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of Engineers**

Hydrologic Engineering Center

HEC-EFM

Ecosystem Functions Model

Quick Start Guide

Version 1.0
June 2008

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Ecosystem Functions Model, HEC-EFM, Quick Start Guide

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CHAPTER 1

Introduction

The Ecosystem Functions Model (HEC-EFM) is a planning tool that aids in analyzing ecosystem response to changes in flow regime. The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers is developing HEC-EFM to enable project teams to visualize existing ecologic conditions, highlight promising restoration sites, and assess and rank alternatives according to the relative change in ecosystem aspects.

Central to HEC-EFM analyses are "functional relationships". These relationships link characteristics of hydrologic and hydraulic time series (flow and stage) to elements of the ecosystem through combination of four basic criteria: 1) season, 2) flow frequency, 3) duration, and 4) rate of change.

After relationships are developed, HEC-EFM performs statistical computations to analyze flow and stage time series for the specified criteria and produces a single flow value for each relationship. This process can then be repeated on alternative flow regimes to compare different project scenarios and indicate the directions of change of ecosystem health.

In addition to the statistical computations, HEC-EFM analyses typically involves hydraulic modeling, which can translate statistical results to water surface profiles and spatial layers of water depth, velocity, and inundation areas. Geographic Information Systems (GIS) can then be used to display these generated layers as well as other relevant spatial data (i.e., soils, vegetation, and land-use maps).

Data requirements of HEC-EFM are related to the level of detail desired by the modeler. If only statistical results are desired, then required data consists only of the flow regimes to be analyzed and the eco-hydro relationships. If the user intends to visualize statistical results spatially, data (and software) requirements increase significantly and include flow and stage time series, eco-hydro relationships, digital topography, a geo-referenced hydraulic model, and any other spatial data relevant to the ecosystem investigations.

This quick start guide provides an overview of the software followed by examples that demonstrate its application. The text has been formatted to help readers keep track of the different types of information presented. *Italics* are used to identify *software features* that are available through the user interfaces of HEC-EFM. Underlines are used to identify model input data, which includes the names of flow regimes and relationships used in the demonstration project. **Bold** is used to highlight **key information** for individual sections of text.

CHAPTER 2

User Interface

The main interface of HEC-EFM consists of a titlebar, a series of menus, four tabs (*Properties*, *Relationships*, *Tables*, and *Combo Relationships*), a message bar, and a *Recalc* button (Figure 1). Most features are located on the tabs. The rest of this section provides more detail for those tabs.

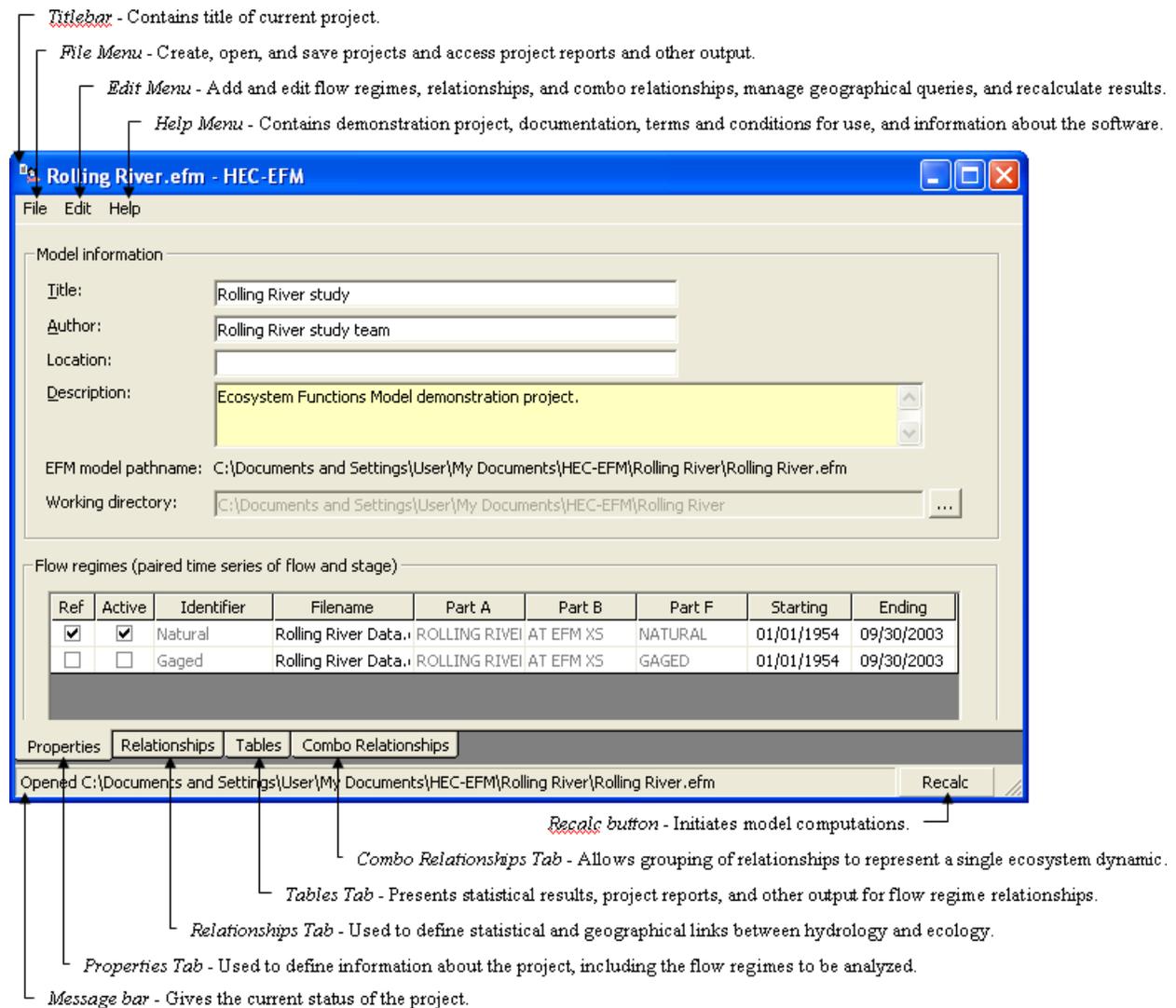


Figure 1. Key components of the main interface of HEC-EFM.

2.1 Properties

The *Properties Tab* contains information relevant to the model as a whole and is divided into two frames: *Model Information* and *Flow Regimes* (Figure 2).

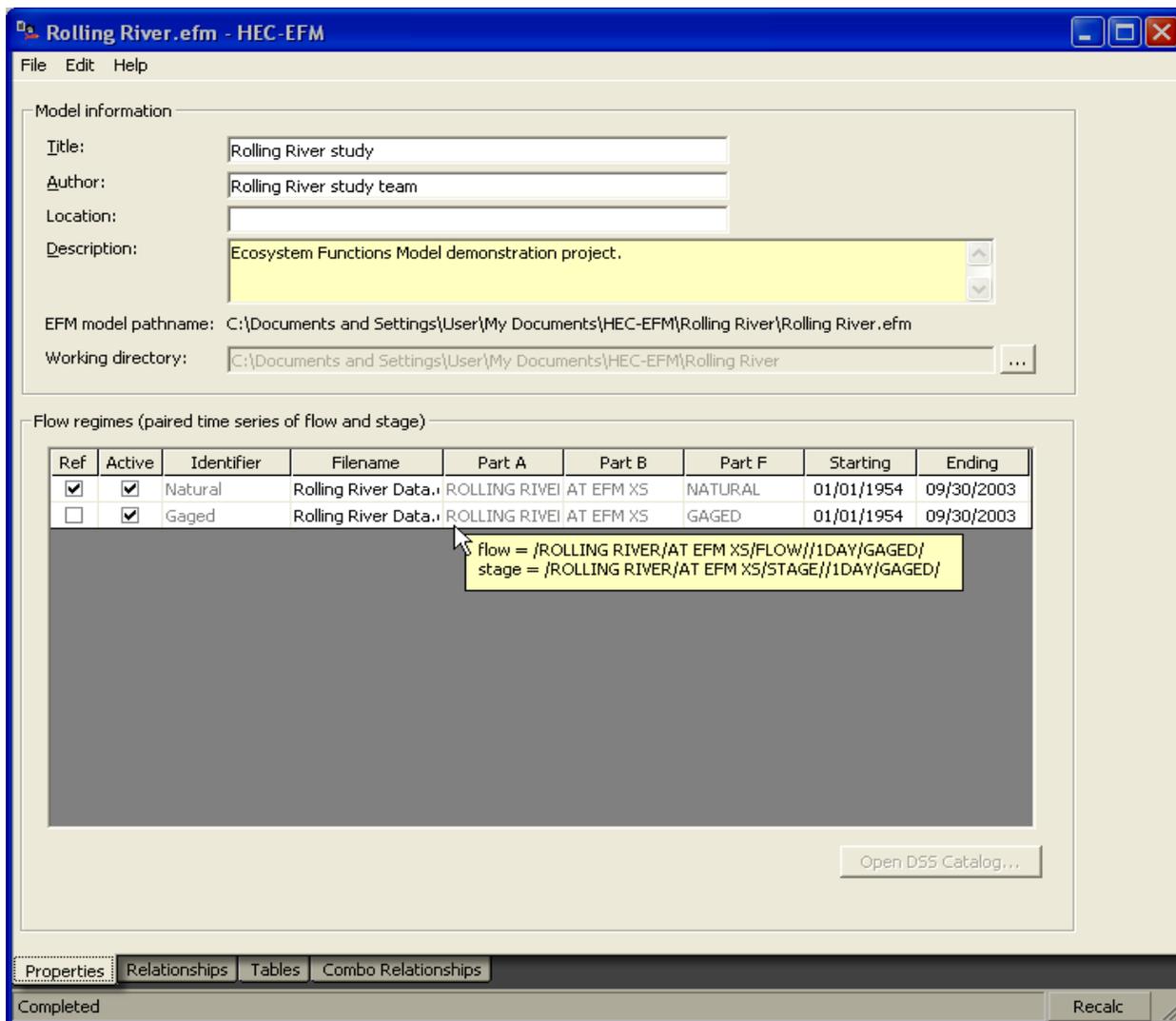


Figure 2. The *Properties Tab* of the main interface of HEC-EFM is used to document information about the project and to define the flow regimes to be analyzed. Two flow regimes (Natural and Gaged) are shown.

Model Information – *Model information* documents metadata in relation to the project. To simplify file management and study organization, each HEC-EFM project has a working directory that contains all input and output files. This allows projects to be zipped up and shared easily between users.

Flow Regimes – An HEC-EFM "flow regime" is defined as two concurrent daily time series that reflect conditions at a single location in the study area. Typically, a flow regime is composed of time series of daily mean flow and daily mean stage data. HEC-EFM accepts input data from several text formats (i.e., comma, space, and tab delimited) and from HEC Data Storage System

(HEC-DSS), which is the database used by HEC models for storage of time series and other data. The start and end dates for flow regimes are controlled by the user, which can be a handy feature when analyzing only part of the period of record. HEC-EFM does not allow missing data.

2.2 Relationships

HEC-EFM "relationships" are statistical representations of links between hydrology and ecology. Relationships are typically developed by teams of scientists and engineers using a combination of expert knowledge and scientific literature. Relationships are defined on the *Relationships Tab*, which is broken up into four frames: *Statistical queries*, *Geographical queries*, *Other queries (nonstandard)*, and *Options* (Figure 3).

