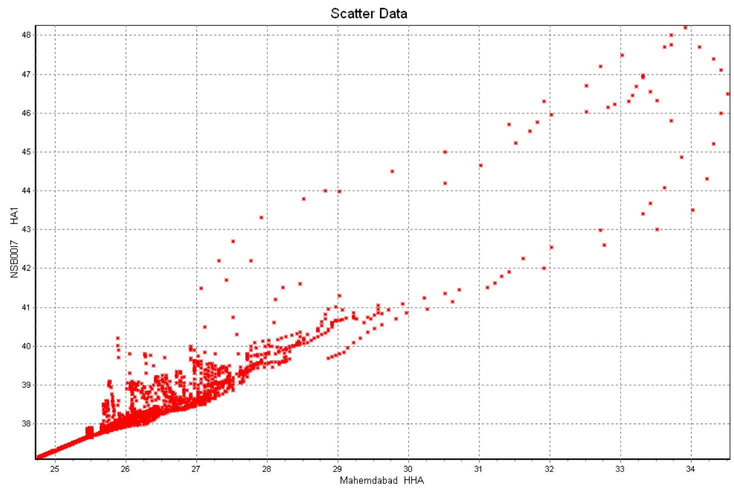


Fig.21

A loop is observed in the plot as peak at one station does not correspond to peak at other station and so are other data due to certain time lag. Upon executing the function, HYMOS automatically optimized a time lag in order to maximize correlation coefficient and returns a best fit curve with lesser scattering. This step fills in two cells in first row as 4.535 hr. Before saving the relation, user must visit the Graph and Report options on Hymos function box to ensure the fitness of curve (**Fig.22).** Once satisfied, relation can be saved by clicking on 'Save Relation' tab for its retrieval later.

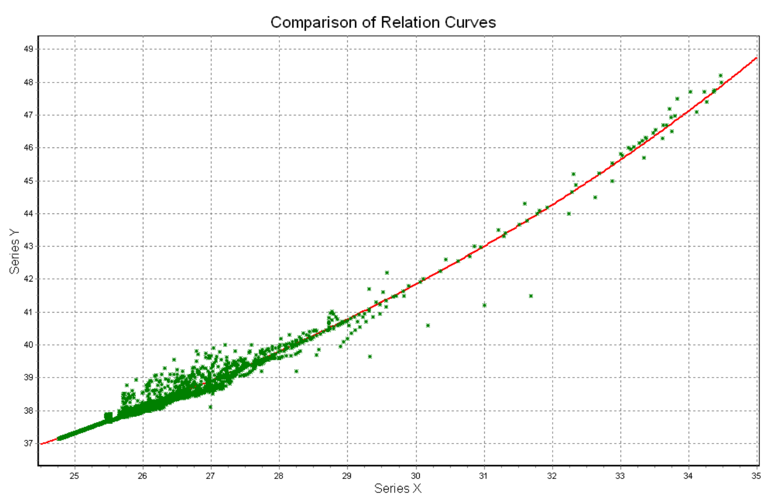


Fig.22

Once a relationship in memory saved as above, user is required to elect 'Interpolation' in Data Validation and Completion folder on Hymos Function box (**Fig.23)**. This pops up another window for interpolation purpose; where one needs to select Relation filling in tab and series having breaks. Clicking on appropriate series and pressing 'Series' tab in the middle populates the Relation pan with relation available in the memory for selected series. 'Execute' the function and press 'Graph' on Hymos function box to ensure interpolated data occupying gap part (**Fig.24)**.

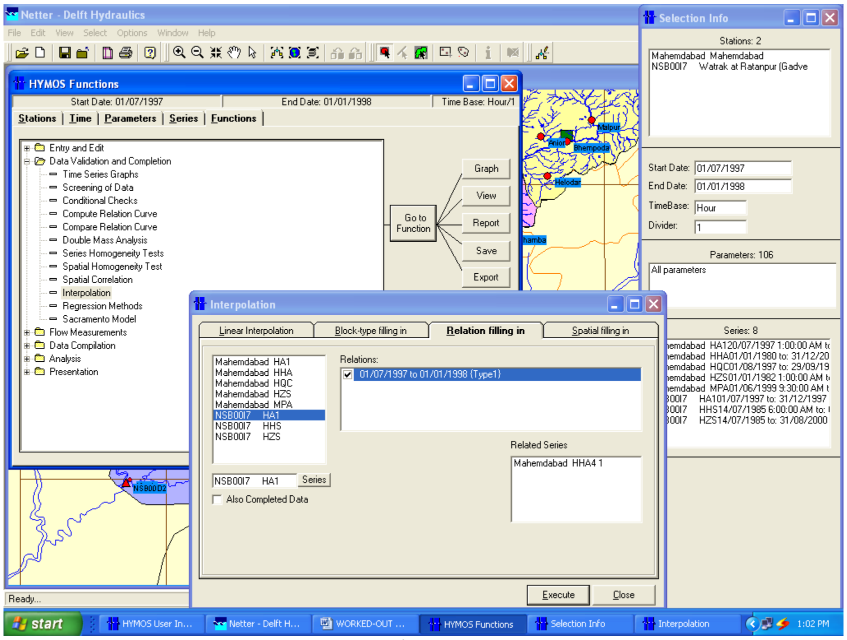


Fig.23

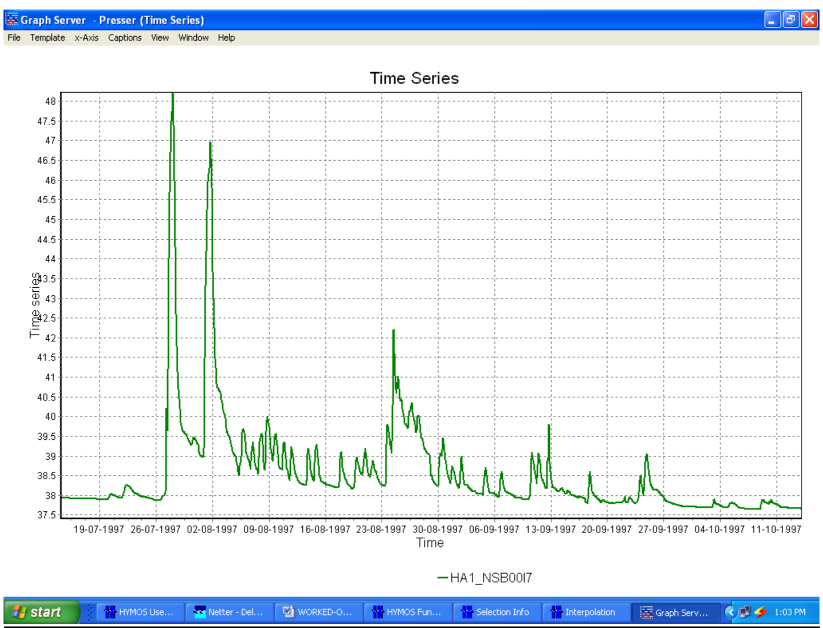


Fig.24

Stage is now reached to save the series by clicking on 'Save' tab on function box. Check the box on the 'Save Data to Database' box and press 'ok' (**Fig.25)**.

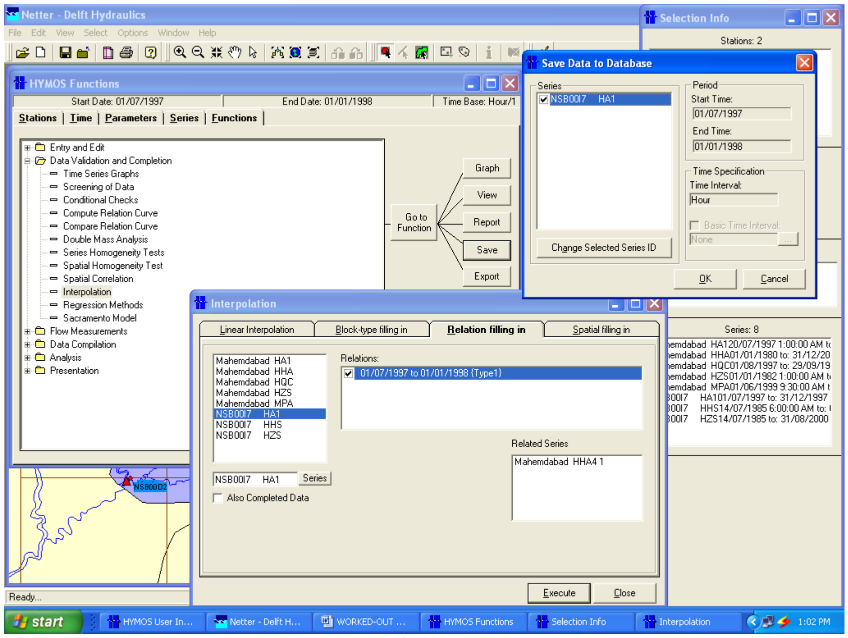


Fig.25

Test series (NSB00I7 HA1) where break was introduced, original series, i.e. NSB00I7 HHS and Mahemadabad HHA series have been collectively plotted next by selecting these series on Time Series Graphs window; executing the function; & clicking on Graph tab on Hymos function box (**Fig.26 &_Fig.27)**. Departure from original series is a consequence of scatter of data and a relationship with less than ‘1’ correlation coefficient.

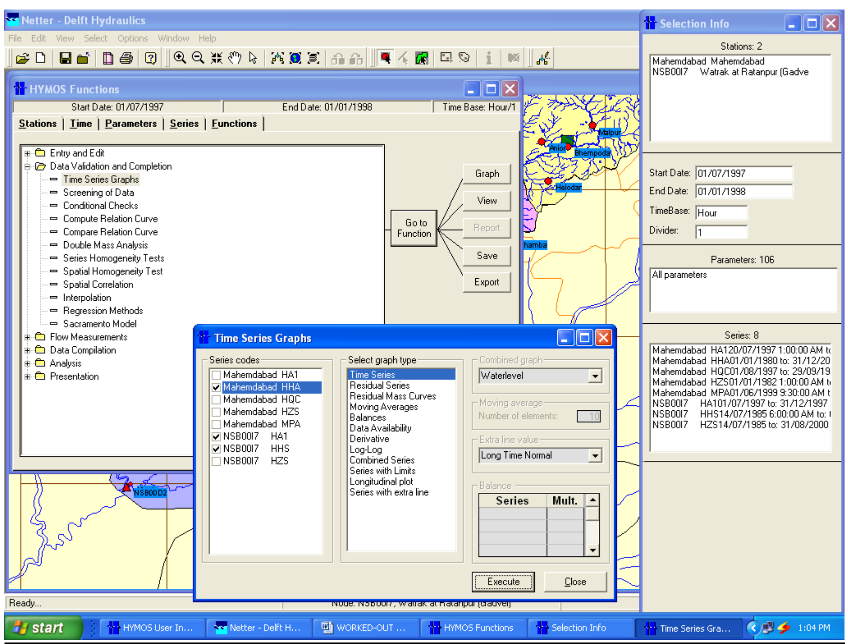


Fig.26

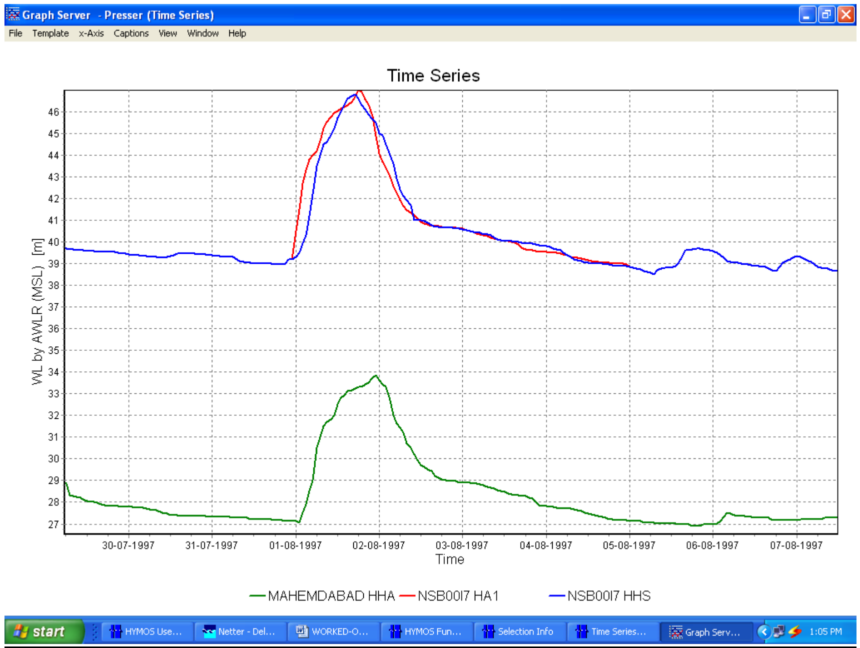


Fig.27

Illustration of this chapter is quite useful if it is read with 'Training Module no. 22 & Training Module no. 23' brought out during HP-I.

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FITTING OF RATING CURVE – Simple Rating Curve

Illustration of this chapter focuses on fitting a rating curve. For this, we **choose ‘KHEDA BASIN by *double-clicking*** on it to carry out elementary exercise subsequently. Alternatively, you may select the desired work area and press *open* button (**Fig.1**). This leads you to *NETTER SCREEN* (**Fig.2)**.

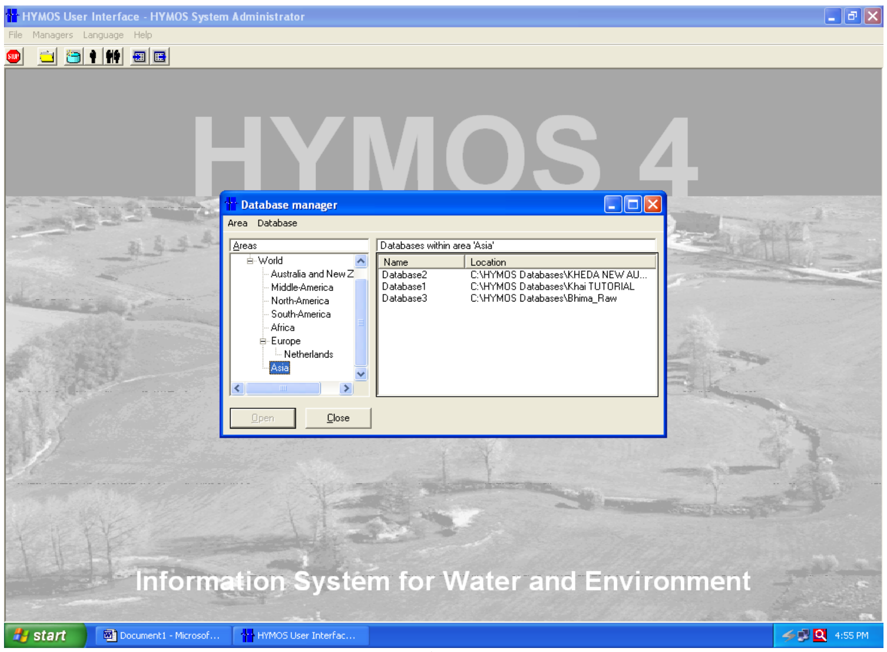


Fig.1

The netter screen contains a host of hydro-meteorological sites’ name and provides links to database files of these stations to work with. To select a particular or a group of stations, do the following:

3. Hold down *Shift/Ctrl* key and click the desired *stn/s*.
4. Press right mouse button and select *process data+HYMOS.*

For the current exercise, select *MEHAMADABAD* site and *press HYMOS.*

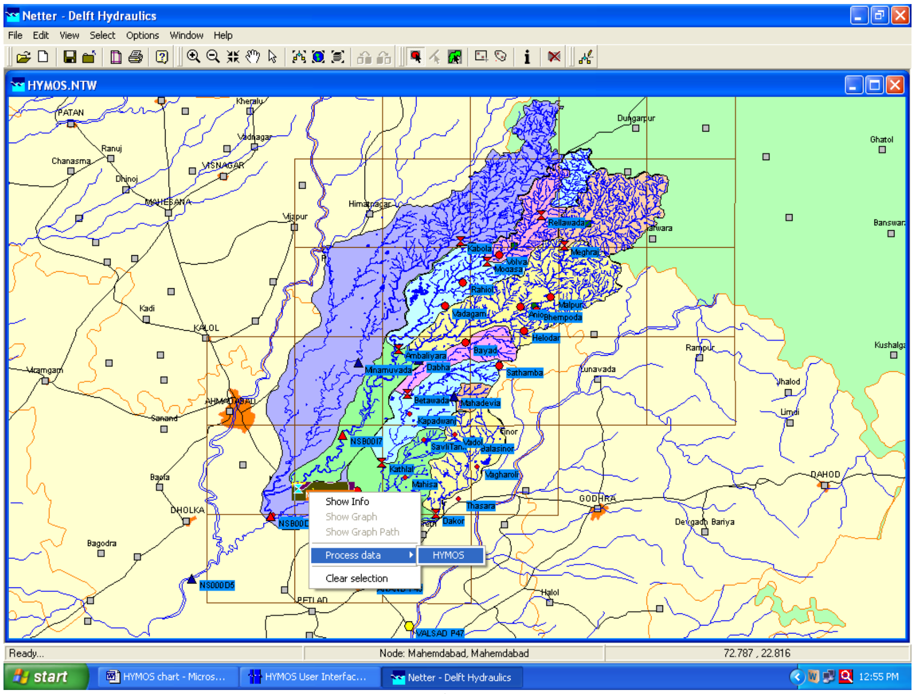


Fig.2

Pressing HYMOS, a HYMOS function box pops up containing various *tabs* on menu bar (**Fig.3)**. Most commonly used tabs are *Time* and F*unction* tabs. *Time tab* allows the user to select the period and time base of the station(s) according to the purpose. Function tab holds multiple folders each having numerous functions within. These *keys; selected upon+go to function button* open different boxes; each performing specific functions. **Press time tab and enter**

Start time: 01/08/1997, End time: 30/09/1997, Time base: hr

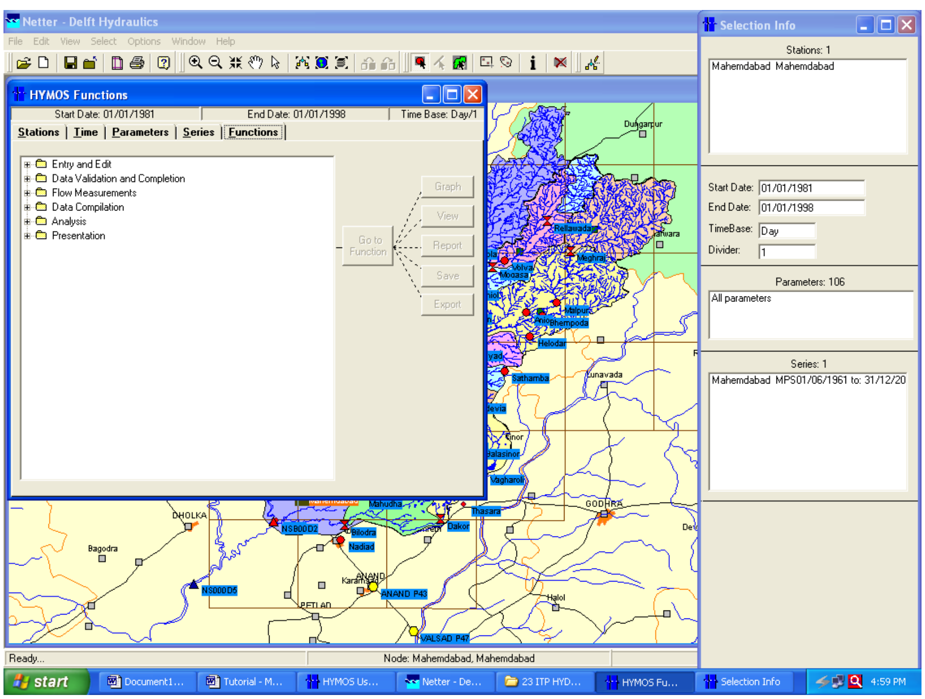


Fig.3

Fitting a relationship between gauge and observed discharge data and its utility in analysis and validation of hydrological data is warranted for a wide range of applications with obtaining a continuous computed discharge series being the most significant one. ***Training Module no.29*** unfolds the methodology used for fitting a rating curve and a set of factors influencing scattered plot of discharge data. Another must-see reference is ***Indian Standard 15119 (part 2): 2002***, which features methodologies involved in determination of the stage discharge relation. HYMOS helps user import a set of data from SWDES software and fit a rating curve under *Steady Flow Condition (?)* followed by its validation. The following screenshots guide the user to carry out this operation step by step.

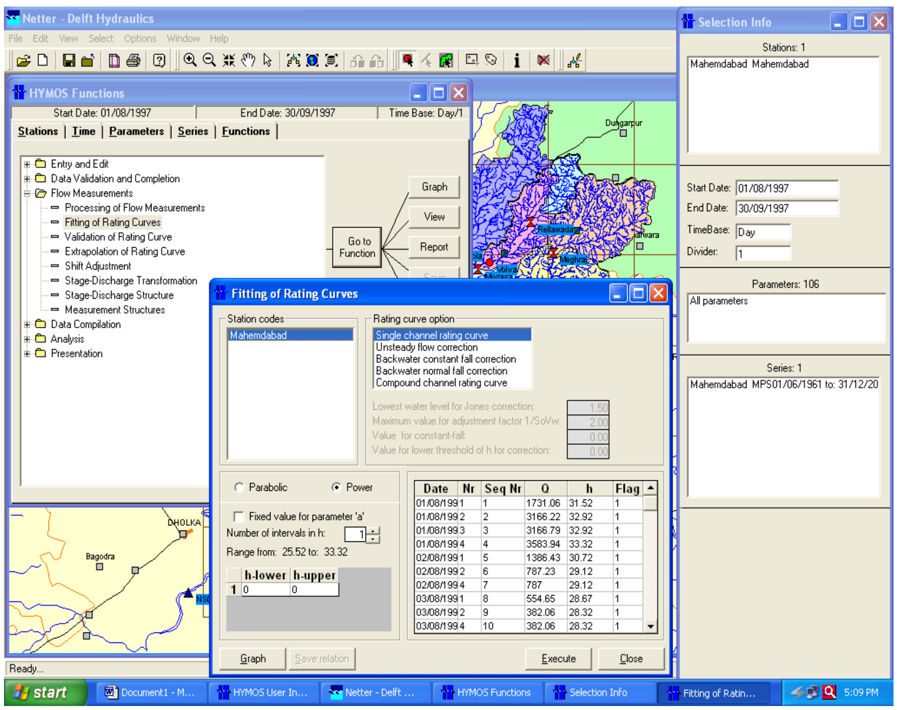


Fig.4

- Press *function and open flow measurement folder* (**Fig.4) &** Select *Fitting of Rating Curve* option; Press button *Go to Function*
- Pops-up a Fitting of Rating Curve box
- Select Station, all G-D data stored in database appears in the lower right part of this window
- Define h, water level range in the lower left two cells; just above these cells, range appears from **25.52 to 33.32**. User (beginner) may keep this range for analysis to begin with. If user is keen to develop two rating curves according to river geometry at sites, a spin button against Number of interval in h can be used. If there is more than two rating segments, ranges are to be kept overlapping and an optimum value will be searched and reported by HYMOS.
- Must press Graph on this window to look at scattered plot. You may toggle between natural and log axis by pressing appropriate buttons on the plot (**Fig.5**). A larger size point **(+)** in the middle of plot indicates the first data of the entire set. Upon clicking on this point, R1 appears close to it. A similar hitting on any other point results R suffixed with a number indicating its sequence number on the data list. Data in the lower right slot will also scrolled up/down automatically in a manner that shows sequence number and listing of selected data. User, here, can also replace '1' in the last column with '0' to exclude data from analysis. A line message also appears on this plot suggesting how to remove a point from analysis which user believes an outlier. Removal of an outlier (s) from analysis hugely impacts the final result and therefore greatest caution is involved in this process. Outliers may appear in the

data for reasons of manual and/or systematic errors; changes in river geometry; variation in manning coefficient or even for unknown reasons. Consequently, removal/retention/modification does need consideration of all possible reasons. A mere eye judgment and their removal are no prudent way to handle outlier (s).

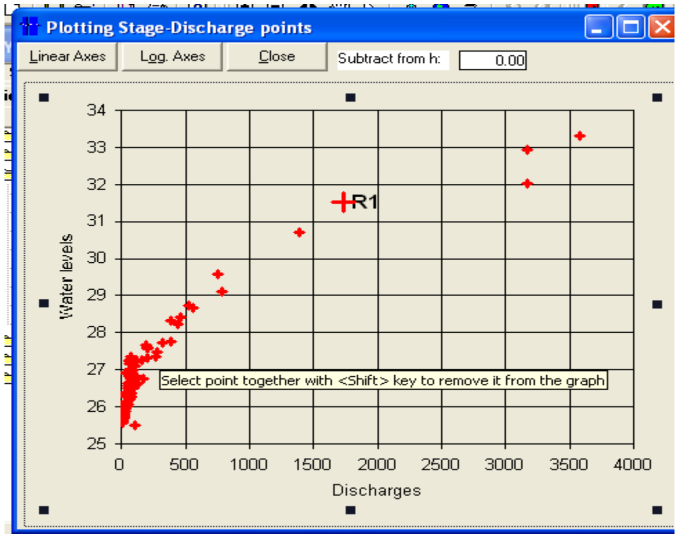


Fig.5

A number of points clubbing together and distinctly falling apart from rest of other data in similar range of water level also drops hints of their affiliation of different period or population. A group of data exhibiting such plots needs to be handled separately for fitting a curve. Similarly,

- Set empty cells (**Fig.6) &** press *Execute* button.

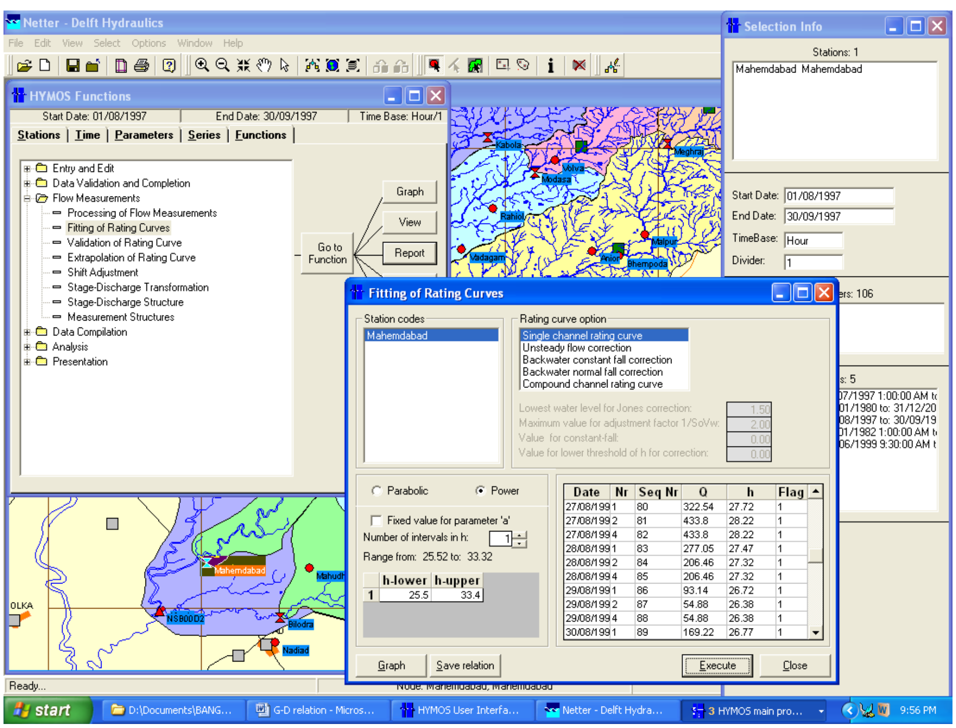


Fig.6

To view results, choose various buttons one by one on HYMOS function box. The options available are:

Graph- Plot of scatter points plus best fit curve (**Fig.7**)

View – obs G-D vis-à-vis computed G-D

Report –Tabular presentation of all relevant information involved in fitting of rating curve exercise (**Table 1**).

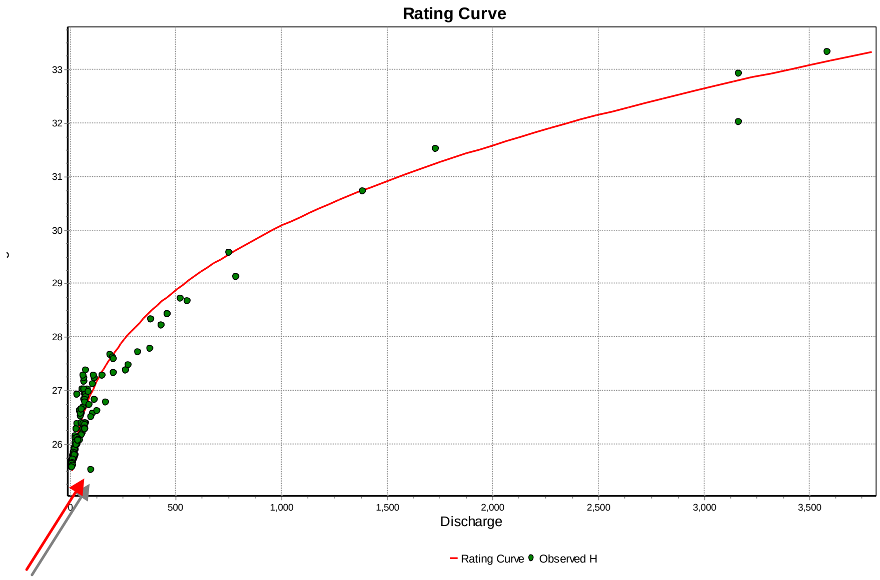


Fig.7

Table 1

Given boundaries for computation of rating curve(s)

interval	lower bound	upper bound	nr. of data
1	25.500	33.400	181

Power type of equation q=c*(h+a)**b is used

Boundaries / coefficients

lower bound	upper bound	a	b	c
25.50	33.40	-24.220	3.021	.4810E+01

Number	W level	Q meas	Q comp	DIFf	Rel.dIFf	t*Se
	M	M3/S	M3/S	M3/S	0/0	0/0
1	31.520	1731.060	1949.365	-218.305	-11.20	33.26
2	32.020	3166.220	2381.234	784.986	32.97	34.95
3	32.920	3166.790	3311.726	-144.936	-4.38	37.75
4	33.320	3583.940	3793.358	-209.418	-5.52	38.91

Overall standard error = 70.139

Statistics per interval

Interval	Lower bound	Upper bound	Nr.of data	Standard error
1	25.500	33.400	181	**70.61**

HYMOS returns a best fit power equation with discharge related to water level in following form

$$Q = c^* (h + a)^b$$

Where, a, b, & c are coefficients whose values are a part of the report. % standard error in the end of the report signifies how wide the dispersal of data around the best fit line is and has no linked with the literal meaning of error. Nevertheless, every effort must be made to bring this figure down by either fitting more than one rating equation with given set of data or splitting the data into two time periods exhibiting distinct changes in either river geometry or bed roughness. A higher st error also results in cases where site is always or partially affected by backwater or unsteady flow condition. A judicious decision, when st error is unreasonably higher, is key to fitting a best fit curve.

A Discussion on Minimising/Bringing Down St Error (here it is 70.61%)

We will take a ***Pause*** here to understand various alternatives and to pick up the most suitable one to fit a curve with lowest possible St Error.

1. A crude way to reduce this figure is to drop/delete all seemingly outliers (plotted point/s away from rest of the points). This approach is strongly discouraged and should never be resorted to until a point or points in question is/are investigated for its doubtfulness, and also additional alternatives discussed below are exhausted.
2. A glance at water level hydrograph at this site for the current period suggests relatively high water level in August. Following month records low water level. A two distinct water regime Means River flowed in two different hydraulics conditions, and therefore, data generated during the period represents two populations. Statistics demands separate analysis of data coming from different populations. Working on this concept, data under this current exercise can be split into two time period – from 01/08/1997 to 30/08/1997 and from 01/09/1997 to 30/09/1997. While splitting the data, user should also guard against the minimum length of data needed for fitting a rating curve. To get more details, user is advised to refer to training module 'How to analyse Stability of SD relations'.
3. An abrupt change in river geometry/cross-section over depth is another factor that influences the slope of plotted points. This simple fact underlines presence of two or even more zones; each having its impact over the plot differently. This guides us to fit a curve in two parts/ranges- lower and higher. Under this criterion, user' s water level selection for analysis of data observed in August would be from 25.5 to 28 for lower part, and 27 to 33.4 for higher part (see **Fig.7**). Having executed, this submits St Error of 21.15 & 29.65 for two parts respectively.
4. An analysis of September data initially yields St Error of 113.22. A scrutiny of plotted points reveals one data (see **Fig.7**) away from rest of data, a suspected outlier (for a water level of 25.52m, observed discharge is 100.3m. Before dropping it from analysis, user must verify it for its correctness from original record. Assuming this data as dubious, if it is dropped from analysis, resultant St Error is 16.33.

Having convinced with the report in the backdrop of above discussion, press *Save Relation* on *Fitting of Rating Curve box (**Fig.6**).* Close the box now. The software keeps this equation in memory for later use.

A finalized curve as before does need validation. ***What is validation?*** User must refer to ***Training Module no.30*** to know more about it. To validate curve, select V*alidation of Rating Curve* option and press *Go to Function* button (**Fig.8**). Facing you is a box of V*alidation of Rating Curve.* Select station and choose appropriate rating curve for validation if there is more than one equation for different periods. Press *Execute* followed by pressing *Report* button on HYMOS Function box.

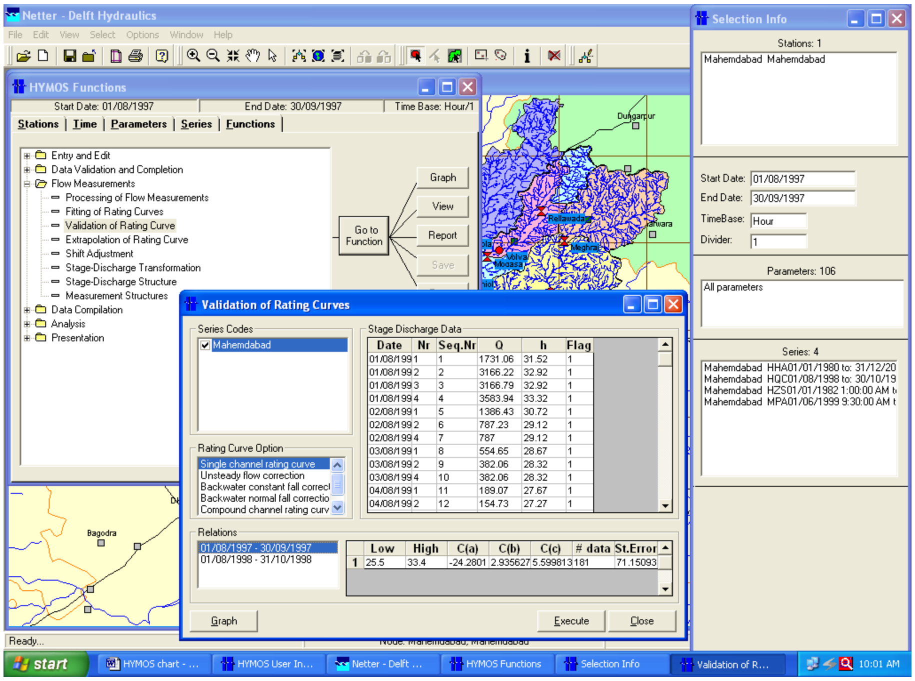


Fig.8

Examine the result, if it is okay (**Table 2**). If not, redefine the curve keeping discussions narrated earlier and by following earlier steps of *Fitting of Rating Curve*.

Table 2

1	25.650	12.870	14.167	-1.297	-9.15	15.85
2	25.620	10.790	13.288	-2.498	-18.80	16.28
4	25.620	10.790	13.288	-2.498	-18.80	16.28
1	25.590	11.400	12.446	-1.046	-8.41	16.73
2	25.560	10.340	11.641	-1.301	-11.18	17.20
4	25.560	10.340	11.641	-1.301	-11.18	17.20

Overall standard error = 70.139

Statistics per interval

Interval	Lower bound	Upper bound	Nr.of data	Standard error
1	25.500	33.400	181	70.61

Results of student T-test on absence of bias

Interval	Degrees of freedom	95% T-value	Actual T-value	Result
1	360	1.967	1.102	Accept

A T-value of this report is a statistical parameter and test toward absence of bias of best fit curve and plotted points. A value within a range of +/- 1.96 is an acceptable range.

A fitted rating curve together with water level data either hourly or three times a day are essential inputs for all subsequent analysis, validation, compilation, presentation and so on. The succeeding sections demonstrate how to generate a no-break runoff series. A generated runoff series help assess the daily/ monthly flow or mean discharge data in addition to annual flow. If previous test is okay, we need to generate a no-break runoff series by transforming stage into runoff series by applying just fitted rating equation.

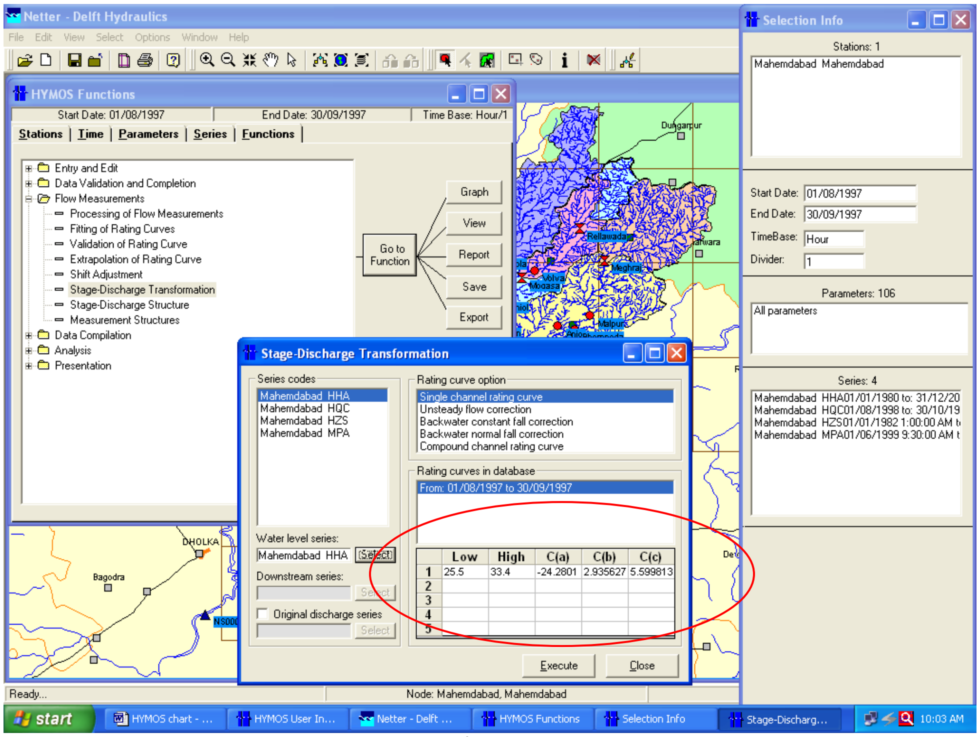


Fig. 8a

Select *Stage-Discharge Transformation* option and click on *Go To Function* button to have another window in the middle (**Fig 8a**). Select *Mahemadabad HHA* series. Right lower box produces all rating curves relevant to this site. Select the right one among them. Press *Execute* command and open the Graph to check if there is plot available. *View* option tabulates all hourly runoff data so transformed.

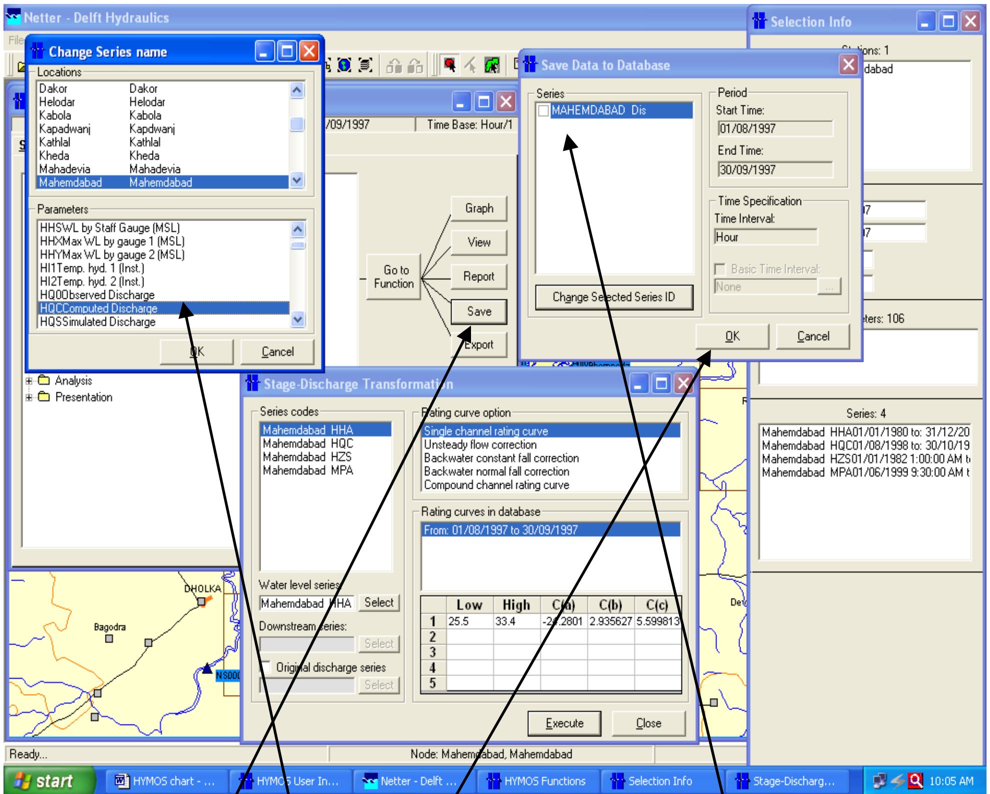
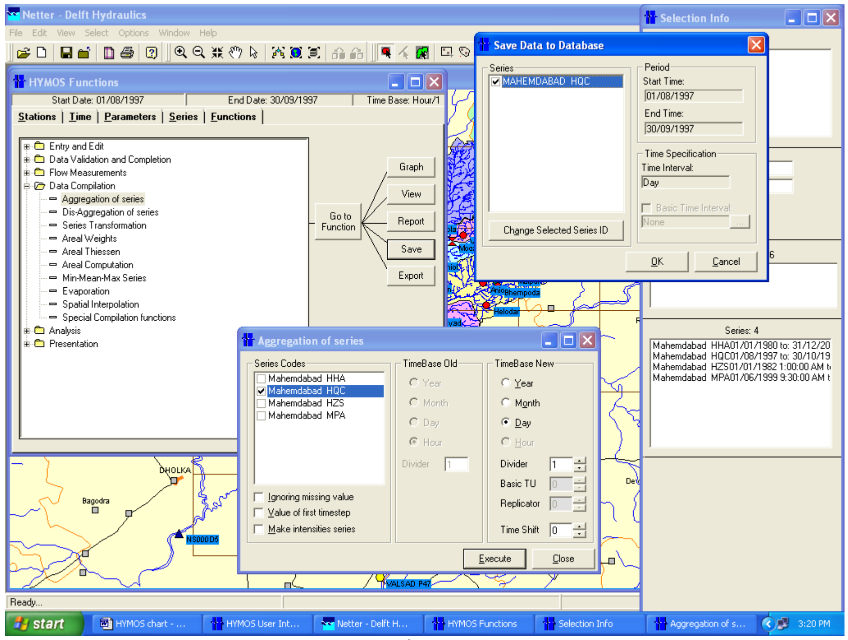


Fig.9

The runoff series so generated requires to be saved permanently. To perform this, press Save button (**Fig. 9**). Now check the station box on and press *Change selected series ID*. Choose *HQC computed discharge* option here and press OK. Last option is to click on OK here to save runoff series. View option contains the hourly runoff series.



(**Fig.10**

As of now, we have had a Mahemadabad HQC runoff series saved on an hourly basis. A number of hydrological analysis calls for daily, monthly or annual discharge data. This task can be accomplished by adopting options shown in (**Fig.10**). Open *Data Compilation* folder and select *Aggregation of series* option. Check the *Mahemadabad HQC* series and press Execute. Don' t forget to check the availability of plot by pressing *Graph* button. Once confirmed, press Save. This pops up another box as shown in upper right corner. Check the box and press OK. Once done, close all open boxes but HYMOS Function & Selection Info. Press *Time* tab on *HYMOS Function* box. Select *time base* as Day in place of Hour (**Fig.11)**.

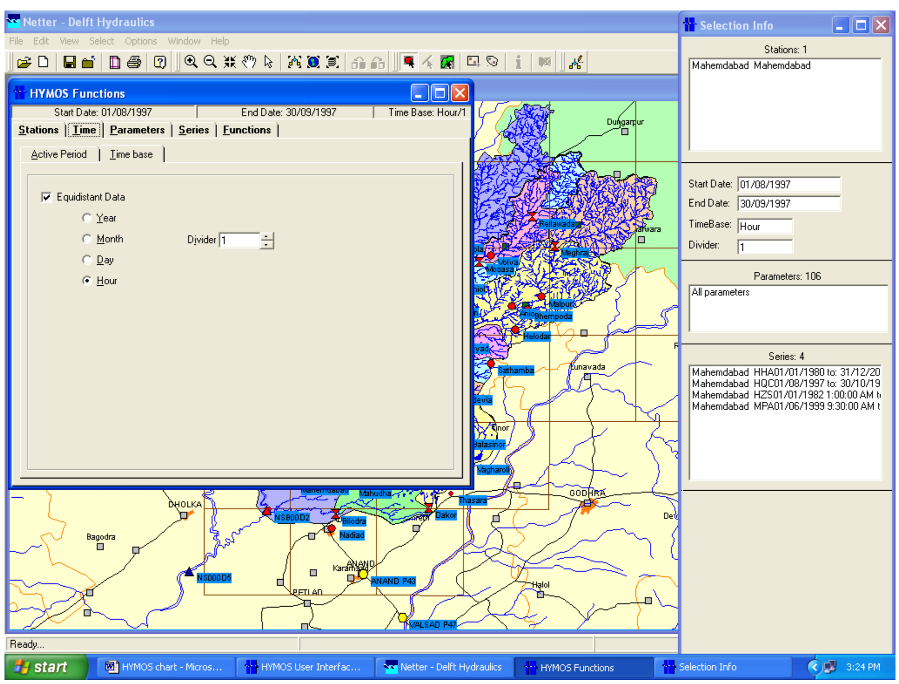


Fig.11

Press *Function* tab again. Open Folder *Presentation* and select *HTML report and* press *Go to Function* button (**Fig.12)**. Select *Mahedabad HQC* series. Then enter template file as: C:\Program Files\HYMOS 4\HTML Report Sample\SW HTML Reports\Report 9; Daily flow\DAILY Flow.htmL

Alternatively, click on browse button adjacent to this cell and select a file by browsing above path and pressing ok. Give *Execute* command.

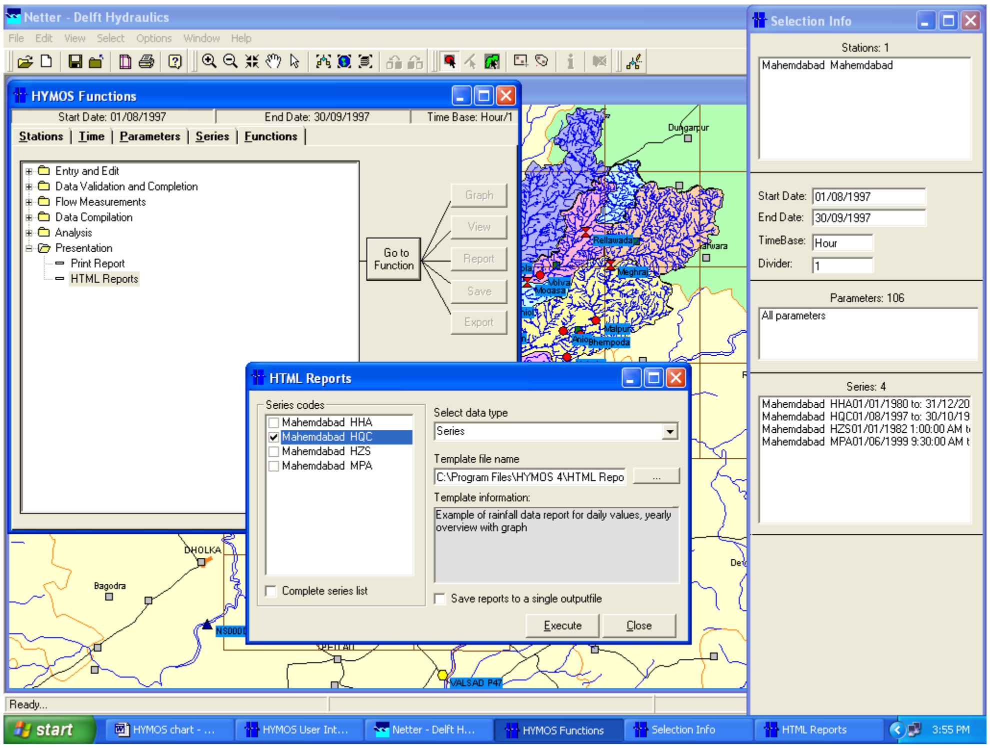


Fig.12

Close all boxes and *EXIT HYMOS.* Follow the path defined as above for template file to find an HTML report of daily flow by Mahemadabad name along with chart. This forms a piece of information to be a part of water year book.

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FITTING OF RATING CURVE – Backwater Effect

Preceding chapter demonstrates how to establish a rating curve under steady flow condition using HYMOS. However, whatsoever measures we employ in siting an ideal river gauge station; still other constraints lead us to select a gauging station which may be prone to frequent hydraulic conditions differing from steady state. Often times, a river reach witnesses backwater effect due to operation of a hydraulic structure or some tributaries joining the main stream in the downstream. On the other hand, in monsoon, unsteady flow is usually observed at several stations in our country. These conditions call for an altogether different approach to fit a relationship involving more variables, for instances, gauge, discharge, water surface slope or rate of rise/fall of water level. Here too, HYMOS offers the user to select appropriate options to fit rating curves. The screenshots, as below, show how to fit a rating curve under backwater effect. To begin with, we shall first use '**Constant Fall Method'** .

Upon clicking on 'HYMOS' shortcut key on the desktop or selecting HYMOS through *programs option,* enter *username & password* to obtain following screenshot (**Fig.1**)

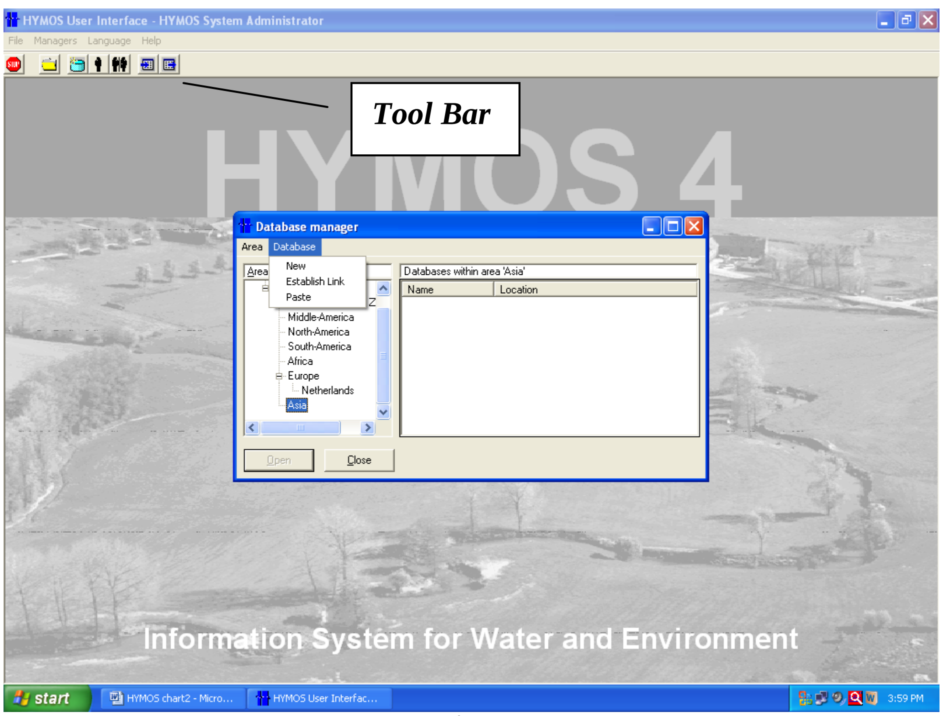

Fig.1

Go to *tool bar* and select *Database manager* to get a dialog box in the middle of screen. Pressing New on the Database list box will pop-up a *location for database window (***Fig.2)**. Select a path *c:\hymosdabase* and click on *create.* By opening up a new box, software asks for the name of folder where the user wishes to store its data. Type 'backwater' or as you wish and press *ok and* again *ok* on second box to close these boxes. These initial steps create *database1* with its location marked against it in the right part of the database manager box (**Fig.3)**. Right clicking on database1 lets the user modify database1 name by any other name.

