FINAL REPORT
2000-483-325

A GIS – TxRR Model for East Matagorda Bay

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Submitted to the Texas Water Development Board
In fulfillment of Grant # 2000 483-325

Center for Research in Water Resources
University of Texas at Austin

May, 2001

Abstract

The Texas Water Development Board uses a rainfall-runoff model called TxRR to simulate ungaged flows discharging directly into Texas bays and estuaries. In this report, a geospatial database of watersheds and soil parameters for TxRR is built for drainage into East Matagorda Bay. A systematic procedure is described by which data from the National Hydrography Dataset and the National Elevation Data set can be combined to define a set of watersheds for this coastal basin. This procedure includes processing of Statsgo soils data to determine Green and Ampt soil properties for these watersheds. Improvements are made to the execution of the TxRR model such that it is more tightly integrated into its Visual Basic interface. Additional Visual Basic code has been created so that TxRR can read and write data to the ArcGIS Hydro data model, a standardized representation of spatial and temporal data for water resources. By integrating TxRR and the ArcGIS Hydro data model, a system can be created for the operation of TxRR for any drainage area along the Texas coastline.

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1. Introduction

TxRR (Texas Rainfall-Runoff) is a rainfall-runoff simulation model designed to create sequences of daily flows for ungaged areas near Texas bays and estuaries. The Texas Water Development Board (TWDB) wishes to improve the implementation of TxRR by making it more closely tied to geospatial data from Geographic Information Systems. Benefits of better integration with GIS include improved methods for drainage area delineation, soil parameterization, and conversion of gage rainfall to rainfall over watersheds. Research on building a better GIS basis was initiated at the Center for Research in Water Resources (CRWR) by TWDB with an initial project on applying TxRR to Corpus Christi Bay (Perales et. al., 2000). At the time that study was initiated, TxRR was a Fortran program that did not have good capabilities for displaying graphs of precipitation and flow data, and also it had no mechanism for routing water through landscape. TxRR was, and is, a vertical water balance model applied to a particular watershed. At the beginning of the research, two approaches suggested themselves:

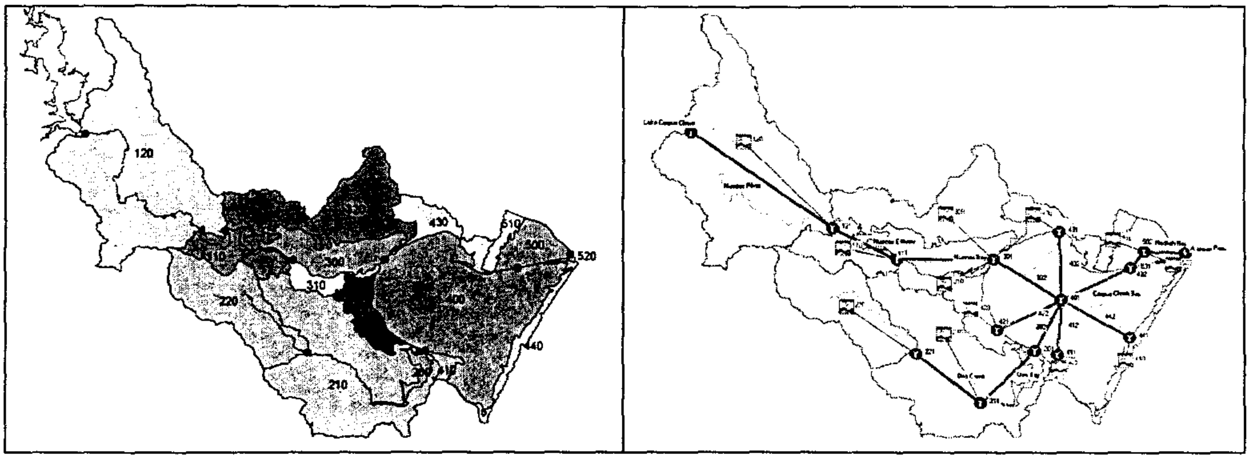
- **Method 1:** Incorporate TxRR results into the HEC-HMS model from the US Army Corps of Engineers, and use the CRWR-PrePro preprocessor for HEC-HMS to do the spatial data processing
- **Method 2:** Run TxRR as a standalone program which is linked to GIS for geospatial data processing and for storage and retrieval of spatial and temporal data

In the Corpus Christi Bay study, conducted in 1999, Method 1 was adopted. This study focuses on drainage to East Matagorda Bay, and uses Method 2. In particular, it is demonstrated how the TxRR model can be linked to ArcInfo and ArcView version 8.1, due for release in May 2001, by using the ArcGIS Hydro data model as a connecting mechanism.

Corpus Christi Bay Study

In the Corpus Christi Bay study, Method 1 was adopted. The HEC Data Storage System (DSS) was used to store and manipulate time series files. TxRR was used to create runoff data for drainage areas, and the results were read into HEC-HMS. The ArcView program CRWR-PrePro was used to create a Basin file for HMS, which describes the landscape for hydrologic simulation. Method 1 was executed successfully but it proved to be difficult to use for several reasons:

- The HEC-HMS model is a stand-alone hydrologic simulation model and is not designed as a shell into which other models can be readily inserted. In particular, import and export of time series data from DSS proved to be very tedious. There were many file manipulations involved, and it was obvious that some automated system for handling them was needed.
- The process of defining drainage areas to coastal basins proved to be sufficiently different from that for inland drainage areas that the automated terrain processing method in CRWR-PrePro for generating the HMS Basin file was of limited value. A considerable amount of hand-editing was needed to connect the model drainage areas together, particularly for those draining directly into the bays.



GIS and HEC-HMS representations of drainage into Nueces Bay and Corpus Christi Bay

East Matagorda Bay Study

In the study described here, a new bay and estuary system is examined, East Matagorda Bay. In addition, Method 2 for GIS-model integration has been adopted, namely TxRR has been run deriving its data directly from the GIS database.

The following objectives have been accomplished in this study:

1. A procedure is defined for selecting and editing the National Hydrography dataset so as to produce a stream network suitable for the delineation of coastal drainage and implemented to define the stream and coastline network for East Matagorda Bay.

2. The stream network is combined with the National Elevation Dataset for land surface topography and used to define a set of elementary drainage areas. Selected drainage areas are combined into three watersheds draining to East Matagorda Bay watersheds

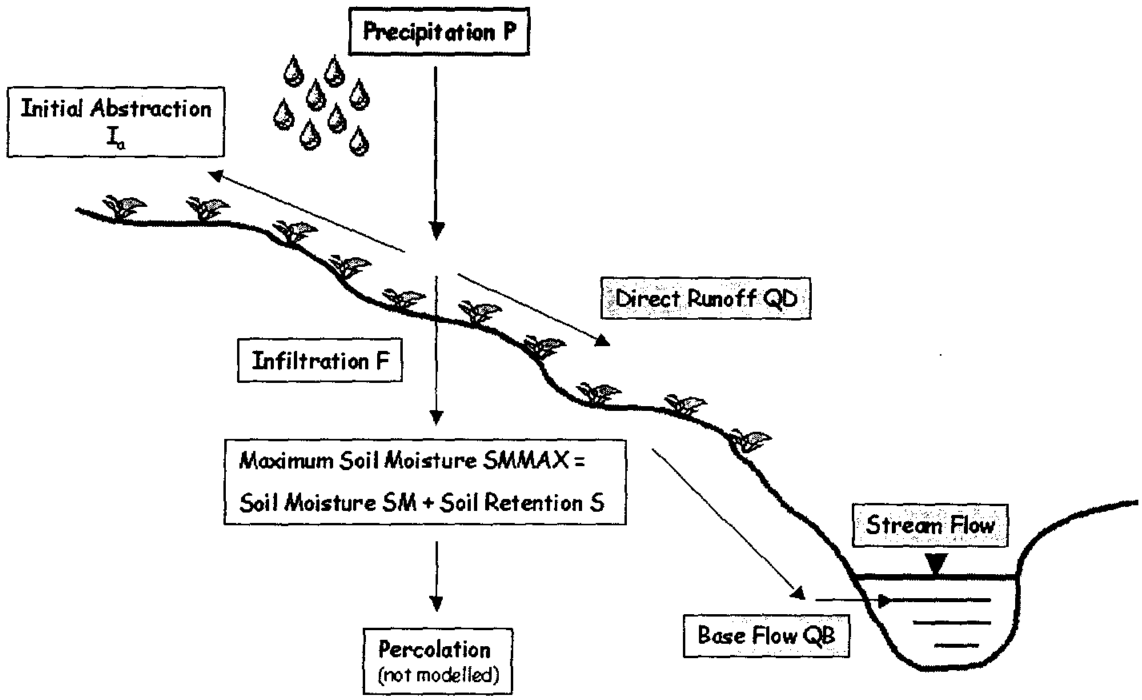
3. A procedure for determining Green and Ampt soil parameters for these watersheds is applied to determine soil parameters for East Matagorda Bay

4. The Visual Basic interface to TxRR has been streamlined so that the Fortran code is called without having to use a separate DOS window.

5. Additional Visual Basic procedures have been written so that the time series files for TxRR can be read from and written to the Time Series database of the ArcGIS Hydro data model.

Background Information on the TxRR Model

TxRR is a rainfall-runoff model using daily time steps to simulate runoff over a long period of years. Within the model, a daily soil water balance is used to partition precipitation P on the land surface is partitioned into an initial abstraction I_a, infiltration F, and direct runoff QD. Some of the infiltrated water can return subsequently to the stream as base flow QB. The sum of direct runoff and baseflow forms stream flow. The model parameters are determined by calibration against observed streamflow at locations where stream gage data exist. Once calibrated, the model is applied with the same parameters to coastal drainage basins without stream gaging data.

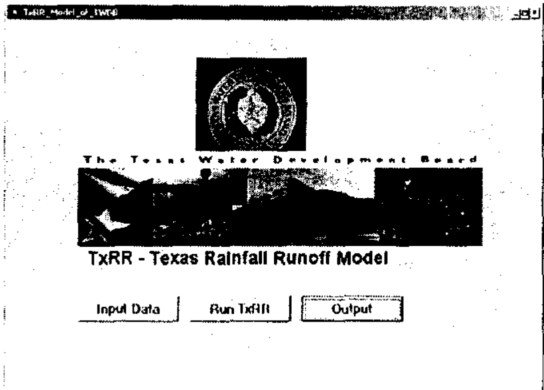


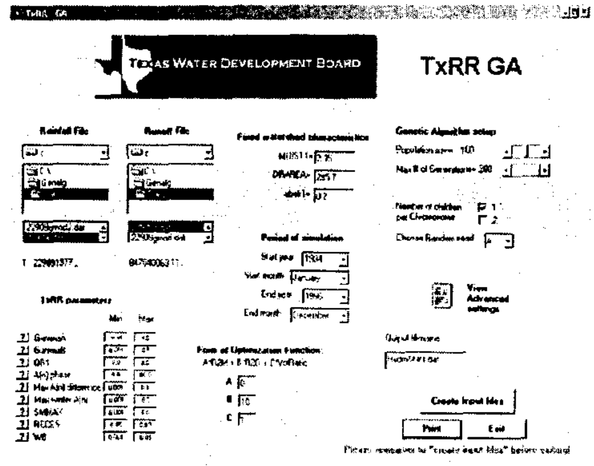
TxRR rainfall-runoff processes

Visual Basic Interface for TxRR

TxRR was originally developed by Dr Junji Matsumoto at the TWDB as a Fortran program. During 2000, Dr Barney Austin at TWDB built a Visual Basic Interface for TxRR to display precipitation and streamflow data. He also linked TxRR to a Genetic Algorithm for calibrating its parameters. There are thus two versions of TxRR: the version used when calibrating the model to known streamflow data, and a simpler version used when running the model to generate flows. Dr Austin's interface to TxRR created the input text files to run the model, required the user to open a separate DOS window to execute TxRR, then open the interface again to read TxRR's text output files and display them. The Visual Basic interface to TxRR is definitely a significant step forward in making the model more user friendly, and the Genetic Algorithm for determining model parameters is also a useful step forward. Dr Austin also applied a new unit hydrograph in TxRR using the Gamma function.

In this report, the Visual Basic interface to TxRR is further improved, and linked to the ArcGIS Hydro data model to supply geospatial and temporal data for operation of TxRR.



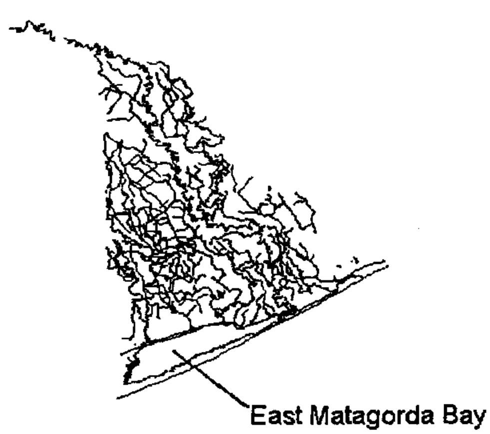


Visual Basic Interfaces for TxRR

2. Defining Coastal Drainage Basins – East Matagorda Bay

The domain of application of TxRR is the coastal basins of Texas, of which there are eight principal coastal basins, named for the rivers which drain to the coast between them: Nueces – Rio Grande, San Antonio – Nueces, Lavaca – Guadalupe, Colorado – Lavaca, Brazos – Colorado, San Jacinto – Brazos, Trinity – San Jacinto, and Neches – Trinity. These basins in turn encompass a number of bays and estuary areas considered as separate modeling units for application of TxRR. The subject area for this study is East Matagorda Bay, which is the main bay in the Colorado – Lavaca coastal basin.

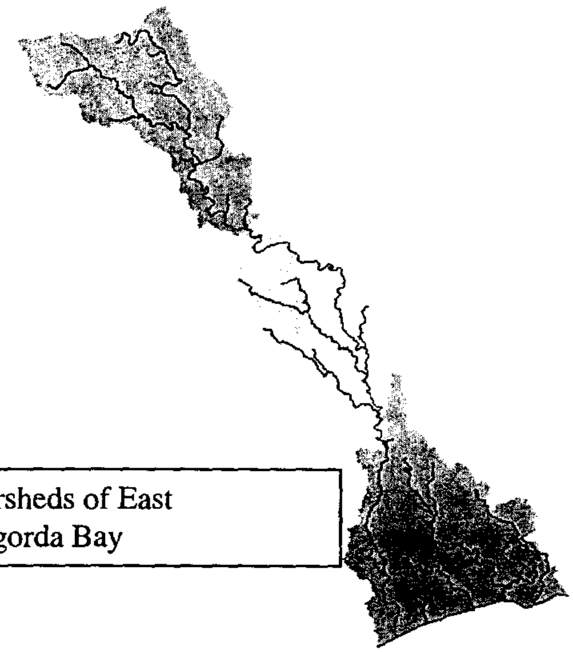
Coastal Basins of Texas



East Matagorda Bay and the rivers draining into it (derived from the National Hydrography dataset)

Goals

The purpose of this chapter of the report is to develop a procedure to define coastal drainage basins. The following exercise allows the user to develop drainage basins for any coastal area. Furthermore, the exercise also demonstrates a method to analyze the soils of the area of interest. The study area for this exercise is the watersheds draining to East Matagorda Bay, which can be seen to the right.



Watersheds of East Matagorda Bay

Obtaining the National Hydrography Dataset

The first step in defining a coastal drainage basin is to define its streams and waterbodies using the National Hydrography Dataset (NHD). Download the stream networks of interest from the website http://nhd.usgs.gov., the homepage for the National Hydrography Dataset. The data on this site can be downloaded by referencing the USGS Cataloging Unit, or a map can be used to determine the areas which are of interest. The file that is downloaded is a *.tgz file. This file must be uncompressed before it can be used. The programs needed for this purpose are Gzip.exe and Tar.exe, which can be downloaded from links attached to the NHD website. The NHD is in Geographic Coordinates.

The Cataloging Units used to define East Matagorda Bay and surrounding drainage areas are:

- East Matagorda Bay
  USGS Cataloging Unit: 12090402
  http://www.epa.gov/surf3/hucs/12090402/

- Central Matagorda Bay
  USGS Cataloging Unit: 12100401
  http://www.epa.gov/surf3/hucs/12100401/

- Navidad
  USGS Cataloging Unit: 12100102
  http://www.epa.gov/surf3/hucs/12100102/

- Lower Colorado
  USGS Cataloging Unit: 12090302
  http://www.epa.gov/surf3/hucs/12090302/

- Lower Brazos
  USGS Cataloging Unit: 12070104
  http://www.epa.gov/surf3/hucs/12070104/

- Austin-Oyster
  USGS Cataloging Unit: 12040205
  http://www.epa.gov/surf3/hucs/12040205/

- San Bernard
  USGS Cataloging Unit: 12090401
  http://www.epa.gov/surf3/hucs/12090401/

Two other datasets are needed for defining the coastal drainage system: Digital Raster Graphic Maps and Digital Elevation Models of land surface terrain.

Digital Raster Graphic Data. This data is available through the Texas Natural Resources Information System (TNRIS). The URL is:
http://www.tnris.state.tx.us/DigitalData/drgs.htm

Digital Elevation Models of the region of interest. This data is available through the Texas Natural Resources Information System (TNRIS). The URL is:
http://www.tnris.state.tx.us/DigitalData/DEMs/dems.htm.

Standard methods for defining drainage basins are described at:
http://www.ce.utexas.edu/prof/olivera/prepro/ExerciseDelineate/delinex.htm. In this report, modifications to the existing exercise will be described in order to develop the most current method for defining coastal drainage basins. The basin of interest for this report is East Matagorda Bay.

2.1 Creating an NHD Stream Network for the Region

The following instructions describe how to develop a stream network for the region of interest. It is recommended to build a stream network larger than the area needing to be delineated. This over-sizing of the stream network reduces errors in the delineated drainage areas that would otherwise occur.

First the downloaded NHD files must be uncompressed using Gzip.exe and Tar.exe. The uncompressing can be completed with the commands below from a DOS command prompt. Be sure to specify the correct directory path to use the gzip.exe and tar.exe programs.

