FINAL REPORT RWO 203

Analysis of Hydrologic Data for the White River Basin

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Introduction:

The value of the natural resources of the White River Basin (Basin), AR is recognized by the area's designation as a "Wetland of International Importance". The Basin constitutes one of the Nation's largest remaining intact forested wetland landscapes, second only to the Atchafalya Basin. It supports the North American continent's largest concentration of over-wintering mallard ducks, a world-class trout fishery, the last vestige of a big river fishery remaining in the Mississippi River Basin, and numerous threatened and endangered species. The continued viability of this wetland ecosystem depends on the suitability of the hydrologic environment to the resident flora and fauna. Numerous modifications of the Basin hydrologic features in the past century have seriously impaired the sustainability of these resources. The Basin-wide alterations of hydrologic processes (e.g., impoundment and regulatory releases of flows and volumes in the upper reaches, navigational modifications of lower reaches, and consumptive demands for agricultural use throughout) have affected the hydrology of the system profoundly. The result is highly regulated flows and stages, vastly altered hydrologic patterns, over-stabilized water levels, and disruption of seasonal water distribution patterns. Given the critical nature of hydrology in regulating the structure and function of wetland ecosystems, the impacts have been devastating, particularly to the critical bottomland hardwoods that support the Basin's fish and wildlife resources. To date these piece-meal, system-wide, hydrologic alterations have commutatively degraded the habitat value of this resource for fish and wildlife in the Basin, and have lead to changes in their numbers and distributions. In spite of the enormous stakes involved, there has been no comprehensive characterization of the Basin hydrology.

System alterations such as channel deepening, dam construction, water allocation plans, and flood control measures are currently pending. These projects will potentially further modify the hydrologic environments of the Basin, and no doubt require mitigation measures. In addition, there is genuine interest in restoring aspects of the Basin's historic hydrologic regime within some set of reasonable limits. In order to proceed with this effort, the anticipated effects of these modifications and restorations on the Basin ecology require thorough study of the area's historic hydrology, so that connectivity among Basin precipitation patterns, flow fluctuations, and land use changes can be made. A basin hydrologic characterization is an initial component of this effort. The focus of this effort was to determine and assemble the data set from which characterization of the hydrologic environments of the Basin using historic and recent water level, flow, (primarily by USGS-WRD) at locations throughout the Basin could proceed.

Data Management

Acquisition and Compilation of Data

The Compilation of hydrologic data for the White River Basin (Basin) was an ongoing process throughout the duration of this project. Available stage and discharge data for USGS stream gauges have been collected from varying source and compiled on the accompanying CD.

Discharge Data:

The USGS NWIS website allows for public access to a large amount of historic stream flow data. Available stream flow data for USGS stream gauges in the Basin has been downloaded and can be viewed in the accompanying data files.

Stage Data:

Although most of the historic stream flow data is online, the collection of historic stage data has presented a challenge in retrieval. A request was made during Fall 2000 to the Arkansas USGS office for all available stage data within the basin. A search by USGS revealed that nearly all historic stage data (pre 1970) are not in electronic format, and much of the hard copy data has been sent away to archives. They began the process of requesting and copying archived data, which was received at UF by Winter 2001. Stage data for the time period of 1974 – 1999 are archived electronically by the USGS and were downloaded via FTP (144.47.191.199).

Transcription of Selected Data:

Although most of the discharge data was already available in an electronic format and can be used in the IHA program, the decision was made to also include stage in the analysis. This decision was based on the reasoning that water levels may be a more appropriate measure of potential impacts to wetlands than flows. Since it was not practical to enter all the data into excel that was sent by the USGS, a select number were chosen for entry.

In order to select the most appropriate sites for entry which would best represent the entire watershed, the WRB was subdivided into it sub-basins. Available data was grouped by sub-basin. Within a sub-basin, each site was evaluated for data availability; i.e. sites were chosen based on which one had the longest period of record. If more than one site within a sub watershed was appropriate, than the choice was made based on placement within the watershed. Those sites farthest downstream were chosen, as they would yield a more inclusive representation of the sub-watershed hydrology.