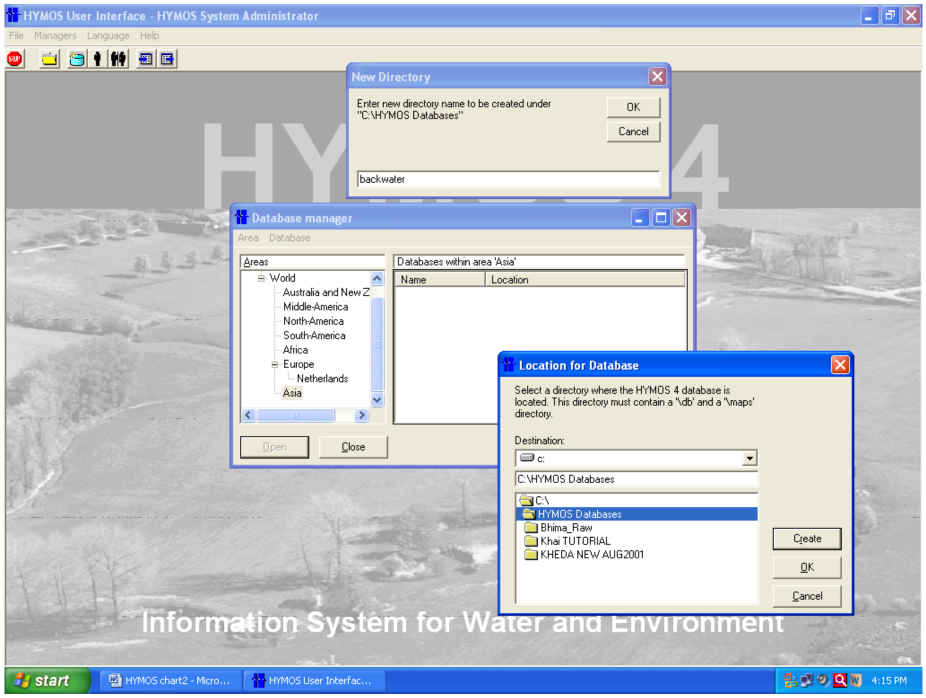

Fig.2

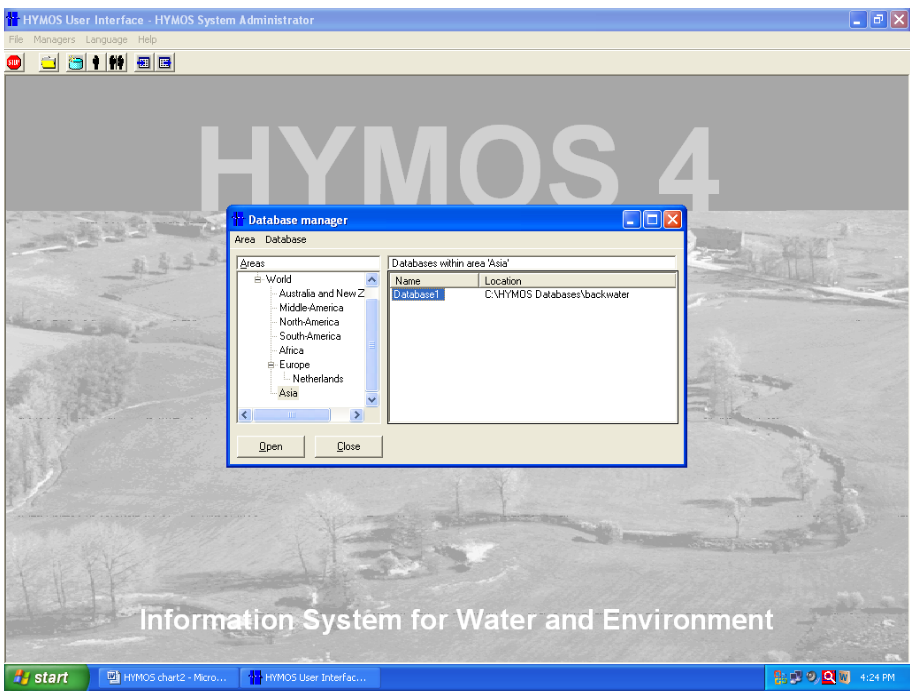

Fig.3

Double clicking the *database1* or alternatively, selecting the *database1* and clicking *open* button at the bottom of box takes the user to netter screen (**Fig.4)**.

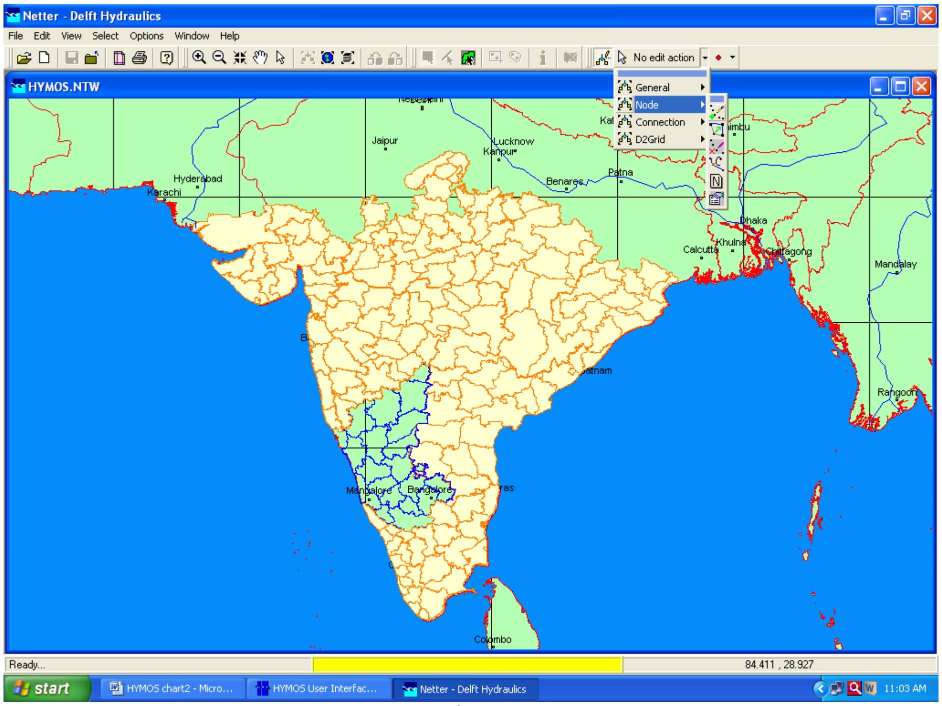

Fig.4

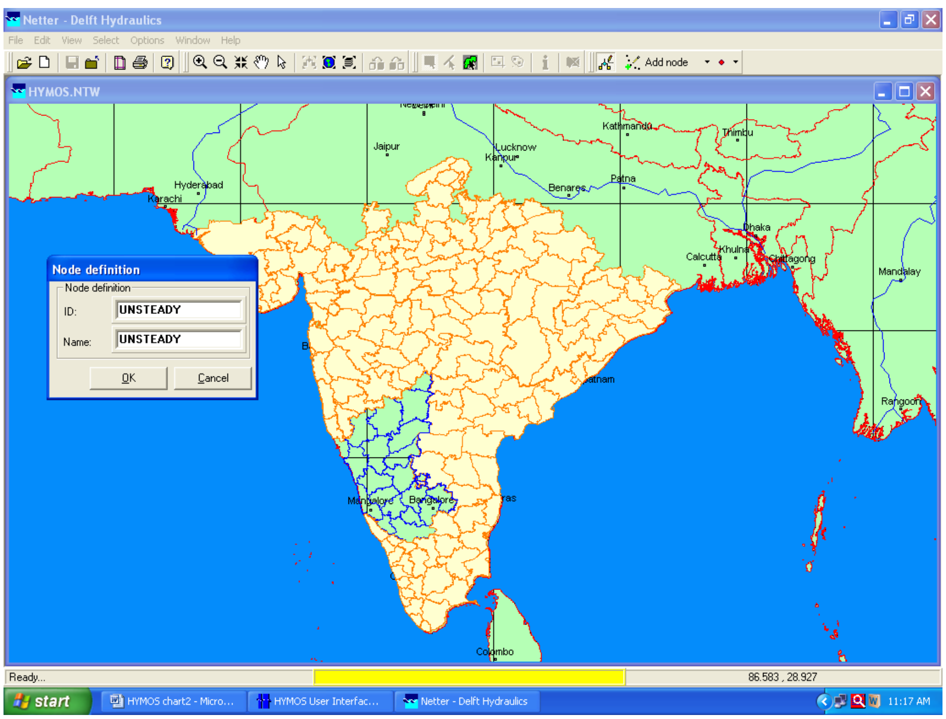

Fig.5

Select last icon on the tool bar 'edit network' followed by activating 'inverse triangle' to get dropdown menu. Go to nodes and select first option in yet another listing located by it. This selection pops up another box asking the user to enter name and ID of a station (**Fig.5)**. Here, we enter station name as UNSTEADY & ID as UNSTEADY. Press OK to get a pen like cursor to locate the station where the data are observed at. Locate the station somewhere and follow the steps thereafter to open HYMOS function box; as executed in one of the previous exercises. *Pl note that these steps are essential only when records of a site are required to be keyed in directly in*

HYMOS. In case, data of a site is imported from SWDES into HYMOS, these steps can be dispensed with. One of the exercises in the booklet explains process of data import from SWDES to HYMOS.

Having finished with a series of steps as listed above, user is set to define, using options available on the HYMOS function box, the salient features of sites by opening up Station Characteristics box (**Fig.6)** and pressing Save button at the bottom of it. The steps are: Function > Entry and Edit > Stations-Stations Characteristics > Go to Function. On this box, enter 01/01/2000 and 01/02/2000 as date established and date closed respectively and catchment area as 100. Go to time tab and modify the start and end date as 01/01/2000 and 01/02/2000. Again press Function tab.

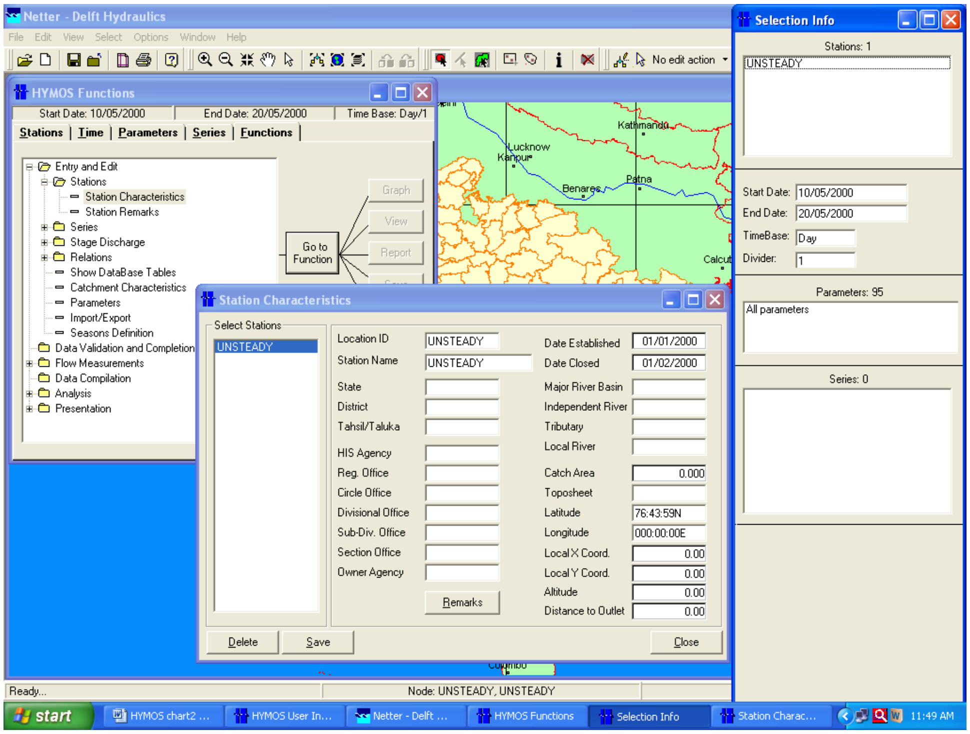

Fig.6

The UNSTEADY (a hypothetical site name) site is often frequented by backwater presence and measurement at this site, during 01/01/2000 to 10/01/2000 yielded following set of data. Skimming through the set of data, i.e., observing the fall between Centre line & D/S sections reveals the varying slope of water surface during the observation period. The observation of fall on daily basis is another variable that influences the scatter of G-D plots and introduces substantially higher standard error of estimate, unless this factor is accounted for fitting a rating curve. In reality, we witness two kinds of sites-firstly which experiences backwater effect constantly like a site located near coastal area (due to tidal presence) and secondly which observes this presence only during particular period or time. The first case is dealt with by **Constant Fall method'** and the latter by '**Normal Fall Method' .** The succeeding steps demonstrate the use of HYMOS software to handle both cases with same set of data. The exercise begins with entry of observed data for UNSTEADY site (**Fig.7**). Steps are: Function-Entry and Edit-Stage Discharge-Stage-Discharge Data-Go to function. Sequence of it presents an Add Stage Discharge Data box where user has to feed the daily data one after another (**Table 1**).

Date & time: 01.01.2000 & 08:00:00
Observation no. 1
Water level: 2.35 Discharge: 15 Fall: 0.15 (2.35 minus 2.2)

This is for the first day observation. Complete it for all ten days in similar way. Pl ensure to press SAVE button each occasion you finish the entry for a day. Once completed, close the Add Stage discharge Data box.

Table 1

Date	*Water Level At Centre line, m*	*Water Level at D/S section ,m*	*Discharge, cumec*	*Fall in m (2-3)*
1	*2*	*3*	*4*	*5*
01/01/2000	2.35	2.2	15	0.15
02/01/2000	2.38	2.33	9	0.05
03/01/2000	2.5	2.3	26.8	0.20
04/01/2000	2.52	2.4	25	0.12
05/01/2000	2.54	2.5	19	0.04
06/01/2000	2.6	2.47	38	0.13
07/01/2000	2.67	2.6	35	0.07
08/01/2000	2.67	2.56	42	0.11
09/01/2000	2.77	2.69	54	0.08
10/01/2000	2.79	2.64	65	0.15

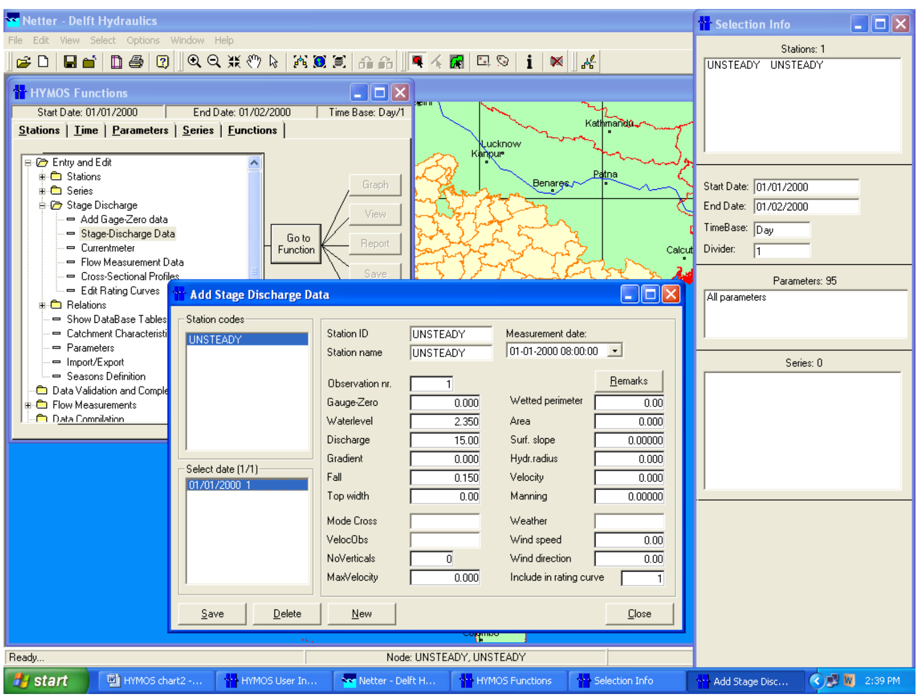

Fig.7

Till now, we have successfully located a 'UNSTEADY' site and completed data entry for a given period of time. To establish a rating curve under backwater condition, fall in addition to corresponding water level and discharge values have also been fed in the system. This point forward, we will seek to fit a curve first by single channel rating curve followed by backwater methods. Fitting of a rating curve by first option (**to know how, visit the steps outlined in one of the earlier exercises**) yields a standard error of estimate of **21.99 %.** The significant scatter of plot is obvious as site has presence of backwater altering the water surface profile constantly. To turn to fit another curve to account for fall, select 'Backwater Constant Fall Correction' and enter *1* against *value for constant fall followed by* pressing 'Execute' button (**Fig.8**).

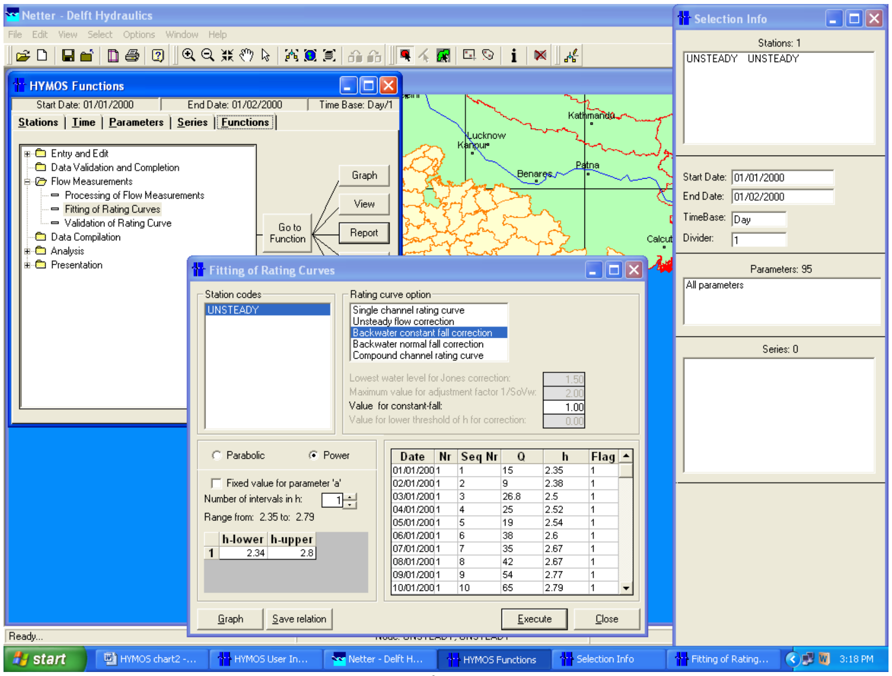

Fig.8

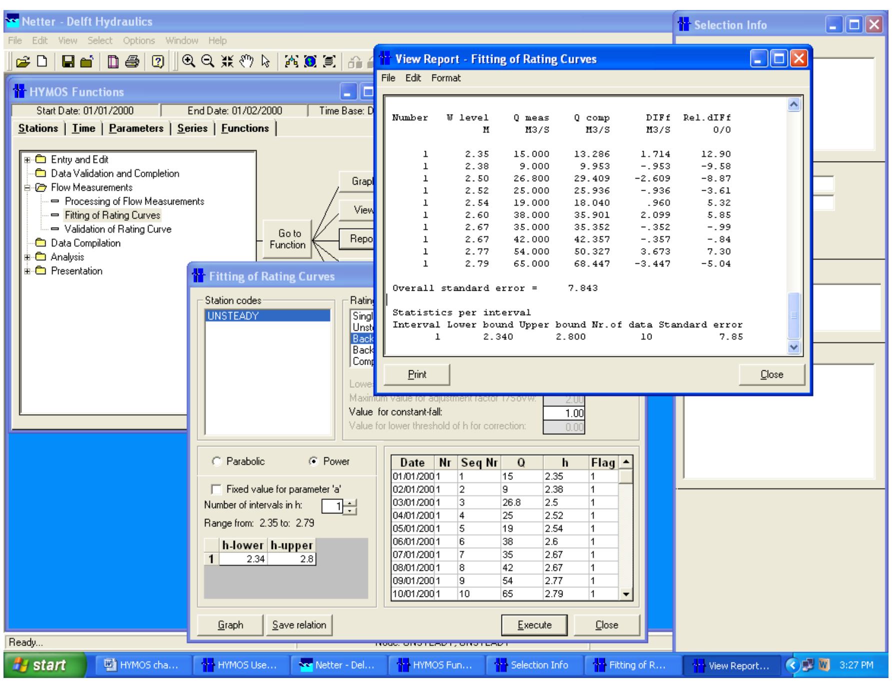

Fig.9

Constant Fall Method is also known as 'Unit Fall Method' when value for constant fall is taken as unit. A perusal of Graph & report file indicates marked reduction in scattering and standard error of estimate. This time, it is only **7.85% (Fig.9).**

At this point, user is strongly advised to

1. familiarize fully with the contents of the report file;

2. take down the couple of equations therein and seek to master the way to calculate computed discharge with known water level and fall values. Report file returns rating equations in following form;

   Power type of equation **q=c*(h+a)**b** is used

   Boundaries / coefficients

lower bound	upper bound	**a**	**b**	**c**
2.34	2.80	-1.840	2.635	.1674E+03

   Backwater correction is of the form: **Q=Qn*(F/Fn)**p**
   with: **Fn** = 1.000 & **p** = .400

3. User may verify the result by calculating Qcomp for a Water level value of 2.35 and corresponding fall of 0.15 (the first value of the set)

W level	**Q meas**	**Q comp**	**DIFf**	**Rel.dIFf**
	M3/S	*M3/S*	*M3/S*	*0/0*
2.35	15.000	13.286	1.714	12.90

4. replace the value for constant fall with any number and notice the change and seek to understand it. As a rule of thumb, most frequently observed fall value or one is selected for fitting a curve;

5. User themselves may analyze the impact of not fitting a curve without accounting for fall for a site frequented with backwater. User may compare here the two standard error of estimate values arrived at by two approaches; one of which duly considers fall as another variables.

Preceding paragraphs deal with plotting a rating curve for a site perpetually affected with backwater. Still, there are a few examples of discharge observation sites where influence of backwater is restricted to either the water level in a tributary joining the main river somewhere downstream or the operation of gates of a hydraulic structure down the reach. In other words, observed data of such locations is an assemblage of data representing two populations- one which is free from backwater effect while others affected with it. If a site happens to be located in a section such as this, fitting of rating curve is attempted by 'Normal Fall Method'. This task is accomplished by choosing 'Backwater Normal Fall Correction' option on Fitting of Rating Curve box keeping the same set of data (**Fig.10)**. The only change needs to be done is to flag backwater free data by '2' and affected observations by '1'. The value of fall associated with each observation help user flag data appropriately as lower fall values signify the presence of backwater. Value for lower threshold of h for correction is taken as 2.35. **If user is convinced that presence of backwater effect is visible only above a particular water level, the same water level is selected as lower threshold of h for correction.** This also means that all observations below this level are backwater free data independent of the gate operation or discharge in the tributary downstream. Having done this, press 'Execute' button and peruse Report file.

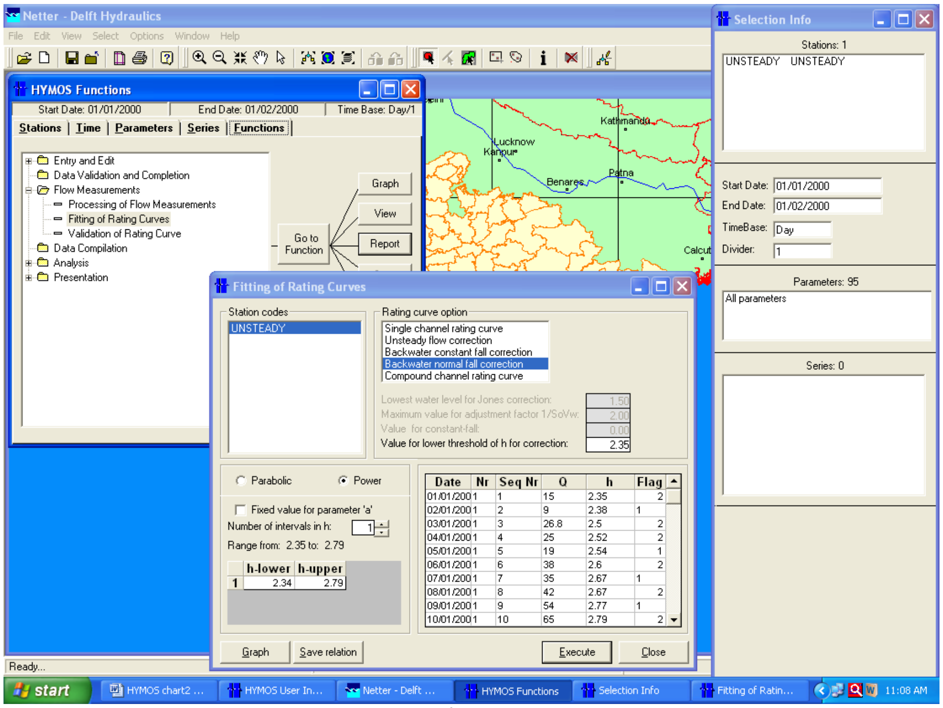

Fig.10

The extract of report file produced as under defines 3-set of equations. These equations help a data analyst obtain computed discharge data for given water level and corresponding fall values.

Power type of equation q=c*(h+a)**b is used
Boundaries / coefficients

lower bound	upper bound	a	b	c
2.34	2.79	1.242	12.571	.1578E-05

Backwater correction is of the form: Q=Qn*(F/Fn)**p
with: Fn=a+b*H+c*H**2 : a= 11.4985
b= -8.5415
c= 1.6004
p= .4000

Applicable for levels above: 2.350

User may flag observation of day 2 as '2' and notice changes in result. To verify the result obtained, we may use these equations to calculate Qcomp value for Water level = 2.38 and Fall = 0.05

Number	W level	Q meas	Q comp	DIFf	Rel.dIFf
	M	M3/S	M3/S	M3/S	0/0
1	2.35	15.000	15.125	-.125	-.83
1	2.38	9.000	9.036	-.036	-.40

To highlight the capabilities of HYMOS, a small set of sample data was chosen. So, certain anomalies in the behaviour of equations obtained as above (+ve a coefficient) are not ruled out. Once satisfied with the equations and result of the fitting, press 'Save Relation' to let software save the relationship for future references.

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FITTING OF RATING EQUATION – Unsteady Flow Conditions

Preceding chapters demonstrate how to establish a rating curve under steady & backwater flow condition and reach where occurrence of these kinds of flow is likely. In a slightly different condition and especially in monsoon, unsteady flow is usually observed at several stations in our country. Unsteady flow is associated with rapid rise and fall of water level during flood. Observed gauge and discharge data of this period, if plotted on abscissa and Y-axis forms a closed loop in the middle of plot; often termed as 'Hysteresis'. Fitting a relationship for unsteady conditions involves accounting for rate of rise and fall of water level in addition to corresponding observed gauge & discharge data.

Upon clicking on 'HYMOS' on the desktop or selecting HYMOS through *programs option,* enter right *username & password* to obtain following screenshot (**Fig.1)**. Like previous exercise, click open the 'Database manager'. Go to 'Database' and click on 'Establish link'.

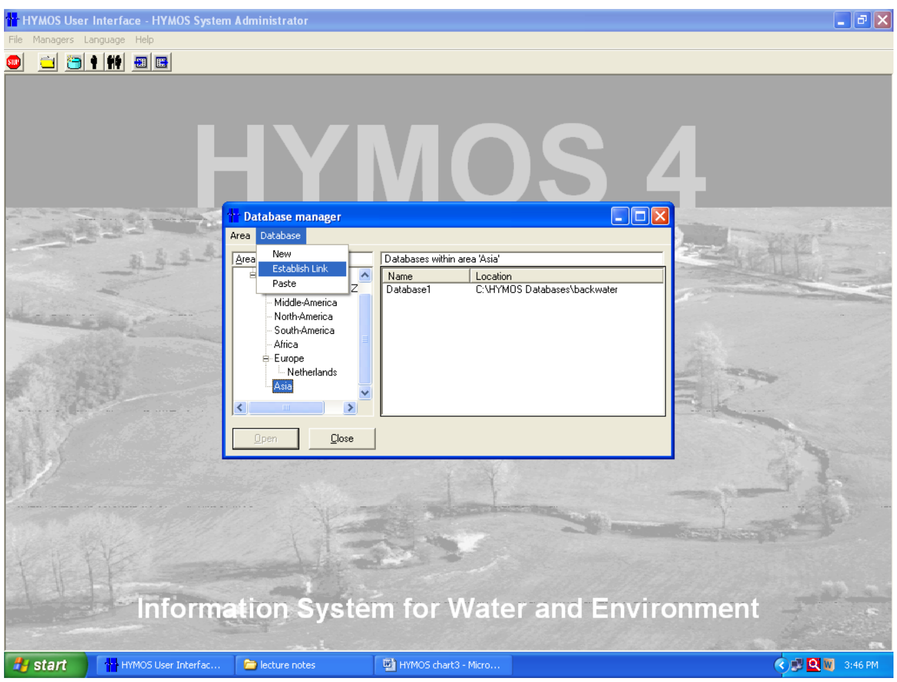

Fig.1

This pops up a window (**Fig.2)** to locate existing HYMOS database box, where user has to locate the database file by this path C:\HYMOS Databases\KHEDA NEW AUG2001 and press 'Ok'. This leads to the appearance of Database2 file on Database manager box.

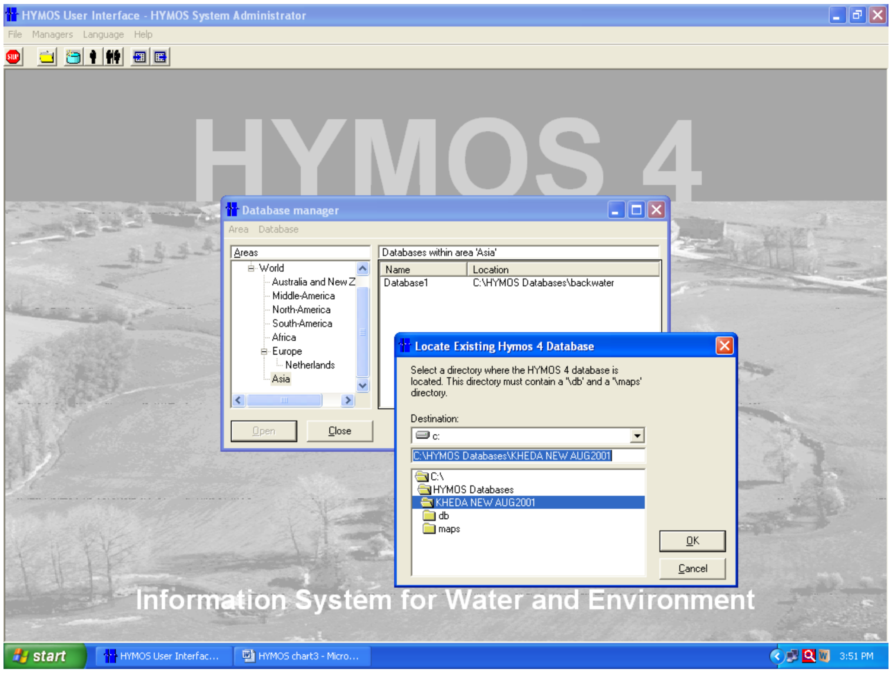

Fig.2

Select the Database2 file name double clicked it to get 'netter screen'. Netter Screen displays the host of hydro-meteorological stations in KHEDA basin in Gujarat state (**Fig.3)**. One station, i.e., Mahemadabad located in the southern part of the basin, is known to have been affected by unsteady flow condition in past and is selected for current example. Clicking on 'HYMOS' lets the user work with Hymos Function box.

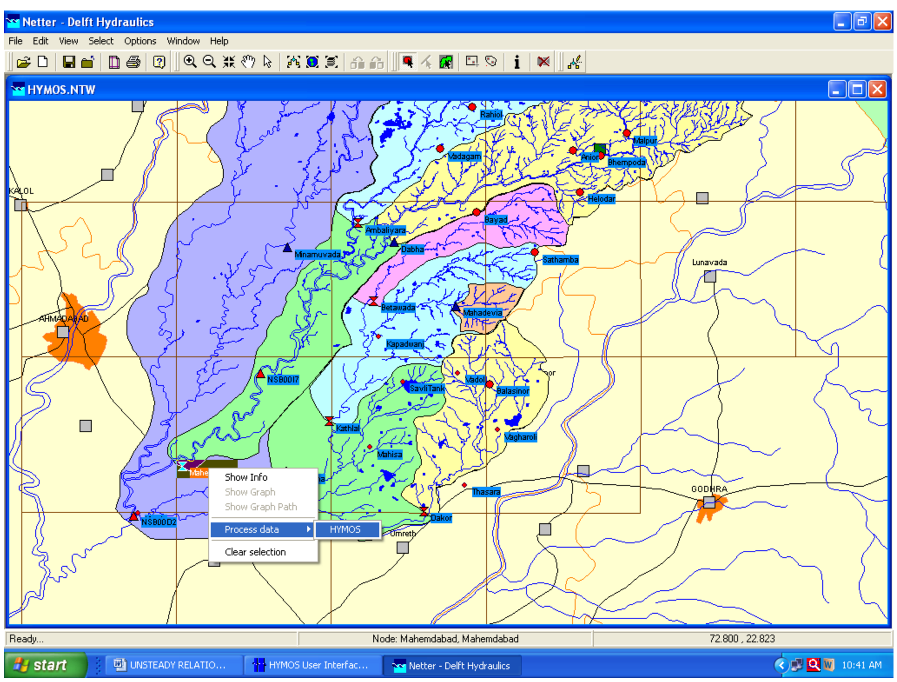

Fig.3

Press the Time tab on Hymos Function box to enter start and end date as 20/07/1997 & 24/08/1997 respectively (**Fig.4)**. Next, the time base will be marked as 'Hour'. Function tab is clicked this after.

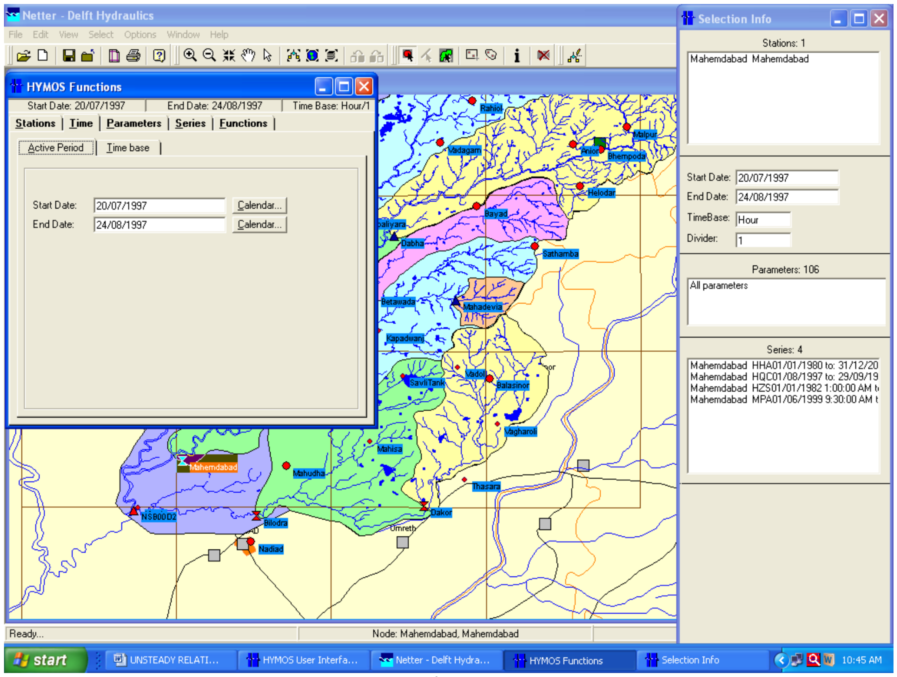

Fig.4

Now, open the Data Validation and Compilation folder and select Time Series Graphs followed by pressing 'Go to Function' button (**Fig.5)**. Upon doing so, user will have time series Graph box, as below, containing a family of tools. For current study, check the Mahemadabad HHA tiny box. From the second column, select the derivative option followed by pressing Execute button. This command of HYMOS results a graph and a series showing change in water level on hourly basis. This implies that the resulting series bears a unit of 'm/hr' with + and – sign indicating rise and fall in level. To view the graph and series so generated, Graph and View button on Hymos Function box are pressed in turn.

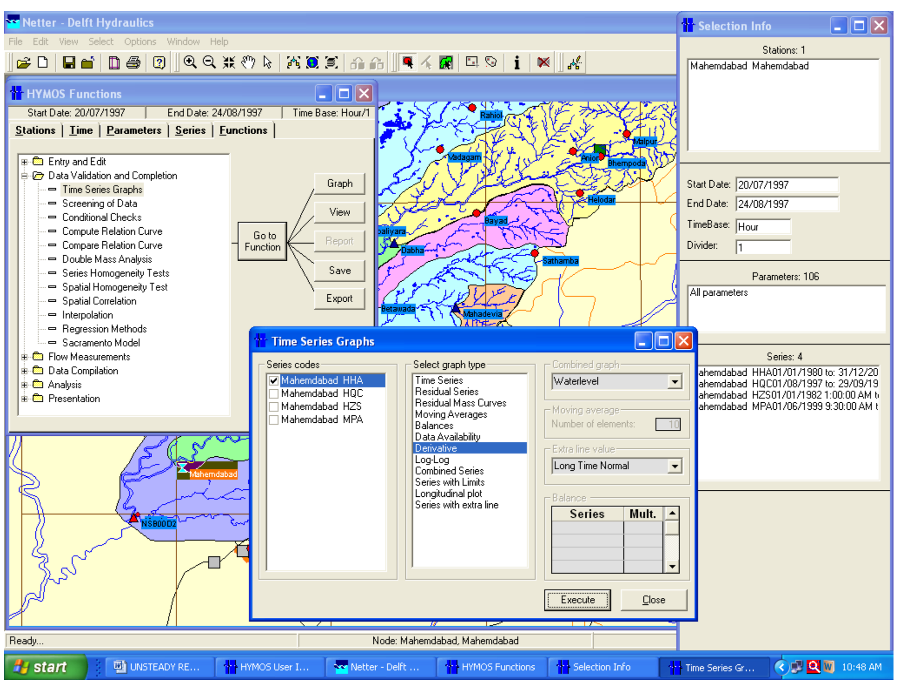

Fig.5

The graph output (**Fig.6)** suggests two spells of highly unsteady state which might have impacted the observed discharge (it is explored a bit later). Timing of occurrence of sudden rise and fall of water level during the passage of flood wave also help the user narrow down the start and end date by using Time tab. A cursory look at the graph hints this period from 27/07/1997 to 04/08/1997. Once this is over, the series so obtained in 'm/hr' needs to be saved in for getting another series in 'm/day' unit. This step is entirely a software need for fitting a rating curve with unsteady correction and one of the series transformation tool available on Function box assist user to develop it (succeeding paras cover this aspect).

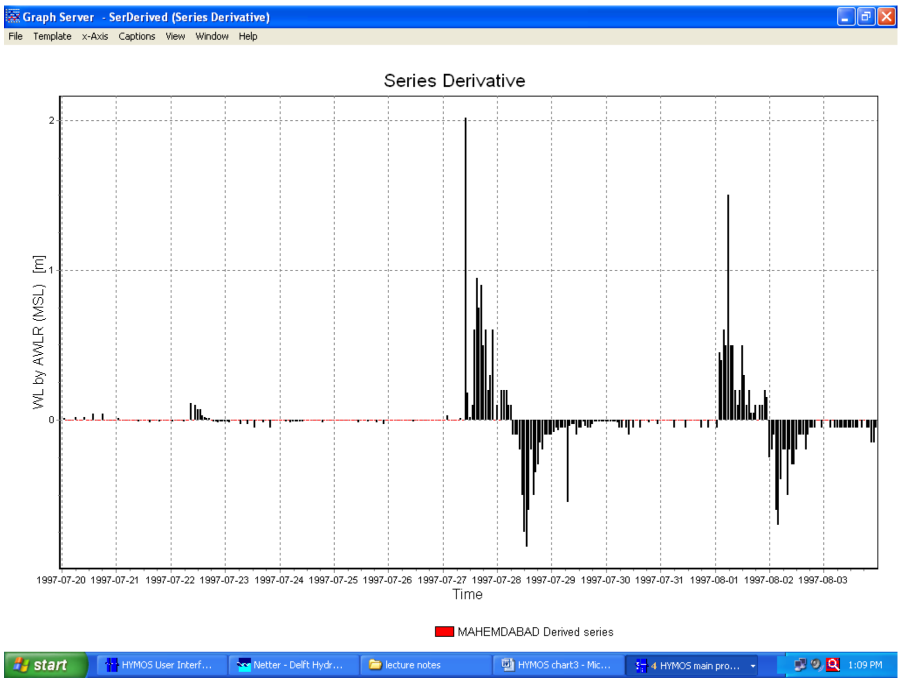

Fig.6

The screenshot in **Fig.7** leads to saving the derivative series'. The steps are: 'Save' on Function box-Change selected series ID button on Save Data to Database box-choose Mahemadabad station and HA1 Temp hyd on Change Series name box-Ok on this box- tick the check box on Save Data box-Ok. Having done this, a series Mahemadabad HA1 will appear on Time Series Graphs. At this stage, user can close this box. Mahemadabad HA1 series is in 'm/hr' unit and is to be converted into m/day unit by opening up the Data Compilation folder on HYMOS Function box under Function tad and selecting series transformation followed by go to function.

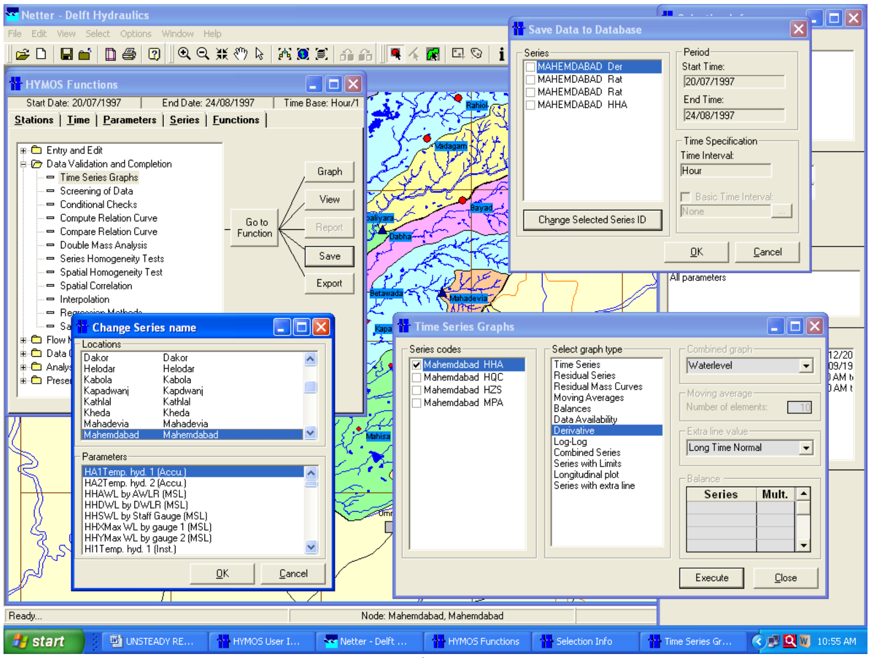

Fig.7

User gets a screen as in **Fig.8**. Select Mahemadabad HA1 series, this also as resulting series, first algebraic equation from upper right listing and click >> tab below. This fills in the blank cell with current series. Cell next to it is a coefficient to be multiplied with each value of parent series. A value of '24' fed here converts 'm/hr' into 'm/day'. Press 'Execute' to let the software generate desired series.

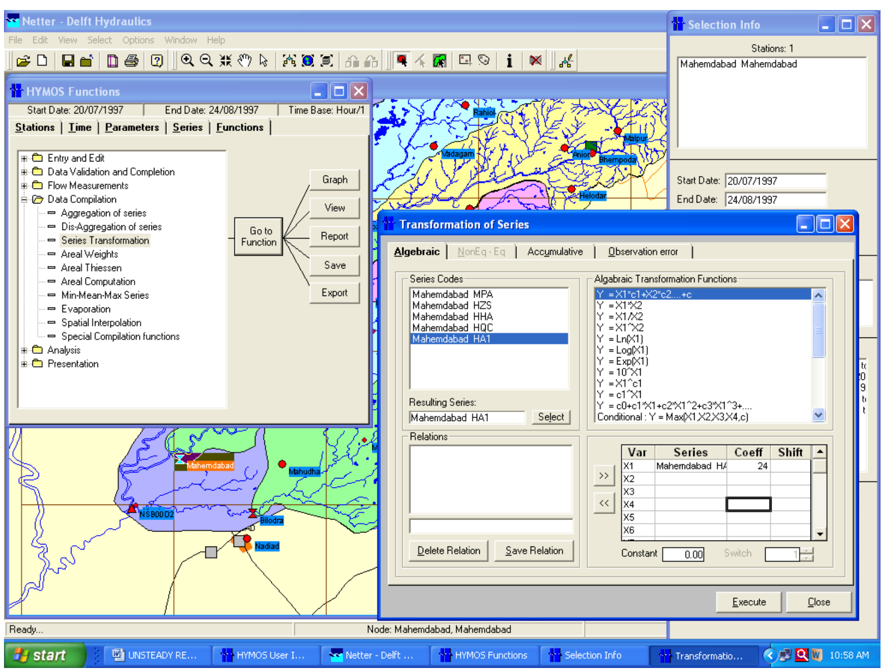

Fig.8

By following steps as highlighted in **Fig.7**, a series now with 'm/day' can be saved. This series can be seen or edited by selecting appropriate commands as highlighted hereunder: Entry and Edit-Series-Edit Data-Go to Function-selecting Mahemadabad HA1 and by opting check box to show graph (**Fig.9**). An extract of this series when unsteady flow is dominating is produced in **Table1**.

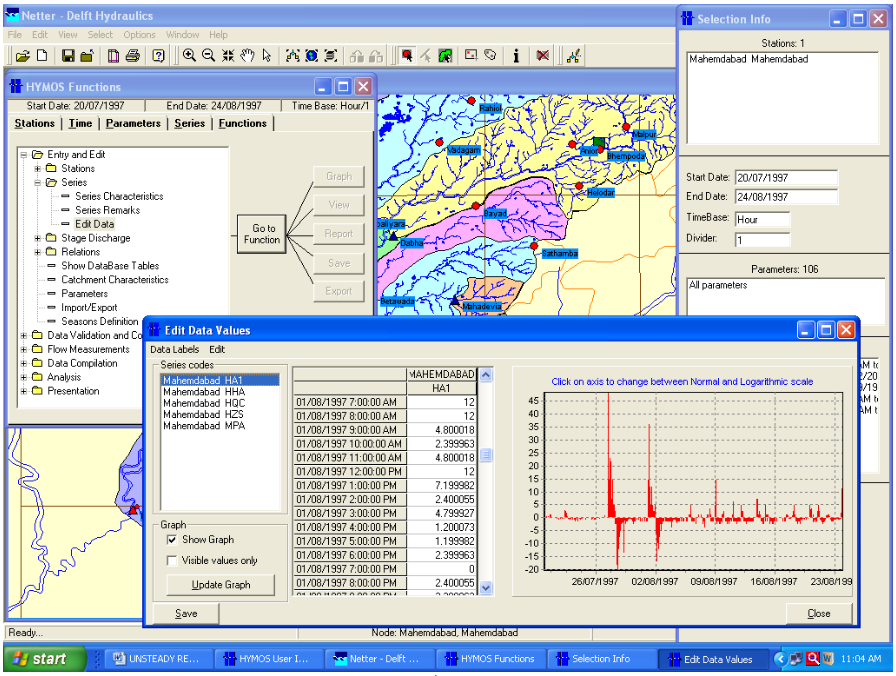

Fig.9

Table 1

MAHEMDABAD					
Date & Time	**WL**	**Dh/dt In m/day**	**Date & Time**	**WL**	**Dh/dt in m/day**
27/07/1997 8:00	25.9	0.24	**28/07/1997 8:00**	**34.32**	**-2.40**
27/07/1997 11:00	28.1	4.32	**28/07/1997 11:00**	**33.52**	**-12.00**
27/07/1997 14:00	28.82	14.40	28/07/1997 14:00	31.32	-14.40
27/07/1997 17:00	31.42	21.60	28/07/1997 17:00	30.27	-8.40
29/07/1997 8:00	28.28	-0.96	30/07/1997 8:00	27.62	0.00
29/07/1997 11:00	28.12	-2.40	30/07/1997 11:00	27.47	0.00
29/07/1997 14:00	28.01	-0.24	30/07/1997 14:00	27.42	0.00
29/07/1997 17:00	27.87	-1.20	30/07/1997 17:00	27.37	0.00
31/07/1997 8:00	27.27	0.00	01/08/1997 8:00	31.52	12.00
31/07/1997 11:00	27.22	-1.20	**01/08/1997 11:00**	**32.02**	**4.80**
31/07/1997 14:00	27.22	0.00	**01/08/1997 14:00**	**32.92**	**2.40**
31/07/1997 17:00	27.22	0.00	**01/08/1997 17:00**	**33.22**	**1.20**
02/08/1997 8:00	30.72	-12.00	03/08/1997 8:00	28.67	-1.20
02/08/1997 11:00	29.92	-7.20	03/08/1997 11:00	28.52	-1.20
02/08/1997 14:00	29.52	-2.40	03/08/1997 14:00	28.37	-1.20
02/08/1997 17:00	29.12	-2.40	03/08/1997 17:00	28.27	-1.20

Table 1 lists the date, time and corresponding water level and dh/dt in ‘m/day’. dh/dt here stands for change in water level versus change in time. dh/dt data corresponding to water level exceeding 32m, picked up from **Table 1**, and are entered in Add Stage Discharge Data box (**Fig.10)**. This box appears after selecting Stage discharge Data function under Stage Discharge subfolder of Entry and Edit main folder. User has to first mark the right date and time on lower left box. The software retrieves all data of this day but gradient data. User has to enter correct dh/dt one by one in gradient cell followed by pressing ‘Save’ on each occasion. With this, the user has updated the stage discharge data field with gradient information, indicative of unsteady flow characteristic at site.

Note- SWDES software offers the data handlers to enter dh/dt data facility. A properly filled in SWDES data sheet thus obviates above steps and user can directly jump to ‘Fitting of Rating curve’ function. This saves considerable time.

