RiverWare Workspace Functional Analysis

Author: Kenny Gruchalla

1.0 Introduction

This document describes the functional analysis for the re-implementation of the RiverWare workspace. The impetus behind this work is the need to visualize RiverWare accounting networks. The current workspace architecture cannot support the visualization of RiverWare accounting networks. Furthermore, the RiverWare workspace lacks many modern GUI features that users have come to expect in a commercial software application. In effort to modernize the RiverWare workspace and provide support for new types of information visualization (i.e., the visualization of the account network), a redesign of the RiverWare workspace is being investigated.

The primary purpose of this document is to flesh out the high level requirements for the workspace that will be implemented during the accounting visualization work. The visualization of the accounting network will be a feature of the RiverWare workspace. The current workspace architecture cannot support the visualization of RiverWare accounting networks.The current workspace provides only a single static view of a model. Complex simulation models are already suffering from a data occlusion problems (see Figure 1). The addition of a visualization of the accounting structure will only exacerbate this problem. Each simulation object can contain many accounts, producing an exponential explosion of topological complexity. The visualization of the accounting network will have to be dynamic, allowing the user to control varying levels of detail to explore the accounting space. The visualization of the accounting network may have to be provided as an alternative view of a model. The current workspace will have to re-architected to support these features. The workspace forms the foundation upon which the accounting visualization will be implemented. Therefore, this document provides the functional analysis of that foundation. The functional analysis and requirements of the accounting visualization feature will be provided in a separate document.

The ultimate goal of the workspace re-architecture is to design for change. There are many different visualization and interactive features that are applicable to the RiverWare workspace. The visualization of the accounting network is just one example. RiverWare users have expressed interest in GIS features, animation features, and annotation features. The goal is to design a framework that is flexible enough to accommodate these and other advanced visualization features. This is in contrast to the current design that provides only a single static view of the model. Therefore, this document will attempt to identify a set of characteristic features that the workspace architecture should be capable of supporting.

2.0 Functional Analysis

This section provides an overview of the current RiverWare workspace functionality and describes many of the features that have been repeatedly requested by RiverWare users and sponsors, as well as, features that may useful in the future versions of RiverWare. This section does not exclusively list the requirements for the new RiverWare workspace. Instead, it attempts to provide an enumeration of functionality that may be applicable to the RiverWare workspace. The requirements for the workspace will be likely be a smaller subset of these functionalities. And the software design should provide the extensibility to support many of these functional items in the future, as funding allows. Each functional item has a “requirements recommendation” subsection. Each of these subsections discusses

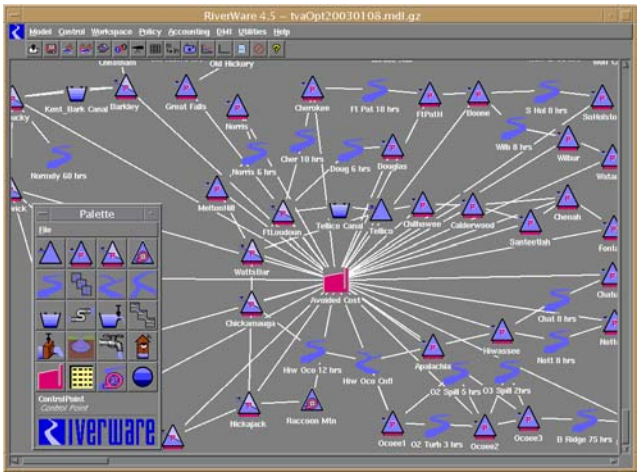

Figure 1: RiverWare Workspace.

whether or not the functional item should be adopted as a workspace requirement for the initial redesign to support the visualization of accounting networks.

The RiverWare workspace is the primary user interface and provides the primary view of the simulation space where models are built and modified. The workspace consists of main window, menu bar, tool bar, and icon view. The menu bar provides access to all user interface components of the RiverWare system. The toolbar provides shortcuts to many of these components. The icon view is a scrollable canvas that provides the primary interface to view and interact with the simulation objects, and the relationships (links) between objects. Each object represents a physical feature of the river basin and is represented by an icon on the workspace. A model is constructed by dragging object icons off of a palette and onto workspace, populating those objects with data, setting engineering methods on those objects, and linking objects together.

