Real-time Scour Risk Identification and Information Management Evaluation

FINAL REPORT - FHWA-OK-08-05

ODOT SPR ITEM NUMBER 2190

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16 . ABSTRACT

This report describes accomplishments and presents the design and evaluation of the information system, called ScourCast™. The ScourCast™ system is capable of providing plan of action and other bridge information in a single site, and real-time modeling and monitoring of flow rates at scour-critical bridges. System support for this project is provided to the University of Oklahoma by Vieux and Associates, Inc., Norman Oklahoma, for the Oklahoma Department of Transportation (ODOT), Bridge Division. This project develops design requirements and evaluates the effectiveness of a real-time scour risk identification system that can be used as a countermeasure for scour-critical bridges. The resulting system assists in the identification of elevated risk conditions and track agency responses in the context of a GIS and database documentation as a real-time operational system. The system utilizes GIS information to effectively communicate the location of scour-critical bridge locations that have recently experienced significant hydrologic events. The ScourCast™ system responds to a national need established by the updated National Bridge Inspection Standards (NBIS) regulation, 23 CFR 650.313.e.3.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units					Approximate Conversions from SI Units				
Symbol	***When you know***	***Multiply by***	***To Find***	***Symbol***	***Symbol***	***When you know***	***Multiply by***	***To Find***	***Symbol***
		LENGTH					***LENGTH***		
in	*inches*	*25.40*	*millimeters*	*mm*	*mm*	*millimeters*	*0.0394*	*inches*	*in*
ft	*feet*	*0.3048*	*meters*	*m*	*m*	*meters*	*3.281*	*feet*	*ft*
yd	*yards*	*0.9144*	*meters*	*m*	*m*	*meters*	*1.094*	*yards*	*yds*
mi	*miles*	*1.609*	*kilometers*	*km*	*km*	*kilometers*	*0.6214*	*miles*	*mi*
		AREA					***AREA***		
in^2	*square inches*	*645.2*	*square millimeters*	mm^2	mm^2	*square millimeters*	*0.00155*	*square inches*	in^2
ft^2	*square feet*	*0.0929*	*square meters*	m^2	m^2	*square meters*	*10.764*	*square feet*	ft^2
yd^2	*square yards*	*0.8361*	*square meters*	m^2	m^2	*square meters*	*1.196*	*square yards*	yd^2
ac	*acres*	*0.4047*	*hectacres*	*ha*	*ha*	*hectacres*	*2.471*	*acres*	*ac*
mi^2	*square miles*	*2.590*	*square kilometers*	km^2	km^2	*square kilometers*	*0.3861*	*square miles*	mi^2
		VOLUME					***VOLUME***		
fl oz	*fluid ounces*	*29.57*	*milliliters*	*mL*	*mL*	*milliliters*	*0.0338*	*fluid ounces*	*fl oz*
gal	*gallon*	*3.785*	*liters*	*L*	*L*	*liters*	*0.2642*	*gallon*	*gal*
ft^3	*cubic feet*	*0.0283*	*cubic meters*	m^3	m^3	*cubic meters*	*35.315*	*cubic feet*	ft^3
yd^3	*cubic yards*	*0.7645*	*cubic meters*	m^3	m^3	*cubic meters*	*1.308*	*cubic yards*	yd^3
		MASS					***MASS***		
oz	*ounces*	*28.35*	*grams*	*g*	*g*	*grams*	*0.0353*	*ounces*	*oz*
lb	*pounds*	*0.4536*	*kilograms*	*kg*	*kg*	*kilograms*	*2.205*	*pounds*	*lb*
T	*short tons (2000 lb)*	*0.907*	*megagrams*	*Mg*	*Mg*	*megagrams*	*1.1023*	*short tons (2000 lb)*	*T*
		TEMPERATURE (exact)					***TEMPERATURE (exact)***		
°F	*degrees Fahrenheit*	*(°F-32)/1.8*	*degrees Celsius*	*°C*	*°C*	*degrees Fahrenheit*	*9/5(°C)+32*	*degrees Celsius*	*°F*
		FORCE and PRESSURE or STRESS					***FORCE and PRESSURE or STRESS***		
lbf	*poundforce*	*4.448*	*Newtons*	*N*	*N*	*Newtons*	*0.2248*	*poundforce*	*lbf*
lbf/in^2	*poundforce per square inch*	*6.895*	*kilopascals*	*kPa*	*kPa*	*kilopascals*	*0.1450*	*poundforce per square inch*	lbf/in^2

Disclaimer

The contents of this report reflect the views of the author who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views of the Oklahoma Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. While trade names may be used in this report, it is not intended as an endorsement of any machine, contractor, process, or products.

Hard Copies are available upon written request from the Printing Services Branch. The Planning and Research's Research Manual is available at a cost of $2.87 per copy plus shipping and handling.

Acknowledgement

For technical assistance and guidance, we acknowledge the Bridge Division, Oklahoma Department of Transportation, especially Leslie Lewis, Kacie Braddy and Michael Kimbro. Support for this project provided by Vieux and Associates, Inc., Norman Oklahoma is gratefully acknowledged.

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1. INTRODUCTION

This project report describes accomplishments in Phase III, *Real-time Scour Risk Identification and Information Management Evaluation*, and presents the design and evaluation of the information system, called ScourCast™. The ScourCast™ system is capable of providing plan of action and other bridge information in a single site, and real-time modeling and monitoring of flow rates at scour-critical bridges. System support for this project is provided to the University of Oklahoma by Vieux and Associates, Inc., Norman Oklahoma, for the Oklahoma Department of Transportation (ODOT), Bridge Division.

This report demonstrates the ScourCast system functionality and its evaluation for real-time scour risk identification system as a countermeasure for scour-critical bridges. The resulting system assists in the identification of elevated risk conditions and track agency responses as a real-time operational system. While such a system does not "fix" the scour problem, it is envisioned as a useful tool for monitoring and prioritizing scour-critical bridges. The system utilizes GIS information to effectively communicate the location of scour-critical bridge locations that have recently experienced significant hydrologic events.

The benefit of the ScourCast™ system to FHWA and ODOT Division Engineers is the ability to track the current conditions at a scour-critical bridge and to assemble critical information necessary to take appropriate actions when high flow rates occur at scour-critical bridges. This project responds to a national need established by the updated National Bridge Inspection Standards (NBIS) regulation, 23 CFR 650.313.e.3. This regulation requires states to develop a plan of action for bridges that are scour critical. ScourCast™ supports the management and response plan for monitoring scour-critical bridges within the State of Oklahoma to comply with the NBIS regulations.

The implementation of this system is divided into four phases, with each corresponding to a Federal fiscal year, which are summarized as follows.

Phase I

June 1 2006 - September 30, 2006: System Design and Planning. Evaluate system requirements, develop a rapid prototype, and implement an effective scour monitoring system. Deliverables during Phase I included streamflow gauging station data, geospatial data, RainVieux radar-rainfall processing, Vflo™ hydrologic models, and development of the ScourCast™ web site.

Phase II

October 1, 2006 - September 30, 2007: During Phase II, the system functionality was expanded and enhanced to provide additional information management on scour-critical bridges. Identified system design requirements were incorporated into the system.

Phase III

October 1, 2007 - September 30, 2008: During Phase III, the system was expanded to include remaining scour critical bridges, insertion of Oklahoma-specific information, system implementation, and evaluation of operational performance of the system.

This report is organized with the following sections:

1. Introduction
2 Project Accomplishments
3. Summary and Conclusions
4. References, and
5. Appendices

2. PROJECT ACCOMPLISHMENTS

During Phase III, the system functionality was expanded and enhanced to provide additional information management on scour-critical bridges. System design requirements identified in the previous phase were incorporated into the system. Setup of the model for additional watersheds complements the bridges that were setup in earlier phases. The specific tasks carried out in PHASE III are described as follows.

1. Develop and incorporate watershed models for remaining scour-critical bridges

1.1. Setup watershed models for remaining two-thirds of scour-critical bridges.

The scour-critical bridges have been setup in this phase for all locations provided by ODOT that require monitoring as a countermeasure. These bridges include both span and culvert type construction. Maps of each watershed containing these bridges are included in the Appendix. The geographical distribution of contributing drainage areas for the scour-critical bridge locations are shown in Figure 1.

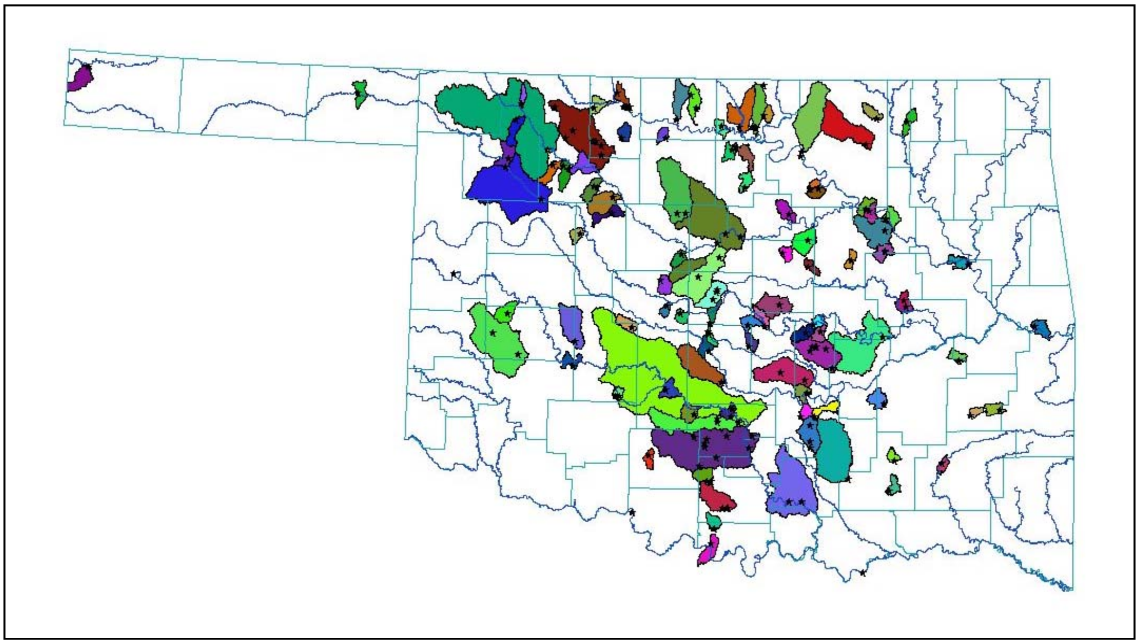

Figure 1 Geographic distribution of drainage areas for scour-critical bridge locations

For the selected subset of bridge locations, the Vflo watershed models were setup and evaluated by comparison of USGS Q2, 5, 10, 25, 50, 100, and 500-yr discharge with modeled discharge produced by input of 2, 5, 10, 25, 50, 100, and 500-yr rainfall. The summary of watershed models setup in PHASE III is presented in the Appendix.

The Vflo model was setup for the scour critical bridge locations planned during Phase III. Digital datasets were assembled and processed for input to the hydrologic model, Vflo™. Digital elevation models, stream hydrography and 12-digit HUC boundaries were used to delineate watersheds draining to the scour critical bridges. NRCS Soils and NLCD land use/cover describe the infiltration, soil moisture, and hydraulic roughness parameters in the model. For real-time operation, a climatological evapotranspiration rate is included to control soil moisture tracking, which allows the model to be properly initialized for the next heavy rainfall event.

Bridge Inspection Report Database was updated. Scour event inspection reports exist as scanned Adobe PDF documents, and contain necessary information for input. Population of the database with selected elements from the inspection reports was accomplished by loading the transcribed information into the SourCast database for use in the system.

1.2. Evaluate consistency with USGS regional flow frequency regression equations and make modifications to the models where needed.

Each model was tested to evaluate consistency with USGS Peak Flood Magnitude discharge estimates for the Q2, 5, 10, 25, 50, 100, and 500. This was accomplished by input of the regional precipitation amounts for 2, 5, 10, 25, 50, and 100-year quantiles for the 3-hr duration. The discharge produced from each precipitation quantile is compared with the USGS peak flood magnitude for the same return period. If bias is found such that the synthetically generated discharge over or under predicts, then the model is evaluated to identify any needed improvement. Some bias is expected because the USGS regional peak flood magnitudes are produced from regression equations that do not account for basin specific characteristics related to landuse/cover, soils, or basin shape.

1.3. Incorporate USGS regression flow rates for each bridge into the ScourCast display system.

Each scour-critical bridge has been assigned an estimated Q2, 5, 10, 25, 50, 100, and 500 year return interval threshold based on flow rate based on the USGS Peak Flood Magnitude estimation method (Torterelli, 1997) and entered into the database. These frequency flow rates are used to control the display icons and for notification according the thresholds assigned for each bridge.

2. Monitor and evaluate the system performance and operational status/statistics

2.1. Evaluate performance for six months of continuous data from archival rainfall on the system.

Performance of the system was evaluated from 12-Dec-06 to 11-Nov-08, longer than a six month period. The rainfall produced by RainVieux is used to supply the Vflo models of each basin with precipitation input. Vieux & Associates configured 13 NEXRAD radars to produce a seamless mosaic of rainfall for input to the Vflo models. The radar reflectivity is converted to rainfall through use of applicable Z-R relationships, which is then adjusted to remove bias. The bias correction factor is a multiplicative scalar applied to each pixel and updated every 15-minutes. The bias correction factor plotted as a timeseries is presented in Figure 2. A factor of 1.0 indicates no correction was made. A bias correction of 0.5 indicates that the radar rainfall accumulation was lowered by half. As evidenced by the wide variation in the bias correction factor, β, considerable effort is expended by the system to enhance the accuracy, and shows that gauge-correction is beneficial, improving the system performance.

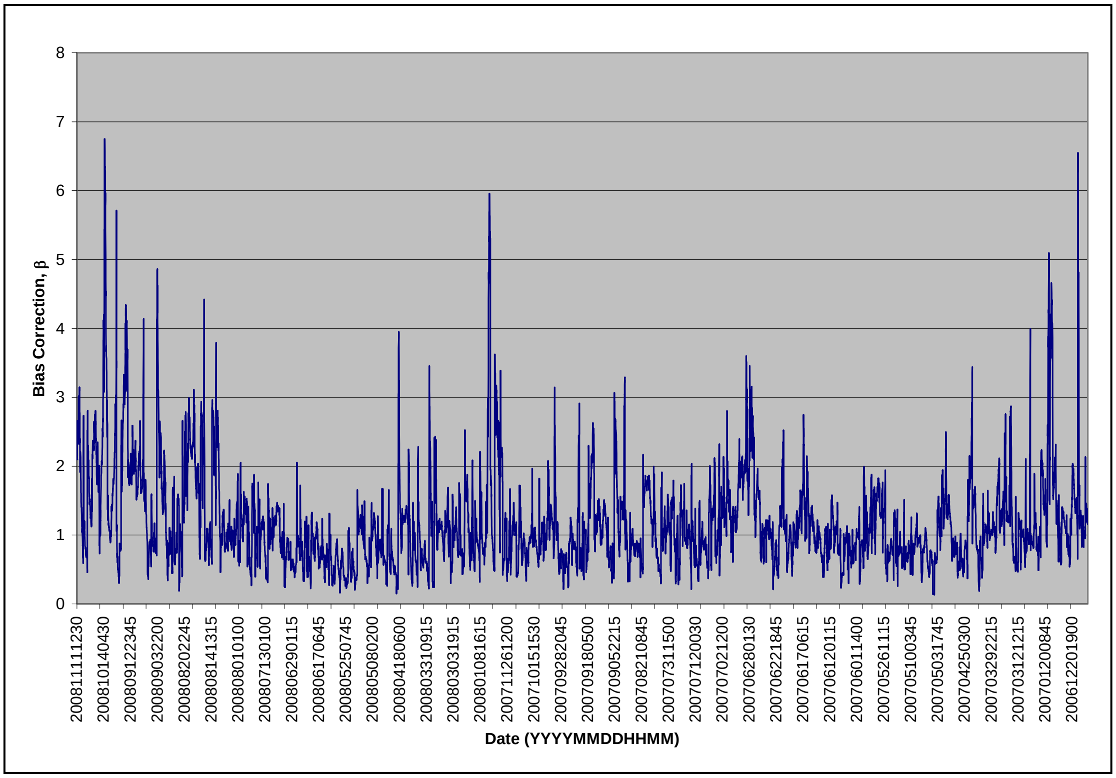

Figure 2 RainVieux bias correction factor timeseries (12-Dec-06 to 11-Nov-08)

Enhancing radar rainfall accuracy is achieved using rain gauge data provided by the Oklahoma Mesonet. The rain gauge accumulation is compared to the radar accumulation to compute the bias correction. After bias correction, there remain some random departures that can be attributed to local wind effects and spatial scale differences between the two observational systems. Examining 15,966 data pairs, the radar and gauge accumulations can be evaluated according to system performance and accuracy. The average difference between corrected and uncorrected radar rainfall measured by rain gauge is shown in Figure 3. The median average difference before correction is 43%, while after correction the median average difference is reduced to 16%, amounting to an improvement in accuracy by 2.6 times. Some of the larger average differences occur during light rainfall when radar and gauge accumulations are small but differ by large percentages.

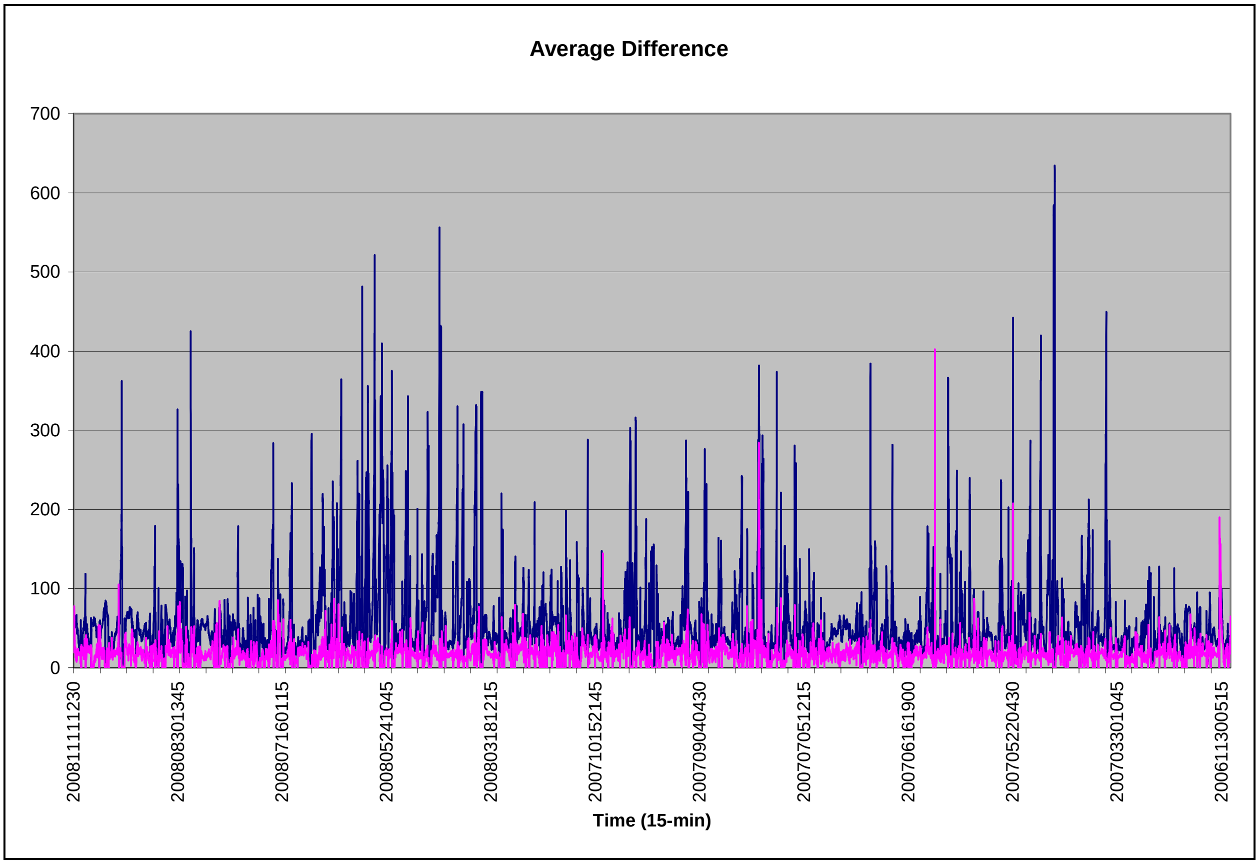

Figure 3 Corrected and uncorrected timeseries of average difference (12-Dec-06 to 11-Nov-08)

The number of gauges used varies by the areal coverage of a rainfall event with larger scale events affecting more gauges. When the timeseries of gauges used is plotted, there appears to be gauges that used on a nearly continuous basis statewide as seen Figure 43. The median number of gauges used per event is nine during this period, and the maximum of 73 occurring on 30-Dec-06. During the period affected by remnants of Tropical Storm Erin, 19-Aug-07, a maximum of only 35 gauges were used.