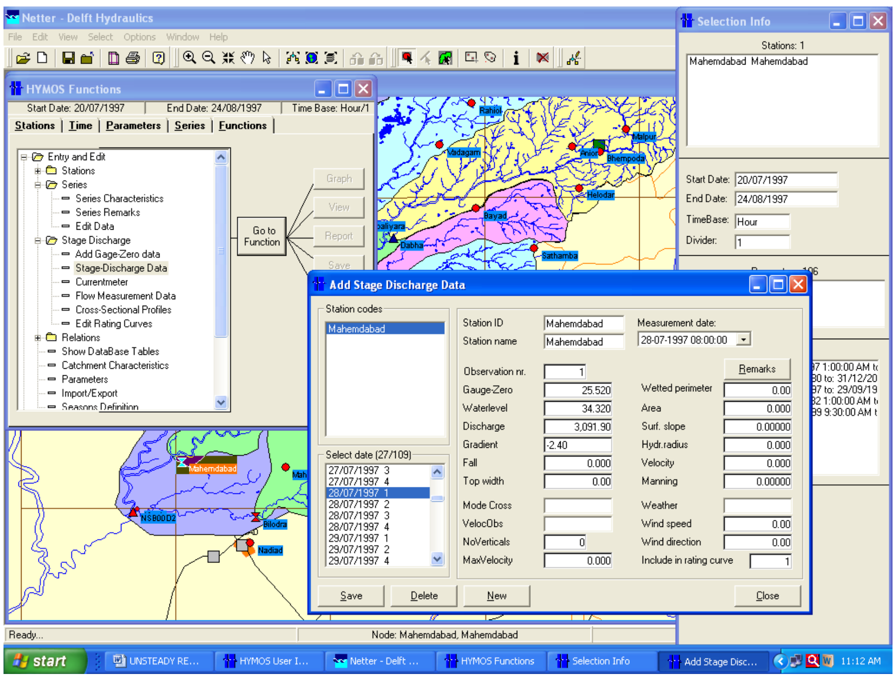

Fig.10

This point forward and assuming comfortable familiarity with the software by the user, steps to obtain screenshot (**Fig.11)** are intentionally skipped here. User is rather advised here to concentrate on the scatter of data. Point R3 is far away from other set of data and therefore is discarded from the current analysis by holding down the ‘Shift’ and clicking over the R3. Still, the user is strongly suggested to skim through the original manuscript of R3 data (RD-1 form) before eventually erasing it from the memory. Now, the user themselves, by selecting point above 32m on Plotting window; looking into lower right data set on Fitting of Rating Curve’ box and also referring to **Table 1,** can notice a loop or Hysteresis. Hysteresis points are encircled in **Fig.12.**

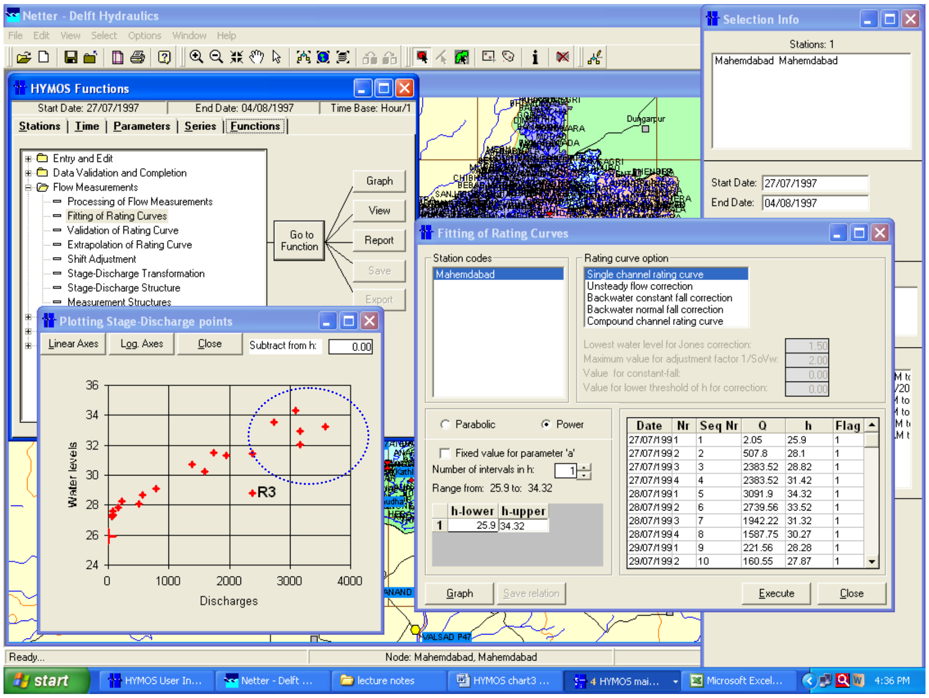

Fig.11

This justifies the entry of gradient values for water level exceeding 32m only. Before, attempting to unsteady flow correction, a curve with current option is fitted which results in a St Error of Estimate as 47.72 and a curve as below. Pl notice the band here as software apllies no correction to account for dh/dt under this option.

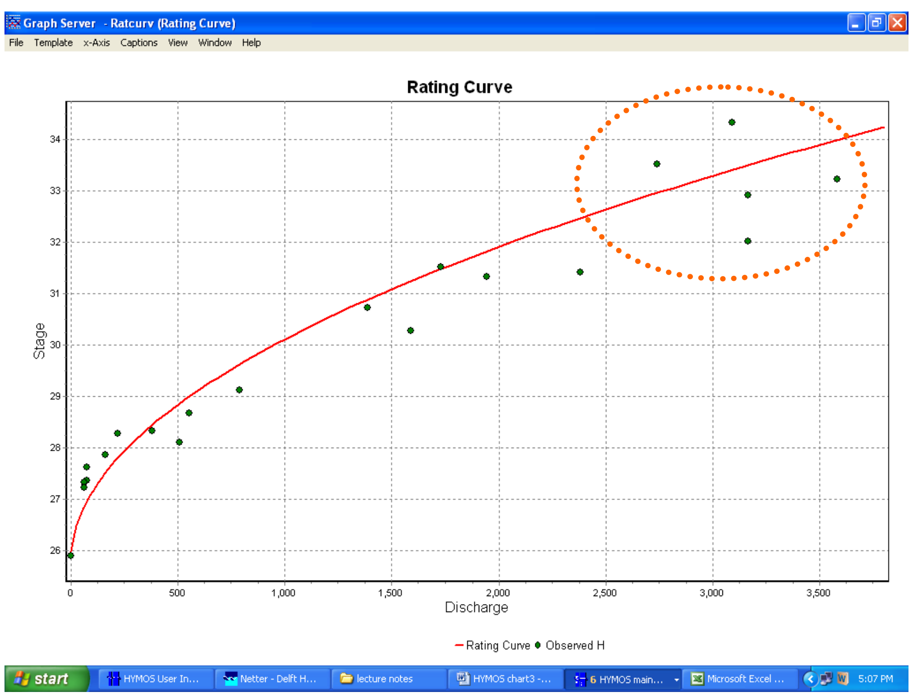

Fig.12

Now, a selection is made for unsteady flow correction with 32 as lowest water level for Jones correction (**Fig.13)**. Pressing ‘Execute’ , this function not only returns a much smoothened plot of data around the loop (**Fig.14)** but also brings down the error to 43.44. It is left to the user to imagine the cause of higher range of st error and measures to exercise control over it.

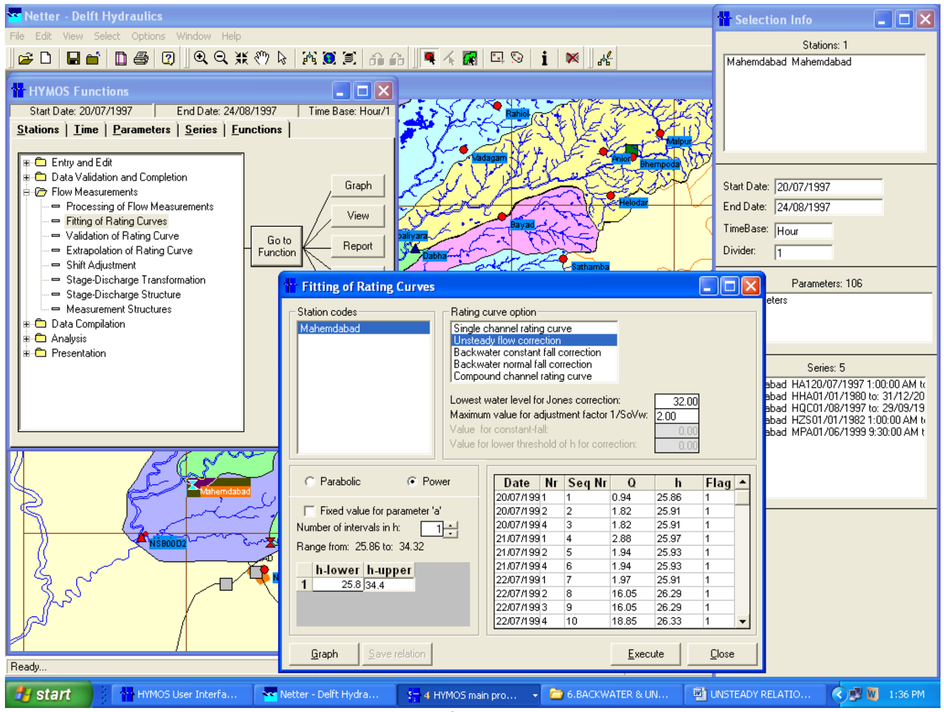

Fig.13

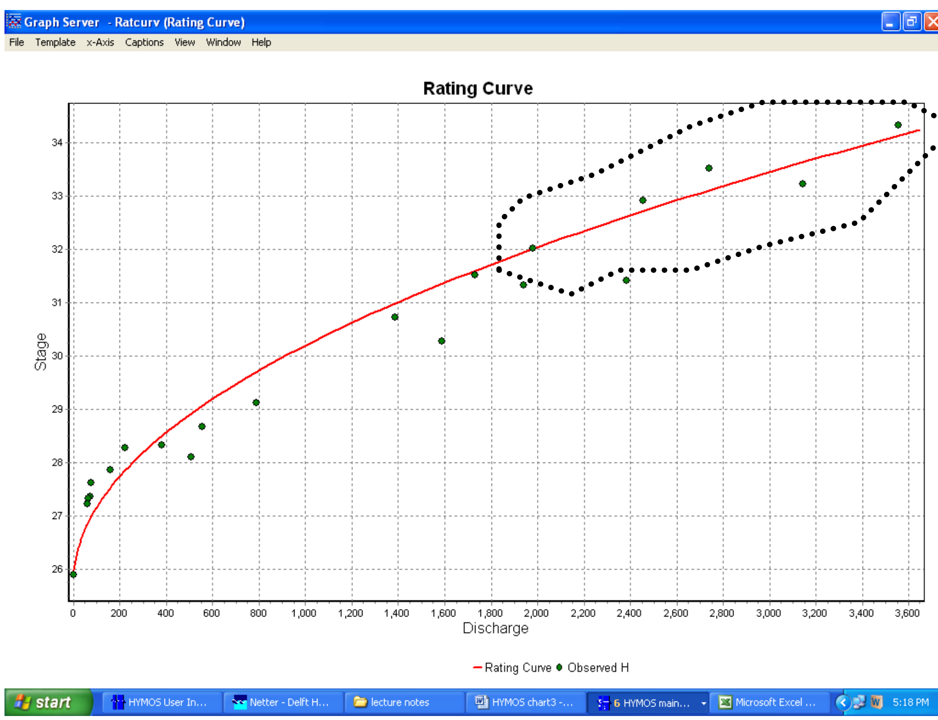

Fig.14

An extract of report files placed next states the similar outcome. Data, which were covered under Jones correction, are painted yellow. Though this exercise considers only one range of rating curve, user may use their discretion based on river geometry/bed profile and fit rating curve accordingly.

(A) – by Single Channel Rating method

Power type of equation q=c*(h+a)**b is used

Boundaries / coefficients

lower bound	upper bound	a	b	c
25.90	34.32	-25.770	1.998	.5325E+02

Number	W level	Q meas	Q comp	DIFf	Rel.dIFf	t*Se
	M	M3/S	M3/S	0/0	0/0	
1	25.900	2.050	.902	1.148	127.27	78.52
2	28.100	507.800	288.601	219.199	75.95	22.28
4	31.420	2383.520	1694.242	689.278	40.68	25.40
1	34.320	3091.900	3876.816	-784.916	-20.25	31.93
2	33.520	2739.560	3185.857	-446.297	-14.01	30.22
3	31.320	1942.220	1634.854	307.366	18.80	25.17
4	30.270	1587.750	1075.195	512.555	47.67	22.86
2	27.220	60.890	111.864	-50.974	-45.57	27.95
1	31.520	1731.060	1754.689	-23.629	-1.35	25.64
2	32.020	3166.220	2072.799	1093.421	52.75	26.81
3	32.920	3166.790	2712.064	454.726	16.77	28.88
4	33.220	3583.940	2944.201	639.739	21.73	29.56
1	30.720	1386.430	1300.755	85.675	6.59	23.81
2	29.120	787.230	596.194	191.036	32.04	21.22
4	29.120	787.000	596.194	190.806	32.00	21.22
1	28.670	554.650	446.898	107.752	24.11	21.23
4	28.320	382.060	345.617	36.443	10.54	21.70

Overall standard error = 46.706

Statistics per interval

Interval	Lower bound	Upper bound	Nr.of data	Standard error
1	25.900	34.320	22	47.72

(B) Post Unsteady Correction

Boundaries / coefficients

lower bound	upper bound	a	b	c	
25.90	34.32	-25.760	2.000	.5080E+02	- **eq -1**

Coefficients for the equation 1/S*Vw=f(h)

lower bound	upper bound	a3	b3	c3
32.00	34.32	-31.097	1.987	-.031

1/SVw =a3+b3h+c3h^2 - **eq -2**

Where, a3,b3 and c3 are coefficient given above.

Number	W level	Q meas	Q comp	DIFf	Rel.dIFf
	M	M3/S	M3/S	M3/S	0/0
1	25.90	2.050	.995	1.055	106.05
2	28.10	507.800	278.042	229.758	82.63
4	31.42	2383.520	1626.286	757.234	46.56
1	34.32	3091.900	3232.951	-141.051	-4.36
2	33.52	2739.560	3056.632	-317.072	-10.37
3	31.32	1942.220	1569.337	372.883	23.76
4	30.27	1587.750	1032.639	555.111	53.76
2	27.22	60.890	108.252	-47.362	-43.75
1	31.52	1731.060	1684.251	46.809	2.78
2	32.02	3166.220	3180.776	-14.556	-.46
3	32.92	3166.790	3357.247	-190.457	-5.67
4	33.22	3583.940	3220.424	363.516	11.29
1	30.72	1386.430	1248.951	137.479	11.01
2	29.12	787.230	573.209	214.021	37.34
4	29.12	787.000	573.209	213.791	37.30
1	28.67	554.650	429.970	124.680	29.00
4	28.32	382.060	332.773	49.287	14.81

Overall standard error = 43.496

Statistics per interval

Interval	Lower bound	Upper bound	Nr.of data	Standard error
1	25.900	34.320	22	44.34

HYMOS, based on the user input, fits a relation betwwen water level and 1/cS0 or 1/SVw (same thing) factor of second order polynomial type **(eq-2)** and apllies it in conjunction with rating equation to account for unsteady effect. A plot between water level and 1/cS0 (using Excel sheet) exhibits a pattern as in **Fig.15**.

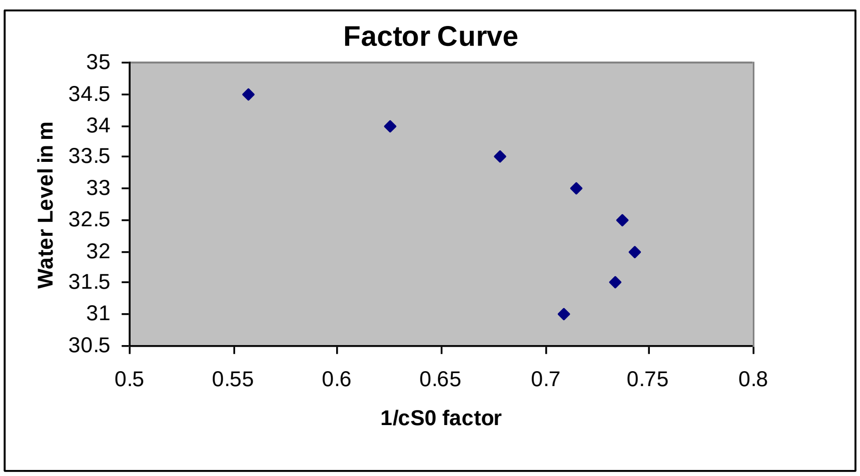

Fig.15

In reality, loops of curve are rarely as clearcut as shown here and produce varied shapes but showing a pattern as above.

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EXTRAPOLATION OF RATING CURVE

Having finalized rating curve under different hydraulic conditions, another significant step prior to stage discharge transformation is to seek interpolation or extrapolation of rating curve in order to get discharge data corresponding to stages beyond rating curve limits on either side. In the current exercise, following step by step methods help user achieve this objective. For this exercise, we export data from SWDES software to HYMOS followed by its import in HYMOS environment for detailed study. For extrapolation study, we choose hydrological data of MANCHERIAL site for a period between **01/01/1998 and 31/12/1998**. The entire steps involved in import from SWDES and its retrieval in HYMOS are deliberately skipped here as the same have been explained in one of initial chapters.

On 'Database Manager' box select Mancherial database to open up netter screen. This point beyond, user is expected to finalise the rating curve under steady condition for this site (**Fig.1**) and save the relation so derived.

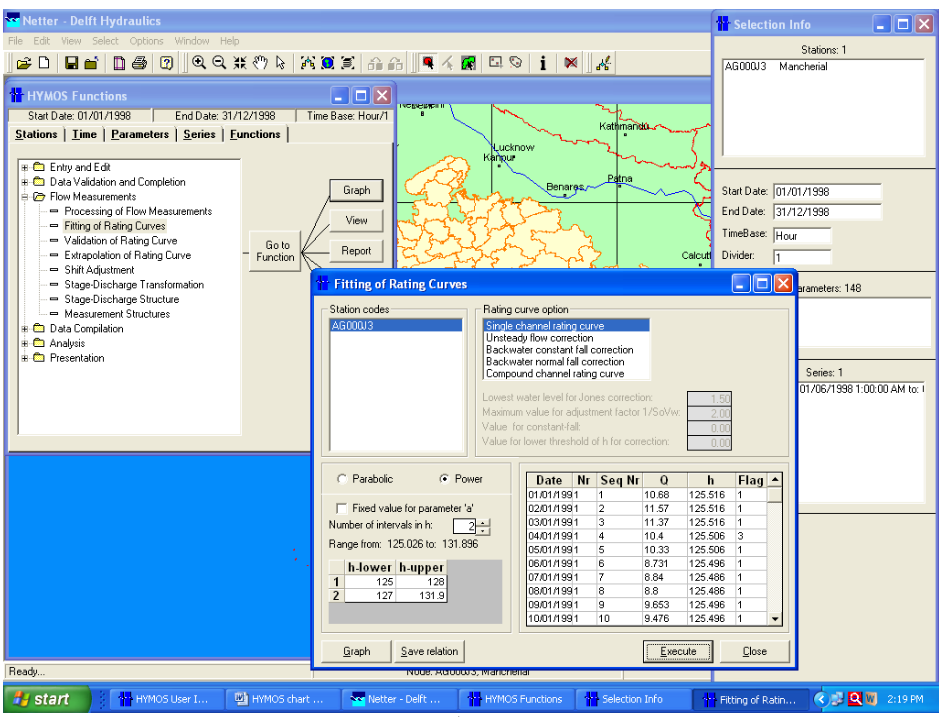

Fig.1

Power type of equation q=c*(h+a)**b is used

Boundaries / coefficients

lower bound	upper bound	a	b	c
125.00	127.70	-124.130	5.331	.1538E+01
127.70	131.90	-126.201	1.737	.6719E+03

Skipping all intervening steps till a rating curve is saved in the memory, we now select Extrapolation of Rating Curve' option on HYMOS function box (**Fig.2**). The relevant screenshot of **Fig.2** depicts dates and Time Base details as well. Select 'Extrapolation of Rating Curve' function and press 'Go to Function' .

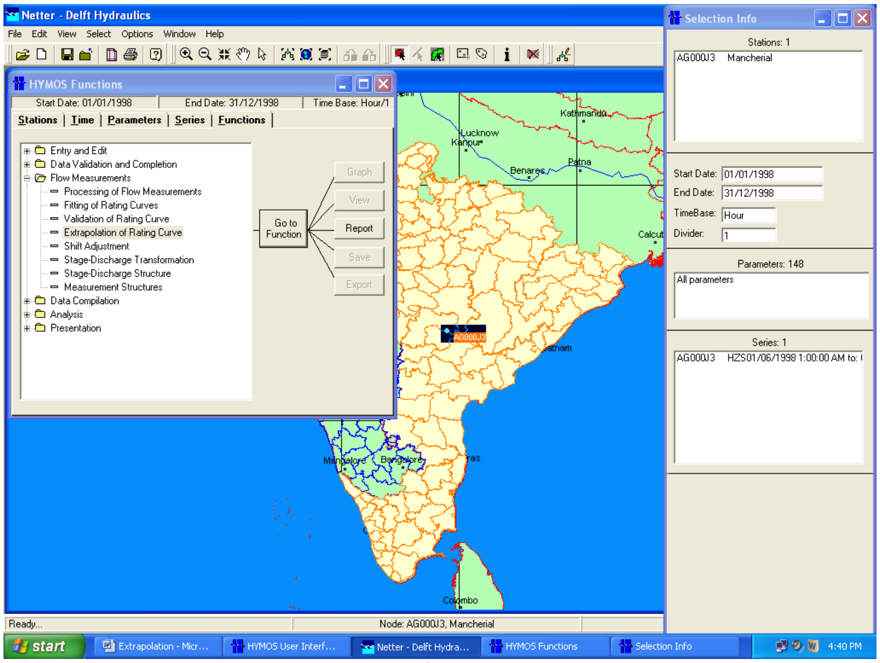

Fig.2

This brings up 'Extrapolation of Rating Curve' box (**Fig.3)**.

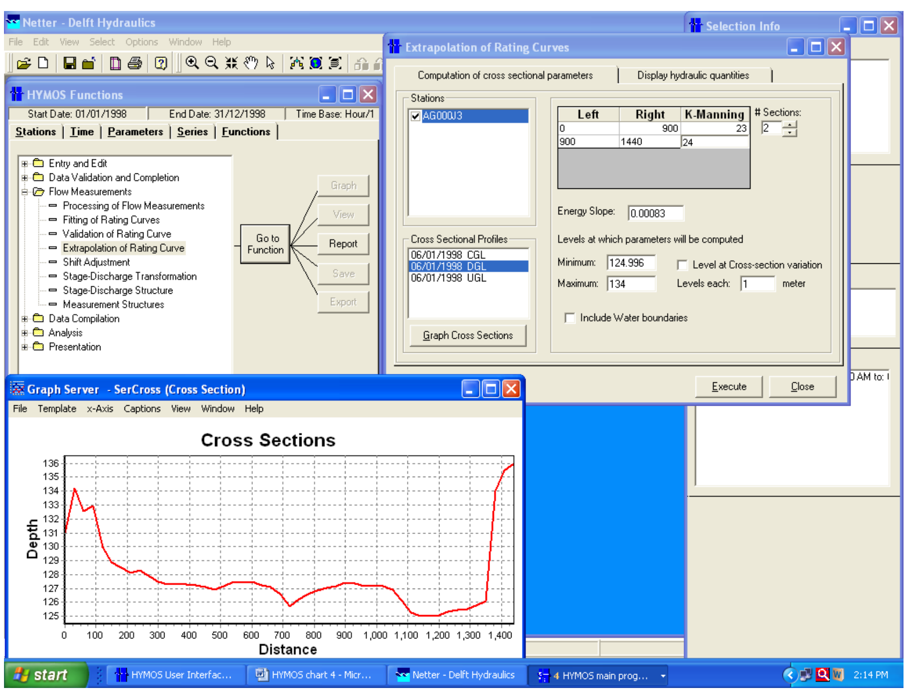

Fig.3

Check the box on by the station name to turn it active. This will pile up cross-section profiles of the station under consideration observed during the selected period. Open up the cross section of the centre line to look at the river geometry and decide upon the location of main channel and adjacent over banks. For this exercise, we assume two sections of river spanning from to 0 to 900 and 900 to 1440 and assign two values of K-Manning (pl note that K-Manning is inverse of 'n' – manning coefficient value' appropriately.

To achieve K-manning value, press 'Display Hydraulic quantities' (**Fig.4)**. Now press 'Execute' and select 'H vs sqrt(s)/n' followed by clicking on 'Show graph' .

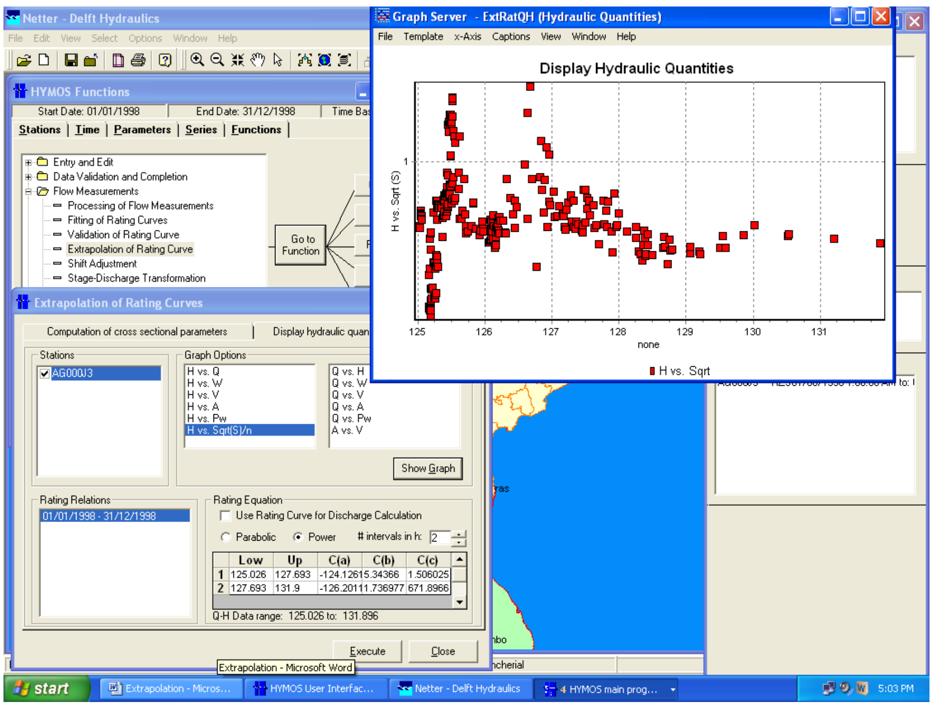

Fig.4

A glance at the graph reveals **sqrt(s)/n** approaching a value of around **0.65 to 0.70** at higher ranges of water levels. Study of stage discharge data of the station further reveals surface slope around **0.00083 (Fig.5)**. Information shown in bold here aid user to conveniently deduce 'n' and eventually K-Manning. Noticing that banks usually have higher n-value than main channel, we select K-manning as 23 and 24 for banks and main channel respectively. Go back to 'Computation of cross sectional parameters' screen and insert values. Press 'Execute' and open up report file to get discharge data for a range beyond rating curve. For this example, upper limit of rating curve is 131.9m while extrapolation sought is upto 134m. Here, HYMOS has a limitation in incorporating extrapolated discharge automatically in the database of the station. User has to do this manually by selecting 'Add stage discharge data' function under 'Entry and Edit' folder followed by 'stage discharge' folder (**Fig.5**). With this new set of data, a fresh rating curve for extrapolated range needs to be fitted along with preceding ranges and saved for stage discharge transformation task. For more details, user may refer to ***'Training Module no. 31'*** .

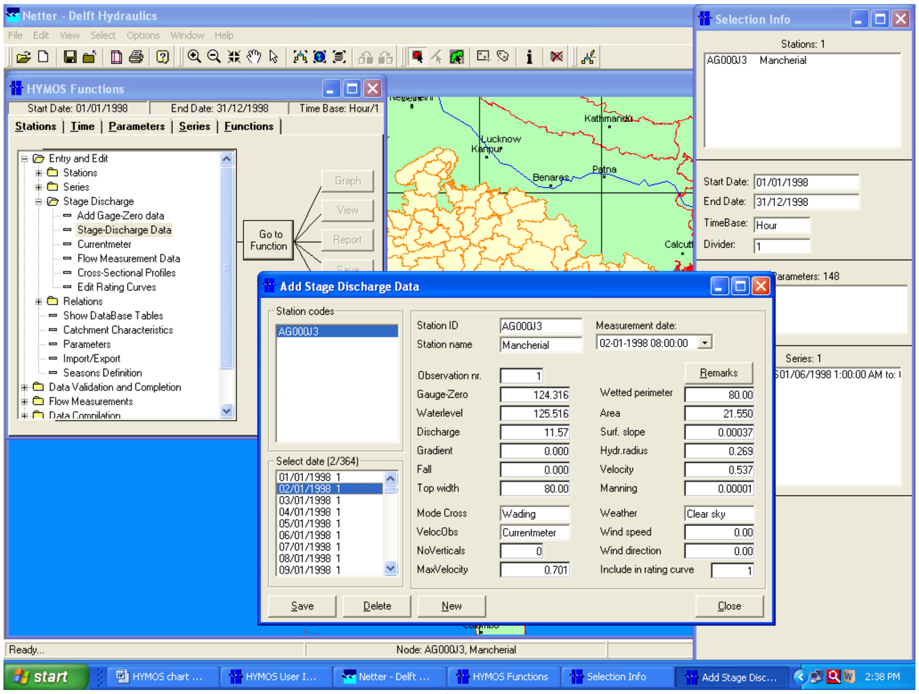

Fig.5

Computation of cross-sectional parameters

Station : AG000J3
Date : 1998 1 6

Section 1

Left bound .00 m, right bound 900.00 m from initial point
Water boundaries included

K-Manning: 23.0, Sqrt(S).K-Manning: .6862

Stage	Width	Wetted Perimeter	Area	Hydraulic radius	A*R**2/3	Q
m	m	m	sq-m	m	m**(8/3)	m3/s
125.00	.000	.000	.000	.000	.00	.00
126.00	25.055	26.549	3.195	.120	.78	.53
127.00	185.887	187.397	87.687	.468	52.85	36.26
128.00	637.935	639.458	580.543	.908	544.31	373.48
129.00	752.871	754.422	1291.319	1.712	1847.76	1267.85
130.00	780.546	782.175	2058.516	2.632	3923.93	2692.43
131.00	790.759	792.583	2844.033	3.588	6665.94	4573.87
132.00	809.980	811.909	3644.402	4.489	9916.81	6804.48
133.00	866.564	868.563	4472.338	5.149	13335.94	9150.53
134.00	894.427	896.497	5352.834	5.971	17617.35	12088.25

Section 2

Left bound 900.00 m, right bound 1440.00 m from initial point
Water boundaries included

K-Manning: 24.0, Sqrt(S).K-Manning: .7160

Stage	Width	Wetted Perimeter	Area	Hydraulic radius	A*R**2/3	Q
m	m	m	sq-m	m	m**(8/3)	m3/s
125.00	.000	.000	.000	.000	.00	.00
126.00	255.086	255.097	163.631	.641	121.70	87.14
127.00	314.971	315.021	448.825	1.425	568.29	406.89
128.00	457.204	457.534	871.323	1.904	1338.70	958.49
129.00	460.976	461.802	1330.412	2.881	2693.64	1928.62
130.00	464.747	466.070	1793.274	3.848	4403.29	3152.70
131.00	468.519	470.339	2259.907	4.805	6434.93	4607.34
132.00	472.291	474.607	2730.312	5.753	8765.92	6276.30
133.00	476.062	478.876	3204.488	6.692	11379.31	8147.46
134.00	479.834	483.144	3682.437	7.622	14261.80	10211.29

Stage	Discharge/section		>>> Total Discharge
125.00	.00	.00	.00
126.00	.53	87.14	87.67
127.00	36.26	406.89	443.15
128.00	373.48	958.49	1331.98
129.00	1267.85	1928.62	3196.47
130.00	2692.43	3152.70	5845.13
131.00	4573.87	4607.34	9181.21
132.00	6804.48	6276.30	13080.78
133.00	9150.53	8147.46	17297.99
134.00	12088.25	10211.29	22299.54

Extrapolation of discharge by conveyance method is highly sensitive to roughness value, and therefore a reasonable value in harmony with site condition must be fed in the system. An extrapolated value can also be verified by applying other methods such as channel routing by conventional methods or by dynamic channel routing. User may use soft tools such as HEC-HMS or HEC-RAS software for this purpose.

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VALIDATION OF RAINFALL DATA

Inclusion of errors in rainfall data is often attributed to fault in instrument; its upkeep; errors contributed by observers etc. Such errors, if go unnoticed further, are bound to affect hydrological analyses significantly. HYMOS offers a range of tools to detect errors, if any and tools to modify it to maintain consistency and continuity of rainfall data. One such tool in HYMOS is spatial consistency test. In the paragraphs to come, this has been illustrated with relevant HYMOS screenshots.

To demonstrate the application of this test, Vadagam MPS series (daily series) of Kheda catchment is selected by adopting steps outlined in initial chapters. Once Hymos Function window appears on the screen (**Fig.1**), set time period and time base as 01/07/1988 (start date); 30/09/1988 and days respectively under time tab. Now, select Spatial Homogeneity Test function in Data Validation and Completion folder and press Go to Function button. Spatial Homogeneity Test window that pops up subsequently needs selection of Vadagam MPS series; entry of absolute, admissible error normally as 50; relative, multiplier to st Dev as 2.0; check box on for MPS series (above search button); radius of influence as 25km; power to distance factor as 2.0. No normalization button would be selected.

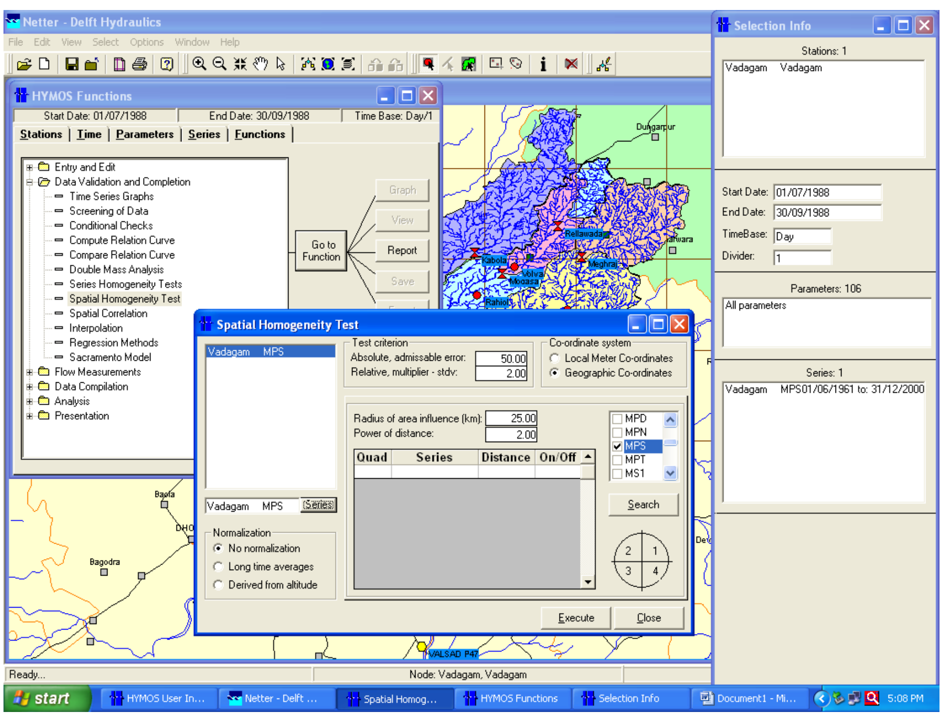


Fig.1

Once completed, search button is pressed to let software look for neighbouring stations within a radius of 25km around Vadagam site and populate the field in the middle (**Fig.2**). Right most cells of this part of window allow the user to decide inclusion or exclusion of station (s) in the analysis by putting 1 or 0 respectively. While doing so, an attempt should be made to ensure stations (two at least) in each quadrant to remove bias in the result.

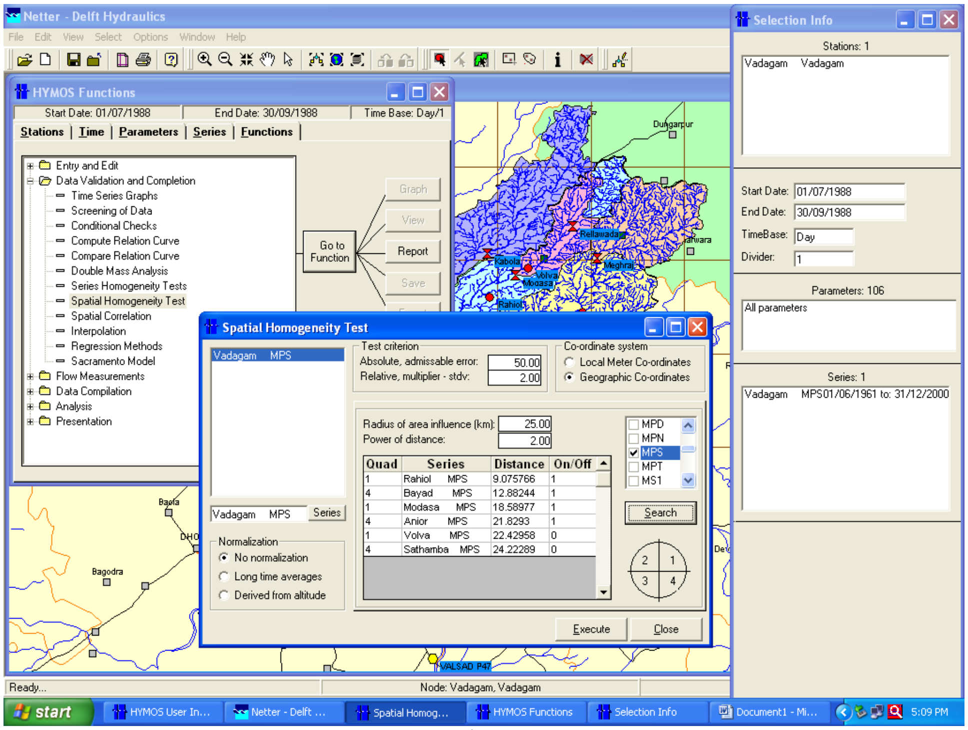


Fig.2

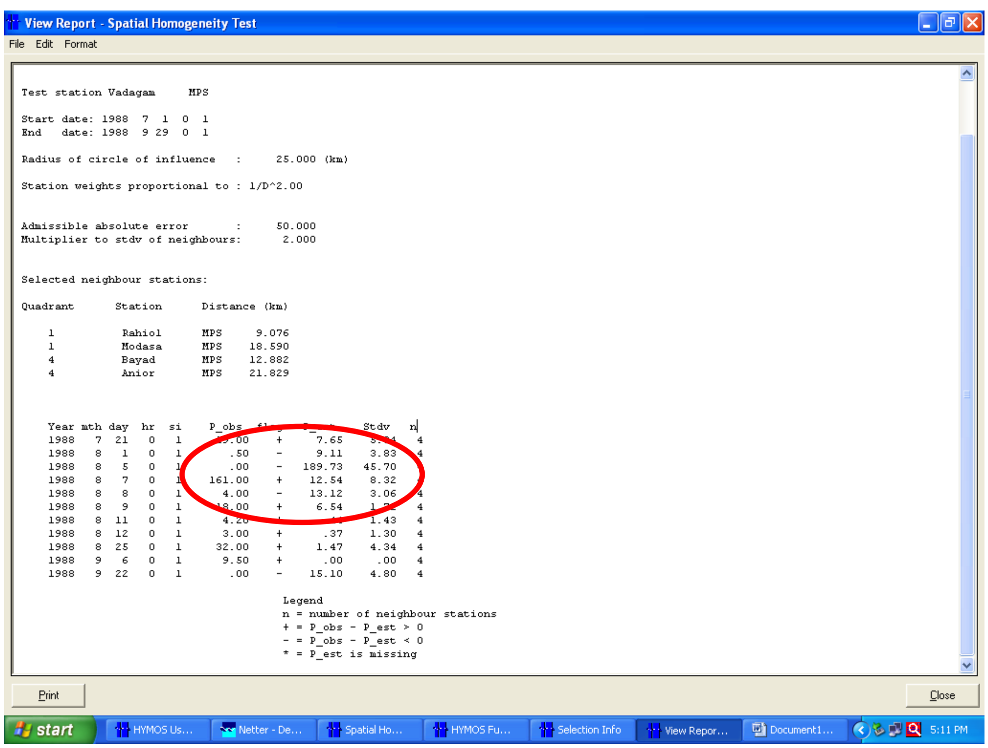


Fig.3

This step is possible only when one or more quadrants have more than two stations in it. Press Execute now and click on Report button to look into resultant report file for inconsistencies in the record (**Fig.3).**

Fig.3 tabulates the estimated as well as observed rainfall record at Vadagam site. Encircled patch of this report highlights suspected entry around 5th of August 1998. User may note down all suspected period for scrutiny of record separately. Scrutiny is accomplished by picking up Anior, Bayad, Modasa, Rahiol stations from Netter screen besides Vadagam keeping time period and time base in such a manner that covers the suspected period. Now, choose Screening of data under Data Validation and Completion folder and subsequently pressing go to function tab (**Fig.4**). Select all MPS series followed by Tabulation screening option. Click on Execute button.

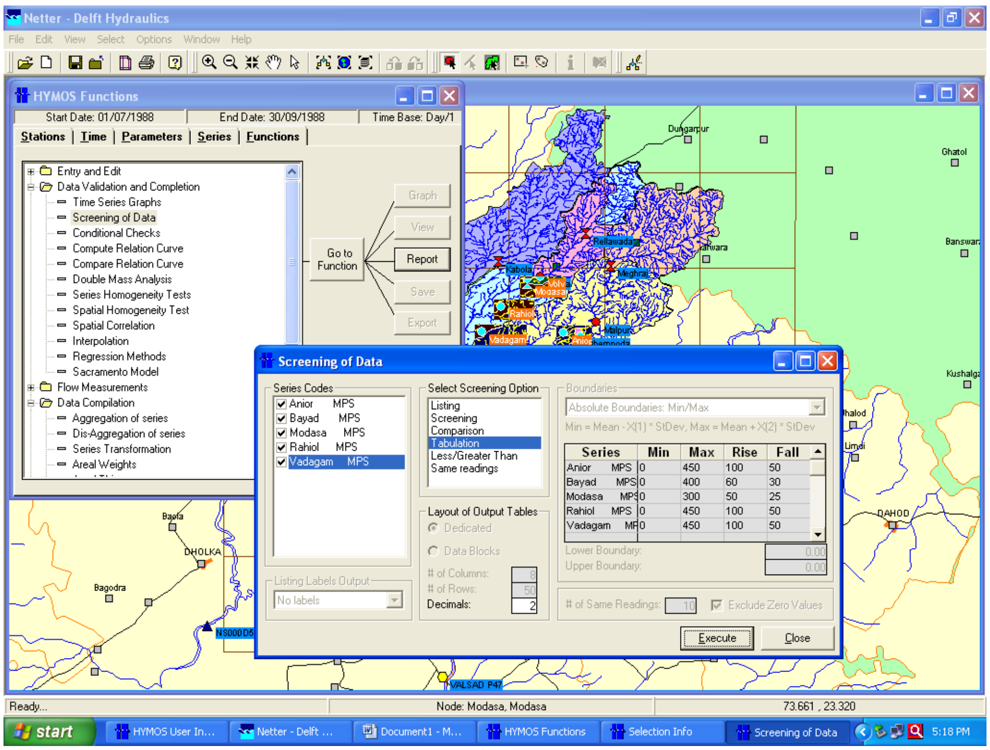


Fig.4

Clicking on Report tab on Hymos function box produces report file listing daily rainfall recorded/aggregated for stations under study (**Fig.5**). Move around the suspected period to trace inconsistencies in the record. User at this stage may promptly recognize the mistake and revisit the Vadagam MPS series to modify the entry. To edit data, select Entry and Edit> Series> Edit data function> Go to Function to have Edit data values window (**Fig.6).** Scroll up/down to respective date/period and modify/shift/replace values as needed and save the record.

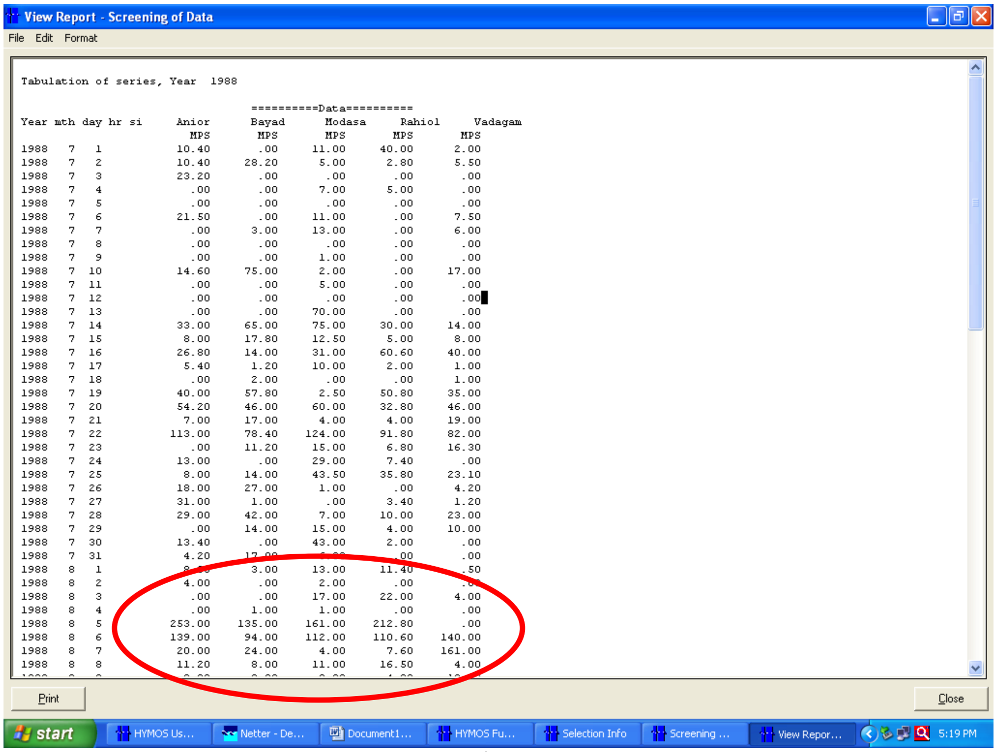


Fig.5

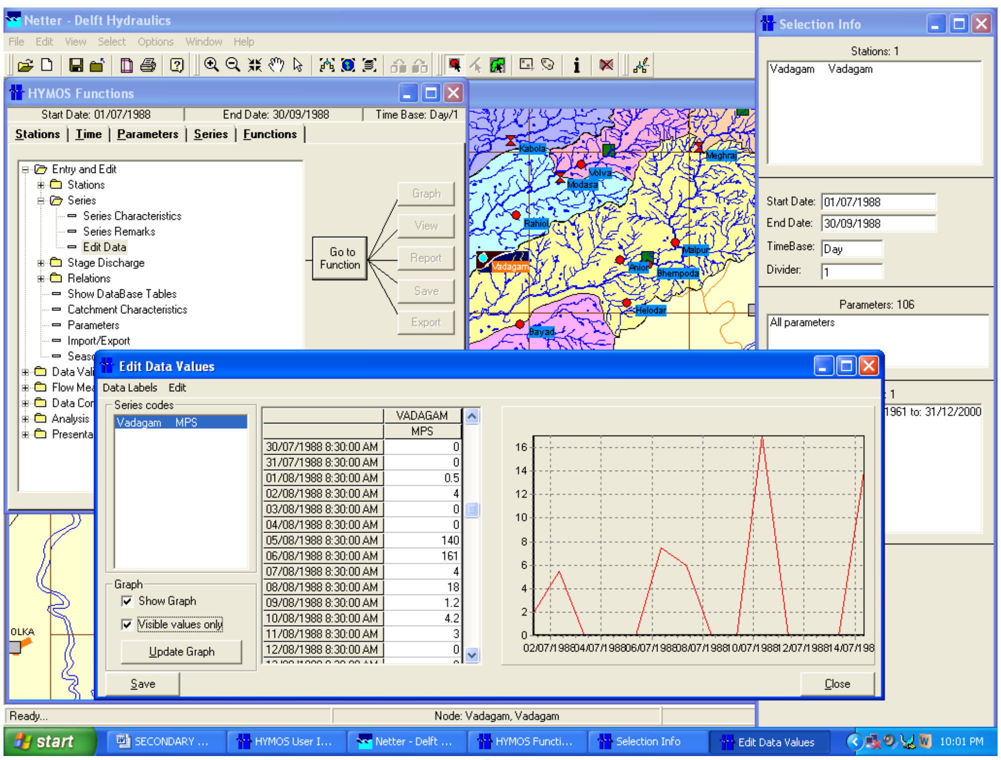


Fig.6

Double mass analysis is yet another tool available to detect inconsistencies in the record arising because of shifting of station itself or significant changes around the station influencing adversely the record of rainfall events. This analysis is normally carried out based on the availability of long term rainfall record at base as well as test station. For the current exercise, Vadol is test station while Kapadwanj, Mahisa and Thasara form base stations. Accordingly, stations would be picked up from Netter screen to enter Hymos function box as usual. Time period and time base are selected as shown in **Fig.7.** Now, select Double Mass analysis function under Data Validation and Completion folder to press go to function. This pops up Double Mass analysis window. Select Vadol MPS series as Selected series. Select year button which automatically filled in the length of data in year. A numerical value of 92 against number of elements in year implies 92 days data each year beginning from 01/07/1970 would be considered for analysis. This is so because period considered for analysis witnesses active rainfall activity while preceding and succeeding period notice usually subdued or nil rainfall. Press Execute button to let HYMOS finish the analysis. This exercise involves a multitude of data for analysis, HYMOS may warn the user about proceeding further. Ignore such warning and proceed ahead by choosing 'ok' .

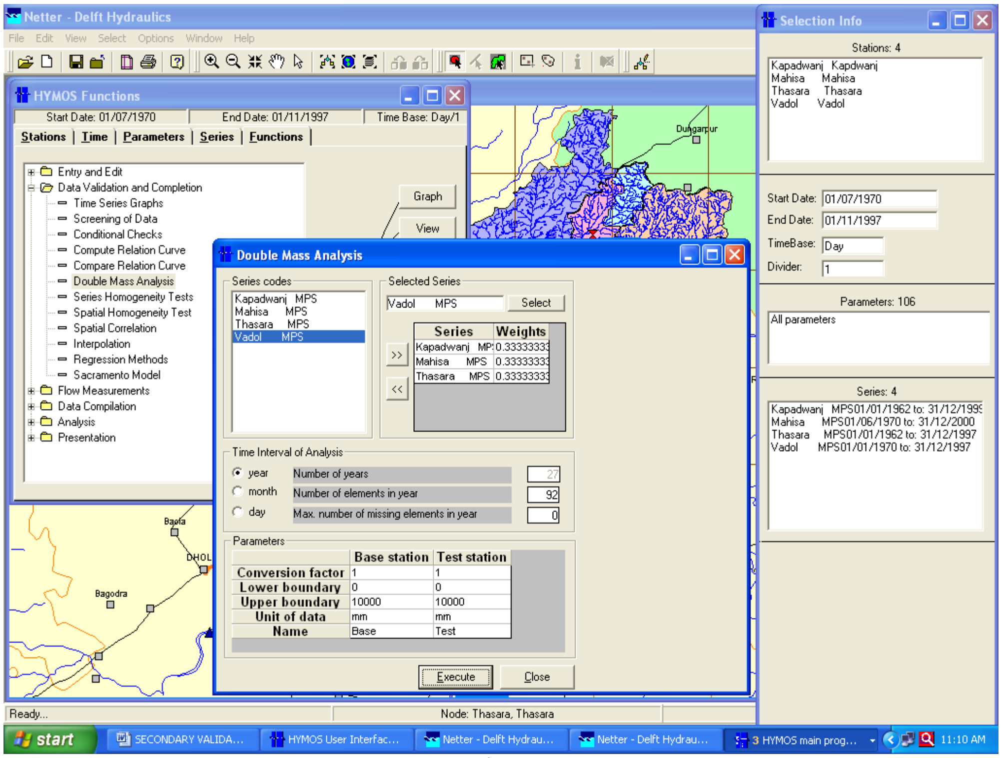


Fig.7

Graph & Report command on HYMOS Function box renders a plot (**Fig.8**) and a report (**Fig.9**) plotting/listing year wise accumulated rainfall at test station and accumulated averaged rainfall at base stations. Extracted information in this form reveals shift in pattern in the year 1984 and beyond signifying a need for examination of causative factors; estimating correction factor; and introducing correction factor to test station record accordingly. User at this stage is suggested to refer to ***'Training Module no. 10'*** before applying correction factor and proceeding further.