Digital Elevation Model (DEM):

Digital topographic data was compiled (DEMs at 1:24,000, 30 m resolution) for use in future basin-wide hydrology models from http://www.gisdatadepot.com/dem/. These DEMs have not been assembled. Instead, DEMs at 1:250,000 were compiled and merged to create a DEM of the WRB from http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/states.html. In addition, GIS layers for counties, cities, roads, sub-basins, dams, and hydrography in the WRB were downloaded from http://nationalatlas.gov. In addition to these layers, a GIS layer for gauging stations was created, containing the latitude and longitude of each station, and a listing of what stage and discharge data is available and what format it is currently in (hard copy vs. electronic). This provides a quick and useful tool for assessing what data is available in the basin.

Compact Disc:

The accompanying CD contains copies of available data. All hydrologic data in electronic format is available and is separated by discharge, stage (recent and historic), and data used in hydrologic analysis. GIS data are available and are separated by GAP analysis, DEMs @ 1:24K unassembled (Arkansas and Missouri), DEMs @ 1:250K unassembled, and a DEM of White River Basin (DEM assembled) (Table 1). A copy of this report is also included on the CD.

Table 1: Contents of CD.

Folder	Contents
GIS Data	GAP Analysis, DEM @ 1:24K, DEM @ 1:250K
GIS Layers	GIS Layers for Representing White River Basin
Hydrologic Data	Stage Data (historic and recent), Discharge Data, IHA Data
Report	Final Report and supporting documents

In order to use the GIS layers provided, the ArcView 3.2 software package from ESRI is recommended. Owing to idiosyncrasies of this software and its file-management limitations, users should create their own projects and add the appropriate provided layers as desired.

Hydrologic Analysis:

Several modifications to the basin have occurred over the last fifty years (Table 2). In order to assess the impact of these changes, hydrologic data (discussed above) were compiled for use in an evaluation of changes in stage and flow within the WRB.

Nine USGS stream gauges were selected for use in this analysis, based on data availability and location (Table 3) (Figure 1). These stations represent a large portion of the watershed (Figure 2). Figure 2 shows the data from each station that were analyzed using trend analysis and the Indicators of Hydrologic Alterations (IHA) program.

Table 2: Dates of dam construction in the White River Basin

Impoundment	Date
Norfolk Lake	1943
Clearwater Lake	1948
Bull Shoals	1951
Table Rock	1956
Beaver Lake	1963
Greers Ferry Reservoir	1962

The IHA program, developed by The Nature Conservancy, is an easy to use tool to analyze changes in hydrologic regime characteristics over time. It allows the user to identify changes in the magnitude, timing, frequency, and duration of water flows and levels. According the Richter et al. (1996), IHA defines a series of biologically relevant attributes that characterize intra-annual variation in water conditions and then uses an analysis of the inter-annual variation of these attributes as the foundation for comparing hydrologic regimes before and after a system has been altered by human activities.

Table 3: USGS gauging stations used in IHA analysis.

Gauge Number	Gauge Name	Basin	Years of IHA Analysis	
7055000	White River Near Flippin, Ark.	Bull Shoals Lake	1951	1950
7060500	White River At Calico Rock, Ark.	Middle White	1943 & 1951	1950
7075000	Middle Fork Of Little Red Riv At Shirley, Ark.	Little Red		1962
7069000	Black River At Pocahontas, Ark.	Lower Black	1948	1950
7074500	White River At Newport, Ark.	Upper White-Village		1950
7077000	White River At Devalls Bluff, Ark.	Lower White-Bayou Des Arc		1950
7077800	White River At Clarendon, Ark.	Lower White		1950
7077380	Cache River At Egypt, Ark	Cache	Trend Analysis	1980
7069500	Spring River At Imboden, Ark.	Spring	Trend Analysis	1950
7072000	Elevenpoint River Nr Ravenden Springs, Ark.	Eleven Point	Trend Analysis	1950

Results:

The IHA program was run for both discharge and stage data. Since the magnitude of flows are so much greater than that of stage, changes in hydrologic regimes are easier to spot using results from flow analyses. Nevertheless, results for both flow and stage are summarized for each station in Appendix A (discharge data) and Appendix B (stage data). As a rule of thumb, changes causing a percent deviation of 30 or more were considered a significant alteration (Doug Shaw (TNC), personal communication, 2001).

