St. Paul District

US Army Corps of Engineers®

EAU GALLE RIVER BASIN, WISCONSIN

EAU GALLE RIVER GSSHA WATERSHED MODEL

STATUS REPORT

October 2006

EAU GALLE RIVER BASIN, WISCONSIN
GSSHA WATERSHED MODELING
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1 INTRODUCTION

This research was conducted in response to a request from the State of Wisconsin Department of Natural Resources (WI-DNR) to the U.S. Army Corps of Engineers (USACE), St Paul District, for planning assistance under Section 22 of the Water Resources Development Act (Public Law 93-251). Funding was provided by the WI-DNR and USACE, St. Paul.

As is the case with many rivers and lakes within Wisconsin, urban development and changes in land-use have the potential to significantly impact environmental quality, particularly water quality in the Eau Galle River, Spring Valley Reservoir and Lake Eau Galle Reservoir. Tools are needed to provide resource managers the capability to analyze the impacts of changed land-uses on lake and stream environments.

2 WATERSHED BACKGROUND

The Eau Galle River watershed drains approximately 250 sq. miles of rolling agricultural and wooded areas. The Eau Galle is approximately 46 stream miles long and empties into the Chippewa River. There is approximately 524 feet of vertical drop from the upstream edge of the watershed to its outlet on the Chippewa River. The Eau Galle River has four major tributaries, Cady, Knights, Arkansas and Missouri Creeks. Many of the tributaries originate in steep coulees.

There are two major lakes within the watershed. The upstream-most lake is the Eau Galle Reservoir at Spring Valley, Wisconsin. Its control structure, Spring Valley Dam, is owned and operated by the St Paul District US Army Corps of Engineers. This lake is also referred to as Lake George.

Lake Eau Galle is located in the southern part of the watershed near the town of Eau Galle. The dam at Lake Eau Galle is a hydropower. The Lake Eau Galle Hydro Dam is owned by Dunn County, and is operated by a privately owned producing company.

The watershed drains the Villages of Woodville, Spring Valley, Elmwood, Eau Galle, and Arkansaw. None of these villages have experienced significant urbanization to date. **Plate 1** is a site map of the watershed.

3 STATUS OF COE GSSHA MODELING EFFORTS

In FY 2002, the St Paul District USACE modeling effort for the Eau Galle Watershed began. The initial scope of work called for data collection and assembly of a gridded hydrologic model, using the USACE Engineering Research and Development Center (ERDC)'s Gridded Surface and Subsurface Hydrologic Analysis (GSSHA) software. The USACE ERDC Aquatics Laboratory (a USACE laboratory based in Spring Valley, Wisconsin) collected discharge, precipitation and water quality data in the upper part of the watershed during the growing seasons of 2002 and 2003. The farthest south that the ERDC Aquatics Laboratory collected data was on Cady Creek, near Elmwood, Wisconsin.

In FY03, the St Paul District started preparing and assembling the digital data requirements for the GSSHA. Because digital SSURGO soils were not readily available for Pierce County, a considerable amount of effort was spent digitizing the county soil survey maps to complete the digital soils map across the Eau Galle Watershed. A digital land use coverage was downloaded and processed and a 100 meter grid digital elevation model was set up for the GSSHA model. More details about the digital data layers are given in Section 5, Data Compilation.

In FY04, an initial GSSHA model was assembled from the digital data layers prepared in FY03. A uniform hypothetical rainfall event was applied to the watershed.

In FY05, the GSSHA model was enhanced to accept lakes and reservoirs. The Spring Valley Dam and reservoir (Spring Valley, WI) was incorporated into the GSSHA model.

In the early part of FY06, some preliminary calibration was done for the surface water component of the model. Precipitation and hydro-meteorological data was compiled and formatted for GSSHA. The GSSHA model's link to the subsurface had not been established. The calibration was not working well for several reasons: The small time step required by GSSHA necessitated the use of detailed precipitation and discharge information (15 minute time intervals) at the gages. It appeared that the rating curves for the stream gages (on Eau Galle River near Woodville, Knights Creek and Cady Creek) were not validated for the highest discharges observed during the 15-minute stage readings. The model was not connected to the groundwater at this point.

During the spring of 2006, the St Paul District discussed the Eau Galle Watershed Project with USACE's Engineering and Research Development Center (ERDC) and was encouraged to hear that ERDC would adopt the upper portion of the Eau Galle Watershed (down to Spring Valley Dam) as a demonstration project. **Plate 2** illustrates the extent of ERDC's demonstration project. The scope of the demonstration project was to add the link to the groundwater and bedrock surfaces, calibrate the model and enhance the GSSHA program's capabilities to determine nutrient and sediment loadings. The ERDC demonstration project was to be completed before the end of the fiscal year (September 30, 2006) and the St Paul District was to receive some assistance in taking the smaller calibrated model and extending the calibrated parameters to the rest of the watershed.

As of the September 30, 2006 ERDC has not completed their GSSHA demonstration and has not fully completed coding their GSSHA model for the sedimentation and new nutrient components of the GSSHA program. The following list summarizes the tasks accomplished by ERDC programmers during the summer of 2006:

- Funded the St Paul District Survey Crew to survey some cross sections at three stream gage locations where the rating curves were in question.
- Refined the stream network (secondary and tertiary streams) required for drainage
- Coordinated more detailed survey of channel geometry for river links upstream of Spring Valley Dam.
- Processed additional rain gage and hydro-meteorological data for the watershed provided to ERDC by the Aquatics and Ecology Lab.
- Developed a groundwater layer for the entire Eau Galle Watershed.
  - Researched and obtained available information on the aquifer properties and aquifer bottom elevations with assistance from St Paul District
  - Prepared a bedrock layer to define the aquifer bottom elevations

    - Linked groundwater to the stream network for the demonstration area
    - Established initial conditions by simulating several seasons until the groundwater levels were near actual water table elevations in and around the Eau Galle Watershed
- Developed a partially calibrated surface water GSSHA model.

Because ERDC's demonstration project was not completed before the end of the fiscal year, the St. Paul District has not been able to use the calibrated parameters from their demonstration project and apply it to the rest of the Eau Galle watershed. As with the case with other state-of-the art models under development, there is a considerable amount of coordination required between the programmer and engineers using the software to be sure all steps are taken to prepare the data sets and input files where program documentation lags in development. ERDC has given a preliminary indication that their demonstration project may be completed in December 2006. Completing the GSSHA program coding to handle nutrients and completing the Eau Galle Demonstration project remains a high priority for ERDC and the St Paul District.

4 METHODOLOGY

GSSHA is hydrologic analysis program that computes surface runoff using 2-dimensional finite difference overland flow routine using physically based parameters for each cell in the watershed. GSSHA uses 1-dimensional channel routing. A GSSHA model can also be linked to the groundwater. GSSHA uses a 2D vertically averaged finite difference groundwater routine, a 1D finite difference infiltration routine and a 1D finite difference network stream flow routine. The presence of seeps and springs within the Eau Galle River Watershed is indicative of the complexity of the geology, and one of the reasons why GSSHA was chosen as the preferred model for this watershed. Because of the potential for changing land use within the Eau Galle River Watershed, GSSHA holds an edge over other hydrologic models because the impacts of changed land use or land cover can be modeled down to field scale.

5 DATA COMPILATION

5.1 Digital Elevation Model

The USGS National Elevation Dataset (NED) with a grid resolution of 30 meters was downloaded for this study, but this resolution resulted in very long simulations and a decision to increase grid size to 100 meters for computational efficiency. The 100 meter resolution preserves the general watershed slopes and runoff characteristics and facilitates accurate definition of landuse change and spatial variability of the physical relationships both on the surface and sub surface that are critical to determining watershed response to hydrologic inputs. Grid cells in the 100-meter digital elevation model (DEM) were manually modified to eliminate pits and flat spots that would cause model instability and erroneous results in the watershed simulation. The elevation of some stream cells were also modified so that the stream profiles were smooth and the interaction between the stream cells and the ground water worked together.

5.2 Streamflow

Plate 3 shows where stream gage information was available within the Eau Galle Watershed. Historic stream flow measurements from this watershed were obtained from various sources as shown in Table B-1.

Table B-1: Eau Galle River Watershed - Stream Flow Records

Station ID	Drainage Area (sq. mi.)	Period of Record	100Yr Discharge (cfs)
Eau Galle River nr Woodville, WI USGS Gage 05369900 ERDC Aquatic Lab-Eau Galle @18.5	39.4	1978-1983, 2001-2003	Not Available
Eau Galle River Low Water Bridge at Spring Valley Previous USGS Gage 05369945 ERDC Aquatic Ecology Lab -Eau Galle @26.3	47.9	1981-1996	Not Available
Spring Valley Dam USACE Reservoir	63.8	1969-2006	3450 *
Eau Galle River at Spring Valley, WI USGS Gage 05370000	64.1	1944-2006	Not Available
Cady Creek at County Rd P ERDC Aquatic Ecology Lab	23.1	2002,2003	Not Available
Knights Creek at Rd X. ERDC Aquatics Ecology Lab	7.8	2002,2003	Not Available
Eau Galle River at 4.3 ERDC Aquatics Ecology Lab		2002	Not Available
Eau Galle River at 12.7 ERDC Aquatics Ecology Lab		2002	Not Available
Carr Creek ERDC Aquatics Ecology Lab		2002	Not Available
Lake Eau Galle hydropower plant Dunn County	173.4	Discharges collected for simulated period only.	8432*

Note *As published in Dunn County, Wisconsin Flood Insurance Study, 1996.

During both years 2002 and 2003, the USACE ERDC Aquatic Laboratory operated two gages to measure flow, total suspended solids and nitrogen and phosphorus species. Velocity transects were run across the streambed at different stage elevations to generate the rating curves for Cady and Knights Creek.

Observed discharges on Knight's Creek and Cady Creek were recorded every 15-minutes. The daily average stage was computed, and then using the ERDC Aquatics Lab's fitted rating curve the discharges were computed. The instantaneous peak for the simulation period falls outside the range of observed values for the fitted rating curve. Knights rating curve was valid for discharges less than 87 cfs and stages less than 3.9 feet. Cady's rating curve was valid for discharges less than 180 cfs and stages less than 2.6 feet.

The rating curve for the Eau Galle River at Eau Galle River Low Water Bridge at Spring Valley (upstream of the Spring Valley Reservoir) was developed by the USGS for their discontinued gage. The USGS developed the ratings for the Eau Galle River at Woodville and Spring Valley. However, when reviewing the peaked nature of the May 2003 rainfall event, it was determined that more detail was needed to get adequate definition of the hydrograph shape.

Through partnership with ERDC, some cross sections were surveyed at Cady Creek, Knights Creek and at the USGS gage near Woodville to help define the upper portions of their rating curves. The details of the rating curve development are included in Appendix A.