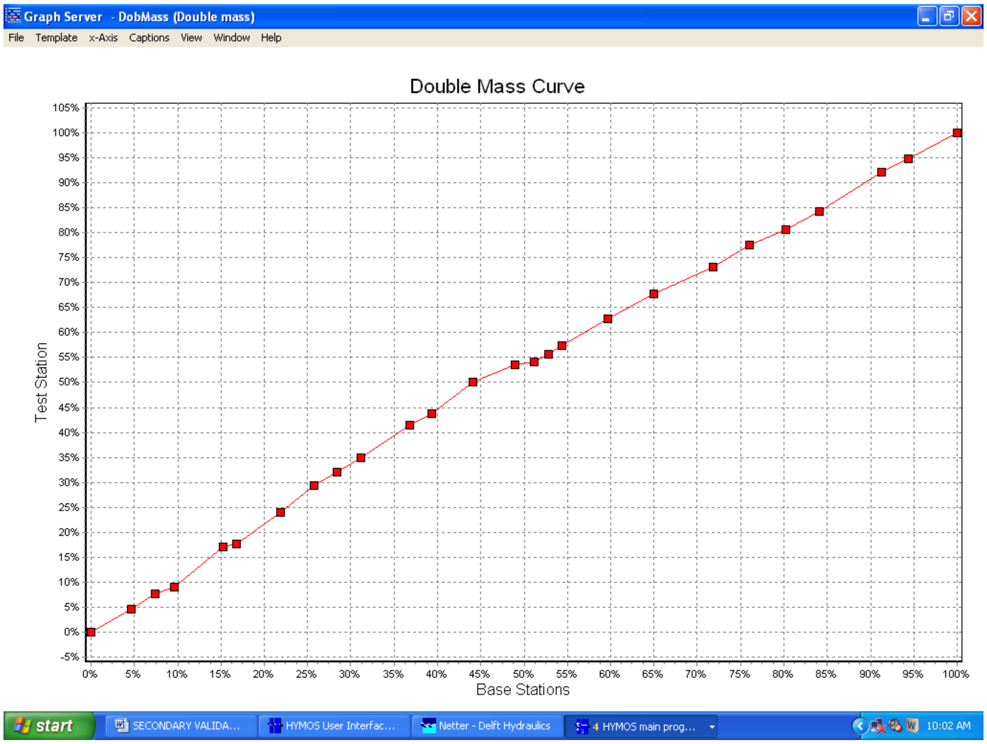
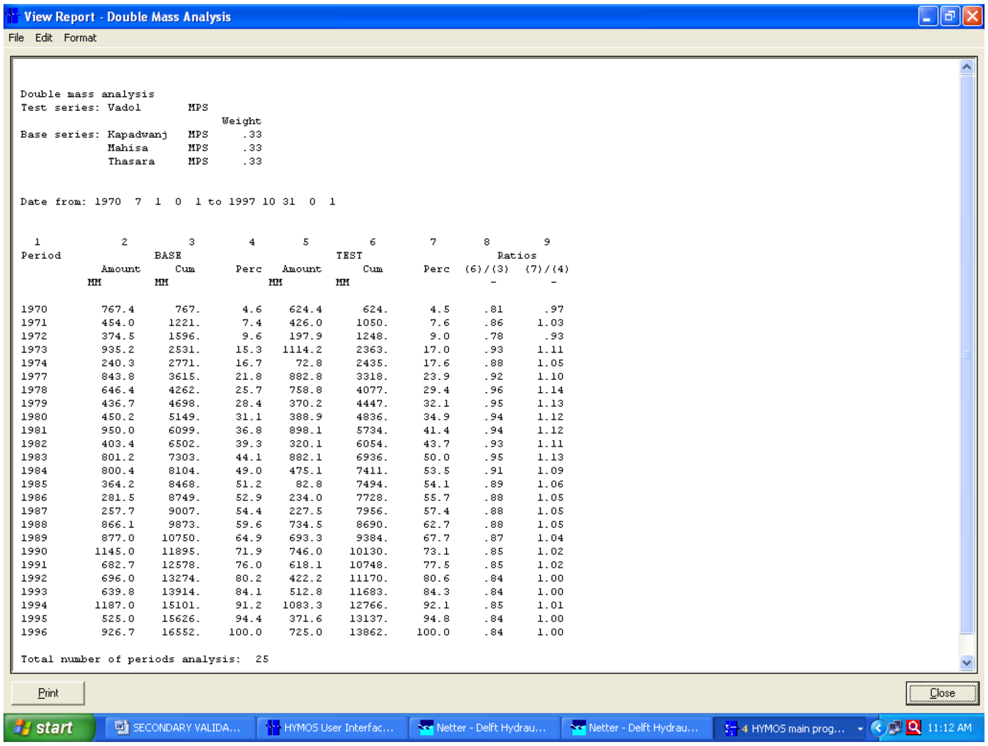


Fig.8



Double mass analysis
Test series: Vadol MPS

Base series		Weight
Kapadwanj	MPS	.33
Mahisa	MPS	.33
Thasara	MPS	.33

Date from: 1970 7 1 0 1 to 1997 10 31 0 1

1	2	3	4	5	6	7	8	9
Period	BASE			TEST			Ratios	
	Amount MM	Cum MM	Perc	Amount MM	Cum MM	Perc	(6)/(3) -	(7)/(4) -
1970	767.4	767.	4.6	624.4	624.	4.5	.81	.97
1971	454.0	1221.	7.4	426.0	1050.	7.6	.86	1.03
1972	374.5	1596.	9.6	197.9	1248.	9.0	.78	.93
1973	935.2	2531.	15.3	1114.2	2363.	17.0	.93	1.11
1974	240.3	2771.	16.7	72.8	2435.	17.6	.88	1.05
1977	843.8	3615.	21.8	882.8	3318.	23.9	.92	1.10
1978	646.4	4262.	25.7	758.8	4077.	29.4	.96	1.14
1979	436.7	4698.	28.4	370.2	4447.	32.1	.95	1.13
1980	450.2	5149.	31.1	388.9	4836.	34.9	.94	1.12
1981	950.0	6099.	36.8	898.1	5734.	41.4	.94	1.12
1982	403.4	6502.	39.3	320.1	6054.	43.7	.93	1.11
1983	801.2	7303.	44.1	882.1	6936.	50.0	.95	1.13
1984	800.4	8104.	49.0	475.1	7411.	53.5	.91	1.09
1985	364.2	8468.	51.2	82.8	7494.	54.1	.89	1.06
1986	281.5	8749.	52.9	234.0	7728.	55.7	.88	1.05
1987	257.7	9007.	54.4	227.5	7956.	57.4	.88	1.05
1988	866.1	9873.	59.6	734.5	8690.	62.7	.88	1.05
1989	877.0	10750.	64.9	693.3	9384.	67.7	.87	1.04
1990	1145.0	11895.	71.9	746.0	10130.	73.1	.85	1.02
1991	682.7	12578.	76.0	618.1	10748.	77.5	.85	1.02
1992	696.0	13274.	80.2	422.2	11170.	80.6	.84	1.00
1993	639.8	13914.	84.1	512.8	11683.	84.3	.84	1.00
1994	1187.0	15101.	91.2	1083.3	12766.	92.1	.85	1.01
1995	525.0	15626.	94.4	371.6	13137.	94.8	.84	1.00
1996	926.7	16552.	100.0	725.0	13862.	100.0	.84	1.00

Total number of periods analysis: 25

Fig.9

Following is an excerpt of this module showing the method to work out correction factor.

$$\alpha_1 = \frac{\sum_{i=1}^{T_1} P_{test,i}}{\sum_{i=1}^{T_1} P_{base,i}} = \frac{6936}{7302} = 0.9498$$

and

$$\alpha_2 = \frac{\sum_{i=T_0}^{T_2} P_{test,i} - \sum_{i=T_0}^{T_1} P_{test,i}}{\sum_{i=T_0}^{T_2} P_{base,i} - \sum_{i=T_0}^{T_1} P_{base,i}} = \frac{13862 - 6936}{16721 - 7302} = 0.7353$$

Thus the correction factor, if the latter portion is to be corrected to exhibit an average slope of α_1 , is:

$$Correction\ \ Factor = \frac{\alpha_1}{\alpha_2} = \frac{0.9498}{0.7353} = 1.2916$$

Thus all the rainfall values after the year 1983 have to be increased by a factor of 1.2916 to correct the rainfall data at VADOL for improper exposure condition and thus to make it consistent in time. This is done by carrying out data series transformation using linear algebraic option.

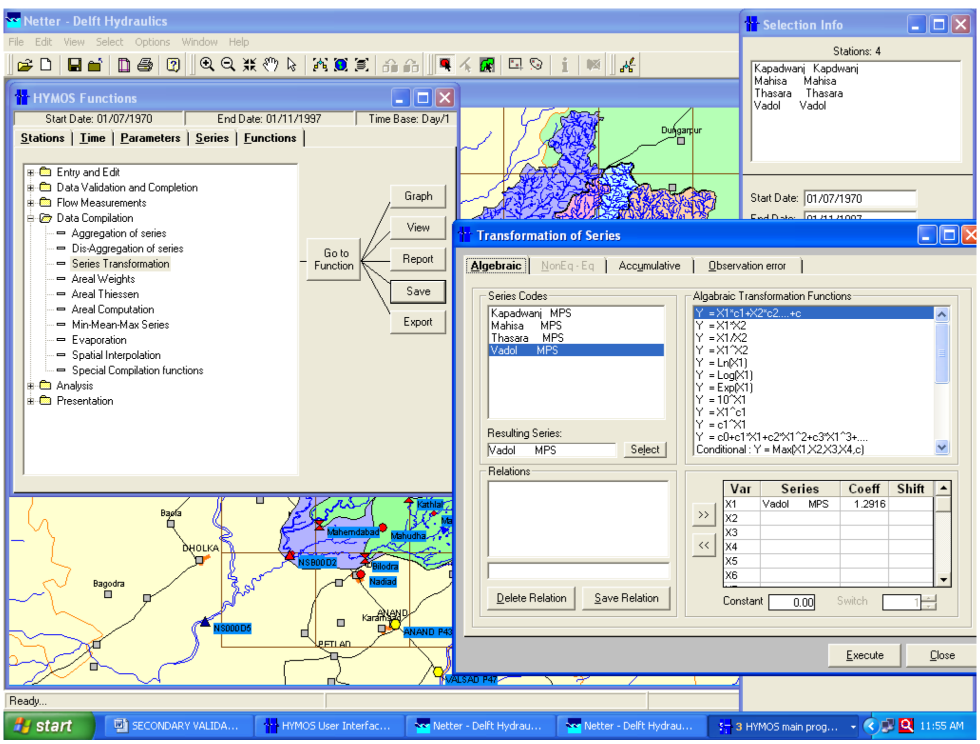


Fig.10

As pointed out in the preceding para, the correction has to be incorporated since 1984. Accordingly, while finishing this job, care has to be exercised to change the time period beginning from 01/07/1984 and not from 01/07/1970 as shown in **Fig.10**. A function of HYMOS needed for this conversion is shown in **Fig.10**. First mark Vadol MPS and use >> button to fill in lower right cells. Proper selection of algebraic transformation function is also important. Execute the window and save the modified series using Save button on Hymos Function window.

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ESTIMATION OF MISSING RAINFALL DATA; AREAL ESTIMATION OF RAINFALL; AGGREGATION OF RAINFALL SERIES

Rainfall data, very often, lack continuity and consistency for reasons stated earlier. Additionally, site conditions around the rain gauge such as obstructions in the near vicinity etc. do influence the correct observations of rainfall. Happily, as rainfall records at one station bear significant correlation with stations nearby, various methods are available to fill in missing range of data. These methods also help in spotting erroneous values in the series. Succeeding illustrations displays several functions of HYMOS to fill gaps in rainfall records of a site. In this chapter, focus is on the use of HYMOS software and therefore, to understand the applicability of method (s) elaborated hereunder in varying conditions, relevant reference materials quoted at appropriate places may be referred to.

(A) Arithmetic Average Method

This method assigns equal weights to all base stations and is used when normal rainfall at test station is within 10% of the normal rainfall observed at adjoining stations.

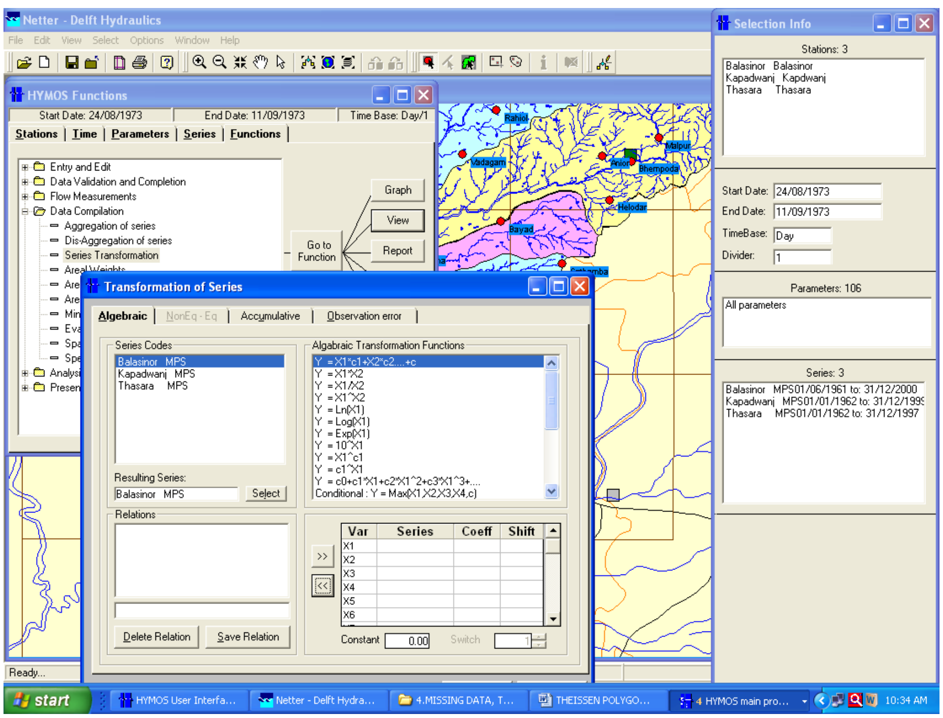


Fig.1

To determine estimates at base station Balasinor, additional two stations namely Thasara and Kapadwanj are to be selected with time period from 24/08/1973 to 11/09/1973 and time base as day' . Pl note that all stations exist in Kheda catchment. The selection of stations; and subsequent changes under time tab of Hymos function box are universal in HYMOS software and are attended to as explained in one of the preceding chapters. Once completed, open up the Data compilation folder and select Series Transformation function before clicking on the Go to Function tab (**Fig.1**). This pops up a Transformation of Series box. For the current example, select Balasinor MPS and press select button below it. The empty cell is now populated with resulting series as Balasinor MPS.

Now, select remaining two stations (**Fig.2**), click over '>>' button. As this method fixes equal wt to stations, for two stations, a weight of 0.5 is entered. For more than two stations, weight will change according to the number of stations chosen as test stations. Resulting series would be determined by algebraic function as selected therein. Press 'Execute' to let the software compute the values. Pressing upon View button on Hymos Function box presents the computed figures for Balasinor site.

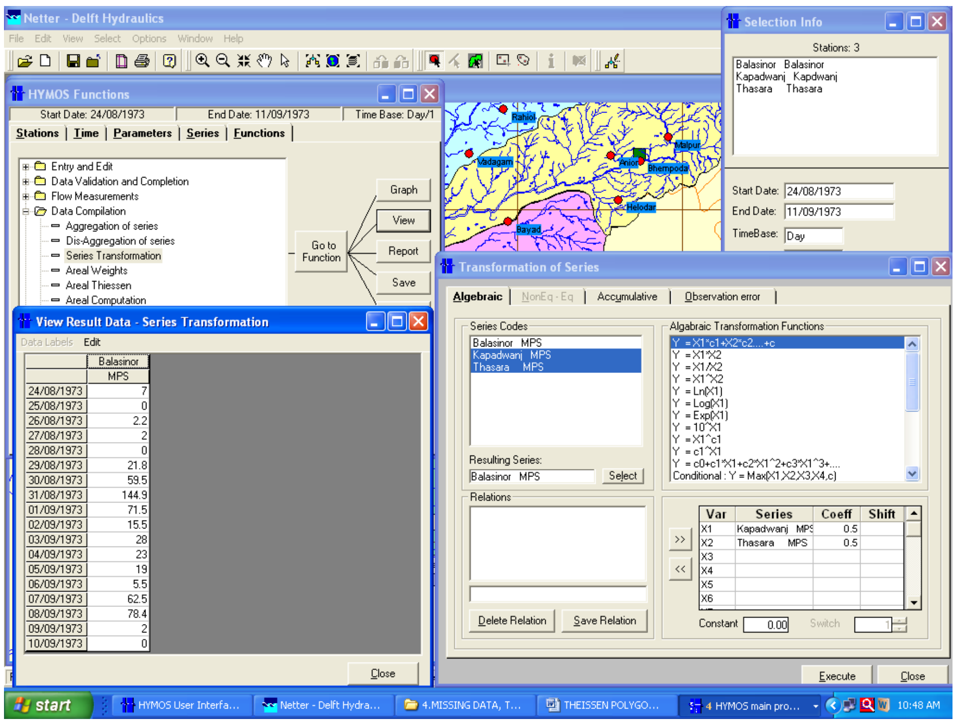


Fig.2

(B) Normal Ratio Method

This method is employed when normal rainfall at test station differs from a group of base stations by more than 10%. We will continue with the identical set up as above except change in selection of suitable function. Pl select 'Interpolation' function under 'Data validation and completion' folder followed by clicking on 'go to function tab' (**Fig.3**). This brings up another box with four tabs on top of it. On extreme right is 'spatial filling in' tab. Select it. For normalization, 'long time averages' option is chosen here. Like previous example, resulting series is Balasinor and is selected following steps described earlier. Similarly, remaining two stations are populated after hitting '>>' button in the middle. Long time average/normal rainfall of these stations is as under:

Balasinor	=	715mm
Kapadwanj	=	830mm
Thasara	=	795mm

These values are required to be entered in cells against respective stations (**Fig.4**). Press Execute' . Again select view to have result.

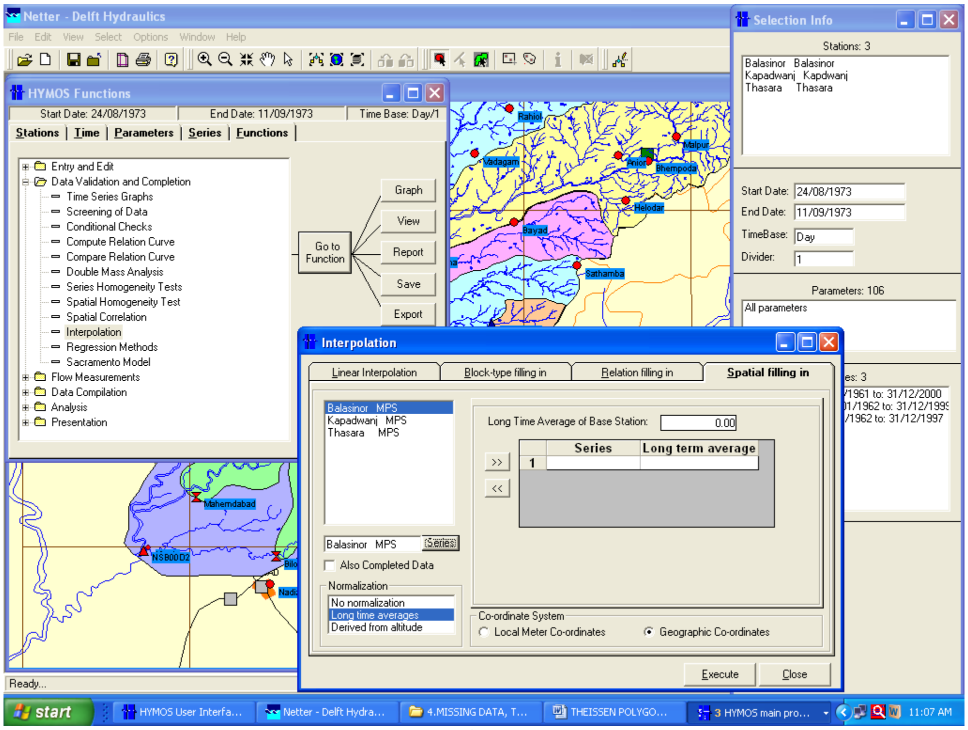


Fig.3

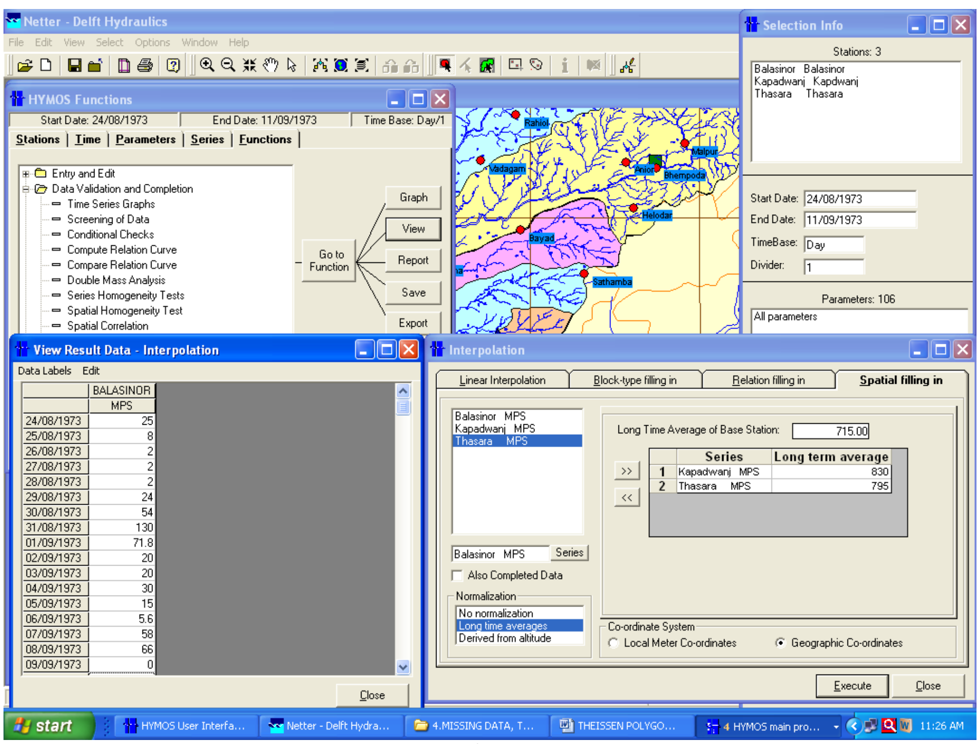


Fig.4

(C) Distance Power method

This method assigns weight to respective base stations with their distance from base station. It is commonly observed that nearer stations exhibit higher degree of correlation than those located farther away. For the current study, select Savlitank as test station with period from 15/08/1994 to 21/09/1994 and time base as day (**Fig.5).** Now, press Parameter tab on Hymos function box and select HA1 series (not shown in fig). Now, press function tab and select Series characteristics and click on 'go to function' button. On Series characteristics box, press Add series button to get another window. Check on the box and press 'ok' . This step adds Savlitank HA1 blank series to series characteristics box. Press 'save' button below on this box. At this stage, don' t forget to deselect the HA1 series under Parameters tab. Return to Function tab.

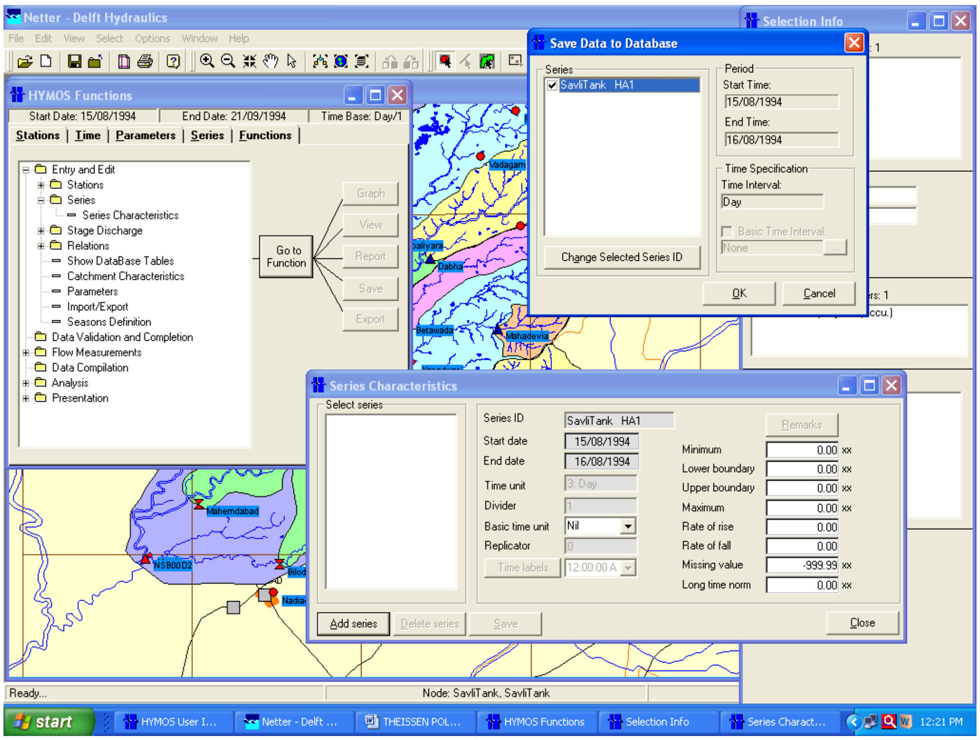


Fig.5

Now, select 'Interpolation' function under 'Data validation and completion' folder followed by clicking on 'go to function tab' **(Fig.6**). This time we choose no normalization option. Select series Savlitank HA1 and press select button below to mark the resulting series as Savlitank HA1. Radius of influence in km is 25 and power to distance is normally kept as 2. Scroll up/down the series check boxes by it and mark on for MPS series. Choose geographic coordinates and then click on 'Search' button.

Note – Fig.5 is used to create a blank Savlitank HA1 series. In similar way, user may also create blank series as Balasinor HA1 for comparing with observed record or filling gaps.

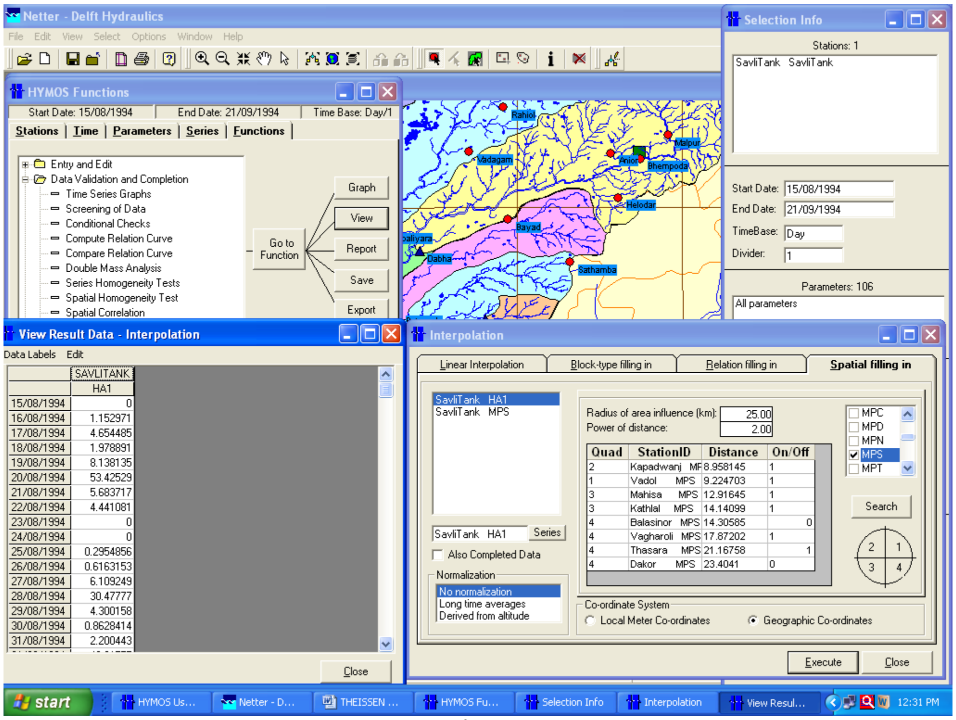


Fig.6

The software populates the central part of this window with stations within radius of influence indicating their quadrants; distance from base station and an option to keep stations on/off for their inclusion in the analysis. Amend the 1/0 values in on/off column as above and press 'Execute'. Selection of 'view from Hymos function box returns the estimated series. For more details on inclusion or exclusion of any station from the analysis and to know more about these methods, user is strongly recommended to refer to '***Training module no.10'***. Report of the example is placed below (**Fig.7**)

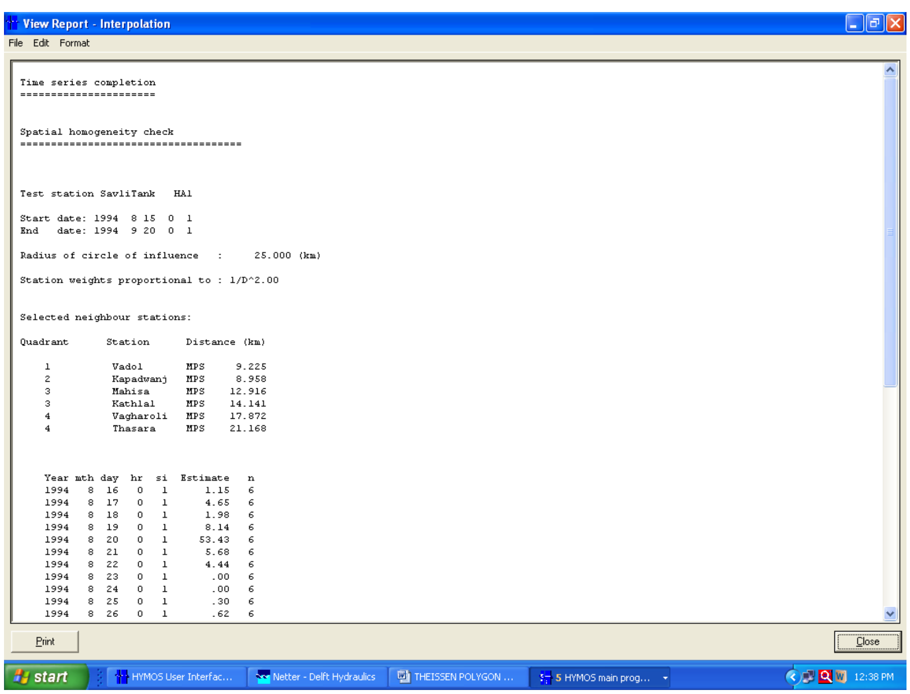


Fig.7

Once user is convinced with the result, click on 'save' button. This pops up another window. Check the box by Savlitank HA1 and press 'ok' (**Fig.8**). Hymos saves this series for later use.

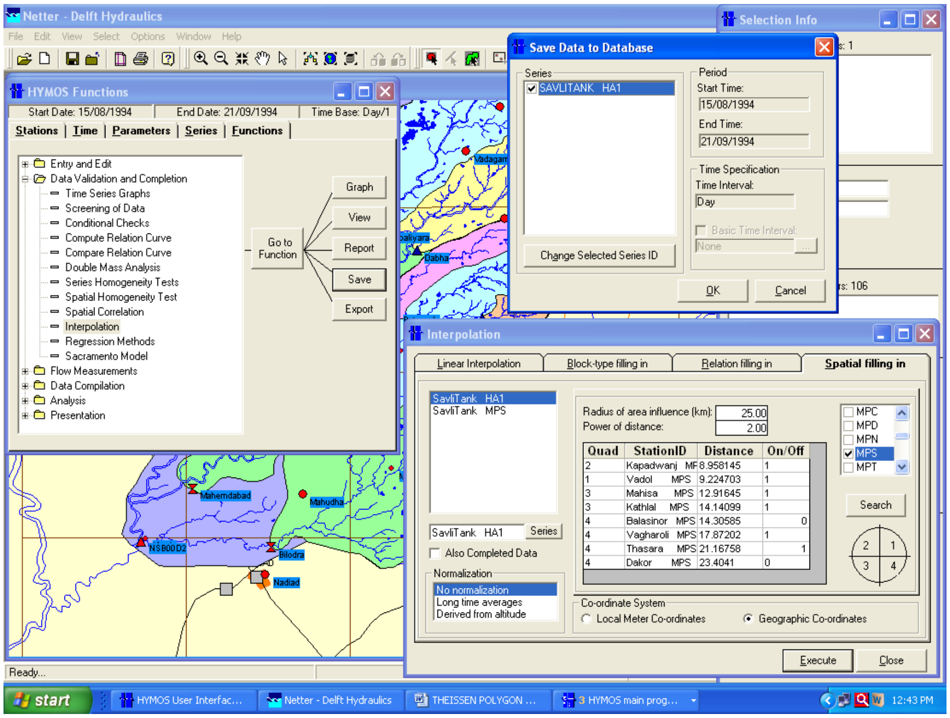


Fig.8

(D) Areal Estimation by Thiessen Polygon

This point beyond, we seek to determine average rainfall over Bilodra basin by selecting 13 rainfall stations spread over the area (**Fig.9**). Place cursor over anyone of the station, right click the mouse, and press Process data + HYMOS to reach **Fig.10.**

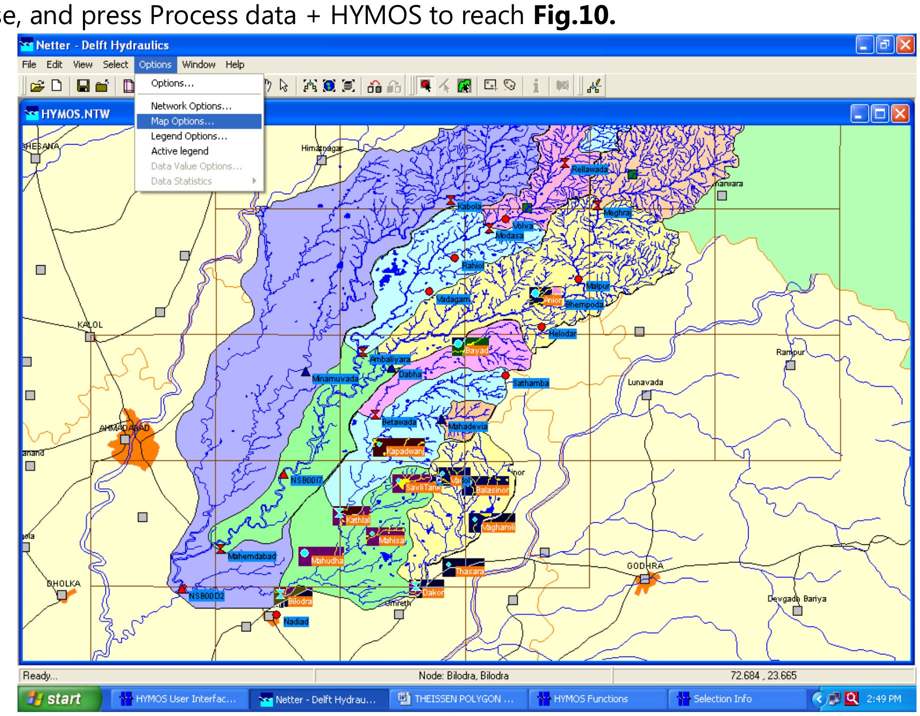


Fig.9

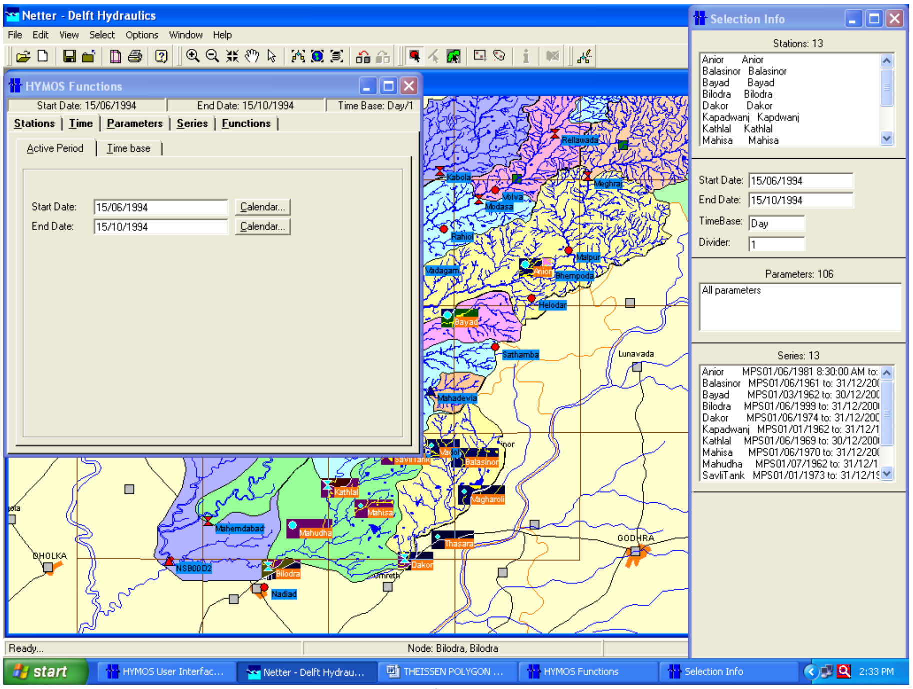


Fig.10

User is requested to change time period and time base as shown in the figure and select MPC series under parameter tab (**Fig.11**). This figure followed by another one (**Fig.12)** highlights the similar steps performed earlier to create Savlitank HA1- a blank series. Pl note that **Fig.12** are akin to **Fig.5** of this chapter. Once done, a Bilodra MPC series would be added to memory. As instructed previously, don' t forget to deselect MPC series before proceeding ahead.

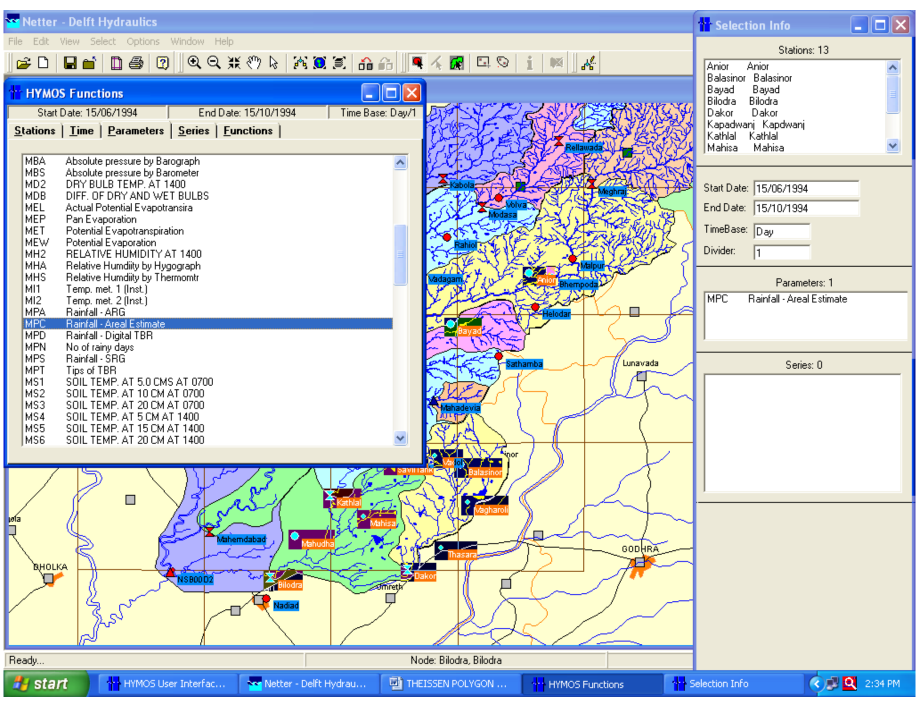


Fig.11

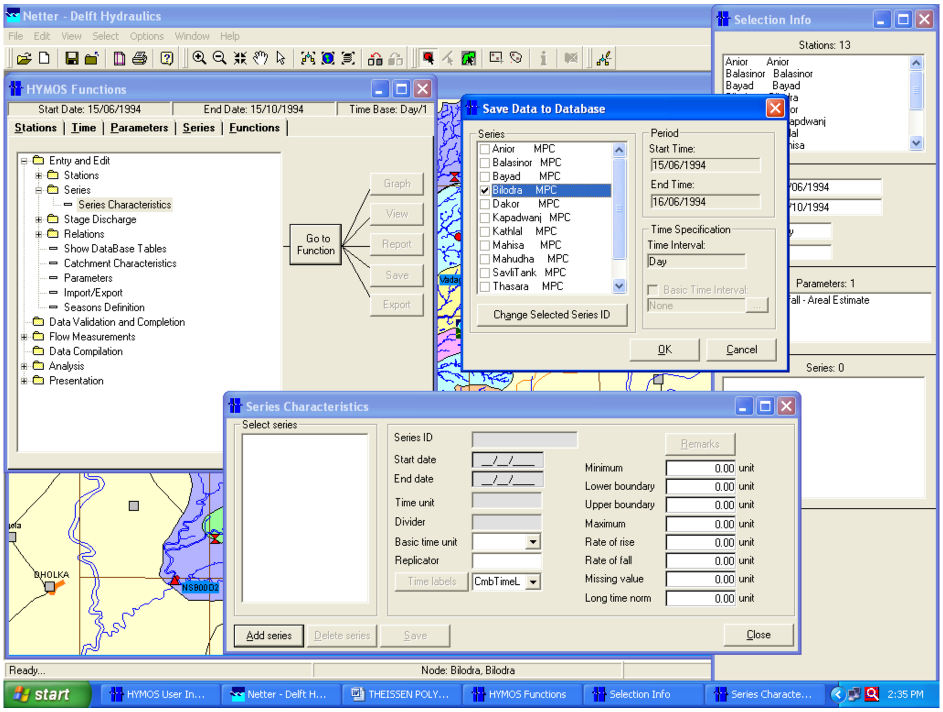


Fig.12

Thiessen weight calculation and Thiessen polygon outlines are determined based on daily rainfall series, i.e., MPS series of all sites under selection. This aside, it is essential that all selected sites must have no-break rainfall series. This is ascertained by choosing Time Series function (**Fig.13);** selecting all MPS series (place cursor inside the series codes box and right click mouse button); data availability under graph type and pressing Execute button. Graph button on Hymos Function window, once clicked, plots data availability status of all stations (**Fig.14)**

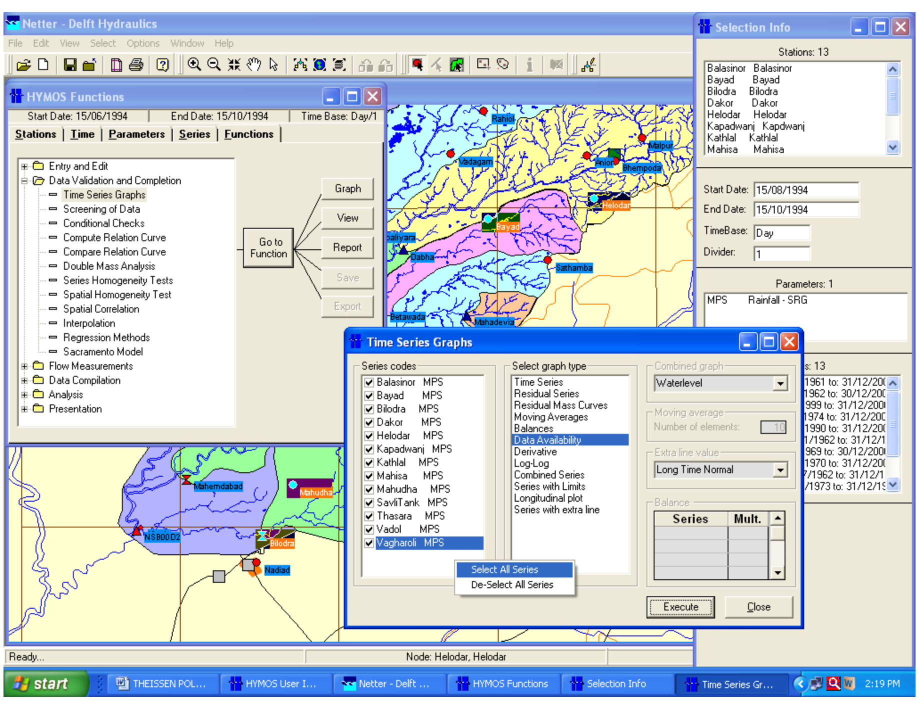


Fig.13

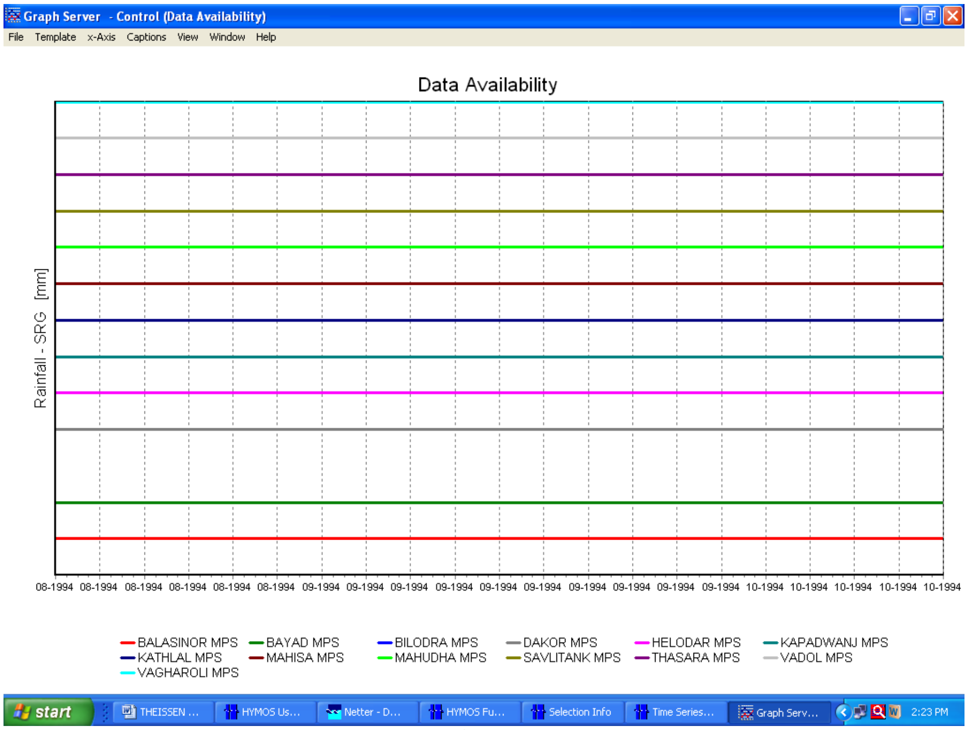


Fig.14

A glance at this plot reveals Bilodra MPS as blank series and therefore, this series would be excluded from analysis. Now, select Areal Thiessen under Data compilation folder and press go to Function tab (**Fig.15).**

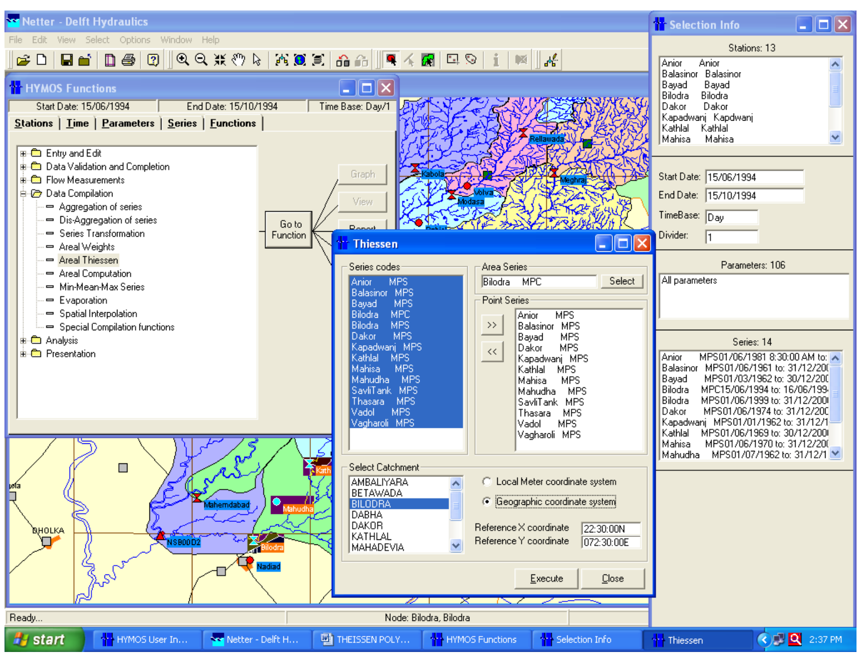
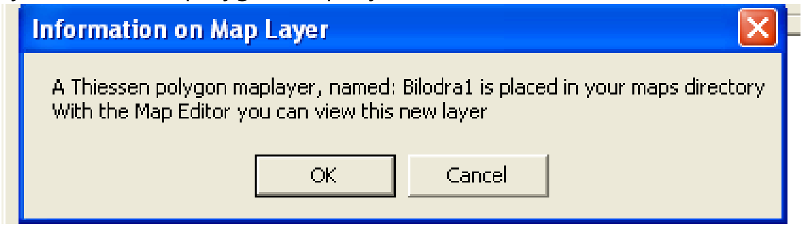


Fig.15

This pops up a window containing all daily series pertaining to these sites. If this box is crowded, go to Parameter tab on Hymos function window and select only MPC & MPS series. This step removes all other series on the list. Right click on the series box and select all stations and press

'>>' . All series now appear in Point Series box. Deselect Bilodra MPS and Bilodra MPC series by using '<<' button. Also ensure that this box is populated by continuous MPS series only. Select Bilodra MPC series from series code box and press select button for Area series on top. Highlight Bilodra as catchment in the box below. Geographic coordinates are obvious choice in HYMOS. Press 'Execute' now.

Hymos will notify the Thiessen polygon map layer name as below for its retrieval later.



Minimise all windows but Netter screen. Select Options on menu bar followed by choosing Map option from dropdown menu (**Fig.16).**

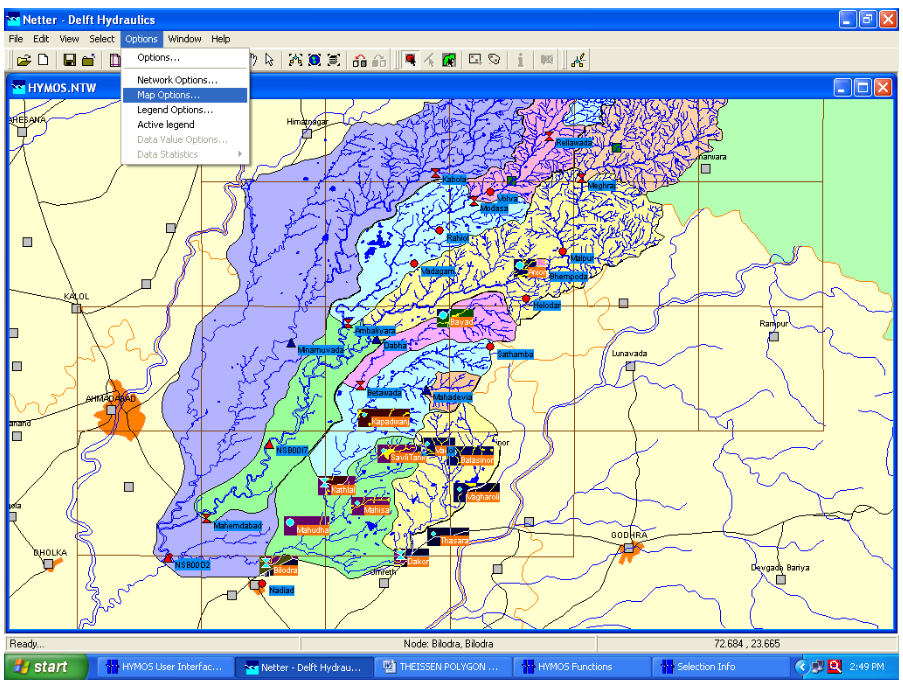


Fig.16

This brings up Map Properties window **(Fig.17).** Click on the add layer button (first button on this window) to have another add layer window. Browse under map folder of Kheda basin to trace Bilodra1 map layer. Highlight it and press open. Click on the Apply button on Map Properties window to add a layer of Thiessen polygons for Bilodra catchment (**Fig.18).**

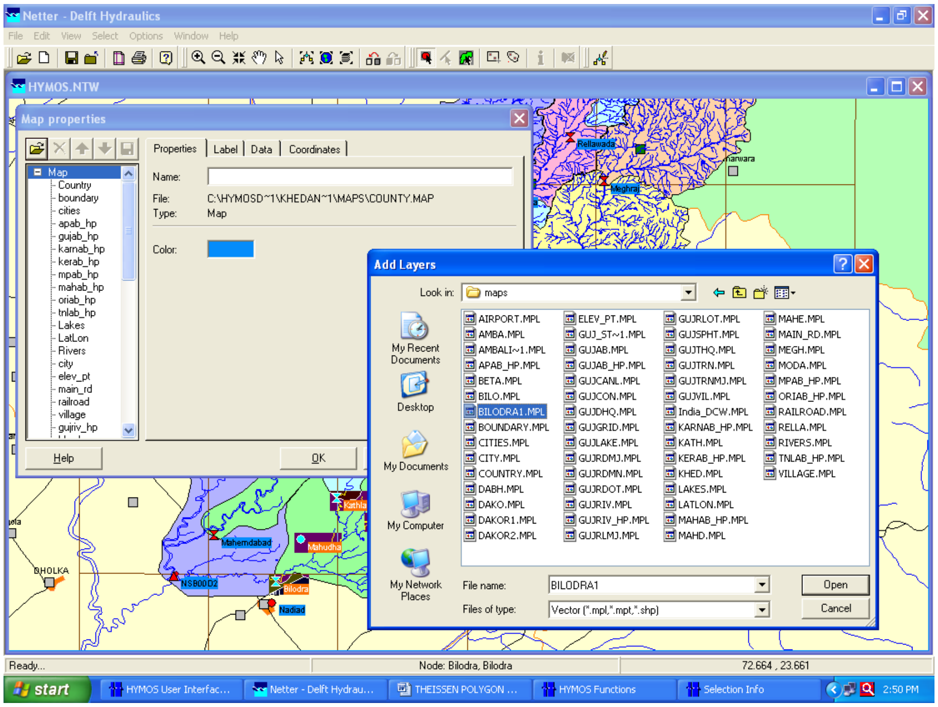


Fig.17

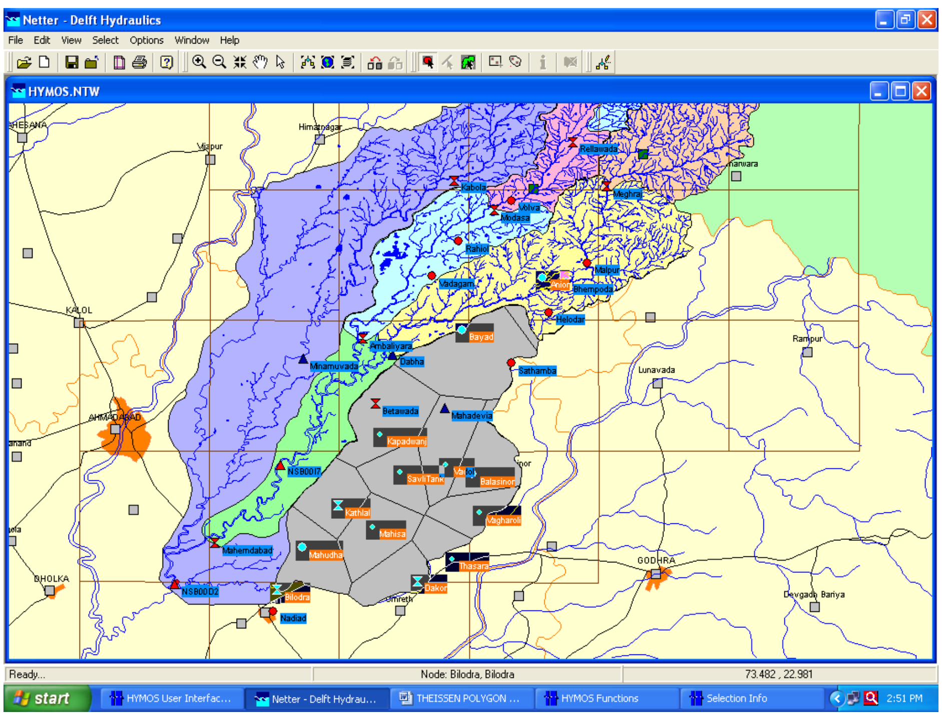


Fig.18

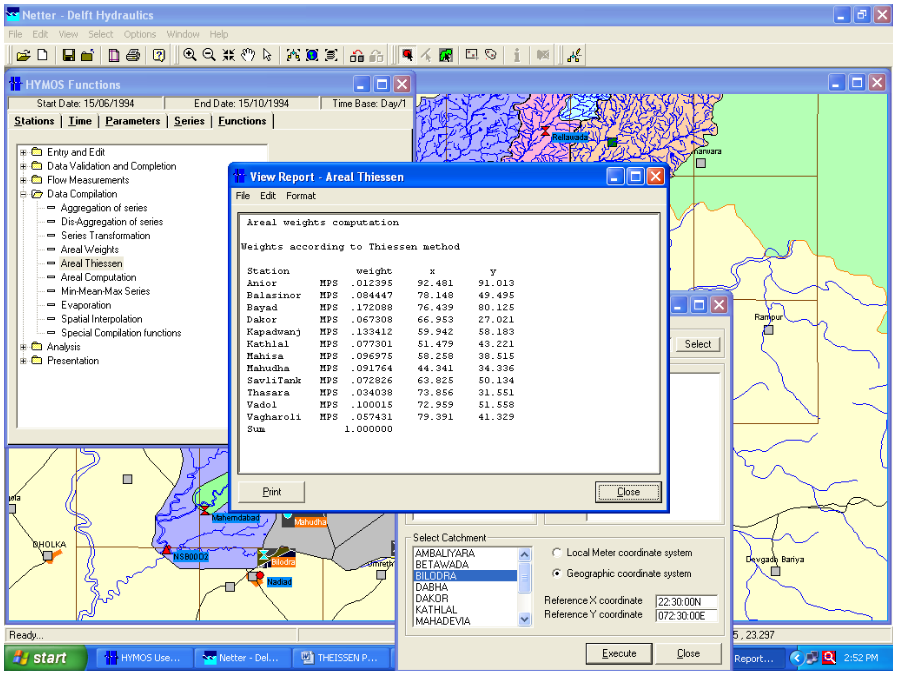


Fig.19

Report button on Hymos function box, once pressed presents **Fig.19**. It displays the weights of each station which would be considered for averaging the rainfall for the basin. Having determined the weights as above, select Areal computation function appearing just below the Areal Thiessen and use Go to Function button to open Areal Computation window (**Fig.20**). Select Bilodra MPC series and concerned TH relations followed by Execute command.