The workspace was implemented using the Galaxy GUI toolkit. Galaxy is antiquated toolkit and does not provide many GUI features available in most modern commercial applications. The workspace does provide the ability to scroll the icon view. However, there is no concept of panning, zooming, or resizing the icon area. The Galaxy implementation provides no tooltips, no status bar, and no context sensitive popup menus. Furthermore, Galaxy's parent company, Visix, declared bankruptcy in the late 1990s. Galaxy was purchased by another company, but development and support of the toolkit has basically ceased. As a result, Galaxy's user base is rapidly shrinking. CADSWES believes Galaxy is becoming a liability to RiverWare, as it is conceivable that in the near future Galaxy will not be supported for new operating system upgrades. In an attempt to be proactive, CADSWES is in the process of incrementally phasing out and removing Galaxy from Riverware.

Qt, a very sophisticated commercial GUI toolkit, was selected as the replacement for Galaxy. All new GUI work at CADSWES is being developed in Qt. Work being done to existing Galaxy GUI is evaluated to determine if the existing GUI should be ported to Qt. The decision is based on the level of effort and level of funding. When it is decided that an existing GUI should be rewritten in Qt, a redesign of the GUI is favored over a straight port of the functionality. The visualization of the accounting network represents new GUI work, and it will be implemented in Qt. As mentioned, this work will require a significant redesign to the existing GUI workspace. The existing workspace will be ported to Qt. This warranted for two reasons. In order to support a Qt implementation of the accounting visualization, the workspace foundation needs to be written in Qt. And second, the changes to the workspace will exceed the level of effort necessary to give grounds for a Qt port.

Commonly requested workspace features include:

- ## Zooming / Smaller icons

  Large models require views at various levels of detail. Multiscale viewing is a standard feature in many interactive applications. In RiverWare, the user should be able to zoom in and focus on a particular area of the model, but also be able to zoom out to understand the context of the detailed areas. Unfortunately, the relative size of the icons in the workspace is currently fixed. The users have no way of examining an area in more detail and are provided only a very crude overview of the model using the locator viewer.

  Level of Effort:

  With the introduction of Qt, providing a complete and robust zooming capability should be reasonably straight forward. There are two standard implementations that could be used for the new workspace. Qt provides a simple 2D canvas widget, QCanvas, that is capable of handling very large work areas. And Qt provides a QGLWidget, providing the ability to render OpenGL graphics. Either implementation would provide a standard mechanism to implement a zooming capability.

  Requirements Recommendation:

  Zooming is a standard and fundamental user interface and will be essential to support accounting visualization. Therefore, a rich zooming interface should be adapted as a requirement for the new workspace. The zooming functionality should include the ability to zoom-in on an area by selecting the area with a drag box. Predefined zoom level buttons, similar to the plot dialog, should also be provided.

- ## Configuration of workspace size

  The current workspace window is resizable, but the size of the underlying workspace “canvas” is fixed. This places an upper limit on the geographical size of a model. This is an arbitrary constraint that the current implementation places on the user. Clearly, the size of the underlying model canvas should be adjustable. Ideally, the size of the model canvas would dynamically adjust to the fit the size of the model. When objects are removed the size of the canvas would “shrink”. When objects were dragged outside the canvas area, the area would automatically resize to accommodate.

  Level of Effort:

  Given the capabilities of Qt, an adjustable model canvas should be relatively simple to implement. The difficulty of providing a dynamically resizable canvas is an open question, and it will largely depend on the actual implementation of the model canvas.

  Requirements Recommendation:

  The current fixed size of the workspace is an arbitrary constraint placed on RiverWare modelers. A resizable model canvas may not be strictly necessary for the accounting visualization. However, it is a low-level feature that will likely to difficult to implement after-the-fact. Therefore, a resizable model canvas should be adopted as a requirement.

- ## Context-sensitive popups

  Context-sensitive popup menus provide menu choices that vary subtly according to what functional area of the interface you are working in. Typically, a context-sensitive menu is created with a right mouse button click. These menus provide an alternate way of interacting with interface. For example, if a user were to

right mouse button click over a reservoir object they might be presented with the following choices: Open Object, Delete Object, Duplicate Object, etc.

Level of Effort:

The context-sensitive menus would not provide any new functionality, but a different mechanism to interact with the model. Qt already provides a framework to support these types of menus. Therefore, the only development necessary would be the development of the menus themselves. This would be a minimal effort.

Requirements Recommendation:

Context-sensitive popup menus are standard feature in most commercial applications. The workspace should support a rich set of these menus. This will greatly facilitate interacting with the accounting topology, and should be adopted as are requirement for the initial workspace rewrite.