5.3 Precipitation Gages

The precipitation gages available for this study are listed in Table B-2. The precipitation gages used in the ERDC demonstration in the northern part of the watershed are illustrated in **Plate 4**. The precipitation station data available for the entire Eau Galle Watershed are shown in **Plate 5**.

Table B-2: Eau Galle Watershed Precipitation Stations

Precipitation Station Location	Monitoring Agency	Latitude NAD 83	Longitude NAD83	Frequency of Measurement
10th Ave West	ERDC Aquatics Lab	552177	4968920	15 min
County N	ERDC Aquatics Lab	558081	4972664	15 min
I94 West	ERDC Aquatics Lab	552548	4976356	15 min
County B	ERDC Aquatics Lab	556687	4976851	15 min
County E	ERDC Aquatics Lab	558576	4983531	15 min
I94 East	ERDC Aquatics Lab	563628	4975540	15 min
10th Ave East	ERDC Aquatics Lab	561493	4969081	15 min
Eau Galle Aquatics Lab	ERDC Aquatics Lab	559334	4967034	15 min
Spring Valley Dam	COE			24 hour
Spring Valley	NWS Coop			24 hour
Durand	NWS Coop			24 hour
Eau Galle Lake - Hydropower Dam	Dunn County – Contractor			12 hr

The need for sub-minute time steps for the GSSHA simulations requires more refined and accurate precipitation records. **Plate 6** illustrates the need for detailed precipitation measurements. The finest time increment for the recorded precipitation records was 15-minutes.

HEC DSS-Vue was used to store and manage the precipitation data for all precipitation gage data.

The Spring Valley NWS Coop precipitation gage data was plotted along with the precipitation records maintained at the Corps Dam. Upon reviewing some rainfall events, it became obvious that the NWS cooperative rain gage reader was lumping weekend total rainfall depths into Monday's reading as shown in **Plate 7**. The precipitation depths recorded at the COE dam were adopted for Spring Valley. Additional data screening was accomplished as much as possible to resolve similar problems at other NWS cooperative gages. The availability of 15-minute precipitation at the Eau Galle Aquatics and Ecology Laboratory came to light at the time of the ERDC demonstration project. With this precipitation data, the NWS and COE daily gages at Spring Valley may not be needed for the watershed-wide analysis.

Using a macro written for DSS, the daily precipitation gage data were given the temporal distribution as the 15 minute recording gages. Since County N was the 15-minute precipitation gage located farthest south, and closest to the daily recording gages, it was used for temporal distribution. In 2002, when County N gage was not operational, the other 15-minute recording gage at County D and E was used. The Theissen polygon method was adopted within GSSHA to spatially distribute the four 15-minute precipitation gage data over the Eau Galle River Watershed.

The availability of 6-hour precipitation at the Lake Eau Galle Hydropower came to light at the time of the ERDC demonstration project. Extension of the GSSHA model to the lower portions of the drainage basin should incorporate this data to give an anchor to the precipitation in the lower part of the basin.

5.4 Hydro-Meteorological Parameters (HMET)

Hourly hydro meteorological data is required to run a long-term simulation in GSSHA. The Minneapolis/St Paul Airport was adopted at the climate station for this study. Date, hour, pressure, relative humidity, sky cover, wind speed, temperature, direct radiation and global radiation were parameters that were compiled and formatted as required by the GSSHA model. There are not many stations that record this type of data. The Minneapolis/St Paul Airport was the closest climate station to the Eau Galle River Watershed.

5.5 River Cross Section Geometry

Channel routing in GSSHA is dependent on the geometric parameters provided to the GSSHA model in the "river links". The geometry for the river "links" within the GSSHA model came from various sources. A site visit was conducted in the northern half of the watershed to take pictures and estimate channel dimensions and land surface conditions for 14 sites on Carr Creek, Cady Creek and the Eau Galle River. Field Scientists from the ERDC Aquatics lab surveyed several smaller streams in the upper part of the watershed. Cross sections for a short distance downstream of the Spring Valley Dam were available from a cross section survey in St. Paul District USACE map files (references 8,9). Cross sections just upstream of Lake Eau Galle were obtained from the Dunn County Flood Insurance Study (reference 6). Approximate channel geometry downstream of Lake Eau Galle was taken from a Dam Break input file supplied by Ayres Associates.

5.6 Control Structures

The Spring Valley Dam is a flood control structure owned and operated by the St Paul District - US Army Corps of Engineers. The rating curve for the outlet was obtained from the Eau Galle Water Control Manual (reference 10). A comparison of the published elevation storage relationship and the volumes computed by the GSSHA gridded model is illustrated in **Plate 8**.

The Lake Eau Galle Hydropower Dam is located in the southern third of the watershed. It is owned by Dunn County, and operated by a private power generation company. A rating curve for the Lake Eau Galle Hydro Dam was obtained from the Consultant who developed the design for the spillway rehabilitation in 1997.(reference 1) The preliminary geometry coded in the GSSHA model for this dam was determined by assigning the USGS quadrangle lake elevation as the lowest elevation of the stepped weir. Pictures were taken at during a watershed visit, and approximate weir dimensions were determined from the picture. A rating curve was developed for the GSSHA model from the approximate weir elevation and dimensions. This preliminary information should be updated and checked against more recently acquired hydraulic analysis and documentation for the site.

5.7 Land Use

The landuse data used to define surface characteristics is from the USGS National Land Cover Dataset (NLCD). The NLCD was interpreted from 30 meter resolution Landsat satellite imagery from approximately the 1992 timeframe. The gridded land use data was converted to polygons using ArcView 3.2. The polygon shapefile required extensive cleaning. The Xtools extension (convert multipart to single part feature) was used to clean and simplify the polygon shapefile by adjoin similar, neighboring polygons. **Plate 9** illustrates the various landuse categories in the Eau Galle River Watershed and the proportions for the dominant categories.

To assess the need for updates for present-day land use, the NLCD was overlaid on aerial photography from the 2004 and 2005 Farm Service Agency Digital Orthophotos. **Plate 10** illustrates this comparison. To date, this watershed has not experienced significant urbanization. The main differences in land use was apparently due to crop rotations, where there was a fairly uniform conversion of hay/pasture to row crop. The approximate ratios of land use categories are reasonable and has not changed significantly since 1992.

5.8 Surface Soil Layer

The surface soil layer used within the GSSHA model defines the permeable layer at the ground surface that water percolates through. It is within this layer that the root mass of the growing vegetation exists. Soils data available in the watershed included the NRCS SSURGO soils data for St. Croix, Dunn and Pepin Counties. At the time of the model development, the SSURGO soil layer for Pierce County was not available. Using Pierce County Soil Survey books, the soil polygons that lay within the Eau Galle Watershed were scanned, georeferenced and digitized on screen. The digital soils data was reduced from the numerous soils series and complexes to USDA textural classes. The predominant surface textural class in the watershed is silty loam, which comprises about 77 percent of the watershed surface soil layer. Loam, loamy sand, rock and wetlands make up the remaining 23 percent of the surface texture and a small portion is in floodplain, open water and miscellaneous land use classifications. The miscellaneous land use classifications which include gravel pits, fill areas and borrow areas cover a very small percentage of the soils coverage and will be assigned appropriate textural classes for estimating infiltration and runoff from those areas. **Plate 11** displays the soils data set that was used to assign textural classifications to the grid. This data will also assist in defining the shallow groundwater characteristics.

5.9 Subsurface Information

The digital bedrock grid was developed using the wiscLITH data compiled by the Wisconsin Geological and Natural History Survey. WiscLITH is a database that includes bedrock formation for select wells around the State of Wisconsin. The bedrock elevation for wiscLITH is accurate to approximately +/- 5 to 10 feet. There may also be some errors in location, which would also transfer to an error in elevation. The wiscLITH data for the study area was processed by querying the wiscLITH FORM-CODE (a numerical code assigned to each geologic group formation or member) of interest and a wiscLITH BEDROCK_CO of 2 (which would indicate that the bedrock was not the first or last unit reported for the well number) or 3 (the last bedrock unit reported for the well number). This query eliminated any wells where the top elevation for the geologic formation was affected by erosion.

The top confining layer and bottom of aquifer were identified throughout the basin. A stair-stepped combination of 3 or 4 different bedrock layers compose the Eau Galle Watershed.

Actual water table measurements were collected for the years of 2002 and 2003 for locations in and around the Eau Galle Watershed. The Wisconsin DNR and other private entities were contacted for available monitoring well locations and well logs.

Table B-3: Eau Galle Watershed Groundwater Measurement Locations

Monitoring Well Location	Source
Woodville Seepage Cells	WIDNR and Cedar Corporation
Hammond Wastewater	WIDNR, Ayres Associates
New Richmond	WIDNR, Chiquita Processed Foods
Hager City, Nestle Purina Petcare	WIDNR, Nestle Purina Petcare
PP-0039 – Pepin County	USGS
PP-0040 – Pepin County	USGS

6 SURFACE WATER MODEL

6.1 Digital Elevation Model Preparation

A gridded hydrologic model of the Eau Galle River was developed within the Watershed Modeling System (WMS). WMS is the GIS interface, developed by Brigham Young University, to prepare data for the GSSHA model. The USGS National Elevation Dataset (NED) 30-meter grid was re-sampled within WMS to generate a 100 meter digital elevation model (DEM) of the land surface. Individual grid cells were manually adjusted to eliminate pits and flat spots in the DEM that would cause instability or erroneous results in the GSSHA simulation. In addition the cells along the watershed boundaries were reviewed to ensure that they flowed in to the Eau Galle Watershed. The 100-meter grid offers a reasonable scale to maintain the slope characteristics within the overland flow plain and also is a fine enough resolution to assign land use at scales that are sensitive to current cropping and land use practices. This resolution will facilitate the targeting of BMPs that will be applied to certain land uses for future model applications. The individual cells within the gridded model are populated with physical relationships derived from the available GIS layers including available digital soils data, land use/land cover data representative of the 1992 era.

6.2 Stream Network Preparation

The density of stream networks in the watershed was increased until the grid was adequately draining. The channel depth, bottom width, side slopes and Manning's "n" values were added to reflect the surveyed or observed channel geometry. The Eau Galle River in the Village of Elmwood has a small in-stream ponding area at Public Avenue. There is a 4-foot rise in the channel elevation at the Public Avenue bridge, extending upstream of the bridge for a distance of approximately 1000 feet. At this stage in model development, the ponding area was not incorporated. If there are substantial algae blooms or water quality issues with this area, the ponding area can be incorporated at a later time.