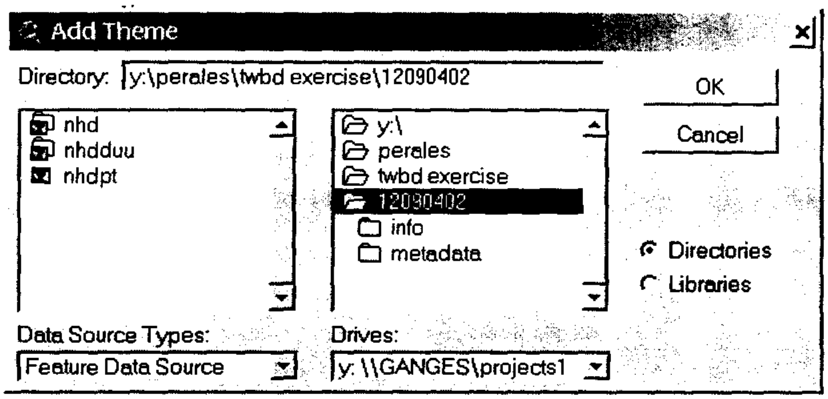
To unzip:

```
C:\ gzip -d 12090402.tgz
```

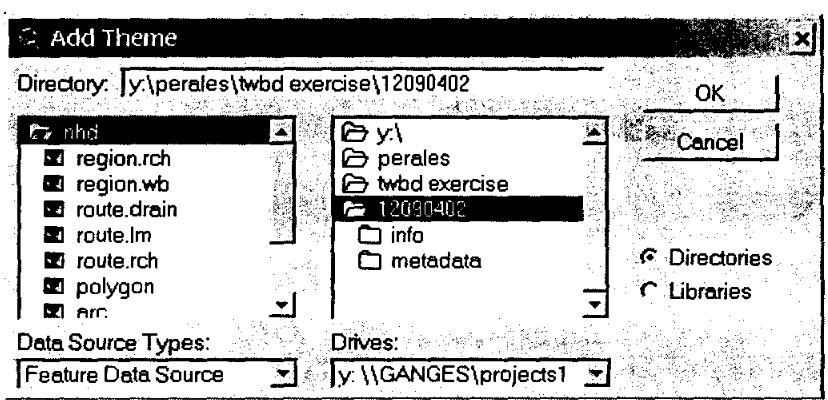
To untar:
C:\ tar xvf 12090402.tar

After the files have been uncompressed, the necessary themes can be added in ArcView 3.2:

To do this press the ***Add Themes*** button. Select the directory where you uncompressed your file and will see a folder named with the CU number



Click the folder labeled ***nhd*** you will see a list of themes. Add the theme ***route.rch*** and ***route.drain*** from the CUs.



Each CU folder will have the same files and they will assign the same name to each file, so we must change the names of the themes to keep the files in order. To do this Go to the ***Theme/Properties*** drop down menu and change their names to USGS cataloging unit number with the distinction between drain and reach (they can't have the same theme name).

Processing the Reach Codes

The NHD uses a system of Reach Codes to index individual NHD reaches. Each code value is a text field with 14 characters, the first 8 representing the HUC unit the reach lies in, and the remaining 6 to specify which stream segment within that HUC unit the reach describes. This 14 character code is too long to be directly converted to an integer value. The following procedure describes how to define an integer value corresponding to the Reach Code.

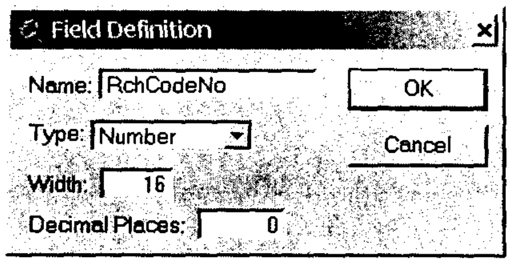
Turn the ***route.rch*** themes into individual shape files by selecting the theme and using ***Convert to Shapefile*** from the ***Theme*** drop down menu.

To edit the attribute table of the shape file press the ***Open Theme Table*** button.

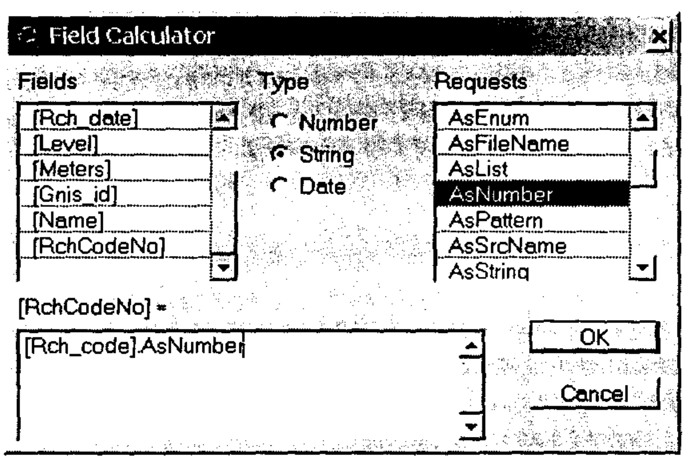
Next start editing the table by selecting ***Table/Start Editing***.

For each CU shape file, add a field to the table by selecting ***Edit/Add Field***.

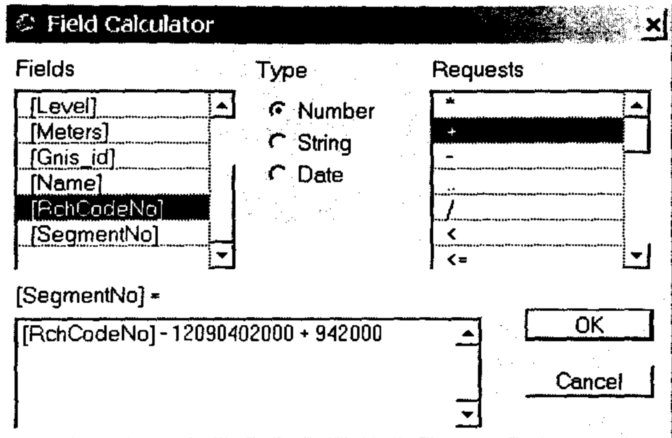
When the Field Definition window opens, name the new field *RchCodeNo*, which is a number field, with 16 characters.

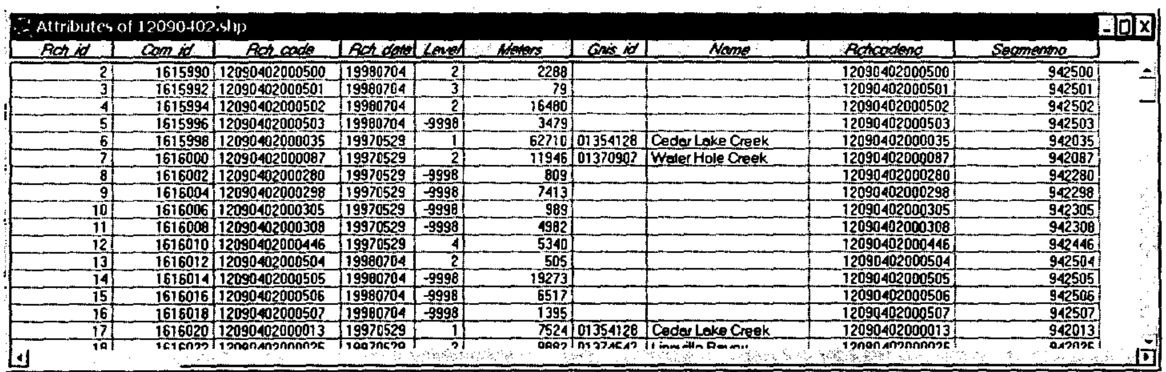


With the new field selected, use the ***Field/Calculate*** option to calculate *RchCodeNo* as Rch_code.asNumber (asNumber is a choice on the right).



Add another field to each attribute table named *SegmentNo*, again a number field with 16 characters. Use the field calculate option to calculate *SegmentNo* as
RchCodeNo – CU#_ _ _ _ _ _ + last CU digit _ _ _ _ _.
See the figure below for an example.





Attributes of 12090402.shp

Rch_id	Com_id	Rch_code	Rch_date	Level	Meters	Gnis_id	Name	Rchcodeno	Segmentno
2	1615990	12090402000500	19980704	2	2288			12090402000500	942500
3	1615992	12090402000501	19980704	3	79			12090402000501	942501
4	1615994	12090402000502	19980704	2	16480			12090402000502	942502
5	1615996	12090402000503	19980704	-9998	3479			12090402000503	942503
6	1615998	12090402000035	19970529	1	62710	01354128	Cedar Lake Creek	12090402000035	942035
7	1616000	12090402000087	19970529	2	11946	01370907	Water Hole Creek	12090402000087	942087
8	1616002	12090402000280	19970529	-9998	809			12090402000280	942280
9	1616004	12090402000298	19970529	-9998	7413			12090402000298	942298
10	1616006	12090402000305	19970529	-9998	989			12090402000305	942305
11	1616008	12090402000308	19970529	-9998	4982			12090402000308	942308
12	1616010	12090402000446	19970529	4	5340			12090402000446	942446
13	1616012	12090402000504	19980704	2	505			12090402000504	942504
14	1616014	12090402000505	19980704	-9998	19273			12090402000505	942505
15	1616016	12090402000506	19980704	-9998	6517			12090402000506	942506
16	1616018	12090402000507	19980704	-9998	1395			12090402000507	942507
17	1616020	12090402000013	19970529	1	7524	01354128	Cedar Lake Creek	12090402000013	942013

In this example, a ReachCode of 12090402000500 is convert to a SegmentNo of 942500, which is functionally equivalent to the original value and short enough to be treated as an integer by ArcView (less than or equal to 2^{31}). This method works if there are less than 1000 segments within a HUC unit, which is the case in most such units. It is possible to develop a different coding system if more records are to be manipulated. This process of ReachCode conversion must be completed for each CU file.

Merging the Reach Files

Now it is possible to merge the reach files without losing data. To merge files, the Geoprocessing Wizard Extension must be turned on, (***File/Extension***: Geoprocessing). To use the wizard go to ***View/Geoprocessing Wizard***. Follow the dialog boxes to merge the themes. Merge all the ***route.rch*** themes. Output is ***nhd_sjb***. Merge all the ***route.drain*** themes. Output is ***drain_sjb***.

Projecting the Reach Files to the Required Coordinate System

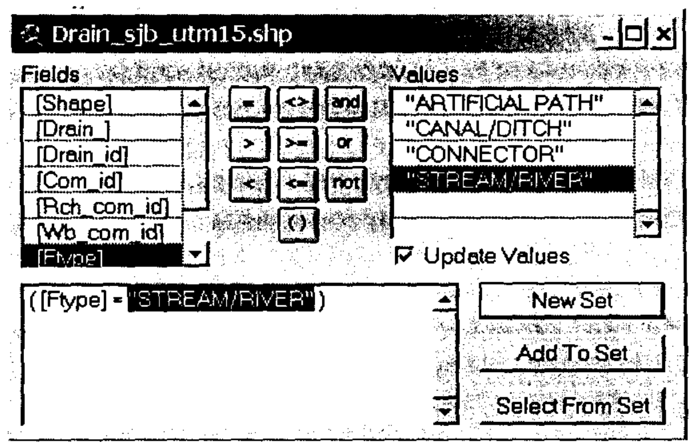
Next, the stream networks must be projected into UTM coordinates so that they can be overlaid with Digital Raster Graphic maps for editing and checking the stream network. Using the ArcView Projector! Extension, (***File/Extensions*** menu), project the two themes to the desired projection. This extension is available with ArcView 3.1. In ArcView 3.2, the Projection

Utility Wizard can be used to achieve the same goal. To do this, make the theme to be projected active and click the ***Projector*** button. Follow the dialog boxes to produce the desired projection. The original NHD data is in geographic coordinates. The themes have been projected to UTM zone 15, with the output themes as ***nhd_sjb_utm15*** and ***drain_sjb_utm15***.

ArcInfo can also be used to project the stream networks
The projection file for UTM 15 is:

Projection UTM
Zone 15
Datum NAD83
Zunits NO
Units METERS
Spheroid GRS1980
Xshift 0.0000000000
Yshift 0.0000000000

Finally, the canals are removed from the stream network.

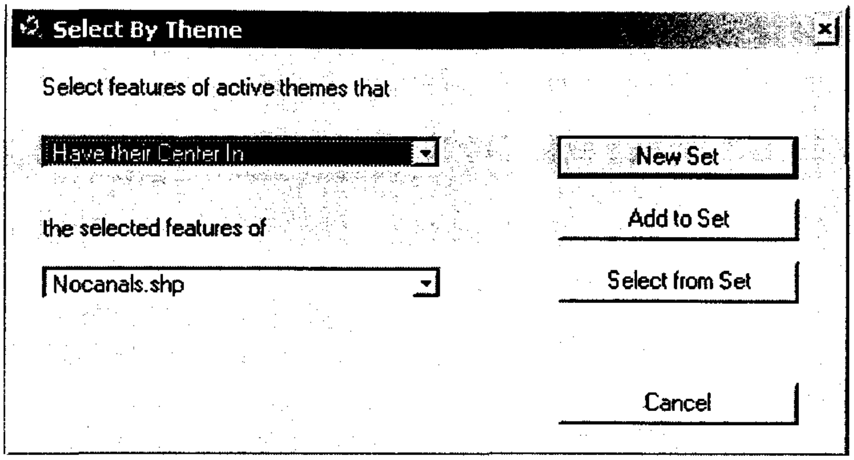


- Delete the themes ***drain_sjb*** and ***nhd_sjb*** from the view. Make the ***drain_sjb_utm15*** theme active.

- In the ***Theme*** menu, query the active theme with the ftype field for ftype = stream/river, as a ***New Set***. Do NOT unselect. Then query ftype = artificial path, and ***Add To Set***. Again, do NOT unselect. Query ftype = connector and ***Add To Set***.

- With the ***drain_sjb_utm15*** theme still active and all the queries still selected, convert to shapefile, with output as ***Nocanals***.

- Make the *nhd_sjb_utm15* theme active and go to the ***Theme*** menu. ***Select By Theme***, all the features in the active theme that "***Have their Center in***" the *Nocanals* theme and press ***New Set***.

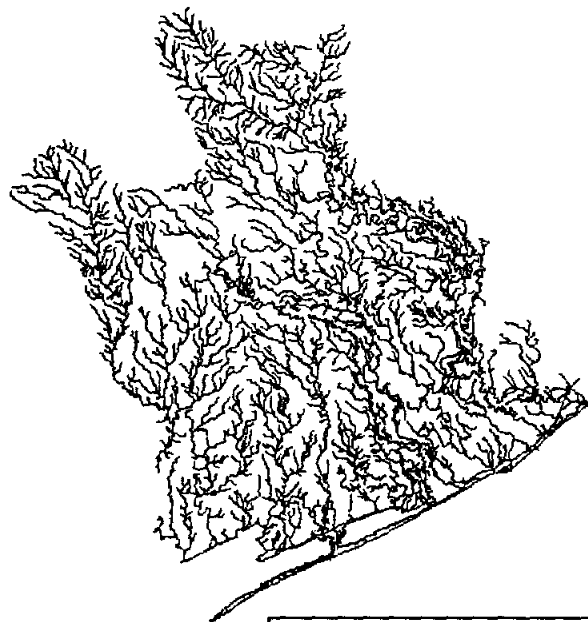


- Go to the ***Theme*** menu, and convert the selection to a shapefile, output is ***Rchnocanal***.

- Go to ArcInfo, and turn the shapefile into a coverage and clean the coverage with the Arc commands:
  1. First a workspace must be created with the command:
     Arc: createworkspace y:\perales\twbd_exercise (<drive>:\directory)
     To check the workspace use the command:
     Arc: w
  2. To create the coverage use the command:
     Arc: shapearc *rchnocanal rchnocanal* (input shapefile, output coverage name)
  3. To clean the coverage use the command:
     Arc: clean *rchnocanal rchnocanal_cl* 0.000001 0.000001 (input coverage name, output coverage name, tolerances which will be changed to the minimum automatically)

- The output theme ***rchnocanal_cl*** has no gaps in it that were not intended to be there. In ArcView, add the theme ***rchnocanal(ARC)*** to the View.

  - Make that theme active, and convert to shapefile, ***Nhdnetwork***. You now have a natural stream network composed of transport and coastline reaches in the NHD.

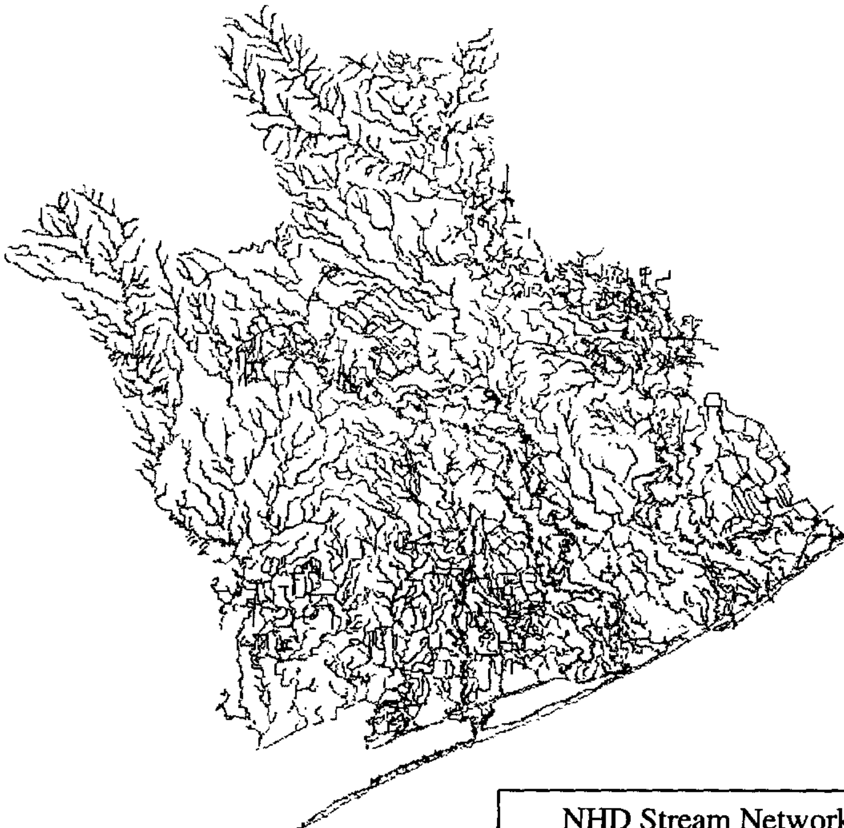


NHD Network of the Matagorda Bay System. Notice that the bay system includes a much greater extent than simply East Matagorda Bay, which is located in the center of the stream network

2.2 Editing the NHD Stream Network

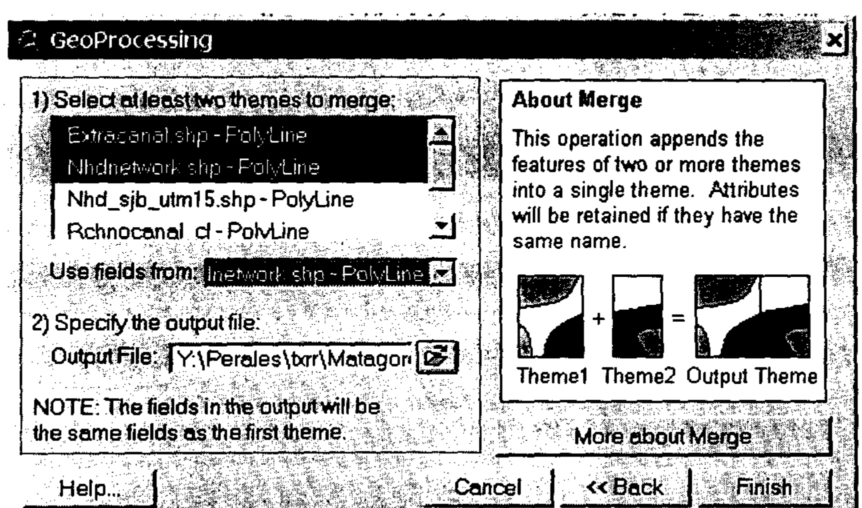
When editing the natural stream network, it is possible to include additional canals, already present in the NHD, which have been eliminated in the previous step. This procedure is an example of adding a canal to the natural network from the original NHD coverage that was needed, and how to retain all of its attribute fields when merging it to the network. The example also pertains to adding just portions of an additional reach, where the length is not what is in the *meters* field of NHD reaches.