- ## Links

  - **Hide links**

    Links are the connections between objects that pass information between objects during a simulation. A link is represented on the workspace by straight line that connects two objects. Currently, all links are shown. There is no mechanism to hide links. As a consequence, some models suffer from occlusions problems when there are multiple links per object. The ability to hide individual links, classes or groups of links is a often requested feature.

    Level of Effort:

    There is nothing inherently difficult about hiding links. Although, more analysis is need to determine how links might be classified.

    Requirements Recommendation:

    The ability to hide links would improve data occlusion problems in many simulation models and will likely be more pivotal for effective accounting visualization. Therefore, some level of control of link visibility should probably be adopted as a requirement, but more investigation is needed. The specifics of the how links are classified and hidden will be presented in the accounting visualization requirements specification.

  - **Stylize Links**

    In the current implementation, all links are displayed identically; although, links propagate values to different slots and different slot types. The ability to stylize or visually customize links would provide a much richer information space.

    Level of Effort:

    There is nothing inherently difficult about stylizing links. Although, more analysis is need to determine how links might be classified.

    Requirements Recommendation:

    The ability to stylize inks would also improve data occlusion problems in many simulation models and will likely be more pivotal for effective accounting visualization. Therefore, some level of control of link style should probably be adopted as a requirement, but more investigation is needed. The specifics

of the how links are classified and hidden will be presented in the accounting visualization requirements specification.

- ## Visualization of Subbasins

  Users can group simulation objects into named subbasins. Subbasins are typically defined to represent connected parts of a basin network. Currently, the objects contained in a subbasin can only be viewed in table form. This has several limitations. For example, it is difficult to determine if a subbasin is contiguous. Users have made requests that the workspace provide visual indication of subbasin membership.

  Level of Effort:

  Several visualization strategies exist for showing aggregate containment. However, it is difficult to determine which strategies might be applicable to the visualization of RiverWare subbasin. More research into the various visualization techniques is needed. The level of effort could be substantial.

  Requirements Recommendation:

  The visualization of subbasin does not appear to be a critical feature for the understanding of accounting networks. Therefore, this should not be adopted as requirement for the initial workspace redesign.

- ## Map/GIS displays

  The simulation objects are typically associated with a physical geographical body (e.g., a reservoir). A natural extension to the workspace would be to geo-locate the simulation objects on a map display. This would likely provide better conceptual association between the model and the physical system for both stakeholders and modelers.

  The Hydrologic Engineering Center's Reservoir System Simulation system, HEC-ResSim, is an example of simulation system similar to RiverWare that is capable of integrating GIS map display into the model. HEC-ResSim is capable of displaying: ArcView Shapefile, AutoCAD DXF, raster images (gif, jpg), USGS Digital Line Graph (DLG), and Digital Elevation Models (USGS, ArcInfo). However, it acts only as a GIS viewer, it does provide the ability to create any of these formats. The concept would be the same for RiverWare. Maps would be built in external GIS applications and then imported and viewed in RiverWare.

Several commercial and open source GIS APIs exist that could be used to facilitate this capability (e.g., Shapelib and OGR). The ability to view and display ArcView shapefiles is the GIS feature most commonly requested by RiverWare users. The Shapefile (.shp) is the spatial data format developed by ERSI for Arc/Info. ERSI is widely accepted as the market leader in GIS. As a consequence, most GIS packages recognize ERSI shapefiles. Shapefiles store nontopological geometry and attribute information for spatial features in a dataset and represent point, line, and area features. The ability to display shapefiles would provide RiverWare users a rich set of maps (see Figures 2, 3 and 4 for three representative examples). The DLG and DXF formats would provide similar functionality; although, they are not as widely recognized. Digital elevation models (DEM) provide a diffent type of information. DEM files contain an array of ground elevations at regularly spaced intervals. This data can be presented as a two-dimensional image (see Figure 5) or a three-dimenisional image (see Figure 6) of terrain. Finally, raster images (e.g., gif, and jpeg) can be used to display any two-dimensional imagry information. For example, raster images could be used to display satellite or radar imagry. Raster images might also be used for non-geographic imagry (i.e., a photo of a dam).