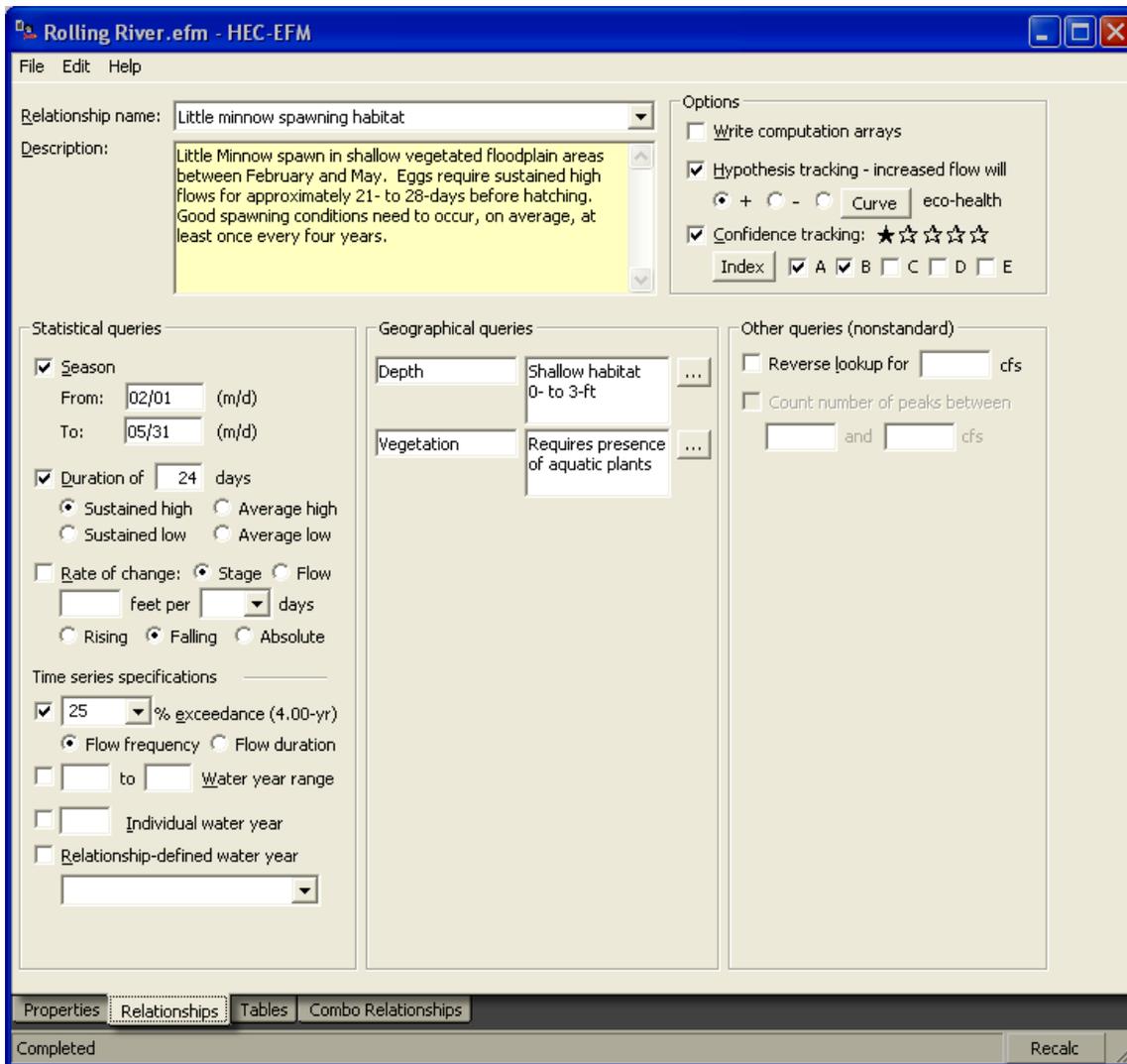


Figure 3. Using the *Relationships Tab* of the main interface of HEC-EFM, modelers define individual relationships as combinations of statistical and geographical criteria.

Statistical Queries – Fields within *Statistical queries* allow users to input criteria (in terms of season, flow frequency, duration, and rate of stage recession) that define the statistical analysis to

be performed for each relationship. All criteria do not need to be filled in for each relationship – only those that are important for the relationship. Time series specifications can be entered as flow frequency (% of years) or flow duration (% of time). *Statistical queries* also offer controls for managing the flow and stage data to be used for the statistical computations. Options are given for water year range, individual water year, or relationship-defined water year, which allows a relationship to be based on the statistical results of a separate relationship.

Geographical Queries – *Geographical queries* allow users to specify criteria that define relationships from a spatial perspective. Geographical queries are created by the user through the *Manage Tags for Geographical Queries* interface (Figure 4), which is accessed by selecting the "Edit – Manage Geo Queries..." menu option. Users create tags and specify the tags that are important for each relationship. This creates a text field in the HEC-EFM interface for recording how the tagged data sets need to be queried in GIS. A tag is a simple name that identifies sets of spatial data layers important to an HEC-EFM project.

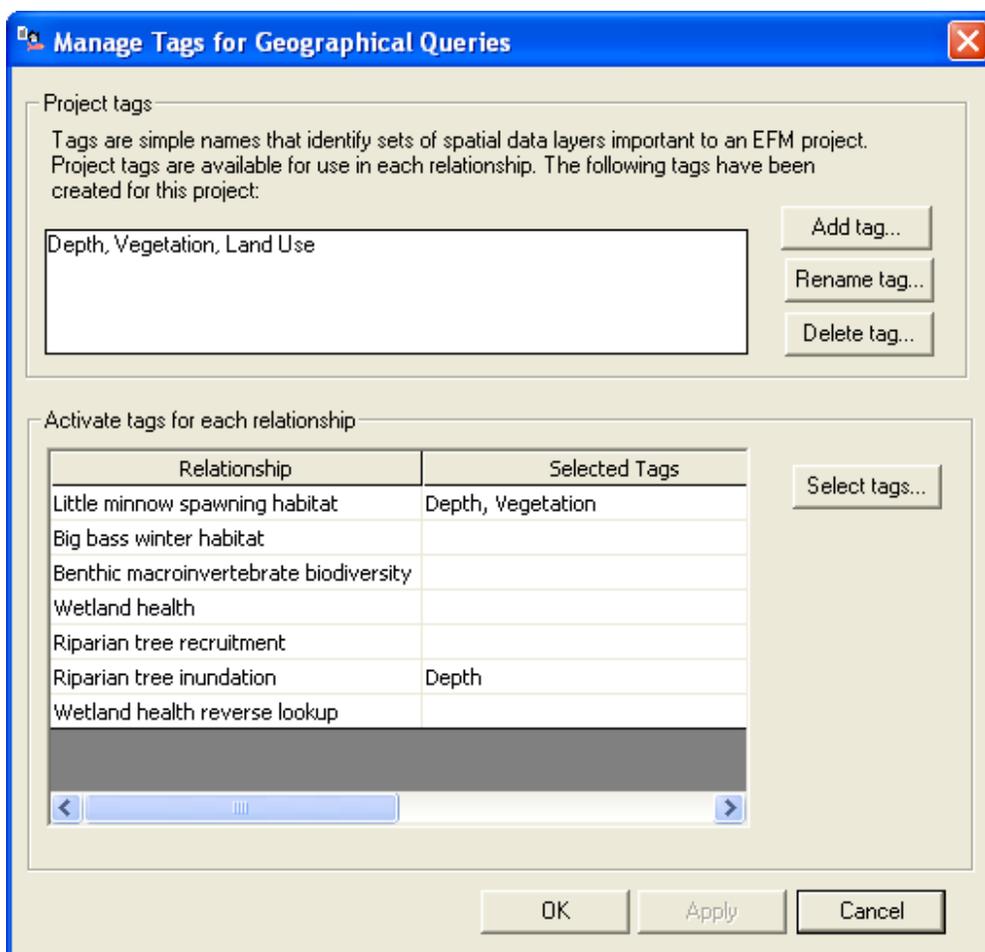


Figure 4. The *Manage Tags for Geographical Queries* interface in HEC-EFM is used or editing and creating tags, which are labels for sets of spatial data important to an HEC-EFM project.

Other Queries (nonstandard) – Statistical results for a standard HEC-EFM relationship is a pair of flow and stage data that meet the statistical criteria specified for that relationship. Currently, the only nonstandard query available is the *reverse lookup query*. Reverse lookups do

not compute a flow and stage, instead the user specifies a flow and HEC-EFM computes the % of years or % of time that flow is equaled or exceeded.

Options – There are three options available for each relationship: *Write computation arrays*, *Hypothesis tracking*, and *Confidence tracking*. The *Write computation arrays* option prompts HEC-EFM to export the statistical computations performed for that relationship. *Hypothesis tracking* allows users to compare the direction of change of eco-health for different flow regimes. The question that hypothesis tracking asks is: "Increased flow will do what to eco-health?" for this relationship. Users have the option of saying that increased flow will help (+), hurt (-), or have a non-linear response (via the *Curve* button) to eco-health. *Confidence tracking* provides a way to track the relative certainty of HEC-EFM relationships. The default is one star. This starting point implies that there is the same amount of scientific understanding for each of the relationships. As confidence in a particular relationship grows, its number of stars can be increased. This occurs at the discretion of the study team, perhaps when the relationship is verified with field data, backed with scientific literature, or approved by a group of scientists or agencies. A common result when analyzing multiple relationships is that for a certain flow regime, some are helped and some are hurt. *Indices* are a tool that can help users look at the net effect of different flow regimes. *Confidence tracking* and *hypothesis tracking* must be in use if you want to include a particular relationship in an index. Indices are computed for flow regimes that are active and not the reference. Each index is computed using a combination of information about relationships and statistical results based on the following equation:

$$\text{Index} = \sum_{i=1..n} (\text{Direction of Change}_i) * (\text{Confidence}_i) * (\% \text{ Change in Eco-value}_i)$$

Where:

i = counter from 1 to *n*

n = number of relationships in the index

Direction of Change_{*i*} = 1, -1, or 0 for relationship_{*i*}

1 indicates that relationship_{*i*} experienced a positive change from the reference flow regime

-1 indicates that relationship_{*i*} experienced a negative change from the reference flow regime

0 indicates that relationship_{*i*} experienced no change from the reference flow regime

Confidence_{*i*} = an integer from 0 to 5 based on the confidence value for relationship_{*i*}

% Change in Eco-value_{*i*} = $\frac{(\text{Eco-value for relationship}_i - \text{Eco-value for relationship}_{\text{reference}})}{(\text{Eco-value for relationship}_{\text{reference}})}$

Note: % change in Eco-value is equal to % change in Flow (using statistical results for flow) when hypothesis tracking does not use the curve option.

2.3 Tables

The *Tables Tab* presents statistical results for flow regime relationships. It is also where users can view project reports and output files (Figure 5). Tables can be printed or copied into other applications. After the *Recalc* button is pressed, the HEC-EFM interface will automatically go to the *Tables Tab* to display the new statistical results.

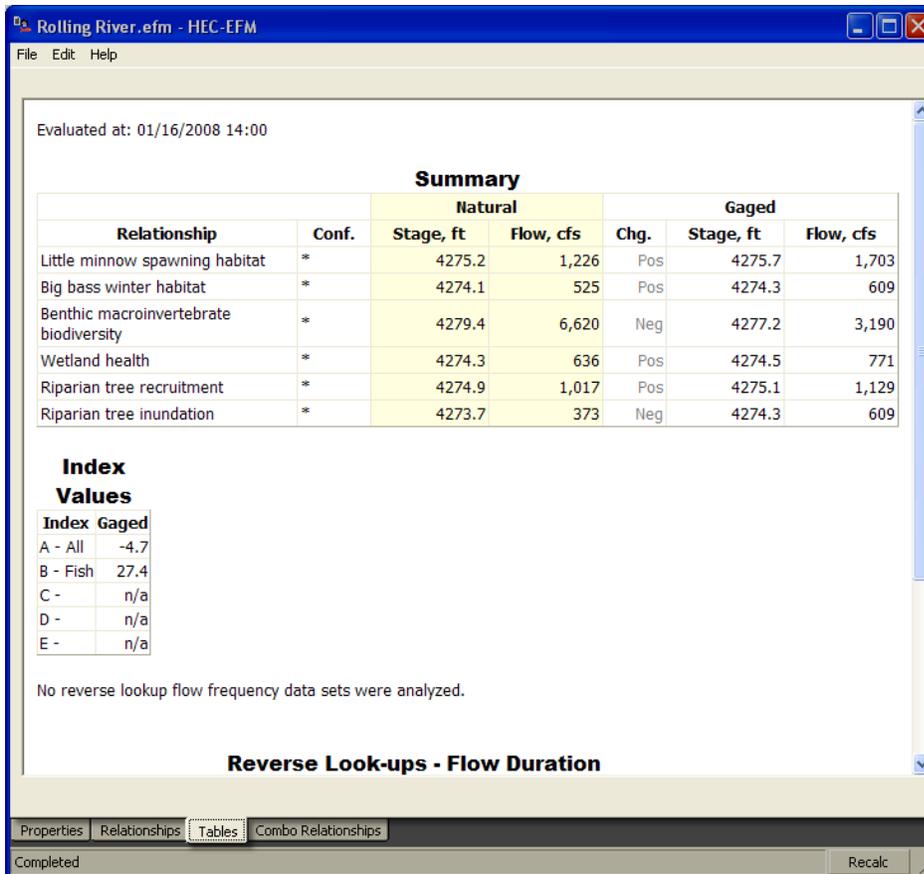
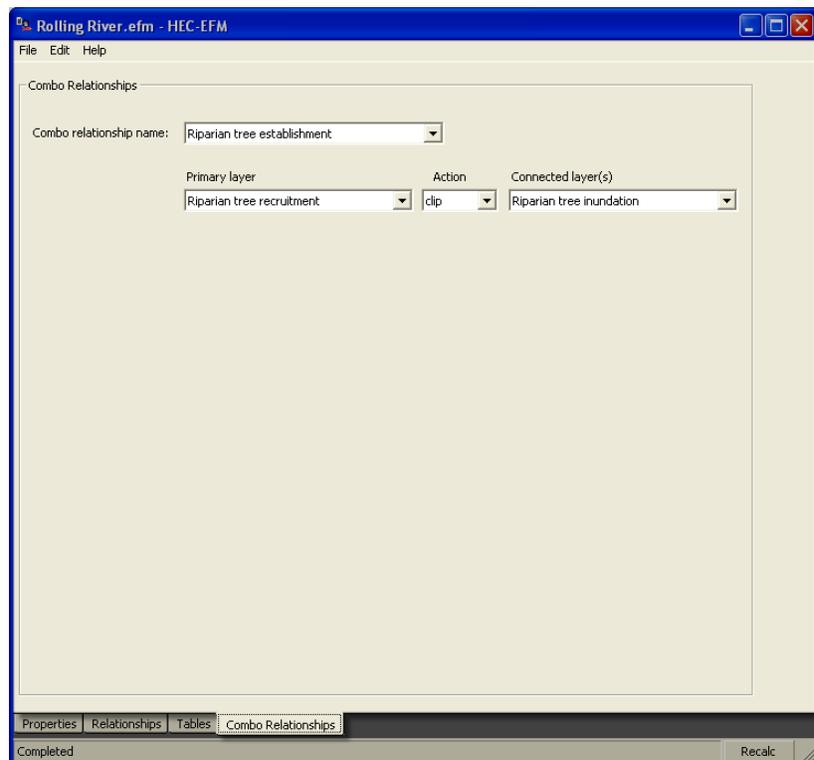


Figure 5. The *Tables Tab* of the HEC-EFM interface is used to display statistical results for simulations (as in this figure), project reports, and computational output.