The RainVieux system tracks the statistical performance automatically and can be viewed from the calibration statistics page internal to the website, which is the source for this evaluation of performance and accuracy. The scatter plot generated by the system for a selected period is shown in Figure 5. The bias correction for this event, 19-Aug-07, was to be 1.748 with a gauge-adjusted average difference of 22.7%.

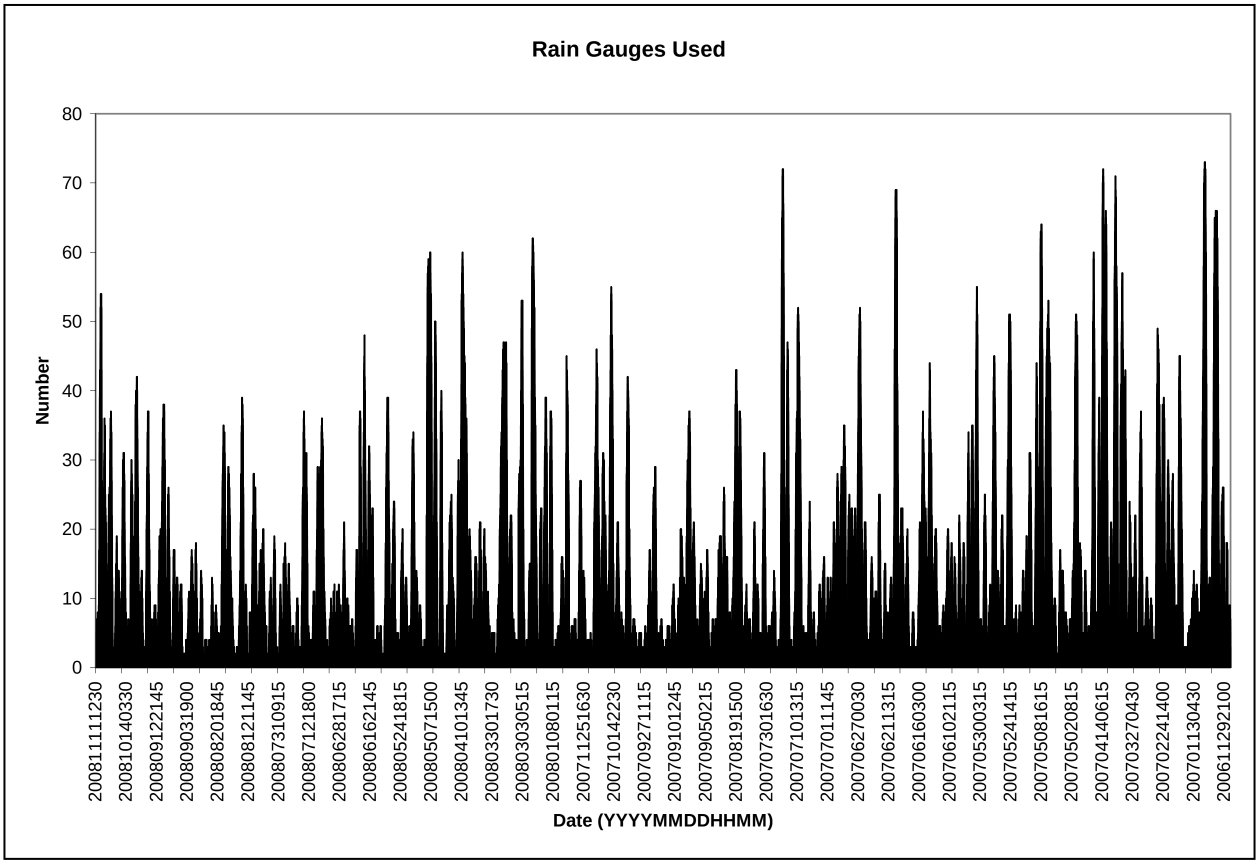

Figure 4 Rain gauges used during radar bias correction of radar rainfall

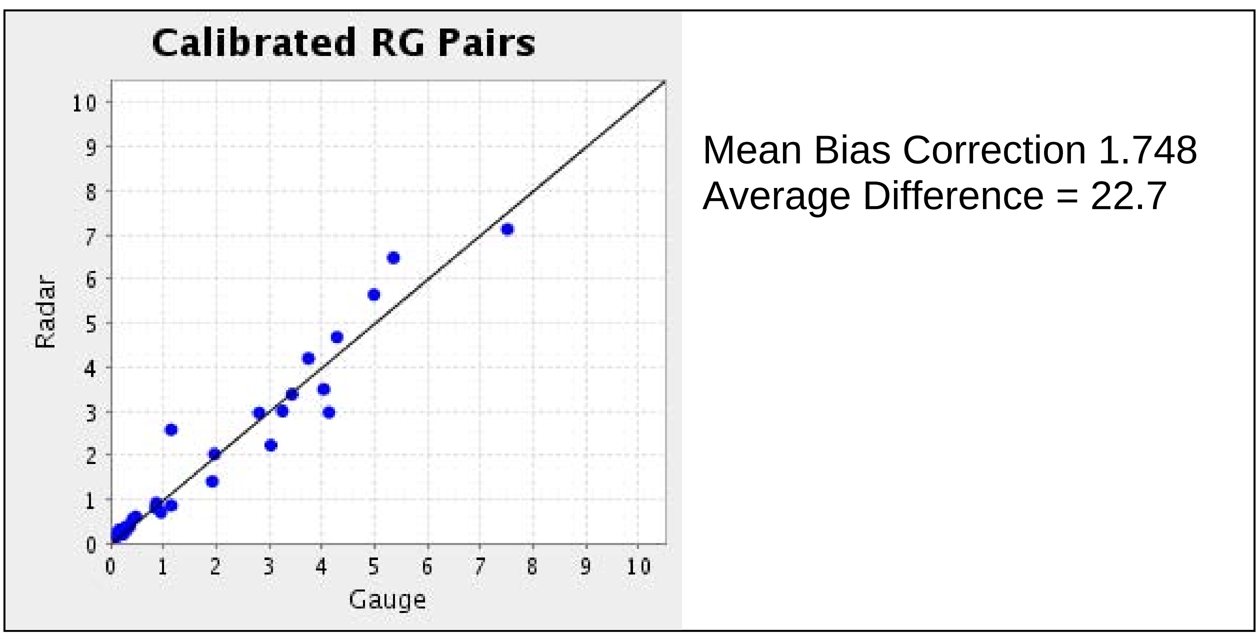

Figure 5 Event-bias corrected gauge and radar accumulations, 19-Aug-07

2.2. Develop scour event criteria and event list for past recorded events.

Scour-critical event criteria was developed for the system using the threshold flood frequencies: 25, 50, 100, and 500 year. The flood frequencies are computed using the USGS WRIR 97-4202 methodology for ungauged locations and from statistical summaries of streamflow for gauged locations. An event engine compares the peak flow rates generated by the hydrologic model Vflo with the flood frequencies. Finally the icon displayed on the website is modified if a bridge has experienced a scour critical event. An icon unique to each threshold is displayed as long as the computed discharge remains above a given threshold.

2.3. Evaluate the performance statistics for specific recorded events and compare forecasts with available high-water marks observed during the March-June 2007 period.

Performance is monitored during recorded events in terms of discharge where available. Note that few bridges have nearby stream gauges, which is one of the motivations for implementing the real-time discharge simulations for scour-critical bridges. The radar and rain gauge data is ingested into the Vflo models to produce simulated flow rates. The bridges monitored since the inception of the system are shown in Figures 6 through 9. The simulated discharge for Bridge 1411 1705 X (NBIS 05418) on Pecan Creek is shown in Figure 6. In Figure 7, simulated discharge is shown for Bridge 4405 1101EX (NBIS17033) over Walnut Creek. Figures 8 and 9 present the simulated flow for Bridge 2546 2022WX (NBIS 17598) and 2546 2022EX (NBIS 17599). In addition to simulated discharge, observed streamflow is plotted in Figure 9 from the stream gauge, USGS 07328500, located approximately four miles downstream from Bridge 2546 2022EX (NBIS 17599). Currently, all bridges setup in Phase III are monitored in real-time using RainVieux and Vflo to predict discharge in each watershed.

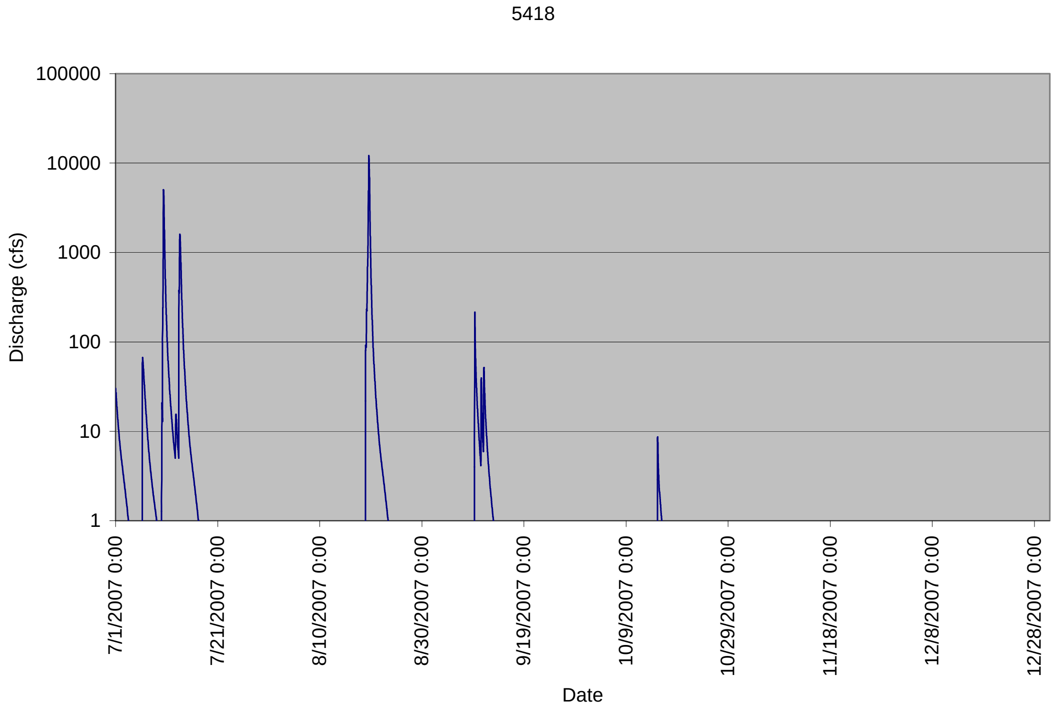

Figure 6 Pecan Creek simulated discharge for Bridge 1411 1705X (1-Jul-07 to 31-Dec-07)

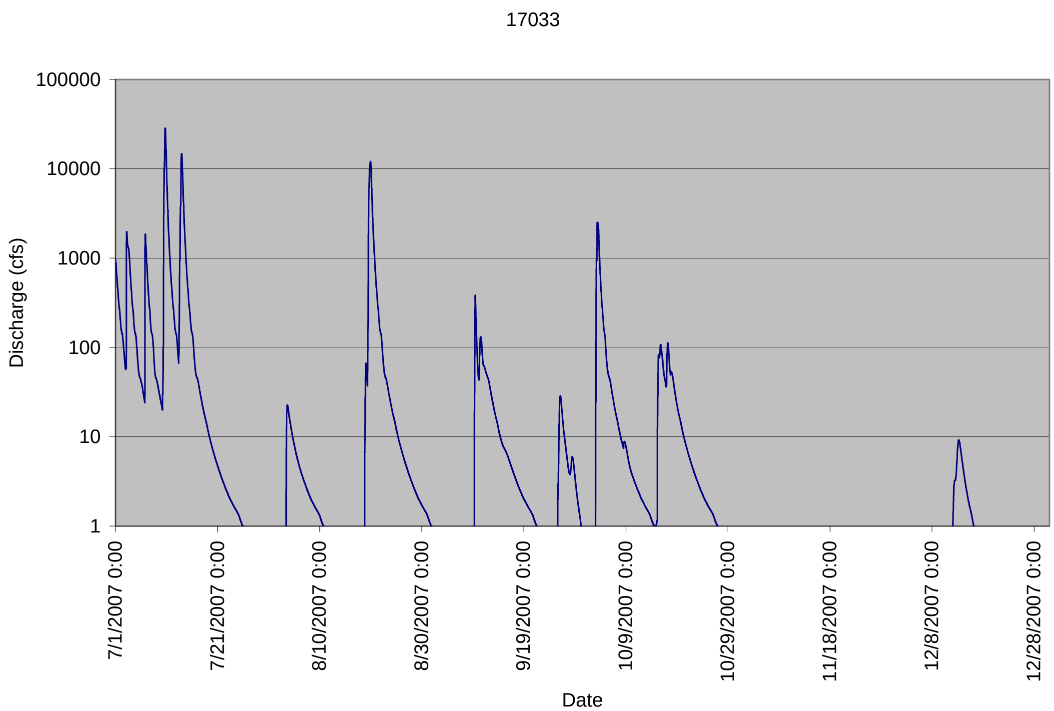

Figure 7 Walnut Creek simulated discharge for Bridge 4405 1101EX (1-Jul-07to 31-Dec-07)

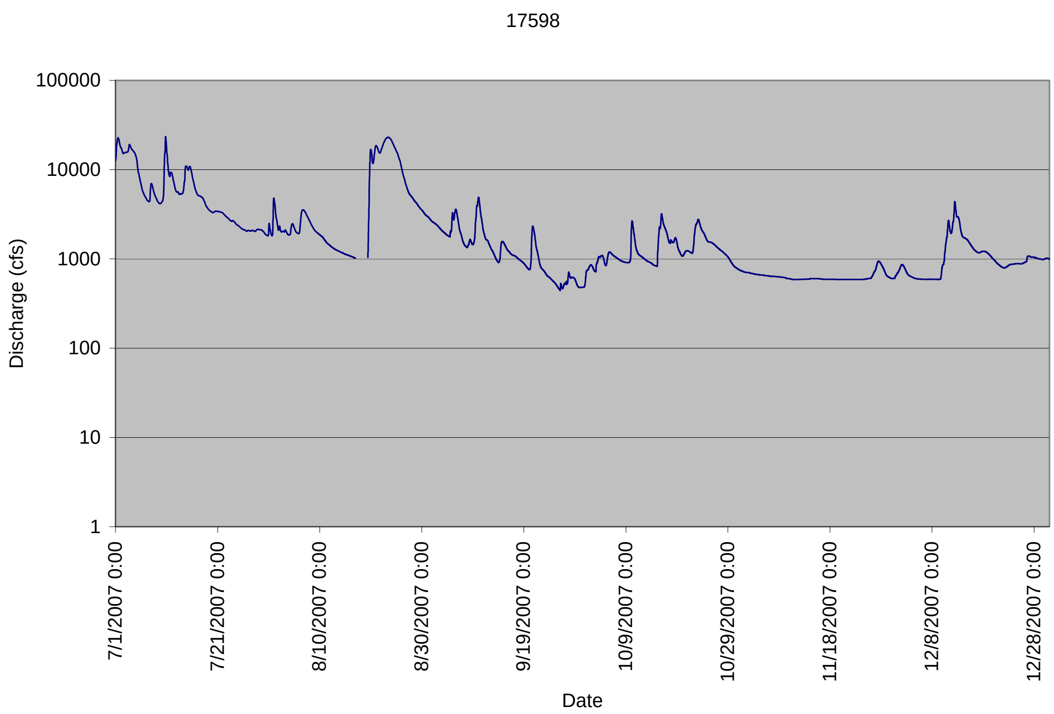

Figure 8 Simulated discharge Bridge 2546 2022WX (NBIS 17598) on I-35 over the Washita River

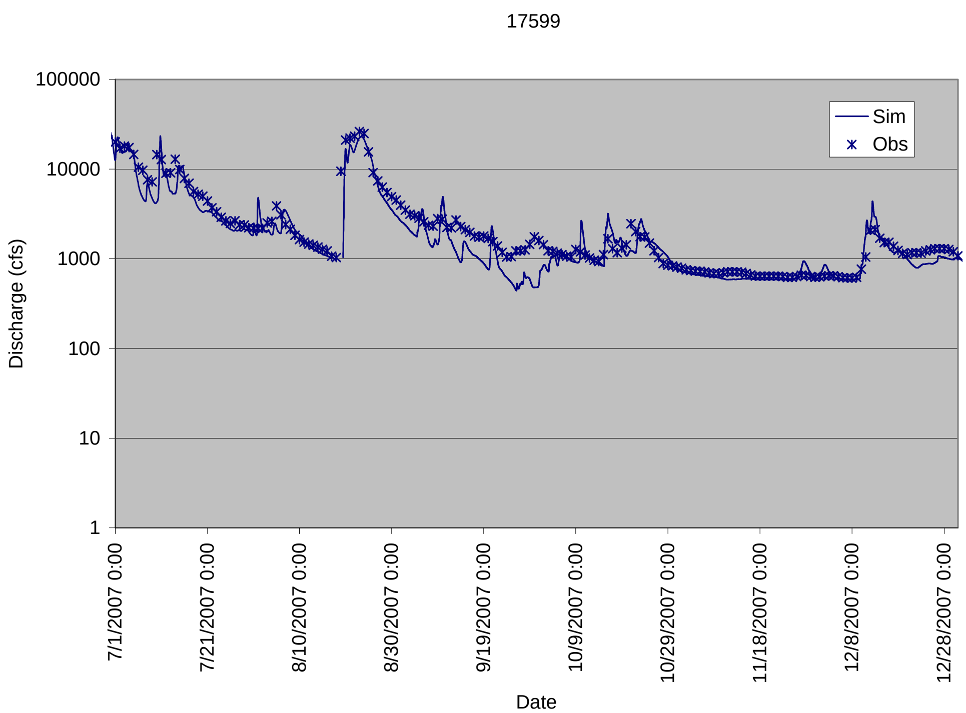

Figure 9 Washita River simulated and observed discharge (1-Jul-07to 31-Dec-07)

During the 6-month analysis period July 1--December 31, 2007, evaluative statistics for the simulated discharge at Bridge 2546 2022EX (NBIS 17599) revealed that the minimum discharge was 249.7 cfs and the maximum was 23,467.5 cfs. There were 44,042 discharge values computed at 15-minute intervals with a mean discharge of 1531.9 cfs for the analysis period. By comparison, the daily observed streamflow at USGS 07328500 had a minimum discharge of 609 cfs and a maximum of 26,300 cfs, and a mean of 3400.3 cfs. The observed and simulated peak discharge occurring on 8/23/2007 is 26300 and 23025.3 cfs, respectively. The accuracy of the simulated peak discharge on this date is 12.45%, which adds considerable confidence to the discharge prediction system for this location.

Analysis of the discharge performance by stratification into classes is accomplished for histogram analysis of the simulated and observed discharge. Figures 10 and 11 show the relative frequency distribution of the observed and simulated discharge, where the frequency of simulated discharge is at 15-minute intervals, and observed discharge at daily intervals.