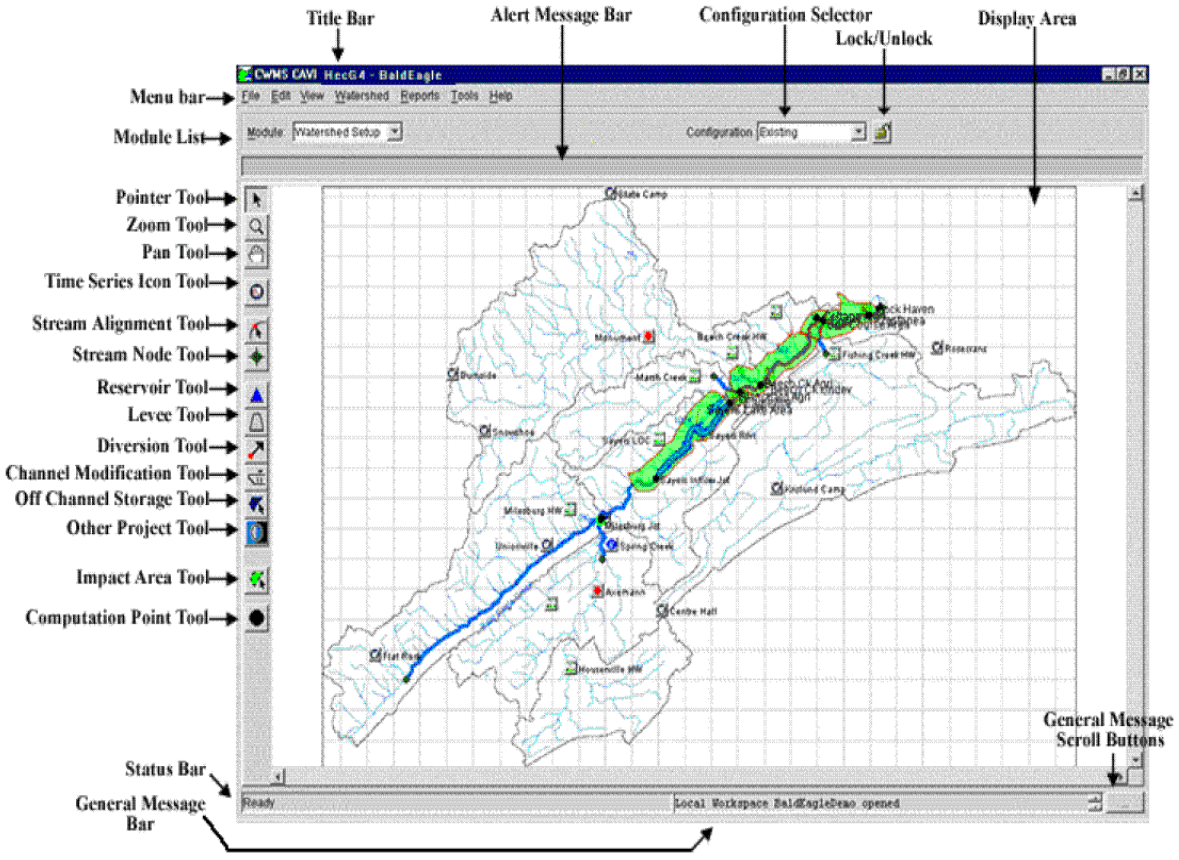

Figure 2: Snapshot of the HEC-ResSim interface. HEC-ResSim is modeling system similar to RiverWare that was developed by the Corps of Engineers. HEC-ResSim is capable of displaying GIS maps integrated with its models. In general, the user interface of HEC-ResSim is a good reference for the redesign of the RiverWare workspace.