- With both the ***Nhdnetwork*** and ***nhd_sjb_utm15*** theme on the view, make the ***nhd_sjb_utm15*** theme active. Select any reaches that need to be included with the ***Select Feature*** button. Convert this selection to a shapefile, output ***extracanal***. Do any splitting of lines/editing BEFORE making the selection.



NHD Stream Network with canals in red.

- Using the ***Geoprocessing Wizard*** from the ***View*** menu, merge the themes ***nhdnetwork*** and ***extracanal***. In the box to specify which fields to use in the merged theme, specify the fields of ***nhdnetwork***. The Output is ***nhdnet2***.



Go to ArcInfo, and turn the shapefile into a coverage and clean the coverage:

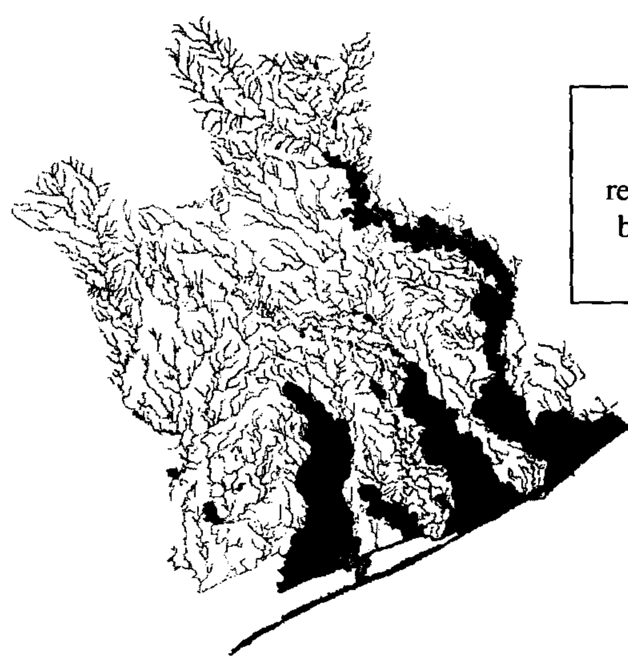
Arc: shapearc *nhdnet2 nhdnet2*
(input shapefile, output coverage name)
Arc: clean *nhdnet2 nhdnet2_cl* 0.000001 0.000001
(input coverage name, output coverage name, tolerances which will be changed to the minimum automatically)

The output theme ***nhdnet2_cl*** will not have any gaps in it, and the correct lengths will be added to a length field. The *meters* field will have the length of the entire reach, if a reach was split before it was added, however the length field will be correct. In ArcView, add the theme ***nhdnet2_cl(ARC)*** to the View. Make that theme active, and convert to shapefile, ***Nhdnetwork2***. This theme is now your edited stream network. (No canals were added to this Network, therefore, ***nhdnetwork.shp*** will be used in the following commands)

It is wise to check the stream network manually for any loops. This process can be made easier with ArcInfo to locate any polygons in the stream network. To do this use the command:

Arc: shapearc *nhdnetwork nhdcoverage*
(input shapefile, output coverage name)
Arc: build *nhdcoverage* poly
(coverage name, subclass)
Arc: clean *nhdcoverage nhdpoly_cl* 0.000001 0.000001
(input coverage name, output coverage name, tolerances which will be changed to the minimum automatically)

Once the polygon coverage has been created in ArcInfo add the theme to the view in ArcView. If there are any polygons, go back to your stream network and edit the network to remove any loops.

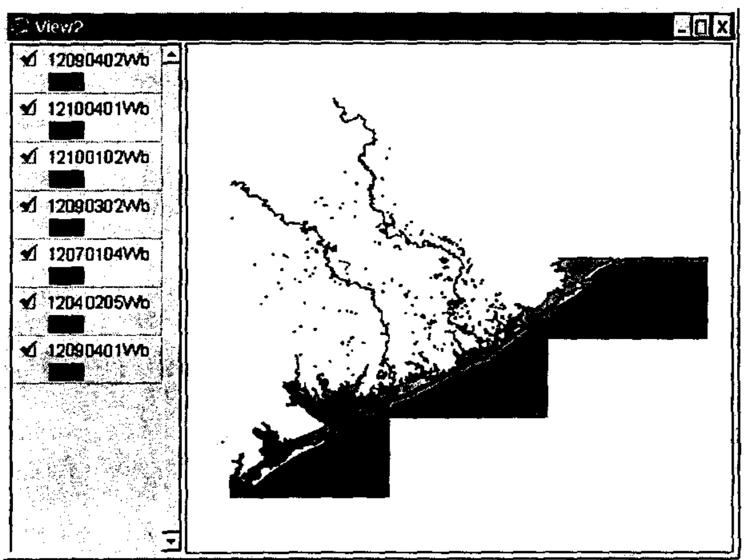


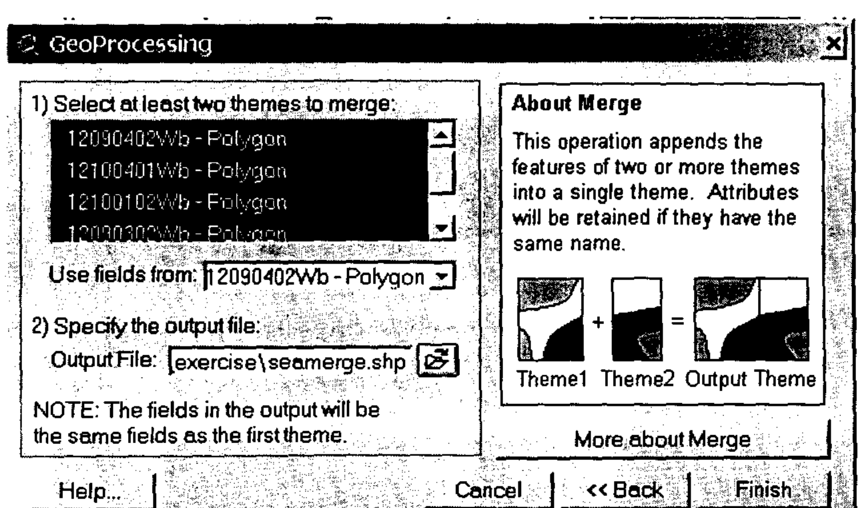
Polygon coverage of the stream network – All polygons must be removed before stream network can be used in to delineate watersheds ArcView

To edit the stream network, make the stream network the active stream. From the ***Theme*** menu select ***Start Editing,*** select a small portion of the stream which is causing a polygon to form, using the ***Select Feature*** button. Press delete. Once all polygons have been broken press ***Stop Editing*** from the ***Theme*** menu and save the edits when you are prompted. Go back to ArcInfo and repeat the steps until a polygon coverage is created that does not contain any polygons.

2.3 Eliminating Isolated Reaches from the Network

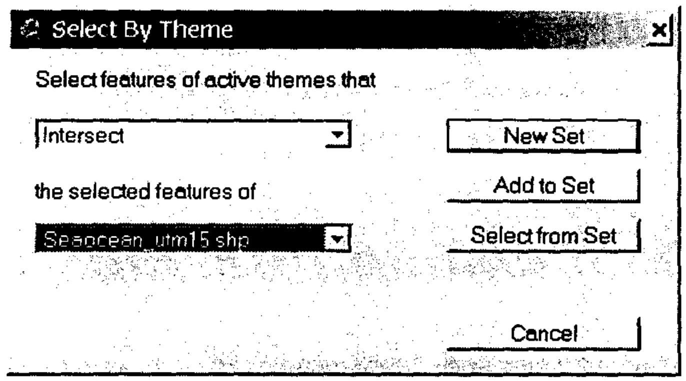
Create ***Seaocean*** theme: Open all the ***region.wb*** themes for each CU. They must all be given individual names that include the CU number such as 12040205wb. From the ***View/GeoProcessing Wizard*** menu, merge these themes into one ***Seaocean*** theme. The themes can be merged all at once by holding the shift key when selecting the themes. From the ***Theme*** menu, ***Query*** the new theme for Ftype= SEA/OCEAN and push ***New Set.***
From the ***Theme*** menu, ***Convert*** selection to a shapefile. Using the Projector! Extension, press the projector button, , project the new theme into the appropriate projection. Here we are using UTM 15.





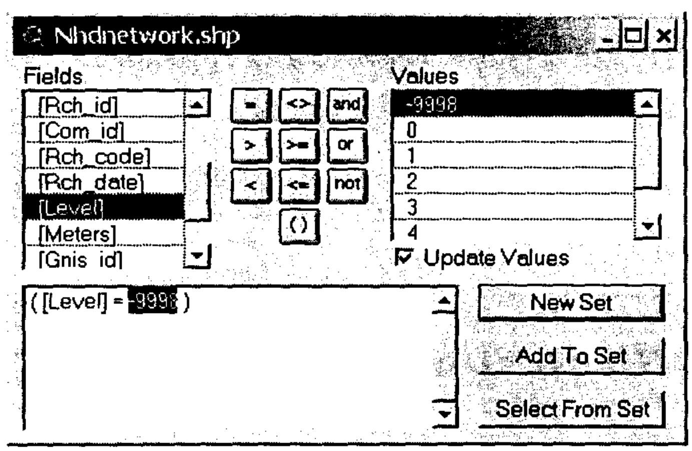
- Create a new theme, ***coastrch***. To create this theme, make the network theme active, and have the ***Seaocean*** theme in the view.

- From the ***Theme*** menu, ***Select By Theme*** of the stream network, those features of the active theme which intersect the ***Seaocean*** theme and press ***New Set***.

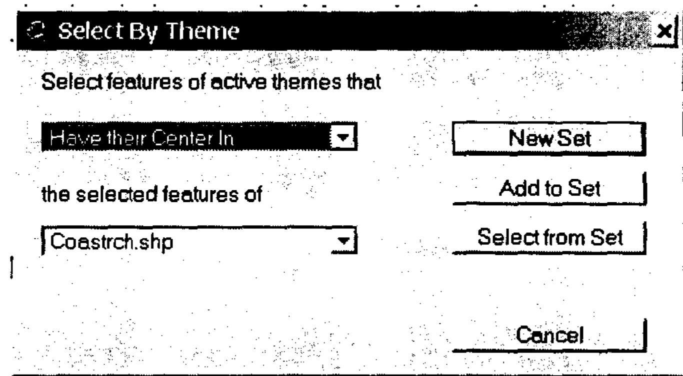


Convert this selection into a shapefile, ***coastrch***. These are the reaches which make up the coastline.

- Create another new theme, *level9998*. From the network theme, query for level = -9998. Convert that selection to a shapefile, ***level9998***.



- Turn on the *coastrch* theme. Make the ***level9998*** theme active, and from the ***Theme*** menu, ***Select By Theme***, the active features which "*have their center in*" the ***coastrch*** theme and press ***New Set***.



- From the ***Theme*** menu ***Start Editing*** the ***level9998*** theme, and delete. The selected arcs (those which make up a coastline) will no longer be included with the level –9998 reaches.

- Make the ***Nhdnetwork*** theme active. From the ***Theme*** menu, ***Select By Theme*** that which "*have their center in*" the *level9998* theme. From the ***Theme*** menu, ***Start Editing*** the ***Nhdnetwork*** theme and delete the selection and ***Stop Editing***. Now the ***Nhdnetwork*** theme has no isolated streams in it, and still contains the coastlines.

2.4 Determining the Waterbody Reaches on the Network

The NHD contains a waterbody reach theme which includes all the waterbodies in the HUC. Many of these waterbodies are isolated ponds, and do not need to be included in any network procedures. This procedure outlines a method of determining which waterbodies actually lie along a path, and eliminates the isolated waterbodies.

- After adding, merging and projecting the waterbody reach theme ***(region.rch)*** in the view (similar to method described to create the Seaocean theme), your output waterbody reach theme is ***wbrch_sjb_utm15*** as seen below.

- With the ***nhdnetwork*** theme added to the view, make the ***wbrch_sjb_utm15*** theme active. Go to the ***Theme*** menu, ***Select By Theme***, choosing "contains the center of" the ***nhdnetwork*** theme.

- This captures all the waterbodies which surround an NHD artificial path that are considered "significant".

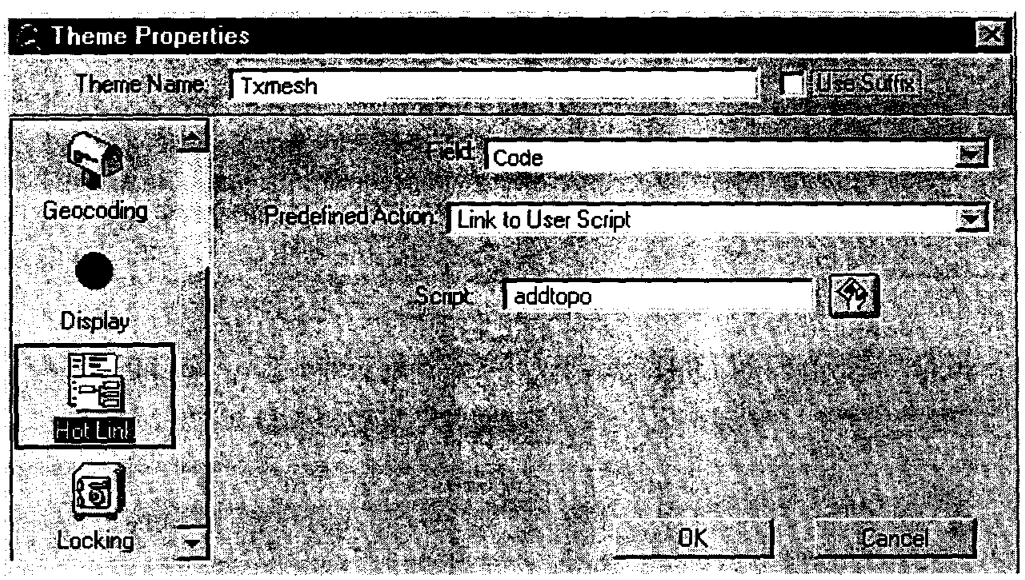
- Convert this selection to a shapefile from the ***Theme*** menu. Output ***wbrchnet_sjb_utm15***. This theme has the waterbodies which lie on the network.

(The term *significance* and *insignificant* are mentioned in Appendix E of *The NHD Concepts and Contents.*) For "insignificant" lake/pond features, those less than 10 acres in area, no separate transport reach was delineated. This is an exception to the *Underlying Feature Rule* of Transport Reach Delineation. Therefore, this method also ignores "insignificant" waterbodies as having a large effect on watershed delineation and does not include them as on the network.

2.5. Checking the NHD Network with Digital Raster Graphic Maps

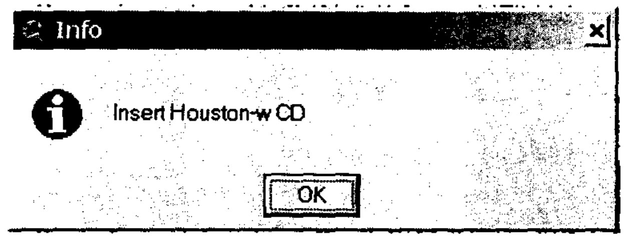
With raster graphic images of topography made available through the Texas Natural Recourses Information System (TNRIS), it is possible to check the ***Nhdnetwork*** that has been built. These DRGs can be called with the Hot Link b

- These DRGs can be called with the Hot Link button that has been included with this project. When starting ArcView the Hot Link button is dimmed, to be able to use it the right theme has to be active. Press the add theme button. And add the ***Txmesh_utm15*** and the ***Nhdnetwork*** files. This will add grid to the view along with the previously construction.
- Make the ***Txmesh_utm15*** the active theme.
- Then the **Theme/Properties** has to be selected. In the dialog box *Hot Link* has to be selected. In the Field cell the *Code* should be chosen. In the Predefined Action cell, Link to User Script is selected if you want to use you own script. Finally select the script *addtopo* in the Script cell and push the OK button.

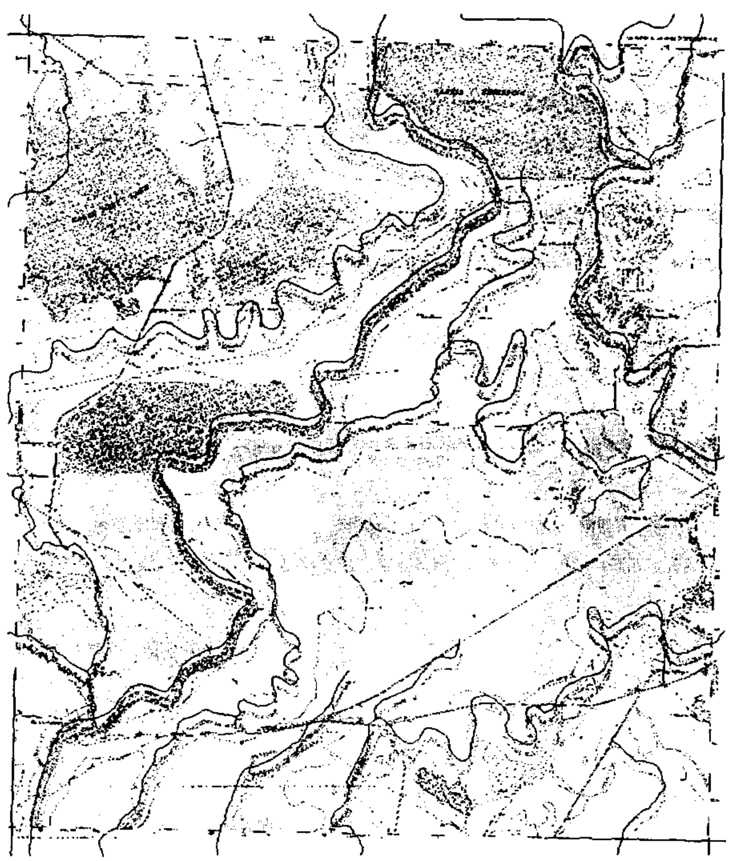


- Now the Hot Link button is available. To use it click the icon and then select the desired grid. This will call for a data CD which contains the correct topographical map. These CDs can be created by downloading the data from TNRIS at: http://www.tnris.state.tx.us/DigitalData/drgs.htm
- With the ***Txmesh_utm15*** theme active press the attribute table button.