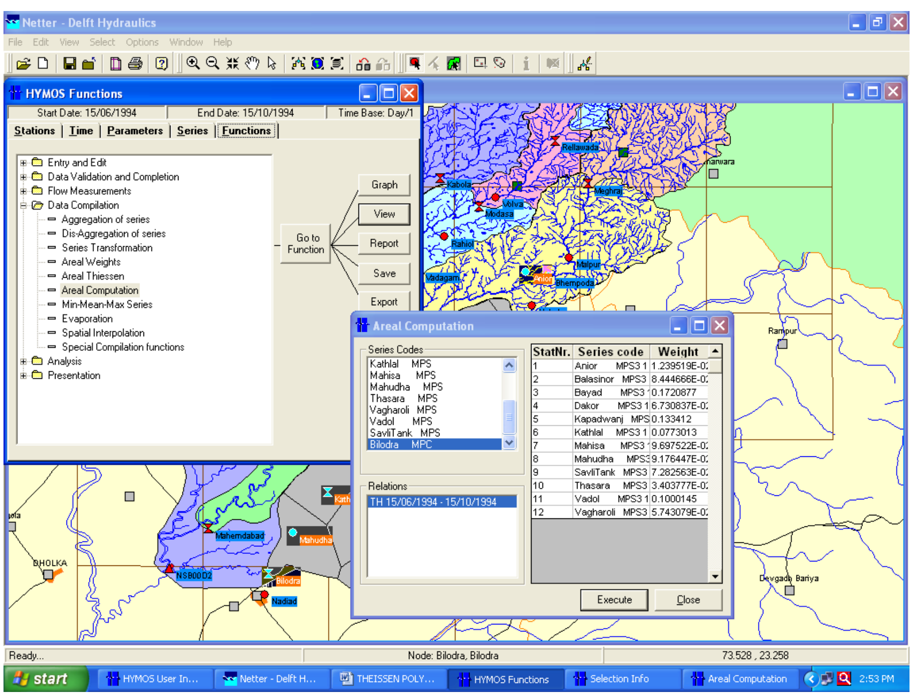


Fig.20

Fig.21 on next page shows average rainfall variation over time and its values as well. These are had by selecting Graph and View options one at a time. To save Bilodra MPC series, user may refer to steps suggested for **Fig.8**. Average series thus generated can be used to simulate runoff over the basin by following anyone of the numerous rainfall runoff models and soft tools such as HEC-HMS. To know more about these methods, user is suggested to refer to '***Training module no.11'*** .

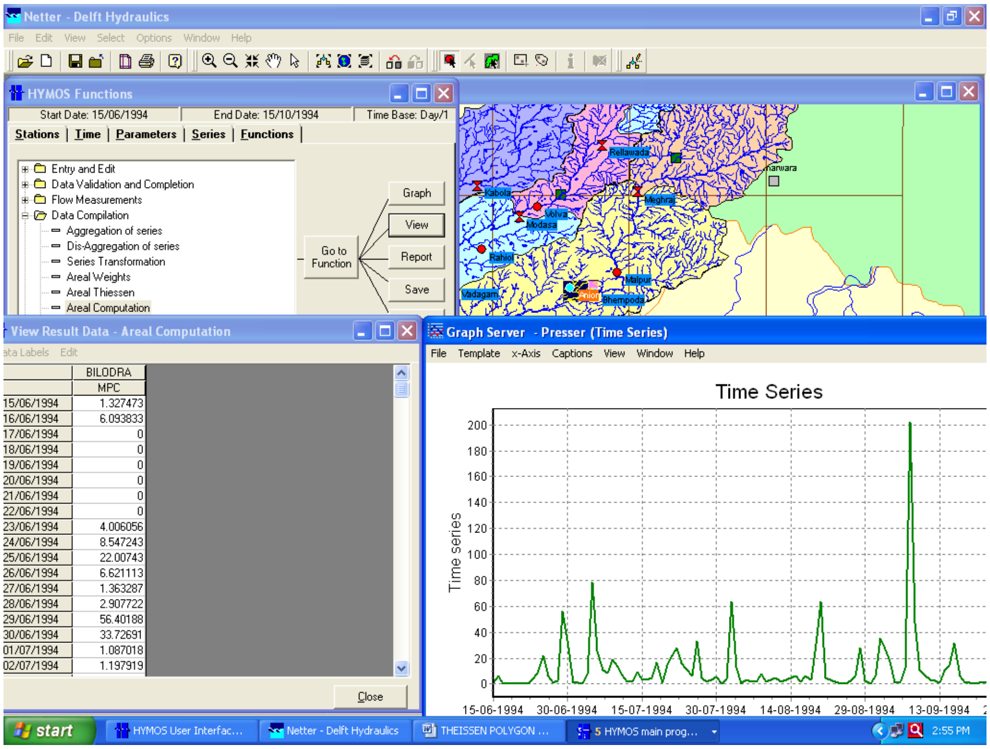


Fig.21

(E) Aggregation of Rainfall series

Subsequent illustrations focus on the rainfall series aggregation from hourly basis to daily basis. This needs rainfall between 09.30 hr of a day and 08.30 hr following day added together with tagging this value as daily rainfall for second day. In SWDES and HYMOS, hourly rainfall series is denoted by MPA series. To perform this exercise, let us pick up Anior station of Kheda basin on Netter screen and select time period and time base as indicated in **Fig.22.** Select Aggregation of series option under Data compilation folder and click on go to Function button. This opens up Window as in **Fig.23.** User has to select Anior MPA series with time shift option as 1 by using spin button by it. Execute command adds all values and places it against following day as daily rainfall data. Selecting View and Graph button on Hymos function window show calculated figures.

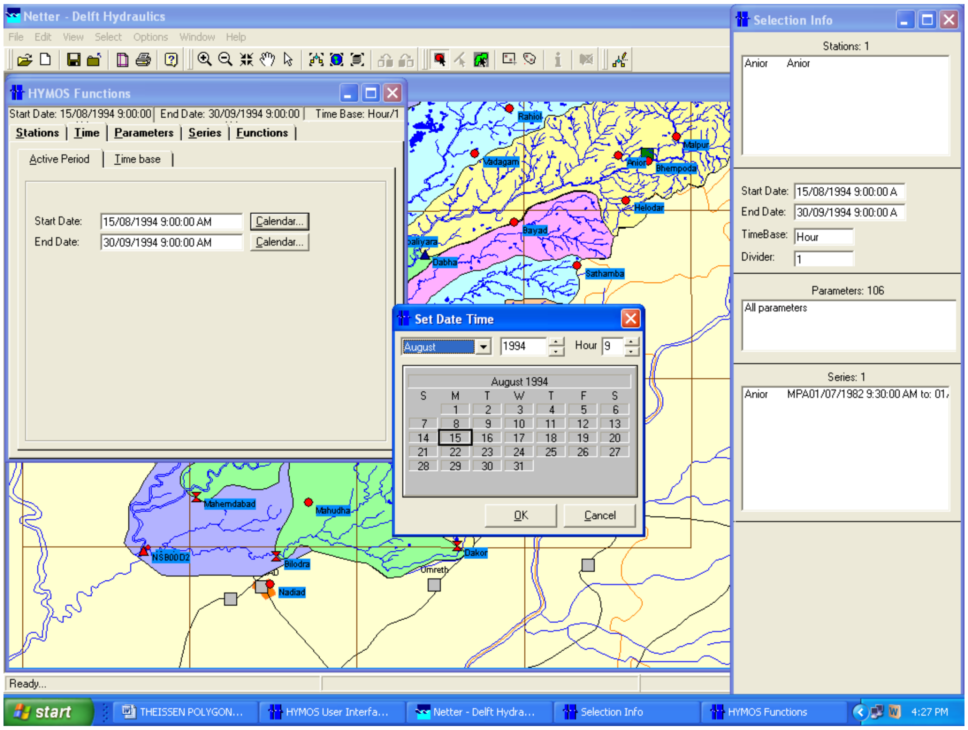


Fig.22

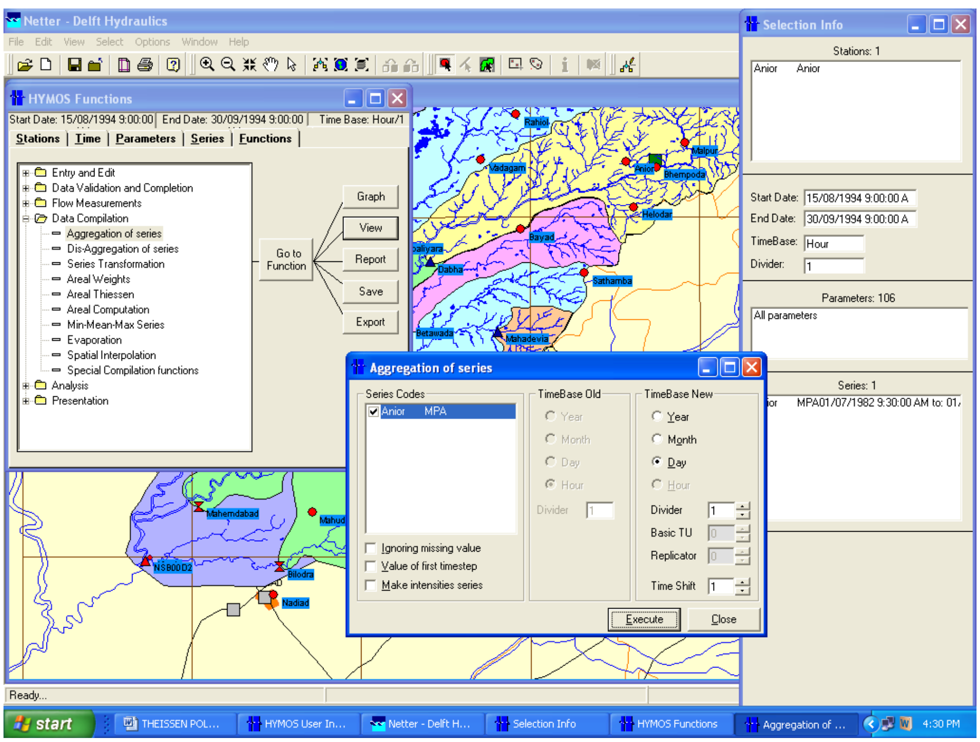


Fig.23

Anior daily series is now required to be saved. This task is attained by selecting 'Save' on Hymos Function window. This brings up another window (**Fig.24).** Press 'Change selected series ID' button to have another window shown lower left corner. Highlight correct series and station name and press 'ok' . Chosen station and series would appear on upper right window. Change the Check slot on and press 'ok' . This saves the daily series for retrieval later.

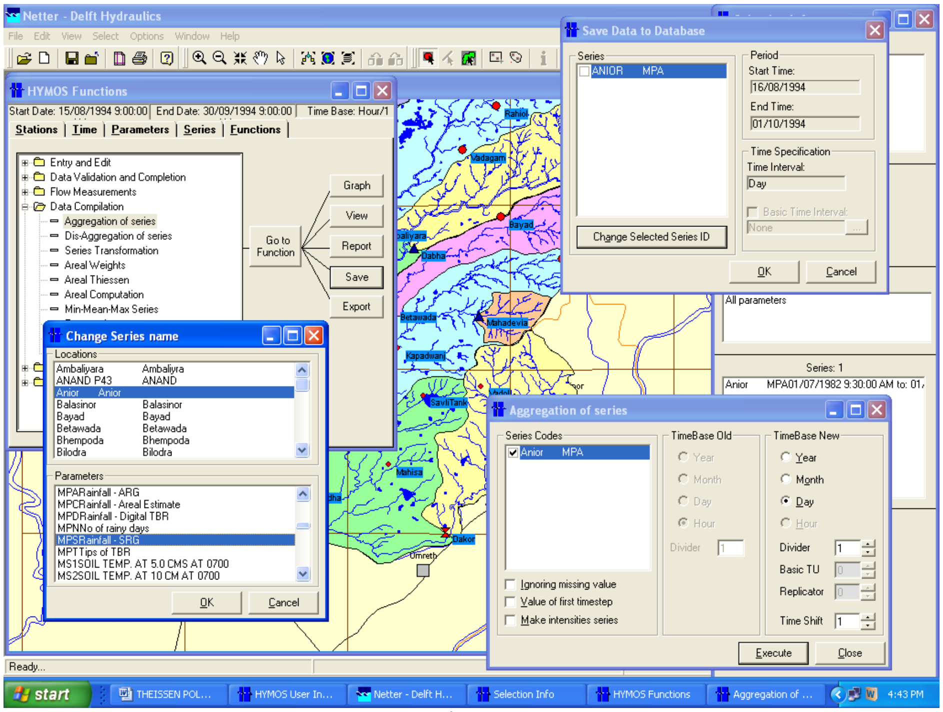


Fig.24

[**Go to Contents**]

RAINFALL-RUNOFF VALIDATION

This chapter is primarily aimed at comparing the average annual rainfall over the basin with annual runoff observed at terminus station of the basin. An average ratio between the two is also termed as runoff coefficient of the basin. Accuracy observed in validation of water level; rainfall records; & fitting a rating curve is central to the accurate result at the end of rainfall runoff comparison exercise. This exercise begins with the selection of a series of station as highlighted in **Fig.1. Stations are Bilodra, Thasara, Kapadwanj, Balasinor, Bayad, Sathamba, Helodar, Savlitank, Vadol, Kathlal, Mahudha, Mahisa, Dakor & Vagharoli.** Stations selected are in and around Bilodra basin and their location is crucial to draw polygons by the software. Having finished with marking of these stations, user has to invoke Hymos Function window. A similar hand-out (average rainfall over Bilodra basin by Thiessen polygon method) has been illustrated in one of the preceding chapters and therefore, user may notice brevity at a few places in paragraphs to come.

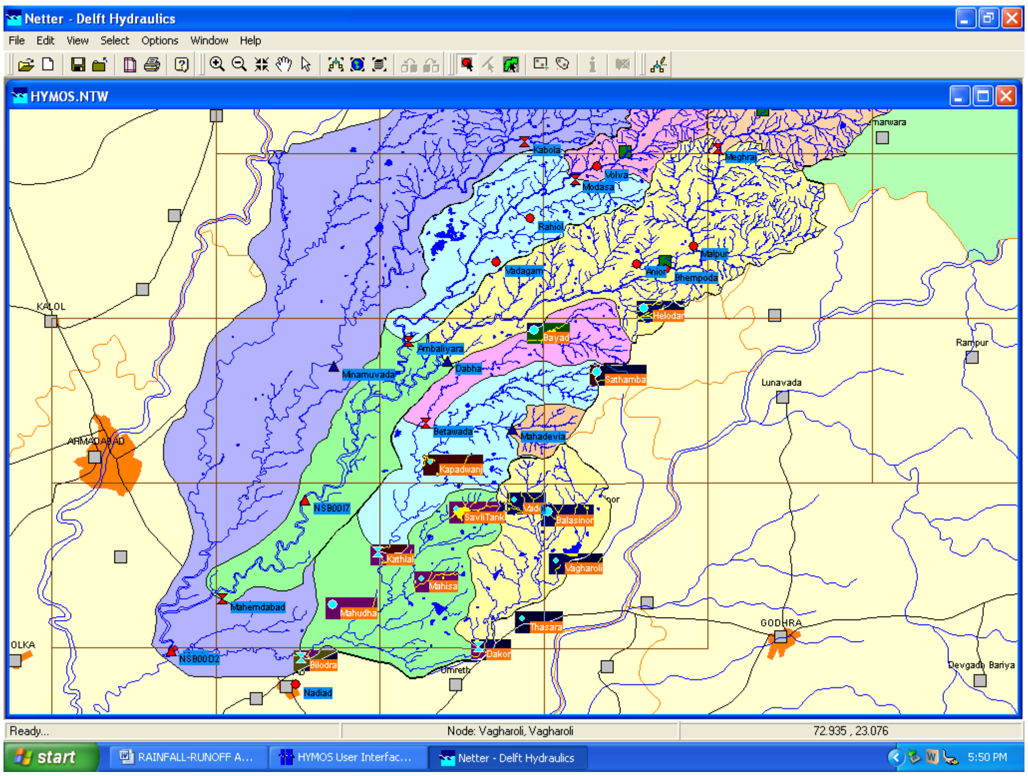


Fig.1

Time period is selected from 01/01/1997 to 01/01/1998 while time base is in day. One of prerequisite to run Thiessen polygon function of the software successfully, the selected MPS series of stations must not have breaks/discontinuity in between. To verify the status of all such series, user may use Time Series Graphs function and selecting Data availability graph type option on relevant window (**Fig.2**). Use of Graph and Report button on Hymos function window help user detect one or more series having breaks in between. A glance at **Fig.3** indicates Bilodra MPS series as one of the series not fit for selection and should be deselected when Thiessen polygon function is invoked.

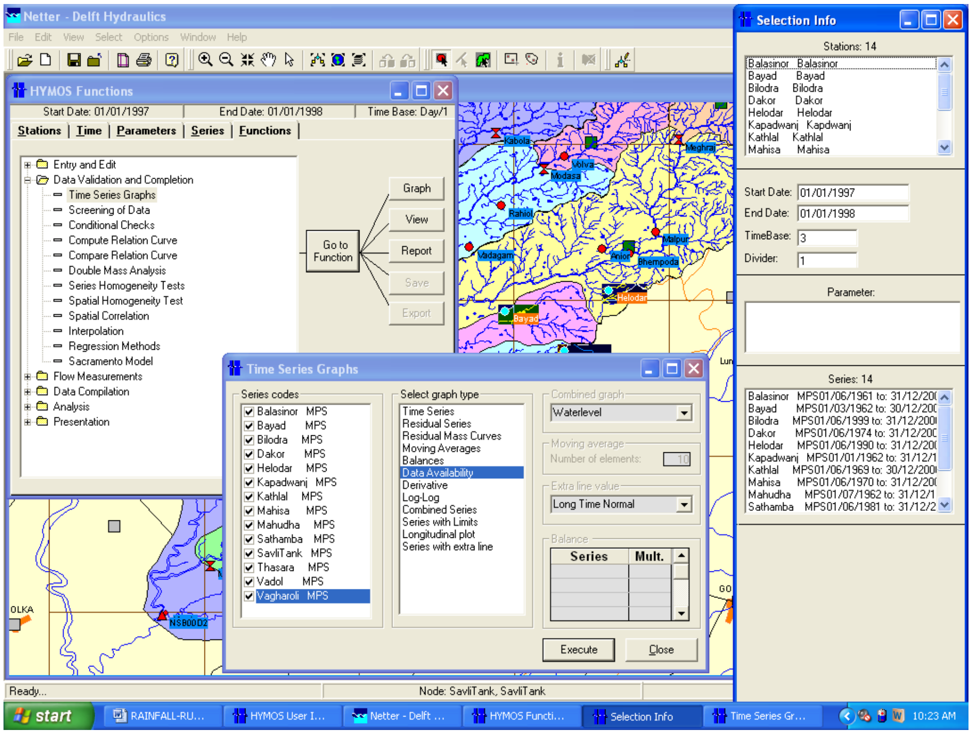


Fig.2

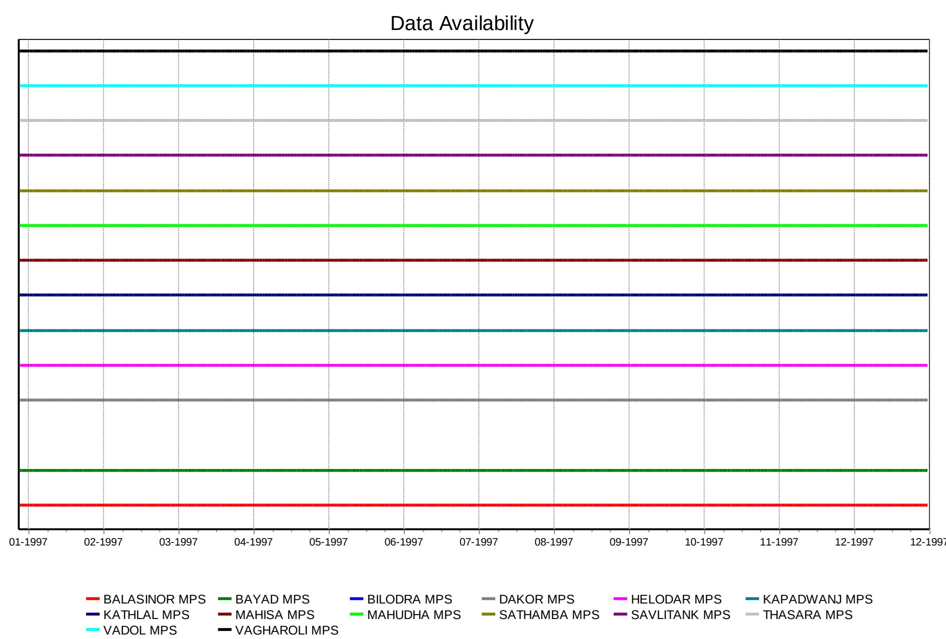


Fig.3

MPS series of all stations is a point rainfall series. With weight assigned to each station by Thiessen polygon method, an averaged series signifying areal rainfall over the basin is determined. We must have a blank MPC – Rainfall Areal Estimate series to store these values. Three figures **Fig.4, 5 & 6** in a row guide the user to create an empty Bilodra MPC series.

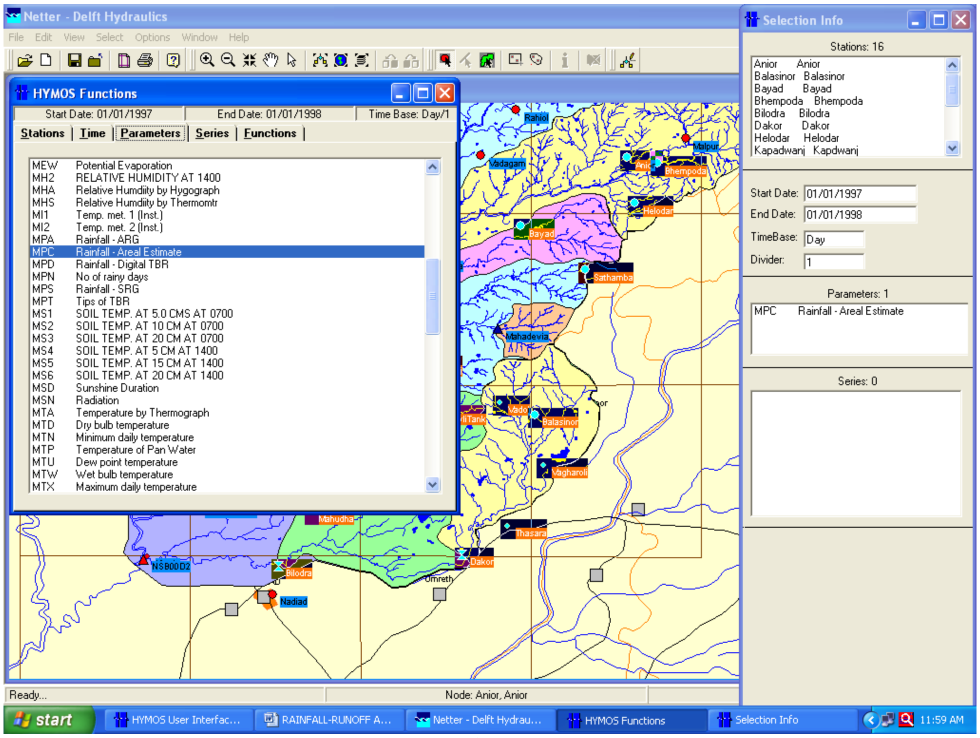


Fig.4

(Parameter tab; scroll up/down to select MPC series)

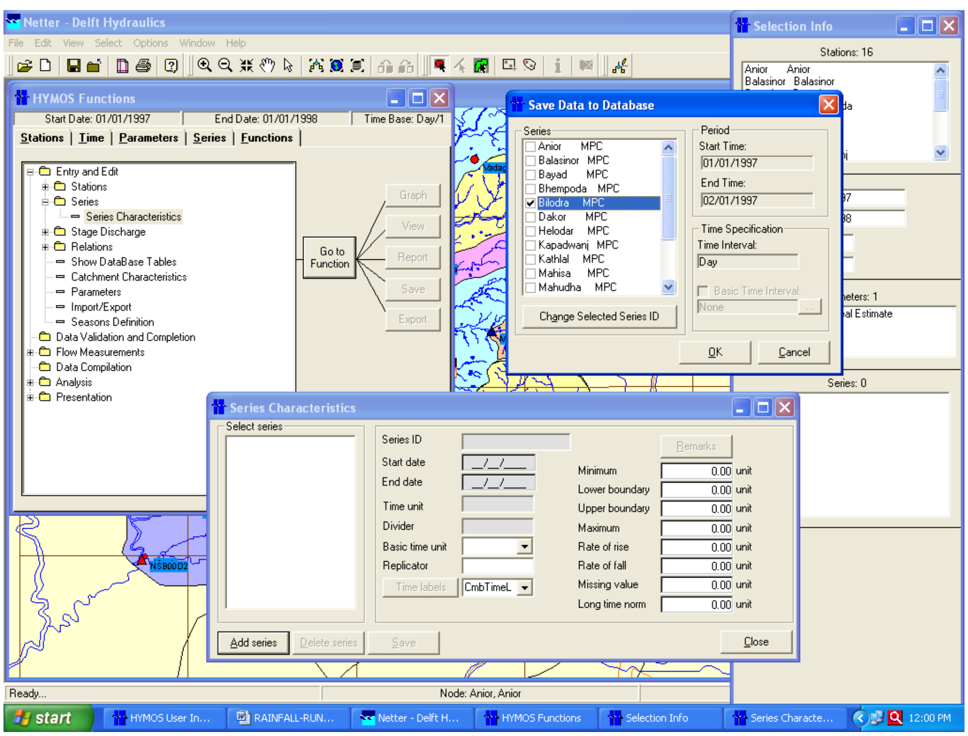


Fig.5

(Add series; check on for Bilodra MPC & ok**)**

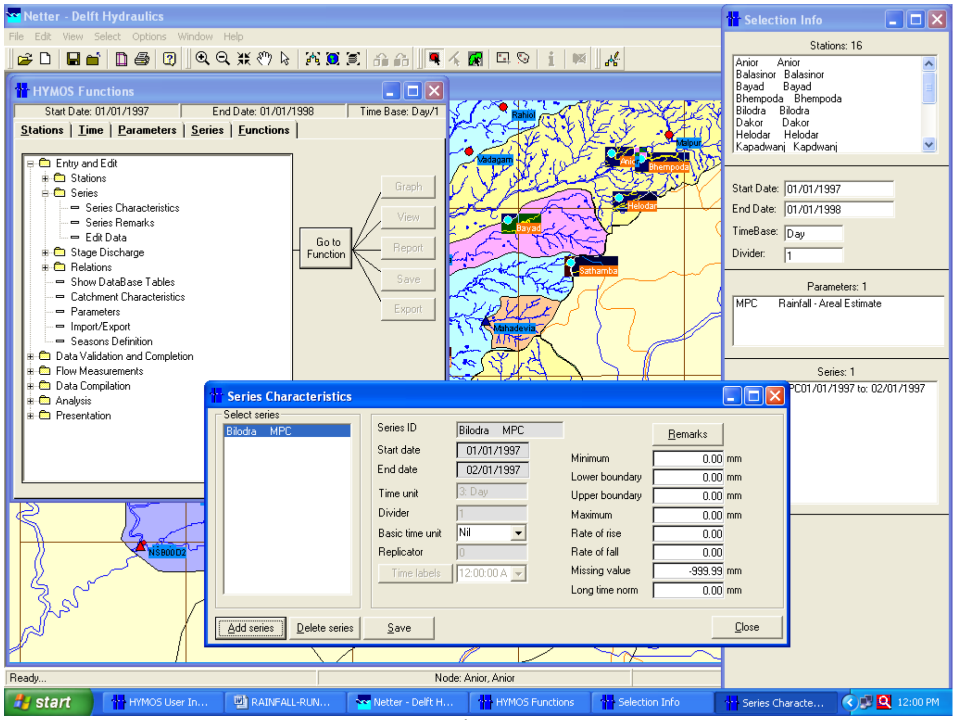


Fig.6

(Save series**)**

Now, in addition to MPC select MPS series from parameters tab and come back to Function tab option. Bring up Thiessen window as shown in **Fig.7.** Populate empty part of the window as indicated therein by using >> button.

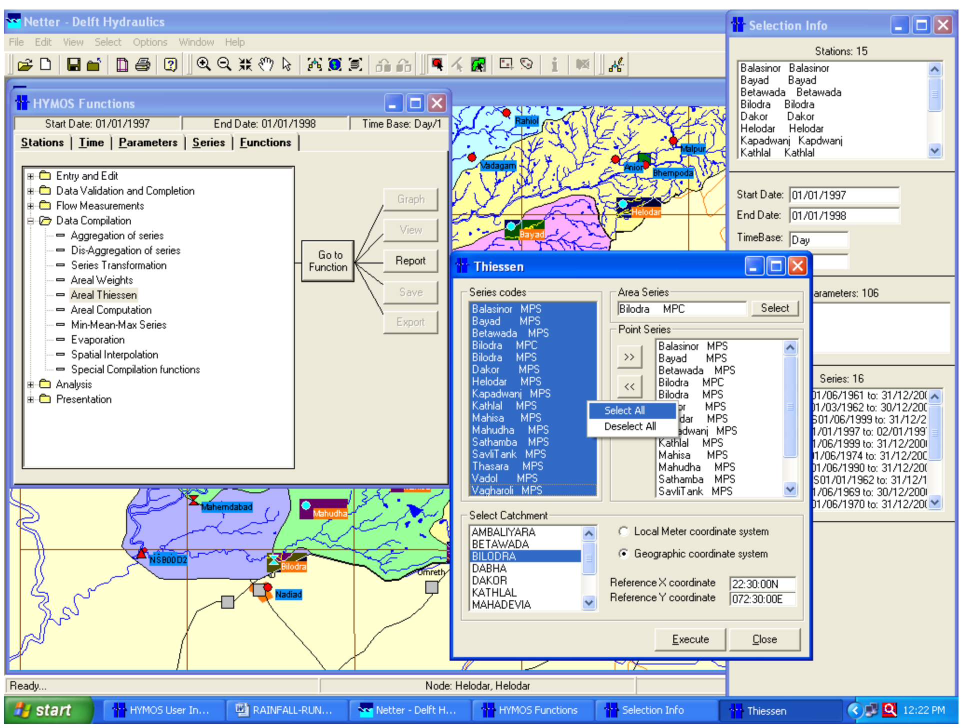


Fig.7

Pl recall our initial findings that Bilodra MPS is a blank series so it is removed from point series along with Bilodra MPC series before executing the function (**Fig.8**). Windows in **Fig.9** are used to overlay polygon layer on Netter screen.

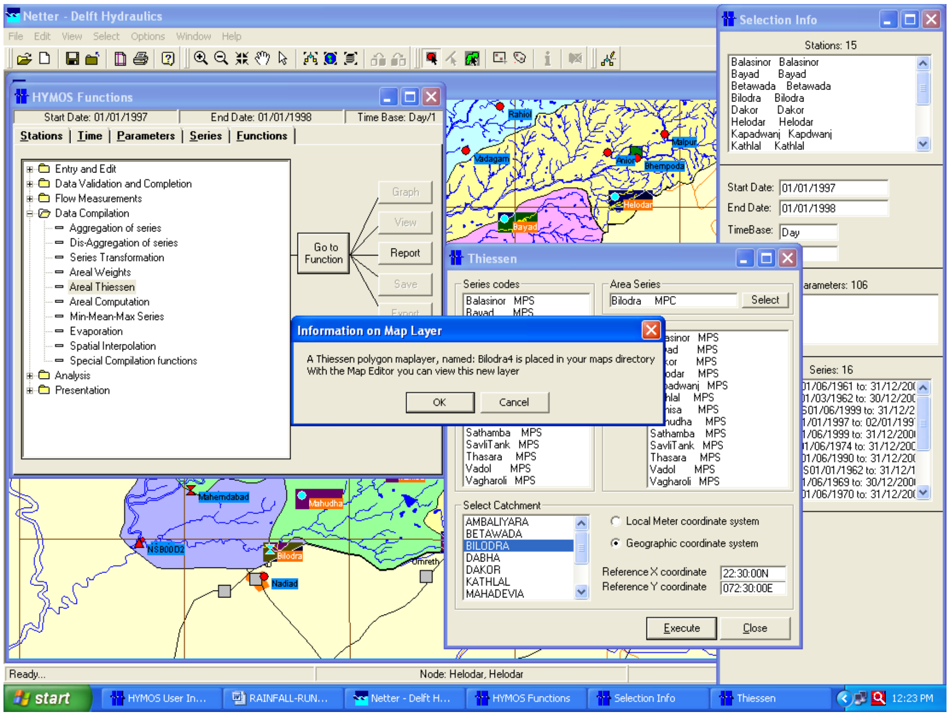


Fig.8

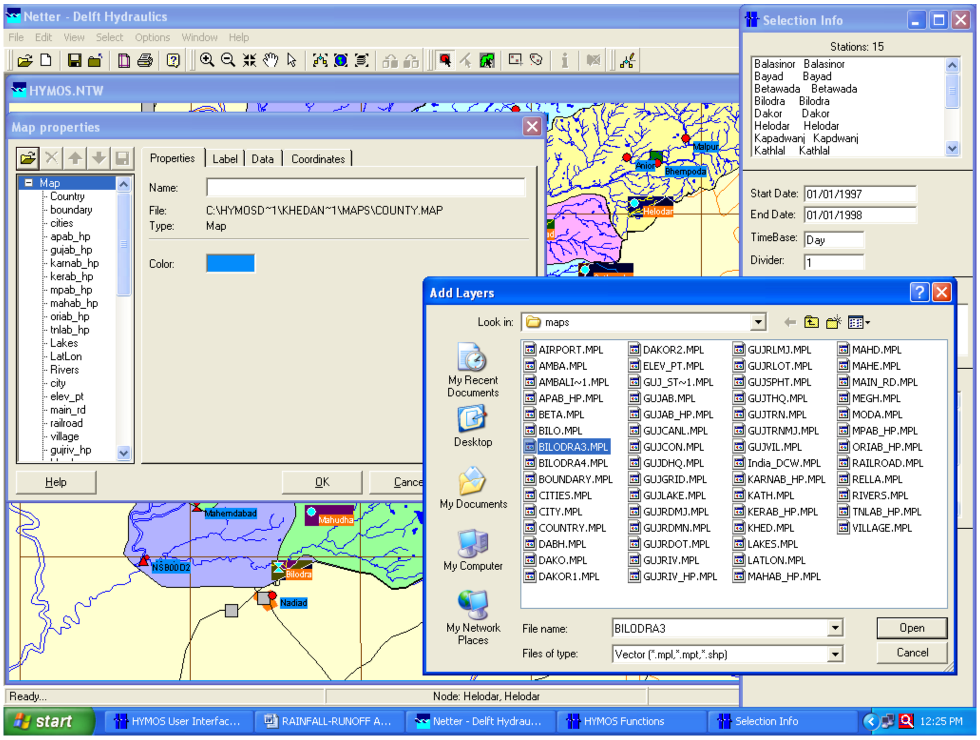


Fig.9

By selecting Areal Computation window; Bilodra MPC series; & Thiessen layer as created by HYMOS and executing the function (**Fig.10**), HYMOS generates areal estimates series in **mm/day** and can be seen by visiting Graph and View buttons on Hymos Function window (**Fig.11**)

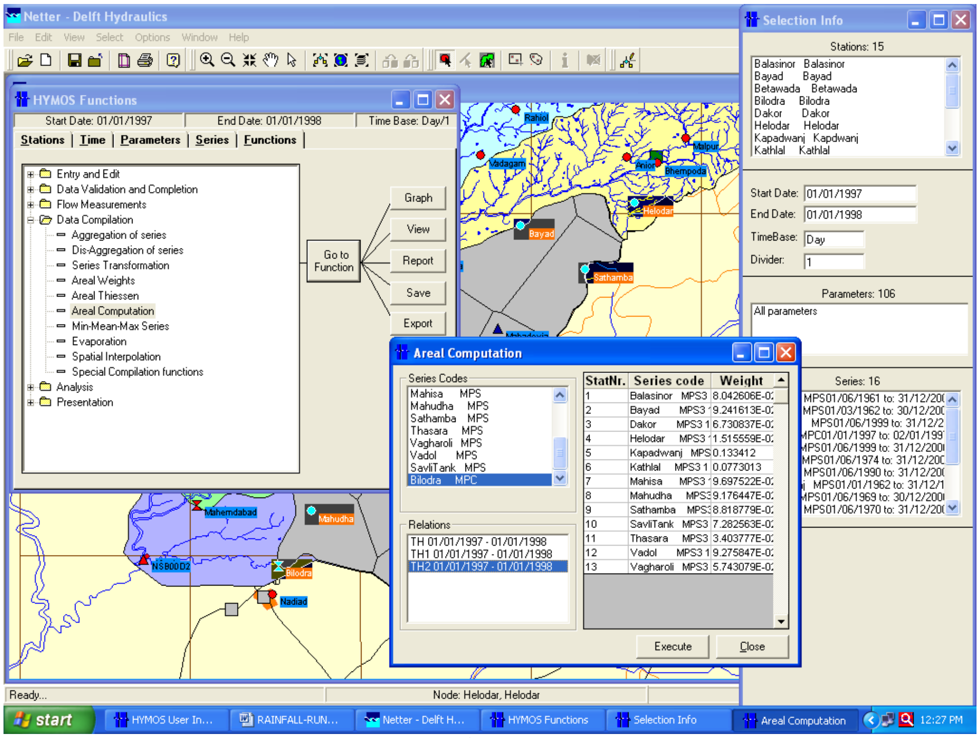


Fig.10

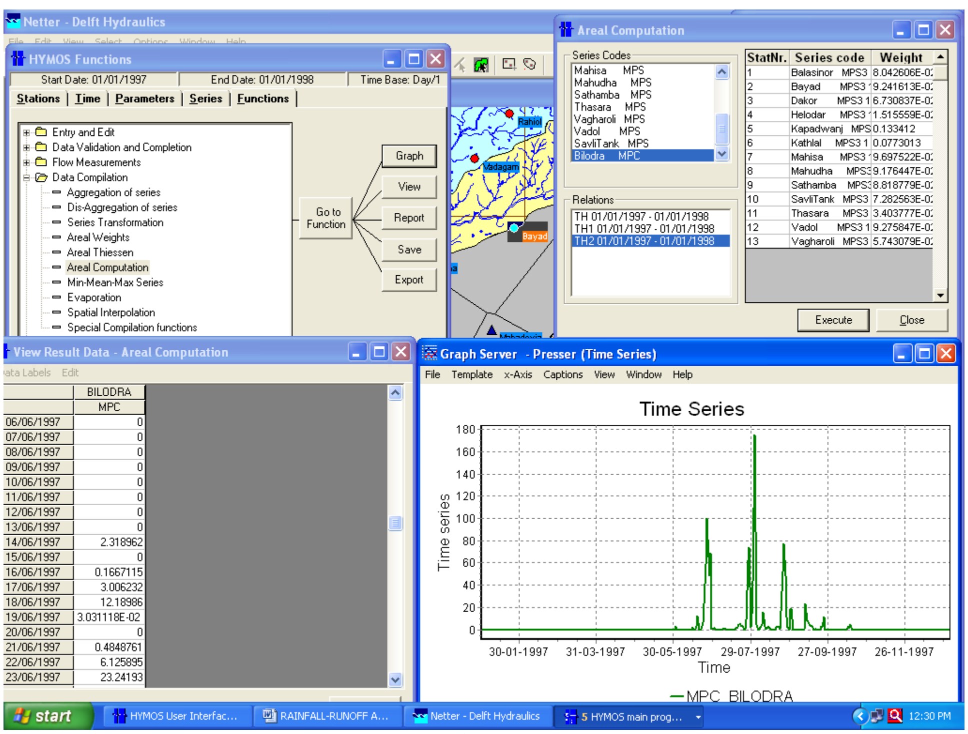


Fig.11

Areal Estimates for Bilodra catchment needs to be saved and is accomplished by save option on Hymos function window. This presents another window. Make appropriate selection and press 'ok' (**Fig.12**).

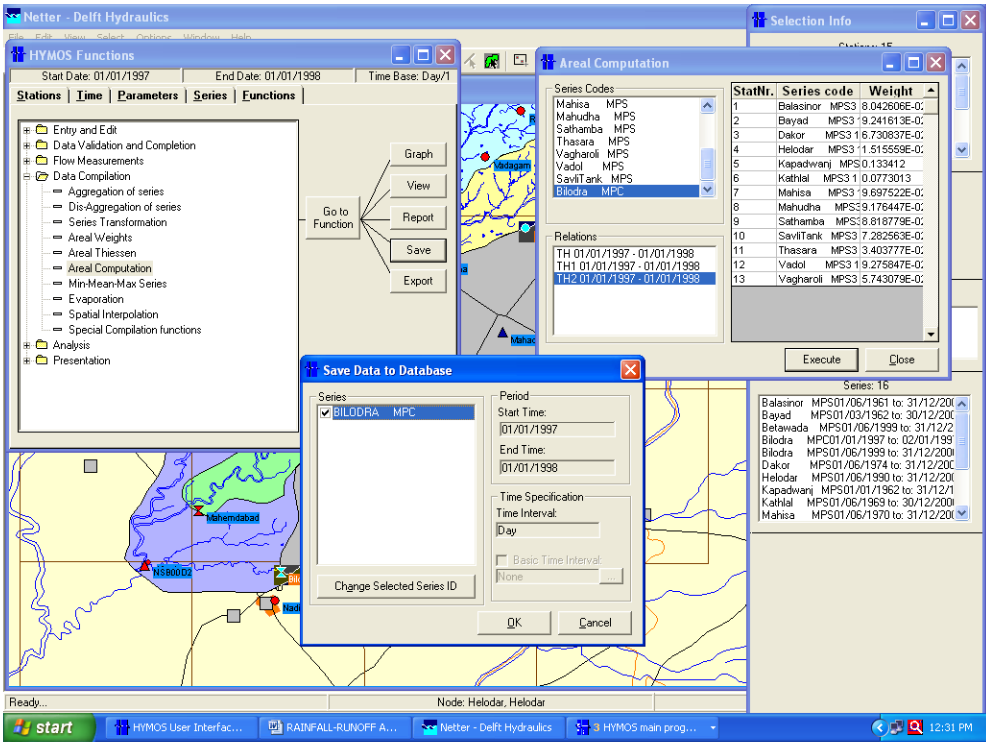


Fig.12

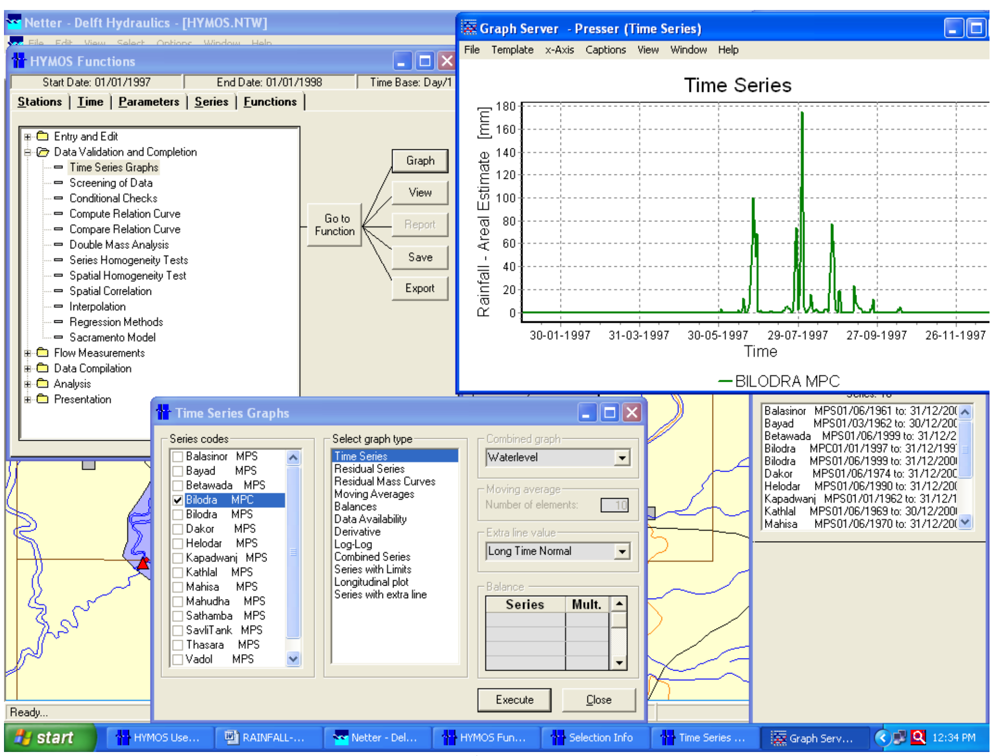


Fig.13

Time series Graph option under Data Validation and completion folder (**Fig.13**) offers a window to verify the saved Bilodra MPC series after steps shown in **Fig.12**. Reaching this stage symbolizes the end of determining areal rainfall for a basin of user defined period; which can be used for rainfall runoff simulation; event based runoff calculation for flood forecasting etc. by adopting numerous methods and soft tools. In the current example, we limit our study to compare it with runoff of the basin for validation of record and to calculate runoff coefficient only. Subsequent illustrations head towards distilling Bilodra runoff series.

To start with, user should use parameter tab to deselect MPC and MPS series and change time base to hr. Next a few screenshots are used to investigate and generate some series prior to begin with fitting of rating cure. It is usually seen that water level at several sites are recorded with reference to some assumed gauge zero value which when added to gauge reading represents water level with respect to mean sea level. Steps in **Fig.14** are followed to pick the gauge zero value initially stored at Bilodra site which is the terminus station for Bilodra basin. Gauge zero for period under consideration is 26.50m.

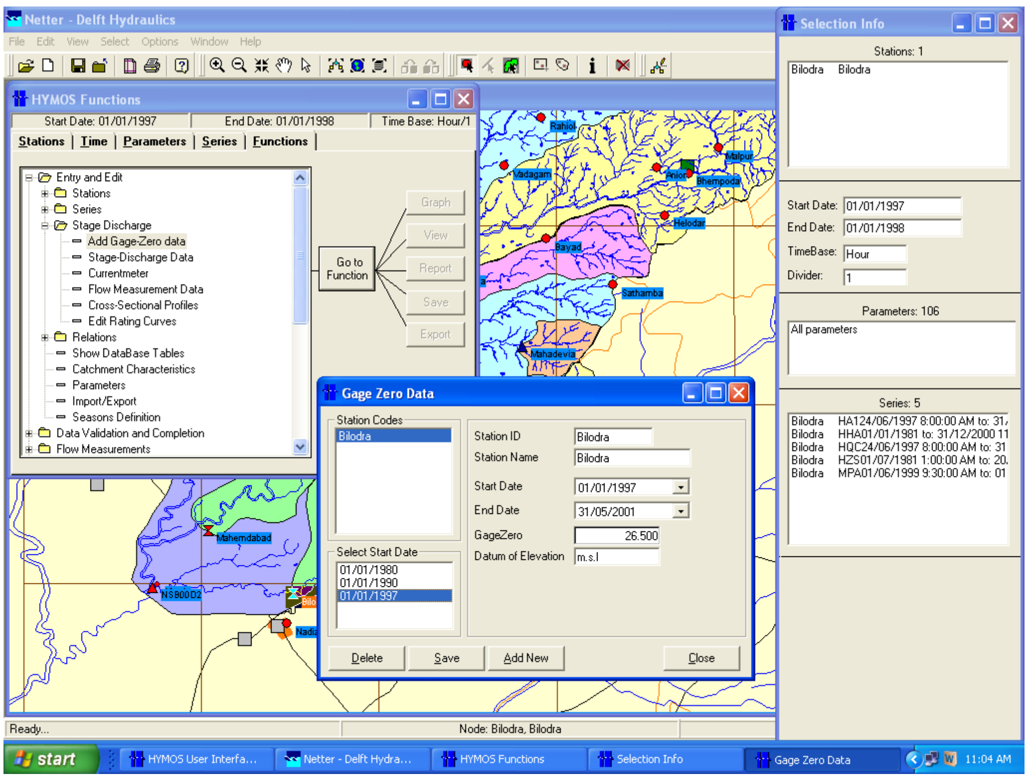


Fig.14

Next move is to create an empty Bilodra HHA series by steps discussed/illustrated several occasions earlier such as creating Bilodra MPC series **(Fig.15).** The step begins with selecting HHA series under Parameter tab. Upon finishing the blank series creation steps, don' t forget to deselect HHA series before getting ready for next steps. Bilodra HZS series is a gauge level series and needs to be added to 26.5m (gauge zero of this site) to create Bilodra HHA series. **Fig.16** guides the reader to perform this task and save it to memory.