6.3 Incorporate In-Stream Lakes into GSSHA

In-stream lakes were coded within GSSHA by defining a lake polygon that connects to the stream segments. Minimum lake elevations were tied into the inflowing and outflowing channels. GSSHA computes the elevation storage relationships based on the DEM elevation of the ground surface. GSSHA's computed elevation storage relationships were compare to the relationships documented in the USACE Spring Valley Dam Water Control Manual (reference 10). The Conservation Pool Elevation for the Corps Reservoir is 286.5 meters (940 feet). The Conservation Pool Elevation is the elevation below which the inactive and water supply storage volumes are contained. At elevation 292.2 meters (960 feet) the campground is evacuated. The difference in volume between elevations 286.5 meters and 292.2 meters, range from 12 to 26 percent. **Plate 8** illustrates the elevation–storage relationship at the Corps Reservoir at Spring Valley.

The lake storage relationship for Lake Eau Galle has not been adequately coded into the GSSHA model at this time. The lake storage relationship for Lake Eau Galle has been identified in a Spillway Rehabilitation analysis by Ayres Associates (reference 1).

The Flood Insurance Study (FIS) for the Village of Elmwood, Wisconsin, indicates that the Soil Conservation Service (now the Natural Resources Conservation Service) has constructed three small watershed dams in the Knights Creek watershed. These structures are located on the North Branch (#4), West Branch (#1), and an unnamed tributary (#5) to Knight's Creek, and each is within about a mile of the Village of Weston. They are all flood control structures without a permanent pool. Since the three structures are relatively small and do not have a permanent pool, it is possible that the flows into the lakes and out of the lakes is about the same, depending on operations. For this study, it is assumed that the dams on the various branches of Knight's Creek have a relatively small impact on the runoff, and will not be coded in the model.

6.4 Mapping Layers and Parameter Definition

Within GSSHA surface soils and land use layers are tied to mapping tables that define the physical parameters that govern the infiltration, evaporation and runoff from the grid cells. Soil mapping is tied to infiltration. The Green and Ampt with Redistribution (GAR) method was selected to estimate the infiltration to the soil. The soil parameters required for GAR are saturated hydraulic conductivity, wetting front suction head, porosity, pore distribution index, residual water content, area reduction depth and initial soil moisture. Initial values of hydraulic conductivity were assigned as per technical readings and as tabulated in the GSSHA User's Manual. The land use mapping is tied to the surface roughness, evaporation and plant transpiration through a mapping table. Manning's "n" roughness values are assigned for each of the land use categories. The evaporation and plant transpiration is computed by the Penman Monteith method that includes the following list of parameters: land surface albedo, wilting point water content, vegetation height, vegetation transmission coefficient and canopy stomatal resistance. To simplify calibration of the Eau Galle Watershed Demonstration GSSHA model, ERDC is combining the land uses and soil types into 10 combinations.

7 LINK TO SUBSURFACE

The importance of a link to the subsurface in the Eau Galle Watershed was evident simply through field observation. The valley in the headwaters part of the watershed is poorly defined and appears as a bowl-shaped depression surrounded by gently rolling hills. Southward and progressing downstream, the valley is well defined, varying in width and bounded on either side by high bluffs whish rise as much as 200 feet above the valley floor at Spring Valley. Seeps and springs are evident in some areas.

To quickly look at the seep and spring potential, a generalized water table map was digitized, and compared to the land surface. **Plate 12** highlights the areas where the water table was higher than the ground surface. Upstream of the Corps Reservoir and Spring Valley Dam, there were small areas near the dam that appear to have potential for springs. Downstream of Spring Valley Dam, the potential for springs was evident along most reaches of the Eau Galle River and its tributaries.

Seeps and springs may have some seasonal response with wet or dry cycles. Groundwater may discharge for a long period of time after a significant event. To quantify the impact groundwater will have infiltration and its influence on base flow during rain free periods, a link to the subsurface was necessary in the Eau Galle Watershed.

The Eau Galle Demonstration Project's link to the sub-surface was established through use of GIS layers for the bedrock (aquifer confining layer) and a collection of actual groundwater levels during simulation period. A bedrock layer was extended beyond the limits of the watershed to define the head boundary and other watershed divides that control the groundwater movement within the watershed. The stream links within the GSSHA surface water model were modified to account for the interface between the ground surface and the groundwater.

8 CALIBRATION

Calibration for the ERDC Demonstration Project has not been completed. Using a fairly dense coverage of observed precipitation and stream flow measurements in the demonstration area, the GSSHA model should be able to be calibrated reasonably well.

In the lower part of the watershed, there is a less dense network of precipitation gages and very little stream gage information. Since GSSHA is very sensitive to the spatial and temporal distribution of precipitation, calibration in the lower part of the basin will be much more difficult. It is reasonable to think that the calibrated parameters from the demonstration project can be applied to the lower part of the basin, as long as the grid resolution is maintained at 100 meters. The goal for calibration of the entire watershed is to perform a calibration for June through September 2002. It is intended that verification of the calibration model would be performed for May through July 2003 when watershed monitoring data was available. The goal of the calibration was to capture a simulation period that extended from June through September when evaporation conditions within the watershed are somewhat constant. This eliminated the need to adjust the evaporation and transpiration parameters for that period. While GSSHA has seasonal ET adjustment capabilities, they will not be used for calibration.

9 FUTURE WORK AREAS

The following activities are identified for future model calibration:

ERDC Demonstration Project

- Complete coding the connection between nutrients and the surface water model.
- Complete the calibration of the GSSHA model using observed stream flow and nutrient data.

Entire Eau Galle River Watershed

- Apply calibration parameters from upstream demonstration project to the entire watershed.
- Complete modifying the 100 meter grid cells at downstream lake, Lake Eau Galle. Ensure that the elevations of the cells reproduce the stage and storage curve. Add modifications to the outlet rule curve. Add any needed calibration of the lake leakage terms.
- Add additional stream segments 2nd and 3rd order streams where the grid does not drain.
- Link groundwater to stream network downstream of Spring Valley Dam.
- Modify groundwater boundary map to the larger watershed size.
- Complete the soils and land use grids to the extent of the groundwater grid.
- Compile stream cross section information for Eau Galle River downstream of Spring Valley Dam. Collect additional cross section geometry parameters where needed. There is very little information available for smaller tributaries.
- Process available stream flow and precipitation data for Lake Eau Galle Dam.
- Collect additional precipitation (15min) and stream flow (15min) data throughout the basin
- Capture stream flow and stage observations for large events, to help verify the upper end of rating curve on USGS and ERDC stream gage locations
- Assess desire to calibrate model for nutrients in the lower part of the basin.
- Apply potential management measures and assess the effects on discharge, sediment and possibly nutrients.

- Simulate future land use conditions and identify critical detention needs and viable watershed restoration alternatives.
- Perform a quantitative analysis of current and future storm water detention needs and parameters needed to address the potential overflow design and permitting requirements.
- Collect nutrient data in the lower part of basin
- Incorporate radar precipitation

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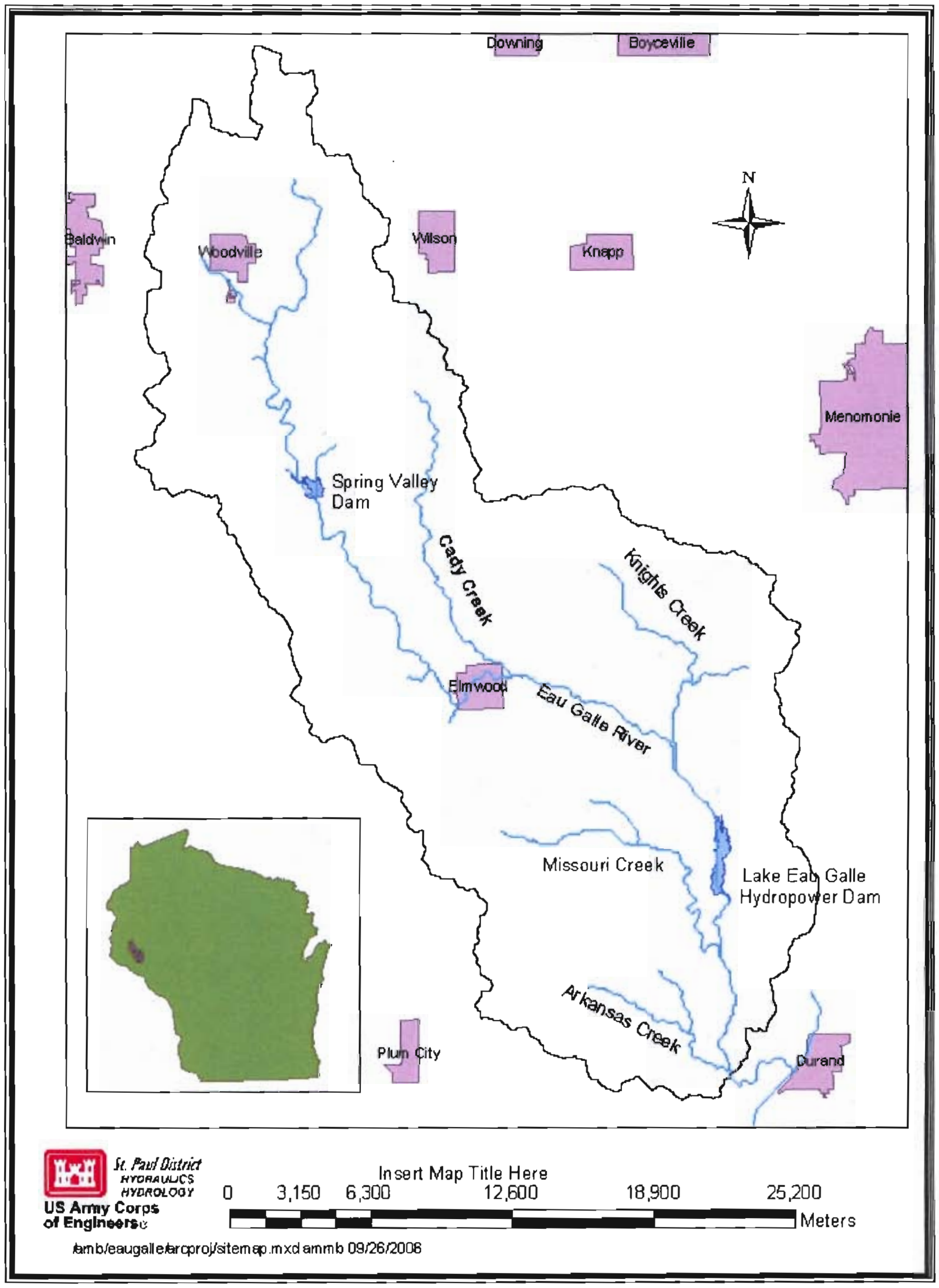