2.4 Combo Relationships

Combo relationships are used to detail how two or more individual relationships are grouped to represent a single ecosystem dynamic. For example, in Figure 6, Riparian tree establishment is defined as Riparian tree recruitment minus Riparian tree inundation.

Figure 6. The *Combo Relationships Tab* of the HEC-EFM interface allows for grouping of separate relationships to represent a single ecosystem dynamic.



CHAPTER 3

Demonstration Project

This demonstration project will consider ecosystem relationships for a cross section of the fictional Rolling River. The progression of tasks is to 1) build eco-hydro relationships, 2) set up the model and compute statistical results, 3) simulate the statistical results with a hydraulic model, and 4) use of GIS to investigate the ecosystem responses spatially.

Two flow regimes will be analyzed. The "Gaged" flow regime has flows and stages that reflect the current management plan for Rolling River, which is regulated by upstream dams. The "Natural" flow regime has flows and stages that reflect how the river would behave without reservoir regulation.

A completed demonstration project with flow regime data can be downloaded via the "*Help – Install Demonstration Project...*" menu option.

3.1 Building Relationships

Each scenario described below presents information about an aspect of the ecosystem that the Rolling River study team would like to investigate, the statistical and geographical queries used to define each as an HEC-EFM relationship, and the logic used to craft those criteria.

3.1.1 Little minnow spawning habitat

The little minnow is a threatened species of fish indigenous only to the Rolling River basin. Little minnow populations have declined (in magnitude and range) as dams and diversions limited access to upstream river stretches and as floodplain areas, critical to little minnow spawning, were transitioned to agricultural lands. Little minnow spawn in **shallow (no deeper than 3-ft), vegetated** floodplain areas between **February and May**. Eggs require **sustained high flows** for approximately **21 to 28 days** before hatching. Little minnow reach sexual maturity in their first or second year and have a lifespan of approximately 6 years. Scientists say that good spawning conditions do not need to occur every year – it would be sufficient if there were good conditions in **25% of years**, so that, on average, each little minnow would have a chance to spawn in their lifespan.

HEC-EFM Relationship:

- Season: 02/01 to 05/31
- Duration: 24-days, sustained high
- Rate of Change: Not applied
- Flow Frequency/Duration: 25% (4-yr) - flow frequency

- Hypothesis: Increased flow will improve (+) floodplain spawning
- Geo-Queries: Depth (0- to 3-ft) and vegetation (aquatic plants)

Comments. For the little minnow, successful spawning depends on having a sustained inundation long enough for the eggs to incubate. These types of scenarios, where any interruption will affect the ecosystem dynamic being modeled, typically use a "sustained" duration query. Sustained highs return a flow that will be that high or higher for the length of the duration. Sustained lows return a flow that will be that low or lower. This relationship also thinks in terms of percentage of years. The *% exceedance - Flow frequency* option returns a flow and stage that are equaled or exceeded in the % of years specified by the user. The *% exceedance - Flow duration* option returns a flow and stage that are equaled or exceeded in the % of time specified by the user.

3.1.2 Big bass winter habitat

A study for big bass showed that fish mortality in a critical over-winter period, **January through May**, was caused by a chronic lack of habitat. Mortalities began to occur when generally poor conditions persisted for more than **two weeks**. Habitat shortages for these fish occur at low flows. Scientists said that these chronic conditions are best represented by **average low flows** and that, since these fish are in the river each winter, using a **typical year (median conditions)** would be a good indicator. The study showed that suitable habitat is proportional to increasing low flows (i.e., higher low flows create more habitat) until those low flows exceed **1,000-cfs**.

HEC-EFM Relationship:

- Season: 1/1 to 5/31
- Duration: 14-days, average low
- Rate of Change: Not applied
- Flow Frequency/Duration: 50% (2-yr) - flow frequency
- Hypothesis: Curve with flow-value points of 0-0, 600-6, 1000-10, 10000-0
- Geo-Queries: Not applied

Comments. The background for big bass used phrases like "mortality...was caused by a chronic lack of habitat...generally poor conditions". These are clues that big bass are somewhat resilient and will be most affected by bad conditions that occur for long periods of time or sporadically, without enough time between episodes for the fish to recover. This scenario is unlike little minnow spawning where the eggs cannot have bad conditions – be dry – for any single day and survive. Relationships like this typically use an "average" duration query.

3.1.3 Benthic macro invertebrate biodiversity

Reservoirs tend to reduce high flows and increase low flows, which creates a more stable flow regime. In these regulated systems, communities of benthic macro invertebrates often have reduced biodiversity because the few species that thrive in the more stable flow conditions out compete all of the others. **Flooding** initiates a return to more natural conditions which encourages the community to rebound to its original biodiversity. Scientists said that the **timing is not important**, but the high flows should occur **once every two years**, on average.

HEC-EFM Relationship:

- Season: 10/1 to 9/30
- Duration: 1-day, average high
- Rate of Change: Not applied
- Flow Frequency/Duration: 50% (2-yr) - flow frequency
- Hypothesis: Increased flow will improve (+) benthic biodiversity
- Geo-Queries: Not applied

Comments. HEC-EFM relationships do not need to be complicated. The background basically says that benthic biodiversity is a function of high flows. So to build this relationship, use statistical queries that focus on high flows of short duration at any time in the water year. Choosing a duration is related to the flashiness of the river system being studied. For the demonstration project, a value of 1-day *average high* was chosen, though any duration between 1- and 7-days would likely be a good indicator.

3.1.4 Wetland health

Water exchange between river and wetland areas has also been noted as a key component of wetland health. With frequent exchange, water quality in the wetlands remains good, but with isolation, dissolved oxygen levels drop, wetland areas become anoxic and aquatic species die. This is only an issue in the warm summer months, **mid-May to mid-September**. A hydraulic engineer on your team has determined that flows of **600-cfs** and higher allow water exchange in your project area and a biologist, familiar with the region, suggests that active exchange for approximately **30% of the time** (in summer) will lead to healthy conditions.

HEC-EFM Relationship:

- Season: 5/15 to 9/15
- Duration: 1-day
- Rate of Change: Not applied
- Flow Frequency/Duration: 30% (of time) - flow duration
- Hypothesis: Increased flow will improve (+) water exchange for Wetland health
- Geo-Queries: Not applied

Comments. This relationship is the first demonstration relationship to use the *% exceedance - Flow duration* query. In this case, healthy conditions are created when active exchange between the river and wetlands occurs 30% of the time. As mentioned in the little minnow comments, using the *% exceedance - Flow duration* option will return a flow and stage that are equaled or exceeded in the % of time specified by the user.

3.1.5 Riparian tree recruitment and inundation

Reservoir influence and transition of floodplain lands to agriculture has proved a destructive combination for riparian tree forests. Through scientific study, riparian tree establishment has been tied to high flows that occur and recede during germination periods. After germination, survival is a function of water level. If inundated, seedlings are prone to drowning and, conversely, if water levels recede too rapidly, roots desiccate and seedlings are lost.

Germination periods for the riparian tree have been shown to occur between **mid-June through July**. Scientists have found that, after germination, if water levels drop by more than **0.58 feet per week** then riparian tree seedlings will have a lower chance of survival. A high stage needs to occur at least once every **10 years** to keep sustainable riparian tree establishment.

HEC-EFM Relationship: Recruitment

- Season: 06/15 to 08/01
- Duration: Not applied
- Rate of Change: 0.58 feet per 7-days - falling (stage)
- Flow Frequency/Duration: 10% (10-yr) - flow frequency
- Hypothesis: Increased flow will improve (+) Riparian tree recruitment
- Geo-Queries: Not applied

Riparian tree seedlings are sensitive to prolonged periods of inundation. **Beginning of August through mid September** represents the time period immediately following the establishment season, where riparian tree seeds would most likely drown if inundated for an extended length of time. **21 days** is the estimated length of time that a seedling could be continuously inundated before it dies. If the **sustained** inundation is less than 0.5-ft, seedlings are more likely to survive. Median conditions (**2-yr**) can be used as an estimate of typical inundation.

HEC-EFM Relationship: Inundation

- Season: 08/01 to 09/15
- Duration: 21-days, sustained high
- Rate of Change: Not applied
- Flow Frequency/Duration: 50% (2-yr) - flow frequency
- Hypothesis: Increased flow will cause Riparian tree inundation to increase (-)
- Geo-Queries: Depth (0- to 0.5-ft)

Comments. This scenario actually requires two individual relationships that are used to represent a single ecosystem dynamic. The real dynamic of interest is the establishment of new riparian tree seedlings. Establishment occurs when flow and stage conditions are suitable for new seedlings to begin growing (recruit) and when the new seedlings survive inundation that occurs later in the growing season.

The recruitment relationship uses the rate of change query. This query starts at the end of the season and works towards the start of the season one day at a time, checking for violations of the rate of change threshold. The flow and stage at the time of the last violation in the user-defined season is recorded as a “seasonal result”. These seasonal results (one pair of flow and stage for each water year) are then ranked into a frequency table. The statistical result for Riparian tree recruitment is interpolated as the 10% exceedance value.

The inundation relationship uses a sustained high query to compute the flow and stage that effectively drown any new recruitment.

These two are used in combination to represent Riparian tree establishment, with the difference between recruitment and inundation results being the portion of recruitment that leads to establishment of new seedlings.

HEC-EFM Combo Relationship: Riparian tree establishment

Primary layer - Riparian tree recruitment

Connected layer - Riparian tree inundation

3.2 Setting Up the Model

3.2.1 Creating a New Project and Defining Flow Regimes

1. Open HEC-EFM and use the "File – New" menu option to start a new project. Enter title, author, and project description into the *model information* section of the *Properties Tab*.
2. Next, identify the working directory for the HEC-EFM project by clicking on the *browse* button located to the right of the *Working directory* text box (Figure 7). Navigate to the folder you would like to use, highlight it, and click *OK*. If you would like to create a new folder to serve as the working directory for your project, use Microsoft Windows Explorer or a similar file browser to create the folder and then identify it using the browser in HEC-EFM. Any folder name and location will work as long as you have security permissions to read, write, and modify folder contents.