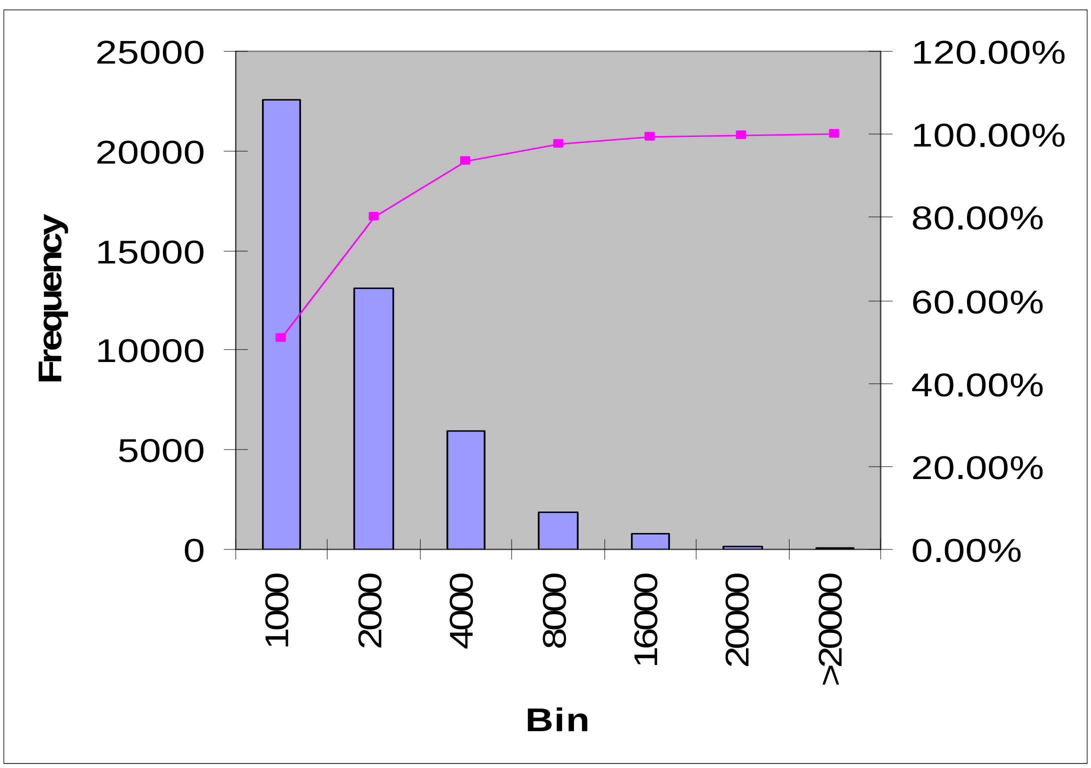

Figure 10 Simulated discharge histogram for July 1 -- December 31, 2007

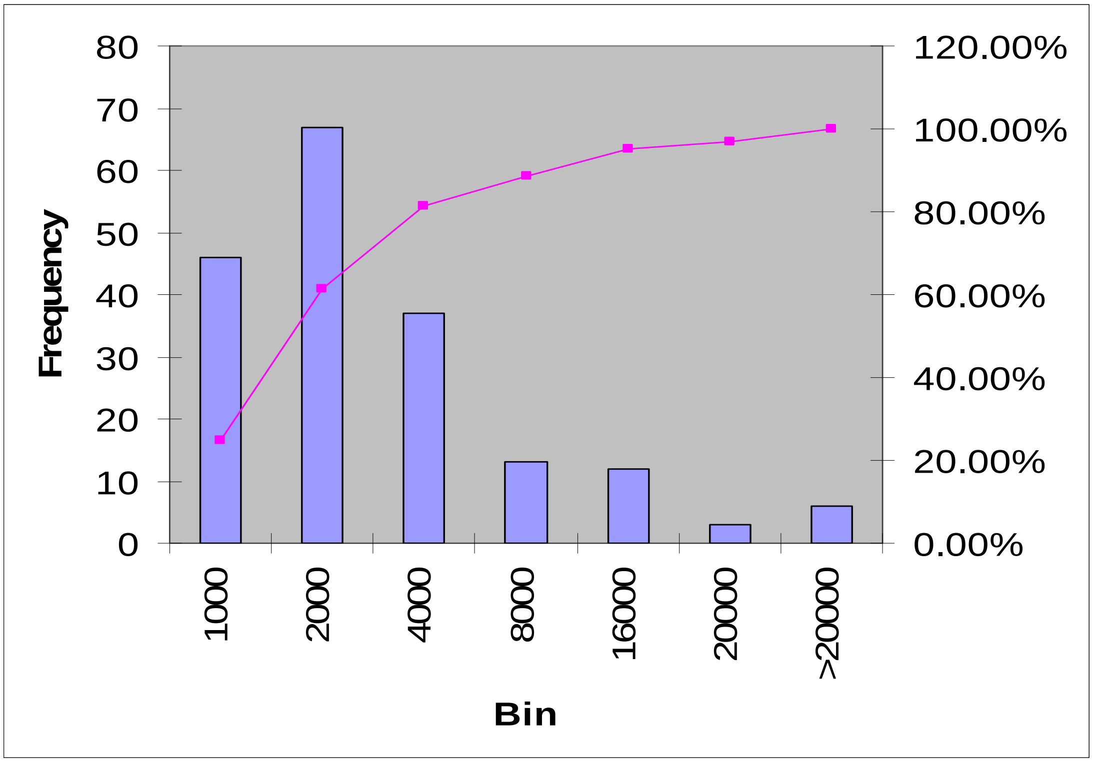

Figure 11 Observed discharge histogram for July 1 -- December 31, 2007

3. Refine the system interface, database, and functionality requirements

The following system items have been implemented in the system database and functionality.

3.1. Incorporate plan of action functionality

The plan of action is a part of the bridge documents and is contained as an element in the database.

3.1.1. Storage of plan of action items in database

The plan of action items is an element in the database.

3.1.2. Retrieval and storage of scour event photos

Photographs are an element in the database, and can be stored for each bridge where provided.

3.1.3. Update and documentation of success of countermeasures

As countermeasure success is documented, the documentation can be uploaded as a bridge document.

3.1.4. Tracking of changes made to plan of action

The tracking of changes made to the plan of action can be performed by the user by uploading a revised or new document.

3.2. Incorporate previous channel profile surveys as cross-sections in the bridge database.

3.2.1. Upload updated Oklahoma-specific Pontis flat files.

Oklahoma-specific information is not contained in the Pontis System operated by FHWA/ODOT. However, when this requirement was made known, an additional file upload and parsing was developed to facilitate the uploading of Oklahoma-specific bridge information. The procedure is now set to read an Excel spreadsheet generated by ODOT that contains the updated Oklahoma data for ingest to the ScourCast database.

3.2.2. Populate ScourCast database with channel profile data

The channel profile data provided has been uploaded in the database, and is accessible via the system display. Each point on a given profile can be queried through the interface. As more profiles are uploaded, a history of scour profiles is developed and stored for ready access. Figure 12 shows the profile for the as-built and during an inspection. The red line in the image shows the profile on January 27, 2008, showing the utility of the system for display of channel profiles.

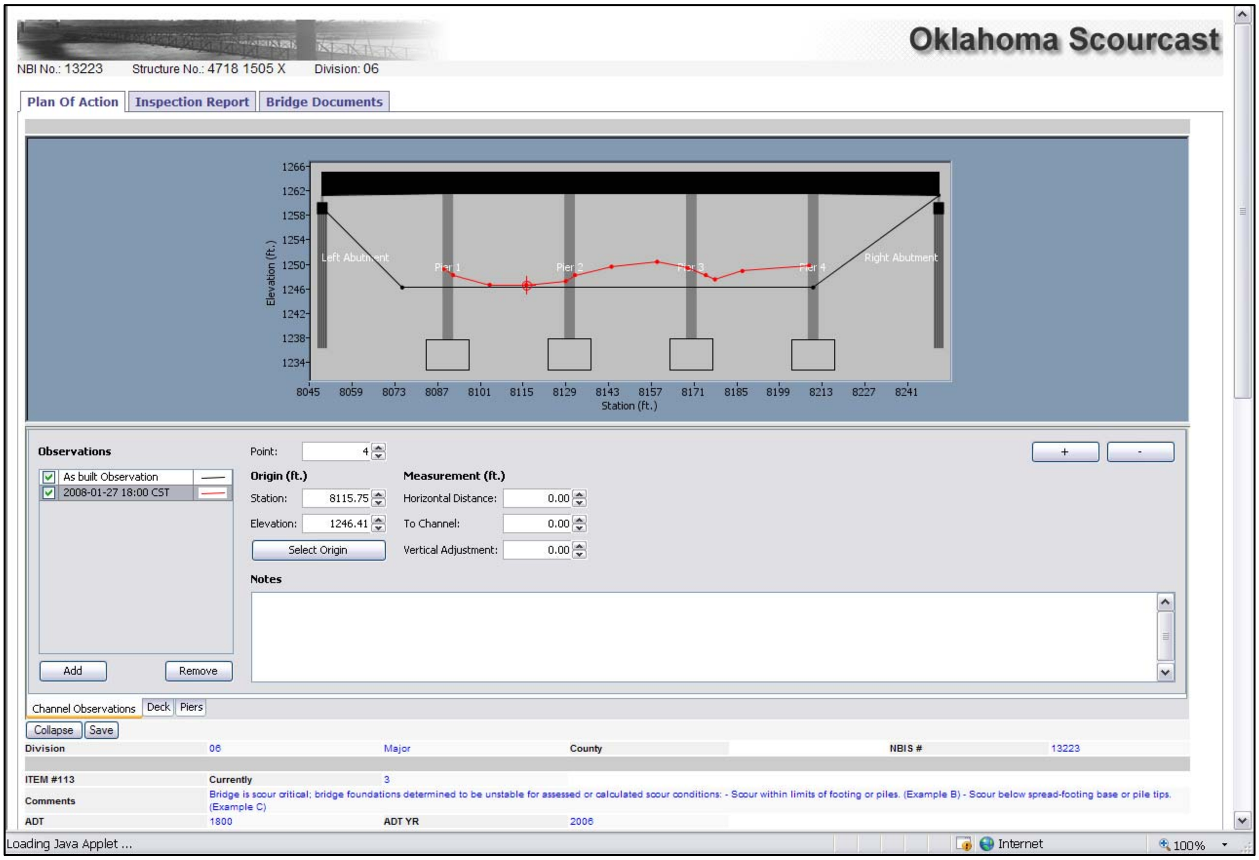

Figure 12 ScourCast channel profile observations

The deck and piers tab on this system shows details when available from uploaded data for each bridge. Figure 13 presents the piers tab with the right abutment selected. The abutment information shows the top of pier, top of foundation, and bottom of foundation.

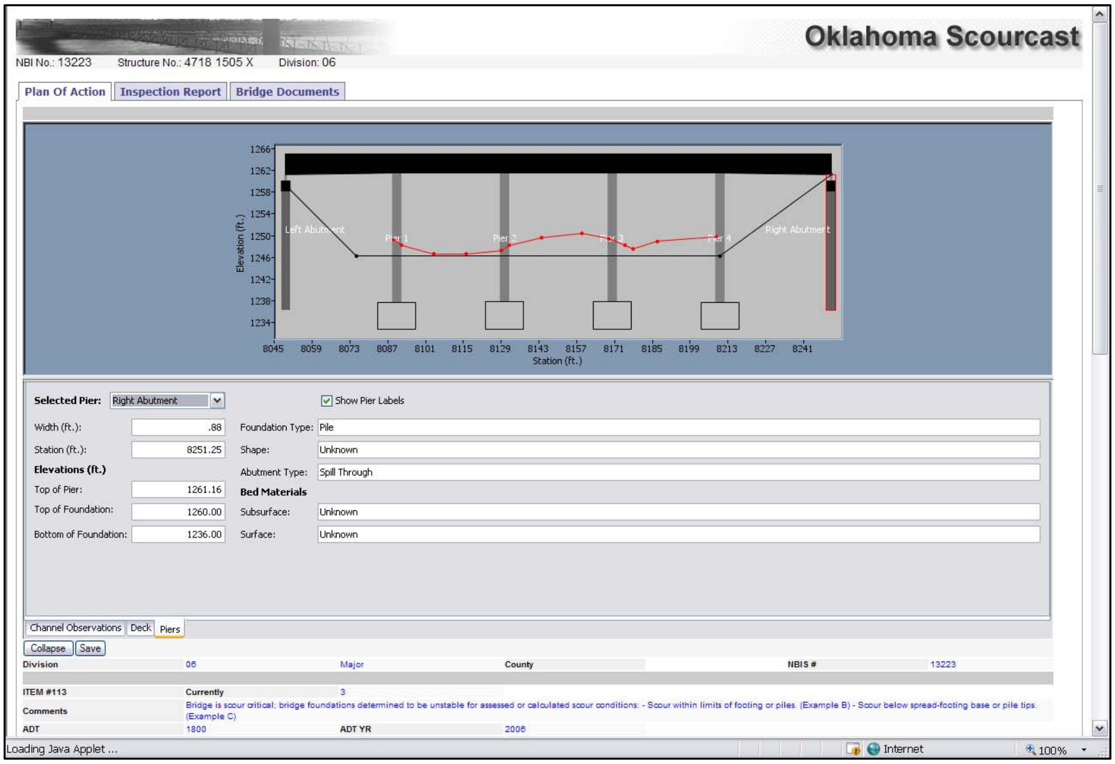

Figure 13 Pier information page showing right abutment and foundation details

3.3. Notification System

3.3.1. Identify notification requirements, events that trigger notification, and who gets notified and by which method. Event criteria will consider the Q2, 5, 10, 25, 50, 100, and 500 year return intervals.

Notification requirements have been established based on the flow quantile threshold. Once email and phone numbers are provided for contact ODOT personnel, event notifications will be sent as text messages when the simulated flow exceeds a flow threshold. During each 15-minute period, the system updates simulated flow rates and compares these values with the Q2 flow rate. A threshold notification sent as a simple text message will notify personnel when simulated discharge exceeds the threshold established for each bridge.

The procedure set for the notification is the insertion of SMS-capable mobile phone numbers and/or email addresses. When an event threshold occurs, a notification will be sent by the system. When provided, these phone numbers and addresses will be sent notifications.

3.3.2. Develop system to provide notification when events occur due to threshold exceeded (Q10), implementation of counter measures, upload of cross-section survey data, and closure plans.

The events identified since the inception of the system are identified by the crossing of a threshold. The flow rate corresponding to the Q2 constitutes an exceedance event. The list of events shown in Table 1 indicates which bridges have exceeded the Q2 threshold in the Divisions during the analysis period. The flow rate and the corresponding Q2 threshold for each bridge and event are shown. Multiple 15-minute periods are shown for some bridges indicating the number of times and the duration that the threshold was exceeded.

Table 1 Bridges experiencing threshold exceedance during the monitoring period

NBI	DIV	FLOW (CFS)	DATE	Q2
5418	6	12047.23	2007-08-19 14:30:00	1540
5418	6	9740.722	2007-08-19 16:30:00	1540
17033	3	12130.37	2007-08-19 23:15:00	5430
17599	3	16849.46	2007-08-20 00:00:00	11100
17599	3	18662.08	2007-08-21 01:00:00	11100
17599	3	23025.34	2007-08-23 10:00:00	11100
17599	3	16464.95	2008-04-11 21:15:00	11100
17599	3	12311.39	2008-06-10 03:30:00	11100
17598	3	16849.46	2007-08-20 00:00:00	11100
17598	3	18662.08	2007-08-21 01:00:00	11100
17598	3	23025.34	2007-08-23 10:00:00	11100
17598	3	16464.95	2008-04-11 21:15:00	11100
17598	3	12311.39	2008-06-10 03:30:00	11100

NBI	DIV	FLOW (CFS)	DATE	Q2
2861	6	246.189	2008-09-12 04:45:00	157
2861	6	241.515	2008-09-12 13:45:00	157
3006	6	430.532	2008-09-12 06:45:00	256
3006	6	260.593	2008-09-12 07:45:00	256
3006	6	259.611	2008-09-12 10:30:00	256
3006	6	376.534	2008-09-12 11:30:00	256
3006	6	370.149	2008-09-12 12:00:00	256
3057	6	622.923	2008-09-12 07:00:00	299
3057	6	305.832	2008-09-12 08:30:00	299
3057	6	310.432	2008-09-12 11:00:00	299
3057	6	461.877	2008-09-12 13:00:00	299
12556	6	357.423	2008-09-12 11:15:00	271
13223	6	16919.07	2008-09-12 09:45:00	1070
13309	6	270.367	2008-09-12 06:30:00	189
13309	6	228.972	2008-09-12 06:45:00	189
13309	6	208.222	2008-09-12 11:15:00	189
13309	6	215.988	2008-09-12 11:30:00	189
19297	6	543.831	2008-09-12 08:15:00	93.7
19297	6	603.36	2008-09-12 09:45:00	93.7
2136	8	676.355	2008-11-06 02:15:00	438
2136	8	455.251	2008-11-06 04:00:00	438
16173	8	6033.666	2008-11-06 04:15:00	2136
16884	4	1325.8	2008-11-05 23:45:00	652
16884	4	690.658	2008-11-06 00:30:00	652
16884	4	1260.859	2008-11-06 02:00:00	652
16884	4	1728.286	2008-11-06 02:15:00	652

There were notable events recorded by the system in both 2007 and 2008. During the period associated with remnants of Tropical Storm Erin, bridges in Division 3 and 6 were found to exceed the specified thresholds during August 19-23, 2007. Bridges NBIS 5418, 17033, 17599, and 17598 located in the Washita River responded to this storm event due to the accumulated depth and broad areal coverage. In 2008, NBIS 17598 and 17598 exceeded the Q2 on April 11 and June 10th. In the Fall of 2008 heavy precipitation occurred on September 12th as shown in Figure 14. Seven Division 6 bridges exceeding the Q2 threshold on this date, and then again on November 5-6th, two bridges in Division 8 and one in Division 4 exceeded the Q2 threshold. The largest exceedance based on flow was at NBIS 13223 in Division 6 when the discharge of 16,919 cfs exceeded the Q2 of 1,070.00 cfs. This event peak discharge exceeded the Q100 but not the Q500. Rainfall total for this event measured by the system is shown in Figure 14 with heavy rainfall over Division 6 as indicated by the scale where more than 6 inches fell. Model predictions are made and compared to flow thresholds of 2, 5, 10, 25, 50, 100, and 500 yr. In 2008, three bridges crossed thresholds. Table 2 shows three bridges on S.H. 8 and two on U.S. 60, along with the predicted flow rates and threshold discharge values for Q100, Q10, and Q25.