PLATE 1 – Eau Galle River Watershed Sitemap

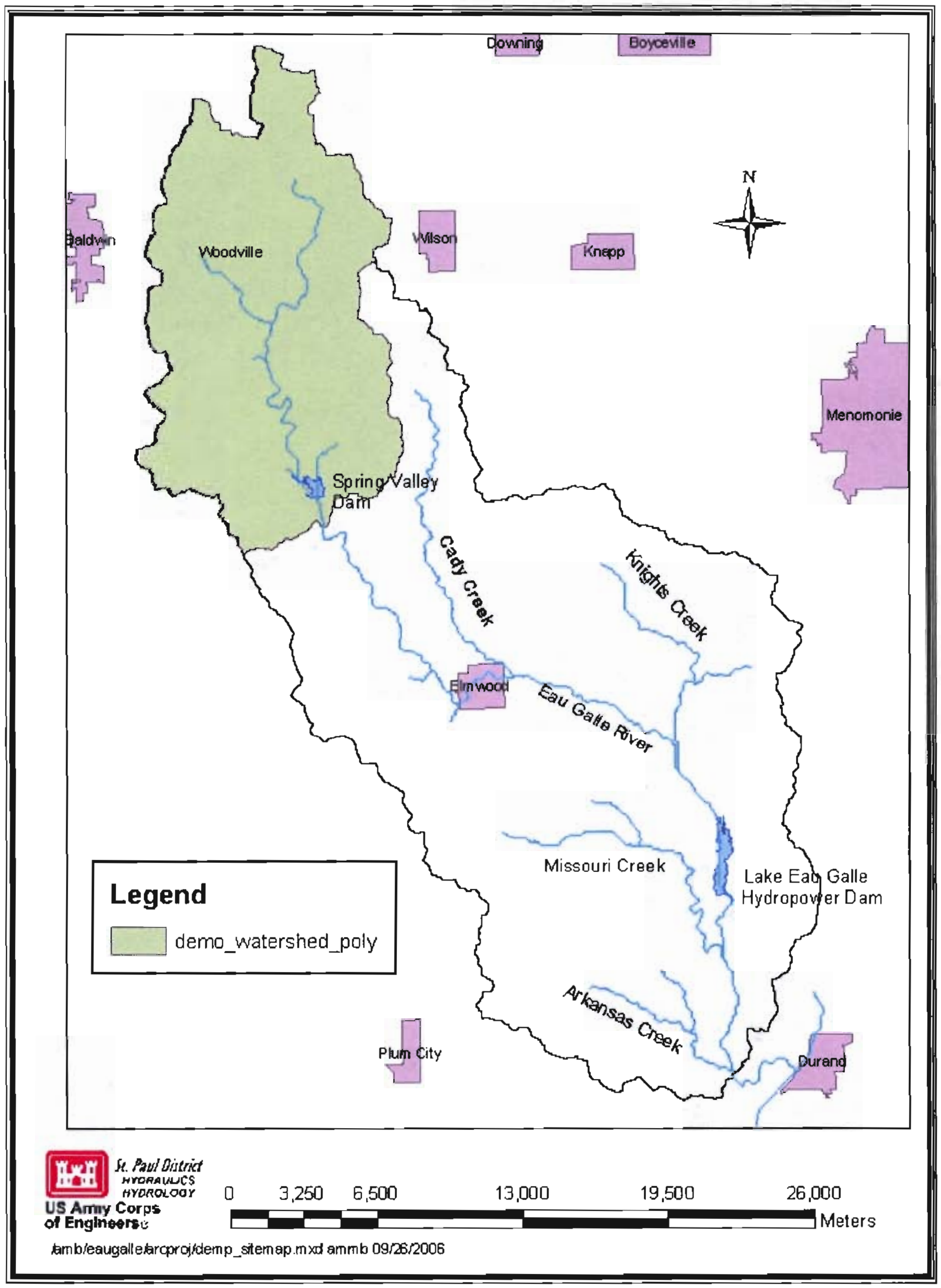

Plate 2: Eau Galle River ERDC Demonstration Project Boundary

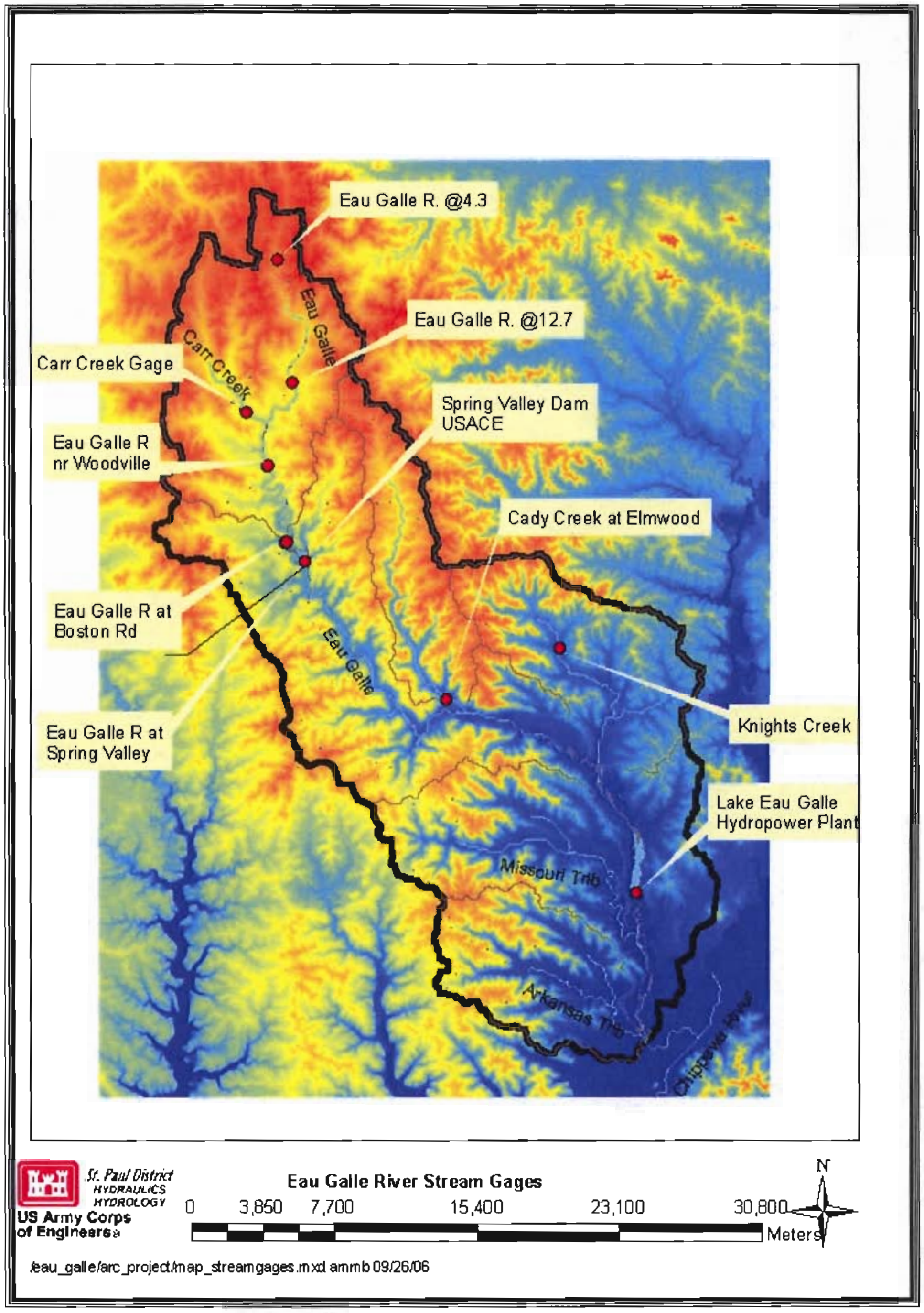

PLATE 3: Eau Galle River Watershed Stream Gages (2002, 2003)

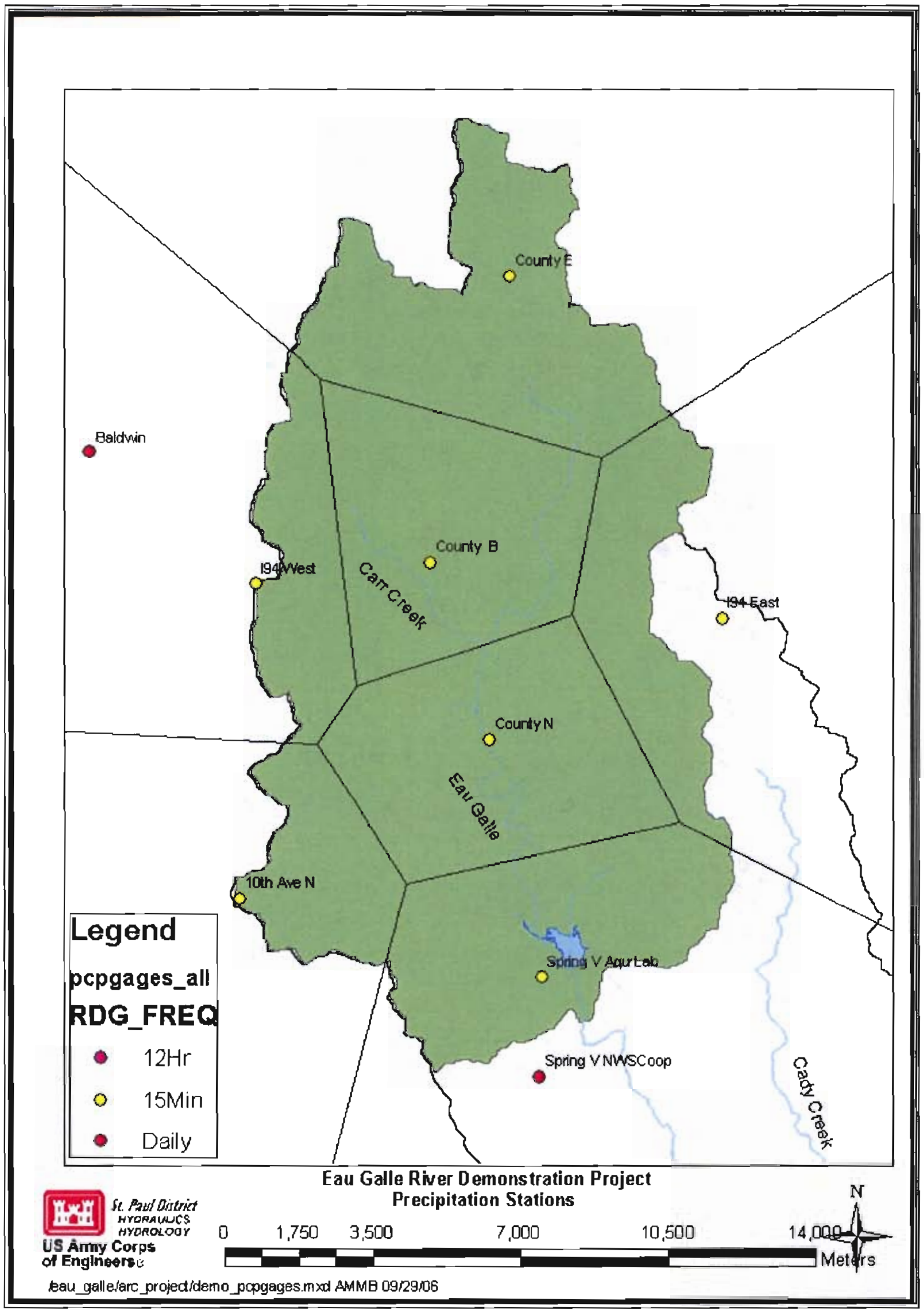

PLATE 4: Eau Galle River Watershed Demonstration Project – Precipitation Gages (2002)