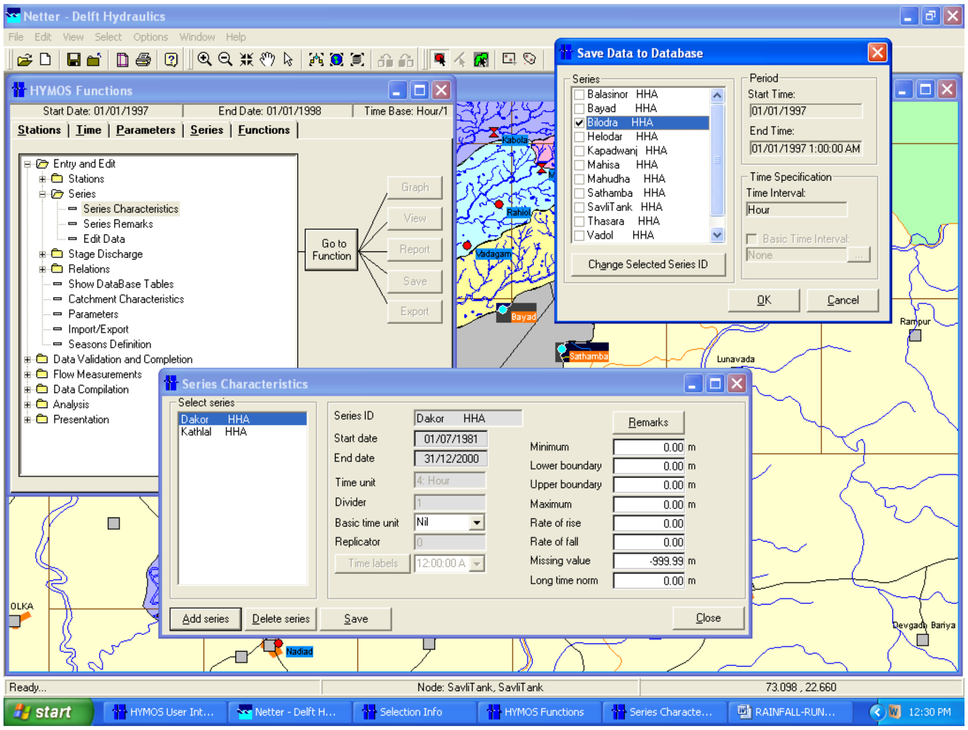


Fig.15

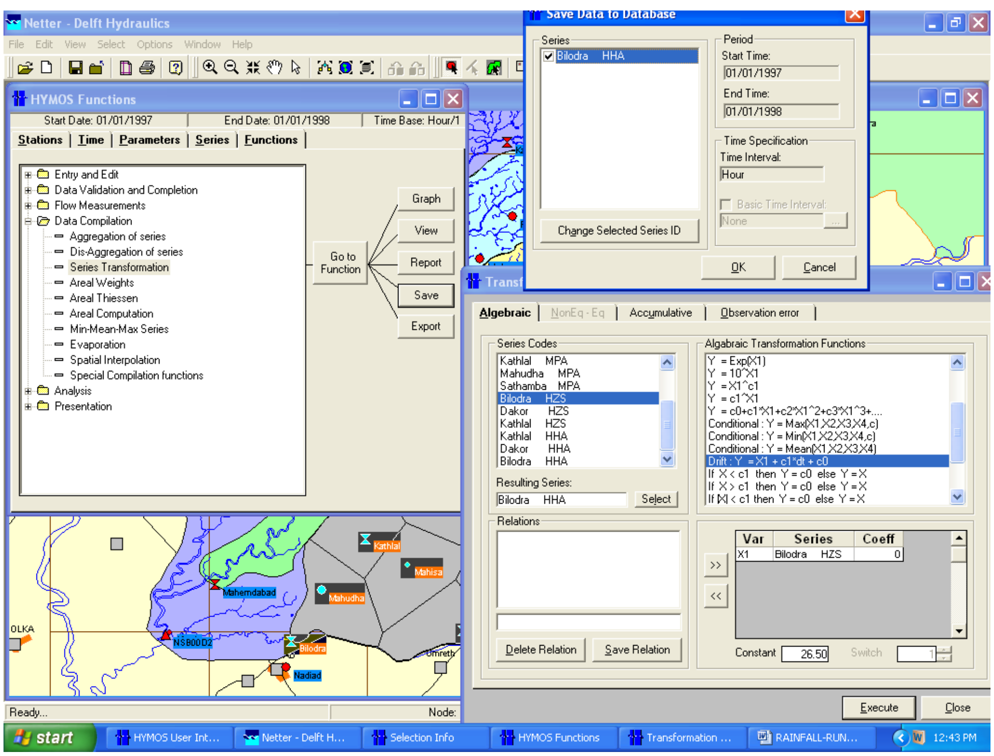


Fig.16

Fig.17 & Fig.18 are two additional screenshots set-up appended here for exploring useful hints. Former is to seek highest/max level touched by water (**36.45m**); while cross-sectional geometry in the latter suggests a level of possible kink in G-D plot. From plot, this zone appears around **27.5 or so**. This piece of information is invaluable when fitting a rating curve.

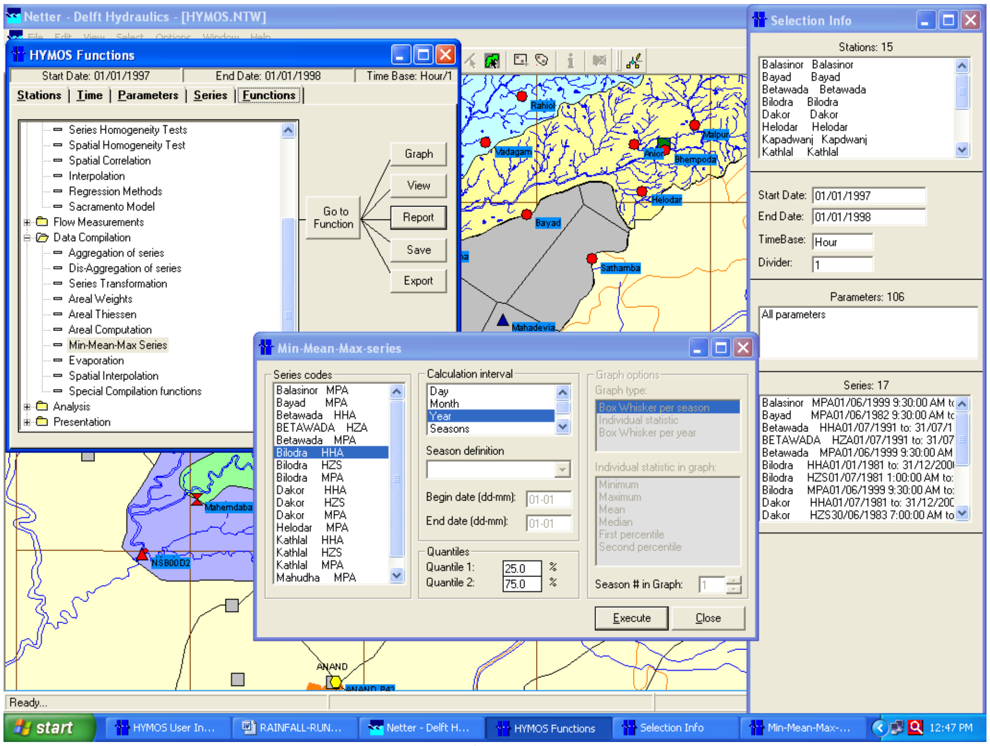


Fig.17

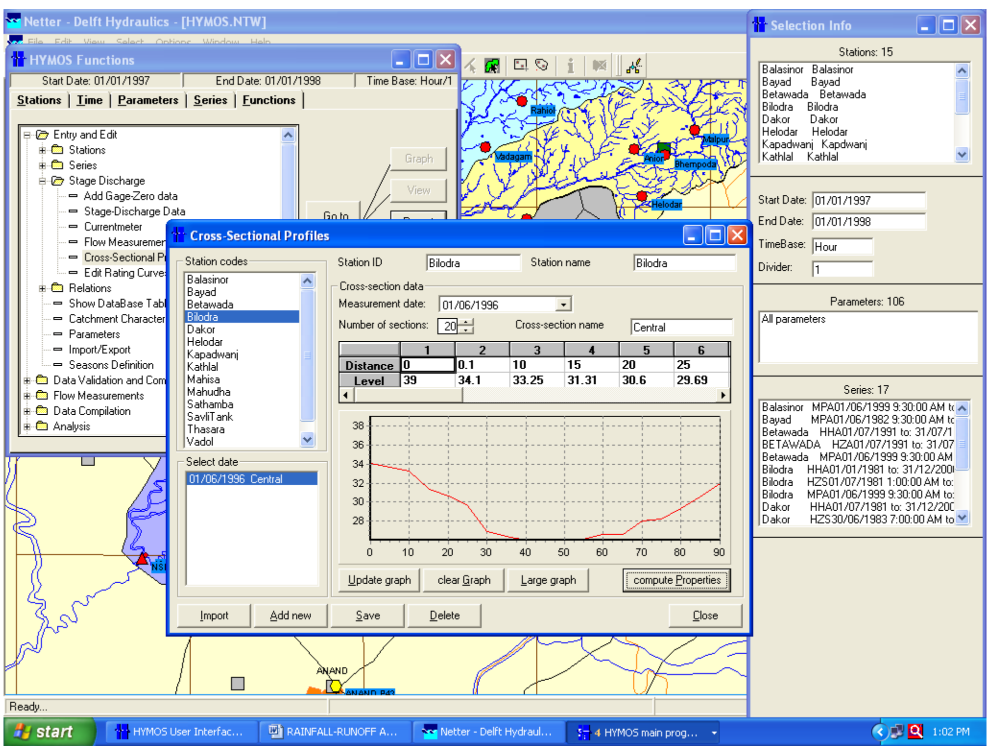


Fig.18

This point beyond, screenshots of HYMOS displays steps required to fit a rating based on water level and corresponding observed discharge data. Fitting a rating curve needs comprehensive understanding of variables involved (water level and discharge); factors introducing scatters of plot; possible location of kinks in rating curve; developing two or more curves for different periods; validation of curve so defined; retention, modification/removal of outlier; statistical parameters and their significance in defining a curve. Lack of knowledge may lead to erroneous fitting of equation having serious bearing on transformed no-break discharge series. Readers are, therefore strongly recommended to refer to ***'Training Module no. 29 & 30 and IS 15119: 2002.*** Fitting a rating curve has already been demonstrated in earlier chapters, & hence steps needed for it have been knowingly skipped here and only involved screenshots have been produced. ***This goes till Fig. 24.*** User lacking familiarity with these figures/steps may revisit earlier chapters to gain better acquaintances with it. This will speed up their handling with the software and current example.

User is also suggested to often visit the report file to check the %standard error of the plotted points around a best fit line and vary the ranges suitably keeping river geometry in mind. A wider dispersion of plot yields higher st error while converse is observed for thinner scatter. What is admissible limit for st error of such plot? A frequently asked question but yet not convincingly defined or understood. It is also recommended to validate the curve before attempting series transformation function of HYMOS.

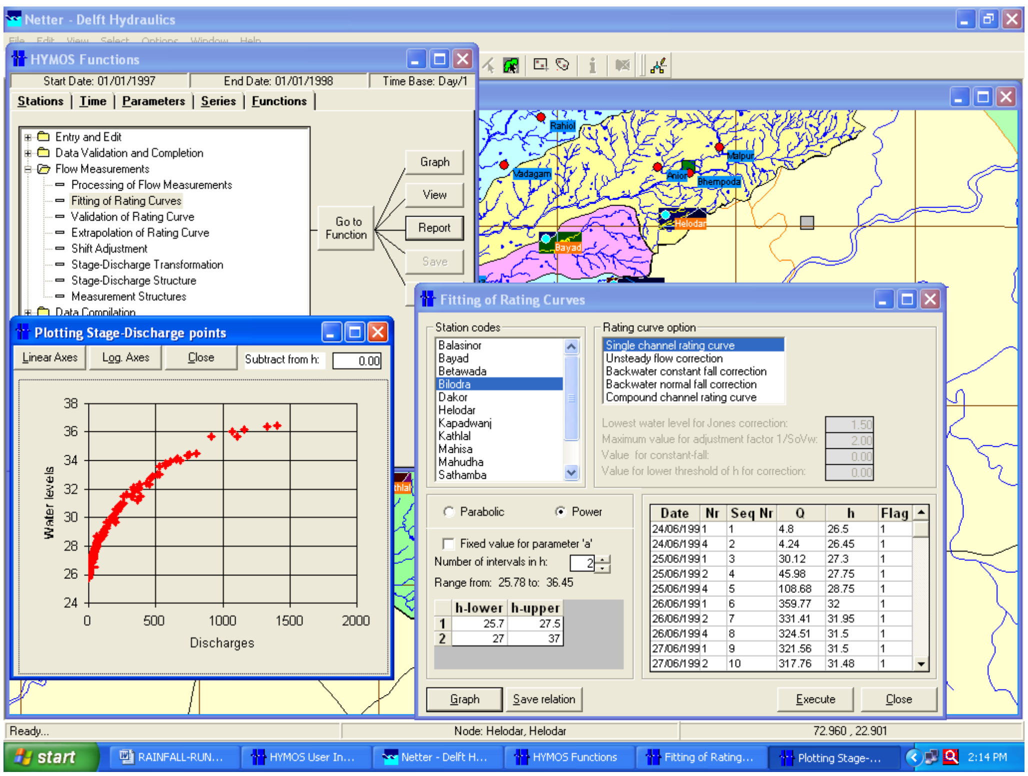


Fig.19

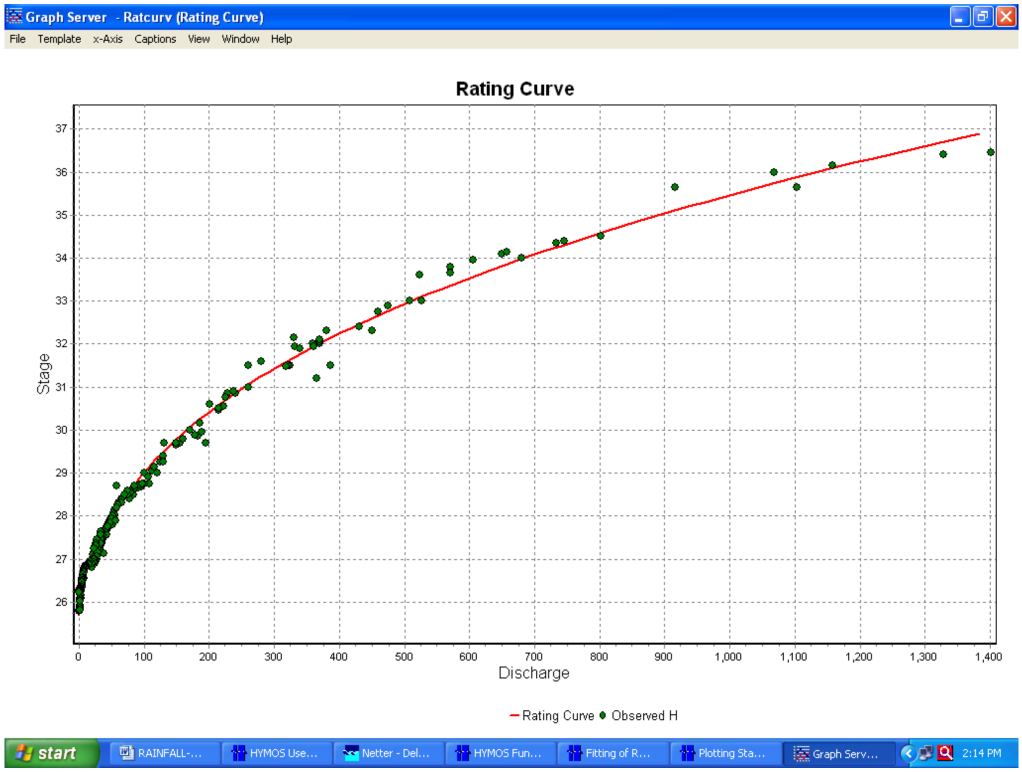

Graph Server - Ratcurv (Rating Curve)
File Template x-Axis Captions View Window Help
Rating Curve
Stage
Discharge
Rating Curve
Observed H

Fig.20

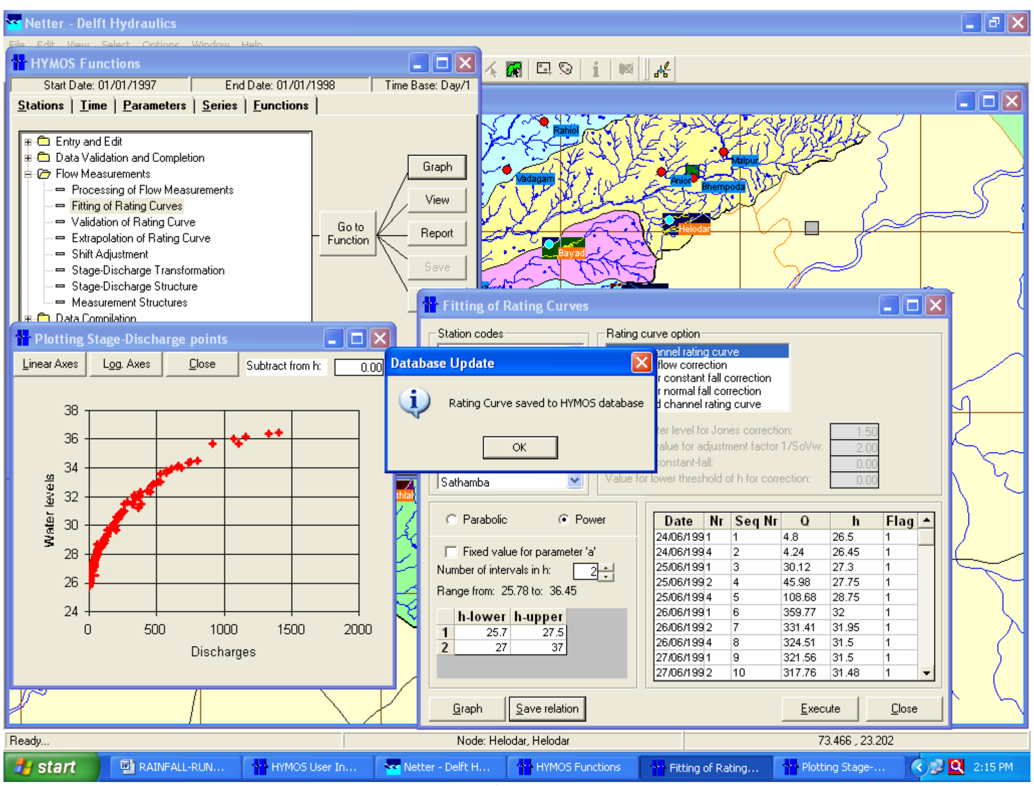

Netter - Delft Hydraulics
HYMOS Functions
Start Date: 01/01/1997
End Date: 01/01/1998
Time Base: Day/1
Stations
Time
Parameters
Series
Functions
Entry and Edit
Data Validation and Completion
Flow Measurements
Processing of Flow Measurements
Fitting of Rating Curves
Validation of Rating Curve
Extrapolation of Rating Curve
Shift Adjustment
Stage-Discharge Transformation
Stage-Discharge Structure
Measurement Structures
Data Compilation
Go to Function
Graph
View
Report
Save
Plotting Stage-Discharge points
Linear Axes
Log. Axes
Close
Subtract from h:
Water levels
Discharges
Fitting of Rating Curves
Station codes
Rating curve option
Database Update
Rating Curve saved to HYMOS database
OK
Sathamba
Parabolic
Power
Fixed value for parameter 'a'
Number of intervals in h:
Range from: 25.78 to: 36.45
h-lower
h-upper
Date
Nr
Seq Nr
Q
h
Flag
Graph
Save relation
Execute
Close
Ready...
Node: Helodar, Helodar

Fig.21

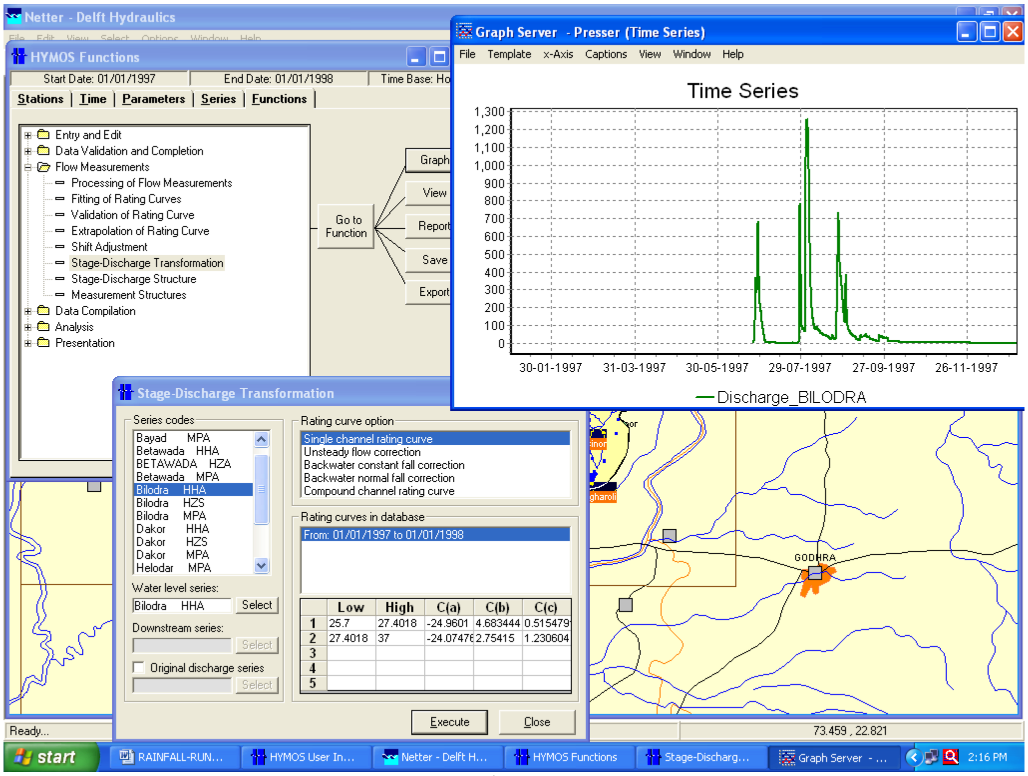

Netter - Delft Hydraulics
HYMOS Functions
Start Date: 01/01/1997
End Date: 01/01/1998
Stations | Time | Parameters | Series | Functions
Entry and Edit
Data Validation and Completion
Flow Measurements
Processing of Flow Measurements
Fitting of Rating Curves
Validation of Rating Curve
Extrapolation of Rating Curve
Shift Adjustment
Stage-Discharge Transformation
Stage-Discharge Structure
Measurement Structures
Data Compilation
Analysis
Presentation
Go to Function
Graph
View
Report
Save
Export
Graph Server - Presser (Time Series)
File Template x-Axis Captions View Window Help
Time Series
Discharge_BILODRA
Stage-Discharge Transformation
Series codes
Rating curve option
Single channel rating curve
Unsteady flow correction
Backwater constant fall correction
Backwater normal fall correction
Compound channel rating curve
Rating curves in database
From: 01/01/1997 to 01/01/1998
Water level series:
Bilodra HHA
Downstream series:
Original discharge series
Execute
Close
GODHRA
Ready...
73.459 , 22.821
start
2:16 PM

Fig.22

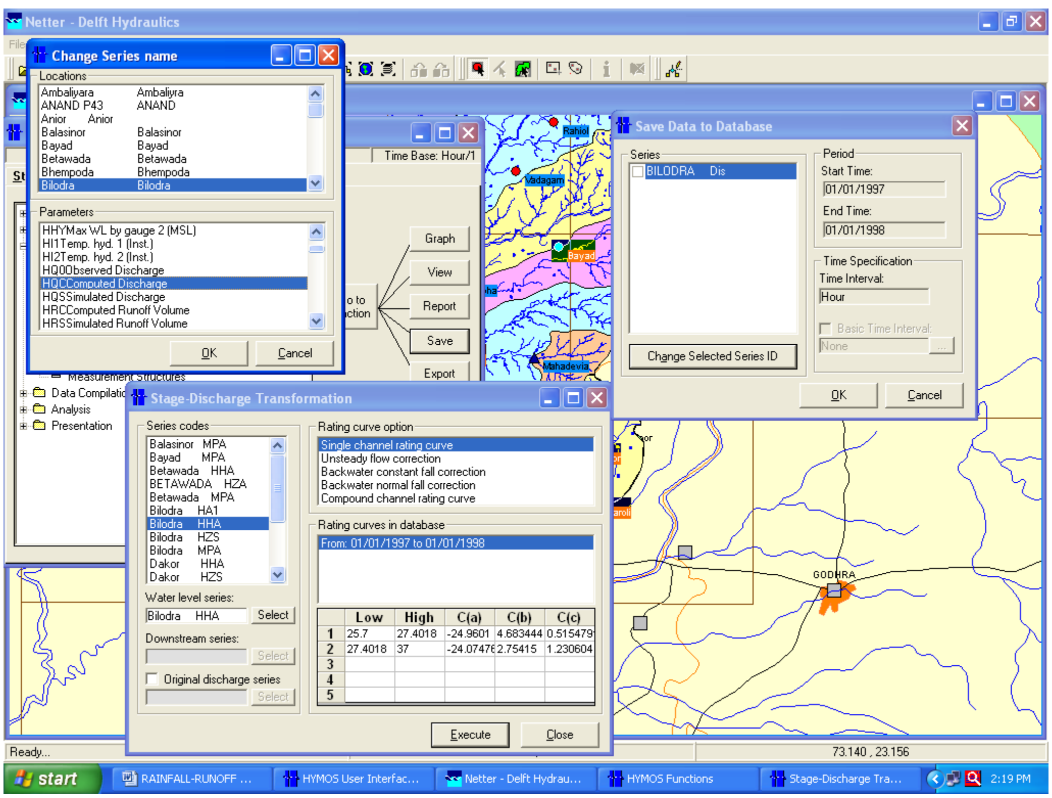

Netter - Delft Hydraulics
Change Series name
Locations
Parameters
HQCComputed Discharge
OK
Cancel
Save Data to Database
Series
BILODRA Dis
Period
Start Time:
01/01/1997
End Time:
01/01/1998
Time Specification
Time Interval:
Hour
Change Selected Series ID
Stage-Discharge Transformation
Series codes
Rating curve option
Single channel rating curve
Rating curves in database
From: 01/01/1997 to 01/01/1998
Water level series:
Bilodra HHA
Execute
Close
GODHRA
Ready...
73.140 , 23.156
start
2:19 PM

Fig.23

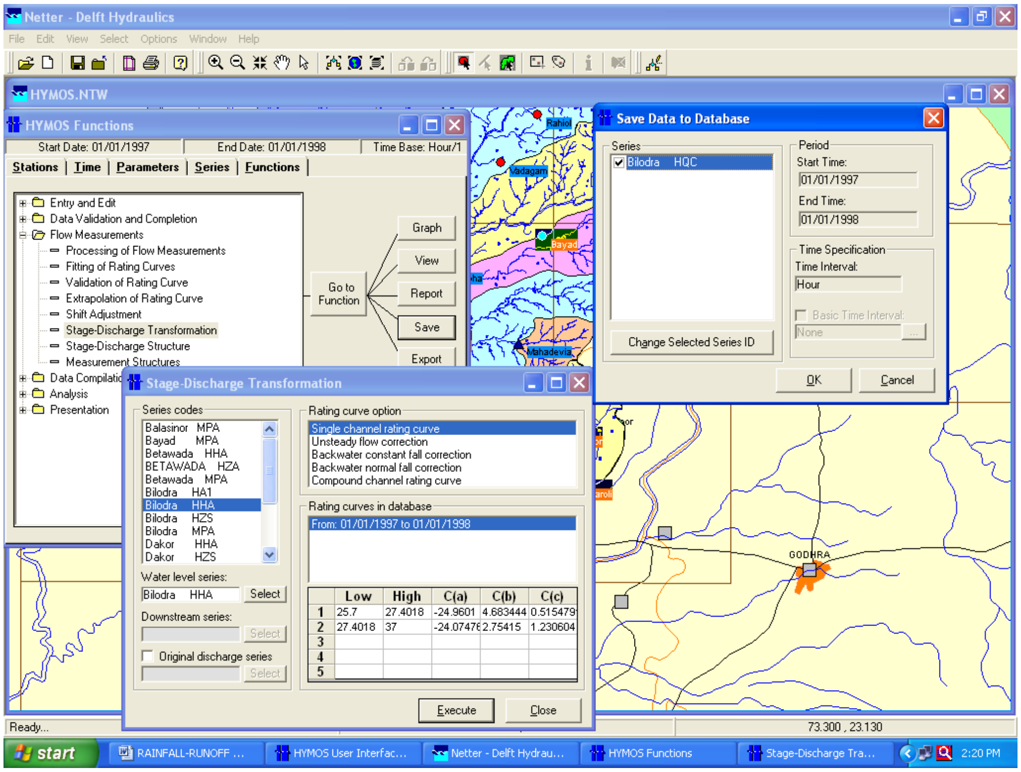


Fig.24

Steps till **Fig.24** save Bilodra HQC in m3/sec (or cumec) on hourly basis as HHA is an hourly series (notice that at present time base is hr). A Bilodra MPC on daily basis has already been created and to compare runoff with it Bilodra HQC series needs to be aggregated to compute daily discharge (mean daily discharge averaging hourly discharge from 0100 hr to 0000hr for each day). A daily discharge will be in m3/sec and must be converted into mm a day runoff to be eligible for comparison with daily rainfall or MPC series. An excerpt of ***Training Module no. 40*** is presented hereunder to have runoff series in mm. Bilodra catchment area is 2121.44 skim. User may use function shown in **Fig.25** to retrieve catchment features. Applying this excerpt, a factor of 0.04073 is required to be multiplied with Bilodra HQC daily series.

Volume is simply the rate in m^3/sec (cumecs) multiplied by the duration of the specified period in secs., i.e. for daily volumes in cubic metres with respect to daily mean flow Q_d in cumecs following equation may be used:

$$V_d\,(cum) = (24 \times 60 \times 60 \text{ seconds})\, Q_d\,(cumecs) = 86400\, Q_d \quad (cum) \qquad (3)$$

Runoff depth is the volume expressed as depth over the specified catchment area with a constant to adjust units to millimetres; i.e. for daily runoff:

$$R_d\,(mm) = \frac{V_d\,(cum) \times 10^3}{Area\,(km^2) \times 10^6} = \frac{V_d\,(mm)}{Area\,(km^2) \times 10^3} = \frac{86.4\, Q_d}{Area\,(km^2)} \qquad (4)$$

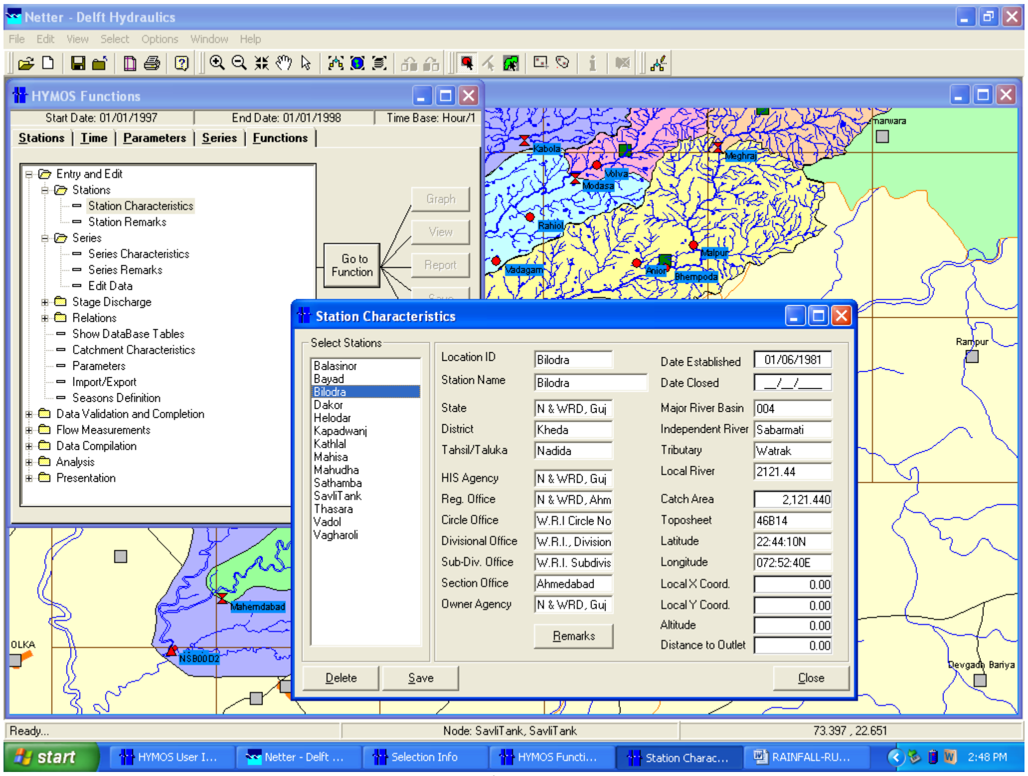


Fig.25

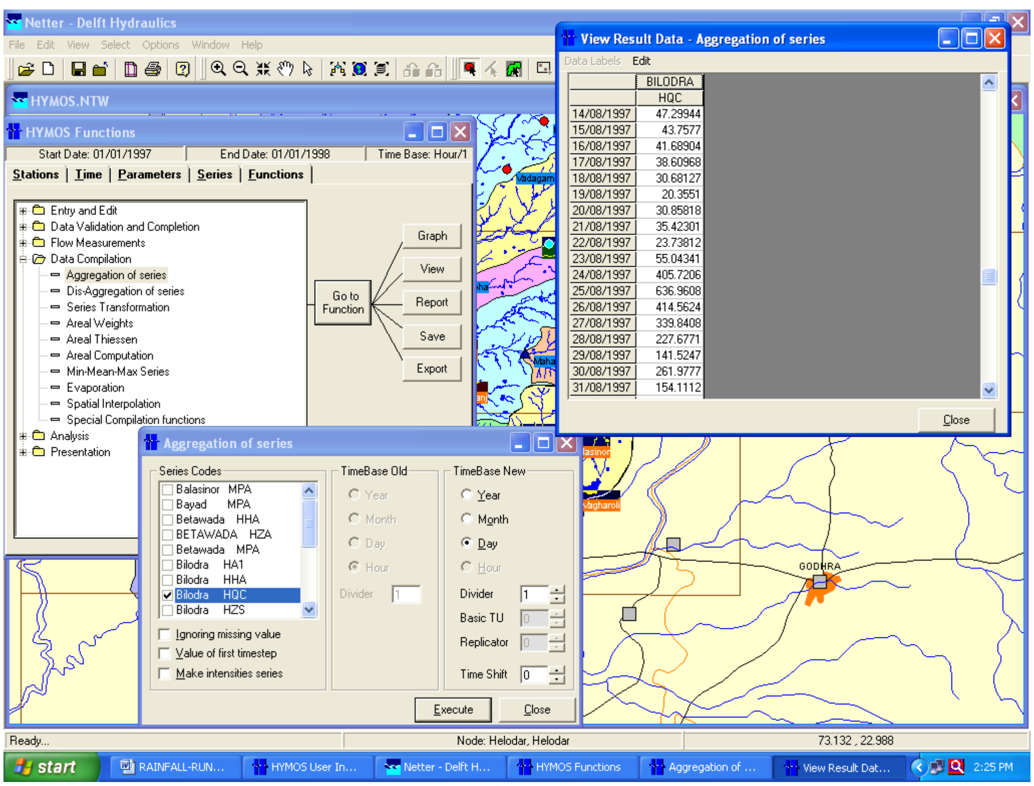


Fig.26

Function in **Fig.26** transform hourly Bilodra HQC series into daily series. Upper right window confirms output of series. Follow **Fig.27** to save the series.

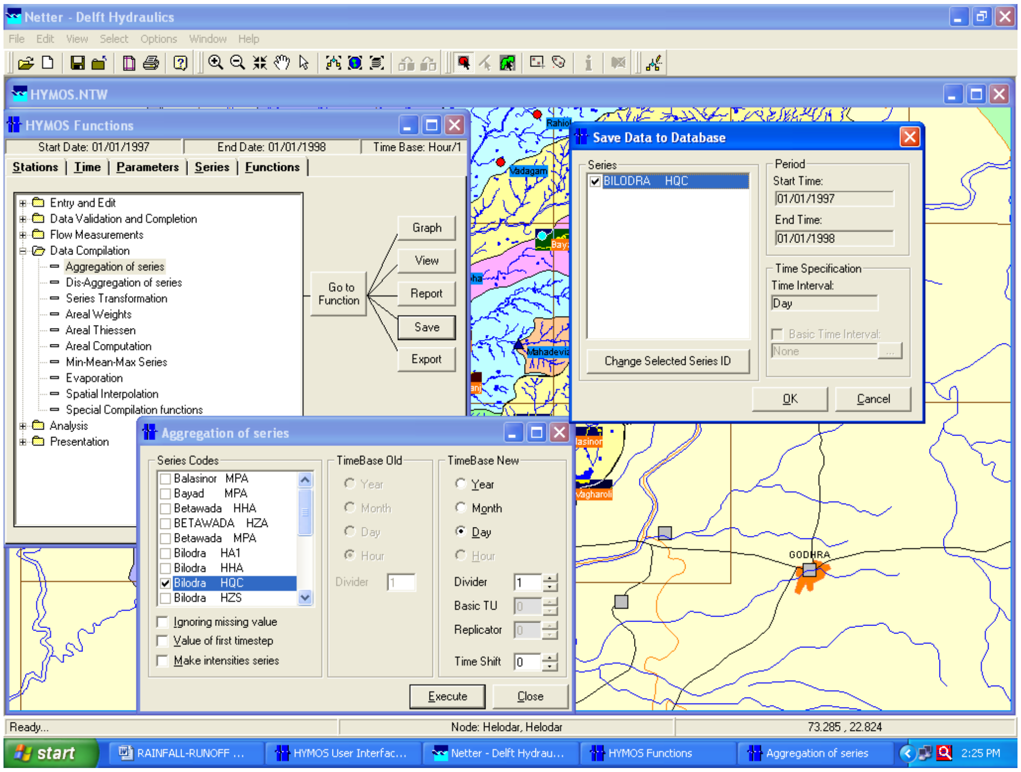


Fig.27

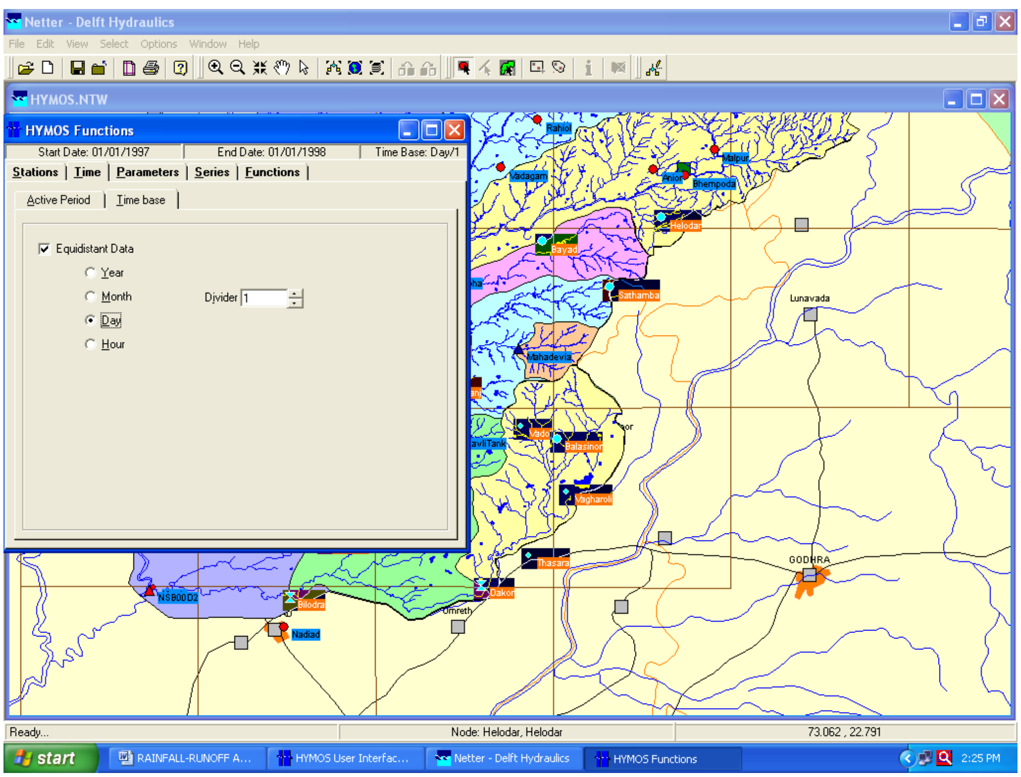


Fig.28

Change time base as 'day' **(Fig.28).** Having done this, HYMOS will retrieve only daily series. Now, we transform Bilodra HQC hourly series by multiplying 0.04073 to each daily discharge data (**Fig.29**). Even if, resulting series bears the identical name, user must save resulting series by other name such as Bilodra HA1 series. By **Fig.30 & 31** these steps would be finished.

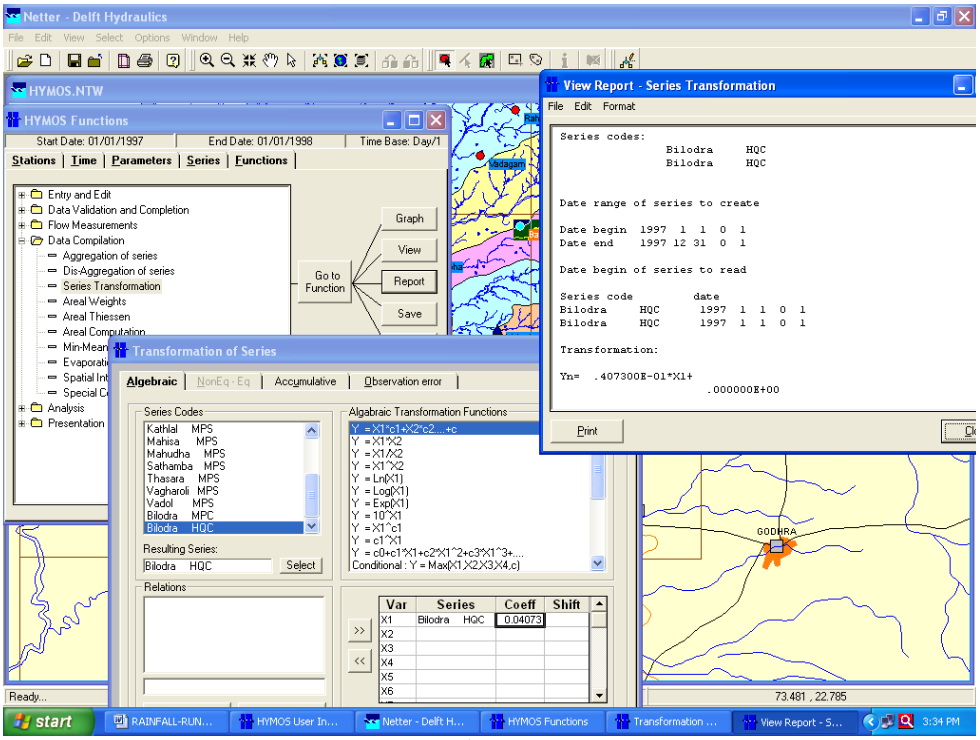

Netter - Delft Hydraulics
HYMOS Functions
Start Date: 01/01/1997
End Date: 01/01/1998
Time Base: Day/1
Stations | Time | Parameters | Series | Functions
Entry and Edit
Data Validation and Completion
Flow Measurements
Data Compilation
Aggregation of series
Dis-Aggregation of series
Series Transformation
Areal Weights
Areal Thiessen
Analysis
Presentation
Go to Function
Graph
View
Report
Save
View Report - Series Transformation
Series codes:
Bilodra HQC
Bilodra HQC
Date range of series to create
Date begin 1997 1 1 0 1
Date end 1997 12 31 0 1
Date begin of series to read
Series code date
Bilodra HQC 1997 1 1 0 1
Bilodra HQC 1997 1 1 0 1
Transformation:
Yn= .407300E-01*X1+
.000000E+00
Print
Transformation of Series
Algebraic
Accumulative
Observation error
Series Codes
Resulting Series:
Bilodra HQC
Select
Relations
Algebraic Transformation Functions
Var Series Coeff Shift
X1 Bilodra HQC 0.04073
GODHRA
73.481 , 22.785
Ready...
start
3:34 PM

Fig.29

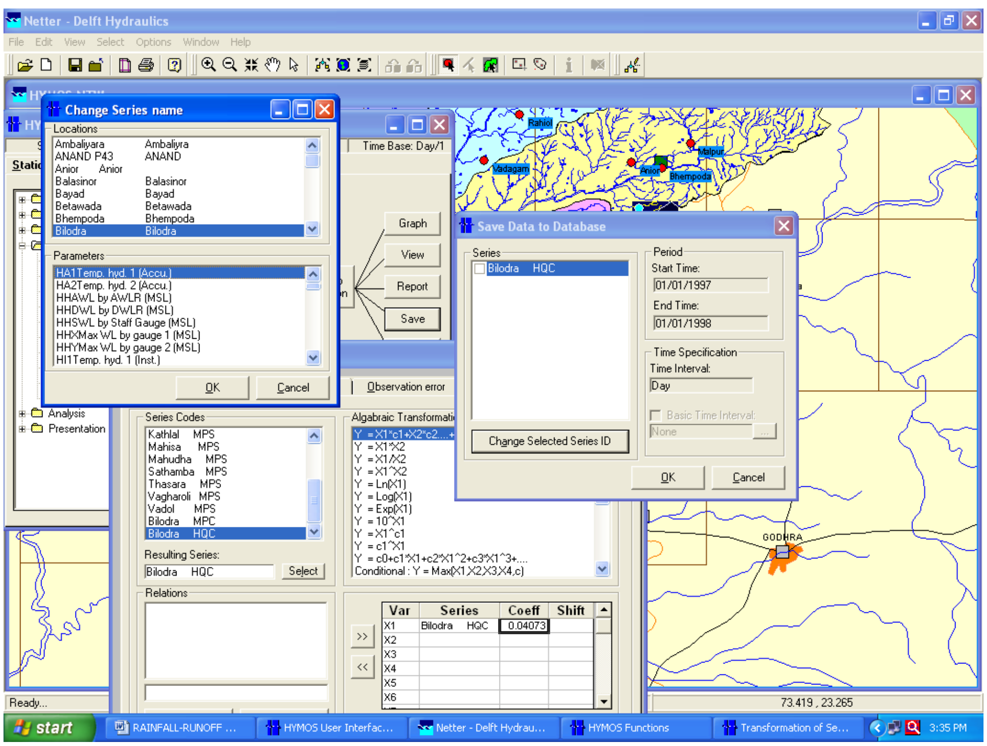

Netter - Delft Hydraulics
Change Series name
Locations
Ambaliyara Ambaliyra
ANAND P43 ANAND
Anior Anior
Balasinor Balasinor
Bayad Bayad
Betawada Betawada
Bhempoda Bhempoda
Bilodra Bilodra
Parameters
HA1Temp. hyd. 1 (Accu.)
HA2Temp. hyd. 2 (Accu.)
HHAWL by AWLR (MSL)
HHDWL by DWLR (MSL)
HHSWL by Staff Gauge (MSL)
HHXMax WL by gauge 1 (MSL)
HHYMax WL by gauge 2 (MSL)
HI1Temp. hyd. 1 (Inst.)
OK
Cancel
Save Data to Database
Series
Bilodra HQC
Change Selected Series ID
Period
Start Time:
01/01/1997
End Time:
01/01/1998
Time Specification
Time Interval:
Day
Basic Time Interval
None
OK
Cancel
Var Series Coeff Shift
X1 Bilodra HQC 0.04073
GODHRA
73.419 , 23.265
Ready...
start
3:35 PM

Fig.30

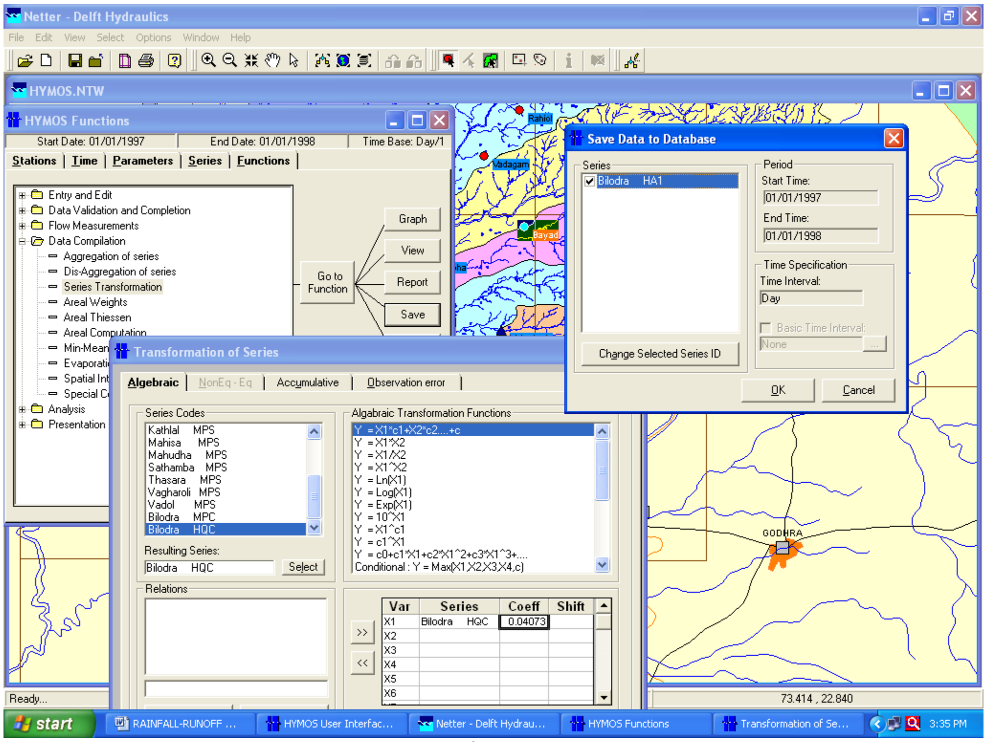


Fig.31

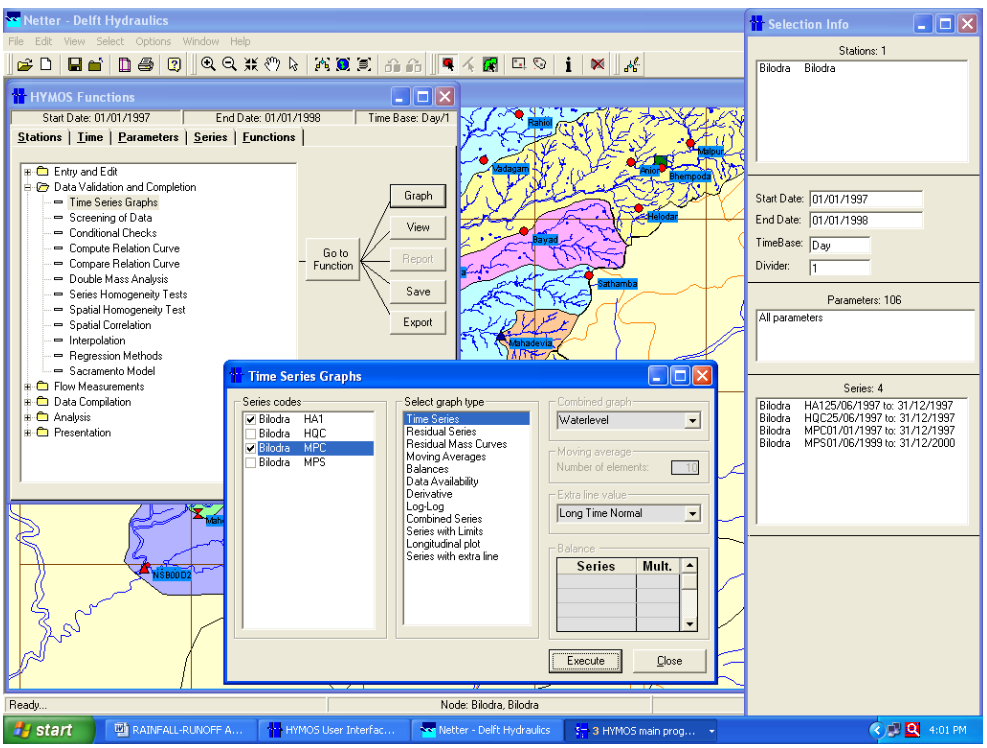


Fig.32

Function shown in **Fig.32** is to compare Bilodra MPC (rainfall) & HA1 (runoff) series. Concurrent plot help user validate steps since beginning by looking at plot and observing occurrence/sequence of rainfall and runoff peaks and their magnitude too (**Fig.33**). For instance, rainfall event must precede corresponding flood hydrograph on time scale. A double clock anywhere on Graph plot pops up Editing window (**Fig.34**) to edit various features on plot.