USGS 07069000 BLACK RIVER AT POCAHONTAS, AR:

The Pocahontas gauging station is located on the lower Black River, downstream of the Clearwater Reservoir, which was built in 1948. An alteration date of 1950 was used in the IHA analysis of this station. Initial review of the flow data did not reveal any obvious alterations to flow. The IHA analysis did not show any significant changes in flows (Table 3). The only obvious alteration to stage was the average increase of two feet during the month of December.

USGS 07072000 ELEVENPOINT RIVER NR RAVENDEN SPRINGS, AR

The Ravendon Springs station, located on the Elevenpoint River, is not currently impacted by any of the dams mentioned above. Water from the Elevenpoint River eventually flows into the Black River, downstream of the Pocahontas gauging station. In order to illustrate that there have been relatively few changes in the hydrologic regime of this area, the IHA analysis was run with an arbitrary impact data of 1950. This date was chosen for consistency with other analyses. With the exception of a significant increase in November discharges, both the discharge and stage results show few significant changes.

USGS 07069500 SPRING RIVER AT IMBODEN, AR

The Spring River flows into the Black River downstream of the Elevenpoint River. Like Ravendon Springs, the Imboden gauging station is not affected by any of the dams within the basin, so for consistency, an arbitrary alteration date of 1950 was used again in the IHA analysis. Similar to the Elevenpoint River, an increase in winter runoff has been witnessed in the Spring River. Otherwise, very little has changed in the way of stage or discharge over the past 59 years.

USGS 07055000 WHITE RIVER NEAR FLIPPIN, AR:

The Flippin gauging station is located directly downstream of the Bulls Shoals reservoir, built in 1951. Of all the stations used for the IHA analysis, it is the farthest upstream on the White River. Review of the hydrograph for this station shows that the hydrologic regime of this station has been severely altered.

IHA analyses for discharge are summarized below:

- From late fall through spring, flows are held back by the dam by up to 55%, and then released during summer and early fall months, increasing by as much as 339%.
- Minimum flows have increased substantially, while maximum flow levels have been greatly reduced.
- The river is reaching low flow levels more often, but these periods are of a shorter duration than before dam construction.
- Both the number of times river reaches high magnitude flooding and the duration of those events has been drastically reduced.

Changes in stage were not as obvious as flow, but several were noted:

- Stages were lowered during the spring months, and raised during the summer months.
- Maximum stages were significantly reduced.
- The duration of both high and low stage events increased.

USGS 07060500 WHITE RIVER AT CALICO ROCK, AR:

Since Calico Rock is located downstream of the Norfolk, Bulls Shoals, Table Rock, and Beaver reservoirs, a date of 1950 was chosen as an average alteration date for the IHA method. One obvious change in flow patterns evident from the hydrograph is the reduction of all high magnitude floods after 1950. Before 1950, flows in excess 10,000 cfs were seen in eleven out of seventeen years. From the period of 1950 to 2000, these floods occurred only twice.

Results for the flow analysis show several alterations:

- The dams are holding back normal spring runoff, which is then released during the summer months.
- Minimum flows have increased from 44.3 to 144%, while maximum flows have been substantially reduced.
- The duration of minimum and maximum flows have been reduced by more than 60%.
- Dams have increased the stability of water levels within the river.

Analysis of stage data shows similar trends:

- Stages are considerably higher during summer months.
- Minimum stages have increased anywhere from 1 to 2 feet, while maximum stages have been reduced by levels ranging from 0.1 to 8.7 feet.
- The duration of extreme conditions has been shortened.

USGS 07074500 WHITE RIVER AT NEWPORT, AR:

The Newport gauging station is located at the confluence of the White River and the Black River. A date of 1950 was used for the IHA analysis. Although they changes in flow are not as extreme as Calico Rock, several changes were noted:

- August and September flows are higher than normal.
- The magnitude of extreme minimums (7, 30, and 90 day) is slightly higher than before alterations. Maximum flows have been decreased.
- The frequency of low flow events has been increased, but the duration of those events is shorter. Both the frequency and duration of maximum flows has decreased.
- The stability of water levels has increased.

USGS 07075000 MIDDLE FORK OF LITTLE RED RIV AT SHIRLEY, AR:

The Shirley gauging station is located upstream of the Greers Ferry reservoir on the Little Red River. The alteration date used for the IHA analysis was 1962, corresponding to the date of dam construction. Although this site is not downstream of a dam, several alterations were noted:

- December flows have significantly increased, while January flows have been significantly lowered.
- Minimum flows have decreased, although the duration on frequency of minimum flows has not been affected.