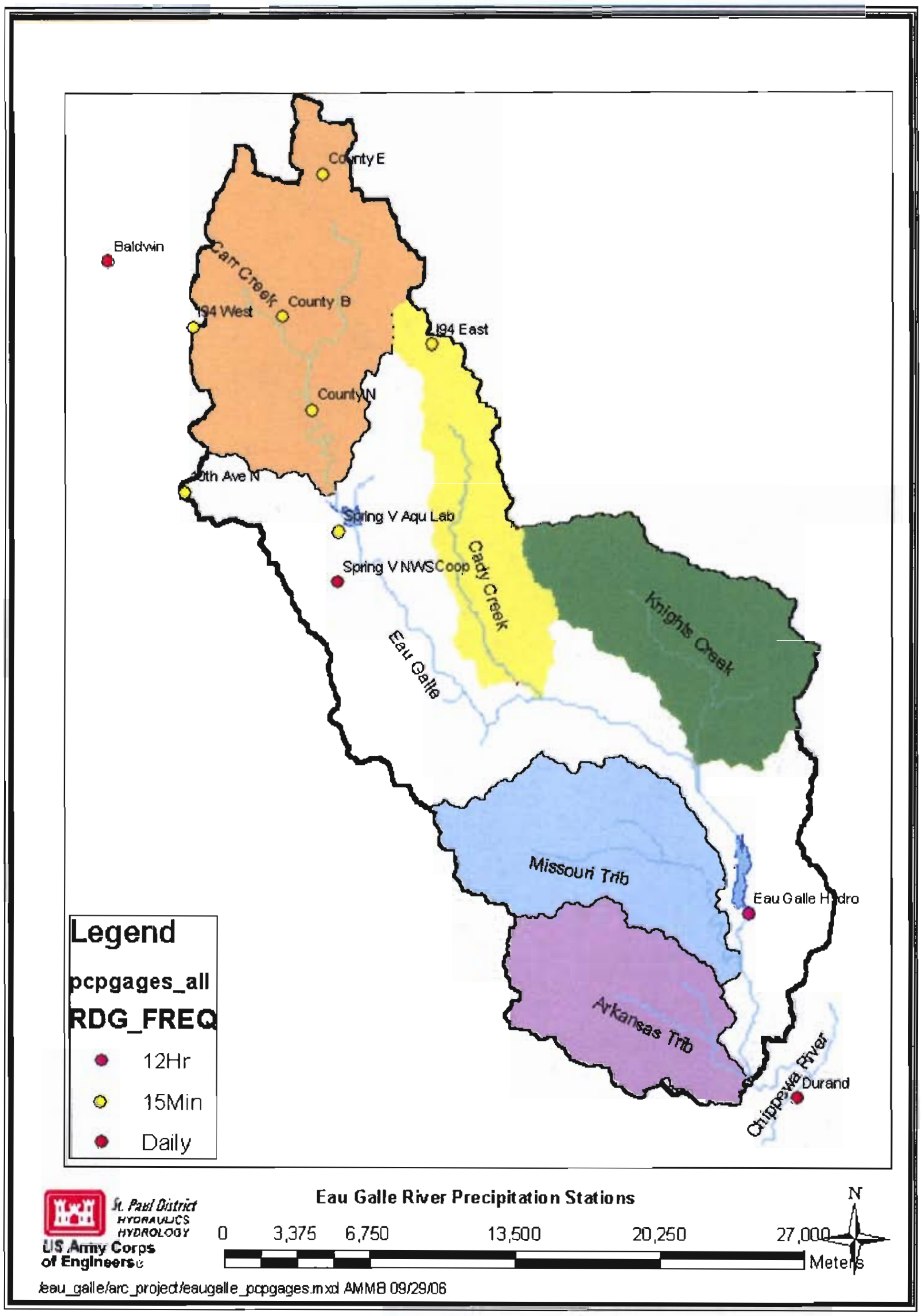

PLATE 5: Eau Galle River Watershed Precipitation Gages (2002,2003)

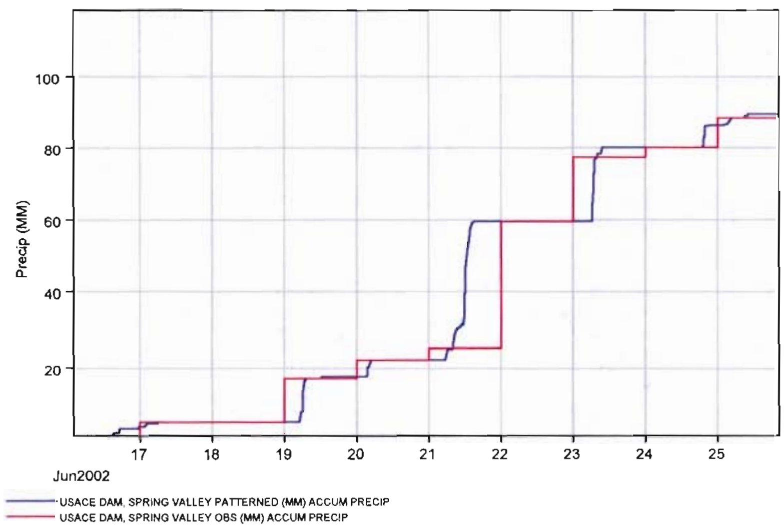

PLATE 6: Daily Versus 15min Precipitation Temporal Distribution

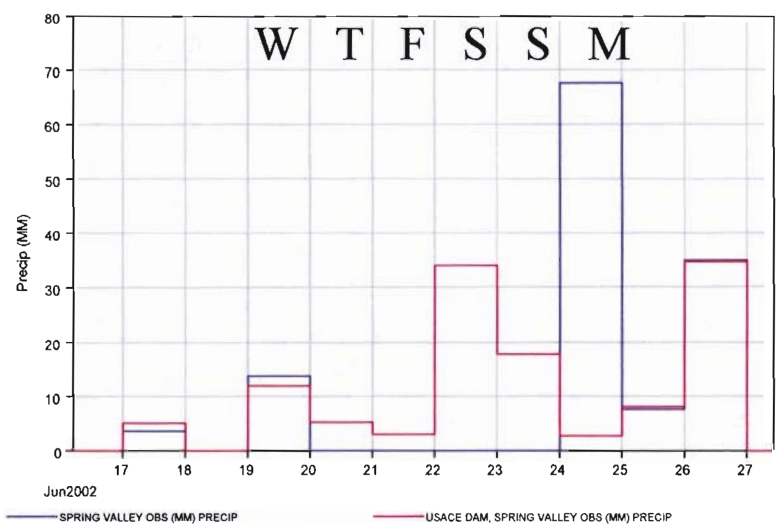

PLATE 7 : Errors in Spring Valley NWS Coop Precipitation Records

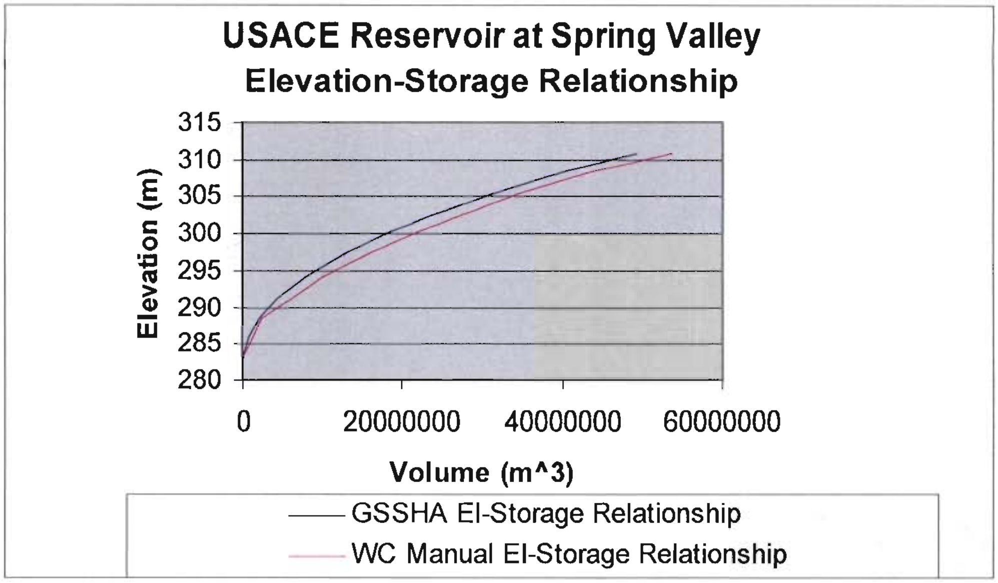

PLATE 8: Elevation Storage Relationship at the USACE reservoir, Spring Valley Dam