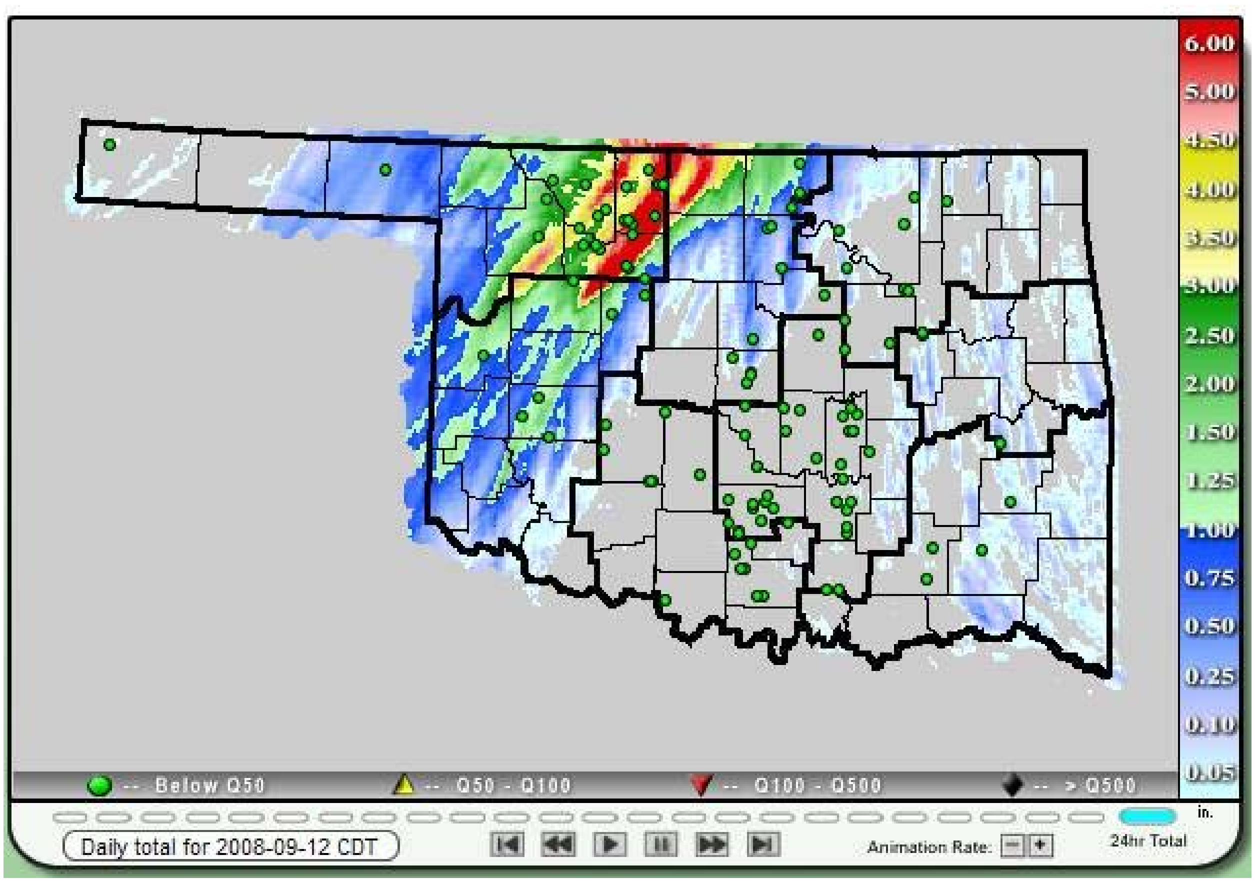

Figure 14 Extreme event on September 12, 2008 detected by threshold exceedance

During the September 11th event, bridge icons changed to show the magnitude of the exceedance. The dashed circle in Figure 15 indicates the bridge icons that were automatically updated to reflect the exceedance level.

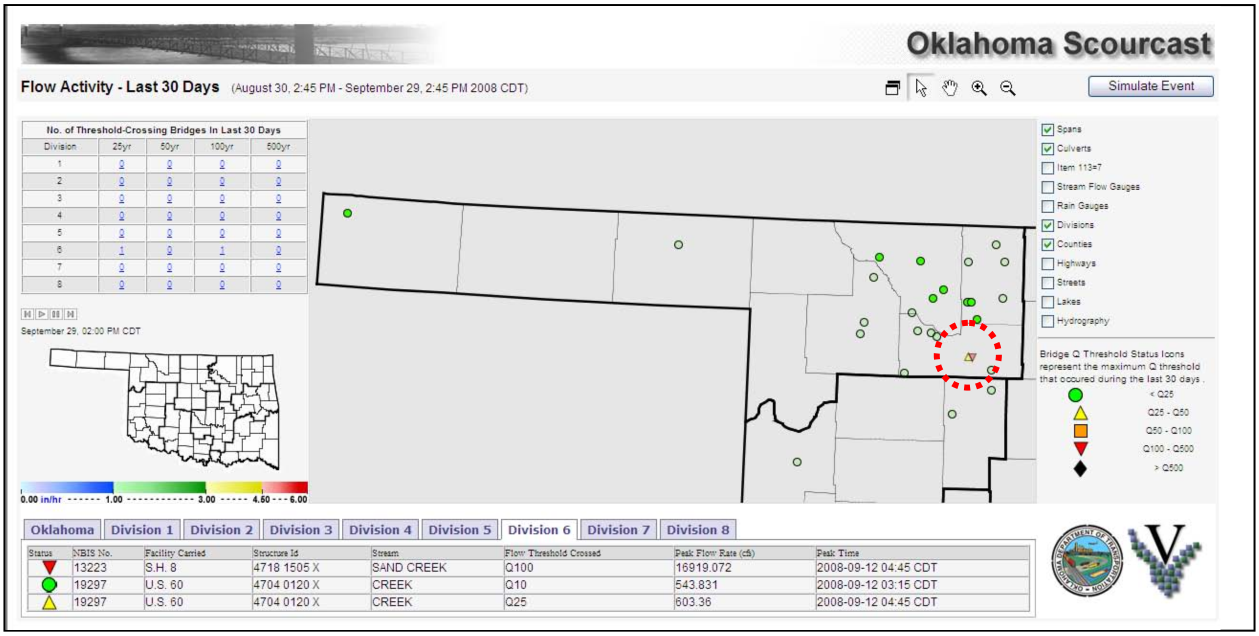

Figure 15 System display showing icons for in Division 6 bridges exceeding thresholds

Table 2 Thresholds crossed for three bridges in 2008, Division 6

Symbol	NBI	Highway	Bridge Number	Creek	Threshold	Peak (cfs)	Date and Time
Red Triangle	13223	S.H. 8	4718 1505 X	SAND CREEK	Q100	16919	2008-09-12 04:45 CDT
Green Circle	19297	U.S. 60	4704 0120 X	CREEK	Q10	543	2008-09-12 03:15 CDT
Yellow Triangle	19297	U.S. 60	4704 0120 X	CREEK	Q25	603	2008-09-12 04:45 CDT

3.3.3. Evaluate criteria for detection and notification of over-topping events

The criteria for notification for over-topping will be initiated in the system as directed by ODOT Bridge Division. This will require identification of the discharge expected to overtop the structure. The frequency of the over-topping event differs for each bridge and may not be readily known for older bridges. With the information provided, bridges that exceed the 500-yr event will be known which is nearly certain to overtop the bridge. Future refinements can be made when more specific information becomes available.

4. Prepare system documentation for system and database schema and functionality.

4.1. Document system functionality for current system and planned expansion

The system contains the functionality as documented below and as found via the website. The following images from the system document the functionality and display configuration achieved in Phase III of this project. The following screen shots document the main information displayed in the website prototype, documenting the system functionality. The homepage for the system is shown in Figure 16 along with the major system display functions.

Homepage

- Real-Time Flow Simulation
- 24hr Rainfall Animation with Total
- GIS Mouseover Data
- Scalable (Zoom – Pan)
- Toggle Layers
- Bridge Q Threshold Status
- Data View by Division

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Figure 16 Homepage showing ScourCast functions on statewide page.

The Division page shows five major parts for the system in Figure 17, which are:

1. Summary Table - No. of Threshold Crossings in the Last 30 days.
2. Current Rainfall over the State of Oklahoma
3. Bridge icons showing threshold exceedance with mouse-over for bridge information
4. Selectable layers for display control and icon legend
5. Threshold crossing summary for bridge showing discharge and time of peak

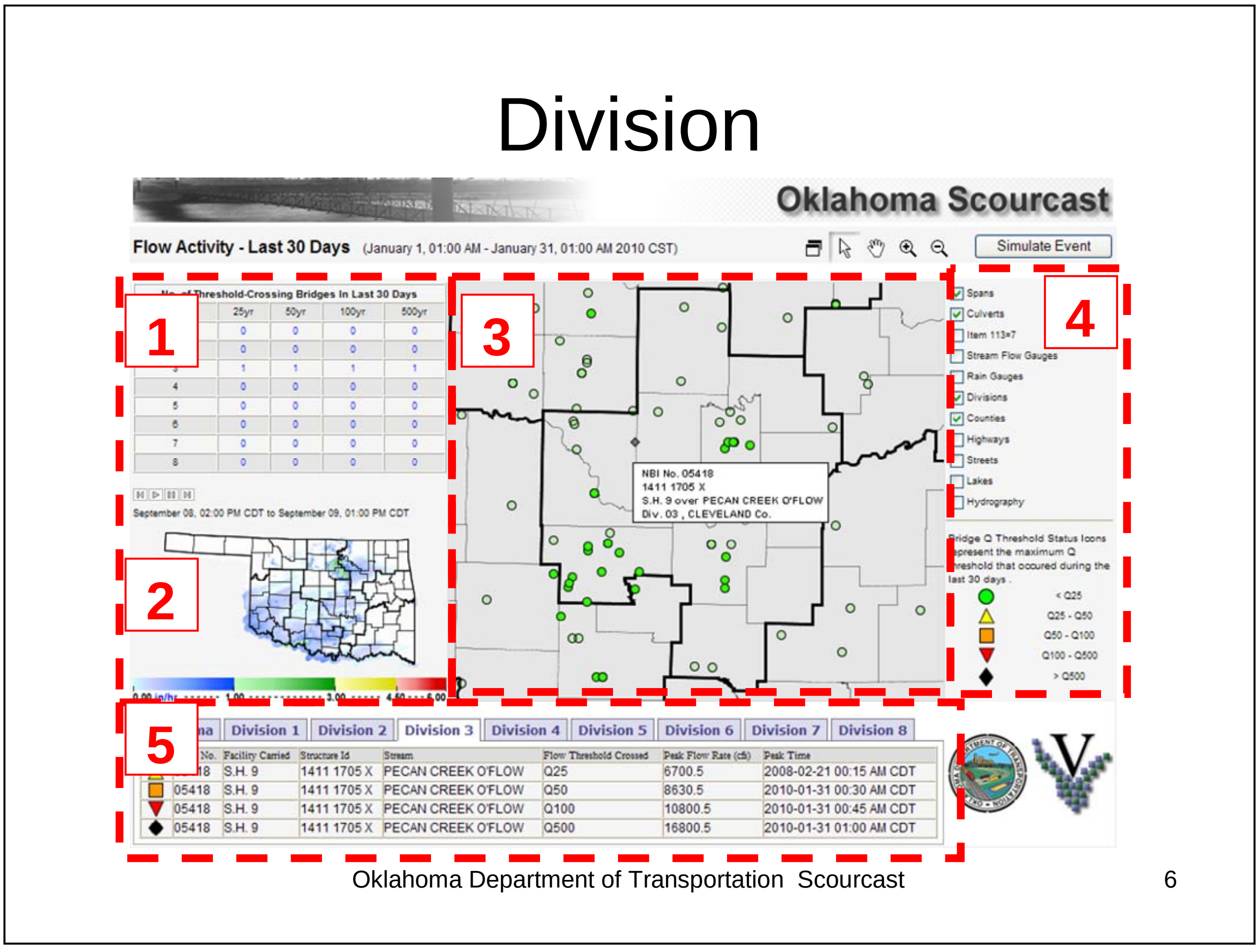
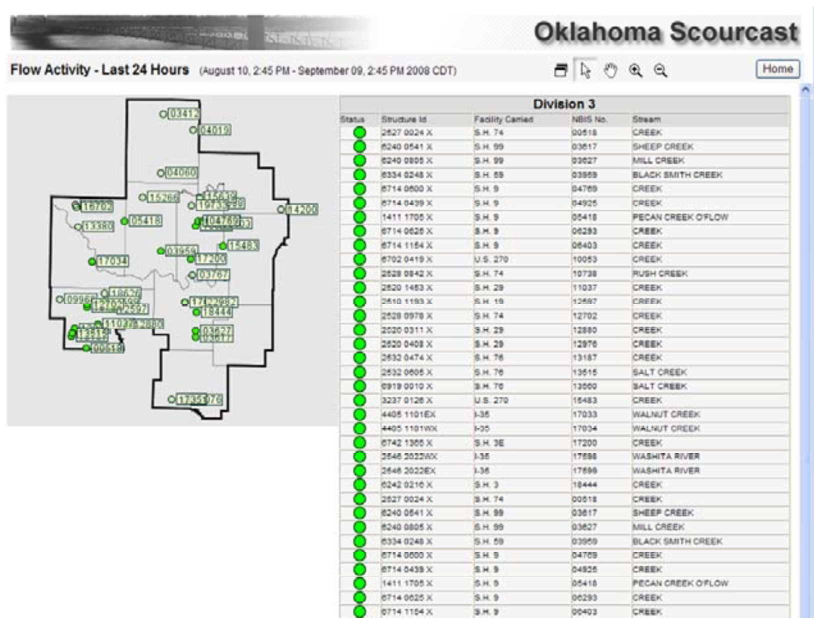


Figure 17 Division Page showing flow activity summary for divisions and current rainfall

Flow activity for the last 24 hours is shown in Figure 18. The summary includes the current icon that indicates if a threshold has been crossed and the magnitude at each bridge with basin, Structure ID, Facility Carried, NBIS, and Creek name.



- Observe Bridge Threshold Status by Division
- Status for the Basin showing Bridge NBI and Structure ID

Figure 18 Flow activity shown for selected division along with NBI and Structure No.

System functionality is displayed in Figure 19 with following elements.

- Bridge Diagram with As-Built and Observed Channel Profiles
- Bridge data loaded dynamically from an updatable Bridge Virtual File (.bvf)
- Plan Of Action (Pontis Data Display)
- NBI-ready Data Display
- User-Created Observed Channel Profiles
- Inspection Report Display (from collected data or .PDF formatted documents)
- Bridge Document Accessibility (.PDFs, images, etc.)

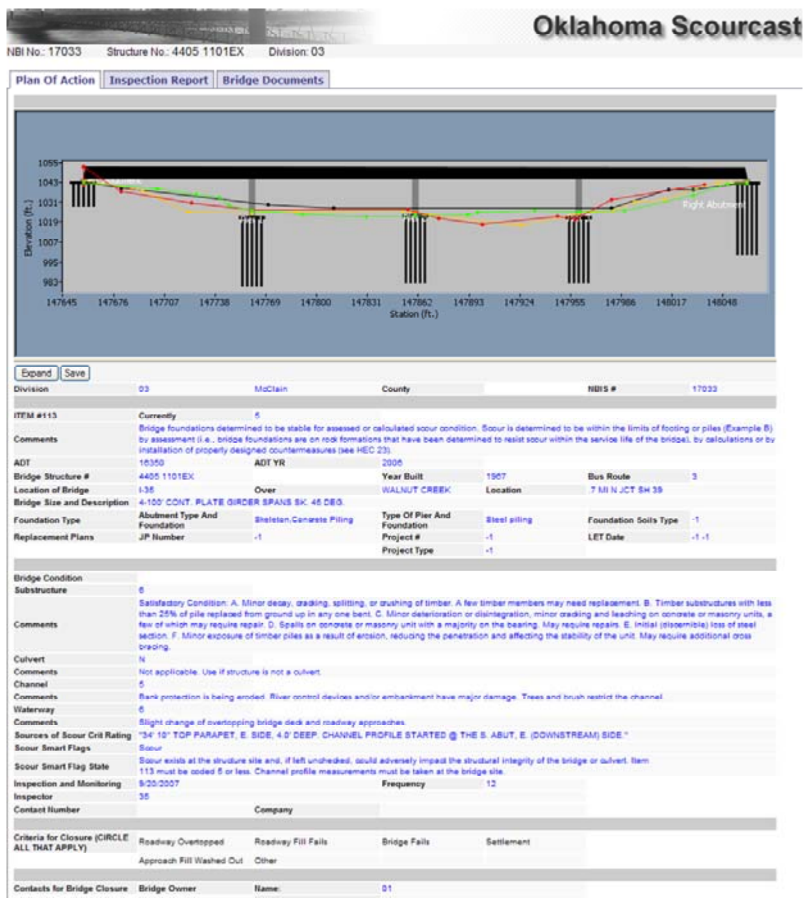
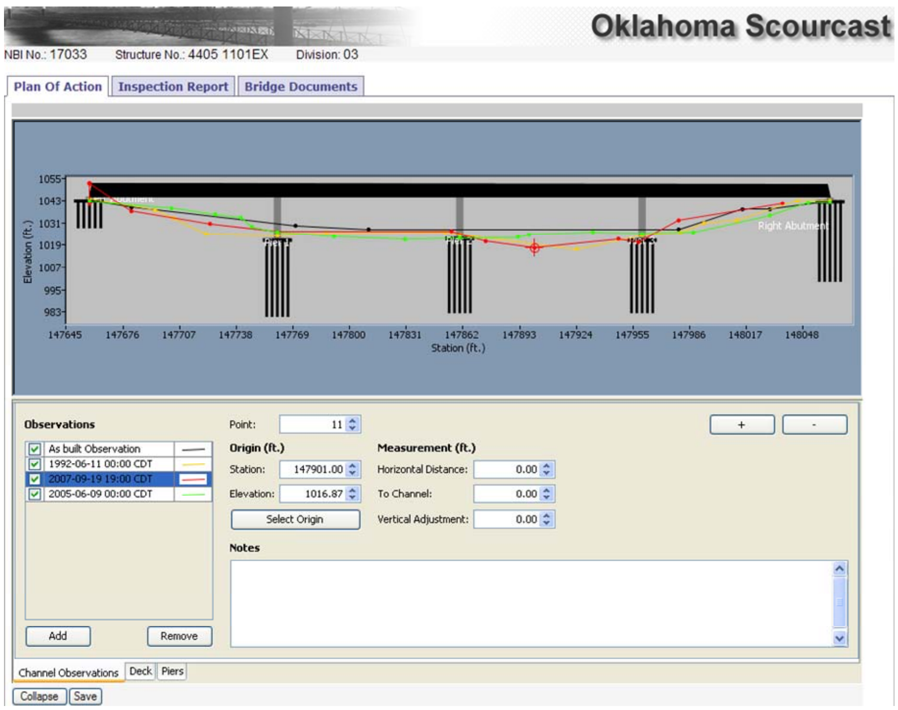


Figure 19 Bridge Diagram, Plan of Action, Channel Observations, and Documents

An applet was written that supports input of the Bridge Diagram and Observed Channel Profile Input. The primary elements and functionality shown in Figure 20 are:

- Bridge View, Add, or Remove Observed Channel Profiles
- View Bridge Deck and Pier Attributes
- Save Updates



- View, Add, or Remove Observed Channel Profiles
- View Bridge Deck and Pier Attributes
- Save Updates

Figure 20 Bridge Diagram and Observed Channel Profile Input

The bridge inspection report, display, and tracking functionality shown in Figure 21 includes the storing and display of the Bridge Inspection Report and supports automated generation when data is available.