With the exception of the duration and frequency of minimum flows being substantially decreased, changes in stage are less noticeable.

USGS 07076000 LITTLE RED RIVER NR HEBER SPRINGS, AR:

Heber Springs is located on the Little Red River, just downstream of the Greers Ferry reservoir. The Little Red flows into the White River downstream of the Newport station.

A hydrologic alteration date of 1962 was chosen due to the Greers Ferry dam construction. Stage data for this site were not available. The flow patterns at Heber Springs have been severely altered by dam. (Note: stage data not available electronically).

- The dam is holding back flow during the winter and spring months, and then releasing it during the summer. The decrease of flows at the station during winter and spring ranges from 31% to 49%. Flow during the summer months is increased by 271% to 410%.
- The minimum flow values have been greatly increased, while the high magnitude flows have significantly decreased.
- The frequency of low flows has risen by over 500%, but the duration of those events has been shortened. Both the frequency and duration of high magnitude flooding has been decreased.
- The frequency by which the river rises and falls has increased by 147 %.

USGS 07077000 WHITE RIVER AT DEVALLS BLUFF, AR:

Devalls Bluff is located downstream all of the reservoirs within the basin, near the Cache River National Wildlife Refuge. To account for this, a date of 1950 was chosen as an average alteration date for the IHA method. Results for the IHA flow analysis show the following changes in hydrologic attributes.

- The magnitude of late summer and early fall flows has increased significantly.
- Minimum flow conditions have significantly increased in magnitude.
- The number of hydrologic reversals per year has increased, meaning that the frequency that the river rises and falls has increased.

Changes in stage due to hydrologic alterations are not as obvious, but some alterations that stand out are:

- Summer stages have increase in magnitude to by as much as 3.5 feet.
- The duration of low periods has decreased.
- The numbers of reversals in stage has increased.

USGS 07077800 WHITE RIVER AT CLARENDON, AR:

The Clarendon gauging station is located downstream all of the reservoirs within the basin, just south of the Devalls Bluff station. As a result, a date of 1950 was also chosen as an average alteration date for the IHA analysis at Clarendon. Similar changes in hydrologic parameters were expected between the two stations due to their close proximity. This was indeed the case. Results for the IHA flow analysis show the following changes in hydrologic attributes (Note: Stage data not available).

- The magnitude of late summer and early fall flows has increased significantly.
- Minimum flow conditions have significantly increased in magnitude. Maximum flow conditions were reduced, although these changes were not as severe as minimum flow changes.
- The duration of minimum flows has been significantly lowered.
- The number of hydrologic reversals per year has increased, meaning that the frequency that the river rises and falls has increased.

Conclusions

As reflected in the IHA analyses at Flippin and Calico Rock, dams on the upstream reaches of the White River have severely impacted the natural flow regime. Human activities have caused little change in flow regime of the Black, Spring, and Elevenpoint Rivers in the northeastern portion of the White River Basin. The Black And White Rivers meet near the Newport gauging station. The severe hydrologic impacts noted at the Calico Rock station are not as extreme at the Newport station. This offset is due to the addition of relatively unaltered flow from the Black River. Downstream of Newport, the White River is receiving altered flow from the Little Red River. It also receives inputs from the Cache River and several other small tributaries. Gauging stations in the southern portion of the basin, near the wildlife refuge, show several alterations in the magnitude and timing of flows.

Future Efforts

Data availability for the Basin is probably on par with that for similar largely undeveloped watersheds of similar size throughout the U.S. Clearly, some significant hydrologic alteration of the basin has occurred in the past. In order to better understand the system as a whole, the major "consumers" of water should be identified. Municipal, agricultural, and urban consumption of water all relate most directly to the discharge within the Basin. However, ecological features such as floodplains respond directly to stage. When performing Basin-wide decision-making tasks, this contrast should be kept in mind. Development of a Basin yield analysis for the consumption of water would be straightforward. For ecological purposes, GIS coverages of DEMs, land use, and vegetation/wildlife could be combined to perform rather direct "what if" modeling for maintaining and/or developing stage "targets" for Basin management. As an example, the DEMs could be used to identify areas likely to be inundated at various stages. Direct comparison of such areas with the appropriate land use and/or vegetation/wildlife coverages would yield a first-cut ecological model for the Basin.