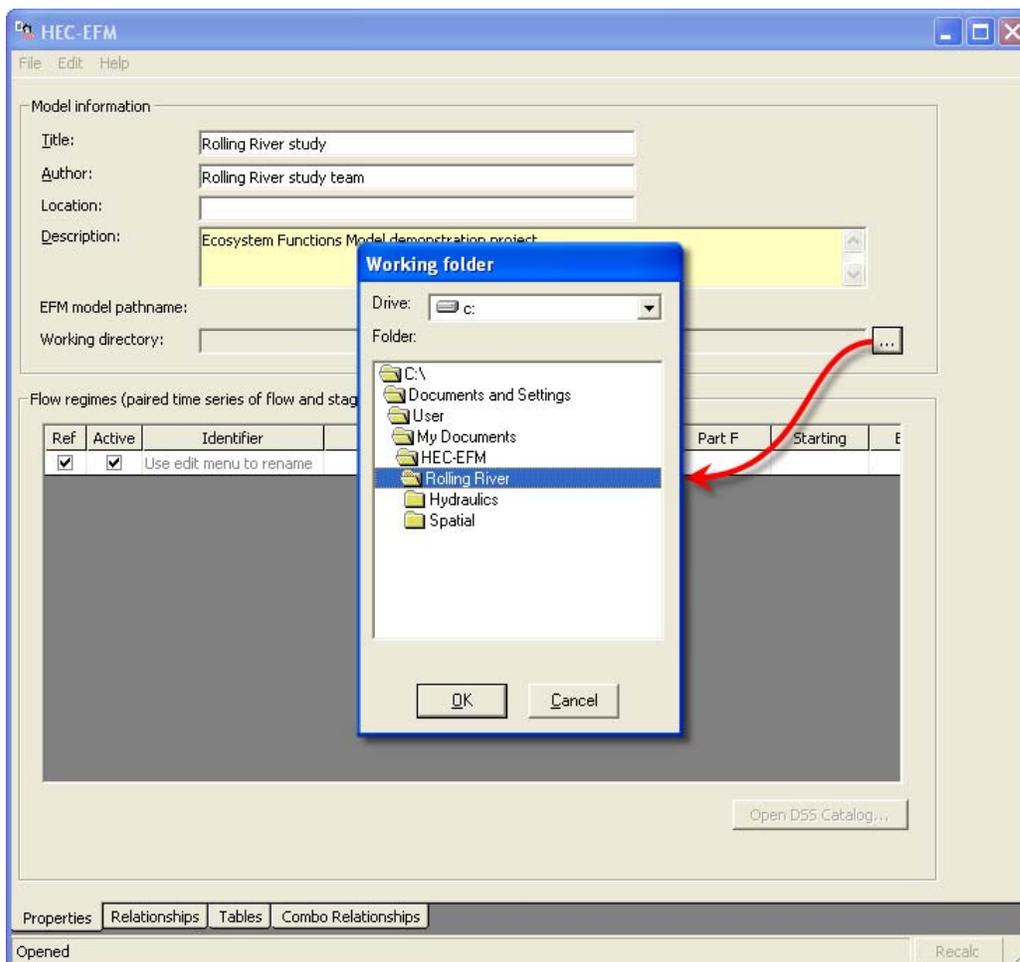


Figure 7. Setting up a working directory.

- Next, place the hydrologic dataset into the working directory. The dataset for this project is part of the completed demonstration project for HEC-EFM, which was copied to your computer when software was installed. To extract the completed demonstration project, use the *"Help – Install Demonstration Project..."* menu option and extract to the working directory.
- Data for the flow regimes are located in "Rolling River Data.dss". The first flow regime acts as a placeholder and must be renamed. Use the *"Edit – Flow Regimes – Rename..."* menu option to open the *Rename Flow Regime* interface. In the *New name* text box, enter Natural and click *OK* (Figure 8).

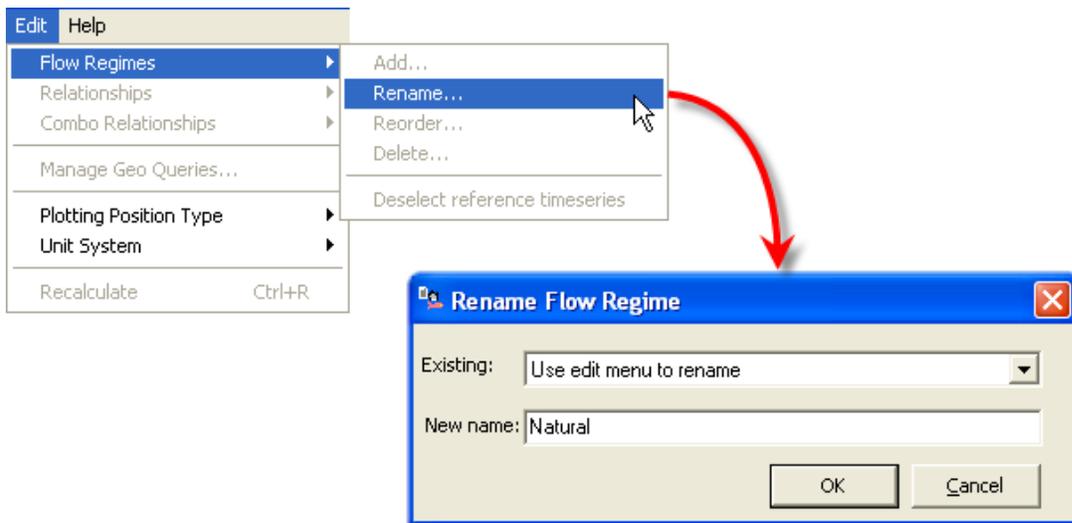


Figure 8. Naming a flow regime.

- Add data to this flow regime by moving the cursor over the *Filename* cell and pressing the *browse* button (Figure 9). Select "Rolling River Data.dss" and click *OK*. *Note: The browse button only appears when you have the Filename cell selected.*

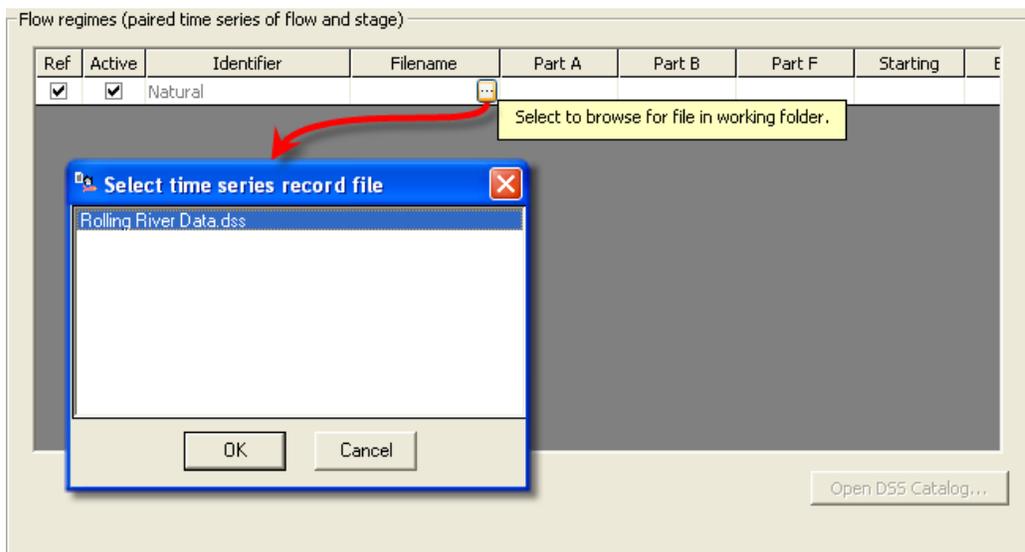


Figure 9. Adding the flow regime data file.

6. Click on the *Open DSS Catalog* button to open the *HEC-DSS Catalog Browser* for that flow regime (Figure 10). Browse to /ROLLING RIVER/AT EFM XS/FLOW//1DAY/NATURAL/, highlight the *f-part* "NATURAL" and click *Select*. HEC-EFM has an auto-mapping feature that looks for stage time series whose *a-*, *b-*, and *f-parts* match the selected flow record. If HEC-EFM finds a match, a message box opens asking whether the matching time series should be used as the corresponding stage values for that flow regime. Click *Yes*. Once both the stage and flow time series have been selected, press *OK*.

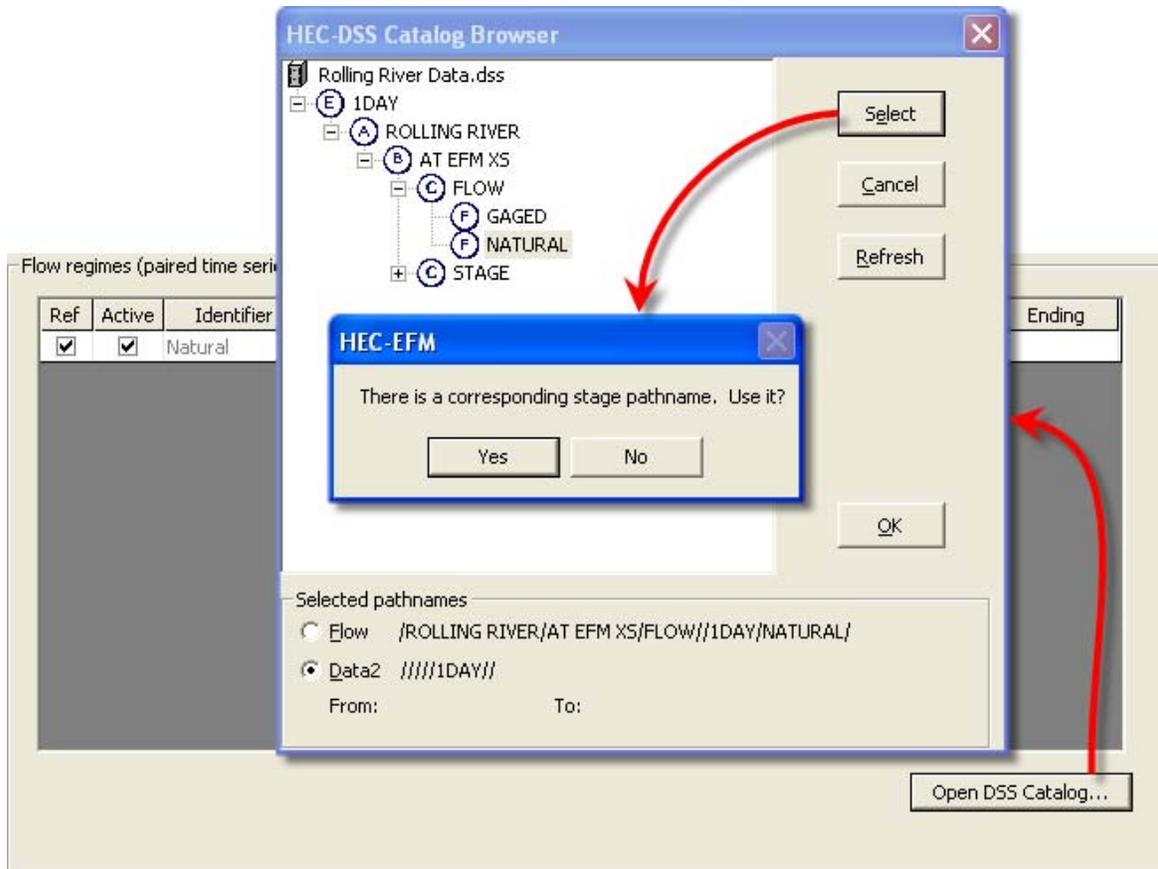


Figure 10. Selecting flow and stage time series.

7. Use the "*Edit – Flow Regimes – Add...*" menu option to open the *Add Flow Regime* interface. In the *Name* text box, enter Gaged and click *OK* (Figure 8). Repeat steps 5 and 6 to add data to the new flow regime. Remember to click the *Open DSS Catalog...* button while the cell highlighted in the table of flow regimes is in the row for Gaged and to select the *f-part* "GAGED" after opening the DSS catalog.
8. It is important to define the reference flow regime. This is the flow regime that serves as the basis for comparison when looking at direction of ecosystem change. In this example, use the Natural flow regime as the reference. To make a flow regime the reference, click on the box in the *Ref* column of that flow regime (Figure 11). In this case, a check mark is already in the box because Natural was the first flow regime entered. Only active flow regimes are considered during calculations.

Ref	Active	Identifier	Filename	Part A	Part B	Part F	Starting	Ending
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Natural	Rolling River Data..	ROLLING RIVER	AT EFM XS	NATURAL	01/01/1954	09/30/2003
<input type="checkbox"/>	<input type="checkbox"/>	Gaged	Rolling River Data..	ROLLING RIVER	AT EFM XS	GAGED	01/01/1954	09/30/2003

Figure 11. Reference and active flow regimes.

- The *Properties Tab* should now look like Figure 12. Use the "File – Save As" menu option to save your project. Be sure to save your project to the working directory. *Note: The completed demonstration project is called Rolling River.efm. Please use a different name for your project.*

Rolling River .efm - HEC-EFM

File Edit Help

Model information

Title: Rolling River study

Author: Rolling River study team

Location:

Description: Ecosystem Functions Model demonstration project.