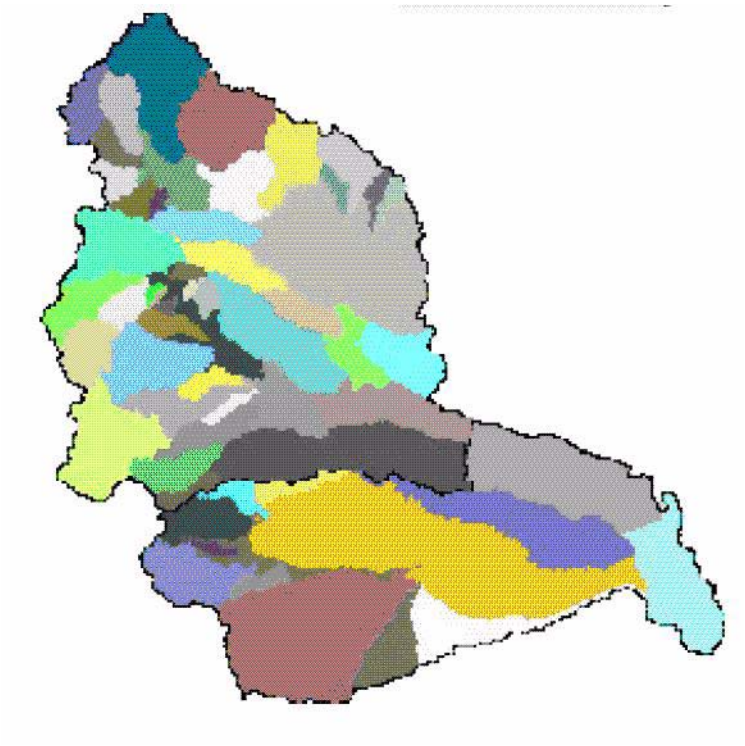

Figure 3: Shapefile delineating the location of 59 Yakima River Basins

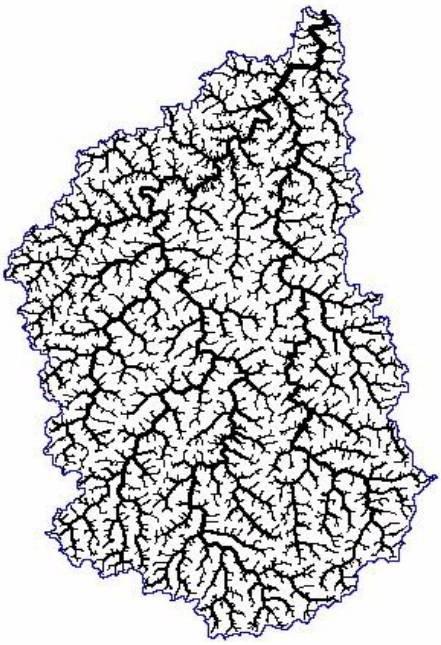

Figure 4: Shapefile depicting the drainage of a basin.

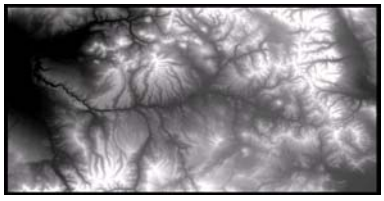

Figure 5: 2D representation of DEM data

Figure 6: 3D representation of DEM data

Level of Effort:

The integration of GIS visualization and interaction capabilities into RiverWare will be a substantial effort that will require dedicated funding. At a minimum, the concept of a geographic coordinate system and geographic projection would need to be added to RiverWare.

Requirements Recommendation:

There is no inherent need to support geographic maps for the visualization of accounting networks. Therefore, GIS capabilities should not be added to the workspace at this time. However, the workspace should be flexible enough to support GIS in the future.

- ## Printing

RiverWare does not currently support printing of the workspace, despite repeated requests for printing support for both printers and large scale plotters. The print feature should be capable of printing a selected region, the current view of the model, or the entire model canvas.

Level of Effort:

Qt does provide a mechanism to print widgets. We've have had success implementing a printing interface for both the SCT and the Plot Dialog. Our experience suggests that each dialog presents its own printing challenges. Printing was one of the more difficult aspects of both the SCT and Plot Dialog developments. The level of effort is therefore assumed to be reasonably difficult. Qt does provide a interface that should allow us to print to any device (i.e., large scale plotter); however, without the hardware this will be impossible to test.

Requirements Recommendation:

Printing is fundamental feature that users expect to find in commerical applications. It is essential that RiverWare provide a rich set mechanisms for the modelers to share the models with each other and with stakeholders. This is true of both simulation and accounting networks. Therefore, printing should be supported in the initial workspace redesign.

- ## Image Export

RiverWare does not currently support any image export of the workspace. The only way to generate an image of a RiverWare model for use in a document is through a third party screen capture utility. The ability to export an image of the workspace is essential for users who wish to document their models.

The image export feature should be capable of exporting a selected region, the current view of the model, or the entire model canvas. Standard (open) graphics image formats should be supported including: PNG, BMP, JPG, PMB, PGM, PPM, XMP, XBM.

Level of Effort:

Qt provides a sophisticated means to export images. However, there will likely be some challenges involved with attempting to capture non-visible regions of the model canvas. Image export will require a very substantial effort; however, a large amount of the effort will be shared with printing requirement.