Eau Galle River Watershed
1992 Landuse

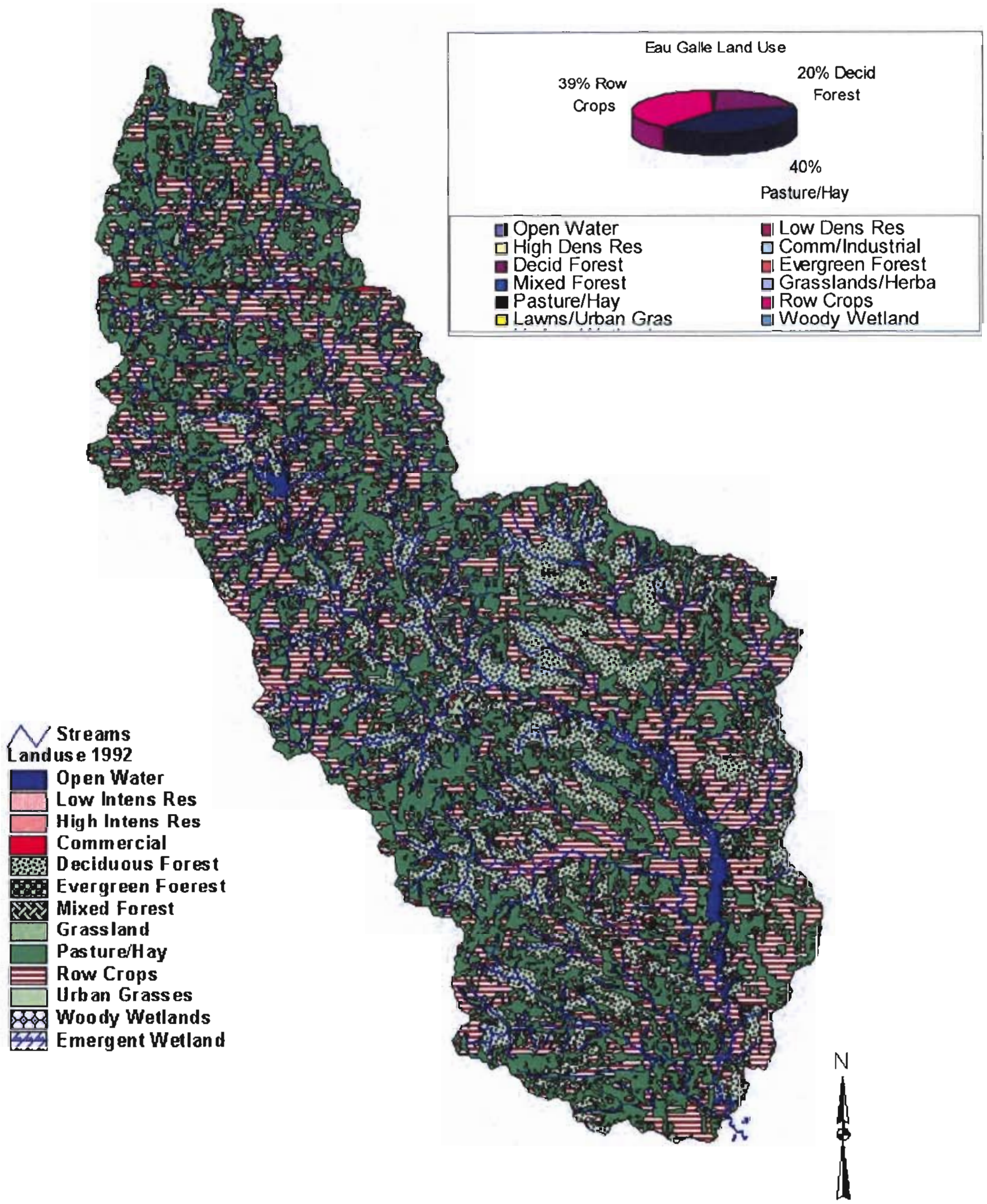

PLATE 9: Eau Galle Watershed Land Use (NLCD 1992)