EFM model pathname: C:\Documents and Settings\User\My Documents\HEC-EFM\Rolling River\Rolling River .efm

Working directory: C:\Documents and Settings\User\My Documents\HEC-EFM\Rolling River

Flow regimes (paired time series of flow and stage)

Ref	Active	Identifier	Filename	Part A	Part B	Part F	Starting	Ending
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Natural	Rolling River Data..	ROLLING RIVER	AT EFM XS	NATURAL	01/01/1954	09/30/2003
<input type="checkbox"/>	<input type="checkbox"/>	Gaged	Rolling River Data..	ROLLING RIVER	AT EFM XS	GAGED	01/01/1954	09/30/2003

Open DSS Catalog...

Properties Relationships Tables Combo Relationships

Completed Recalc

Figure 12. Completed *Properties Tab* for the demonstration project.

3.2.2 Defining Relationships

- The next step is to enter the relationships. Go to the *Relationships Tab* and use the "Edit – Relationships – Add..." menu option to open the *Add Relationship* interface. In the *Name* text box, enter Little minnow spawning habitat and click *OK* (Figure 13).

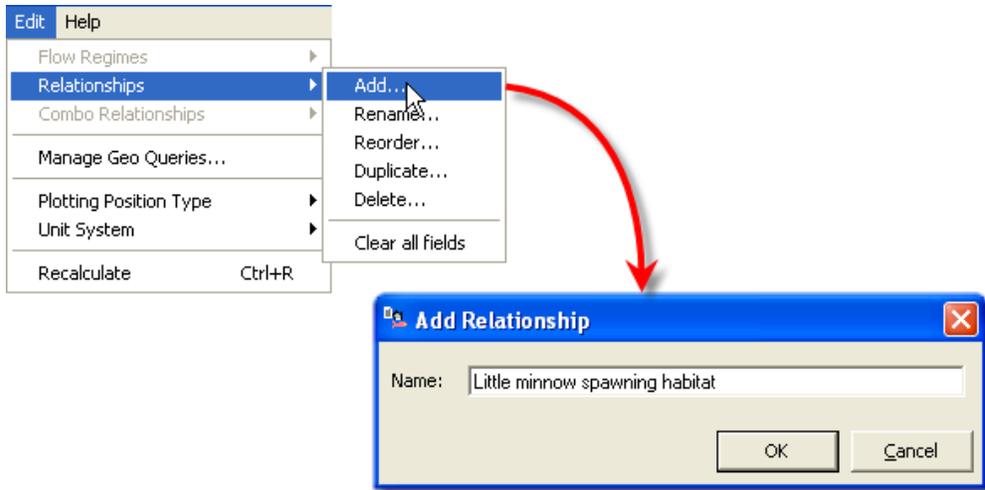


Figure 13. Adding a relationship.

2. Enter a description, statistical queries, and hypothesis for the Little minnow spawning habitat relationship (Figure 14).

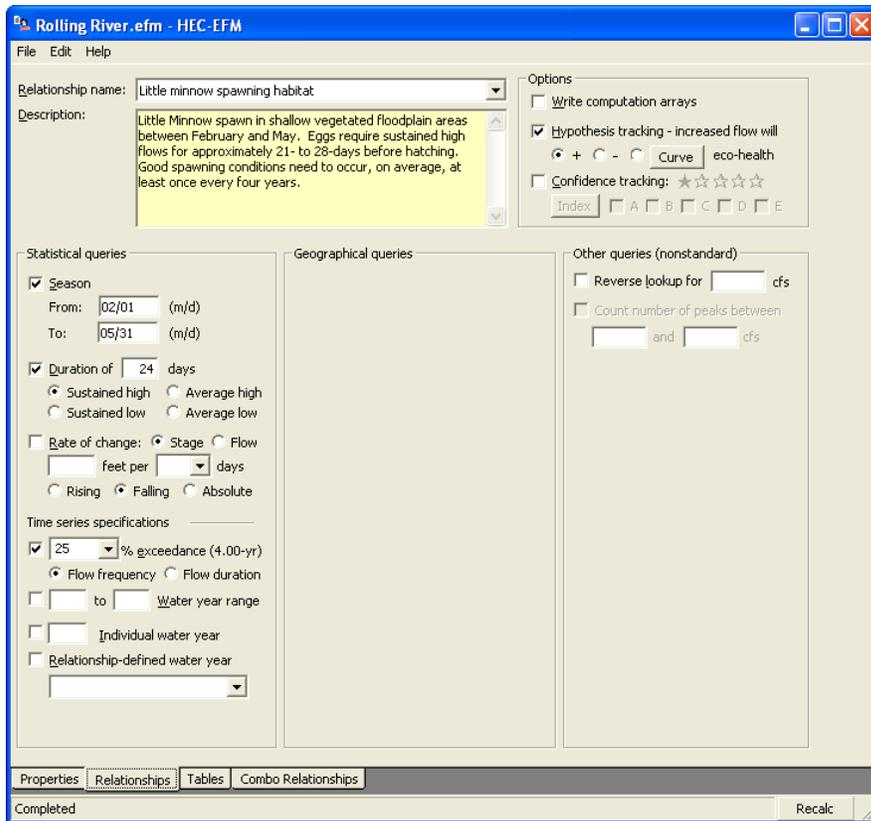
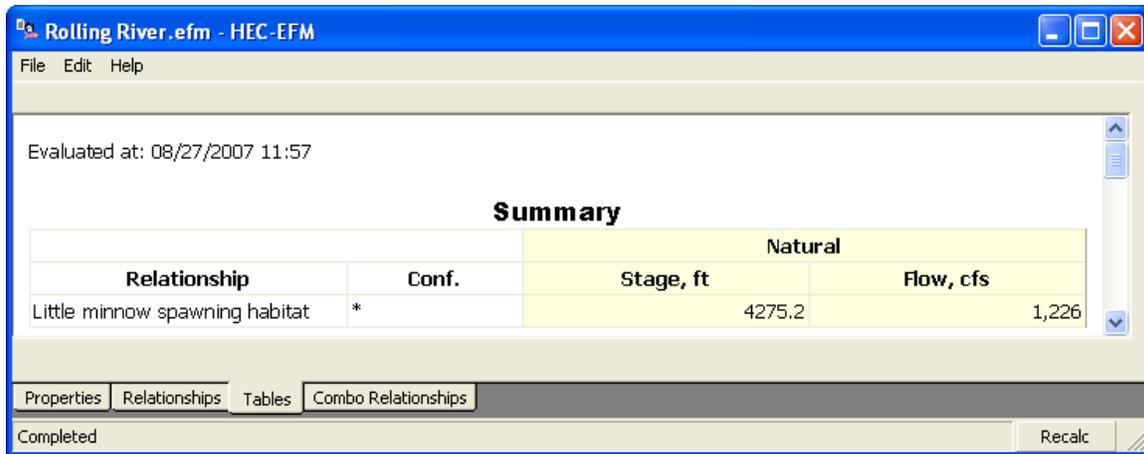


Figure 14. Statistical queries and hypothesis for the Little minnow relationship.

3. Click the *Recalc* button (bottom right of the interface). Results are displayed on the *Tables Tab* (Figure 15).



Rolling River.efm - HEC-EFM

File Edit Help

Evaluated at: 08/27/2007 11:57

Summary

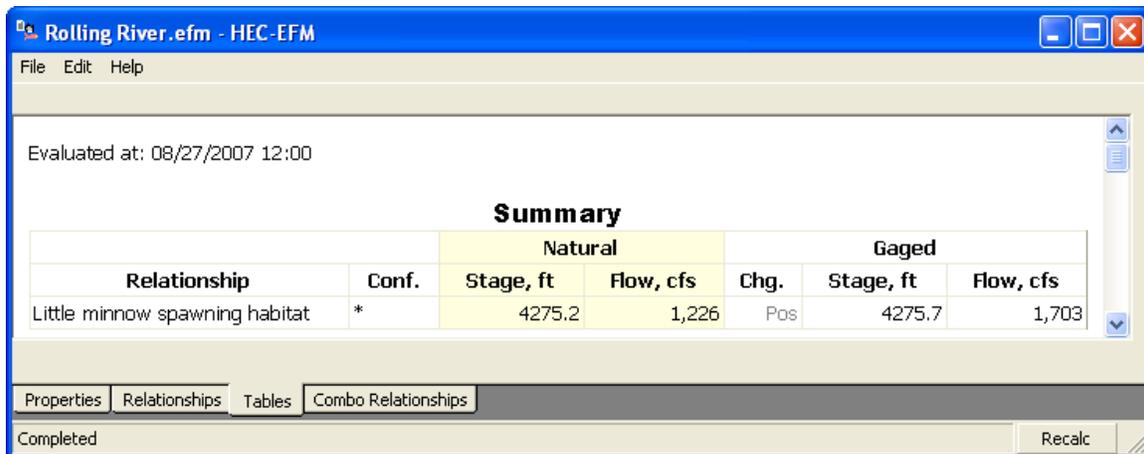
Relationship	Conf.	Natural	
		Stage, ft	Flow, cfs
Little minnow spawning habitat	*	4275.2	1,226

Properties Relationships Tables Combo Relationships

Completed Recalc

Figure 15. Statistical results for the Natural flow regime and the Little minnow relationship.

- Next, click on the *Properties Tab*; activate the Gaged flow regime by checking its box in the *Active* column of the flow regime table. Click the *Recalc* button. Results are now displayed for both the Natural and Gaged flow regimes (Figure 16). *Note: It is important to recognize that the Little minnow relationship was not changed during this step. **Flow regimes and relationships exist independently.** When the second flow regime (Gaged) was activated, HEC-EFM computed statistical results for each flow regime using the same statistical criteria, as defined for the Little minnow relationship. Results are different because each flow regime has its own distinct patterns of flow and stage.*



Rolling River.efm - HEC-EFM

File Edit Help

Evaluated at: 08/27/2007 12:00

Summary

Relationship	Conf.	Natural		Chg.	Gaged	
		Stage, ft	Flow, cfs		Stage, ft	Flow, cfs
Little minnow spawning habitat	*	4275.2	1,226	Pos	4275.7	1,703

Properties Relationships Tables Combo Relationships

Completed Recalc

Figure 16. HEC-EFM statistical results of the Little minnow spawning habitat relationship using both the Natural and Gaged flow regimes.

- The next step is to create geographical queries. Go to the *Relationships Tab* and use the *"Edit – Manage Geo Queries..."* menu option to open the *Manage Tags for Geographical Queries* interface (Figure 17). Click the *Add tag...* button to open the *Add Tag* interface. In the *Name* text box, enter "Depth" and click *OK*. Repeat this step to add another tag named "Vegetation". Now associate the tags with Little minnow spawning habitat by highlighting that relationship in the *Relationship* column and clicking the *Select tags...* button. The *Tag Selector* interface will open. Select *Depth* and *Vegetation* and click the *Add →* button. Click *OK* to save the selections to the *Manage Tags* interface and then click *OK* in the *Manage Tags* interface to save the tags and selections to the project. Text boxes for selected tags will