References

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun 1996. "A Method for Assessing Hydrologic Alteration Within Ecosystems". Conservation Biology 10:1163-1174.

Appendix A: Summary of IHA Analyses for Discharge

Please see "Discharge Figures" Microsoft Excel Spreadsheet.

Appendix B: Summary of IHA Analyses for Stage

Please see "Stage Figures" Microsoft Excel Spreadsheet.

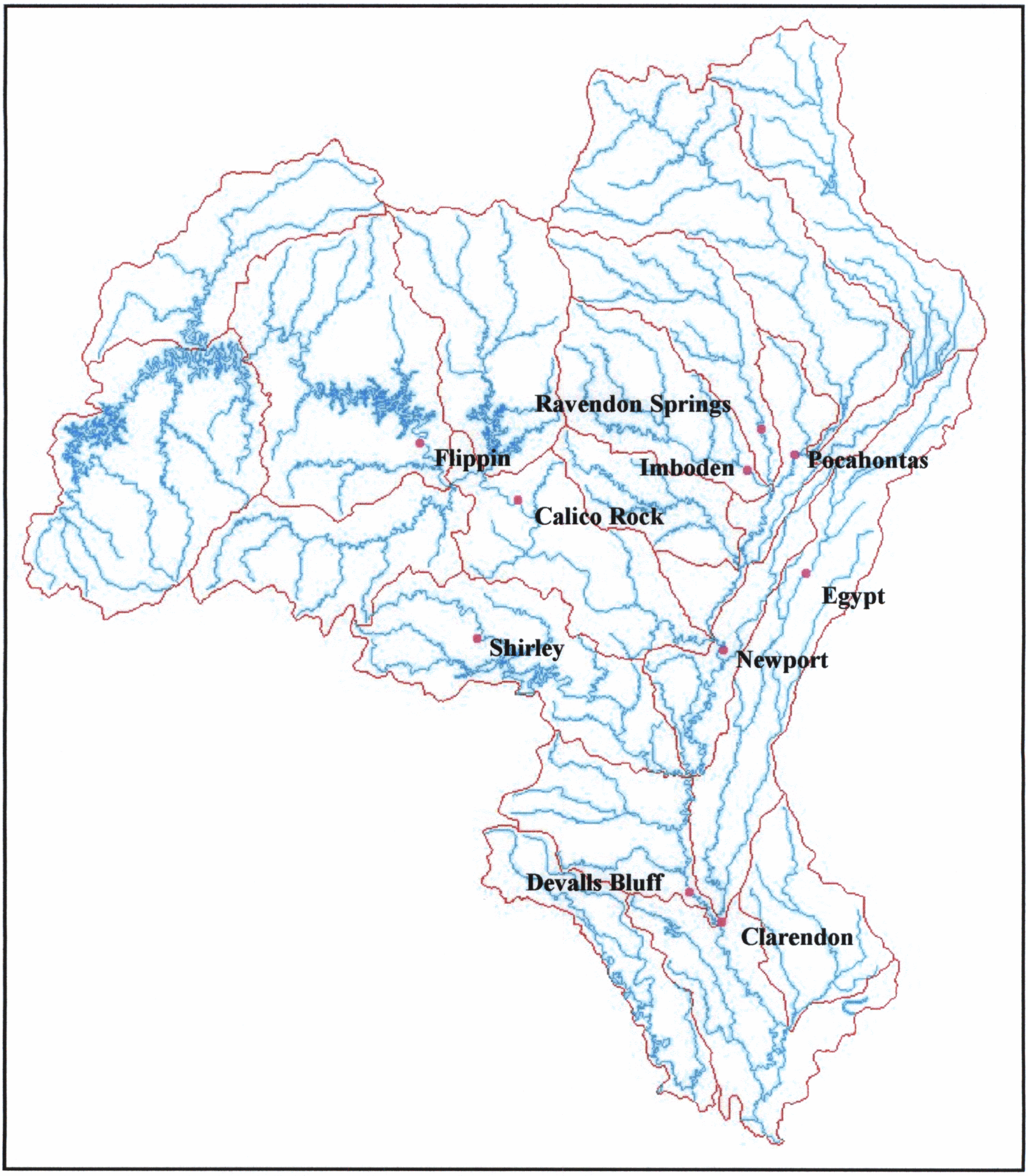

Figure 1: Map showing locations of stations used in IHA analysis.