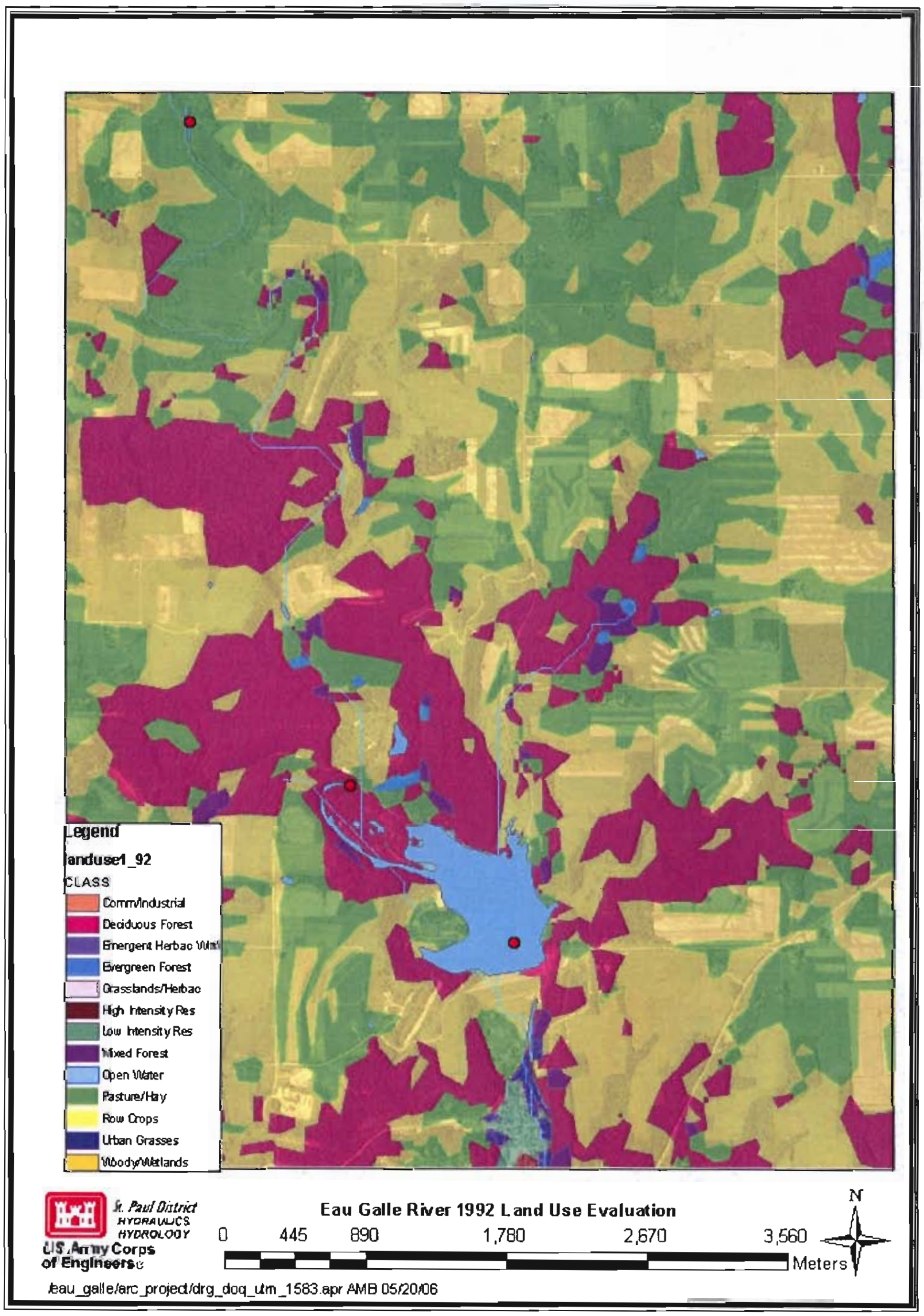

PLATE 10 : Comparison of 1992 Land Use to Digital Orthophotography

Eau Galle River Watershed
Soil Textural Classes

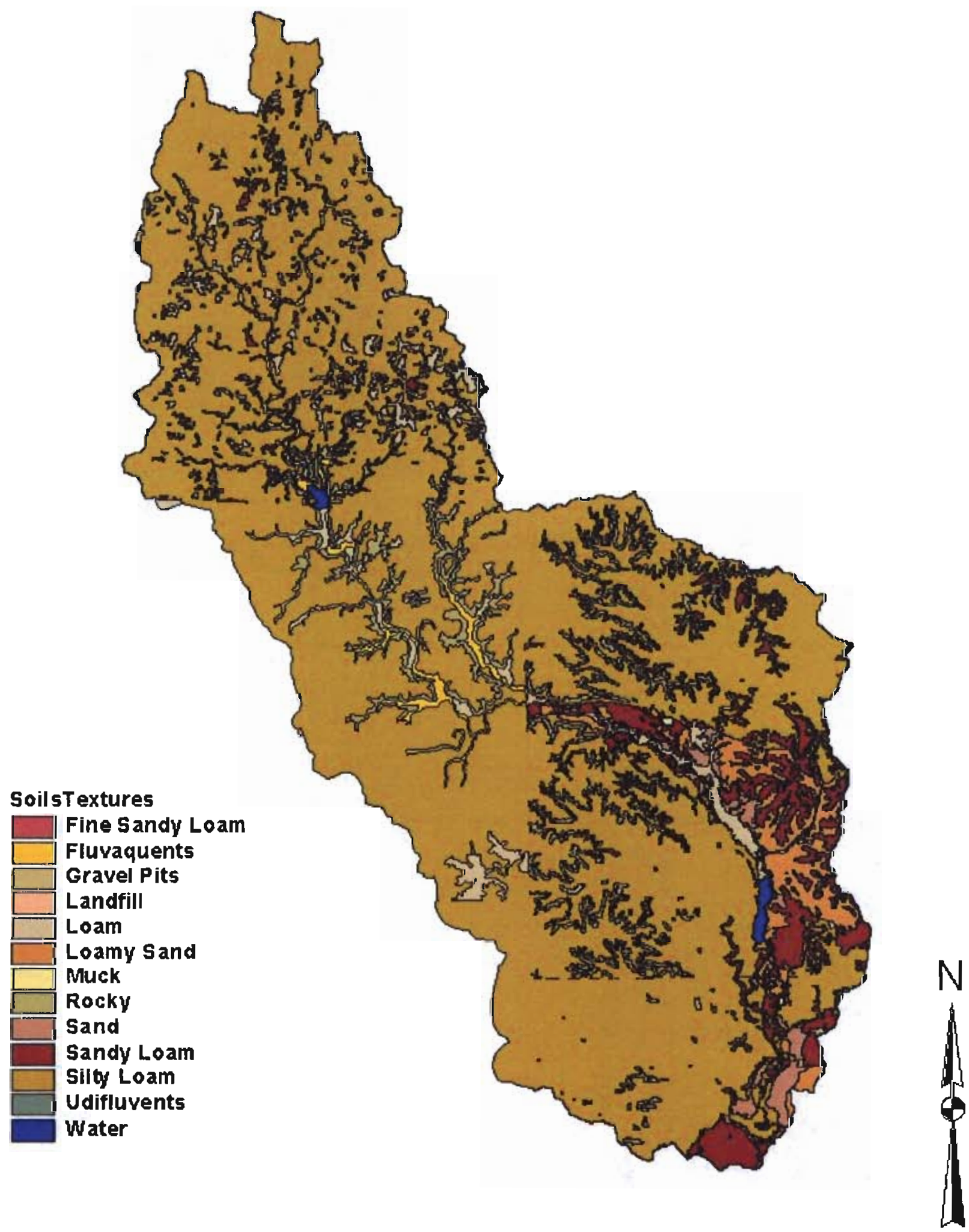

PLATE 11: Digital Soil Coverage of Eau Galle River Watershed

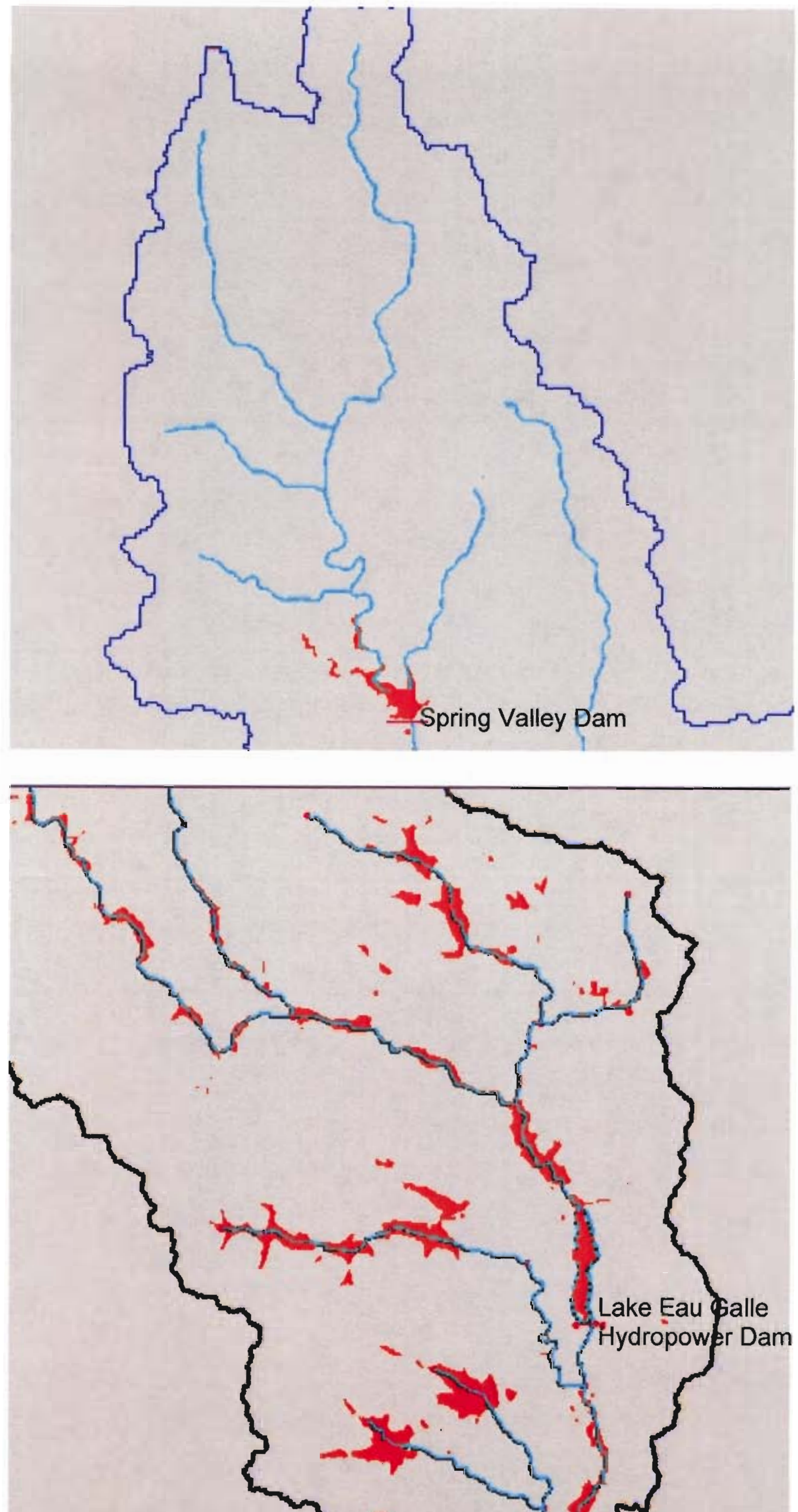

PLATE 12: Locations where generalized water table was above the ground surface in the Eau Galle Watershed

APPENDIX A

Eau Galle River Watershed Rating Curve Development

Eau Galle River Watershed Rating Curve Development

1. Eau Galle River near Woodville, County Road N

The gage on the Eau Galle River at County Road N was a USGS gage that was operated 1978-1983, 2001-2003. The USGS provided their rating curve for the gage. For mean daily discharges, the range of discharges that the rating curve was developed for was adequate. The GSSHA model necessitated the use of a time step finer than daily. The USGS provided 15-minute stage data for the gage. The instantaneous peak stages were not all within the portion of the "verified" rating curve. The verified portion of the rating curve extended to gage height 7.46 with a discharge of 784 cubic feet per second.

The St Paul District Survey Crew surveyed a cross section downstream of County Road N, near the old location of the USGS gage. They also surveyed a "typical" cross section approximately 220 feet downstream of the bridge. The surveyed cross section defines an area of pooled or stagnant water along this channel reach. The Survey Crew verified that the section that was surveyed near the gage location was actually deeper than the downstream section. Discussing this anomaly with the surveyors after the survey was completed, the surveyors relayed that the channel was fairly stagnant and formed a small pool. It appears that riffles and pools are present near the Woodville gage site. At a point further downstream, the channel drops more steeply into an incised valley. More channel invert points should have been surveyed to further identify the extent of the pool in the Eau Galle River, and where it starts dropping off into the valley.

A HEC-RAS model was constructed with the cross section downstream of the bridge near the gage location, and the typical that cross section 220 feet downstream. The typical cross section was copied an additional 5000 feet downstream at a point where the USGS quadrangle showed the 1040 foot contour crossing the Eau Galle River centerline. The downstream cross section may impose some error in this simple model because the accuracy of the USGS Quadrangle is half of a contour interval. The contour interval for this area is 20 feet, thus implying that the error in any elevation would be plus or minus 10 feet. Sensitivity runs were made to assess the impact of the error in the downstream cross section elevation.

Manning's n values within the channel were adjusted upwards to account for the stagnant portion. Manning's n values in the over banks were adjusted to represent heavily wooded stretches of the river. A rating curve was generated with various discharge profiles. The rating curve for the gage location was copied to an excel spreadsheet where it could easily be compared to the USGS rating curve and the observed stage and discharge measurements. **Plate A-1** shows the USGS rating curve along with the rating curve developed with HEC-RAS for the downstream cross section elevation at 1040 feet, as indicated by the USGS quadrangle contour.

It is recommended that the USGS rating curve be adopted. It is also recommend that the USGS or ERDC try to document the flows and stages for an event greater than 1000 cubic feet per second to define the upper part of the USGS rating curve.

2. Cady Creek at County Road P

The gage on Cady Creek at County Road P was a stream gage that was operated by ERDC in 2002-2003. The gage was located on the eastern bridge pier on the upstream side of the bridge. The ERDC Ecology Lab personnel provided their rating curve for the gage. For mean daily discharges, the range of discharges that the rating curve was developed for was adequate. The GSSHA model necessitated the use of a time step finer than daily. ERDC provided 15-minute stage data for the gage. The instantaneous peak stages fell far outside of the "verified" rating curve.

The St Paul District Survey Crew surveyed a cross section upstream of County Road P, at the location of the discontinued ERDC gage. They also surveyed a "typical" cross section approximately 300 feet downstream of the bridge. A HEC RAS model was constructed from just upstream of the County Road P Bridge to the confluence with the Eau Galle River which is approximately 5260 feet downstream. The bridge geometry was surveyed in the field. The typical section was copied downstream to the confluence, and a channel invert that was extrapolated from the Eau Galle River profiles for the Elmwood FIS that terminated approximately 2000 feet upstream of the confluence with Cady Creek. Normal depth was used as a boundary condition, with a channel slope of 0.0012. Manning's n values were adjusted to represent the rating curves measured in the field. The channel banks are very thick with vegetation. It appears that at lower flows, there may be some additional roughness due to downed trees within the channel. **Plate A-2** shows the rating curve that was developed using the HEC-RAS model for Cady Creek. The HEC-RAS rating curve has some irregularity for discharges below 300 cfs. This is due to the adjustment of Manning's n values for ranges of flows. It appears that the rating curve developed by the ERDC Aquatics and Ecology lab is able to reproduce the observed discharges and stages for very small discharges better than the HEC-RAS model. There are obviously local disturbances that are not captured with the coarse HEC-RAS model. It is suggested that the ERDC rating curve be adopted for low flows, and the HEC-RAS rating curve be used for discharges 200 cfs and above.

3. Knights Creek at County Road X

The gage on Knights Creek at County Road X was a stream gage that was operated by ERDC in 2002-2003. The gage location was on the eastern, downstream bridge abutment. The ERDC Ecology Lab personnel provided their rating curve for the gage. For mean daily discharges, the range of discharges that the rating curve was developed for was adequate. The GSSHA model necessitated the use of a time step finer than daily. ERDC provided 15-minute stage data for the gage. The instantaneous peak stages fell far outside of the "verified" rating curve.

The St Paul District Survey Crew surveyed a cross section downstream of County Road X, at the location of the discontinued ERDC gage. The COE survey crew also surveyed channel invert elevations 125, 175, 224 and 275 feet downstream of the County Road X bridge to define the channel invert. Ayres Associates, an Engineering firm that designs many road crossings in the County, provided a typical section and bridge geometry for Starr Road, which crosses Cady Creek approximately 9370 feet downstream. A HEC RAS model was developed using the upstream surveyed cross section near the bridge, and then using the RAS section interpolation routine to transition between the upstream section and the "typical" section by Starr Road. The rating curve generated using the HEC-RAS model is shown in **Plate A-3**. The HEC-RAS does a good job reproducing the discharge-elevation relationship at the County Road X gage.