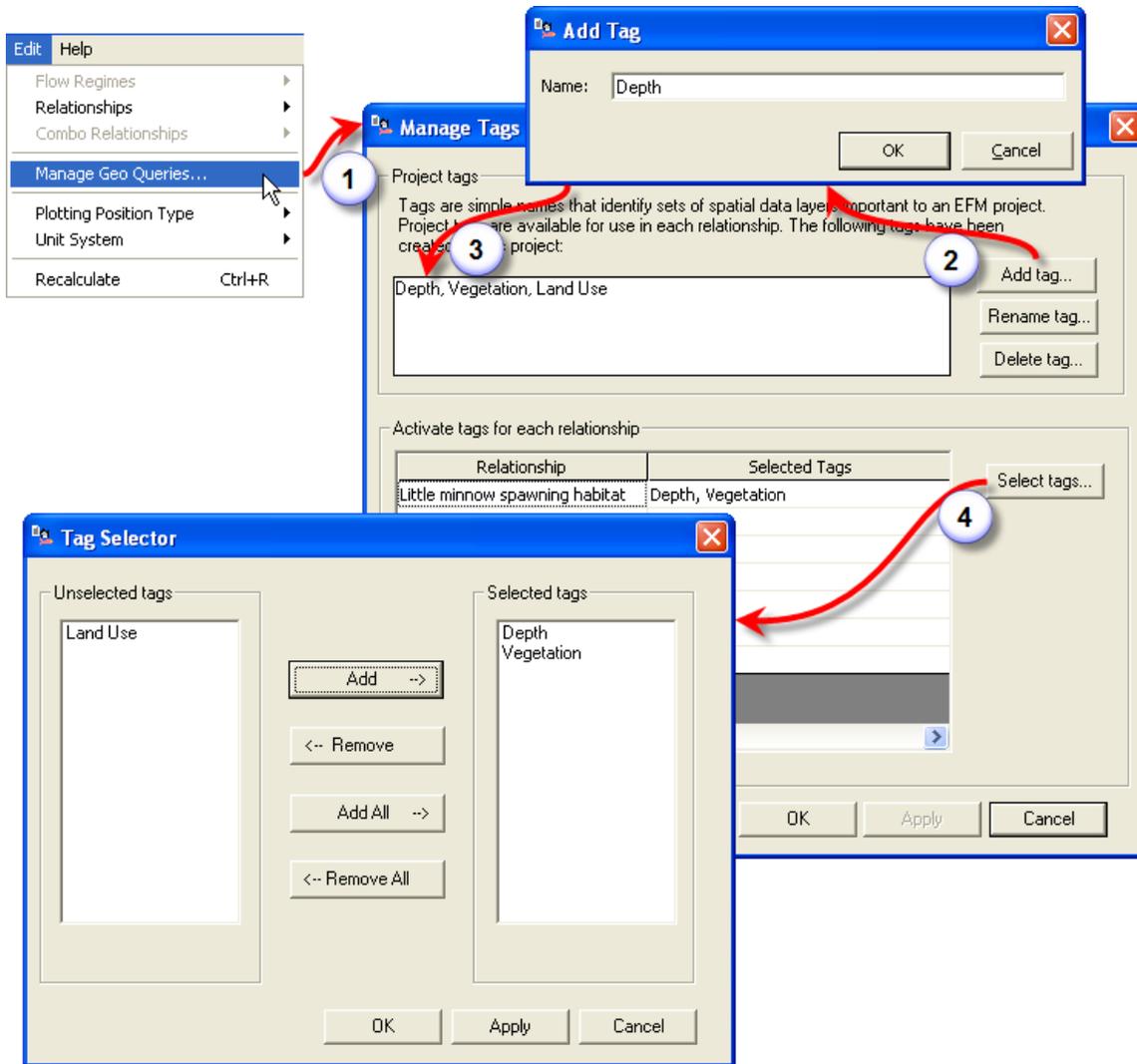


Figure 17. Adding geographical query tags.

appear on the *Relationships Tab*. Enter a description for each of the Little Minnow tags. For Depth, enter "Shallow habitat 0- to 3-ft". For vegetation, enter "Requires presence of aquatic plants" (Figure 18).

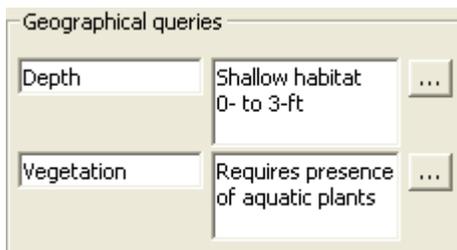


Figure 18. Geographical queries for the Little minnow spawning habitat relationship.

- Repeat steps 1 through 5 for the other relationships (Big bass winter habitat, Benthic macroinvertebrate biodiversity, Wetland health, and Riparian tree recruitment and inundation).

- Turn on *Confidence tracking* for the relationships (Figure 19). For now, leave all relationships at one star.

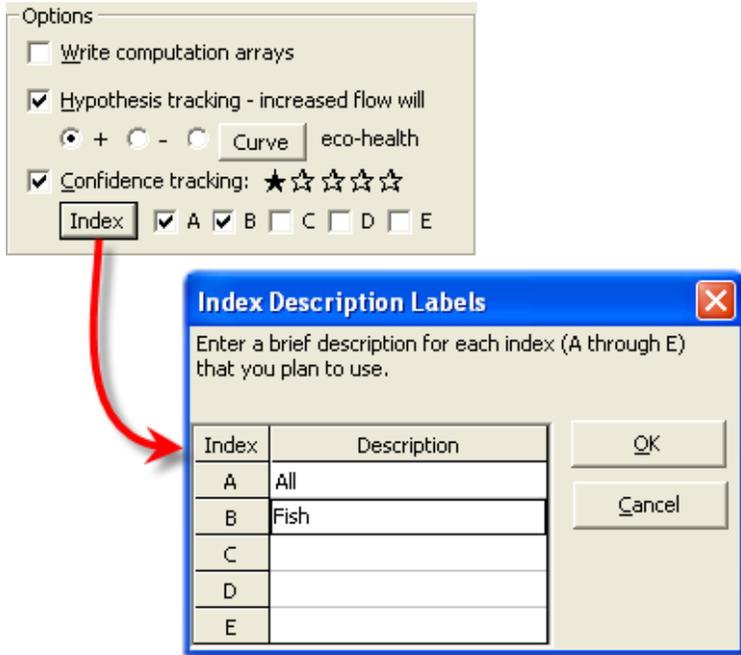


Figure 19. Confidence tracking and indices.

- Next, create indices by clicking the *Index* button in the *Options* frame (Figure 19). The *Index Description Labels* interface will open. Enter "All" for index A and "Fish" for Index B. Associate each relationship with the appropriate indices by checking box A for each of the relationships and also checking box B for Little minnow and Big bass relationships.
- Your project should now have 2 flow regimes, 6 relationships, and 2 indices. Use the "*File – Save*" menu option to save your project and then click the *Recalc* button to compute results.

3.2.3 Results

Four of the six relationships show a positive change for the Gaged flow regime (Figure 20). Riparian tree inundation and Benthic biodiversity show a negative change. Benthic biodiversity had the most significant change in terms of difference in flow results.

Summary						
Relationship	Conf.	Natural		Chg.	Gaged	
		Stage, ft	Flow, cfs		Stage, ft	Flow, cfs
Little minnow spawning habitat	*	4275.2	1,226	Pos	4275.7	1,703
Big bass winter habitat	*	4274.1	525	Pos	4274.3	609
Benthic macroinvertebrate biodiversity	*	4279.4	6,620	Neg	4277.2	3,190
Wetland health	*	4274.3	636	Pos	4274.5	771
Riparian tree recruitment	*	4274.9	1,017	Pos	4275.1	1,129
Riparian tree inundation	*	4273.7	373	Neg	4274.3	609

Figure 20. Summary of HEC-EFM results.

The index values show a negative response (Neg) for all relationships and a positive response (Pos) for the fish (Figure 21). A positive value suggests that the positive changes outweigh the negatives for the relationships in the index.

Index Values

Index	Gaged
A - All	-4.7
B - Fish	27.4
C -	n/a
D -	n/a
E -	n/a

Figure 21. Index values for “All” relationships and only the relationships that are related to "Fish".

The Rolling River has been a popular study area for wetland research. This has led to numerous peer reviewed studies and an abundance of field data. As these studies support the approach used to define Wetland health, change confidence for that relationship to five stars (Figure 22). Leave all others at 1 star.



Figure 22. Confidence tracking increase for the Wetland health relationship.

Click the *Recalc* button. Note that the index value for all relationships goes from negative to positive (Figure 23). Indices are best used as screening tools. Lumping multiple, and pseudo-independent, relationships into one numeric index is an approach to be used with caution.

Index Values

Index	Gaged
A - All	9.5
B - Fish	27.4
C -	n/a
D -	n/a
E -	n/a

Figure 23. Index values after a confidence tracking increase for the Wetland health relationship.

Let’s also look at Wetland health with a *Reverse lookup* query. To do this, use the "Edit – Relationships – Duplicate..." menu option to open the *Duplicate Relationship* interface. In the *Name* text box, enter Wetland health reverse lookup and click *OK* (Figure 24).

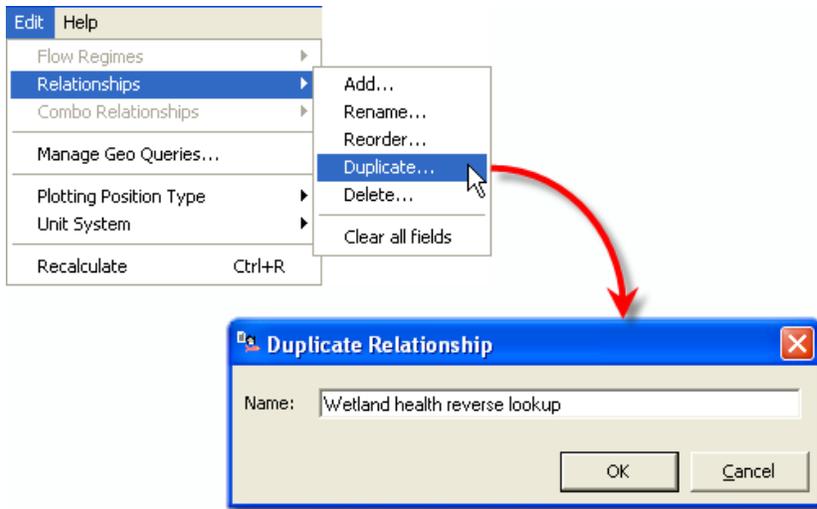


Figure 24. Duplicating a relationship.

Turn on the *Reverse lookup* query by checking its box in the *Other queries* frame. Enter 600-cfs in the text box (Figure 25). Notice that the % exceedance is now grayed out. This is because reverse lookups do not compute a flow based on % exceedance, instead the user specifies a flow and HEC-EFM computes the % of years or % of time that flow is equaled or exceeded. *Note: Non-standard queries (e.g., reverse lookups) cannot be included in the indices.*

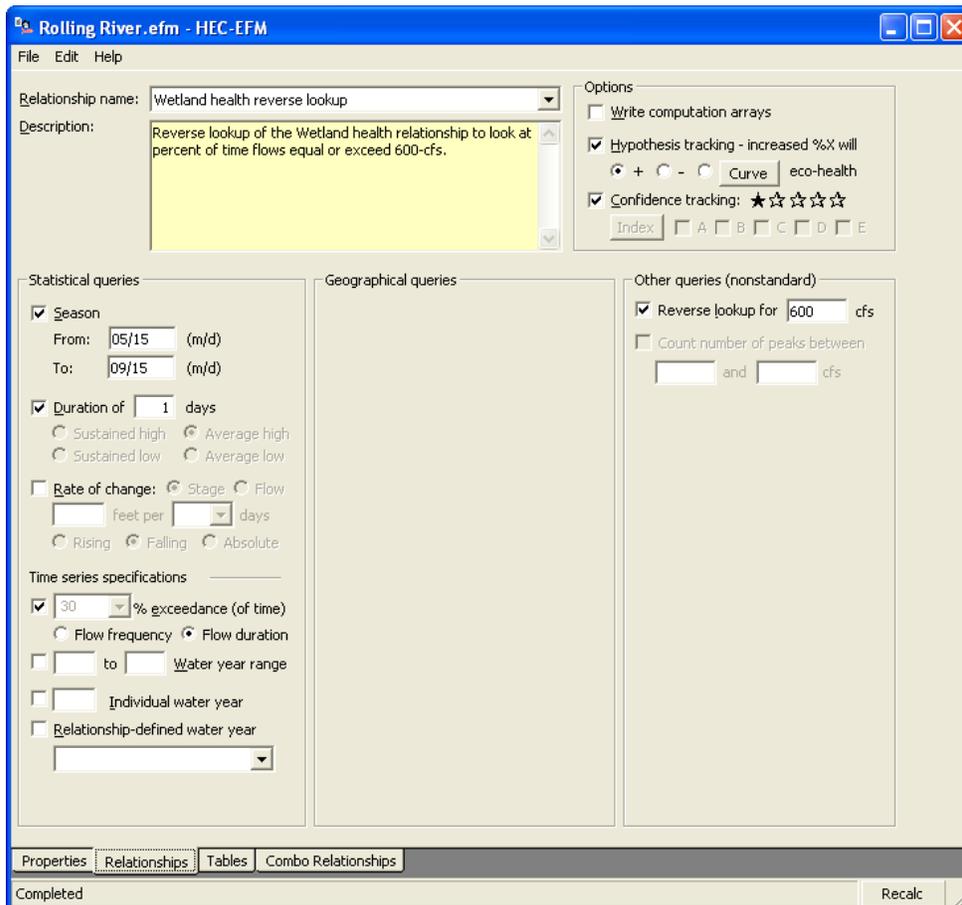


Figure 25. Reverse lookup of the Wetland health relationship in HEC-EFM.

Results for Wetland health reverse lookup show that both flow regimes were above the 30% criteria (Figure 26). Results for the Gaged flow regime (67.1%) nearly doubled the 34.1% of time Natural flows in Rolling River equaled or exceeded 600-cfs.

Reverse Look-ups - Flow Duration

Relationship	Conf.	Natural	Gaged	
		% X, of time	Chg.	% X, of time
Wetland health reverse lookup *		34.1	Pos	67.1

Figure 26. Reverse lookup for Wetland health showing percent of time flows above 600-cfs.

3.2.4 HEC-EFM Output

In addition to the statistical results that are output to the *Tables Tab*, HEC-EFM also generates a project summary report and files of the computations it performs while generating the statistical results. To view the project summary report, use the "*File – Report*" menu option.