Requirements Recommendation:

Image export and printing are related in both need and implementation. Image export will be one of the primary mechanisms for modelers to communicate with policy makers and stakeholders. Image export should be supported in the initial workspace redesign.

- ## Accounting Visualization

  RiverWare supports two parallel representations of water: *physical water* and *paper water.* The physical water is modeled in the simulation objects, and the network of the physical water is displayed on the workspace through simulation object icons and links. The paper water represents water types and ownership and is modeled in the accounting network. RiverWare does not provide any visualization of this accounting network. Currently, the only mechanism to explore the accounting network is through large tables provided on various accounting dialogs.

  The workspace should provide a view of the accounting network. This view maybe independent of the view of the simulation network. This view should depict the accounts and supplies that connect the accounts. Furthermore, the view should be capable of distiguishing account types, supply types, water owners, and water types.

  The accounting networks are typically more topologically complex than the physical water networks, since each simulation object can contain many accounts. This can lead to an exponential explosion of topological complexity of the accounting network. Therefore, the visualization of the accounting network will have to be dynamic, allowing the user to control varying levels of detail to explore the accounting space.

  Level of Effort:

  The level of effort will be described in detail in the accounting visualization requirements and design documents.

  Requirements Recommendation:

  Requirements and design documents that specifically describe the accounting visualization feature of the workspace will follow.

- ## Animation

  At the 2004 RiverWare user group meeting, Brad Vickers demonstrated a short mpeg movie that animated water flows through a river basin (Note: need to contact Brad for specific information). Flows were represented as bar graphs using a three-dimensional perspective (see Figure 7). This type of visualizatoin was introduced as means to provide a user with a more global view of the model's dynamics.

  Level of Effort:

  Adding an animation view to riverware would be a sizable effort.

  Requirements Recommendation:

  Although his type of animation capability would certainly be applicable to accounting, this is likely outside of the scope of the accounting visualzation work. However, the design should be capable of supporting an animation capability in future revisions.

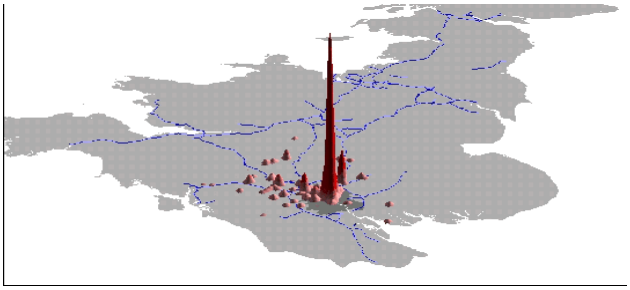

Figure 7: A perspective bar graph could be used to represent slot values in a global animation view of RiverWare.

- ### Annotation

  At the 2004 RiverWare user group meeting, attendees indicated that it would be helpful to have the capability to directly annotate a riverware model. The annontation capabilities would be provided through a simple palette -- text, lines, arrows, hand-drawn lines. This would provide very simple mechanism for modelers to document a model, communicate ideas with each other and stakeholders. This would likely be represent as a transparent drawing canvas (or layer) that could be toggled on or off.

  Level of Effort:

  The development of the annotation interface would be reasonably simple. However, how to efficiently load and save the annotated information with the model will require some investigation.

  Requirements Recommendation:

  Annotation capabilities would be just as applicable to accounting networks as they would be to the simulation networks. However, annotation is not strictly necessary. This feature should be listed as a “soft requirement” (i.e., only if funds/time allow). The design should definitely be flexible enough to support an annotation feature in the future.

- ### Menu, Tool, and Status Bars

  The current menu bar will be a direct port, migrating all current functionality. The port of the current tool bar will maintain all the current functionality. Although, the presentation may change slightly, and tool tips will be added. A status bar, a new feature, will be added to the RiverWare workspace.

  Level of Effort:

  The port of menu and tool bar present no technical challenges.

  Requirements Recommendation:

  In order to provide existing functionality, this work must be done.

3.0 High Level Design Considerations

The functional analysis has exposed the need for two new concepts in the RiverWare workspace: a data layer and a data view.