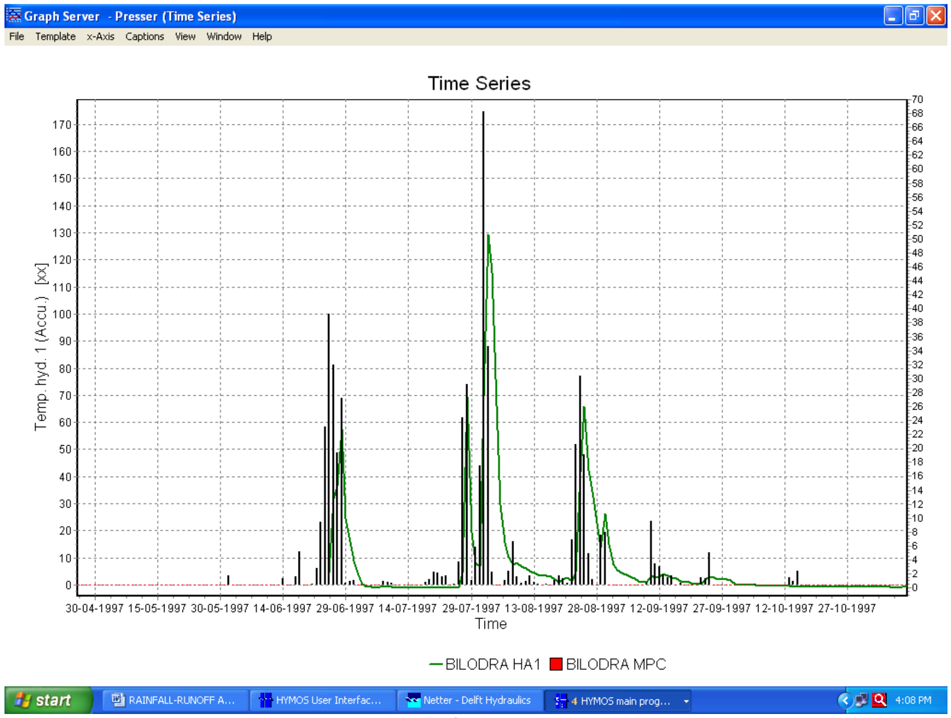
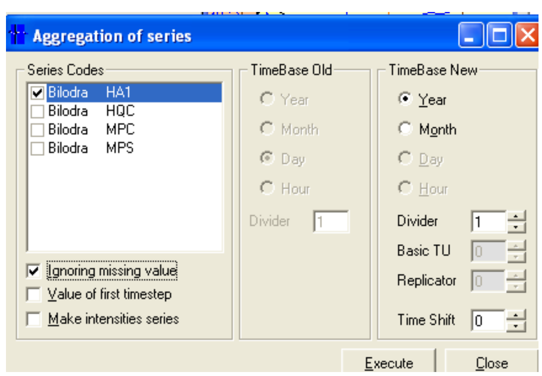


Fig.33

On the Editing window, press ‘Add’ to open up ‘Tee chart Gallery’. Select Cumulative option and click on ‘ok’. Select on Editing window the type(s) of series lines to have been represented by cumulative plot on the chart body (**Fig.35**). **(*Important - Pl note that series for which cumulative plot is intended does not have missing value/s).*** Editing window needs a little more changes to define vertical axis for these lines on left and right axis. A glance at **Fig.36** compares the total rainfall vs. runoff over the basin in defined time period. As a certain fraction of rainfall accounts for various losses over the basin, runoff shall always be less than total rainfall. In the current study, rainfall and runoff are 1270.153mm and 482.626mm respectively. These values can also be had by selecting Aggregation of series of Bilodra MPC and Bilodra HA1 series under Data compilation folder with Year as Time base New. To exclude missing cells from analysis, do check appropriate box at lower left corner ‘on’.



Converse findings or deviation of higher degree from already known figure of runoff coefficient manifests wrong validation of record and fresh look into record and its validation are called for. Storages or diversion of water to another basin nearby will influence runoff to a larger extent. Data handlers must be aware of existence of such arrangement in the basin to ensure correct validation of record.

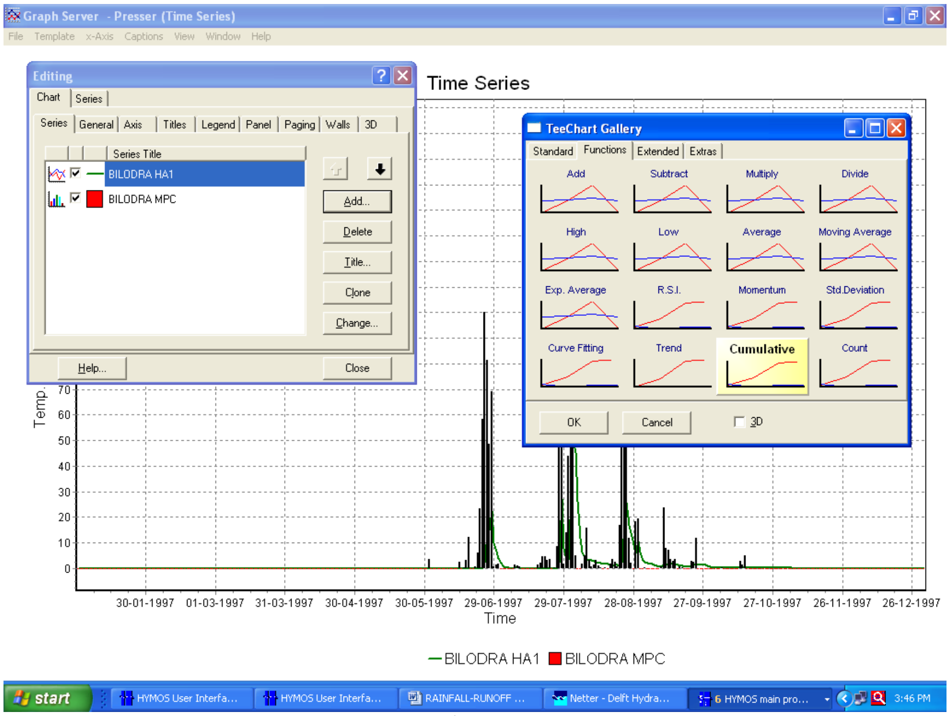

Graph Server - Presser (Time Series)
Editing
Chart
Series
Series
General
Axis
Titles
Legend
Panel
Paging
Walls
3D
Series Title
BILODRA HA1
BILODRA MPC
Add...
Delete
Title...
Clone
Change...
Help...
Close
Time Series
TeeChart Gallery
Standard
Functions
Extended
Extras
Add
Subtract
Multiply
Divide
High
Low
Average
Moving Average
Exp. Average
R.S.I.
Momentum
Std.Deviation
Curve Fitting
Trend
Cumulative
Count
OK
Cancel
3D
Temp.
Time
BILODRA HA1
BILODRA MPC
start

Fig.34

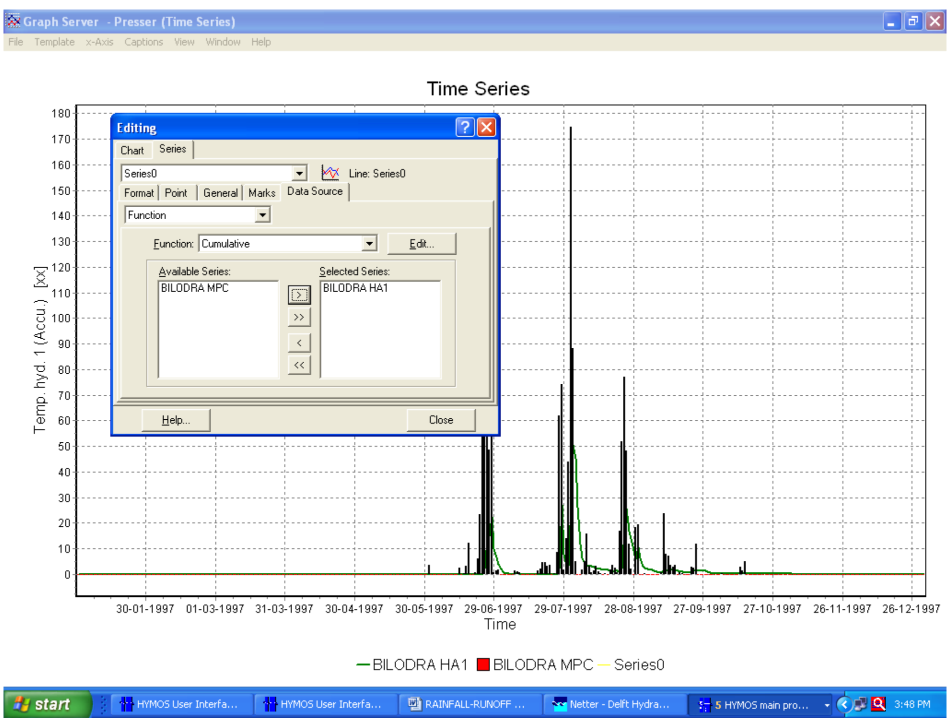

Graph Server - Presser (Time Series)
Time Series
Editing
Chart
Series
Series0
Line: Series0
Format
Point
General
Marks
Data Source
Function
Function: Cumulative
Edit...
Available Series:
BILODRA MPC
Selected Series:
BILODRA HA1
Help...
Close
Temp. hyd. 1 (Accu.) [xx]
Time
BILODRA HA1
BILODRA MPC
Series0
start

Fig.35

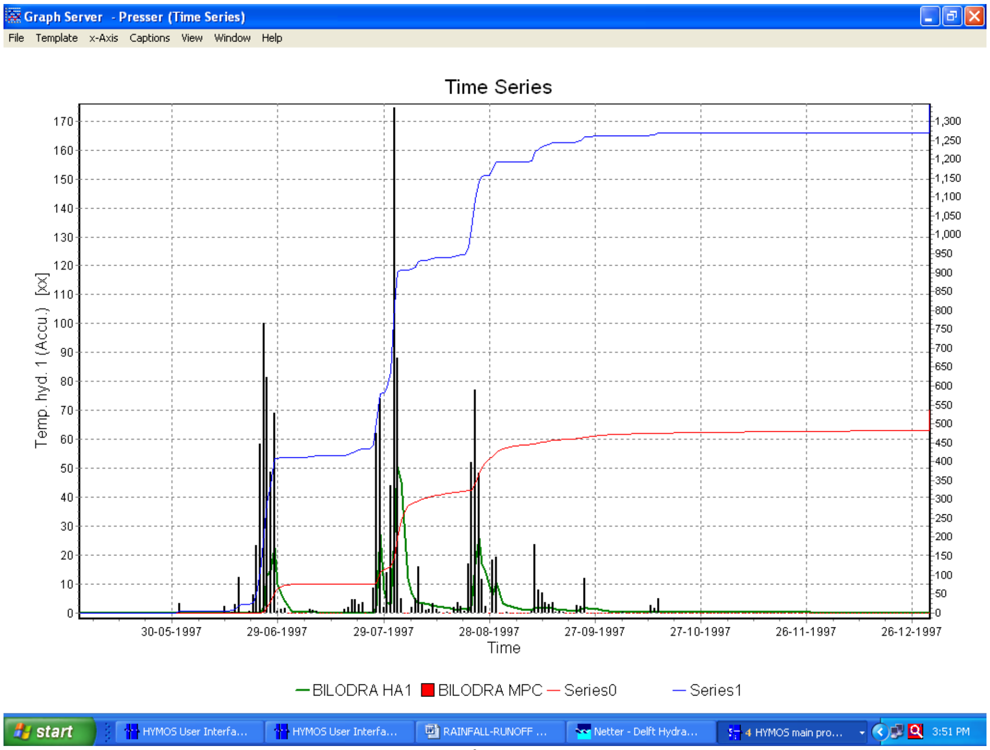


Fig.36

Maintaining that the process finished so far is acceptable, user may proceed to generate final report for use of several agencies. This is achieved by choosing HTML reports function under Presentation folder on Hymos Function window and using Go to Function button to get another window labeled HTML reports (**Fig.37**). First check the series Bilodra HQC and then press browse button to open Template file name. The usual path name is C:\Program Files\HYMOS 4\HTML Report Sample\SW HTML Reports\Report 9; Daily flow. Mark DAILY Flow file and press open. Execute the function. Similar step is followed to get daily rainfall report. This time, select Bilodra MPC series with template file as C:\Program Files\HYMOS 4\HTML Report Sample\SW HTML Reports\Report 1; Daily Rainfall. Mark DAILY RAIN file open it. Execute once again. Come out of HYMOS software and follow paths defined above to open up daily rainfall and discharge HTML reports. These reports appear on ensuing pages.

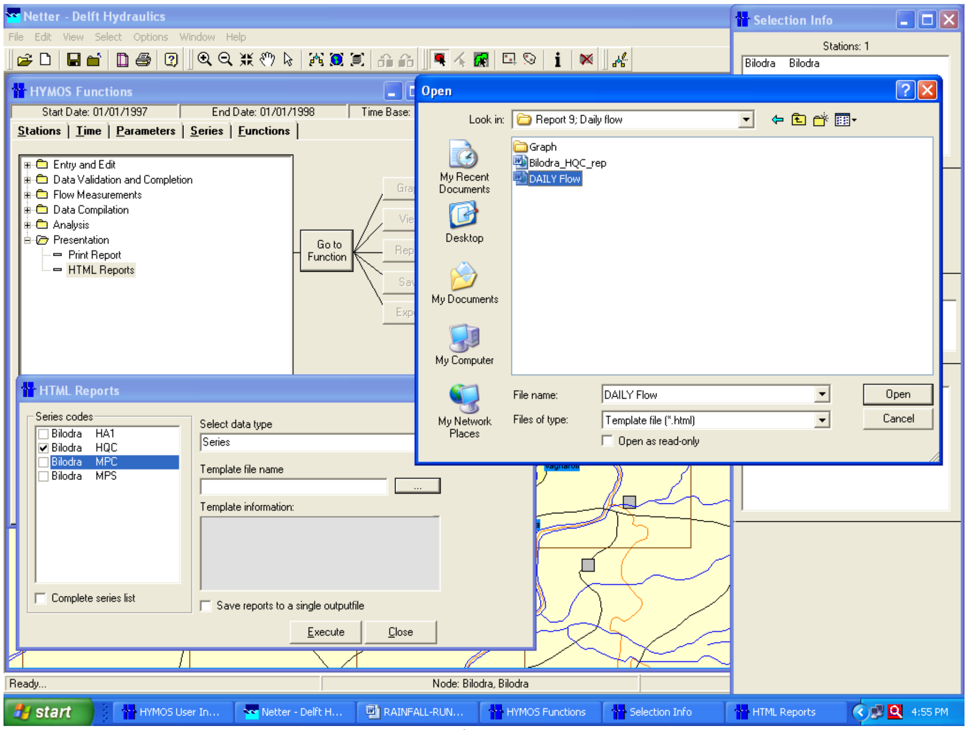


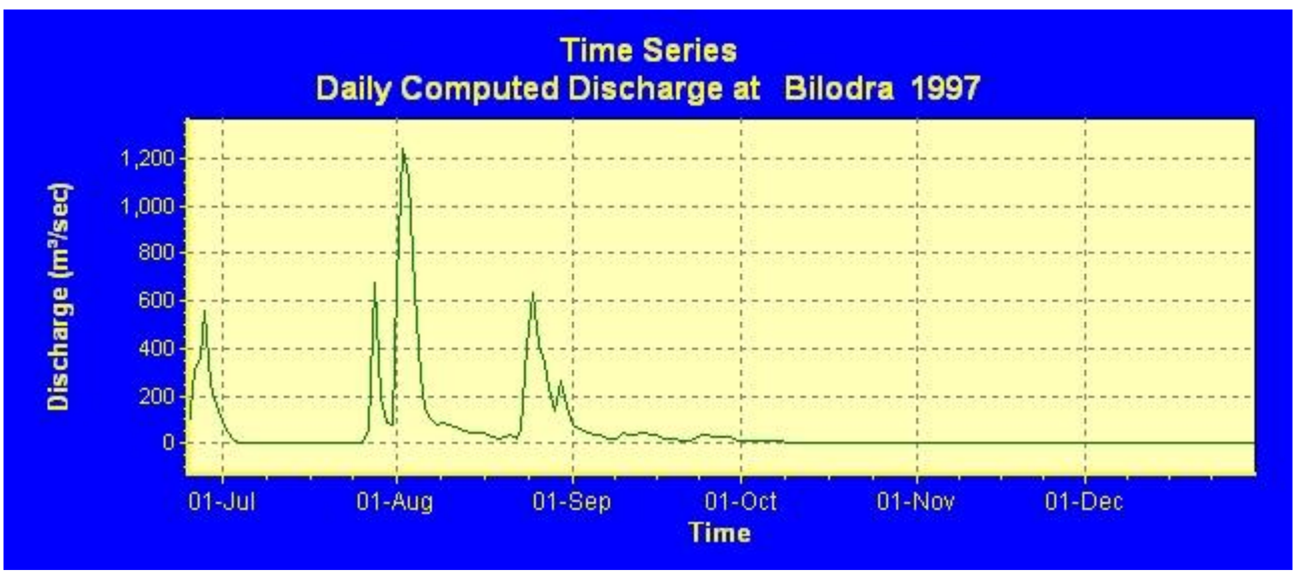
Fig.37

Daily Flow **Year - 1997**

Station Code: Bilodra
Station Name: Bilodra

District: Kheda
Units : m^3/sec

Independent River : Sabarmati
Tributary: Watrak



Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1							94.6	675.0	80.4	11.0	3.7	1.9
2							47.0	1242.1	63.5	10.0	3.8	1.9
3							13.0	1110.5	53.0	9.6	3.2	1.9
4							4.4	640.8	45.2	9.0	2.5	1.9
5							3.1	292.3	38.6	8.7	2.4	1.9
6							2.1	158.7	33.0	8.1	2.3	1.9
7							3.0	107.6	23.7	7.8	2.1	1.9
8							2.5	81.2	19.7	7.3	2.0	1.9
9							3.0	87.5	18.5	6.9	2.2	1.9
10							2.6	75.1	41.6	6.9	2.3	1.8
11							1.2	68.0	36.9	6.6	2.2	1.8
12							1.3	58.4	39.7	6.1	2.2	1.8
13							0.5	52.1	47.8	5.8	2.2	1.8
14							0.4	47.3	41.4	4.9	2.2	1.8
15							0.2	43.8	36.0	4.3	2.2	1.8
16							0.3	41.7	33.4	3.9	2.2	1.8
17							2.1	38.6	23.3	3.9	2.2	1.8
18							1.3	30.7	21.6	3.9	2.2	1.8
19							0.4	20.4	18.4	3.9	2.2	1.8
20							0.3	30.9	14.4	3.9	2.2	1.8
21							0.3	35.4	13.1	3.5	2.2	1.8
22							2.1	23.7	12.0	3.3	2.2	1.8
23							1.0	55.0	30.5	3.4	2.2	1.8
24							0.9	405.7	39.4	3.6	2.2	1.8
25						54.0	0.8	637.0	37.3	3.2	2.1	1.8
26						314.2	0.9	414.6	30.4	3.0	2.0	1.8
27						358.1	52.7	339.8	29.8	2.9	2.0	1.6
28						559.3	674.4	227.7	30.0	3.6	1.9	1.6
29						244.4	195.4	141.5	25.2	3.5	1.9	1.6
30						162.6	86.8	262.0	13.1	3.3	1.9	1.6
31							75.5	154.1		3.7		1.5
Min.	-	-	-	-	-	-	0.2	20.4	12.0	2.9	1.9	1.5
Max.	-	-	-	-	-	-	674.4	1242.1	80.4	11.0	3.8	1.9
#	0	0	0	0	0	6	31	31	30	31	30	31
Miss.	31	28	31	30	31	24	0	0	0	0	0	0
Mean	-	-	-	-	-	-	41.1	245.1	33.0	5.5	2.3	1.8

Yearly statistics :

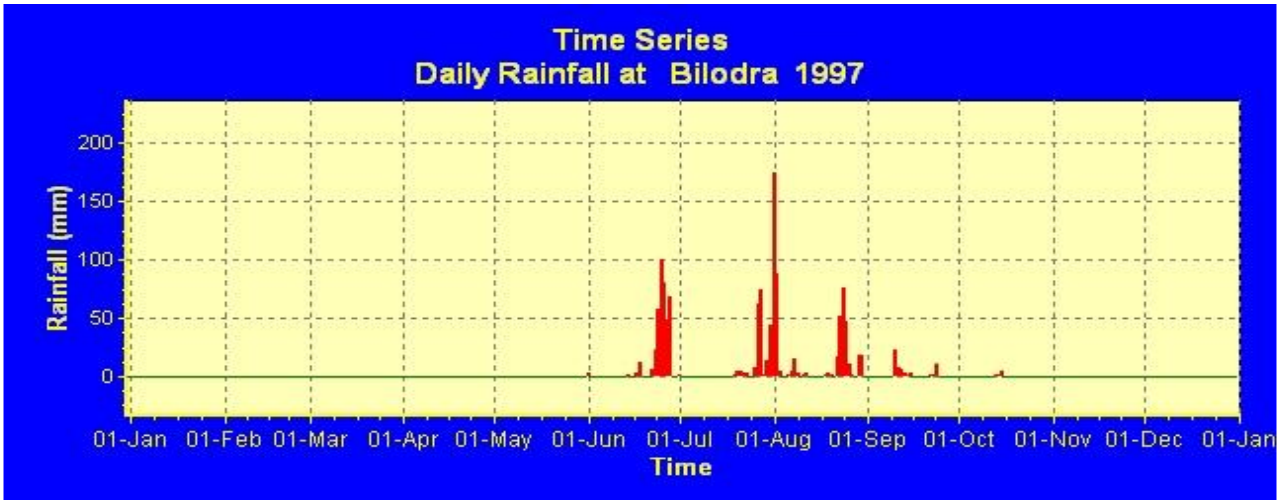
Mean : -	Minimum : - Date : 15/07/1997 12:00:00 AM	Maximum : - Date : 02/08/1997 12:00:00 AM	No. of data : 190 No. of missing data : 175

Daily Rainfall **Year - 1997**

Station Code: Bilodra
Station Name: Bilodra

District: Kheda
Units : mm

Independent River : Sabarmati
Tributary: Watrak



Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	3.4	1.6	174.7	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	88.2	0.1	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	1.3	16.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.0	0.6	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.8	23.7	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	8.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	6.9	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.6	2.7	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.2	2.8	1.5	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	5.1	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.1	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.7	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	12.2	1.2	1.9	0.2	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	2.1	3.5	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	4.7	2.3	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.5	4.6	0.6	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	6.1	3.0	16.8	2.7	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	23.2	3.5	52.0	2.3	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	58.3	0.0	77.0	11.8	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	100.0	0.4	48.3	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	81.3	8.7	11.7	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	48.7	61.9	2.2	0.0	0.0	0.0	0.0

28	0.0	0.0	0.0	0.0	0.0	69.1	74.2	0.1	0.0	0.0	0.0	0.0
29	0.0		0.0	0.0	0.0	0.7	1.8	18.3	0.0	0.0	0.0	0.0
30	0.0		0.0	0.0	0.0	1.3	14.0	19.3	0.0	0.0	0.0	0.0
31	0.0		0.0		0.0		43.9	0.0		0.0		0.0
Mean	0.0	0.0	0.0	0.0	0.0	13.7	7.4	17.9	2.2	0.3	0.0	0.0
Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max.	0.0	0.0	0.0	0.0	0.0	100.0	74.2	174.7	23.7	5.1	0.0	0.0
#	31	28	31	30	31	30	31	31	30	31	30	31
Miss.	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0.0	0.0	0.0	0.0	0.0	410.3	228.5	554.5	67.1	9.7	0.0	0.0

Yearly statistics :			
Mean : 3.5 Sum : 1270.2	Minimum : 0.0 Date : 01/01/1997 12:00:00 AM	Maximum : 174.7 Date : 01/08/1997 12:00:00 AM	No. of data : 365 No. of missing data : 0

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INTENSITY DURATION CURVE (IDF); THEORETICAL DISTRIBUTION CURVE

Subsequent to the validation of rainfall and hydrological data, HYMOS is capable of analyzing them and deducing useful set of information for use of water resources engineers. One such information is Intensity Duration Frequency Curve (IDF curve), which help estimate Qp, peak discharge using Rational formula, i.e., Qp = CiA. Where, C is runoff coefficient; i is intensity of rainfall in mm/hr; and A being catchment area. Duration of rainfall equals time of concentration for the basin under study. Additionally, IDF curves for a set of stations spread over the basin help draw Isopluvial maps of different frequency. HYMOS picks up values of a station for user defined durations and does frequency analysis following Gumbel method. Analysis is presented both in tabular as well as graphical plot. To demonstrate this function of HYMOS, a station named Meghraj of Kheda basin is selected from netter screen. Time period is selected between 31/12/1982 and 01/01/1999 keeping time base as hour (**Fig.1**).

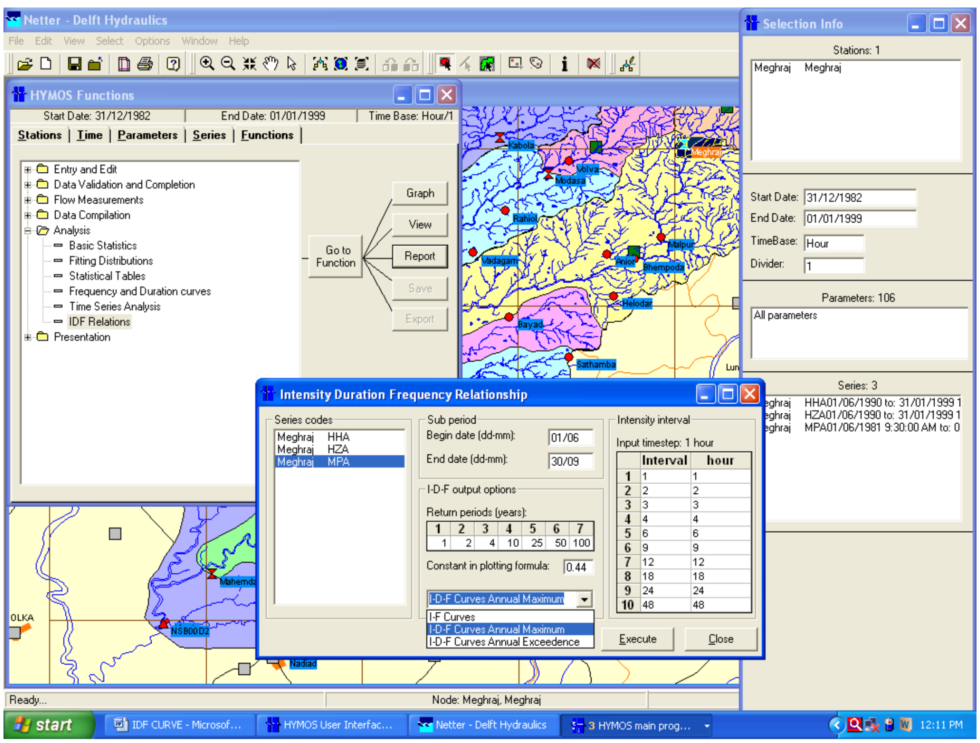


Fig.1

IDF function is chosen under Analysis folder on Hymos Function window. Pressing Go to function button pops up IDF relationship window. On this window, a differing sub period is inputted to capture active rainfall period only. Return period in yrs and Interval will appear as shown in **Fig.1** by default which user may modify as per need. A dropdown menu at lower central part of this window offers three options to select. First two, which pick up annual maximum value each year, are identical with only difference in presenting the analysis plot. Third option picks up annual Exceedance values and presents the result accordingly. **Training module no.12** deals with this aspect extensively and user is advised to refer to it to understand distinction between two methods. **Fig.2** is an output of I-F curves selection.

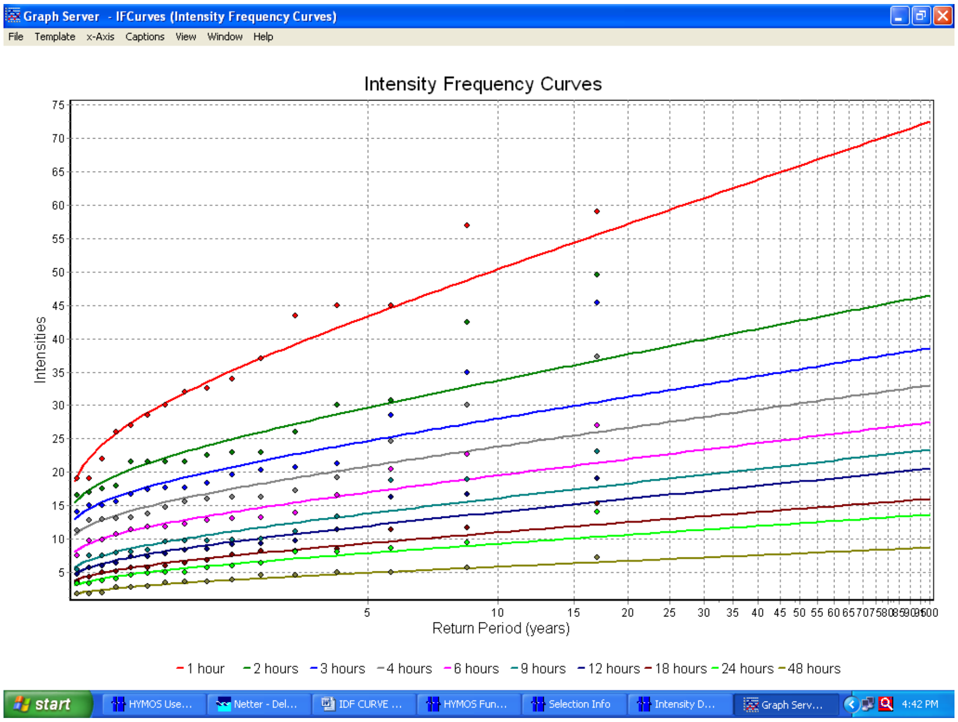


Fig.2

Fig.3 is an output of I-D-F curves

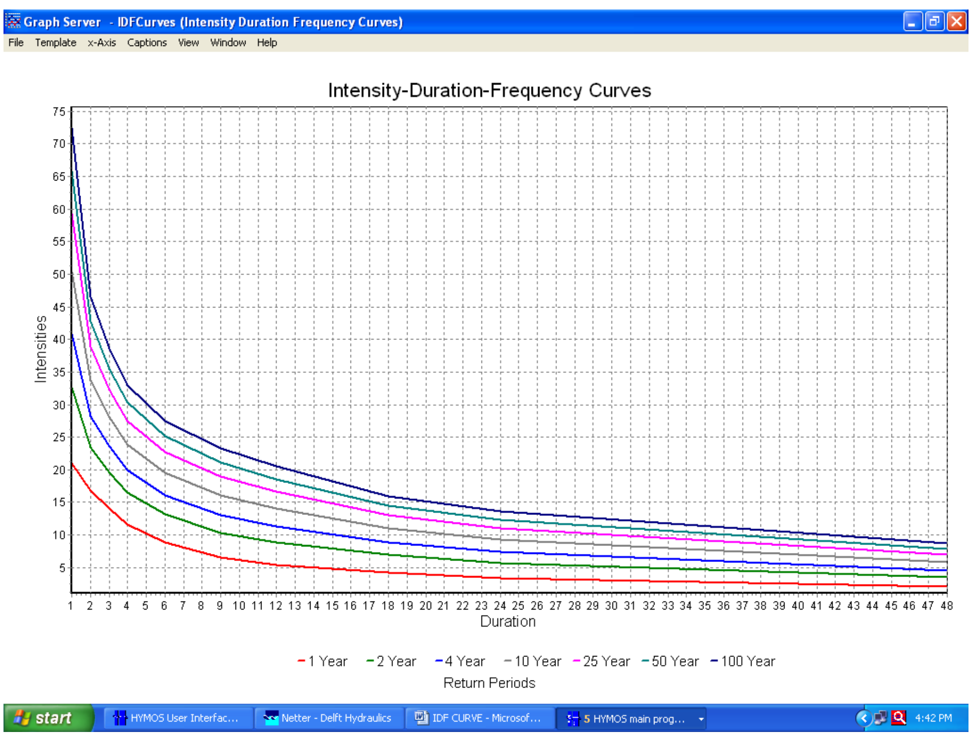


Fig.3

IDF report as shown in **Fig.4** presents intensity values against duration and return period. Using these values an equation in the form of a relationship between I, T and D can also be derived by multiple regression analysis.

$$I = \frac{KT^d}{(D + a)^b}$$

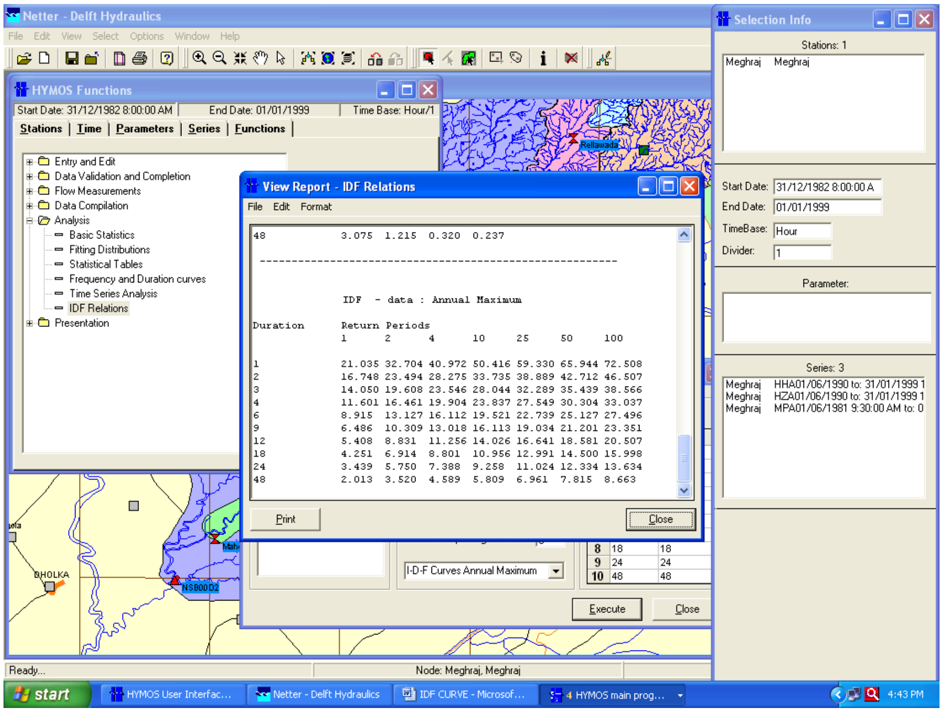


Fig.4

Similar analysis for rest of stations in a basin can be used to draw isopluvial lines. Such maps have been used in Flood Estimation Report published by CWC for several basins in India.

An equally significant analysis is to determine values corresponding to various exceedance probabilities by choosing anyone of the theoretical distribution methods listed by the software. Nevertheless, selection of a particular theoretical distribution method depends upon the statistical parameters of variables such as its mean, standard distribution, skewness coefficient etc. and its closeness with the empirical distribution curve. Such analysis is mostly attempted on annual average series because of their stationary, homogeneous and random character in nature. To know how HYMOS tackles this function, Vadol station of Kheda basin is selected with time period from 01/01/1970 to 01/01/1997 with time base as day to begin with (**Fig.5**). This series is aggregated to obtain annual rainfall for subsequent frequency analysis. This is done by opting Aggregation of series function under Data compilation folder and pressing Go to function button. A new window with Aggregation of series appears in the center.

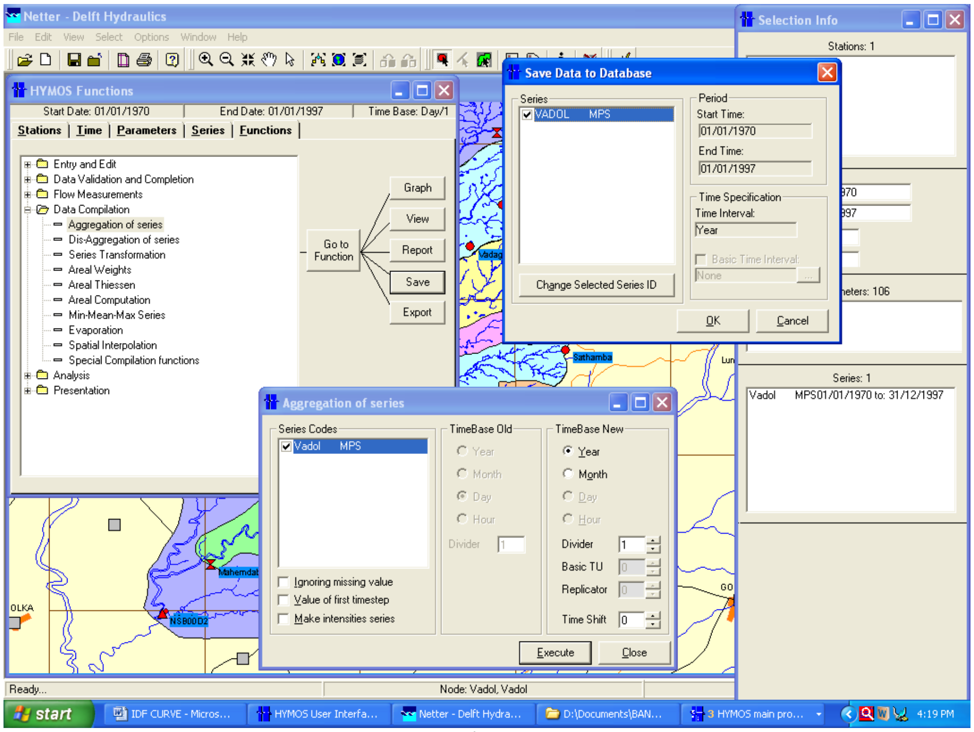


Fig.5

Check the box on by the station name and choose 'year' as time base new. Execute the window. Now, press 'save' on Hymos Function window to have a new window as shown on upper right part. Here too, check the box 'on' and press 'ok' button. The yearly series is now saved in the memory (**Fig.6**).

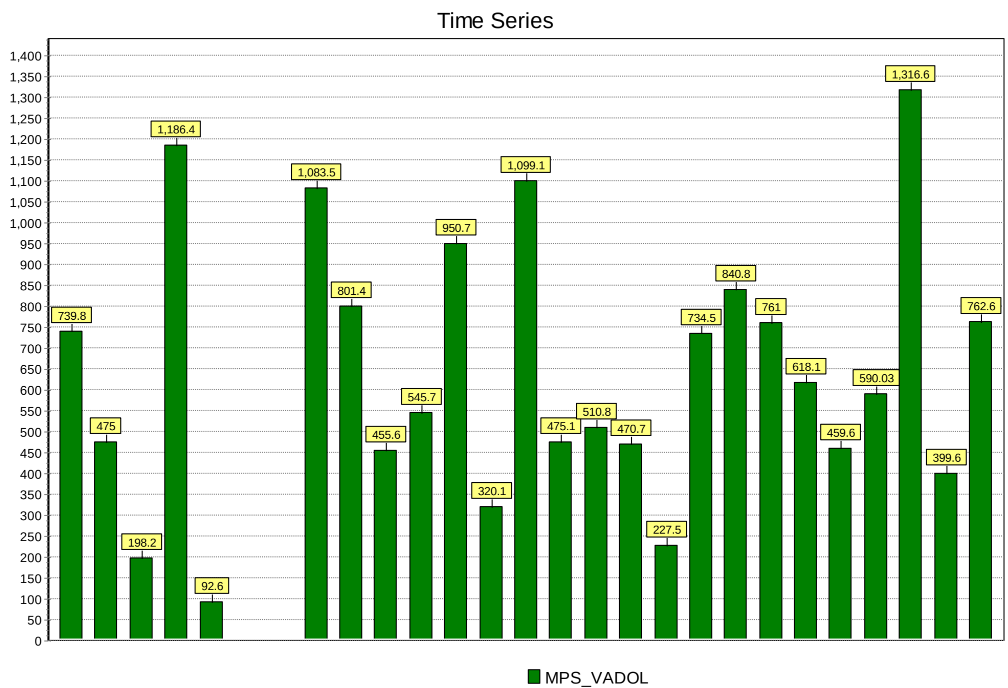


Fig.6

The generated series is now used to perform frequency analysis (**Fig.7**). Now, the time base is changed to Year by using Time tab on Hymos Function box. Once over, again press Function tab and select Fitting distribution under Analysis folder. Press Go to Function to get Fitting of Distribution Curves window. Select station and set other option as therein.

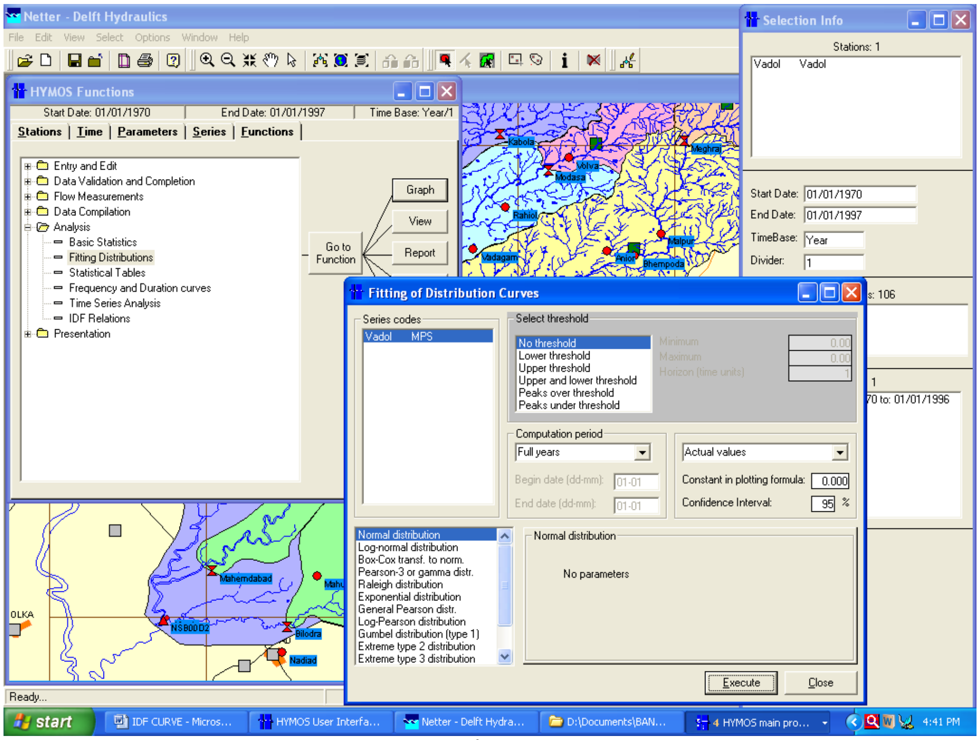


Fig.7

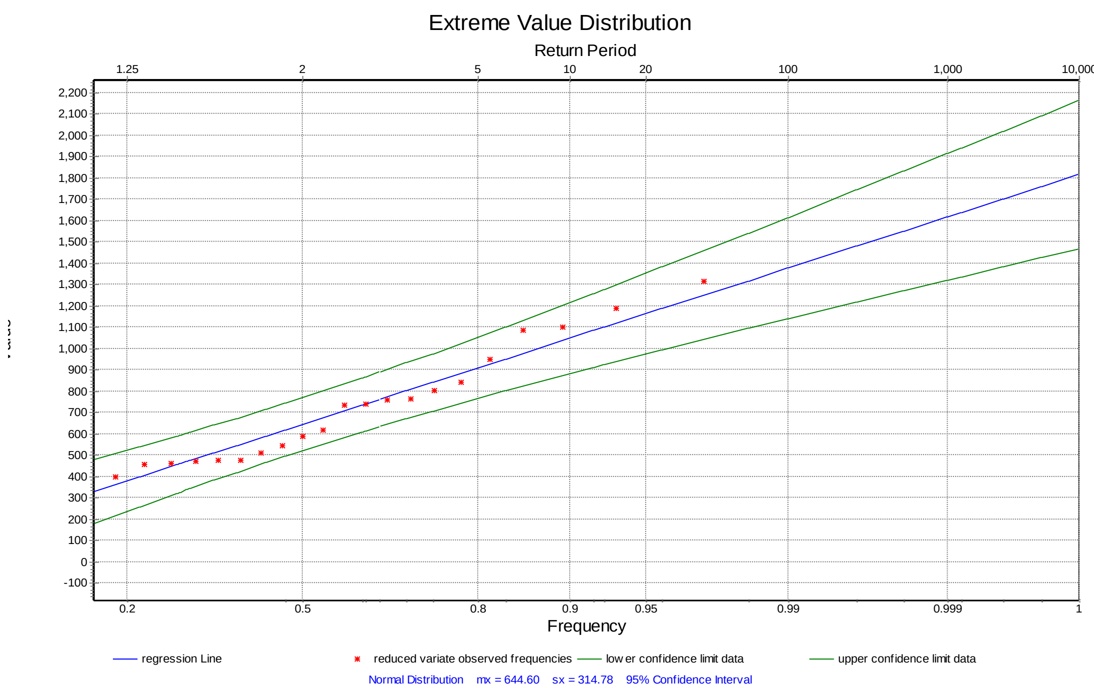
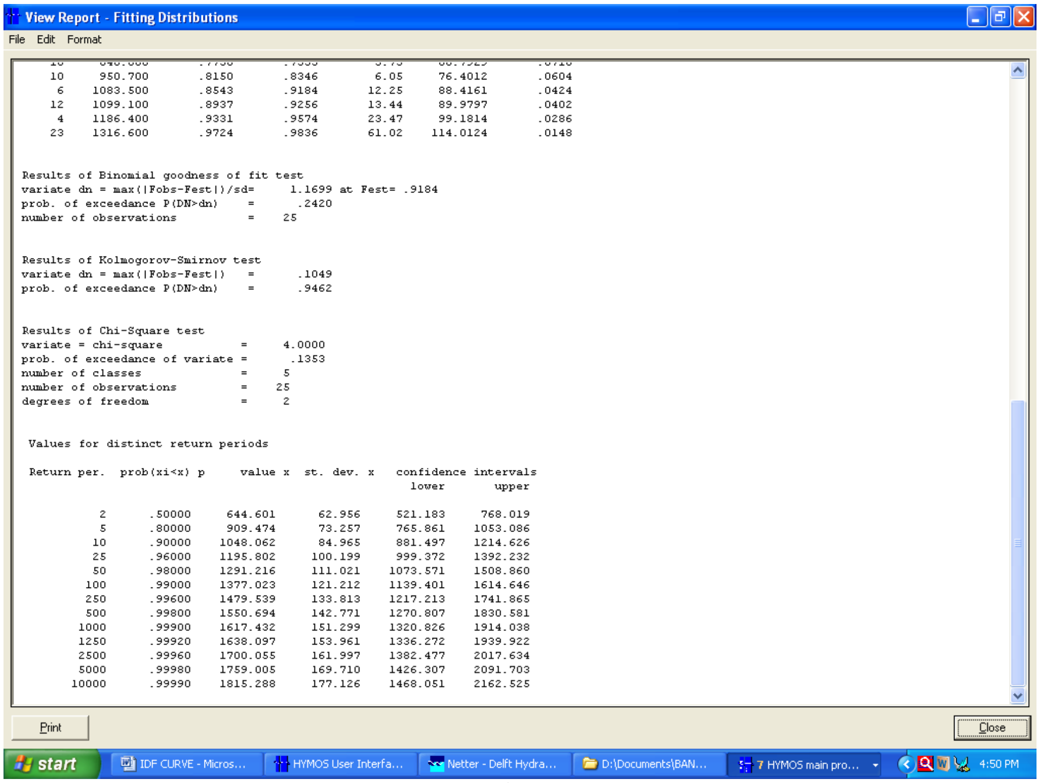


Fig.8

Press Execute and use Graph and Report command on Hymos function window to obtain output (**Fig.8 & Fig.9**).



10	950.700	.8150	.8346	6.05	76.4012	.0604
6	1083.500	.8543	.9184	12.25	88.4161	.0424
12	1099.100	.8937	.9256	13.44	89.9797	.0402
4	1186.400	.9331	.9574	23.47	99.1814	.0286
23	1316.600	.9724	.9836	61.02	114.0124	.0148

Results of Binomial goodness of fit test
variate dn = max(|Fobs-Fest|)/sd= 1.1699 at Fest= .9184
prob. of exceedance P(DN>dn) = .2420
number of observations = 25

Results of Kolmogorov-Smirnov test
variate dn = max(|Fobs-Fest|) = .1049
prob. of exceedance P(DN>dn) = .9462

Results of Chi-Square test
variate = chi-square = 4.0000
prob. of exceedance of variate = .1353
number of classes = 5
number of observations = 25
degrees of freedom = 2

Values for distinct return periods

Return per.	prob(xi<x) p	value x	st. dev. x	confidence intervals lower	confidence intervals upper
2	.50000	644.601	62.956	521.183	768.019
5	.80000	909.474	73.257	765.861	1053.086
10	.90000	1048.062	84.965	881.497	1214.626
25	.96000	1195.802	100.199	999.372	1392.232
50	.98000	1291.216	111.021	1073.571	1508.860
100	.99000	1377.023	121.212	1139.401	1614.646
250	.99600	1479.539	133.813	1217.213	1741.865
500	.99800	1550.694	142.771	1270.807	1830.581
1000	.99900	1617.432	151.299	1320.826	1914.038
1250	.99920	1638.097	153.961	1336.272	1939.922
2500	.99960	1700.055	161.997	1382.477	2017.634
5000	.99980	1759.005	169.710	1426.307	2091.703
10000	.99990	1815.288	177.126	1468.051	2162.525

Fig.9

The lower matrix of fig.9 lists return periods; exceedance probability and corresponding annual rainfall estimates with upper and lower bounds at 95% confidence limit. Even if this demonstration has used annual rainfall series, the similar steps can be followed for annual discharge series or annual maximum and annual minimum series. In addition, user may opt for any other distribution from lower left slot shown in **Fig.7.** To get further detail, reader may refer to '***Training Module no.12***.

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AREAL RAINFALL ESTIMATION BY KRIGING & INVERSE DISTANCE WEIGHTING METHOD

Apart from Thiessen Polygon, HYMOS offers additional tools such as Inverse Distance Weighting and Kriging methods. These methods have been extensively discussed in ***Training module no. 11*** and can be referred to grasp distinction between them and constraints in their application. Unlike Thiessen Polygon method, these methods determine weighted rainfall values at each and every user defined grid point; and based on the average of all grid points covered by basin; calculate areal rainfall of selected catchment/basin. In the current study, a cluster of rainfall stations have been selected for obtaining areal rainfall by all three methods and comparison thereof. Selected stations are Mahemadabad, Mahudha, Thasara, Dakor, Mahisa, Kathlal, Vaghroli, Savlitank, Vadol, Balasinor, Kapadwanj, Bayad, Vadagam, Anior, & Bemoan (**Fig.1)**.

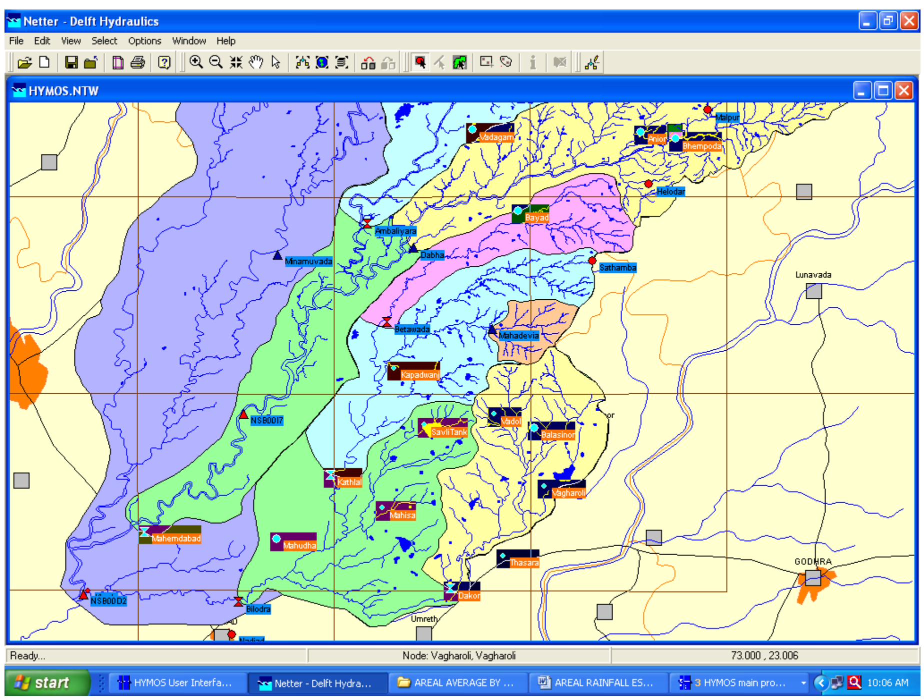


Fig.1

The chosen time period and time base are from 01/07/1982 to 01/01/1995 and day respectively. This chapter, though, demonstrates study based on monthly MPS series, analysis can be performed with daily series too. To begin with, MPS series of selected stations are required to be aggregated to have a monthly series and to seek parameters needed for Kriging method. This is achieved through function selected in **Fig.2**. At this stage, save the data and change the time base from day to month by using time tabs. Two subsequent screenshots (**Fig.3 & Fig.3a**) are used to confirm data availability of sites and their aggregation to monthly series. While operating these windows, ensure that all fields are populated with MPS series only. If there is any other series on the list, deselect it.