- Now push the Hot Link button and click the desired grid. A dialog box will appear which data CD is needed. For instance a grid is select calling the dialog box below.

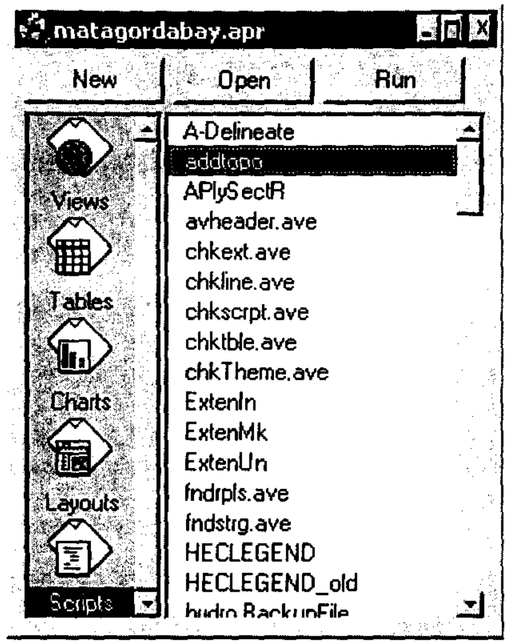


- After inserting the Houston-w CD the OK button is pushed and a digital raster topographic map will appear in the appropriate grid. By comparing the topographic map with the ***Nhdnetwork*** that has been constructed it is possible to find errors. Be sure that the ***Nhdnetwork*** is the top theme.



Although very helpful, this script cannot always identify the appropriate CD. Furthermore, it is possible the CD drive letter must be entered into the script so as to access the data files. To edit the script follow the directions below.

- In the project window click the *Script* icon and double click *addtopo*.



- o When the script appears look for the line:
  theVal2 = "e:/data/O" + TheVal + ".tif".AsString

- o The drive is e. If this is not the letter of the CD drive on the computer processing the data it must be changed to the appropriate letter and the compile button  must be pushed. Once the script has been compiled, then it can be closed and the Hot Link button can be used.

2.6. Building a Digital Elevation Model for the Region

Once the stream network has been constructed, the Digital Elevation Model (DEM) has to be developed. These DEMs can be downloaded from TNRIS.

- o The DEMs have a grid covering a full one degree by one degree region, therefore for large areas several DEMs need to be merged to create one large model. Merging DEMs can be done in ArcInfo with the following commands:

  1. First a workspace must be named with the command:
     Arc: w y:\perales\twbd_exercise (<drive>:\directory)
     To check the workspace use the command:
     Arc: w
  2. Then we must be in the grid format with the command:
     Arc: grid
  3. Finally , merge the DEMs:
     Grid: emmerge = merge (grid1,....,grid2) (output grid = merge (input grids to merge separated by commas))

```
Arc
Copyright (C) 1982-2000 Environmental Systems Research Institute, Inc.
All rights reserved.
ARC 8.1 Beta II (Mon Aug 14 22:41:22 PDT 2000)

This software is provided with RESTRICTED AND LIMITED RIGHTS.  Use,
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12.211/12.212 [Commercial Technical Data/Computer Software] and DFARS
Section 252.227-7015 (NOV 1995) [Technical Data] and/or DFARS Section
227.7202 [Computer Software], as applicable. Contractor/Manufacturer is
Environmental Systems Research Institute, Inc., 380 New York Street,
Redlands, CA 92373-8100, USA.

Arc: w y:\perales\twdb_exercise
Arc: w
 Current location: y:\perales\twdb_exercise
Arc: grid
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GRID 8.1 Beta II (Mon Aug 14 22:41:22 PDT 2000)

Grid: emmerge = merge (int9830, int9731, int9730, int9729, int9631, int9630, int
9629)
Running...    2%
```
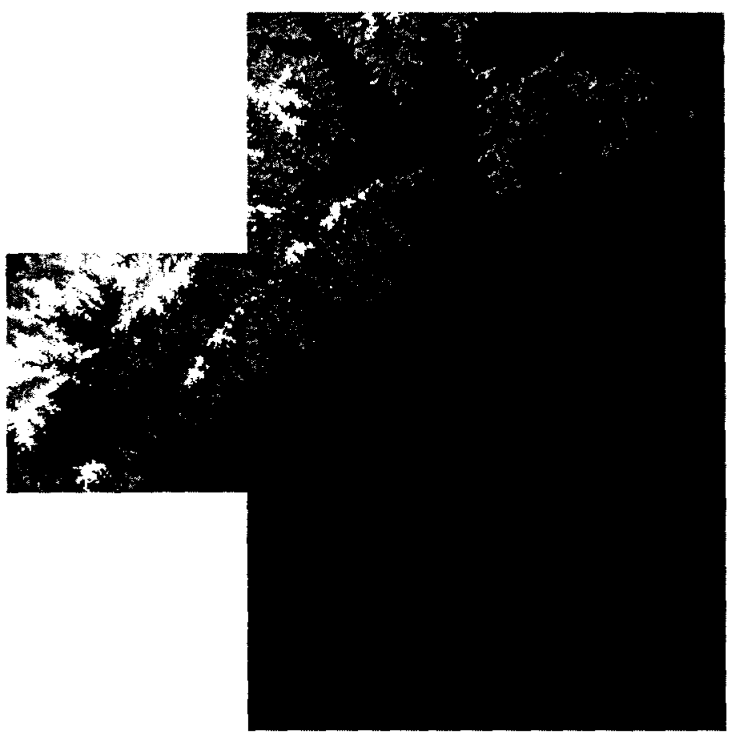

For this particular model seven DEMs were combined to form one large model shown below.



Next the DEM must be projected to match the stream network. For this project we have used UTM

The themes have been projected to UTM zone 15, with the output themes as ***em_u15_grid***. ArcInfo *is* used to project theDEM grids The projection file for UTM 15 is:

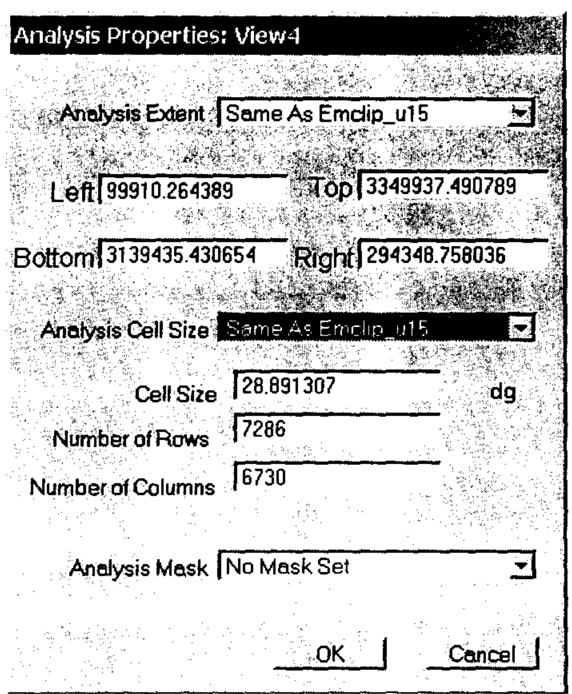
Projection UTM
Zone 15
Datum NAD83
Zunits NO
Units METERS
Spheroid GRS1980
Xshift 0.0000000000
Yshift 0.0000000000

- Next, this projected DEM must be clipped to only include the area of interest. To do this the CU outlines can be used. These CU should have been determined when building the stream network.
  1. Be sure the geoprocessing extension is checked under the **File\Extensions** menu. Using the **Geoprocessing Wizard** from the **View** menu, clip the DEM with the CU outline.

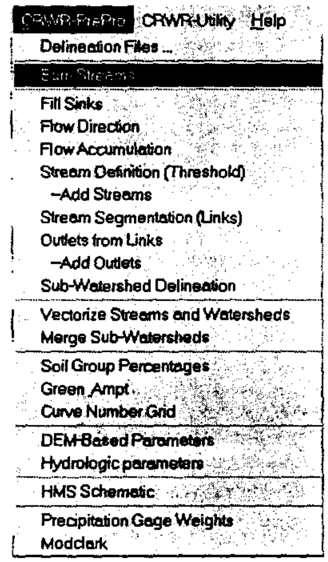
The resulting the DEM is shown below:

2.7. Using CRWR-PrePro to Process the DEM

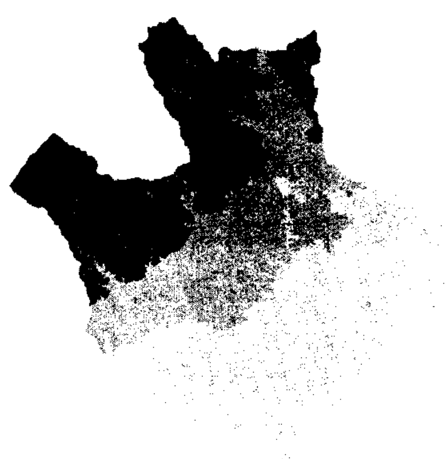
- From the Analysis\Properties menu set the Analysis Extent and Analysis Cell size to be the same as your clipped DEM.



- With the use of CRWR-PrePro, the stream network that has been developed must be burned into the clipped DEM. To do this, both the NHD stream network and the clipped DEM must be in the view and are the active themes. From the **CRWR-PrePro** drop down menu select **Burn Streams.**



In the Elevation Rise dialog box, type in 1000 as the arbitrary elevation rise. Click **OK**. Then click **OK** for the Burn Streams dialog box to save the grid permanently. Turn on the ***Burned_Dem grid.***

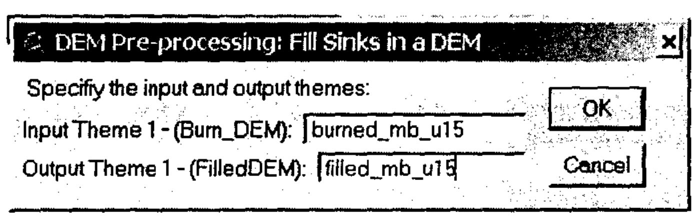


Since this is the temporary grid, you will save the grid in your work\tmp directory, so in case the ArcView crashes, you can rebuild the project easily. Choose **Theme/Save Data**

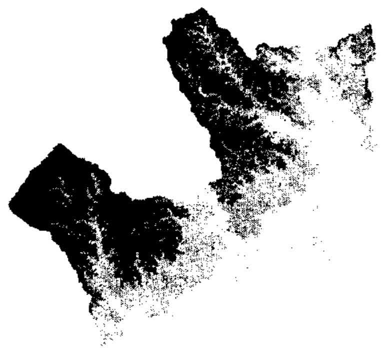
Set and save the grid as ***burned_mb_u15*** in your tmp directory. If highlight the Burned_Dem theme, zoom in near the streams, and use the **Identify** tool, you can see that the stream cell elevations remain as they were on the original DEM surface but the land surface elevations have been raised 1000m higher. This is obviously an artificial terrain surface but you can see that the effect of burning in the streams is to make them distinct in the DEM landscape. Normally, before you burn in the streams you have to ensure that the stream network is continuous and doesn't have gaps between each stream segment.

- Next, the sinks in the DEM must be filled. Most of the DEM data are accurate, however, aberrations do occur in the DEM which cause pits to form in the terrain. These pits need to be filled, otherwise they will cause the wrong flow direction. The **Fill** sinks function raises pit cell elevations so as to level the pits with the surrounding terrain. Only tiny sinks will be filled, since large sinks, such as lakes, are real sinks which we do not wish to remove from the DEM.

  Choose menu **CRWR-Prepro/Fill Sinks**. In the prompted diolog box, choose ***Burned_DEM*** for the Input Theme, click **OK**. The available burned DEM (Burned_Dem) is automatically populated in the Input Theme 1 field. Specify the Output Theme 1 as ***filled_mb_u15***.



Click **OK** to run the function. You will see the blue bar running across the bottom of the View window to indicate that processing is occurring. When it is completed, the new grid ***filled_mb_u15*** will be added to the View window. This process is the most time consuming of all the functions that you will use in this exercise and may take some time to execute on a slower computer.



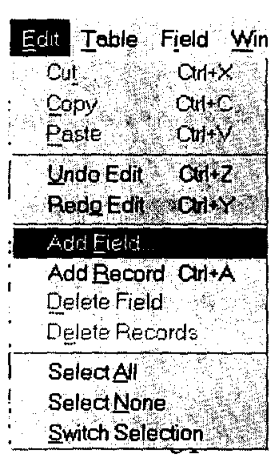
Make the ***filled_mb_u15*** active, choose **Theme/Save Data Set** and save the grid as ***filled_mb_u15*** in your working directory.

Once the stream network has been burned into the DEM and the sinks have been filled, the DEM can now be formatted for coastal delineation.

2.8. Defining the Sea/Ocean Region of the DEM

- With a CU outline of your basin, clip the ***SeaOcean*** theme, created in Step 3: *Eliminating Isolated Reaches from the Network,* using the ***Geoprocessing Wizard***. (Add Extension Geoprocessing, then under ***View*** Menu, ***Geoprocessing Wizard***) The product is ***clip1***.

- Open the ***clip1*** attribute table by pressing the ***Open Theme Table*** button. From the ***Table*** menu select ***Start Editing***, and add a field called Value, type number, width 16 and 0 decimal places, by using the ***Edit/Add Field*** menu.



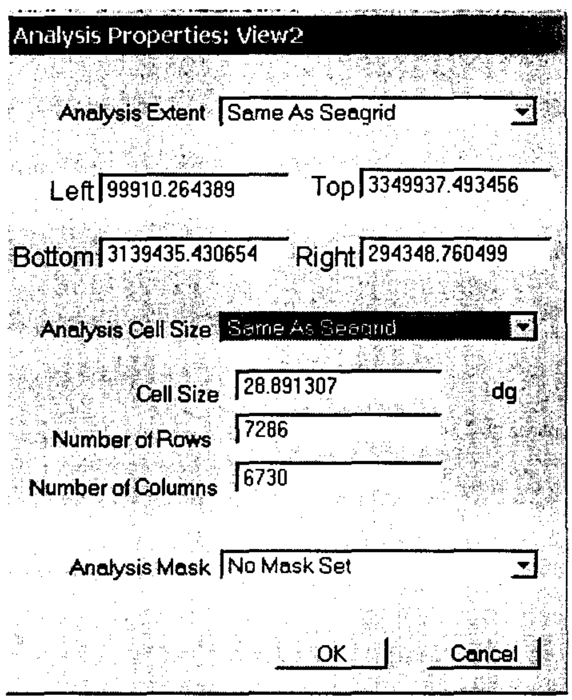
- Do not fill the field. Under the ***Table*** menu ***Stop/Save*** edits, and the records will automatically fill with zero.

- Go to the ***Analysis/Properties*** menu. Make sure to set the Analysis Extent to same as your Filled DEM. Convert ***clip1*** to a grid with the Value Field as the cell value. This grid is ***nwgrd1***. This grid has 0 values where you want no data values and no data values where you want 1 values.

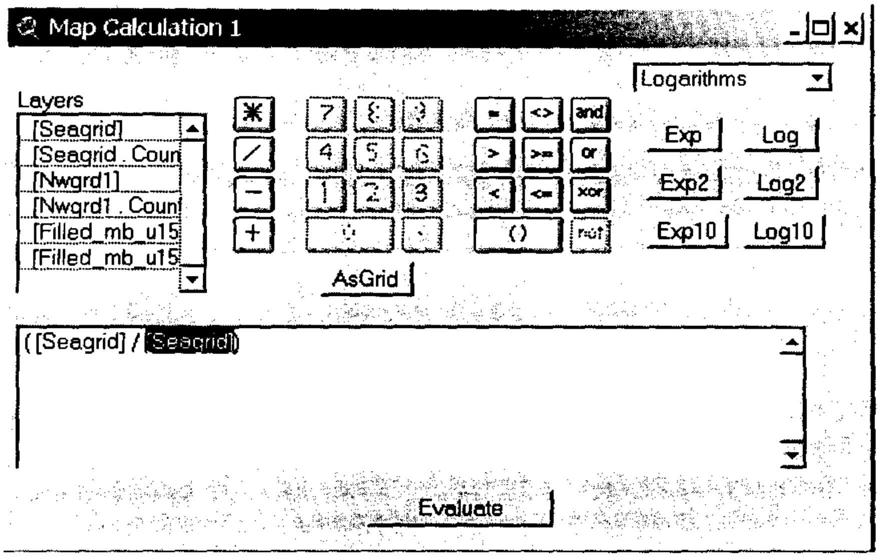
- Go to ArcInfo, go to Grid with the command:
  Arc: Grid.

- At the Grid prompt:
  Grid: Seagrid = isnull (nwgrd1)
  Where ***Seagrid*** is an output grid, isnull places a value of 1 in a cell where the input grid cell is No Data and a 0 where the input grid cell is not No Data. Now you have 0 values where you want No Data and 1 values where you want 1 values.

- Go back to ArcView. In the ***Analysis/Properties***, set the Analysis Extent to same as ***Seagrid***, and the Cell Size same as ***Seagrid***.



- Using the ***Map Calculator*** under the ***Analysis*** menu, do the calculation:
  Seagrid / Seagrid and press *Evaluate*.



Now you have 1 values where you want 1 values and No Data values where you want No Data values. The output is ***Mapcalc1***.

- Under ***Analysis/Properties***, set the Analysis Extent same as ***filled_mb_u15***, and the Analysis Cell Size same as ***filled_mb_u15***. In map calculator, do the calculation: ***Mapcalc1* * *filled_mb_u15***.

Now the DEM will have no data cells where the sea/oceans are and the rest of the DEM values are maintained. This output is your final product. Convert to a grid, and save it to your directory ***(f_mbsea_u15)***. This grid will now be the filled DEM to be used in the subsequent steps CRWR-PrePro.

DEM with the sea cut out

2.9 Completing the Watershed Delineation with CRWR-PrePro

With the DEM grid filled, the flow direction grid can be calculated.

> Choose menu **CRWR-Prepro/Flow Direction**, The Input Theme1 is automatically populated with the FilledDem in this case the ***f_mbsea_u15*** should be used. Type in ***fdr_mbsea_u15*** for the Output Theme.
>
> Click OK. After a short period, a flow direction grid will be added to the View. Turn on the theme.
>
> Make the ***fdr_mbsea_u15*** theme active, choose **Theme/Save Data Set,** and save the grid as ***fdr_mbsea_u15*** in your working directory. To avoid having a lot of legends cluttering up your view window, you can highlight the corresponding themes and use **Theme/Hide Legend** to minimize their display in the window.

Once you finished the flow direction grid, the flow accumulation grid can be calculated.