By default, computation files are not generated automatically by the software. This output option is selected individually for each relationship. To test this feature, go to the *Relationships Tab*, toggle to the Big bass winter habitat relationship, and check the box next to *Write computation arrays* in the *Options* frame (Figure 27). Click the *Recalc* button.



Figure 27. Checking *write computation arrays* box.

A folder named "Arrays" is automatically generated in the working directory to store output, which are generated in XML and DSS formats. The term XML stands for Extensible Markup Language. XML is a handy and widely-used format for archiving and viewing data. Separate XML files are generated for each combination of flow regime and relationship. Each of these files contains the computational steps, statistical results, and frequency curves produced by HEC-EFM. The XML arrays are organized such that the final results are located at the top of the file followed by each computational step in reverse order (Figure 28). Using the "*File – View Array File...*" menu option, select "Gaged_Big bass winter habitat.xml" and click *Open*.

The highlighted value is the statistical result. The table also contains seasonal results for each historical water year in the period of record. This type of information provides more details about the relationships and flow regimes than the statistical results reported on the *Tables Tab* and can be very valuable to HEC-EFM applications.

These same data are stored in a file named "arrays.dss" and are archived according to flow regime and relationship names. The "arrays.dss" file can be accessed using the program HEC-DSSVue, which is available via the HEC website (<http://www.hec.usace.army.mil/>). Figure 29 shows the catalog of data output to DSS for the Big bass winter habitat relationship, time series calculations done to compute seasonal results for the Natural flow regime, and frequency curves of seasonal results for Natural and Gaged flow regimes with the 50% exceedance values selected as the statistical results.

Gaged, Big bass winter habitat

Computations made: 1/22/2008 2:18:30 PM, Rolling River.efm
 Result: Flow = 608.5, Stage = 4,274.273, Closest water year = 1969
 Eco-value = 6.1

Frequency analysis

Plotting position: Weibull

Rank	Frequency	WY	Flow	Stage
1	.0196	1975	868.0	4,274.652
2	.0392	1973	867.9	4,274.688
3	.0588	1984	807.6	4,274.592
4	.0784	1978	776.6	4,274.542
5	.0980	1980	763.6	4,274.522
6	.1177	1977	760.9	4,274.518
7	.1373	1976	745.4	4,274.493
8	.1569	1983	742.4	4,274.488
9	.1765	1998	735.9	4,274.478
10	.1961	1972	705.9	4,274.430
11	.2157	1990	693.3	4,274.406
12	.2353	1964	692.1	4,274.407
13	.2549	1965	683.9	4,274.394
14	.2745	1966	675.1	4,274.380
15	.2941	1958	668.4	4,274.370
16	.3137	1991	666.5	4,274.365
17	.3333	1954	657.3	4,274.352
18	.3529	1979	650.8	4,274.341
19	.3726	1993	650.1	4,274.333
20	.3922	1960	642.6	4,274.328
21	.4118	1974	638.6	4,274.322
22	.4314	1970	637.6	4,274.320
23	.4510	1971	632.2	4,274.312
24	.4706	1968	624.3	4,274.299
25	.4902	1969	612.6	4,274.280
	.5000		608.5	4,274.273
26	.5098	1967	604.5	4,274.267
27	.5294	1982	588.8	4,274.242

This is the statistical result for the Big bass winter habitat relationship and Gaged flow regime. A statistical result is the pair of flow and stage that meet the statistical criteria used to define the relationship.

Figure 28. Excerpt from the XML output file for Big bass winter habitat and the Gaged flow regime.

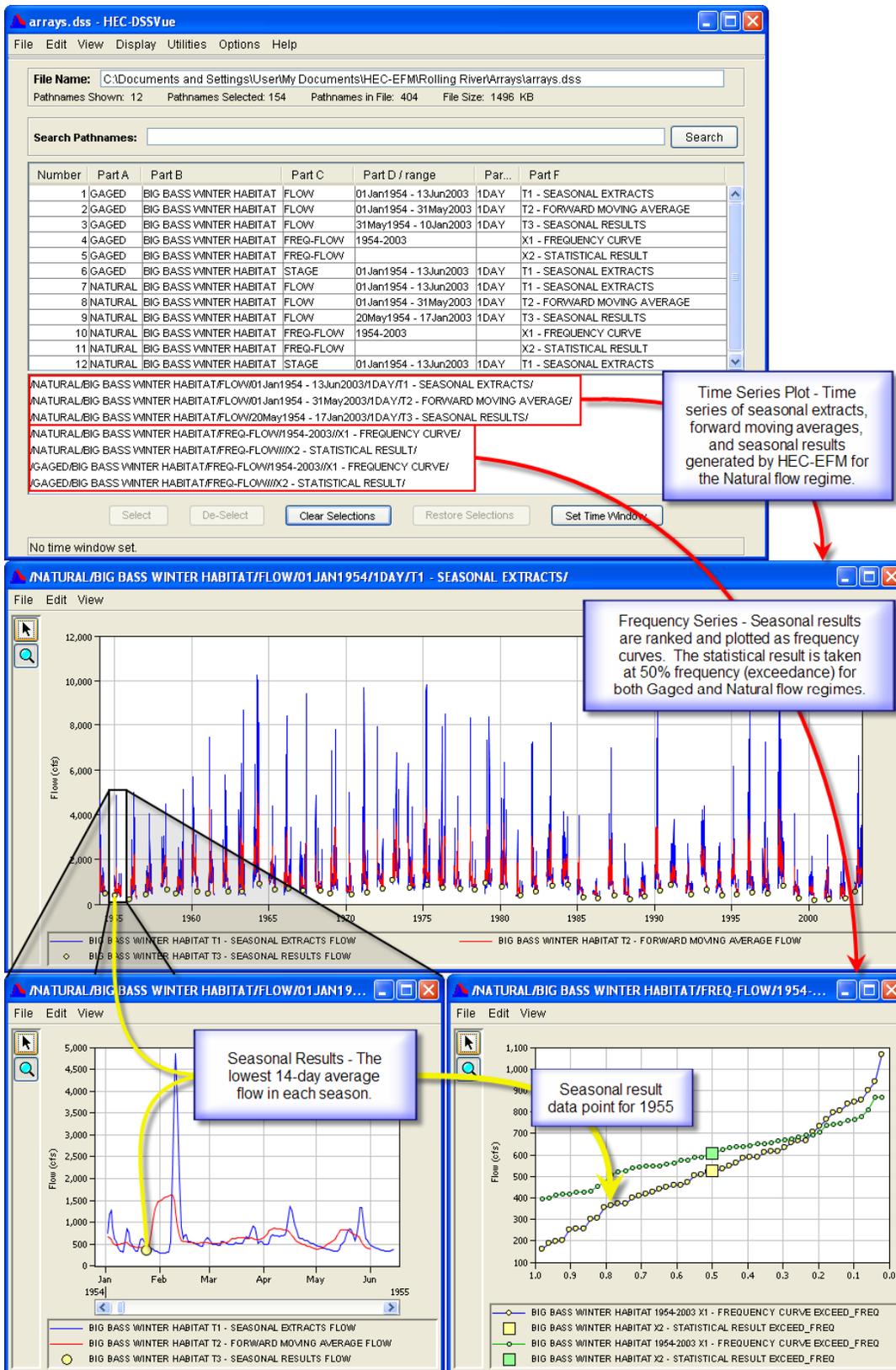


Figure 29. Catalog of HEC-EFM data output to DSS for the Big bass winter habitat relationship. Seasonal results for the Natural flow regime as well as a frequency curve of seasonal results for Natural and Gaged flow regimes are shown.

3.3 Hydraulic Analysis

Spatial analysis of HEC-EFM results can be done using water surface profiles and grids of depth and velocity produced by a geo-referenced hydraulic model. Past applications of HEC-EFM have used HEC-RAS and HEC-GeoRAS, which can be found on HEC's website <http://www.hec.usace.army.mil/>. Documentation on the use of HEC-RAS and HEC-GeoRAS can also be found at the website.

3.3.1 HEC-RAS

The HEC-RAS software is used to simulate one-dimensional steady-flow, unsteady flow, sediment transport, and water temperature (Figure 30). Water surface profiles can be exported to GIS for spatial analysis.

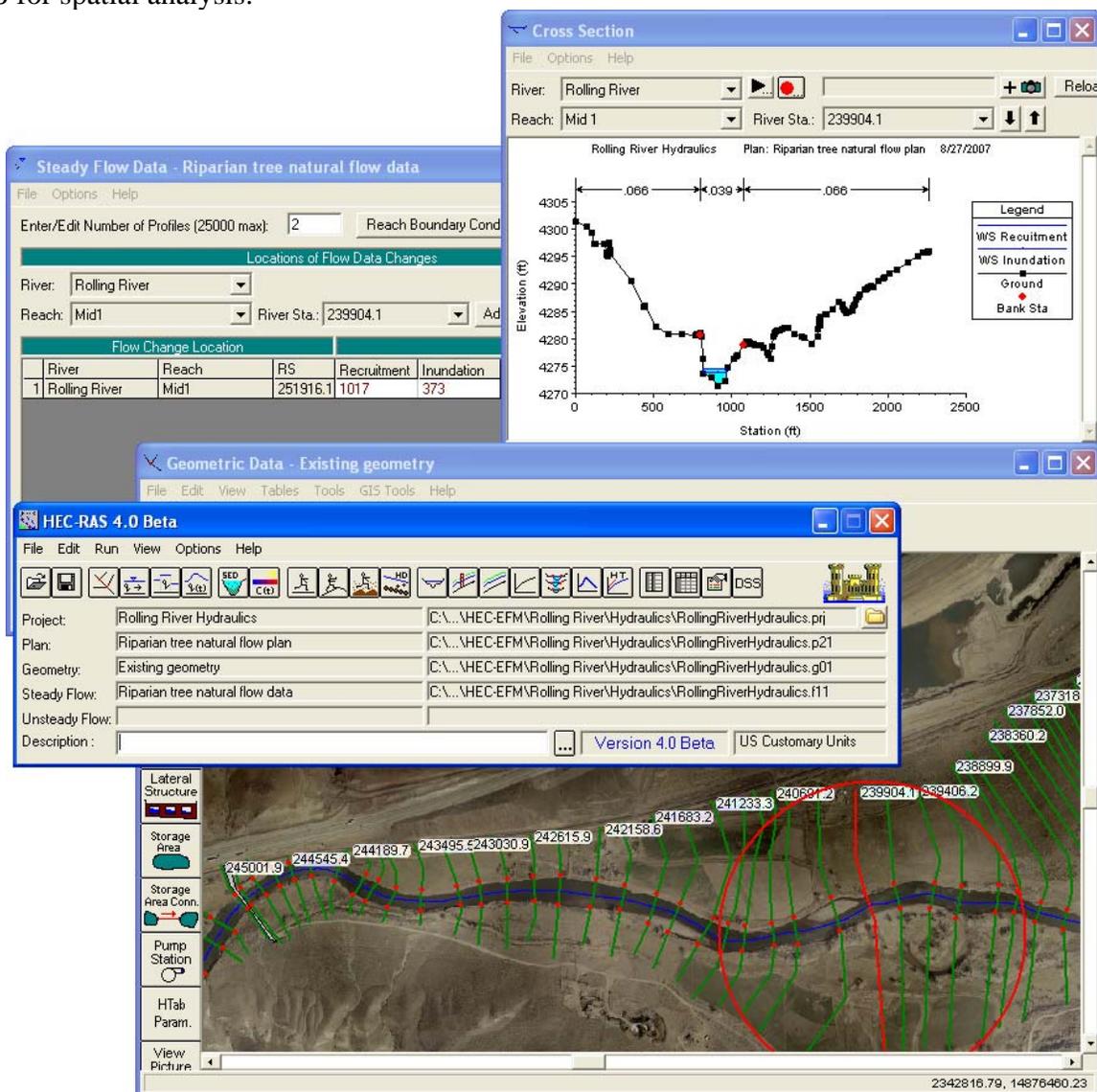


Figure 30. Example of HEC-RAS used to create water surface profiles for HEC-EFM statistical results (Riparian tree recruitment and inundation relationships using the Natural flow regime.)

3.3.2 HEC-GeoRAS

HEC-GeoRAS is a set of procedures, tools, and utilities for pre and post-processing geospatial data in ArcGIS® (Figure 31). With HEC-GeoRAS, water surface profile data exported to GIS can be used with a digital terrain model to calculate depth grids, velocity grids, and floodplain boundary polygons.