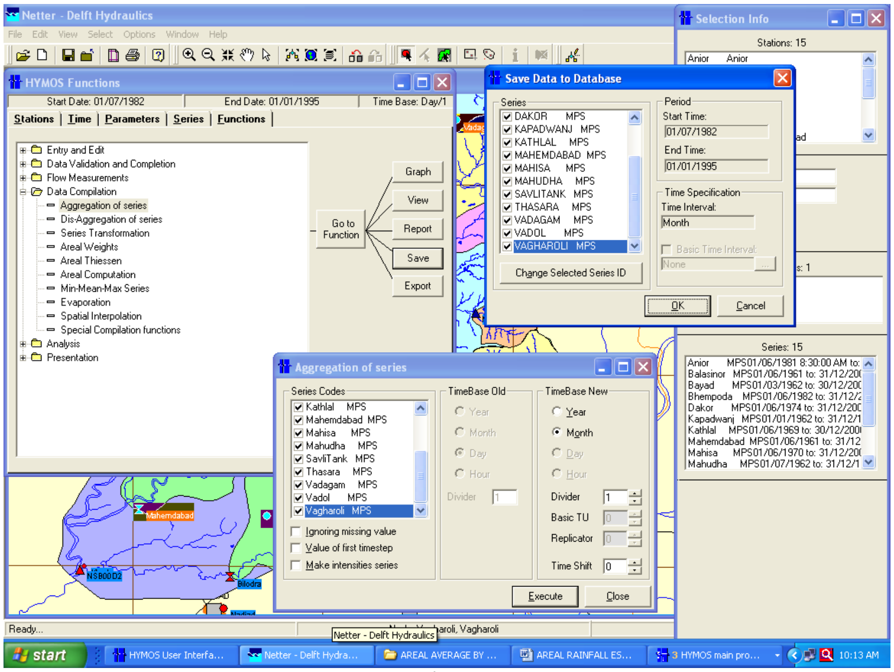


Fig.2

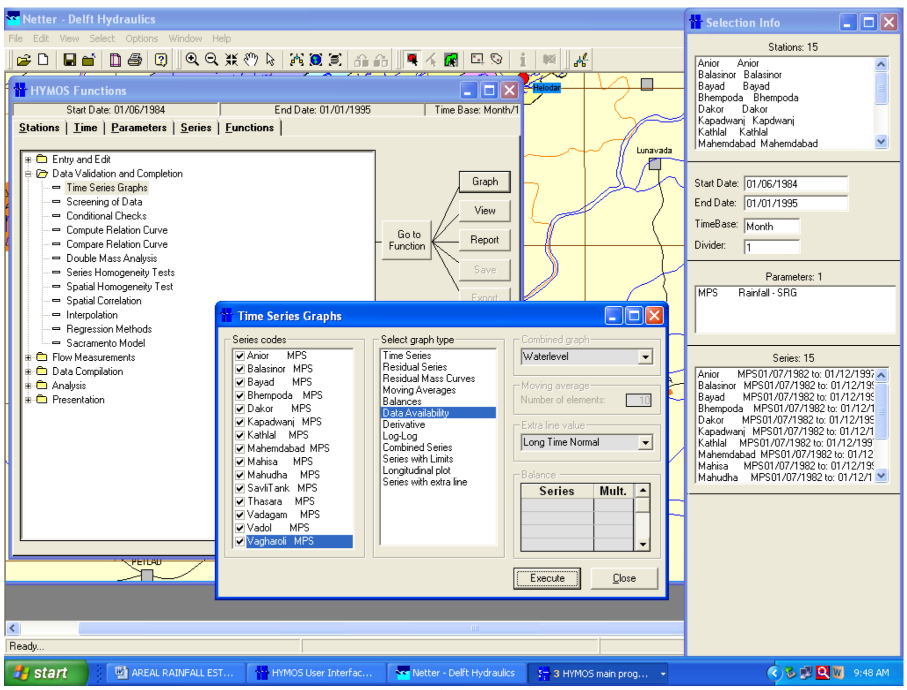


Fig.3

In one of the previous chapters, consistency of rainfall records at a particular station was validated on the premise that there exists some correlation among data observed at neighbouring stations. This correlation exhibits higher values for stations located in close vicinity and decays as distance between stations increases. Additionally, correlation becomes larger with increased time step series. To establish correlation among observed data and its likely decay over distance is captured by function shown in **Fig.4**.

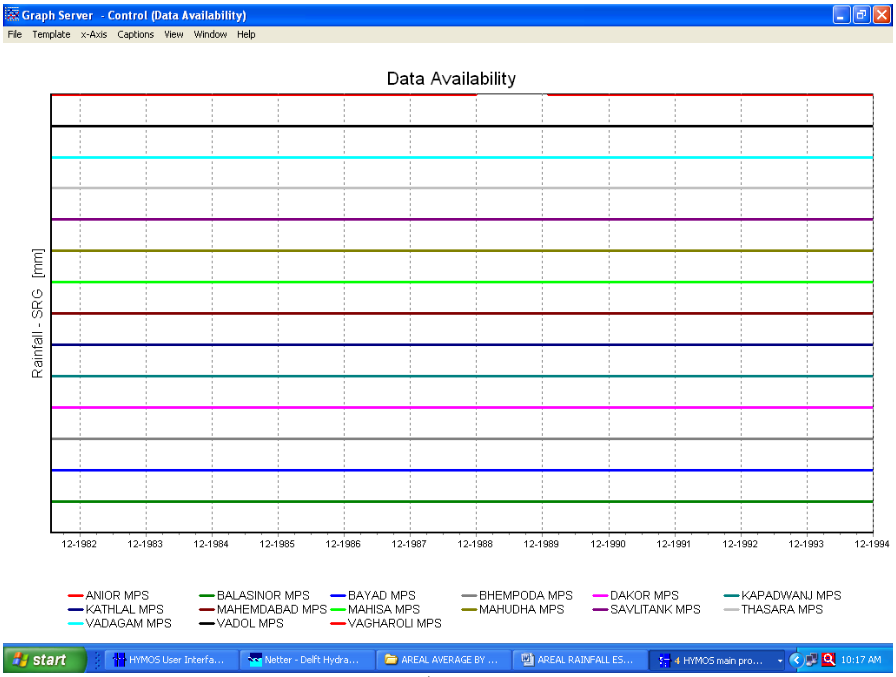


Fig.3a

The function is spatial correlation in Data validation and Completion folder. To develop a correlation, the selections are 10 for time step (this implies that input data for analysis begins from starting date (01/07/1982) to following 10 months; next set of data for analysis restarts from 01/07/1983 and so on till data of all years are exhausted); lower boundary as 10 signifies that all values lower than 10 will not take part in the analysis; check the ro cell off; & a maximum of 100 km as maximum interstation distance. Press Execute. HYMOS fills in calculated ro and do, correlation distance. These are 0.746 and 753 respectively. With these values, a relationship between correlation and distance is now defined. We will apply this set of information a while later.

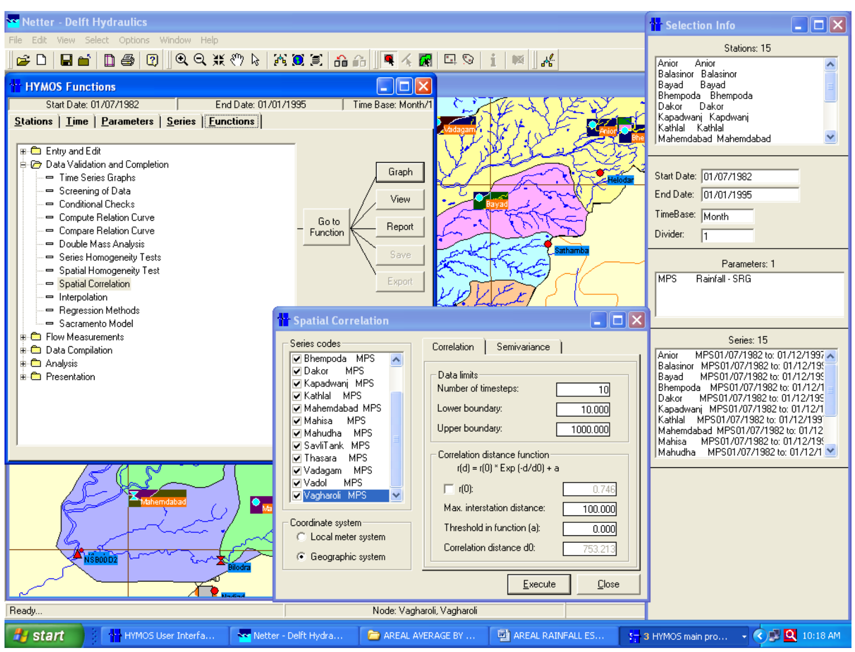


Fig.4

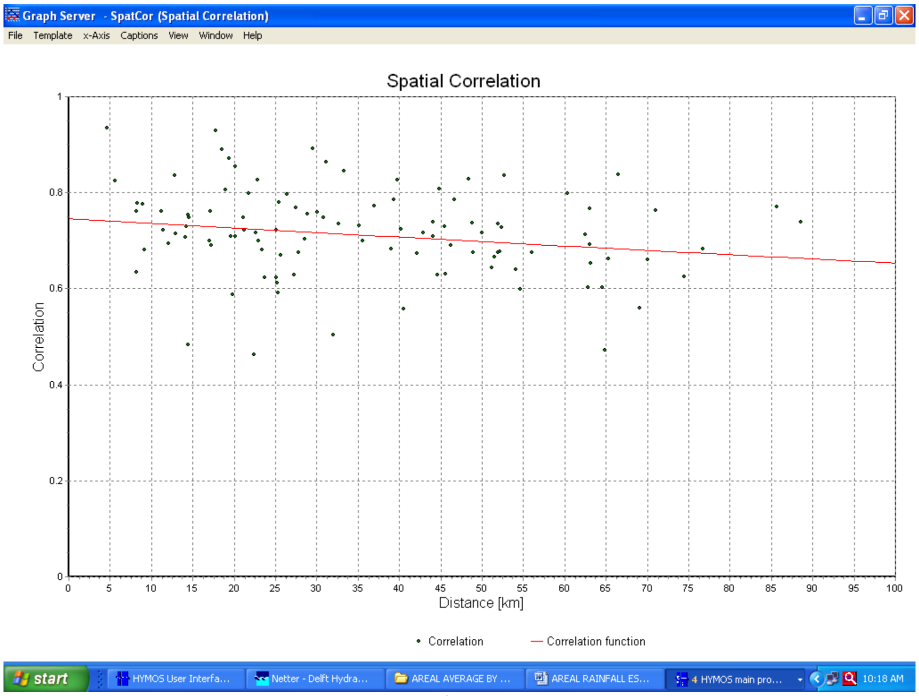
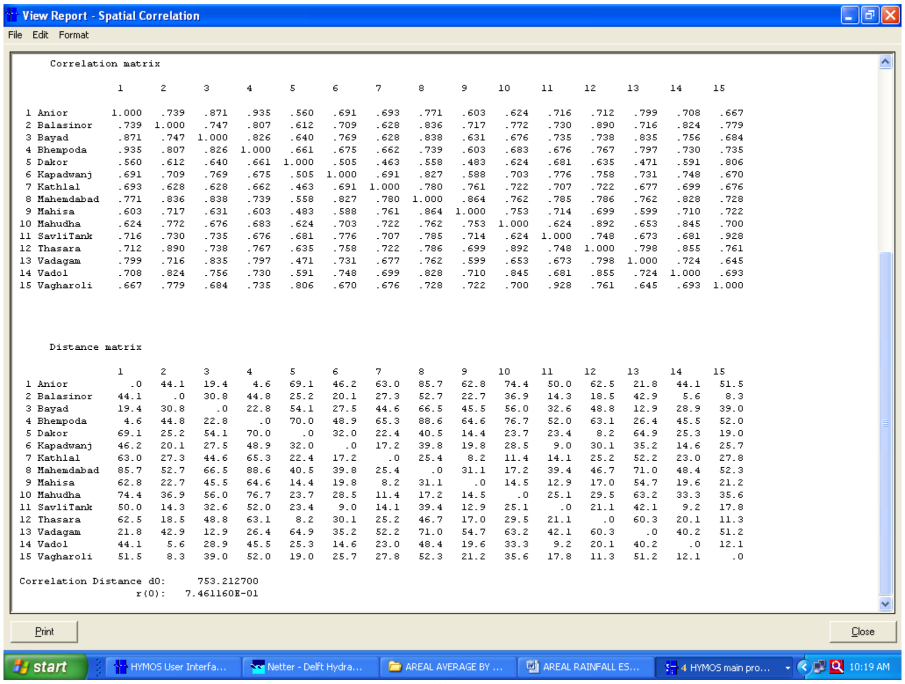


Fig.5

Two figures (**Fig.5 & Fig.6**) are the output of this operation where one exhibits how correlation decays with rise in distance between two stations; and second containing two matrices- one listing correlation between stations and other displaying the distance between them.



View Report - Spatial Correlation

Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Anior	1.000	.739	.871	.935	.560	.691	.693	.771	.603	.624	.716	.712	.799	.708	.667
2 Balasinor	.739	1.000	.747	.807	.612	.709	.628	.836	.717	.772	.730	.890	.716	.824	.779
3 Bayad	.871	.747	1.000	.826	.640	.769	.628	.838	.631	.676	.735	.738	.835	.756	.684
4 Bhempoda	.935	.807	.826	1.000	.661	.675	.662	.739	.603	.683	.676	.767	.797	.730	.735
5 Dakor	.560	.612	.640	.661	1.000	.505	.463	.558	.483	.624	.681	.635	.471	.591	.806
6 Kapadwanj	.691	.709	.769	.675	.505	1.000	.691	.827	.588	.703	.776	.758	.731	.748	.670
7 Kathlal	.693	.628	.628	.662	.463	.691	1.000	.780	.761	.722	.707	.722	.677	.699	.676
8 Mahemdabad	.771	.836	.838	.739	.558	.827	.780	1.000	.864	.762	.785	.786	.762	.828	.728
9 Mahisa	.603	.717	.631	.603	.483	.588	.761	.864	1.000	.753	.714	.699	.599	.710	.722
10 Mahudha	.624	.772	.676	.683	.624	.703	.722	.762	.753	1.000	.624	.892	.653	.845	.700
11 SavliTank	.716	.730	.735	.676	.681	.776	.707	.785	.714	.624	1.000	.748	.673	.681	.928
12 Thasara	.712	.890	.738	.767	.635	.758	.722	.786	.699	.892	.748	1.000	.798	.855	.761
13 Vadagam	.799	.716	.835	.797	.471	.731	.677	.762	.599	.653	.673	.798	1.000	.724	.645
14 Vadol	.708	.824	.756	.730	.591	.748	.699	.828	.710	.845	.681	.855	.724	1.000	.693
15 Vagharoli	.667	.779	.684	.735	.806	.670	.676	.728	.722	.700	.928	.761	.645	.693	1.000

Distance matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Anior	.0	44.1	19.4	4.6	69.1	46.2	63.0	85.7	62.8	74.4	50.0	62.5	21.8	44.1	51.5
2 Balasinor	44.1	.0	30.8	44.8	25.2	20.1	27.3	52.7	22.7	36.9	14.3	18.5	42.9	5.6	8.3
3 Bayad	19.4	30.8	.0	22.8	54.1	27.5	44.6	66.5	45.5	56.0	32.6	48.8	12.9	28.9	39.0
4 Bhempoda	4.6	44.8	22.8	.0	70.0	48.9	65.3	88.6	64.6	76.7	52.0	63.1	26.4	45.5	52.0
5 Dakor	69.1	25.2	54.1	70.0	.0	32.0	22.4	40.5	14.4	23.7	23.4	8.2	64.9	25.3	19.0
6 Kapadwanj	46.2	20.1	27.5	48.9	32.0	.0	17.2	39.8	19.8	28.5	9.0	30.1	35.2	14.6	25.7
7 Kathlal	63.0	27.3	44.6	65.3	22.4	17.2	.0	25.4	8.2	11.4	14.1	25.2	52.2	23.0	27.8
8 Mahemdabad	85.7	52.7	66.5	88.6	40.5	39.8	25.4	.0	31.1	17.2	39.4	46.7	71.0	48.4	52.3
9 Mahisa	62.8	22.7	45.5	64.6	14.4	19.8	8.2	31.1	.0	14.5	12.9	17.0	54.7	19.6	21.2
10 Mahudha	74.4	36.9	56.0	76.7	23.7	28.5	11.4	17.2	14.5	.0	25.1	29.5	63.2	33.3	35.6
11 SavliTank	50.0	14.3	32.6	52.0	23.4	9.0	14.1	39.4	12.9	25.1	.0	21.1	42.1	9.2	17.8
12 Thasara	62.5	18.5	48.8	63.1	8.2	30.1	25.2	46.7	17.0	29.5	21.1	.0	60.3	20.1	11.3
13 Vadagam	21.8	42.9	12.9	26.4	64.9	35.2	52.2	71.0	54.7	63.2	42.1	60.3	.0	40.2	51.2
14 Vadol	44.1	5.6	28.9	45.5	25.3	14.6	23.0	48.4	19.6	33.3	9.2	20.1	40.2	.0	12.1
15 Vagharoli	51.5	8.3	39.0	52.0	19.0	25.7	27.8	52.3	21.2	35.6	17.8	11.3	51.2	12.1	.0

Correlation Distance d0: 753.212700
r(0): 7.461160E-01

Fig.6

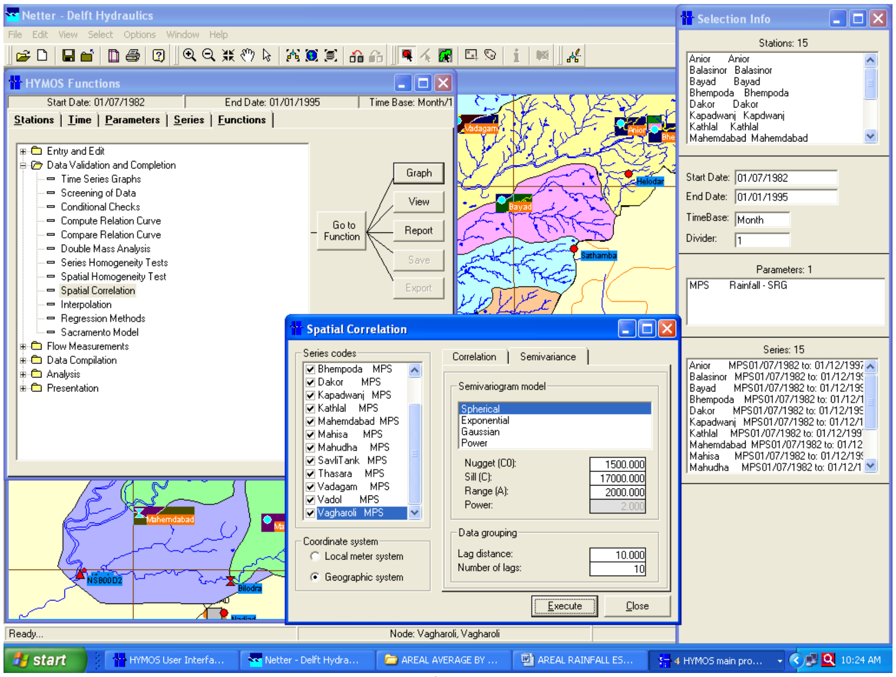


Fig.7

A tab by Correlation tab in **Fig.7** is Semivariance. A click on this tab presents a few empty cells to be entered by user. A few lines hereunder describe the meaning of these parameters. Interested user may refer to ***Training module no. 11*** for more details. To begin with, Sill represents the variance of observed monthly rainfall at selected stations. **Range** is thrice the d0, i.e., 3 * 753. Lag distance, 10km implies semivariance determination for every 10km distance; and number of lag signifies the number of times semivariance would be calculated by HYMOS with 10km incremental distance value.

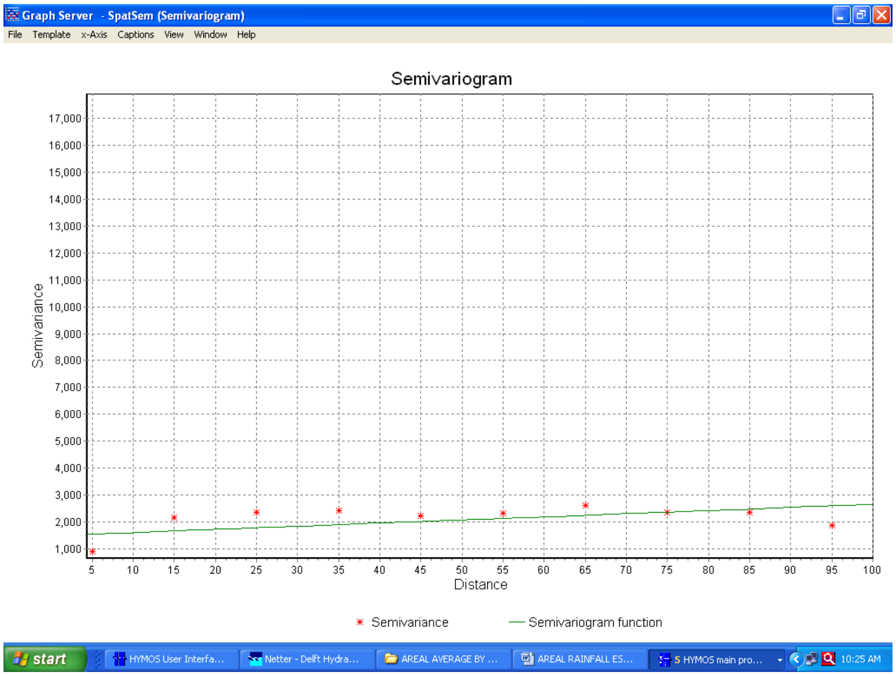


Fig.8

Select spherical as semivariance model and press execute and visit graph as well as report file. With nugget value zero, graph will initially differ from what appears in **Fig.8.** At this stage, user should seek to choose a nugget value in such a manner that plots a best fit line and renders lowest standard error (**Table 1). _**Nugget**, thus arrived at is 1500_.** This table reproduces keyed in values as well as variation in semivariance with distance. Variance, i.e., 16874.12 mm2 marked in color hereunder represents average variance (also called **Sill**) of monthly rainfall data (>10mm) and will be used in Kriging method.

Table 1

Number of timesteps = 150

Variance = **16874.12**

Semivariogram Model: Spherical

Nugget: 1500
Sill : 17000
Range : 2000
Semivariogram calculation

Lag Distance : 10

Number of Lags: 10

Distance	Semivar.	Model Sem.	Difference
5	9.15E+02	1.56E+03	-6.43E+02
15	2.17E+03	1.67E+03	4.94E+02
25	2.35E+03	1.79E+03	5.63E+02
35	2.44E+03	1.91E+03	5.35E+02
45	2.22E+03	2.02E+03	2.02E+02
55	2.32E+03	2.14E+03	1.81E+02
65	2.62E+03	2.26E+03	3.67E+02
75	2.37E+03	2.37E+03	-7.65E-01
85	2.35E+03	2.49E+03	-1.36E+02
95	1.86E+03	2.60E+03	-7.42E+02

Standard Error: 4.51E+02

(A) Kriging Method

In one of the preceding paragraph, we observed how correlation fades with increase in distance. For a catchment marked with hilly terrain and orographic features, rainfall variation over the region is noticed considerably leading to poor or no correlation. Application of Kriging method accounts for this significant catchment characteristics in addition to grid point- station distance; and thus has an edge over other two methods discussed before. Kriging option in HYMOS is available after choice of Spatial Interpolation function in Data Compilation folder and pressing Kriging on relevant window (**Fig.14**). Some of the choices are similar to Inverse Distance method while for spherical semivariogram model, statistical parameters will be entered as therein. User may select the values as distilled earlier and notice the change in the result. Here, values are taken from the ***Training Module no. 11.*** Check the box on in lower mid part of the window to let the HYMOS finish the exercise for first time step only. For current exercise, we have only one set of data for a month. First time step means data for first month will be considered for analysis no matter what is the length of data (one month or even more). If left unchecked, HYMOS will return areal estimation for each time step.

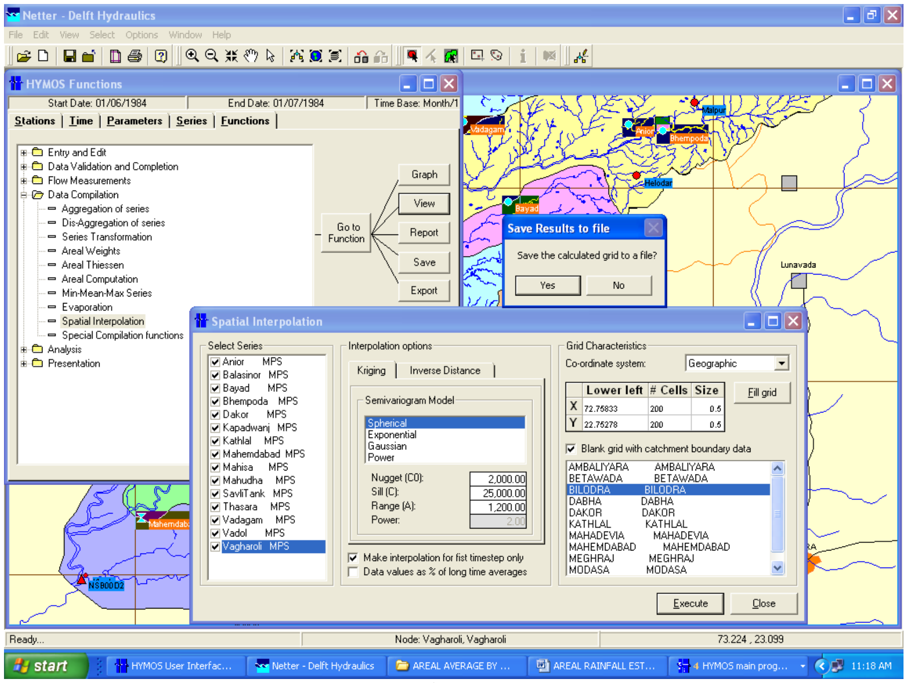


Fig.14

Having executed this window, HYMOS needs location for saving Isohyets and spherical semi-variogram lines one after another (**Fig.15**). Pressing view on Hymos Function box indicates areal rainfall estimation by this method as **21.89mm** as against **18.28mm** by previous method. This point forward, one needs to follow similar steps as illustrated previously to add isohyets layer extracted by Kriging method (**Fig.17**).

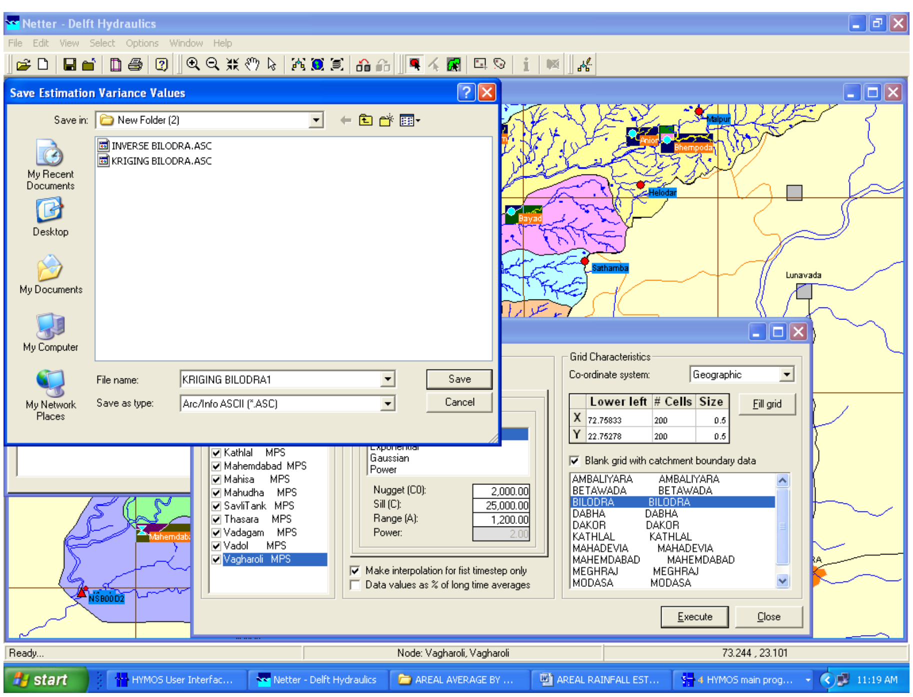


Fig.15

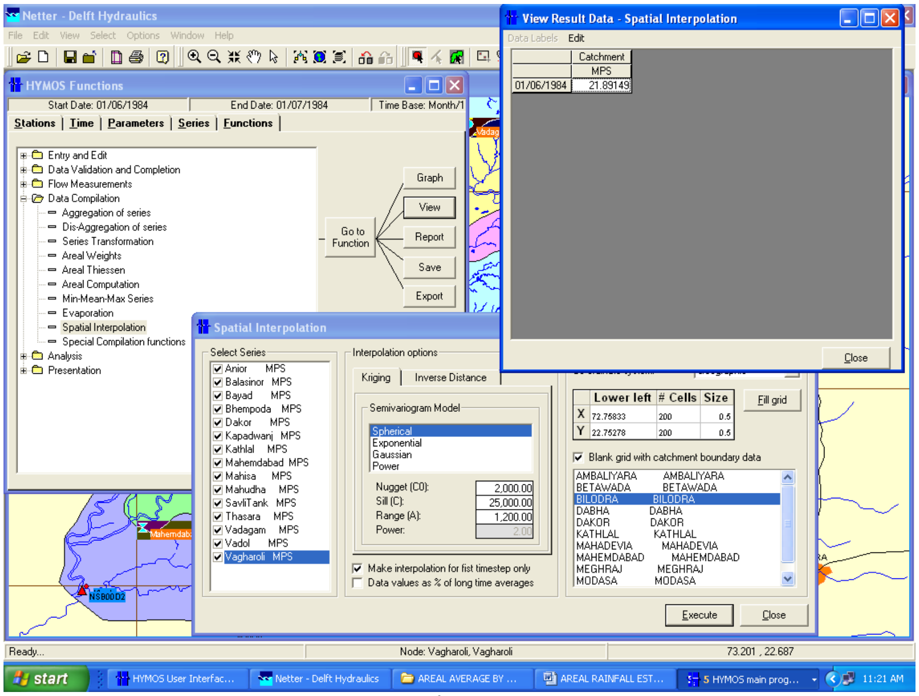


Fig.16

Table 2 contains statistical parameters used in the analysis; location parameters of the stations; & monthly rainfall recorded at each station.

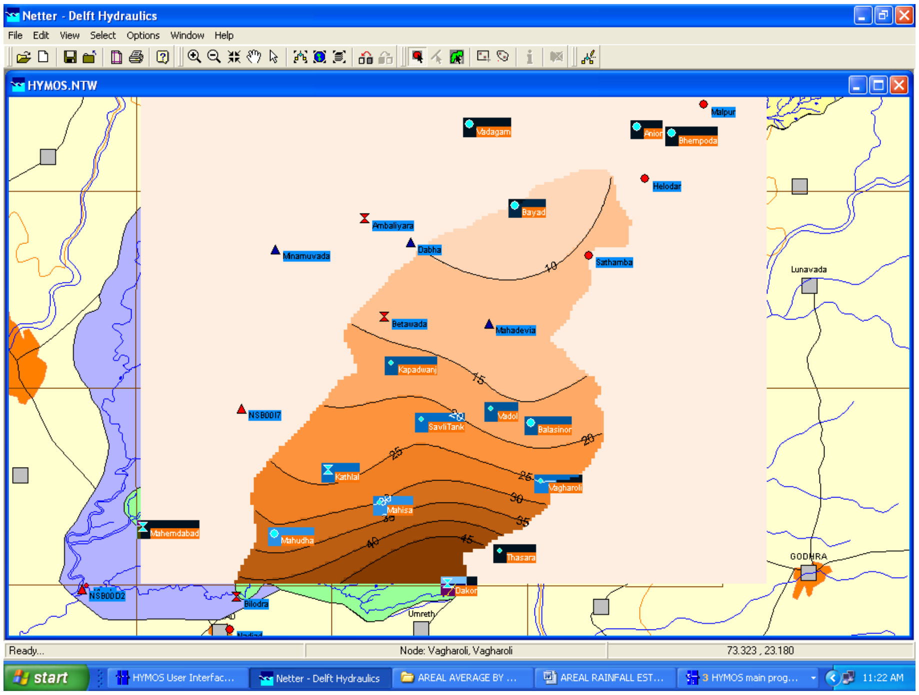


Fig.17

Table 12

Variogram parameters

Nugget (C0) :	2000.000000
Sill (C)	25000.000000
Range (a):	1200.000000

Grid characteristics:

Number of cells in X, Y :	200	200
Origin of X and Y cells :	0.000000E+00	0.000000E+00
Size of X and Y cells :	5.000000E-01	5.000000E-01

Search Radius:	1.000000E+10
Minimum number of samples:	4
Maximum number of samples:	15

Data: Anior MP2 1 at	65.473	63.440	value:	10.40000
Data: Balasinor MP2 1 at	51.140	21.922	value:	.00000
Data: Bayad MP2 1 at	49.430	52.552	value:	1.00000
Data: Bhempoda MP2 1 at	70.007	62.467	value:	18.70000
Data: Dakor MP2 1 at	39.945	-.552	value:	176.00000
Data: Kapadwanj MP2 1 at	32.934	30.610	value:	11.00000
Data: Kathlal MP2 1 at	24.471	15.648	value:	.00000
Data: MahemdabadMP2 1 at	.122	7.998	value:	67.20000
Data: Mahisa MP2 1 at	31.250	10.942	value:	.00000
Data: Mahudha MP2 1 at	17.333	6.762	value:	.00000
Data: SavliTank MP2 1 at	36.817	22.560	value:	54.00000
Data: Thasara MP2 1 at	46.848	3.977	value:	22.00000
Data: Vadagam MP2 1 at	43.604	64.007	value:	.00000
Data: Vadol MP2 1 at	45.951	23.984	value:	.00000
Data: Vagharoli MP2 1 at	52.382	13.755	value:	5.00000

Estimated	40000 blocks
average	17.701320
variance	103.432200

(B) Inverse Distance Method

Both Thiessen and this method works well when topography of the basin is even; free from orographic barrier and rainfall stations are uniformly distributed over the basin. As name suggests, this method assigns weight to stations according to inverse square distance between respective stations grid (s). Initial part of this chapter briefly mentions the way these methods return areal estimation values for user selected basin. To obtain it for Bilodra basin, a spatial correlation function is used in Data compilation folder followed by hitting Go to Function button (**Fig.9**). On a window that appears in **Fig.9**; first pick up all MPS series for analysis; highlight Bilodra basin in lower right box; select coordinate system as Geographic; press Fill grid button underneath; input 200 as cell size; & size of cells as 0.5 in either direction. Execute the function.

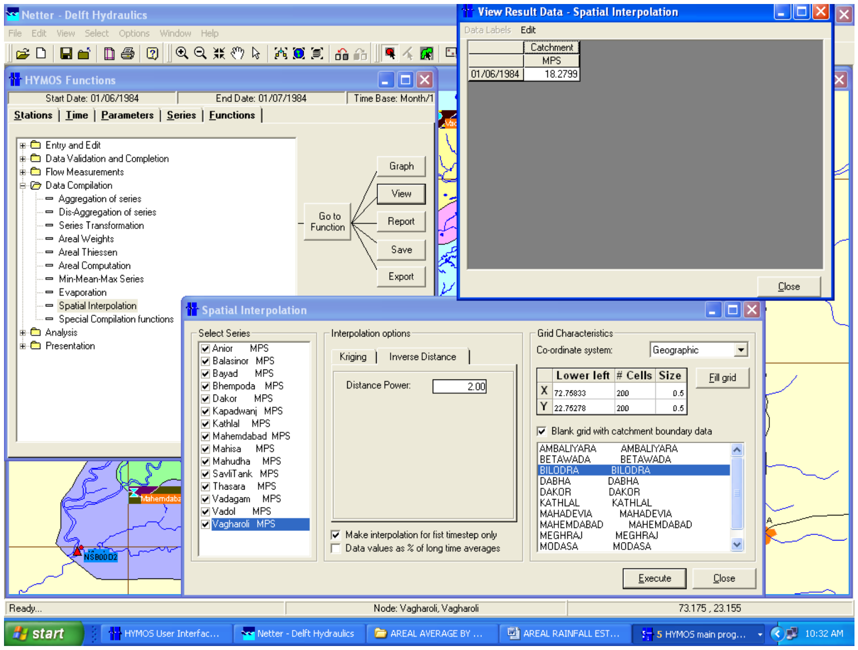


Fig.9

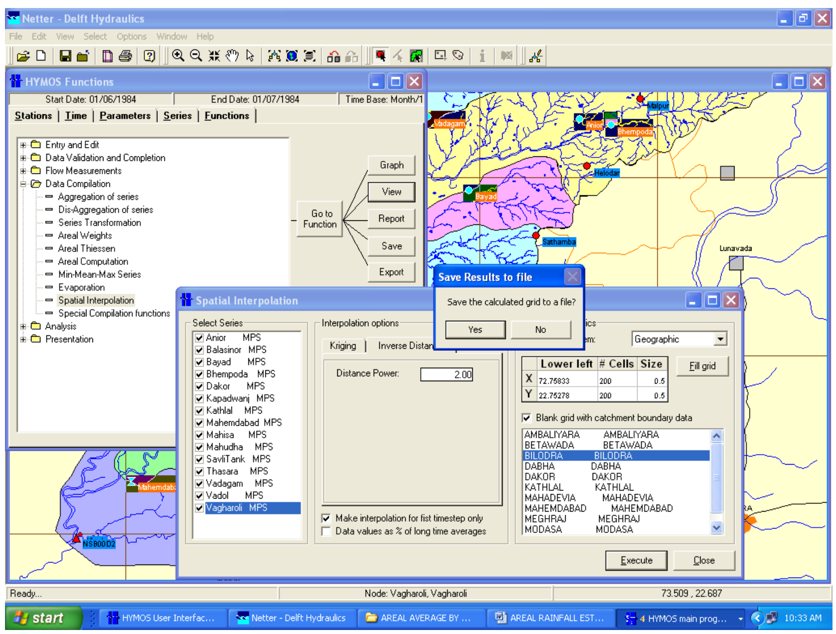


Fig.10

HYMOS pops up a tiny window asking for saving the grid and its location (**Fig.10**). Save the grid (**Fig. 10a**) and invoke option menu on netter screen to add grid layer over the basin (**Fig.11**). User may refer to illustration for **Fig.16** and beyond of chapter IV of this document for steps in detail.

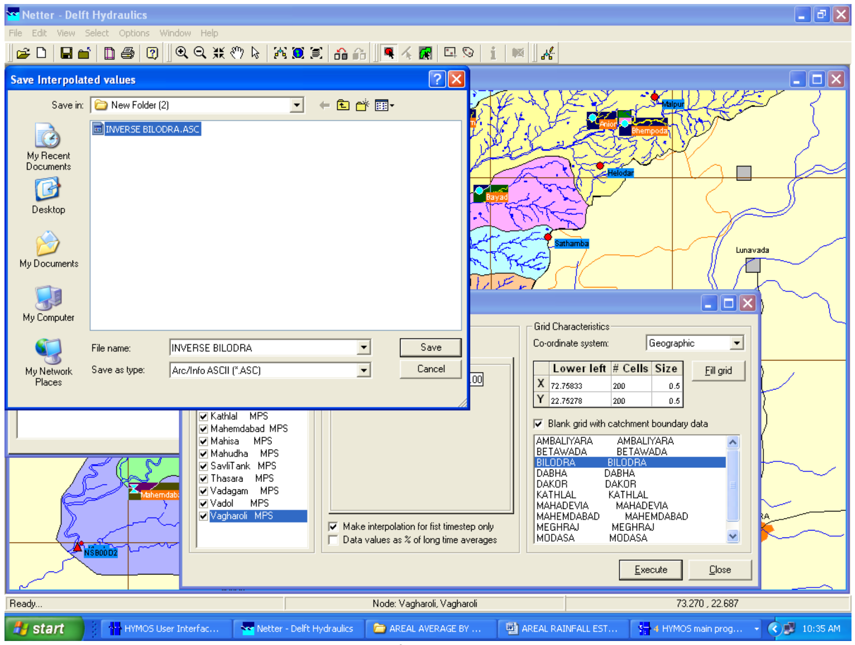


Fig.10a

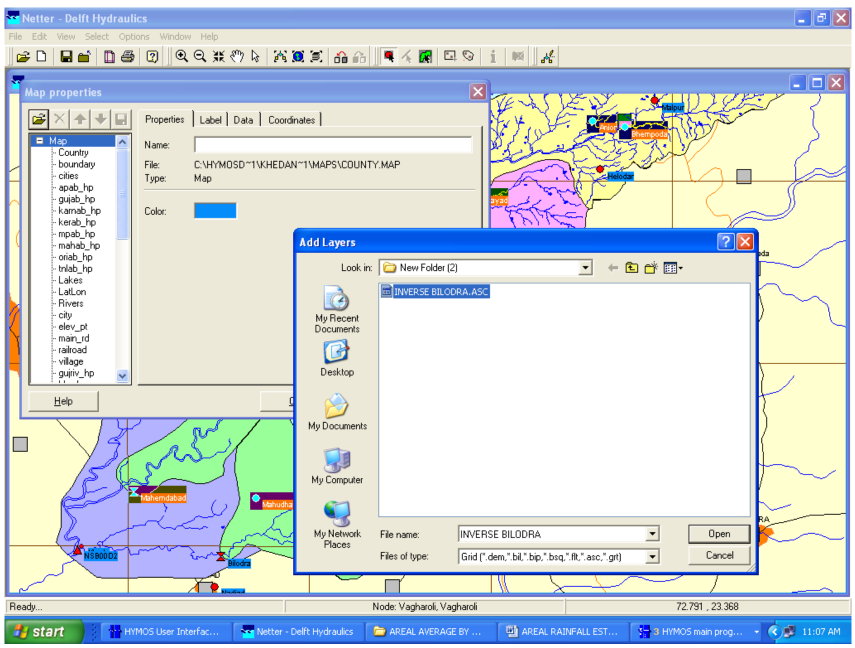


Fig.11

To draw isohyets at equal intervals, user may use Data button on Map Properties windows and click on Classify tab at the bottom thereon (**Fig.12**). A resultant box offers options to set figures of user’ s intent and let HYMOS draw isohyets (**Fig.13**).

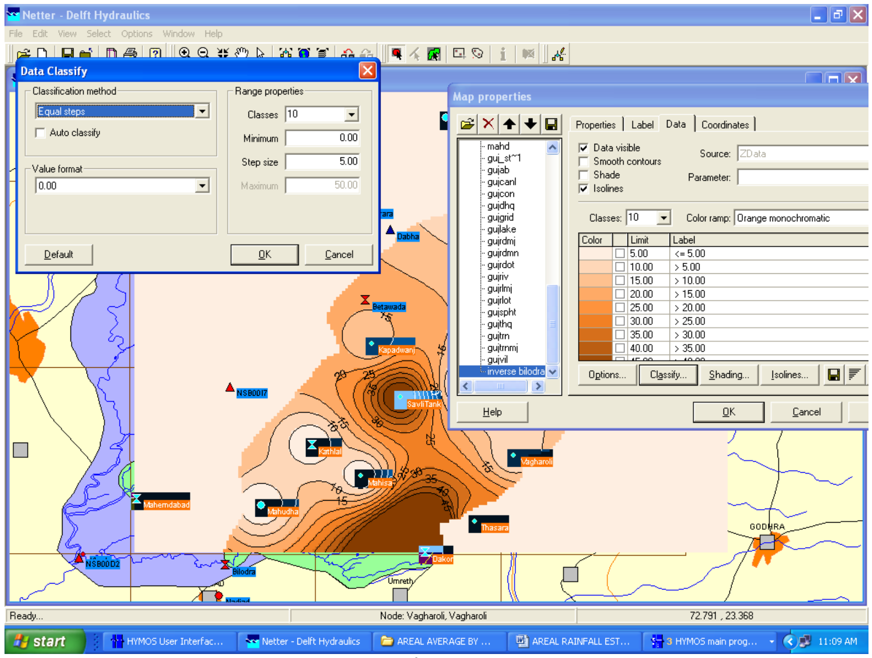


Fig.12

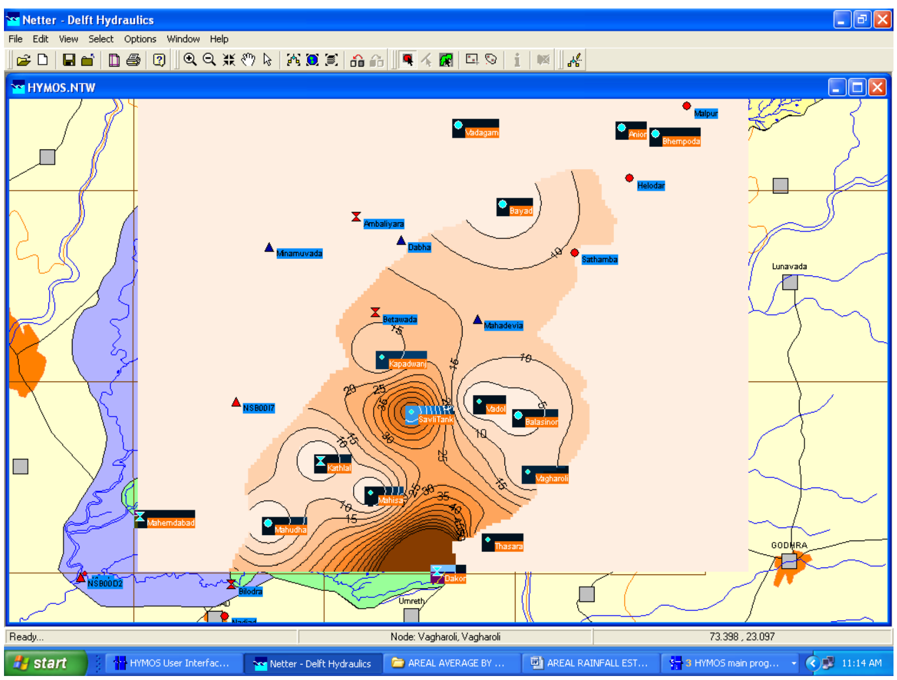


Fig.13

Areal rainfall estimation for Bilodra basin determined by this method is **18.28mm** in the month of June 1984 (**Fig.9**). This amount may be had by clicking on View button on Hymos Function window/box.

(C) Thiessen Polygon Method

Fig.18 to Fig.20 pertains to functions of Thiessen polygon method which returns areal estimation as **18.58mm**. This method has already been discussed a couple of times earlier and reproduction of screenshots hereunder is meant for comparison only. User may notice a slight change in selected stations. This is required to let HYMOS draw isohyets successfully.

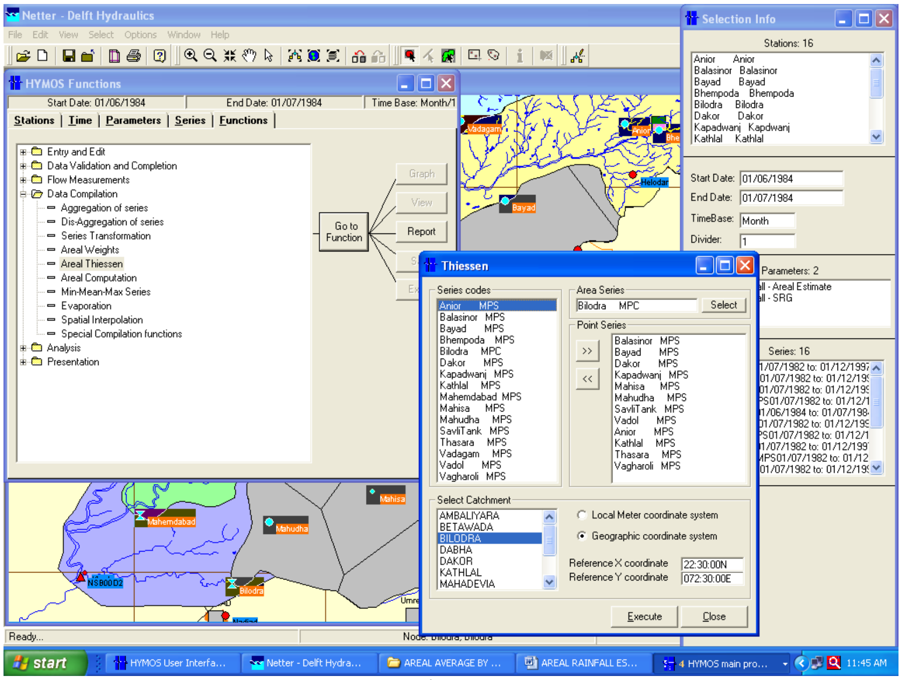


Fig.18

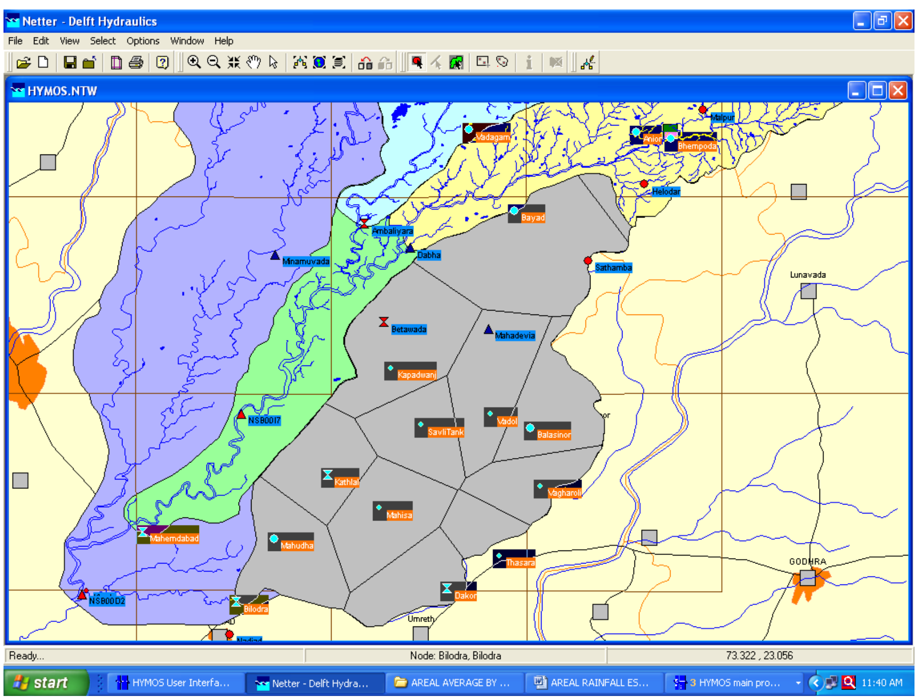


Fig.19

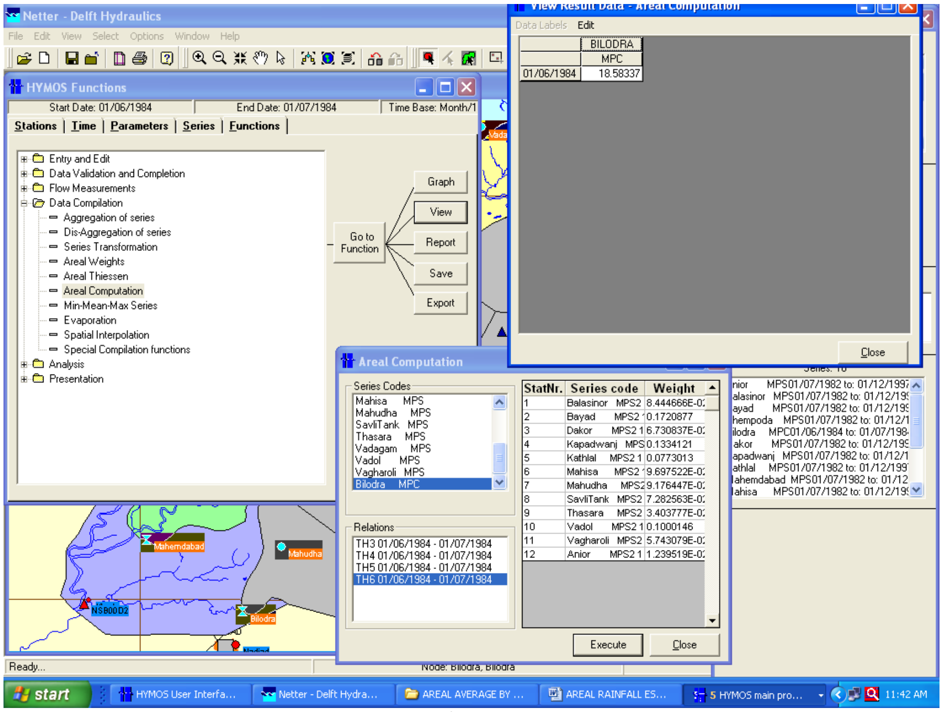


Fig.20

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