> Choose menu **CRWR-Prepro /Flow Accumulation**, The Input Theme is automatically populated with the flow direction grid, in this case, ***fdr_mbsea_u15***.
>
> Type in ***Fac_mbsea_u15*** (Matagorda Bay Flow Accumulation Grid) for the Output Theme.
>
> Click **OK**. After a short period, a flow accumulation grid will be added to the View. You should notice some faint streams moving off to the lower-right corner of View1.

Keep in mind that the darker the color of an individual grid cell, the more grid cells drain into that particular cell.

Click on the Zoom in tool and zoom into a spot in the lower right corner where the two streams join in the grid network. Use the Identify tool to check individual cell values and understand how flow accumulation function counts the number of cells upstream of a particular cell. Follow a particular stream going downstream and see how the flow accumulation value increases as more drainage area is picked up. Focus on a junction and see how the flow accumulation downstream of the junction is the sum of the flow accumulations in the two upstream tributaries.

Next the basic stream network must be constructed.

Before you start to construct the stream network, you have to define the cell threshold or minimum stream drainage area. Choose menu **CRWR-Prepro /Stream Definition (Threshold)**. The Input Theme is automatically populated with the flow accumulation grid, in this case, **fac_mbsea_u15**. Type in **str_mbsea_u15** (Matagorda Bay Stream Grid) for the Output Theme. In the prompt dialog box, change the stream threshold from default **10000** to **25000**. Click **OK**. After a short period, the stream grid guastr will be added to the View. The stream grid has a value of 1 in each cell with a flow accumulation value larger than 25000, and NODATA on all other cells.

Make the **str_mbsea_u15** active, choose **Theme/Save Data Set** and save the grid as **str_mbsea_u15** in your working directory.

Now, the each stream is given a unique ID with the Stream Link function.

Choose **CRWR-Prepro /Stream Segmentation (Links)**. In the pop up dialog box, choose **StreamGrid** to create Link. Click OK. The two Input Themes are should be populated with the flow direction grid (**fdr_mbsea_u15**) and the stream grid (**str_mbsea_u15**). Give the output grid name as **lnk_mbsea_u15**.

Click **OK**. You see the stream link grid **lnk_mbsea_u15** added in the view. To better view the stream link grid, double click on the legend bar to open the **Legend Editor**. In the Legend Editor, choose **Unique Value** for Legend Type, **Value** for Values Field, and **Fruit & Vegetables** for Color Scheme. Click **Apply**, and you see the stream grid is segmented to stream links, with each link having its own unique color and value as shown in the legend bar.

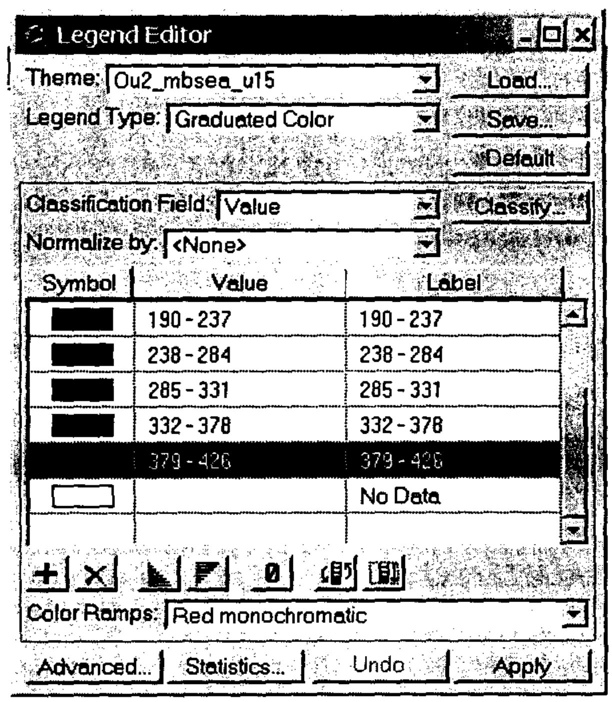
Choose **Theme/Hide/Show Legend** to hide the legend of theme gualnk. Make the **lnk_mbsea_u15** active, choose **Theme/Save Data Set** and save the grid as **lnk_mbsea_u15** in your working directory.

The outlet cell is the cell in each link that has the largest flow accumulation value. All of the cells upstream of the outlet cell flow into the outlet cell.

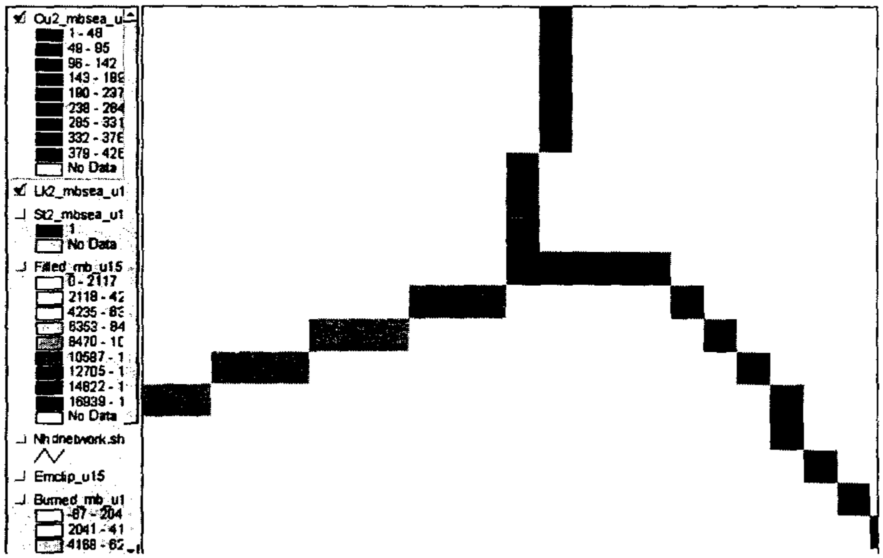
Choose menu **CRWR-Prepro / Outlets from Links**. Choose **LinkGrid** to create the outlet grids. Click **OK**. The two Input Themes are automatically populated with the flow accumulation grid (**fac_mbsea_u15**) and stream links grid (**lnk_mbsea_u15**). Give the output grid name as **out_mbsea_u15**.

Click **OK**. The resulting grid is a scattered set of single cells, each the farthest downstream cell of a stream link.

To better view the outlets grid, double click on the legend of out_mbsea_u15 theme to open the **Legend Editor**. In the Legend Editor, double-click on the first color square under symbol and choose black in the Color Palette. Go back to the Legend Editor and double-click on the last color square above the No Data, and choose the black again in the Color Palette. Then click on the Color Ramp button. You see all of the symbols become black.



Click Apply. Zoom into a spot with many branches, you see the black outlet cells at the farthest downstream cells of stream links.



Notice from the legend, the outlets grid has 426 outlets. Choose menu **Theme/Hide/show Legend** to hide the legend, then the **Zoom to Previous extent** to see the whole region. Make the **out_mbsea_u15** theme active, choose **Theme/Save Data Set** and save the grid as **out_mbsea_u15** in your working directory.

With the links and outlets finalized, you can delineate the watersheds now.

Choose menu **CRWR-Prepro / Sub-Watershed Delineation.** In the prompted dialog box, choose OutletsGrid. Click OK. In the next dialog box, the two Input Themes are automatically populated with flow direction grid **fdr_mbsea_u15** and modified outlets grid **out_mbsea_u15.** Give **wshdgr** as the name for the output watershed grid

Click **OK.** After a short while, the watershed grid **wshdgr** is added to the view. A sub-watershed is a zone of cells with the same cell value as the first outlet cell they drain through. There are a total of 137 watersheds. Make the **wshdgr** active, choose **Theme/Save Data Set** and save the grid as wshdgr in your tmp directory.

Drag the stream link grid **lnk_mbsea_u15**to the top layer in the legend so it can be drawn on the top of the watershed. Double click on the legend of **wshdgr** grid. In the **Legend Editor,** choose **Unique Value** for Legend Type, **Value** for Values Field. Use the default Color Schemes **Bountiful Harvest.** Click **Apply.** Notice that each of the stream segment has a watershed associated with it. Drag the m_out theme to the top of the legend bar. You'll see an outlet at the end of each stream segment. Highlight the **wshgr** theme and use the Identify tool to see some of the watershed value numbers. Highlight the

lnk_mbsea_u15 theme and similar see the stream link numbers in each watershed are the same. Finally highlight the **out_mbsea_u15** theme and see that the outlet grid cell for a give stream link has the same number as the link and the surrounding drainage area. This number, later called the **Gridcode**, plays an important role in connecting watersheds, streams and outlets.

Double-click on the legend of **lnk_mbsea_u15**. In the **Legend Editor**, similarly symbolize it with the **Unique Value** on the Value field using **Bountiful Harvest Color Schemes**. Click Apply.

The **lnk_mbsea_u15** grid magically disappears. This is because each of the links has the same value as its associated watershed. Since you used the same color scheme, each link is assigned the same color as its watershed, so it "dissolves" into the watershed.

Choose menu **Theme/Hide/show Legend** to hide the legend. Click on the Open Table Button  to open the Attribute of wshdgr. Click on the field name Count so it seems indented. Choose menu **Field/Statistics** to see the statistics of the watershed grid wshdgr.

Up to this point, you have been working with grids. Grid is excellent for cell based analysis, however, vector data are easier to use and store. Therefore, grids are usually employed to develop a data set, and the final product is then converted to vector format.

Since a vector polygon does not necessarily have a square shaped border like the grid, when ArcView converts a grid to a polygon, a **dangling polygon** may be created on the edge of an existing polygon. This dangling polygon is a tiny watershed that does not exist, and should be dissolved into the parent watershed polygon to which that drainage area really belongs.

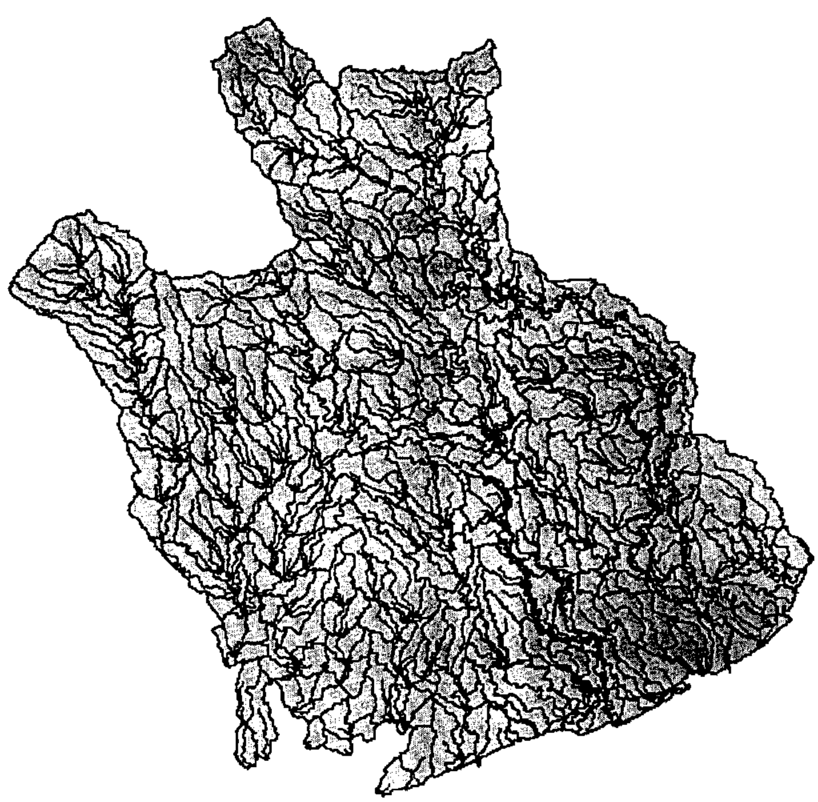
Choose menu **CRWR-Prepro /Vectorize Streams and Watersheds.** In the prompted dialog box, the Input theme has automatically been populated with the watershed grid wshdgr. Give **wshdply** as the output theme name. Click **OK.**

After a short while, you will be prompt with the Vectorize Streams dialog box, choose **LinksGrid**, and then click OK. The two input themes have already been populated. Give **mbriv.shp** as the Output Theme name, click **OK.**

After a short while, you will be prompted a Yes/No dialog box for backing up the **wshdply.shp**. choose **No.** You should be informed that dangling polygon has been merged. Click **OK.**

You will see the blue status bar running. It will stay at 100% for a while, and will seem to be providing no response. Don't worry, it is busy calculating.

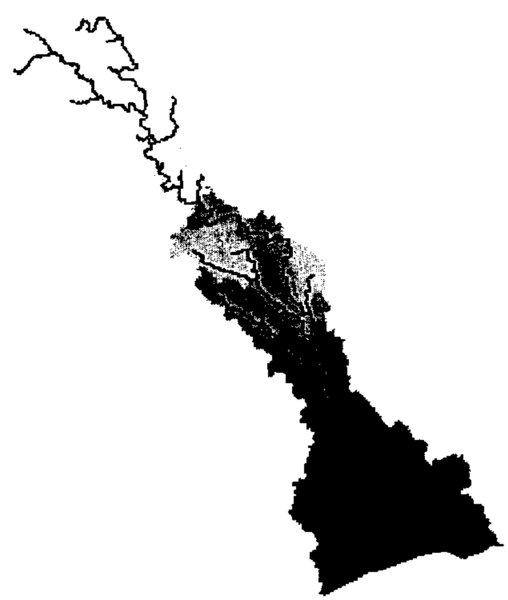
After it has finished, you will see the watershed polygon **Wshdply.shp** and the river line **mbriv.shp** were added into the view.



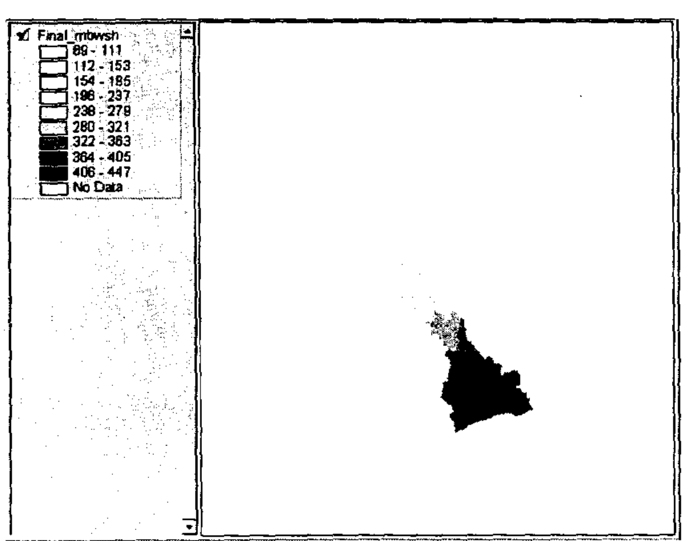
2.10. Merging Subwatersheds

In this study the large region just delineated is broader than is needed just for Matagorda bay. To distinguish the region of interest from the larger region, the required subwatersheds are selected from **Wshdply.shp** and the river lines from **mbriv.shp** and copied to a new pair of shapefiles **Mbwsh.shp** and **Mbrivers.shp**. Use the resulting Mbwsh.shp to clip the watersheds grid produced in the previous step to the required area, and call it FinalMbWsh.

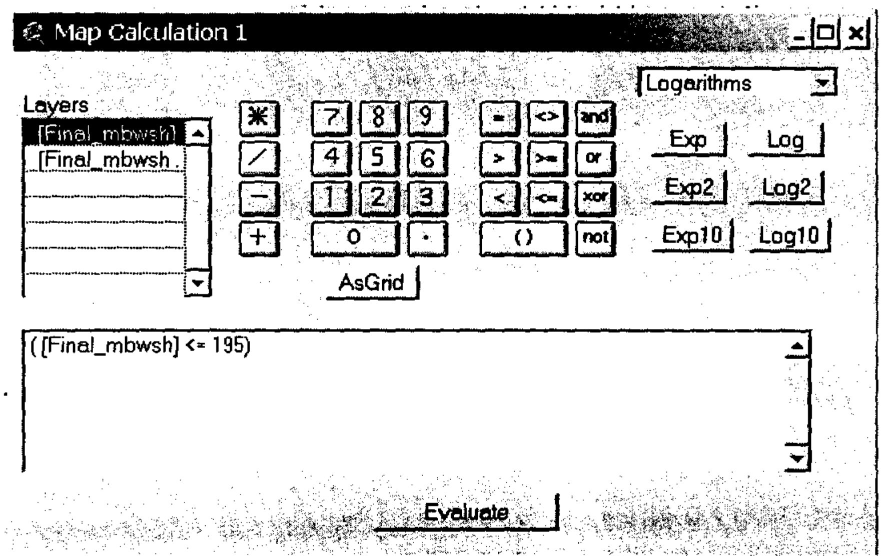
Final Watershed grid and stream network



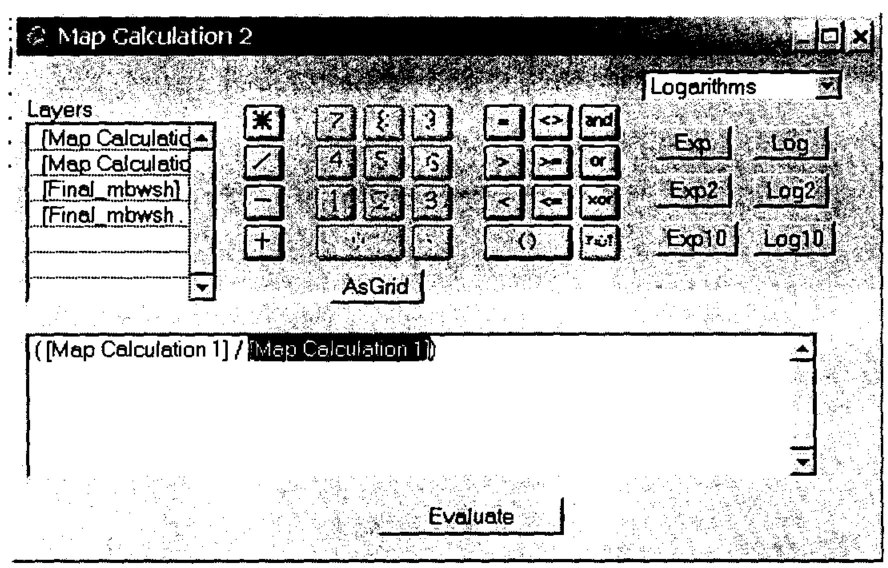
This watershed can be further processed by combining subwatersheds. To do this the map calculator is used to create three subbasins as shown below. First, with the open FinalMbwsh grid, determine the extent of each subbasin with the legend.