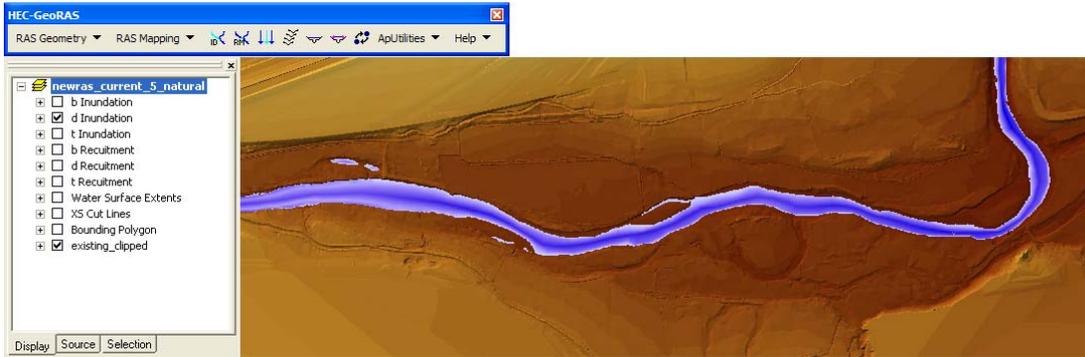


Figure 31. Example of a depth grid computed in HEC-GeoRAS using the water surface profile simulated by HEC-RAS for the statistical results of Riparian tree inundation from HEC-EFM.

3.4 HEC-EFM Analyses with GIS

Geographic information systems are technologies used to store, manage, edit, analyze, and display data that are spatially referenced to the earth. Using GIS in an application of HEC-EFM allows users to analyze data layers produced by HEC-GeoRAS as well as any external data sets that have ecological significance. The following sequence of figures is an example of how GIS can be used to investigate ecosystem response spatially. Results are shown for Riparian tree establishment dynamics in the Natural flow regime. Depth grids were initially created for recruitment (Figure 32) and inundation (Figure 33). The inundation layer was then placed on top of the recruitment layer (Figure 34).



Figure 32. Depth grid created for Riparian tree recruitment. The green area shows where stage recession creates suitable conditions for seedlings to begin to grow.



Figure 33. Depth grid created for Riparian tree inundation. This blue area shows where any new seedlings will be drowned by prolonged inundation.

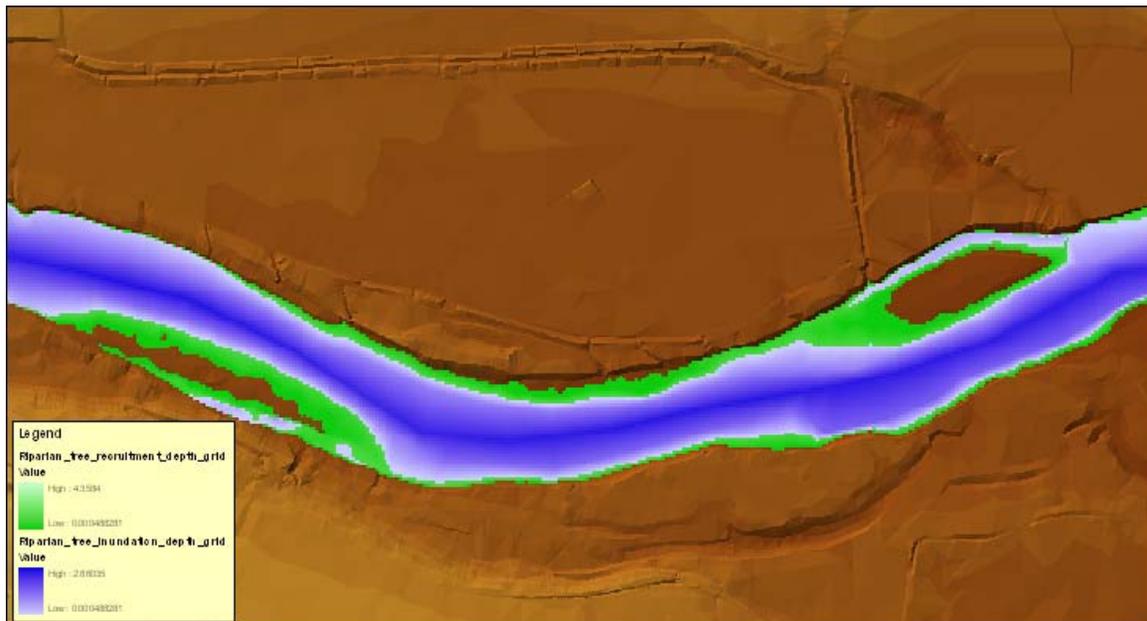


Figure 34. Overlay of Riparian tree recruitment and Riparian tree inundation depth grids.

In accordance with the combo relationship for Riparian tree establishment (Figure 6), the inundation depth grid was clipped from the recruitment depth grid. The resulting layer shows the area where HEC-EFM predicts Riparian tree establishment (Figure 35).



Figure 35. Depth grid created by clipping the inundation depth grid from the recruitment depth grid. The resulting area shows where HEC-EFM predicts Riparian tree establishment.

Information for the Riparian tree inundation relationship mentioned that seedlings were more likely to survive if sustained inundation did not exceed 0.5-ft. Figure 36 shows the area of Riparian tree inundation less than or equal to 0.5-ft. The Riparian tree inundation fringe area can be layered with the clipped layer (Figure 35) to create a new view of predicted and possible (due to the shallow depths) Riparian tree establishment areas (Figure 37).



Figure 36. The yellow fringe shows areas of the Riparian tree inundation depth grid that are less than or equal to 0.5-ft, which may not be deep enough to drown new seedlings.

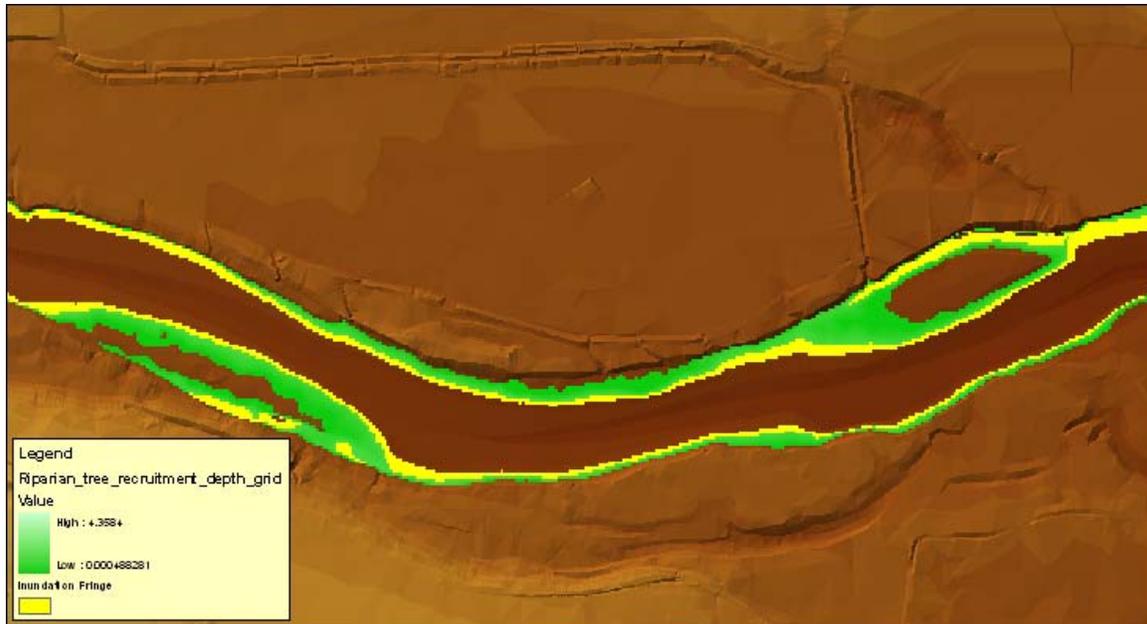


Figure 37. Potential recruitment sites for the Rolling River's Natural flow regime as computed using statistical and geographical queries in HEC-EFM, water surface profiles computed by HEC-RAS, and depth grids produced by HEC-GeoRAS.

So far the demonstration project has focused on comparing flow regimes with different hydrologic scenarios (Natural vs. Gaged). HEC-EFM can also be used to look at changes in topography, which will change the stage time series without changing the flow. Figure 38 shows a comparison of the current topography and a planned restoration project that increases stream meander. The same flows (Natural) are used for each of the channel topographies.

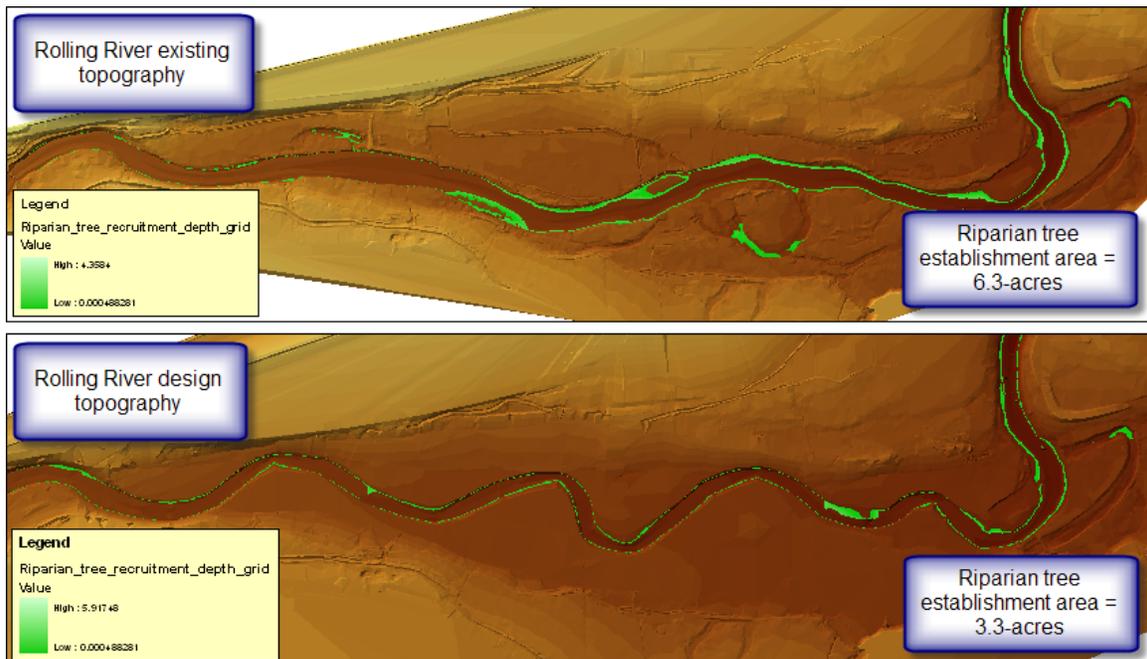


Figure 38. Comparison of Riparian tree establishment in existing and restored topographic conditions.

The following progression of tasks for the demonstration project has now been completed: 1) building relationships, 2) setting up an HEC-EFM project and computing statistical results, 3) simulating the statistical results with a hydraulic model, and 4) use of GIS to investigate ecosystem responses spatially.

Statistical results in HEC-EFM are computed as flows and stages, % exceedances, index values, and directions of ecosystem change. Spatial results are shown as combinations of map layers with each combination presenting a snapshot of an ecosystem dynamic. Layers are typically translated to areas for spatial comparisons of different flow regimes and channel topographies. Working with GIS allows use of other ecologically relevant data. For example, a soils map for Rolling River could be used to intersect the Riparian tree establishment layer (Figure 35) with the extent of suitable soils for riparian trees.

CHAPTER 4

Conclusions

This quick start guide is designed to demonstrate the process used to apply HEC-EFM and to highlight some features of the software. Everything covered in this document and all features active in the software have been tested extensively, but there is still the potential for undetected problems to surface. If a bug or suspect behavior is noted, please refer to HEC's website (www.hec.usace.army.mil/software/HEC-EFM/BugReporting/) for guidance on how to report bugs.

HEC-EFM is still a relatively young software tool. Several new features are being actively developed. Two exciting and ongoing efforts are the HEC-EFM Plotter and HEC-GeoEFM. The plotter is being developed as a tool to streamline access and viewing of output generated by HEC-EFM. Computation output (for both time series data and frequency-based data) will be picked up by the plotter and presented according to flow regime and relationship. Users will be able to quickly view and navigate data for different relationships and flow regimes.

HEC-GeoEFM is a partnered effort between HEC and Environmental Systems Research Institute, Inc. (ESRI) to develop a tool that manages the spatial data and results of HEC-EFM projects. It will also contain a package of features to help users perform the spatial calculations typically done in HEC-EFM studies.

Look for these and other new features in future versions of HEC-EFM.

CHAPTER 5

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