- Bridge Inspection Report (.PDF) ready for viewing
- Inspection Report can be generated dynamically if the data is available

- Bridge Inspection Report (.pdf) ready for viewing
- Inspection Report can be generated dynamically if the data is available

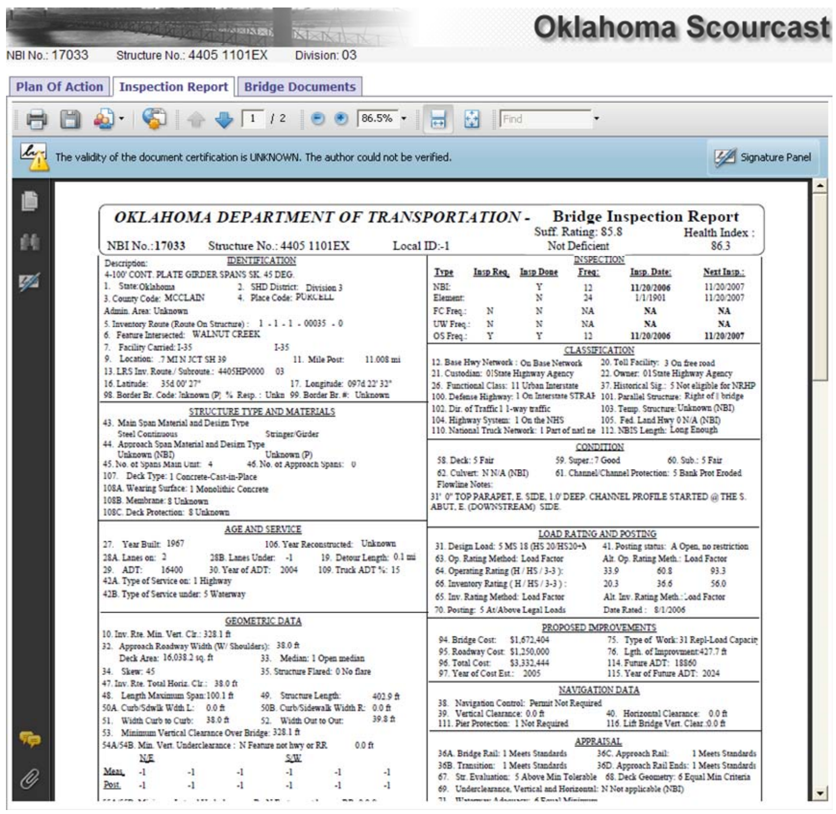
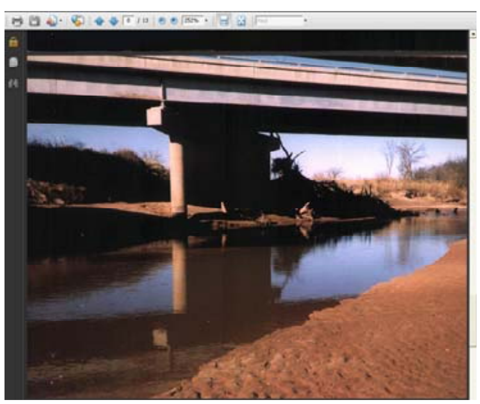


Figure 21 Sample Bridge Inspection Report

One of the most important elements to view in relation to scour is the foundation of the bridge as depicted in Figure 22 with ready access to important bridge documents. The types of documents supported by the system are as follows:

Bridge Documents-

- Bridge Plans
- Foundation
- Photographs
- Scour Documents
- Channel Profile
- Inspection Report
- Pier Sway
- Scour Photos
- Documents
- Load Rating
- Scour Reports
- Fracture Critical Inspection
- Materials Report
- Roadway Plans
- Underwater Inspection



Bridge Documents-
Bridge Plans
Foundation
Photographs
Scour Documents
Channel Profile
Inspection Report
Pier Sway
Scour Photos
Documents
Load Rating
Scour Reports
Fracture Critical Inspection
Materials Report
Roadway Plans
Underwater Inspection

Figure 22 Sample Bridge Document Links

A bridge diagram and data dictionary for main bridge components was developed for display of the graphical diagram. The bridge applet shows the key structural elements of a bridge in relation to observed and predicted scour depths. The two types of structures that can be shown are span bridges and culverts. The diagram shown in Figure 23 shows the relation between observed water channel profiles and the bridge foundation. Elements to be displayed include the bridge deck elevation, piers, and foundation. Adjustments to the bridge deck elevation include vertical curves. A critical piece of information is shown for each bridge, the level entered for Item #113.

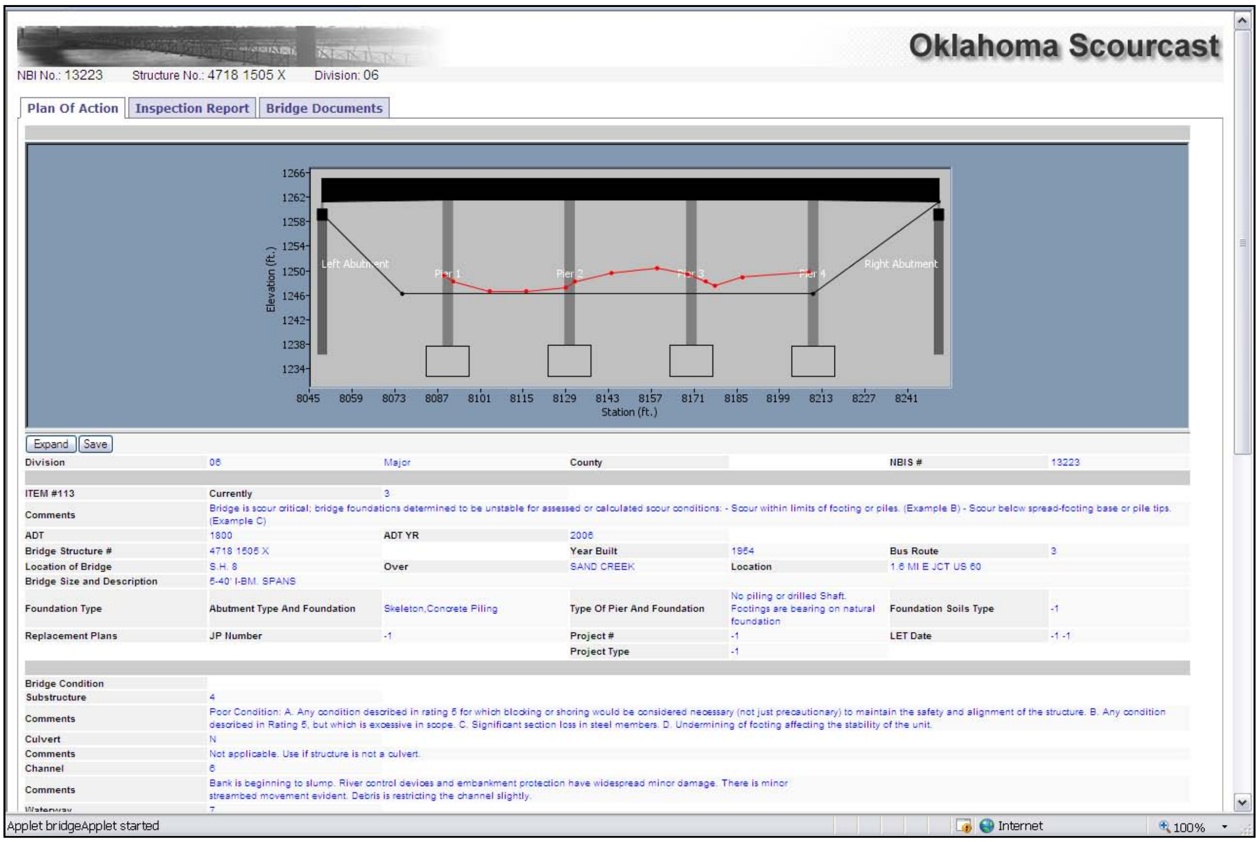


Figure 23 Sample Bridge Diagram Elements

Updating a bridge with profile measurements is an important countermeasure. Modifications in Phase III resulted in an improved form provided for Input of channel observations as shown in Figure 24.

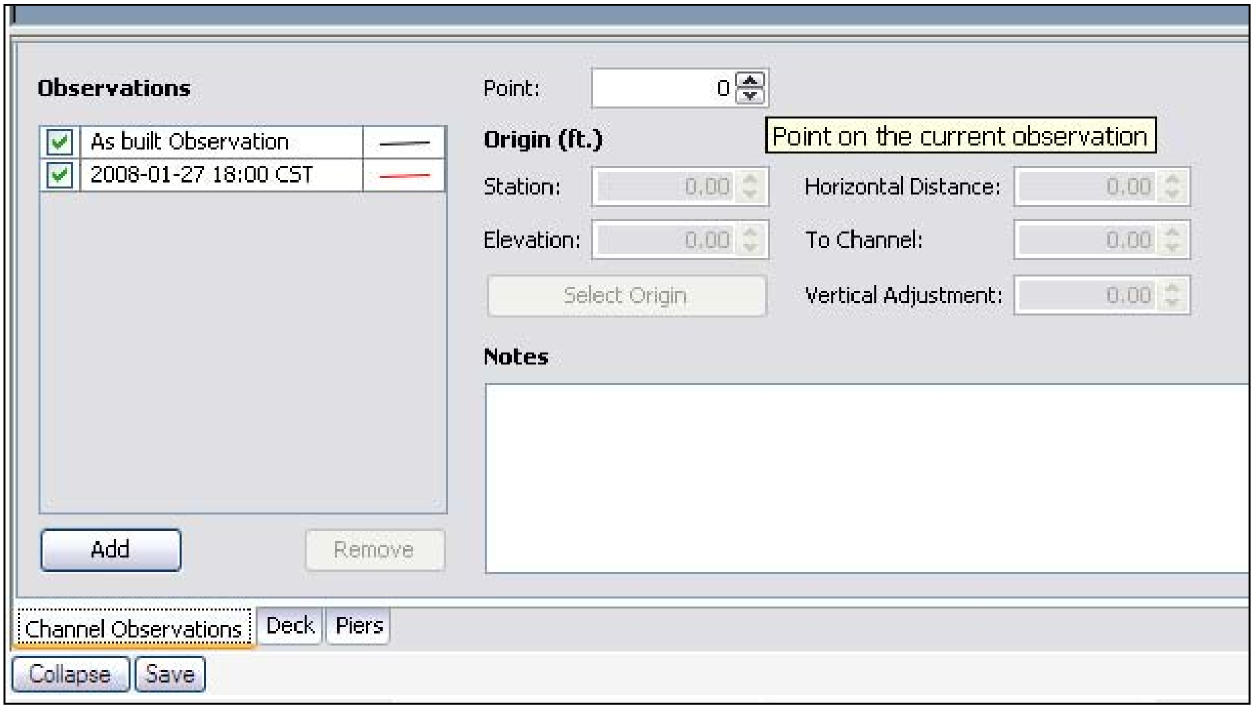


Figure 24 Channel observation input form

4.2. Identify operational requirements and scalability for current and projected bridges in database

The operational requirements for the bridge database have been established and incorporated into the database schema and functionality.

4.3. Publish feasibility, performance, and evaluative benchmarks

Publication of the feasibility, performance and evaluative benchmarks was made during the conference poster presentation in ERAD 2008 - The Fifth European Conference On Radar In Meteorology And Hydrology, Helsinki Finland, June 28-July 3, 2008. The extended abstract, entitled: *Integrated Radar and Hydrologic Modeling for a Bridge Scour Monitoring System*" is contained in Appendix B.

3. SUMMARY AND CONCLUSIONS

The ability to track current flow conditions at a scour-critical bridge is needed because few stream gauges exist near or at these bridges. Accessibility of critical information is necessary to take appropriate actions when high flow rates occur at scour-critical bridges. Real-time scour risk identification serves as a countermeasure for scour-critical bridges. The system provides plan of actions and other bridge information needed for scour critical bridges in Oklahoma. The real-time modeling and monitoring of flow rates at scour-critical bridges helps ODOT monitor conditions that may lead to bridge failure due to undermining of the foundation of these bridges. This project resulted in establishment of a ScourCast™ system with functionality as a countermeasure for scour-critical bridges.

ScourCast™ supports the management and response plan for monitoring scour-critical bridges within the State of Oklahoma in compliance with the FHWA regulations. The resulting system assists in the identification of elevated risk conditions and track agency responses as a real-time operational system. The system for tracking threshold exceedance is demonstrated and found to be feasible through performance evaluation. The ScourCast™ website and database design was evaluated and refined with user comments and functionality requirements.

4. REFERENCES

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3. Richardson, E.V., S.R. Davis, 2001. EVALUATING SCOUR AT BRIDGES. Federal Highway Administration National Highway Institute, Arlington, Virginia 22203. FHWA-NHI-01-001, Hydraulic Engineering Circular, HEC-18.

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5. Lagasse, P.F., M.S. Byars, L.W. Zevenbergen, P.E. Clopper, 1997. BRIDGE SCOUR AND STREAM INSTABILITY COUNTERMEASURES: Experience, Selection and Design Guidance. Federal Highway Administration National Highway Institute, Arlington, Virginia 22203. FHWA-HI-97-030, Hydraulic Engineering Circular, HEC-23.

6. Tortorelli, R.L., 1997. Techniques for estimating peak-streamflow frequency for unregulated streams and streams regulated by small floodwater-retarding structures in Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 97-4202, 39 p.

5. APPENDICES

5.1.1. Appendix A - Maps showing bridges grouped according to Hydrologic Unit Codes (HUC)

5.1.2. Appendix B - Paper published at the ERAD 2008 - THE FIFTH EUROPEAN CONFERENCE ON RADAR IN METEOROLOGY AND HYDROLOGY, Helsinki Finland, June 28-July 4, 2008. Entitled: "Integrated Radar and Hydrologic Modeling for a Bridge Scour Monitoring System"