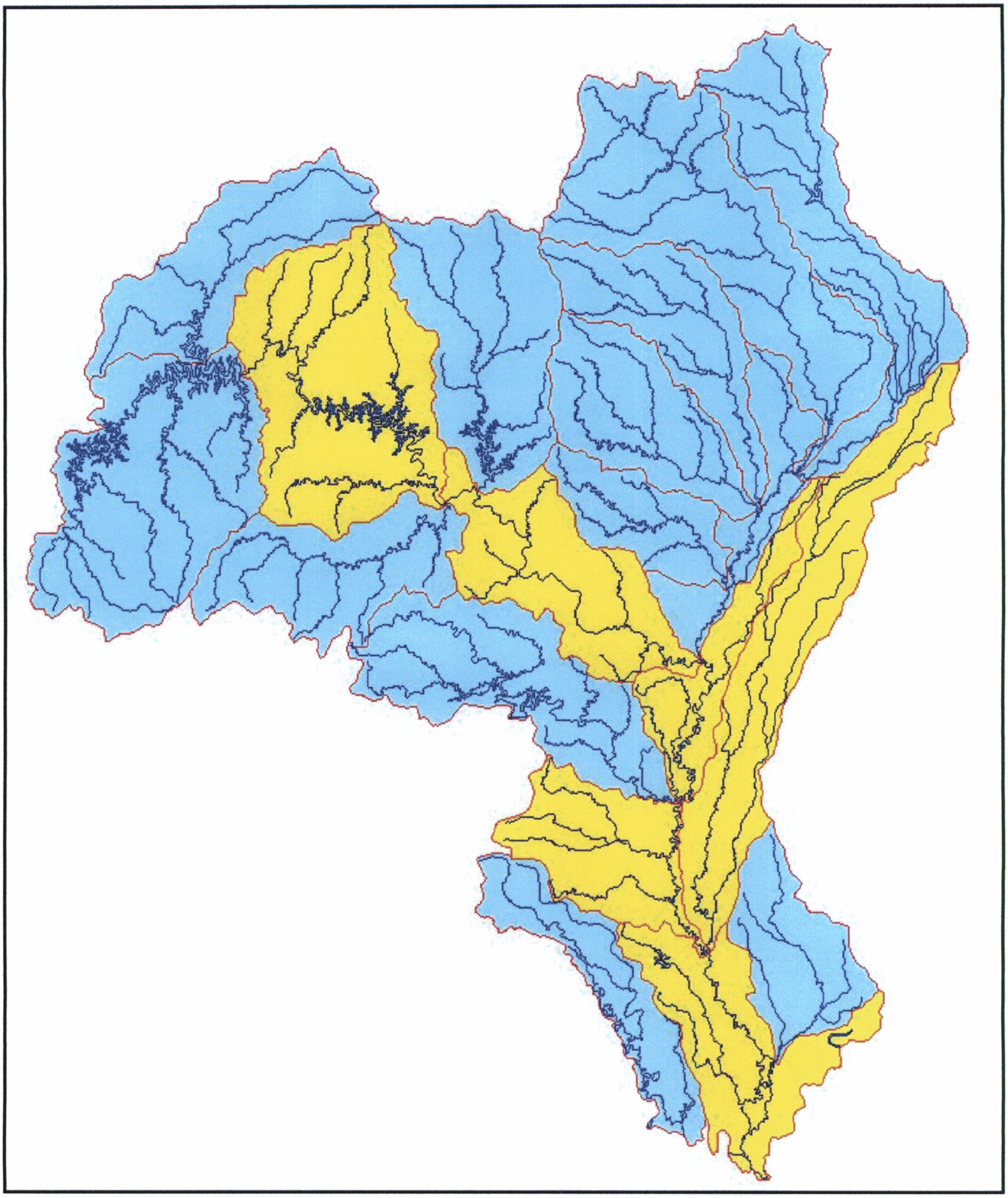

Figure 2: Map showing the White River Basin. Areas highlighted in yellow represent sub-watersheds for which the IHA analyses were performed.