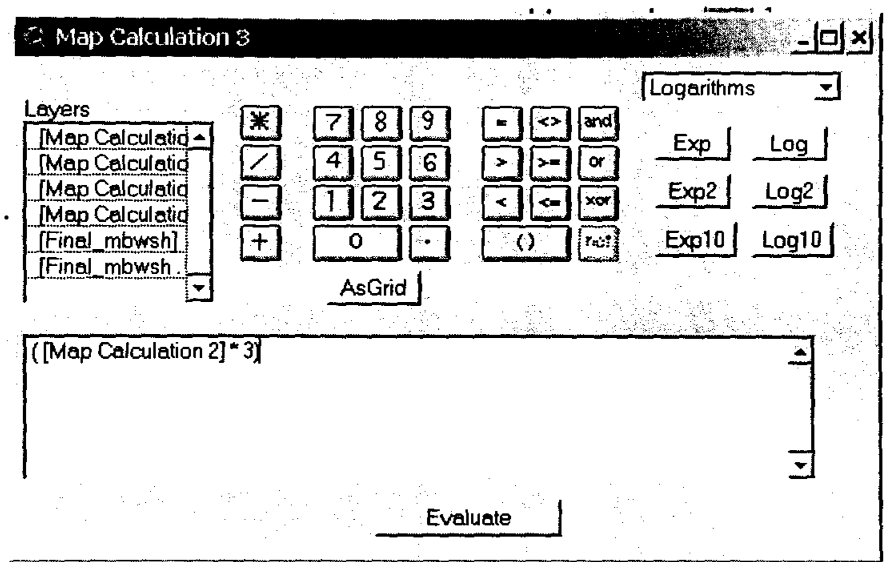
- Now from the **Analysis** menu select **Map Calculator.** When the dialog box opens double click the ***Final_mbwsh*** grid and then the less than or equal to button [<=] and enter 195. Then push evaluate.



After a short while a new grid will be created called ***Map Calculation 1***. This grid will be used in the next map calculation which is Map Calculation 1 / Map Calculation 1.

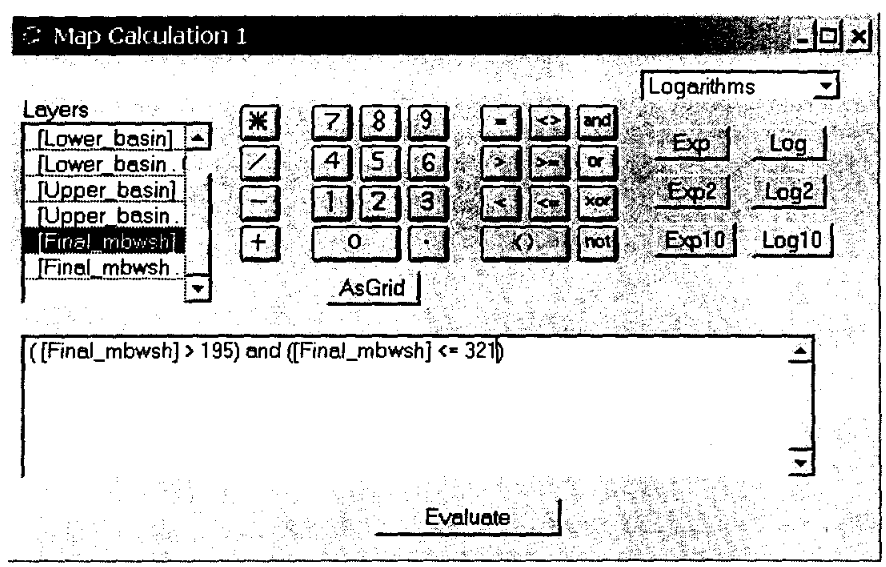


- Again a new grid will be added to the view. This new grid will be given a new watershed value with the calculation: ([Map Calculation2] * 3) as shown in the graphic below.



- This new grid must be saved. Use the **Theme\Save Data Set** to save the new calculation as Upper_basin.

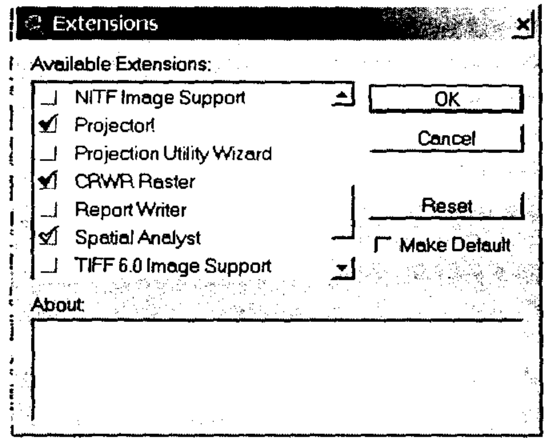
- The remaining basins are created similarly. The calculation for the middle basin is ([Final_mbwsh]>195) and ([Final_mbwsh]<=321) as shown in the graphic below. The lower basin is defined as ([Final_mbwsh]>321).

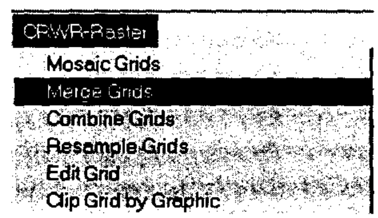


- The watershed value for the lower basin is one therefore it is not necessary to multiply the calculation by a number. However the middle basin should be given a value of 2.

Once all the subbasins have been completed, they must be merged. A process has been previously defined to merge grids using Arc/Info. The following steps will show a method of combining grids within ArcView.

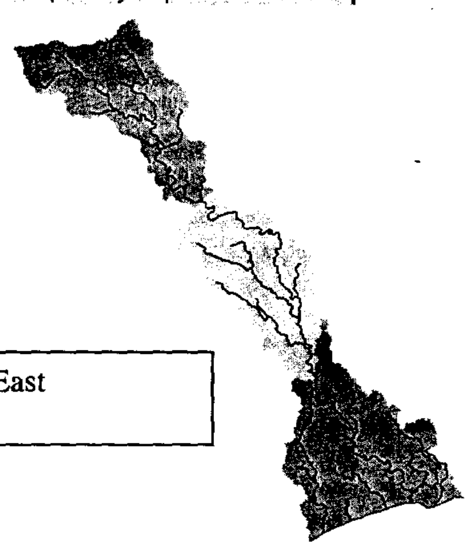
- From the **File** menu select **Extensions**. When the dialog box opens select CRWR Raster and click OK. Now a new drop down menu is available.





- Make the lower_basin the active theme by clicking on the legend. From the **CRWR Raster** menu select **Merge Grids**.
- After a short while a new grid will appear in the view. This grid should be saved using the **Theme/Save Data Set** menu.

The final basin and stream network can be seen to the right.



Watersheds of East Matagorda Bay

2.11. Clipping the Soils Data to the Area of Interest

The following files are needed for this portion of the procedure:

Statsgotx.shp - a shape file of Statsgo map units for Texas. This file can be downloaded from the NRCS website for Statsgo given below.

Database files called ***mapunit.dbf***, ***comp.dbf*** and ***layer.dbf*** supplied by the National STATSGO database. The *mapunit* table holds the key to relating soil attributes to polygons on the map. One record exists in the *mapunit* table for each *mapunit*. A single record in the *mapunit* table relates to one or more components in the *comp* table and the *layer* table. The data tables are available through the National STATSGO database at ftp://ftp.ftw.nrcs.usda.gov/pub/statsgo/dos/arc/data/.

Lookuptable.dbf - a table used to assign Green and Ampt infiltration parameters based on the 12 USDA textures. This table is presented as Table A.1 in Appendix A.

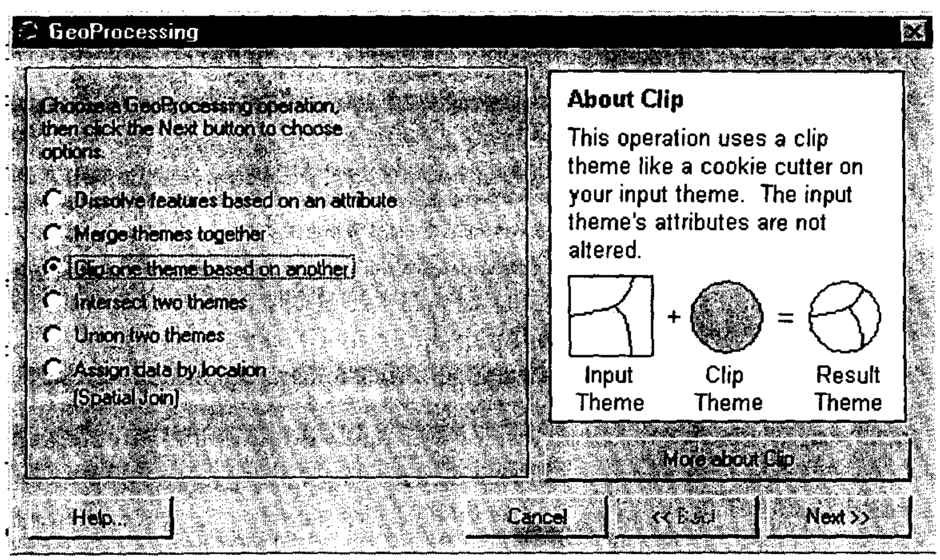
Textconv.dbf - a table used to convert the 719 USGS soil textures to the 12 USDA textures. This table is presented as Table A.2 in Appendix A.

The following steps allow the user to analyze the watershed of interest for soil characteristics.

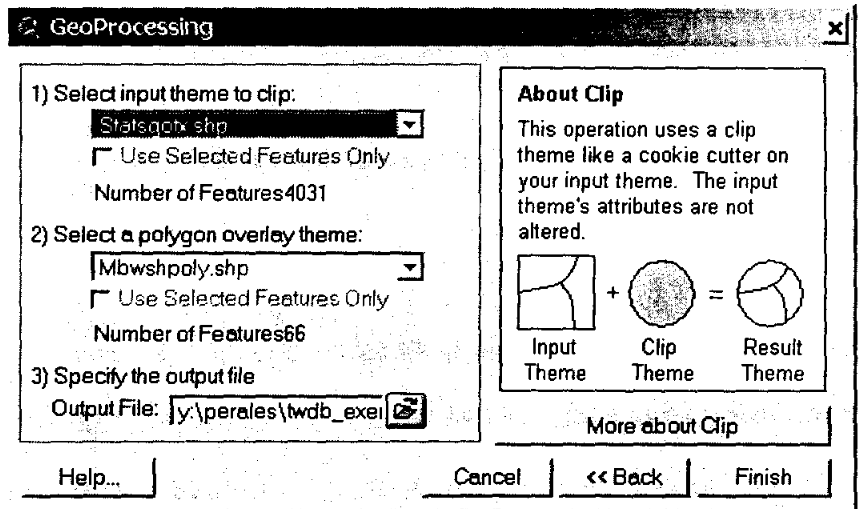
Open a new view and add the themes ***Statsgotx.shp*** and your watershed shapefile (***wshpoly.shp,*** This file was created by the step ***Vectorizing Streams and Watersheds*** under the drop down menu ***CRWR-PrePro*** and can either be the entire watershed or the watershed that has been focused upon in the previous step. Remember that if the focused watershed is used it must first be vectorized.).

- Next add the tables ***mapunit.dbf***, ***comp.dbf***, ***layer.dbf***, ***textconv.dbf*** and ***lookuptable.dbf***.

To use the clipping tool the geoprocessing extension must be loaded. This can be done from the **File** menu under **Extensions.** Once the Extensions dialog box has opened, scroll down and select geoprocessing. Then with the view the active window, under the **View** menu select **GeoProcessing Wizard**. With the GeoProcessing Wizard open, select *clip one theme based on another* and push the next button.

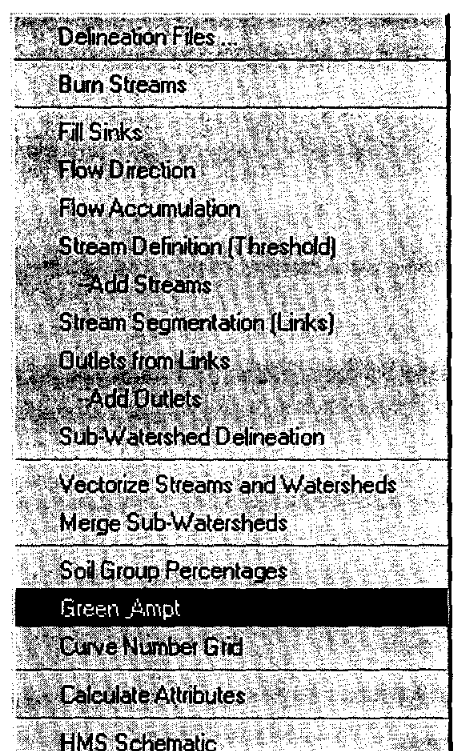


The input theme is the ***Statsgotx.shp*** file and the overlay theme is the watershed of interest.



Then press the finish button and a clipped theme will be put into your view. You should give the clipped soils theme a name you will recognize. Here the clipped soils region is called ***Mbsoil.shp***.

2.12. Determining the Green and Ampt Parameters



To use the script go to the **CRWR-PrePro** menu and select **Green_Ampt**.

There will be a series of dialog boxes that require input themes and tables. Follow the instructions on the dialog boxes. The final dialog box will ask for the *Effective Saturation* of the watershed. The default value is 20% but can be changed.

The program will run for a few minutes. When it is finished a table called **USDA.dbf** will have been added to the list of tables and then you will be prompted to add a new theme to the view. This new theme that is to be added will automatically be called ***Soilintersect.shp.*** Open the attribute table for the ***soilintersect*** shapefile. To do this make sure the appropriate theme is active and then push the open theme table button . Notice that for each mapunit the soils are divided into thirteen (13) categories, the twelve (12)

USDA soil types and water. Furthermore, the Green and Ampt parameters of hydraulic conductivity, suction head, change in moisture content, and initial loss have been added to the table. All of these values have been reduced from the ***USDA.dbf*** table.

Open the ***USDA.dbf*** table. In this table you will notice that each mapunit is made-up of different components. Moreover, each component is made-up of layers. This table is used to assign Green and Ampt parameters to each component. This table acts as a modified component table and is the source of all further calculations. The values for conductivity, suction head and effective porosity are pulled directly from the look-up table. The value of the holding capacity is calculated from the layers table from the expression:

Holding Capacity = sum over its layers of (awcl + awch)/2 * (laydeph - laydepl).

where:

- **Laydepl**- the depth of the top of the layer in inches.
- **Laydeph**- the depth of the bottom of the layer in inches.
- **Awcl**- a lower limit on the estimated water holding capacity in inches of water per inch depth of soil (e.g. a value of 0.16 in/in means that 16 per cent of the soil volume is void space that could be occupied by water).
- **Awch** - an upper limit on the estimate water holding capacity.

These parameters are further reduced in the soils attribute table by using an area weighted average. In the ***USDA.dbf*** table the parameter *comppct* represents an area weighted percentage of each component that makes- up a mapunit. The area weighted hydraulic conductivity and the wetting front suction head values are calculated from the expressions below:

$$\text{Conductivity} = \sum_{\text{component}} \text{Conductivity} * \frac{\text{comppct}}{100}$$

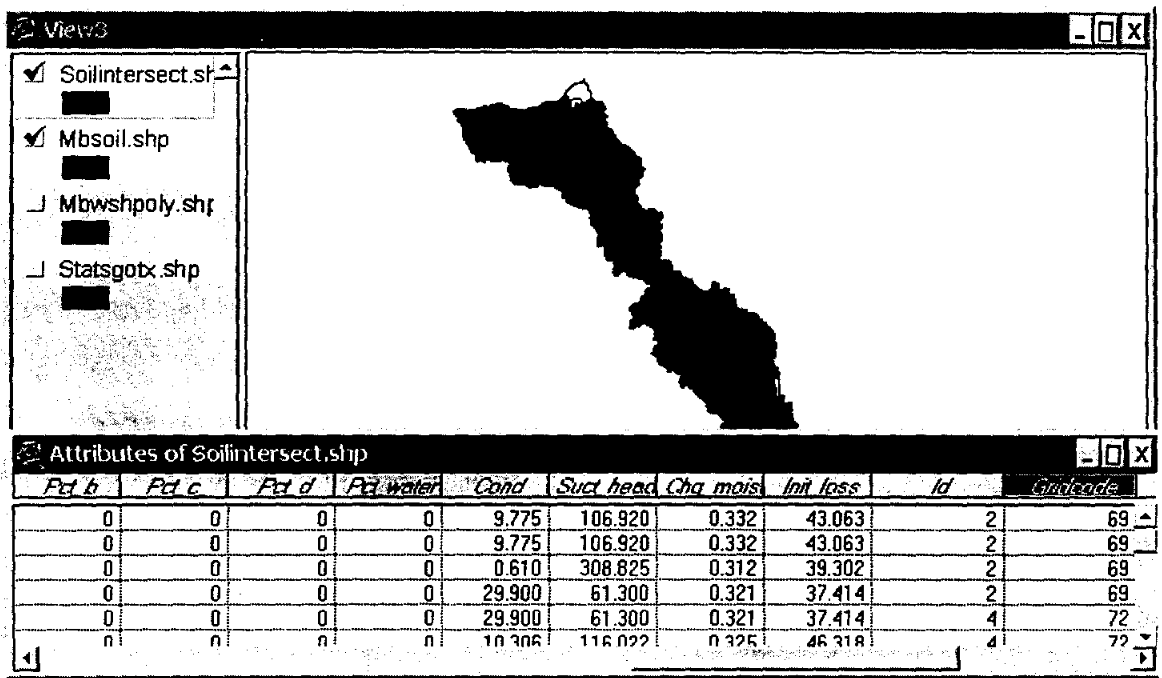
$$\text{Suction Head} = \sum_{\text{component}} \text{Suction Head} * \frac{\text{comppct}}{100}$$

The Change in Moisture Content ($\Delta\theta$) and the Initial Loss values are estimated from a user input Effective Saturation (S_e) value and are area weighted.

$$\Delta\theta = \sum_{\text{component}} (1 - S_e) * \text{Effective Porosity} * \frac{\text{comppct}}{100}$$

$$\text{Initial Loss} = \sum_{\text{component}} (1 - S_e) * \text{Holding Capacity} * \frac{\text{comppct}}{100} * 0.2$$

These weighted parameters are assigned to the mapunits of the ***soil attributes table***. Scroll through the clipped soils attribute table and notice there is only one value for each mapunit. Also included in the ***soil attributes table***, is the percentage of each of the soil types and the percentage of water located within each mapunit.