APPENDIX A

List of Figures

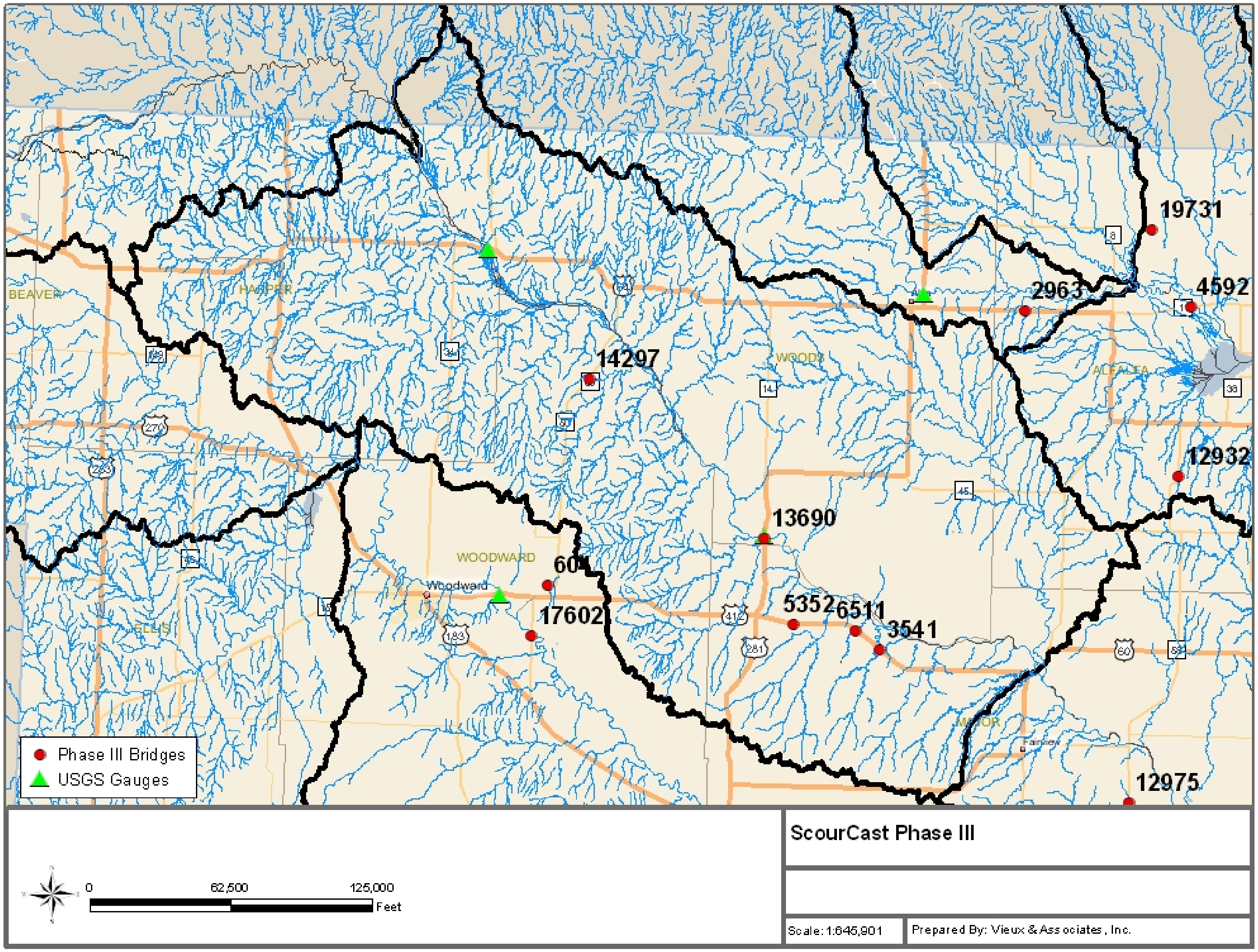


Figure A-1 Bridges in HUC 11050001

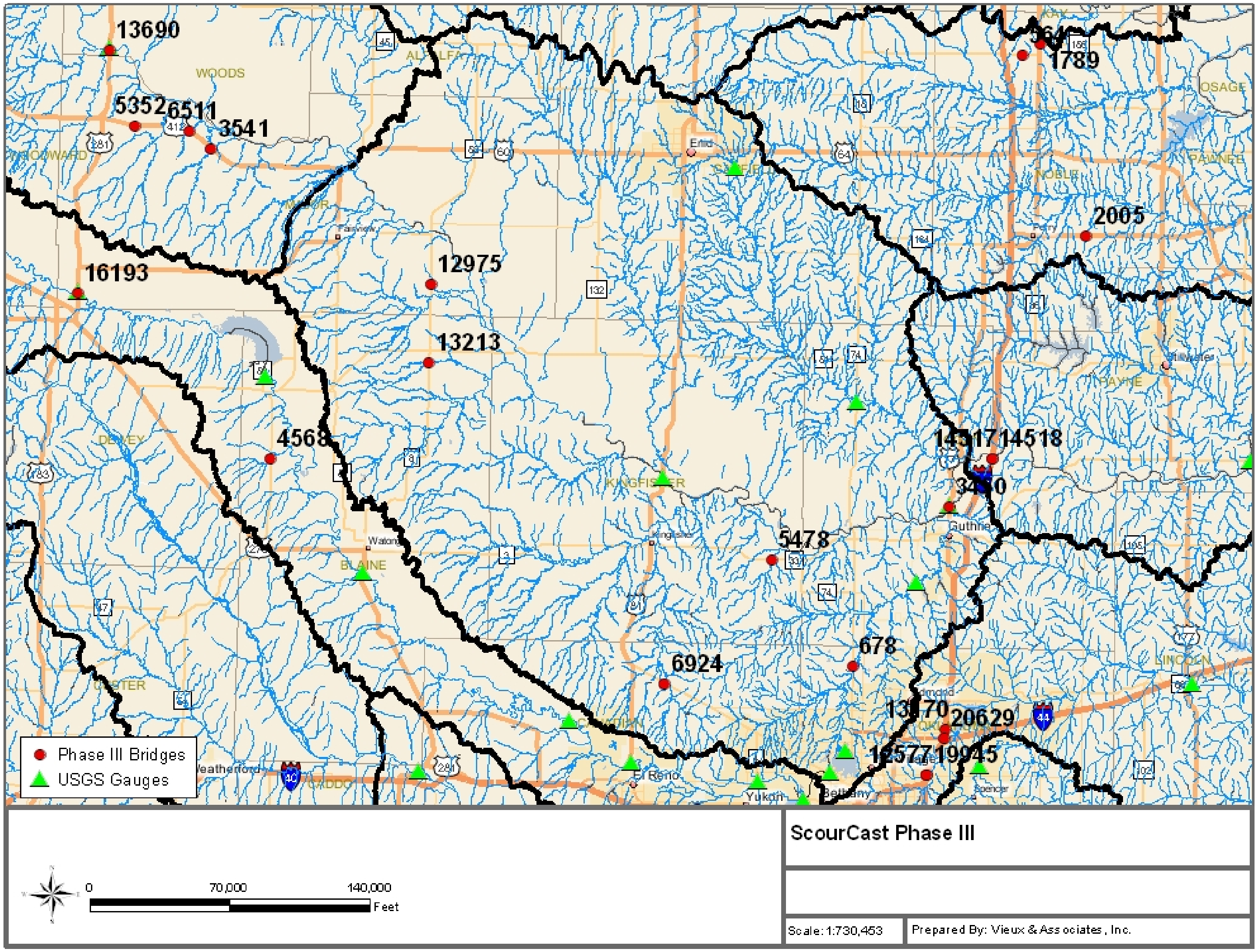


Figure A-2 Bridges in HUC 11050002

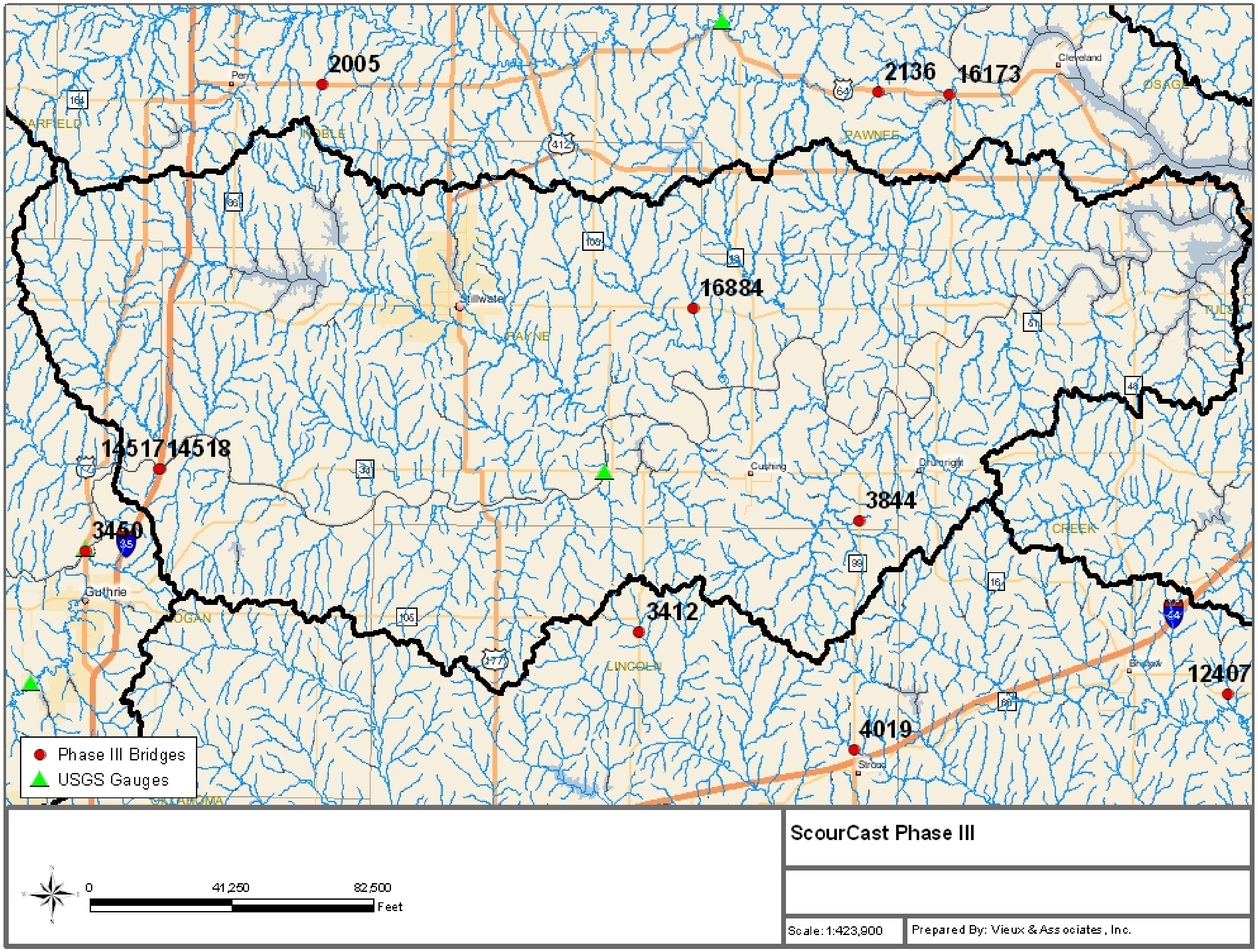


Figure A-3 Bridges in HUC 11050003

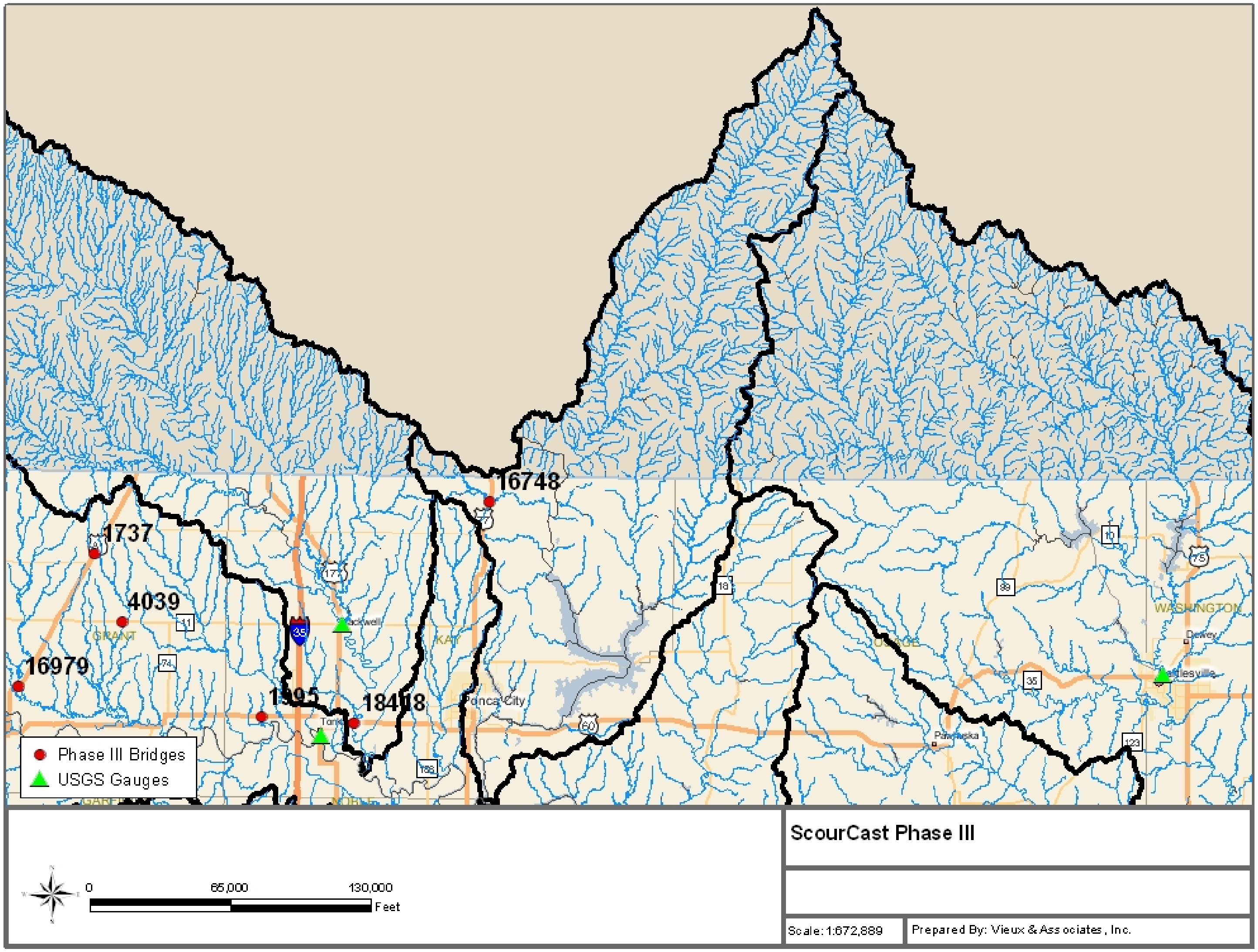


Figure A-4 Bridges in HUC 11060001

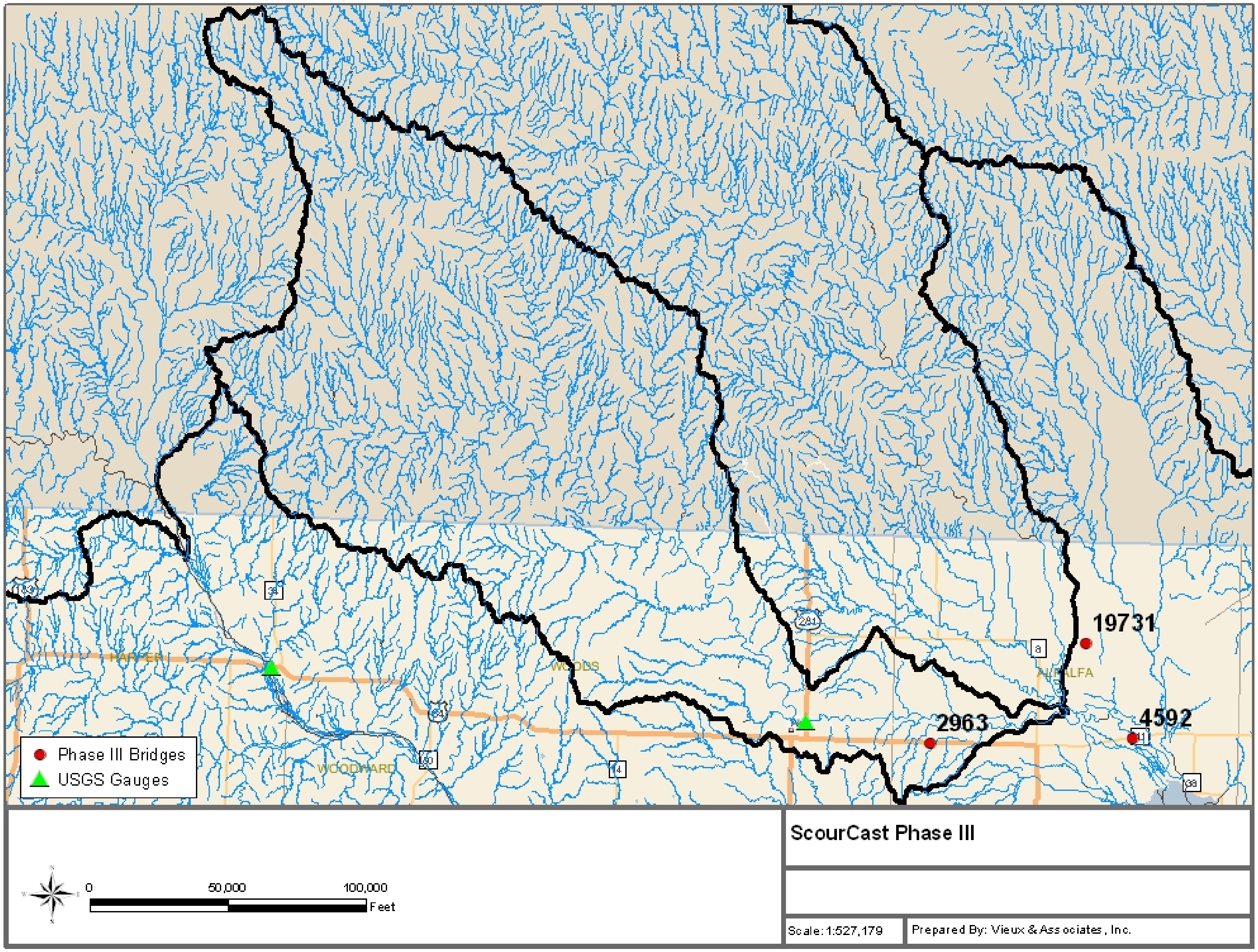


Figure A-5 Bridges in HUC 11060002

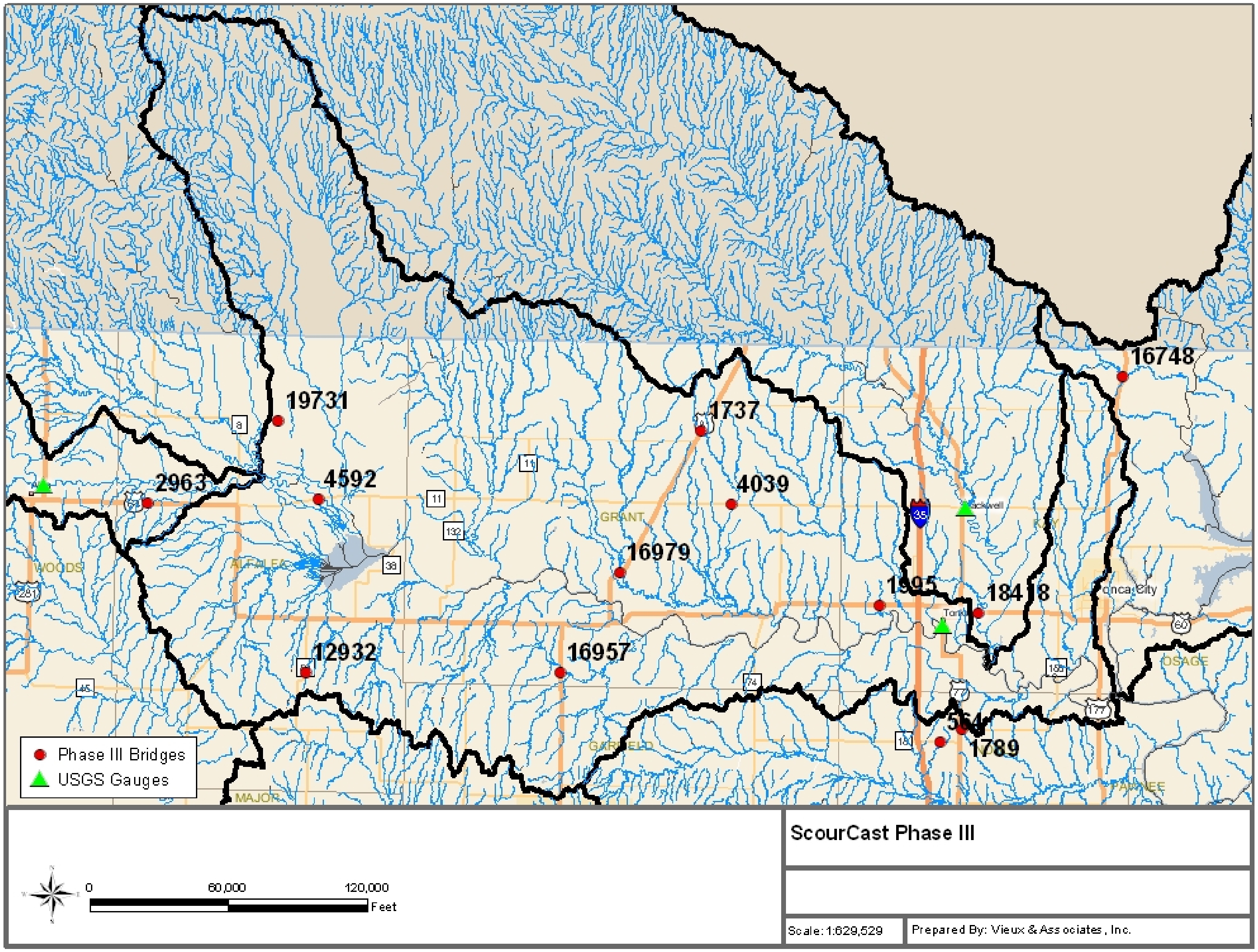


Figure A-6 Bridges in HUC 11060004

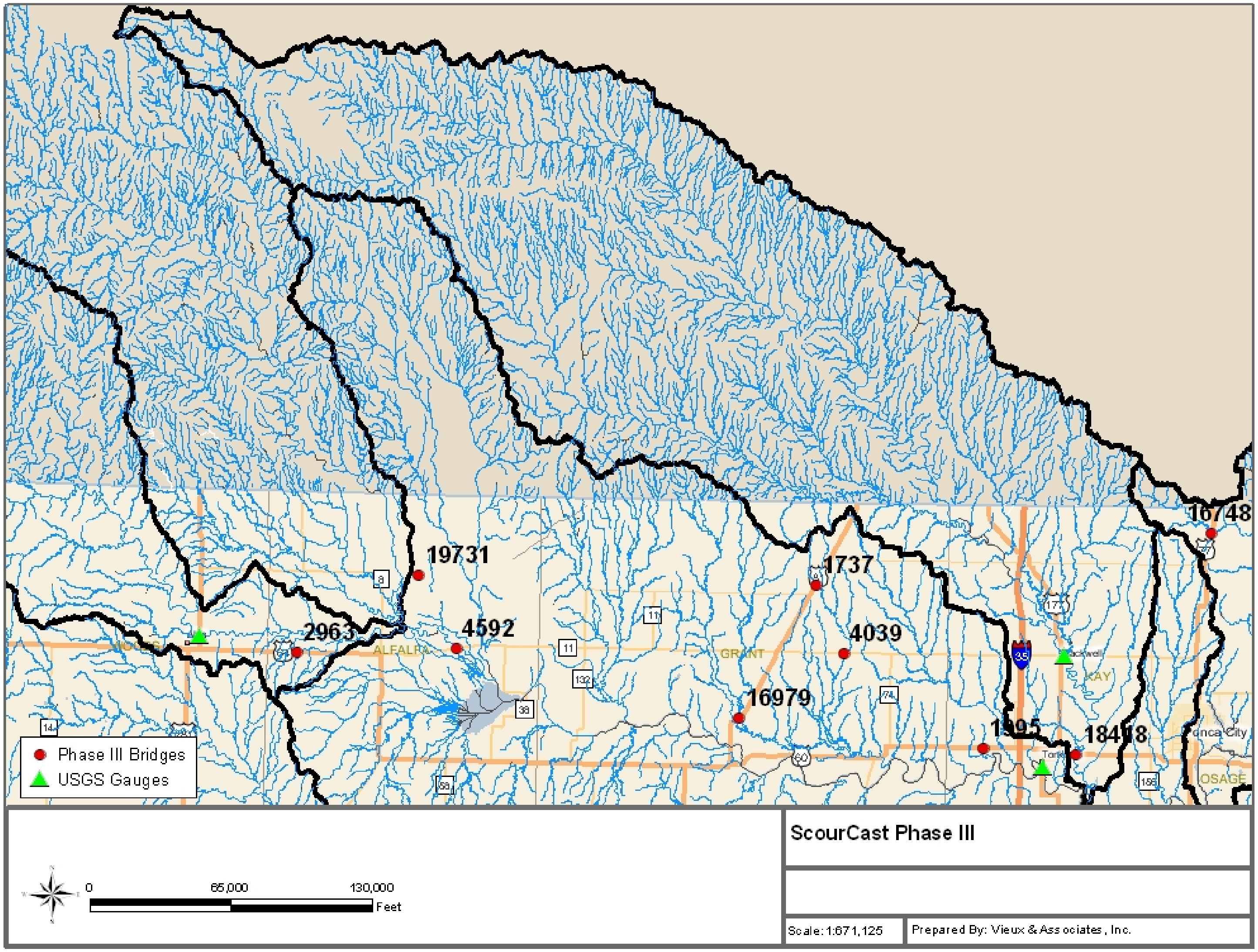
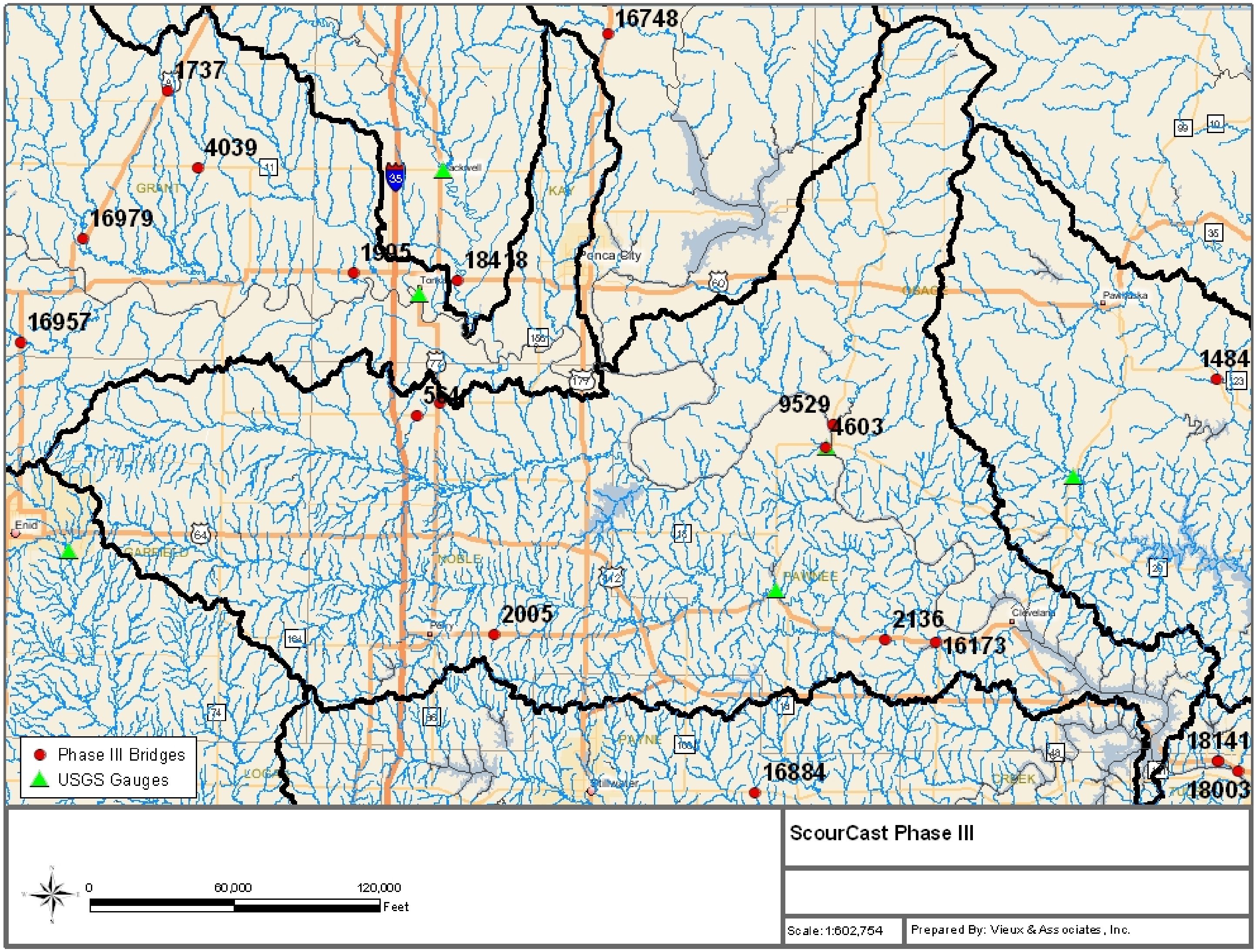