Data layers are like transparencies that can be laid one on top of the other and interactively enabled or disabled. The annotation feature is a good example that demostrates the need for the design to support these layers. The annotation feature would provide transparent canvas that a user could make notes on. The GIS feature is another good example, where each map in the GIS display could be captured in a separate layer. Another possiblity is representing the workspace links in seperate layers to provide varying levels of detail. HEC-ResSim supports the idea of hierarchical layers. This would be applicable feature for RiverWare, allowing us to enable/disable entire groups of layers (i.e., the GIS layers).

A data view is a high level entity. Any particular view might consist of multiple layers. A view would provide a unique way to display some aspect of the model on the workspace. For example, the animation feature might visualize the workspace in a three-dimensional perspective view. This is a completely different view than say the typical two-dimensional plan view currently used by RiverWare. That is, the two views are fundamentally different and cannot occupy the same space simultaneously. The accounting visualization might also be another view of the model, or it may just be a layer that can be placed on top of the simulation network. At any rate, the functional analysis indicates that the workspace should support multiple views, providing a framework to visualize the model in radically different ways.

3.1 Colormap Issues

The current version of RiverWare is based on a 8-bit colormap. This means that RiverWare is restricted to 2^8 (256) colors. Furthermore, RiverWare must share these 256 colors with all other running applications. That is only 256 colors can be displayed simultaneously. If an application uses attempts to allocate colors that are not available in the current colormap, a virtual colormap will be installed. This swaps out the colormap in the graphics hardware with a colormap stored in memory. This is what causes the psychodelic flicker that is occassionally experienced when moving focus from one application to another.

All modern graphics cards support 24-bit color (16 million colors). All Windows machines support 24-bit true color colormaps. Modern Solaris machines should also support 24-bit true color. The hardware capabilities of some of the older Solaris hardware is unknown. Although most (if not all) of our Solaris machines will support 24-bit color, all but one of our Solaris machines are configured for 8-bit color. RiverWare should continue to support 8-bit color, to support user with old hardware (e.g., very old Ultras), but the new workspace should be optimized to run on a 24-bit display. This will provide a much richer visual experience to users on modern hardware.

4.0 Research Issues

The animation functionality raises an interesting research issue: how can the multivariate time-series data associated with a RiverWare model be visualized to gain a better understanding of the global dynamics of the model. All of the other above requirements present infomation about the static topology of the model, not the dyamics of the model. Currently, the only way examine the model's dynamics is by examining individual slots. This makes it very difficult to understand the complex indirect relationships between objects in the model. Visualization of multivariate time-series data is an open research issue in the visualization community.

I have had a few brief conversations with Dr. Henry Tufo and Dr. Liz Bradley of the computer science department on this issue. There **maybe** the opportunity here to develop a novel method to visualize RiverWare's spatial multivariate time-series data. The research potential is clear; however, the difficultly of developing an effective method is still largely unknown. In the comming weeks, I hope to meet with some visualization experts at the NCAR laboratory who have been exploring simular issues.

5.0 References

K. Hornbeak, B. Bederson, C. Palisant. (2002). Navigation patterns and usability of zoomable user interfaces with and without an overview. ACM Transactions on Computer-Human Interaction (TOCHI). volume 9, issue 4, 362-389.

J. D. Klipsch. (2003). HEC-ResSim Reservoir System Simulation User's Manual. US Army Corps of Engineers Hydrologic Engineering Center.

K. C. Clarke. (1997). Getting Started with Geographic Information Systems. Prentice Hall

Watershed and River Systems Management Program: Application to the Yakima River Basin, Washington. USGS Fact Sheet 037-98

K. Gruchalla, B. Eyster. Galaxy Replacement Investigation. CADSWES White paper, July 2002. /projects/riverware/docs/guiRework/GalaxyReplacement.pdf

S. P. Meyer. Geospatial Enabling of WaRSMP: GIS Opportunities for RiverWare. /projects/riverware/docs/Geospatial Enabling of WaRSMP_a.ppt

ESRI Shapefile Technical Description. An ESRI White Paper. July 1998. Downloaded from: www.esri.com/library/whitepapers/pdfs/shapefile.pdf

MapTools.org http://www.maptools.org/

An Atlas of Cyberspaces http://www.cybergeography.org/atlas/geographic.html

W. Muller, H. Schumann. (2003). Visualization Methods for Time- dependent Data - an Overview. Proceedings of Winter Simulation'2003, New Orleans, USA.

T. T. Elvins, VisFiles: presentation techniques for time-series data, ACM SIGGRAPH Computer Graphics, v.31 n.2, p.14-16, May 1997