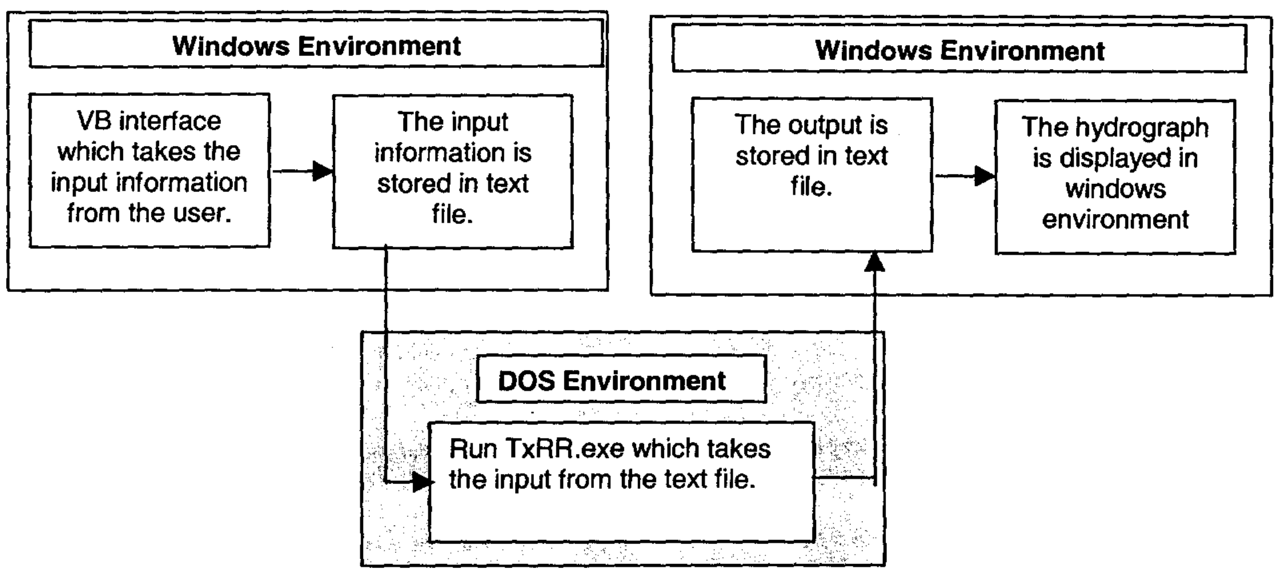


Now, with the ***soilintersect attributes table*** in view, select the field labeled gridcode and press the sort ascending button. Hold the shift button down and select all rows with the same gridcode. In the view the subwatershed with this gridcode will be highlighted in yellow. Notice that the ***soilintersect attributes table*** contains both mapunits and gridcodes. This table provides the connection needed to assign soil parameters to a watershed.

Notice that this table has two area values. The first area value is of the individual polygon of the mapunit and the second area is the area of the entire subwatershed that the mapunit is a part of. The first area value is used to further reduce the data so that each gridcode has only one set of parameters. This set of parameters are then entered into the watershed attributes table. Open the watershed attribute table and select the gridcode field and press the sort ascending button. Notice that there is only one value for each gridcode. Again, this reduction was done by taking the sum of the area weighted mapunit values.

3. Integrating GIS and TxRR

The original Fortran version of TxRR was developed by Dr Junji Matsumoto, and was subsequently modified by Dr Barney Austin. Although the TxRR code modified by Dr Austin had a Visual Basic interface, it was incomplete in the sense that the Visual Basic interface designed for the Fortran code was completely independent and thus the Visual Basic interface and the original FORTRAN code were working independently in different environments i.e. the input interface was in Windows and to run the Fortran TxRR code, we had to open the DOS window and run the TxRR.exe program. The flow chart for this version can be represented as follows:



Original Structure of TxRR Model Operation

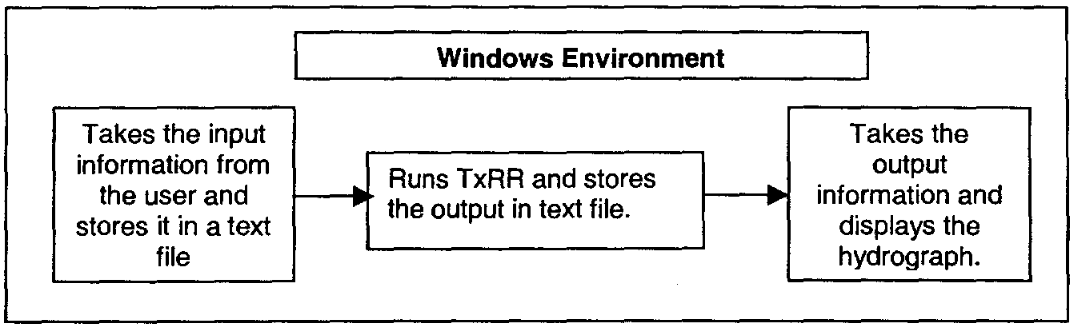
Objectives of GIS-TxRR Integration

Following are the objectives for the GIS-TxRR Integration:

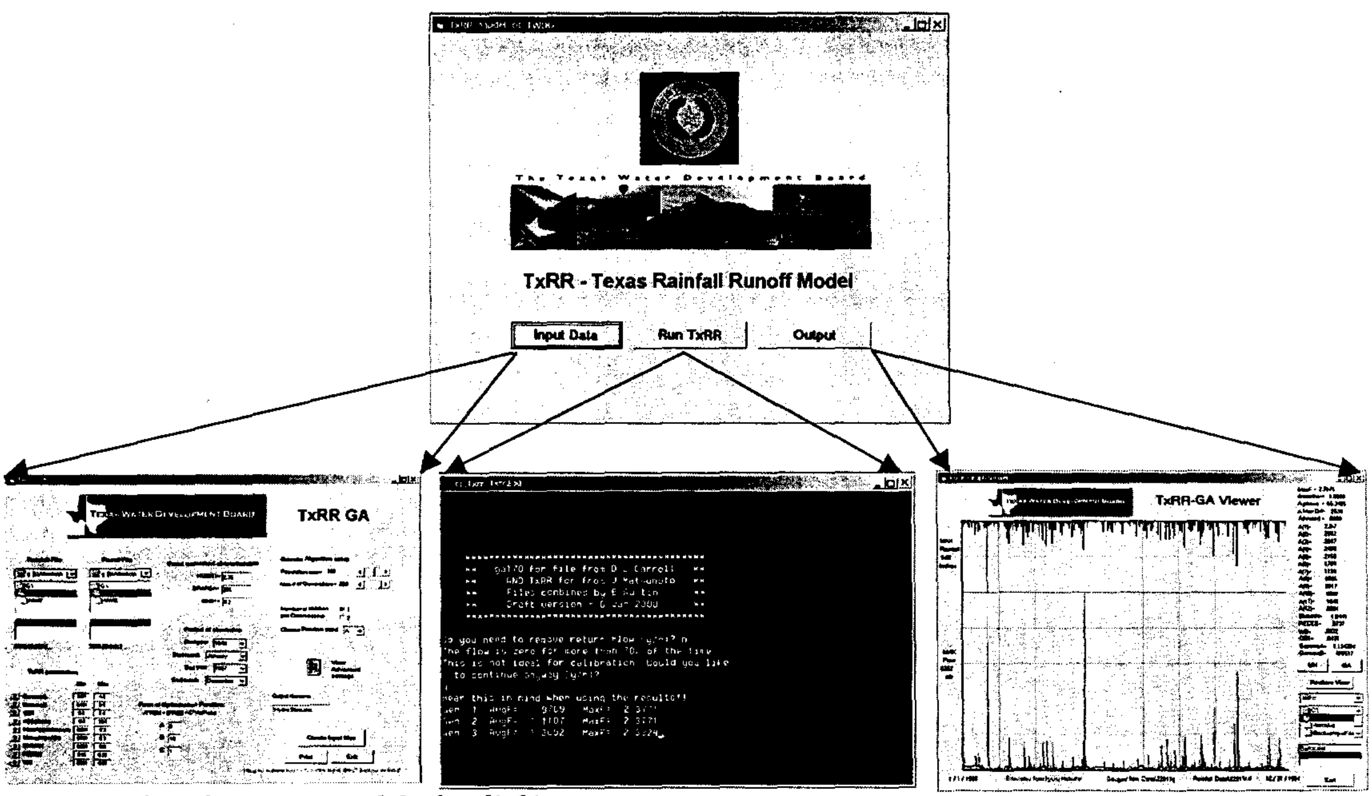
- Due to lack of interconnection between different interfaces and also due to different working environments, using of TxRR is somewhat clumsy. So the first objective is to link all the interfaces into one interface and run the model in the Windows environment.
- Integrate the TxRR model with ArcGIS Hydro Data Model.

3.1 Linking of TxRR and a DOS-Windows Interface

The user interface for TxRR is in Visual Basic. Since Visual Basic is a window-based application it does not support DOS based applications. In other words, it is difficult to run a FORTRAN program from Visual Basic. However it is possible to create a shell in Visual Basic, which can allow a DOS program to run and pause the Visual Basic program unitl the DOS program does its job, and then proceed forward by closing the shell. A Visual Basic code was developed to perform the shelling and TxRR program was made to run in windows environment. Then finally all the interfaces were combined into a single Visual Basic form so that the user now has to run only one program and he/she can perform all the tasks in one interface. The current mode of operations of TxRR is illustrated in the following diagrams. There is also a possibility of making the program DOS independent by converting the TxRR.exe into a DLL (Dynamic Link Library). This possibility has been tested by working on a small fortran code but the possibility of converting TxRR.exe into a DLL file has not been fully explored.



Structure of TxRR Model after linking

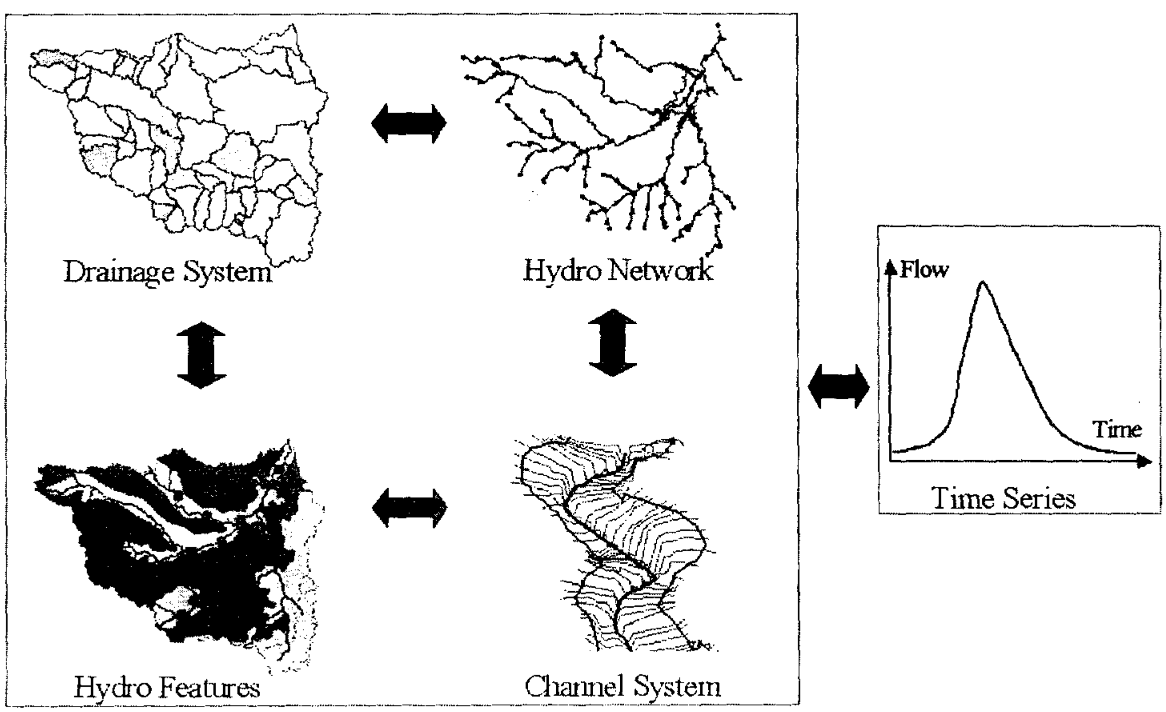


User interface for TxRR Model after linking

3.2 ArcGIS Hydro Data Model

The Geographic Information System software used by the TWDB, ArcInfo and ArcView, is produced by the Environmental Systems Research Institute (ESRI) of Redlands, CA. ESRI is about to release ArcGIS version 8.1, which is a new style of GIS software, more powerful than the ArcInfo version 7 and ArcView version 3 that are currently in use. ArcGIS version 8.1, which includes ArcInfo 8.1 and ArcView 8.1, is built using a Visual Basic interface and object oriented software, which is COM compliant, that is, it adheres to the Microsoft Component Object Model standard, thus permitting the sharing of objects among several programs. This change makes it significantly easier to integrate GIS and hydrologic models than was the case earlier.

CRWR and ESRI have together created a Consortium for GIS in Water Resources to design an ArcGIS Hydro data model for implementation in ArcInfo 8 and ArcView 8. This data model is a set of water resources object classes with links between them, which systematize how geospatial and temporal water resources data can be stored in a GIS. This design has been undertaken through the Consortium in consultation with a wide range of individuals from federal, state and local agencies, consulting firms, and academia. In particular, the design has been closely coordinated with the National Hydrography Dataset group at the USGS and EPA, who have produced the digital version of the stream hydrography of the United States. This is a critical data source now available for delineating coastal drainage areas that was not available at the time of the Corpus Christi Bay study. NHD data for East Matagorda Bay and its drainage systems are used extensively in this report.



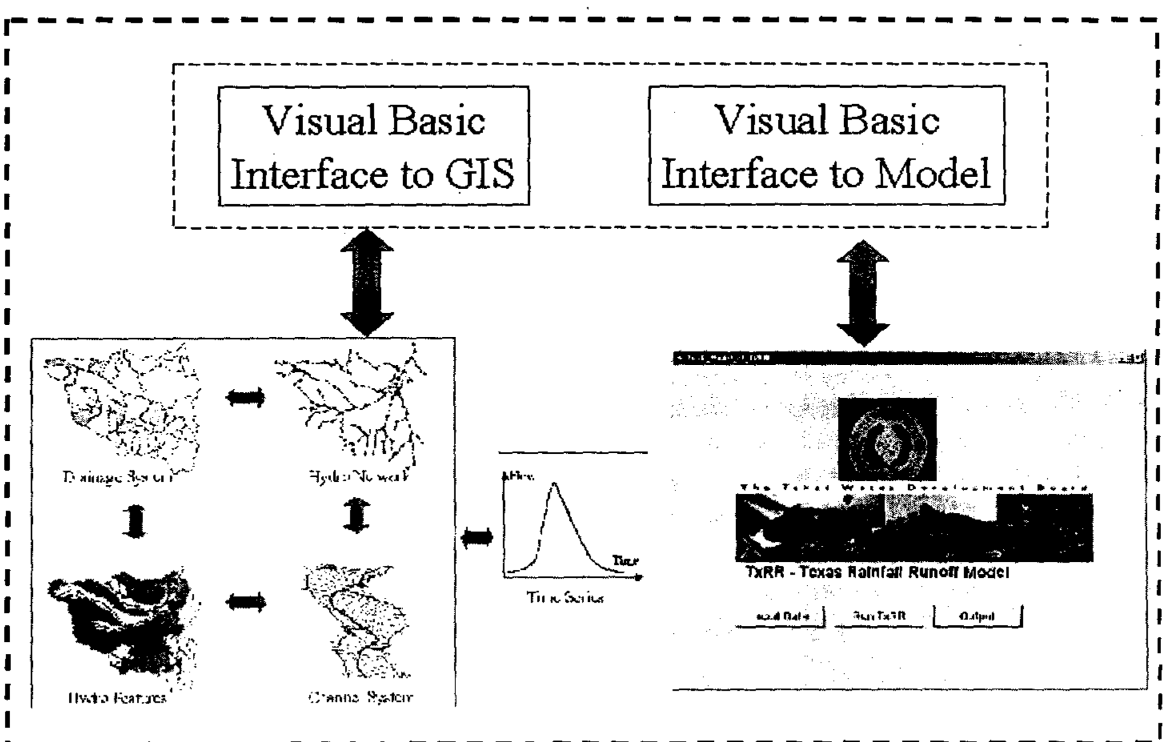
Components of the ArcGIS Hydro data mode

3.3 Integration of TxRR with the ArcGIS Hydro Data Model

The purpose of linking TxRR with ArcGIS Hydro Data Model is to produce a GIS integrated software that can extract time series data from ArcGIS, process it and store the output in ArcGIS Hydro Data Model, which can then be displayed in GIS interface. In other words, the ArcGIS Hydro data model will act as a data support structure and the TxRR model read and write to this structure. The integration of TxRR with ArcGIS is still under development. However, significant progress has already been made in this regard.

All the data in ArcGIS Hydro Data model is stored in MS Access format. In order to run TxRR, the time series data from ArcGIS Hydro Data Model has to be converted into an appropriate format that is recognized by the TxRR code. The TxRR Model requires a time series input of precipitation data and gaged runoff data and the two files required have different formats. A code has been written in Visual Basic, which converts the time series data in ArcGIS Hydro Data Model (which is in MS Access form) to the TxRR input format. This is now working successfully, and this code will be modified to convert the precipitation data from Hydro Data Model into TxRR input format.

The final step will be to develop a tool in Visual Basic, which will combine all these codes and since ArcGIS HydroData Model supports Visual Basic. The final version of this Visual Basic code can be accommodated into ArcGIS Hydro Data Model as an important tool that can be used for rainfall-runoff modeling.



Integration of Visual Basic Interfaces to ArcGIS and to the TxRR Model

4. Summary and Conclusions

The original goal of the research is to construct an improved TxRR model by closer integration with GIS and by better storage and handling of time series. The following objectives have been achieved in this study:

1. A procedure is defined for selecting and editing the National Hydrography dataset so as to produce a stream network suitable for the delineation of coastal drainage and implemented to define the stream and coastline network for East Matagorda Bay.

2. The stream network is combined with the National Elevation Dataset for land surface topography and used to define a set of elementary drainage areas. Selected drainage areas are combined into three watersheds draining to East Matagorda Bay

3. A procedure for determining Green and Ampt soil parameters for these watersheds is applied to determine soil parameters for East Matagorda Bay

4. The use of the Visual Basic interface to TxRR has been streamlined so that the Fortran code is called without having to use a separate DOS window.

5. Additional Visual Basic procedures have been written so that the time series files for TxRR can be read from and written to the Time Series database of the ArcGIS Hydro data model.

Some additional work is needed to completely integrate TxRR with the ArcGIS Hydro data model so that it TxRR can use geospatial and temporal data from the database. However, to achieve a complete integration requires some greater experience in integrating water resources models with the ArcGIS Hydro data model. What has been accomplished so far, and described here, is at the limit of what is possible with the GIS software and tools available at this time.

The drainage areas constructed here for East Matagorda Bay are worked out in a manner consistent with related projects being conducted by the Center for Research in Water Resources. In particular, a similar set of 55 drainage areas in the Houston-Galveston area has been developed to support the Total Maximum Daily Load program of TNRCC, and a related processing of drainage networks for all coastal basins is being done to support the Water Availability Modeling program of TNRCC. If the results of these various projects are all put into the ArcGIS Hydro data model format, and if TxRR is further developed so that it can operate by drawing data from that data model, a framework can be created for a systematic and consistent means of analysis of coastal drainage systems in Texas, both within the Texas Water Development Board, and between the TWDB and related State and Federal agencies.