Figure A-7 Bridges in HUC 11060005



FigureA-8 Bridges in HUC 11060006

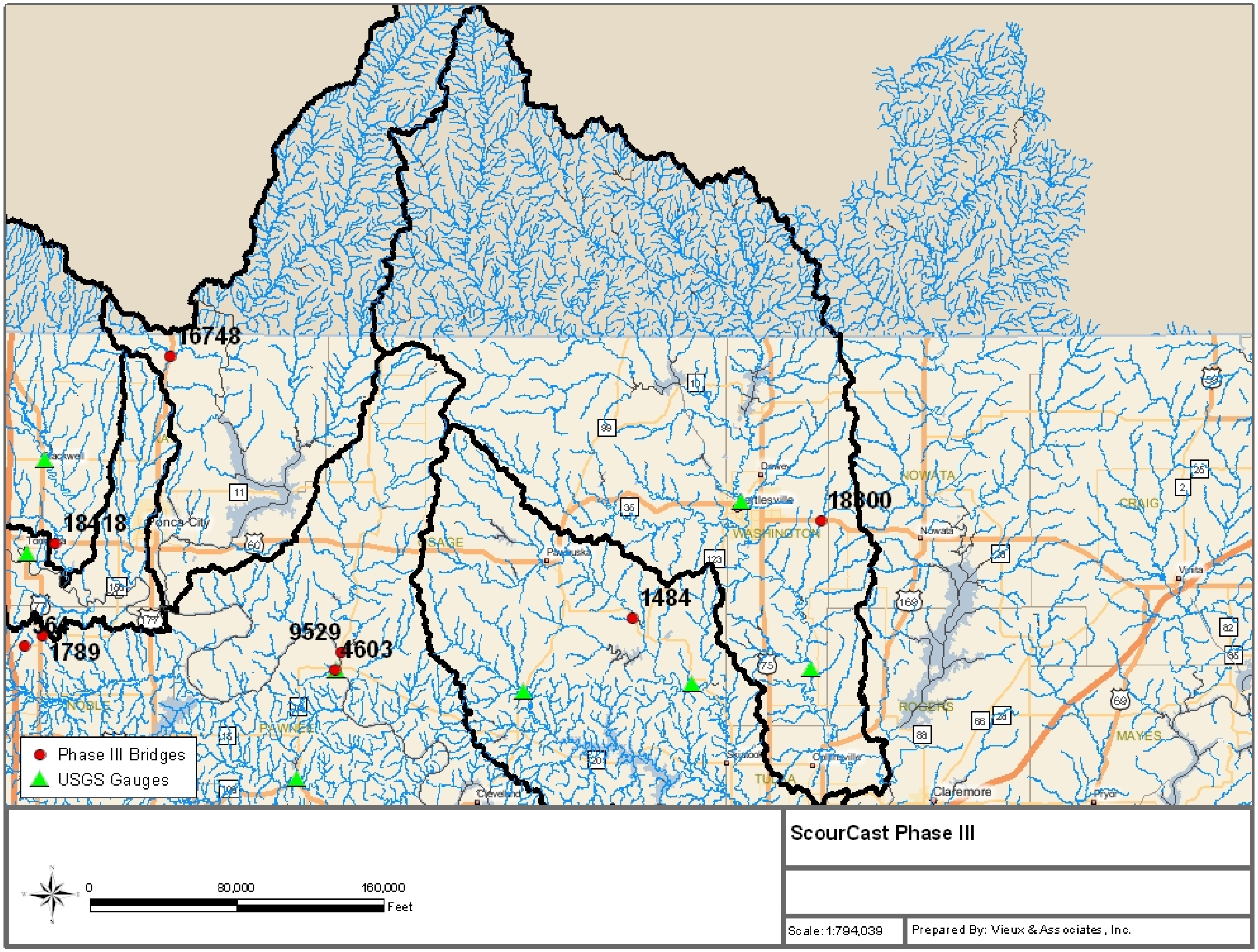


Figure A-9 Bridges in HUC 11070106

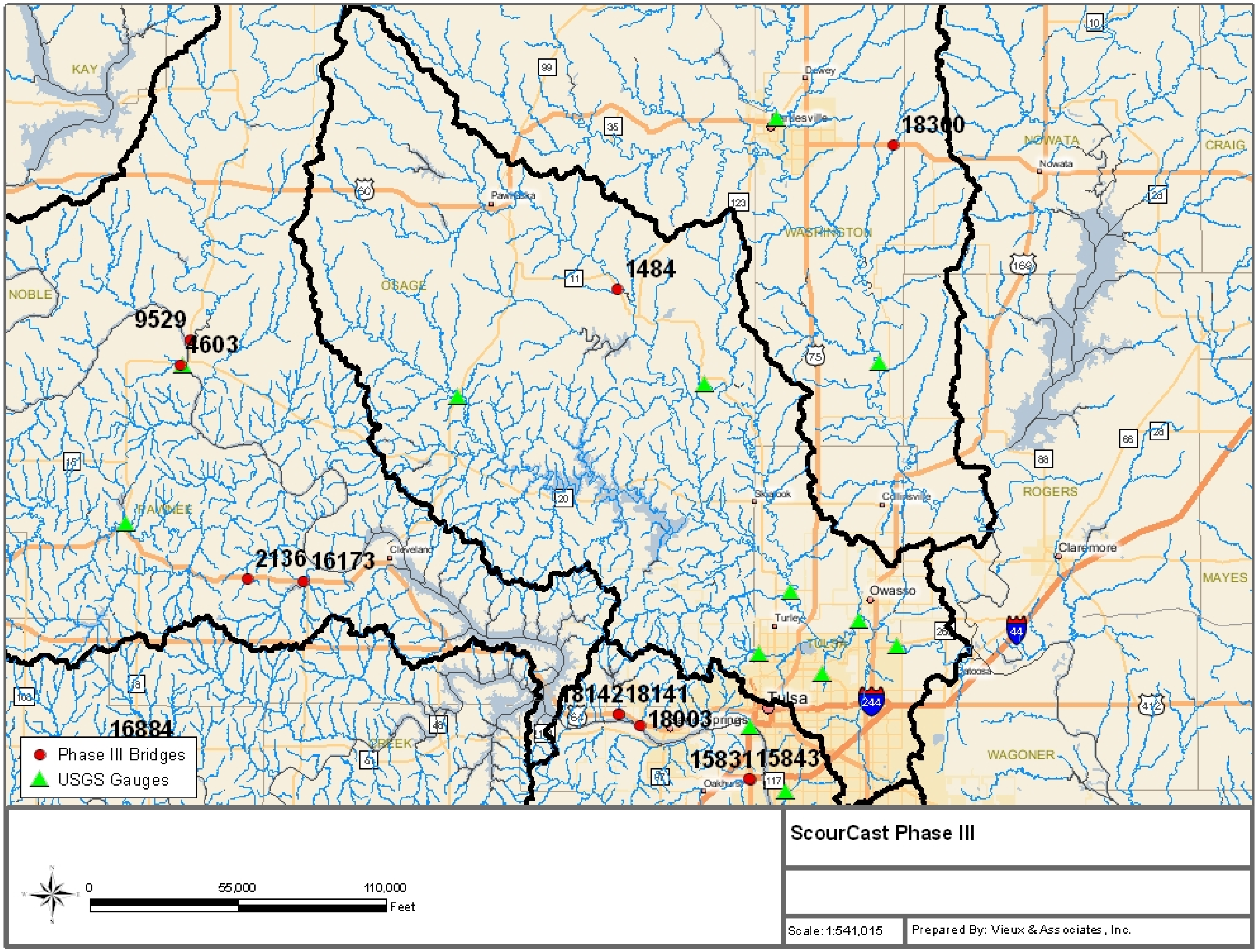


Figure A-10 Bridges in HUC 11070107

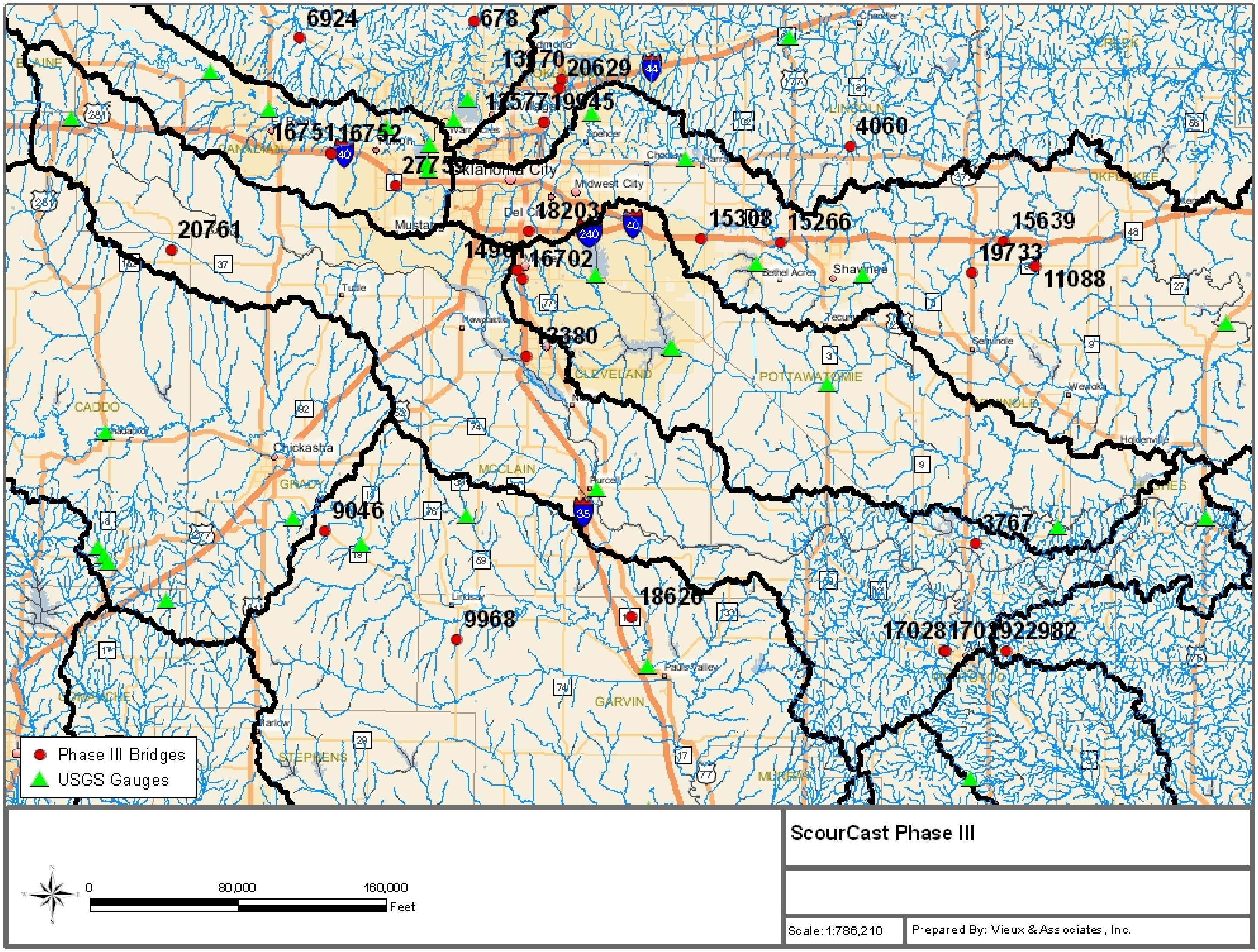
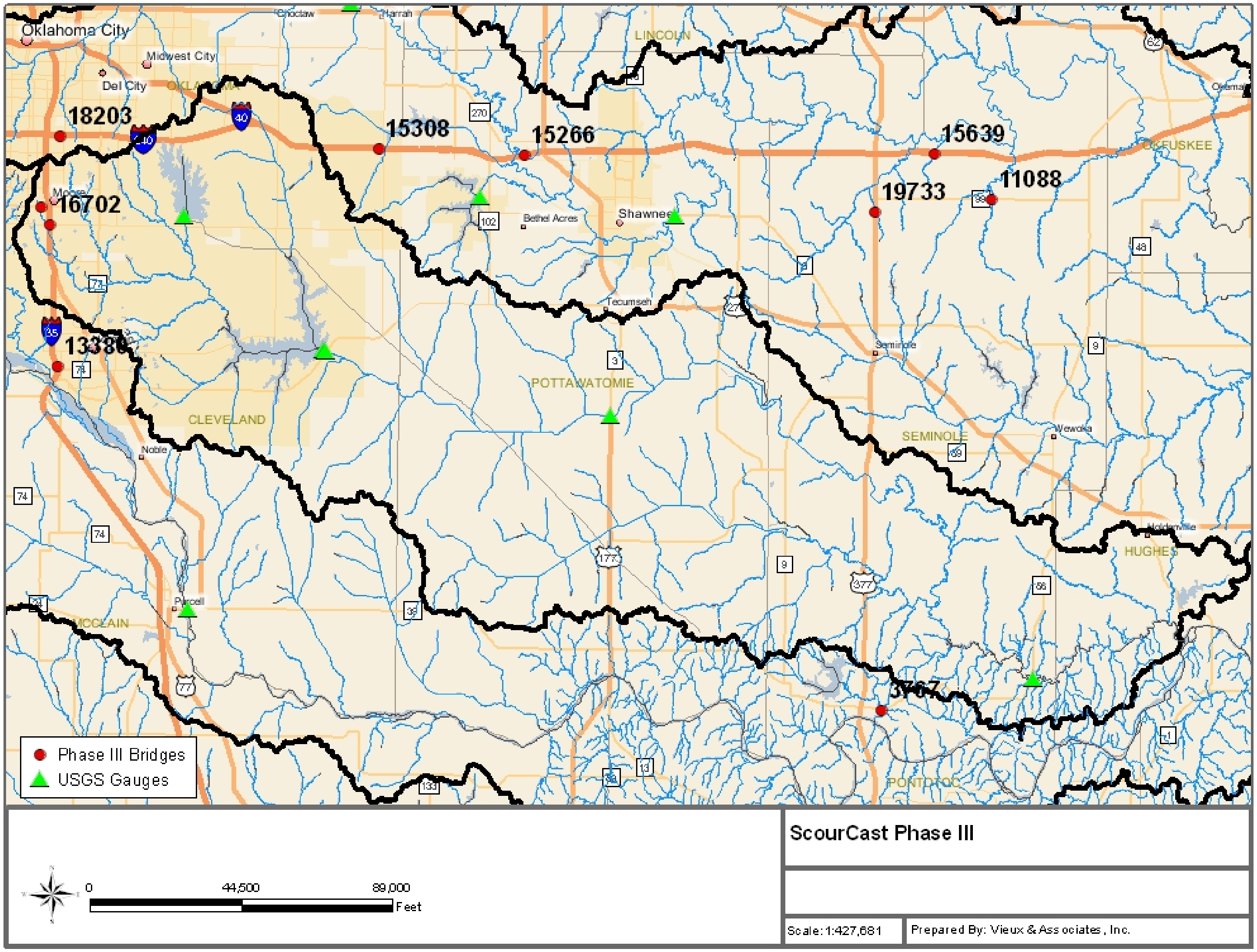


Figure A-11 Bridges in HUC 11090202



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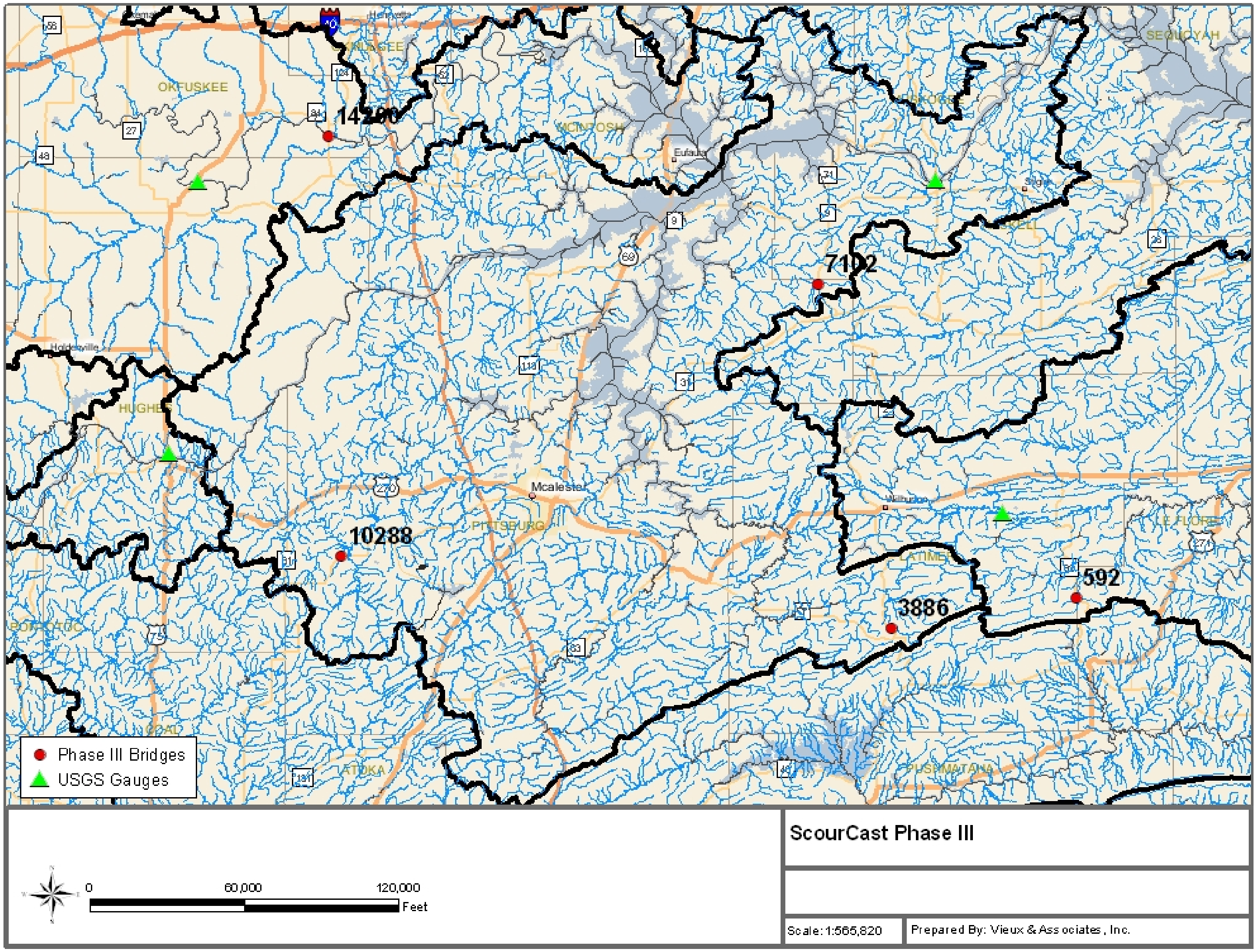