PRELIMINARY
SUBJECT TO REVISION

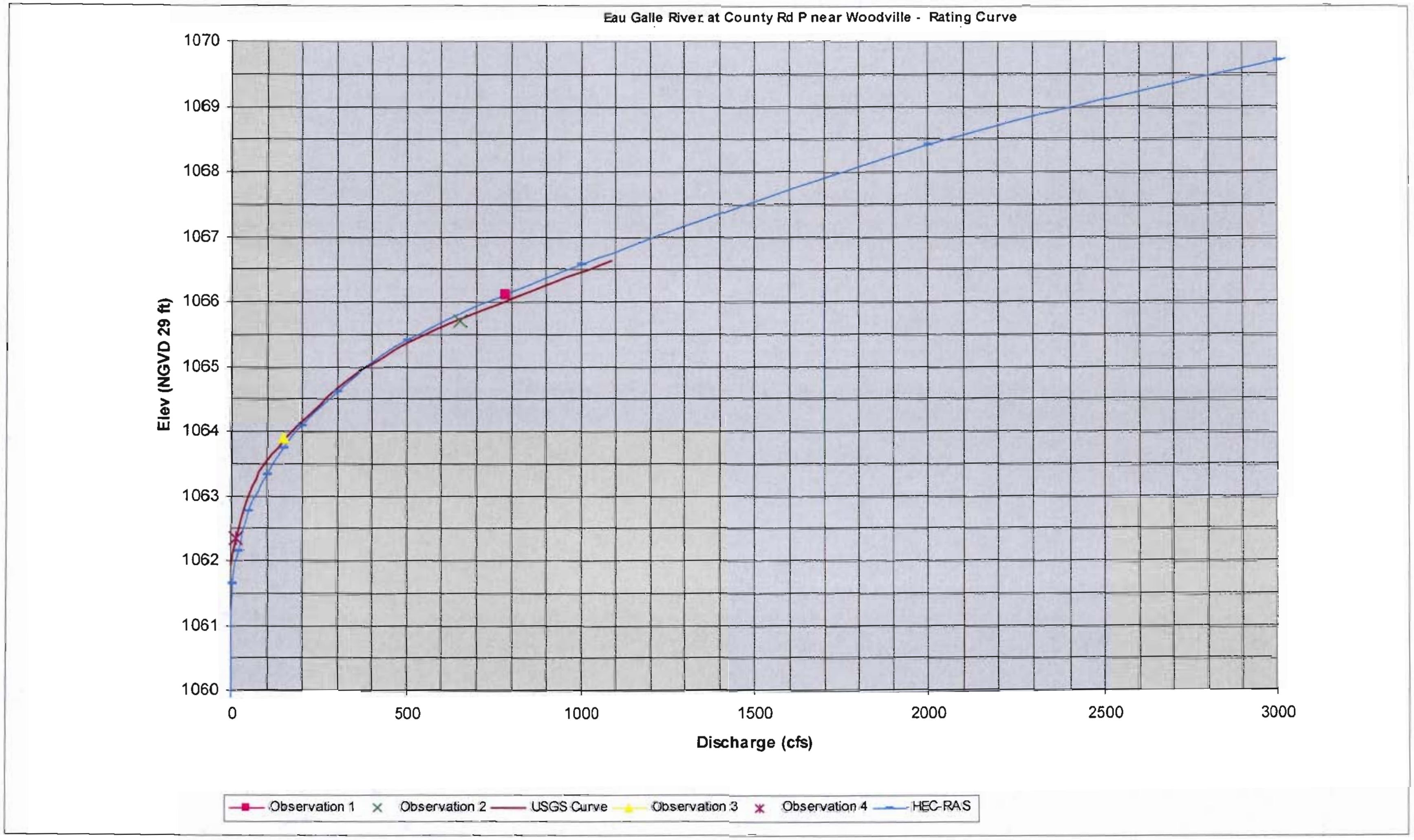

PLATE A-1 Rating Curve for Eau Galle River near Woodville, County Road N

PRELIMINARY
SUBJECT TO REVISION

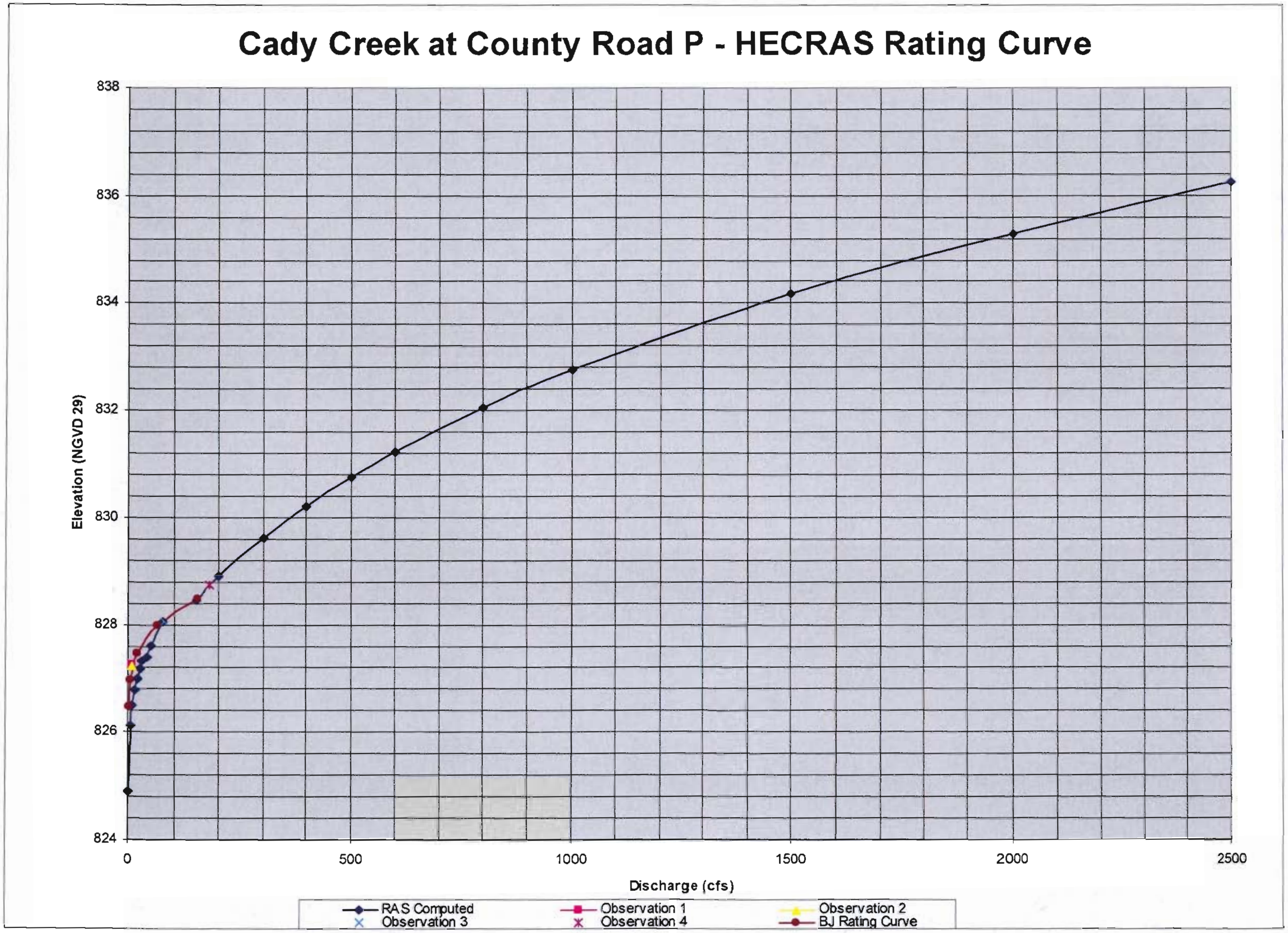

PLATE A-2 Rating Curve for Cady Creek at County Road P

PRELIMINARY
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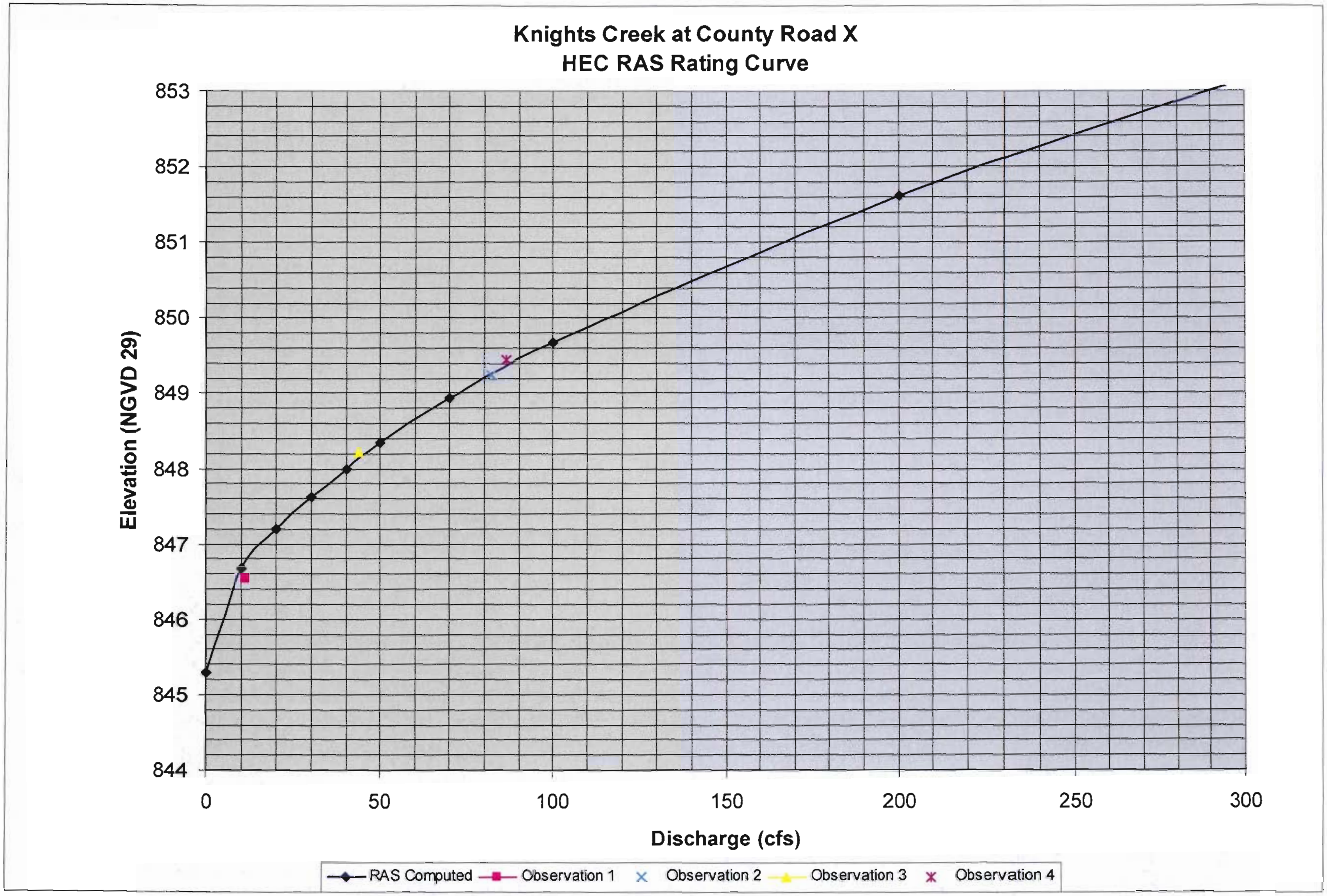

PLATE A-3 Rating Curve for Knights Creek at County Road X