5. References

Chow, V.T., D.R.Maidment, and L.W.Mays, Applied Hydrology, McGraw-Hill, 1988

Reed, S.M., and D.R.Maidment, Use of Digital Soil Maps in a Rainfall-Runoff Model, CRWR Online Report 98-8, Center for Research in Water Resources, University of Texas at Austin, 1988 http://www.crwr.utexas.edu/reports/1998/rpt98-8.shtml

Perales, J.M., R. Gu, and D.R. Maidment, Developing a GIS TxRR Model, Report submitted to Texas Water Development Board, 25 pp., July 2000

Appendix A. Soil Parameter Tables

Table A.1 Green-Ampt Parameters for USDA Soil Classes
Source: Chow, Maidment and Mays (1988), Table 4.3.1

USDA Soil Class	USDA Symbol	Effective Porosity	Wetting Front Suction Head (mm)	Hydraulic Conductivity (mm/day)
Sand	S	0.417	49.5	117.8
Loamy Sand	LS	0.401	61.3	29.9
Sandy Loam	SL	0.412	110.1	10.9
Loam	L	0.434	88.9	3.4
Silt Loam	SIL	0.486	166.8	6.5
Sandy Clay Loam	SCL	0.330	218.5	1.5
Clay Loam	CL	0.309	208.8	1.0
Silty Clay Loam	SICL	0.432	273.0	1.0
Sandy Clay	SC	0.321	239.0	0.6
Silty Clay	SIC	0.423	292.2	0.5
Clay	C	0.385	316.3	0.3
Silt	SI	0.486	166.8	6.5

Table A.3 Relationship between Statsgo and USDA Soil Classes
Source: Reed and Maidment (1998), Appendix D

Statsgo Texture Class	USDA Soil Class
BY-C	C
BY-CL	CL
BY-COS	S
BY-COSL	SL
BY-FS	S
BY-FSL	SL
BY-L	L
BY-LCOS	LS
BY-LS	LS
BY-LVFS	LS
BY-S	S
BY-SC	SC
BY-SCL	SCL
BY-SI	SI
BY-SIC	SIC
BY-SICL	SICL
BY-SIL	SIL
BY-SL	SL
BY-VFS	S
BY-VFSL	SL
BYV-C	C
BYV-CL	CL

BYV-COS	S
BYV-COSL	SL
BYV-FS	S
BYV-FSL	SL
BYV-L	L
BYV-LCOS	LS
BYV-LFS	LS
BYV-LS	LS
BYV-LVFS	LS
BYV-S	S
BYV-SC	SC
BYV-SCL	SCL
BYV-SI	SI
BYV-SIC	SIC
BYV-SICL	SICL
BYV-SIL	SIL
BYV-SL	SL
BYV-VFS	S
BYV-VFSL	SL
BYV-SL	SL
BYX-C	C
BYX-CL	CL
BYX-COS	S
BYX-COSL	SL
BYX-FS	S
BYX-FSL	SL
BYX-L	L
BYX-LCOS	LS
BYX-LFS	LS
BYX-LS	LS
BYX-LVFS	LS
BYX-S	S
BYX-SC	SC
BYX-SCL	SCL
BYX-SI	SI
BYX-SIC	SIC
BYX-SICL	SICL
BYX-SIL	SIL
BYX-SL	SL
BYX-VFS	S
BYX-VFSL	SL
C	C
CB-C	C
CB-CL	CL
CB-COS	S
CB-COSL	SL
CB-FS	S
CB-FSL	SL

CB-L	L
CB-LCOS	LS
CB-LFS	LS
CB-LS	LS
CB-LVFS	LS
CB-S	S
CB-SC	SC
CB-SCL	SCL
CB-SI	SI
CB-SIC	SIC
CB-SICL	SICL
CB-SIL	SIL
CB-SL	SL
CB-VFS	S
CB-VFSL	SL
CBA-C	C
CBA-CL	CL
CBA-COS	S
CBA-COSL	SL
CBA-FS	S
CBA-FSL	SL
CBA-L	L
CBA-LCOS	LS
CBA-LS	LS
CBA-LVFS	LS
CBA-S	S
CBA-SC	SC
CBA-SCL	SCL
CBA-SI	SI
CBA-SIC	SIC
CBA-SICL	SICL
CBA-SIL	SIL
CBA-SL	SL
CBA-VFS	S
CBA-VFSL	SL
CBV-C	C
CBV-CIND	O
CBV-CL	CL
CBV-COS	S
CBV-COSL	SL
CBV-FS	S
CBV-FSL	SL
CBV-L	L
CBV-LCOS	S
CBV-LFS	LS
CBV-LS	LS
CBV-MUCK	O
CBV-S	S

CBV-SC	SC
CBV-SCL	SCL
CBV-SIC	SIC
CBV-SICL	SICL
CBV-SIL	SIL
CBV-SL	SL
CBV-VFSL	SL
CBX-C	C
CBX-CL	CL
CBX-COS	S
CBX-COSL	SL
CBX-FS	S
CBX-FSL	SL
CBX-L	L
CBX-LCOS	LS
CBX-LFS	LS
CBX-LS	LS
CBX-LVFS	LS
CBX-S	S
CBX-SC	SC
CBX-SCL	SCL
CBX-SI	SI
CBX-SIC	SIC
CBX-SICL	SICL
CBX-SIL	SIL
CBX-SL	SL
CBX-VFS	S
CBX-VFSL	SL
CE	O
CEM	O
CIND	O
CL	CL
CN-C	C
CN-CL	CL
CN-COS	S
CN-COSL	SL
CN-FS	S
CN-FSL	SL
CN-L	L
CN-LCOS	LS
CN-LFS	LS
CN-LS	LS
CN-LVFS	LS
CN-S	S
CN-SC	SC
CN-SCL	SCL
CN-SI	SI
CN-SIC	SIC

CN-SICL	SICL
CN-SIL	SIL
CN-SL	SL
CN-VFS	S
CN-VFSL	SL
CNV-C	C
CNV-CL	CL
CNV-COS	S
CNV-COSL	SL
CNV-FS	S
CNV-FSL	SL
CNV-L	L
CNV-LCOS	LS
CNV-LFS	LS
CNV-LS	LS
CNV-LVFS	LS
CNV-S	S
CNV-SC	SC
CNV-SCL	SCL
CNV-SI	SI
CNV-SIC	SIC
CNV-SICL	SICL
CNV-SIL	SIL
CNV-SL	SL
CNV-VFS	S
CNV-VFSL	SL
CNX-C	C
CNX-CL	CL
CNX-COS	S
CNX-COSL	SL
CNX-FS	S
CNX-FSL	SL
CNX-L	L
CNX-LCOS	LS
CNX-LS	LS
CNX-LVFS	LS
CNX-S	S
CNX-SC	SC
CNX-SCL	SCL
CNX-SI	SI
CNX-SIC	SIC
CNX-SICL	SICL
CNX-SIL	SIL
CNX-SL	SL
CNX-VFS	S
CNX-VFSL	SL
COS	S
COSL	SL

CR-C	C
CR-CL	CL
CR-COS	S
CR-COSL	SL
CR-FS	S
CR-FSL	SL
CR-L	L
CR-LCOS	LS
CR-LS	LS
CR-LVFS	LS
CR-S	S
CR-SC	SC
CR-SCL	SCL
CR-SI	SI
CR-SIC	SIC
CR-SICL	SICL
CR-SIL	SIL
CR-SL	SL
CR-VFS	S
CR-VFSL	SL
CRC-C	C
CRC-CL	CL
CRC-COS	S
CRC-COSL	SL
CRC-FS	S
CRC-FSL	SL
CRC-L	L
CRC-LCOS	LS
CRC-LS	LS
CRC-LVFS	LS
CRC-S	S
CRC-SC	SC
CRC-SCL	SCL
CRC-SI	SI
CRC-SIC	SIC
CRC-SICL	SICL
CRC-SIL	SIL
CRC-SL	SL
CRC-VFS	S
CRC-VFSL	SL
CRV-C	C
CRV-CL	CL
CRV-COS	S
CRV-COSL	SL
CRV-FS	S
CRV-FSL	SL
CRV-L	L
CRV-LCOS	LS

CRV-LS	LS
CRV-LVFS	LS
CRV-S	S
CRV-SC	SC
CRV-SCL	SCL
CRV-SI	SI
CRV-SIC	SIC
CRV-SICL	SICL
CRV-SIL	SIL
CRV-SL	SL
CRV-VFS	S
CRV-VFSL	SL
CRX-C	C
CRX-CL	CL
CRX-COS	S
CRX-COSL	SL
CRX-FS	S
CRX-FSL	SL
CRX-L	L
CRX-LCOS	LS
CRX-LS	LS
CRX-LVFS	LS
CRX-S	S
CRX-SC	SC
CRX-SCL	SCL
CRX-SI	SI
CRX-SIC	SIC
CRX-SICL	SICL
CRX-SIL	SIL
CRX-SL	SL
CRX-VFS	S
CRX-VFSL	SL
DE	O
FB	O
FL-C	C
FL-CL	CL
FL-COS	S
FL-COSL	SL
FL-FS	S
FL-FSL	SL
FL-L	L
FL-LCOS	LS
FL-LS	LS
FL-LVFS	LS
FL-S	S
FL-SC	SC
FL-SCL	SCL
FL-SI	SI

FL-SIC	SIC
FL-SICL	SICL
FL-SIL	SIL
FL-SL	SL
FL-VFS	S
FL-VFSL	SL
FLV-C	C
FLV-CL	CL
FLV-COS	S
FLV-COSL	SL
FLV-FS	S
FLV-FSL	SL
FLV-L	L
FLV-LCOS	LS
FLV-LS	LS
FLV-LVFS	LS
FLV-S	S
FLV-SC	SC
FLV-SCL	SCL
FLV-SI	SI
FLV-SIC	SIC
FLV-SICL	SICL
FLV-SIL	SIL
FLV-SL	SL
FLV-VFS	S
FLV-VFSL	SL
FLX-C	C
FLX-CL	CL
FLX-COS	S
FLX-COSL	SL
FLX-FS	S
FLX-FSL	SL
FLX-L	L
FLX-LCOS	LS
FLX-LS	LS
FLX-LVFS	LS
FLX-S	S
FLX-SC	SC
FLX-SCL	SCL
FLX-SI	SI
FLX-SIC	SIC
FLX-SICL	SICL
FLX-SIL	SIL
FLX-SL	SL
FLX-VFS	S
FLX-VFSL	SL
FRAG	O
FS	S

FSL	SL
G	O
GR	O
GR-C	C
GR-CL	CL
GR-COS	S
GR-COSL	SL
GR-FS	S
GR-FSL	SL
GR-L	L
GR-LCOS	LS
GR-LFS	LS
GR-LS	LS
GR-LVFS	LS
GR-MARL	O
GR-MUCK	O
GR-S	S
GR-SC	SC
GR-SCL	SCL
GR-SI	SI
GR-SIC	SIC
GR-SICL	SICL
GR-SIL	SIL
GR-SL	SL
GR-VAR	O
GR-VFS	S
GR-VFSL	SL
GRC-C	C
GRC-CL	CL
GRC-COS	S
GRC-COSL	SL
GRC-FS	S
GRC-L	L
GRC-LCOS	LS
GRC-LS	LS
GRC-LVFS	LS
GRC-S	S
GRC-SC	SC
GRC-SCL	SCL
GRC-SI	SI
GRC-SIC	SIC
GRC-SICL	SICL
GRC-SIL	SIL
GRC-SL	SL
GRC-VFS	S
GRC-VFSL	SL
GRF-C	C
GRF-CL	CL

GRF-COS	S
GRF-COSL	SL
GRF-FS	S
GRF-FSL	SL
GRF-L	L
GRF-LCOS	LS
GRF-LS	LS
GRF-LVFS	LS
GRF-S	S
GRF-SC	SC
GRF-SCL	SCL
GRF-SI	SI
GRF-SIC	SIC
GRF-SICL	SICL
GRF-SIL	SIL
GRF-SL	SL
GRF-VFS	S
GRF-VFSL	SL
GRV-C	C
GRV-CL	CL
GRV-COS	S
GRV-COSL	SL
GRV-FS	S
GRV-FSL	SL
GRV-L	L
GRV-LCOS	LS
GRV-LFS	LS
GRV-LS	LS
GRV-LVFS	LS
GRV-S	S
GRV-SC	SC
GRV-SCL	SCL
GRV-SI	SI
GRV-SIC	SIC
GRV-SICL	SICL
GRV-SIL	SIL
GRV-SL	SL
GRV-VFS	S
GRV-VFSL	SL
GRX-C	C
GRX-CL	CL
GRX-COS	S
GRX-COSL	SL
GRX-FRAG	O
GRX-FS	S
GRX-FSL	SL
GRX-L	L
GRX-LCOS	LS

GRX-LFS	LS
GRX-LS	LS
GRX-LVFS	LS
GRX-S	S
GRX-SC	SC
GRX-SCL	SCL
GRX-SI	SI
GRX-SIC	SIC
GRX-SICL	SICL
GRX-SIL	SIL
GRX-SL	SL
GRX-VFS	S
GRX-VFSL	SL
GYP	O
HM	O
ICE	O
IND	O
L	L
LCOS	LS
LCOS	LS
LFS	LS
LS	LS
LVFS	LS
MARL	O
MI-SIL	SIL
MK-C	C
MK-CL	CL
MK-COS	S
MK-COSL	SL
MK-FS	S
MK-FSL	SL
MK-L	L
MK-LCOS	LS
MK-LFS	LS
MK-LS	LS
MK-LVFS	LS
MK-MARL	O
MK-PEAT	O
MK-S	S
MK-SC	SC
MK-SCL	SCL
MK-SI	SI
MK-SIC	SIC
MK-SICL	SICL
MK-SIL	SIL
MK-SL	SL
MK-VFS	S
MK-VFSL	SL

MPT	O
MUCK	O
NONE	O
PEAT	O
PT-SIC	SIC
PT-SIL	SIL
RB-C	C
RB-CL	CL
RB-COS	S
RB-COSL	SL
RB-FS	S
RB-FSL	SL
RB-L	L
RB-LCOS	LS
RB-LS	LS
RB-LVFS	LS
RB-S	S
RB-SC	SC
RB-SCL	SCL
RB-SI	SI
RB-SIC	SIC
RB-SICL	SICL
RB-SIL	SIL
RB-SL	SL
RB-VFS	S
RB-VFSL	SL
S	S
SC	SC
SCL	SCL
SG	O
SH-C	C
SH-CL	CL
SH-COS	S
SH-COSL	SL
SH-FS	S
SH-FSL	SL
SH-L	L
SH-LCOS	LS
SH-LS	LS
SH-LVFS	LS
SH-S	S
SH-SC	SC
SH-SCL	SCL
SH-SI	SI
SH-SIC	SIC
SH-SICL	SICL
SH-SIL	SIL
SH-SL	SL

SH-VFS	S
SH-VFSL	SL
SHV-C	C
SHV-CL	CL
SHV-COS	S
SHV-COSL	SL
SHV-FS	S
SHV-FSL	SL
SHV-L	L
SHV-LCOS	LS
SHV-LS	LS
SHV-LVFS	LS
SHV-S	S
SHV-SC	SC
SHV-SCL	SCL
SHV-SI	SI
SHV-SIC	SIC
SHV-SICL	SICL
SHV-SIL	SIL
SHV-SL	SL
SHV-VFS	S
SHV-VFSL	SL
SHX-CL	CL
SHX-L	L
SI	SI
SIC	SIC
SICL	SICL
SIL	SIL
SL	SL
SP	O
SR	O
SR-	O
SR-SIL	SIL
ST-SIL	SIL
ST-C	C
ST-CL	CL
ST-COS	S
ST-COSL	SL
ST-FS	S
ST-FSL	SL
ST-L	L
ST-LCOS	LS
ST-LFS	LS
ST-LS	LS
ST-LVFS	LS
ST-MUCK	O
ST-S	S
ST-SC	SC

ST-SCL	SCL
ST-SI	SI
ST-SIC	SIC
ST-SICL	SICL
ST-SIL	SIL
ST-SIL-	SIL
ST-SL	SL
ST-VFS	S
ST-VFSL	SL
STV-C	C
STV-CL	CL
STV-COS	S
STV-COSL	SL
STV-FS	S
STV-FSL	SL
STV-L	L
STV-LCOS	LS
STV-LFS	LS
STV-LS	LS
STV-LVFS	LS
STV-MPT	O
STV-MUCK	O
STV-S	S
STV-SC	SC
STV-SCL	SCL
STV-SI	SI
STV-SIC	SIC
STV-SICL	SICL
STV-SIL	SIL
STV-SL	SL
STV-VFS	S
STV-VFSL	SL
STX-C	C
STX-CL	CL
STX-COS	S
STX-COSL	SL
STX-FS	S
STX-FSL	SL
STX-L	L
STX-LCOS	LS
STX-LFS	LS
STX-LS	LS
STX-LVFS	LS
STX-MUCK	O
STX-PEAT	O
STX-S	S
STX-SC	SC
STX-SCL	SCL

STX-SI	SI
STX-SIC	SIC
STX-SICL	SICL
STX-SIL	SIL
STX-SL	SL
STX-VFS	S
STX-VFSL	SL
SY-C	C
SY-CL	CL
SY-COS	S
SY-COSL	SL
SY-FS	S
SY-FSL	SL
SY-L	L
SY-LCOS	LS
SY-LS	LS
SY-LVFS	LS
SY-S	S
SY-SC	SC
SY-SCL	SCL
SY-SI	SI
SY-SIC	SIC
SY-SICL	SICL
SY-SIL	SIL
SY-SL	SL
SY-VFS	S
SY-VFSL	SL
SYV-C	C
SYV-CL	CL
SYV-COS	S
SYV-COSL	SL
SYV-FS	S
SYV-FSL	SL
SYV-L	L
SYV-LCOS	LS
SYV-LS	LS
SYV-LVFS	LS
SYV-S	S
SYV-SC	SC
SYV-SCL	SCL
SYV-SI	SI
SYV-SIC	SIC
SYV-SICL	SICL
SYV-SIL	SIL
SYV-SL	SL
SYV-VFS	S
SYV-VFSL	SL
SYX-C	C

SYX-CL	CL
SYX-COS	S
SYX-COSL	SL
SYX-FS	S
SYX-FSL	SL
SYX-L	L
SYX-LCOS	LS
SYX-LS	LS
SYX-LVFS	LS
SYX-S	S
SYX-SC	SC
SYX-SCL	SCL
SYX-SI	SI
SYX-SIC	SIC
SYX-SICL	SICL
SYX-SIL	SIL
SYX-SL	SL
SYX-VFS	S
SYX-VFSL	SL
UWB	O
VAR	O
VFS	S
VFSL	SL
WB	O