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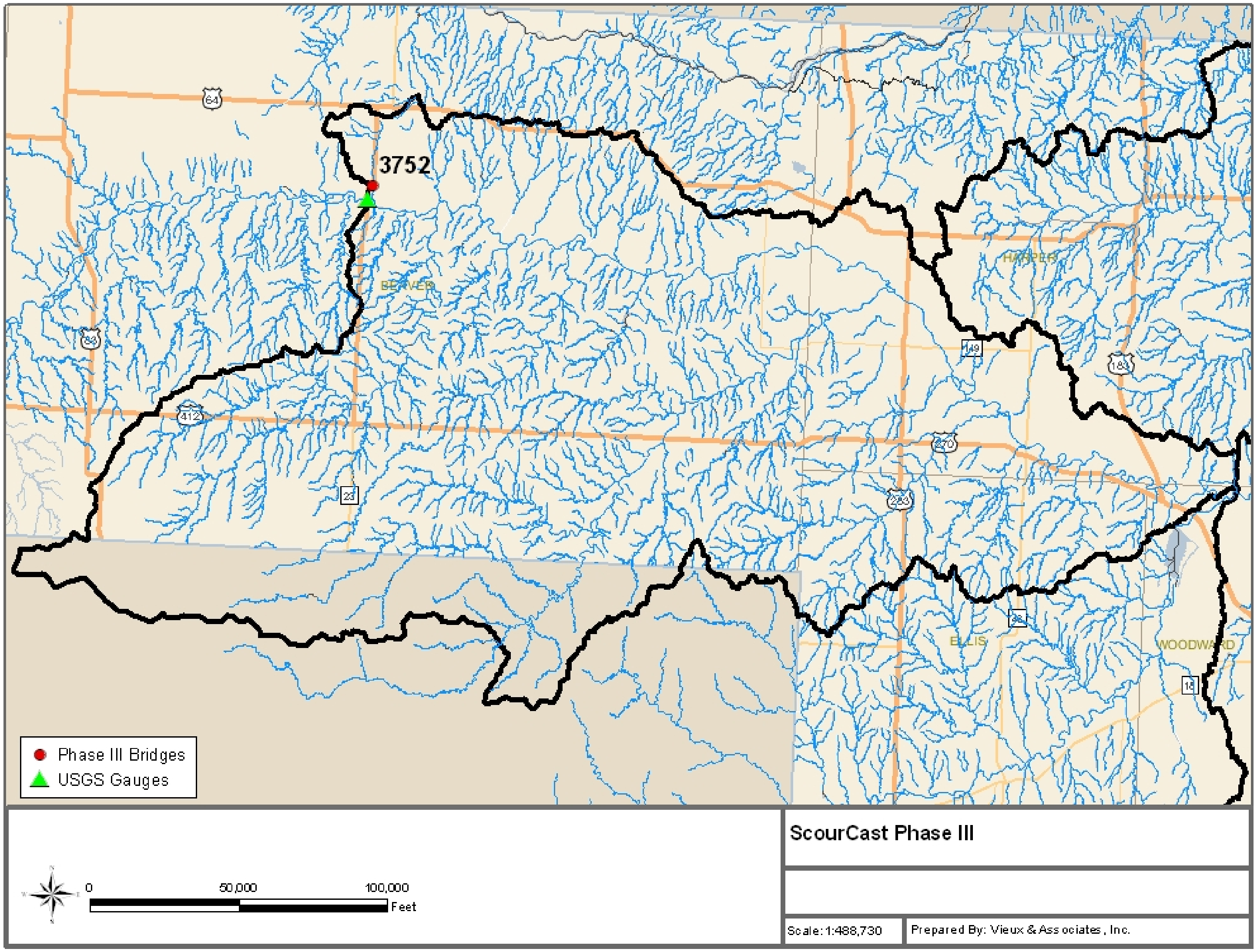


Figure A-14 Bridges in HUC 11100201

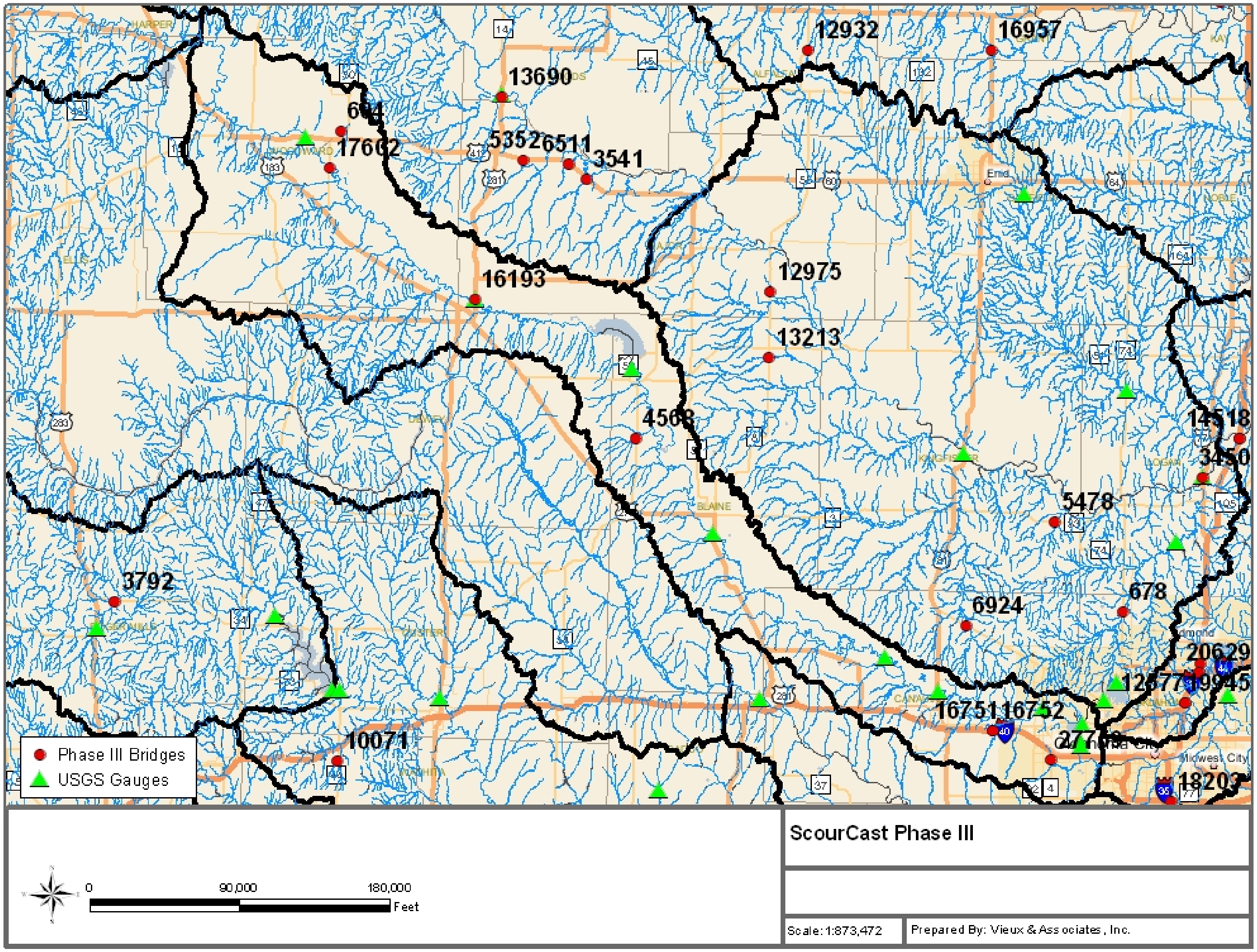


Figure A-15 Bridges in HUC 11100301

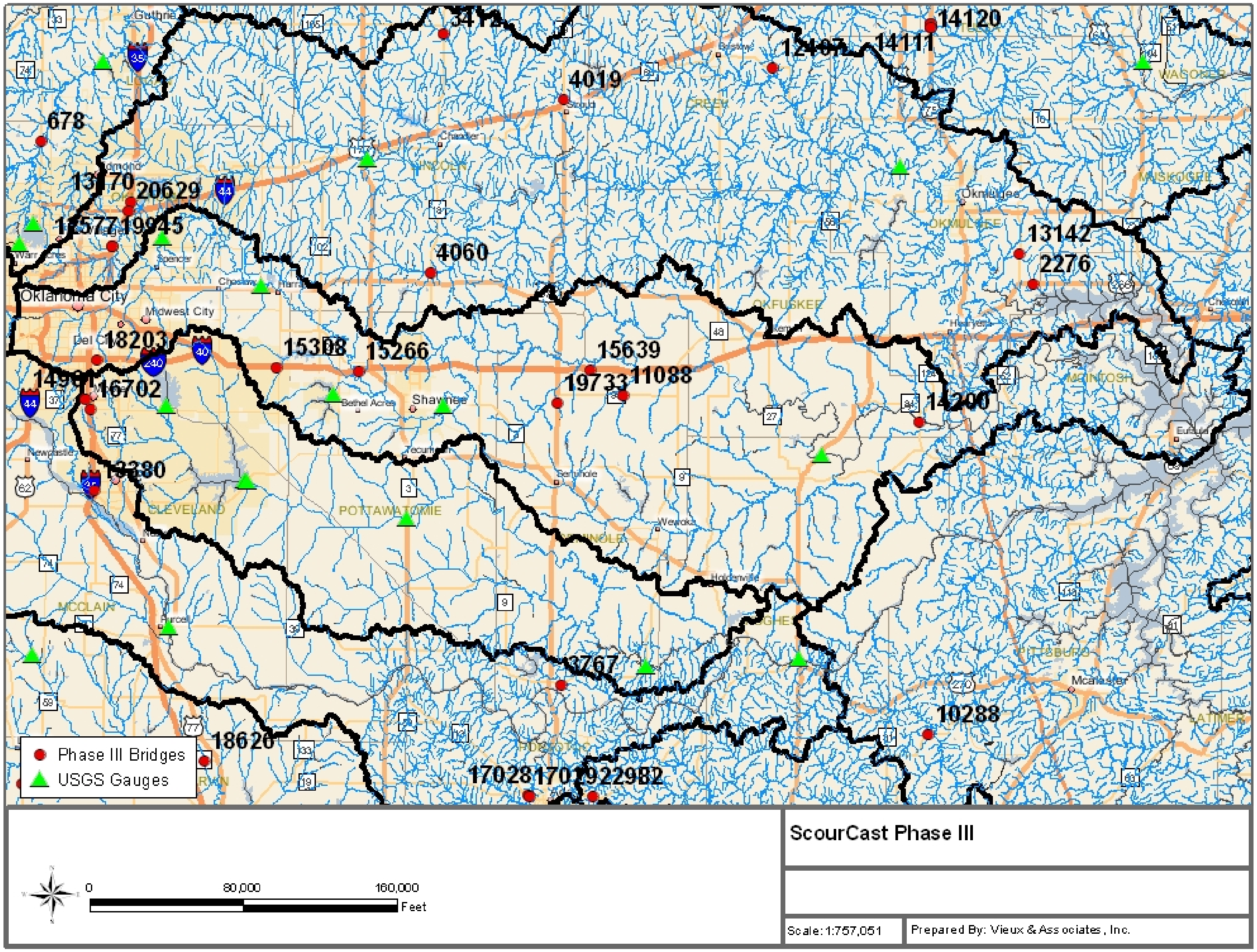


Figure A-16 Bridges in HUC 11100302

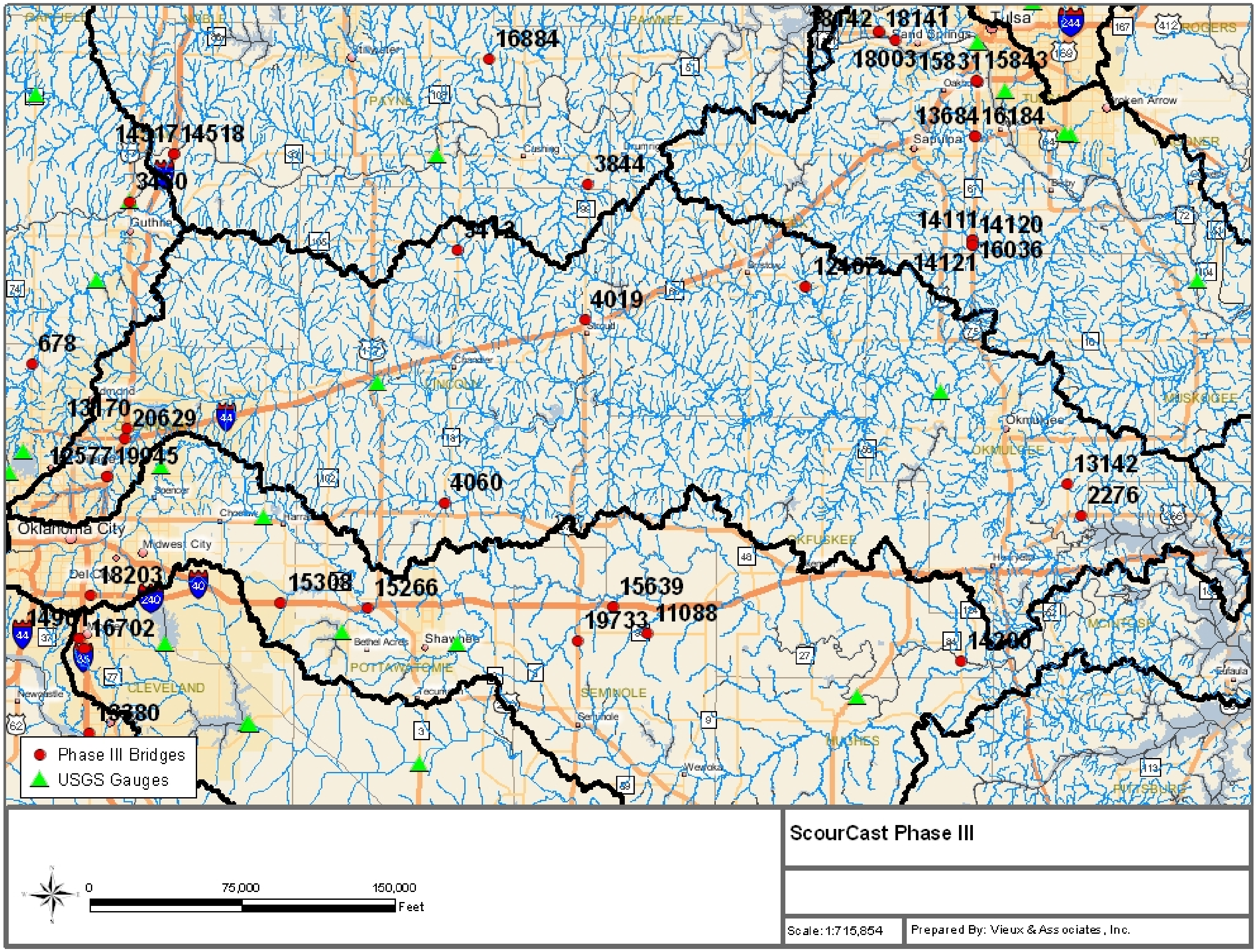


Figure A-17 Bridges in HUC 11100303

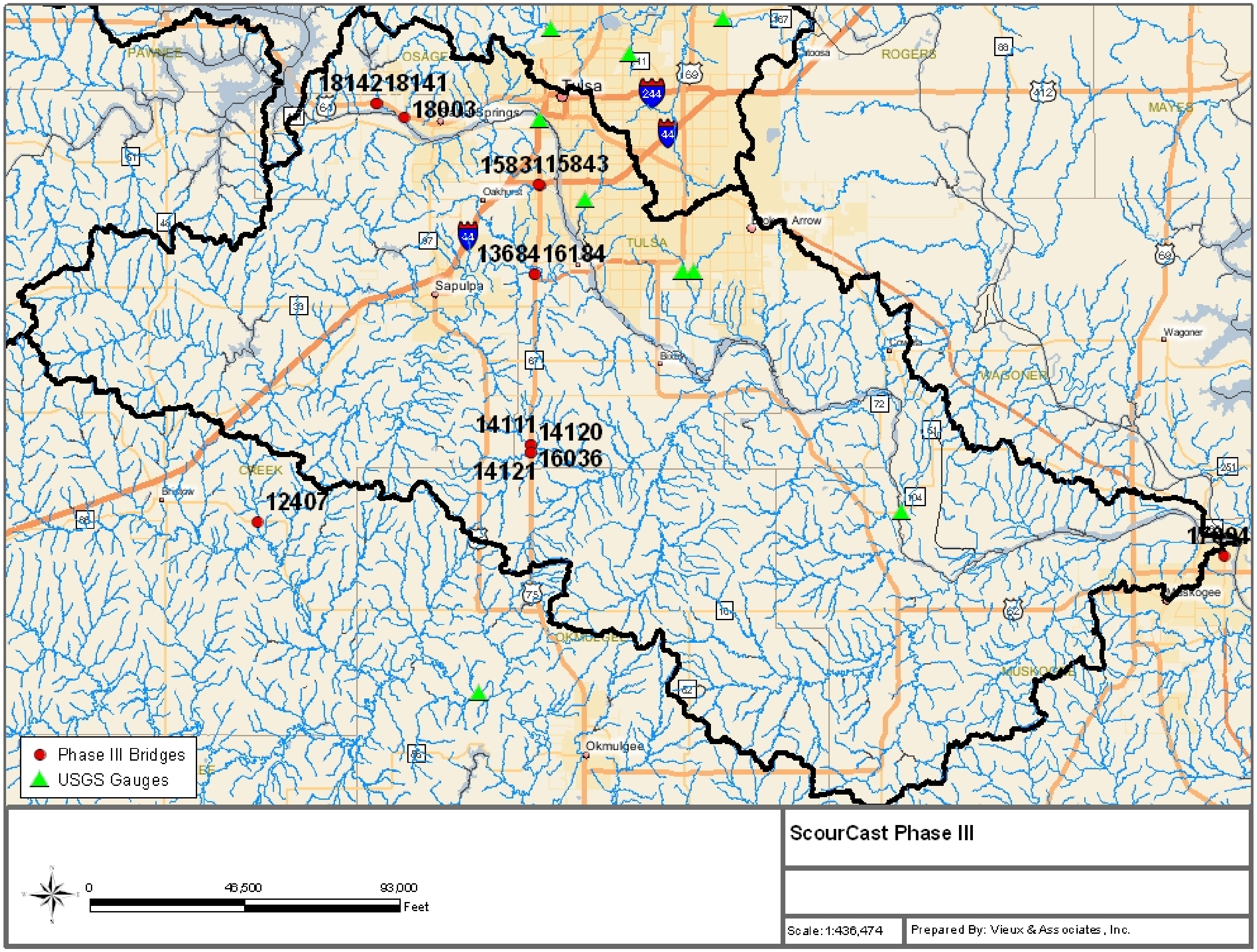
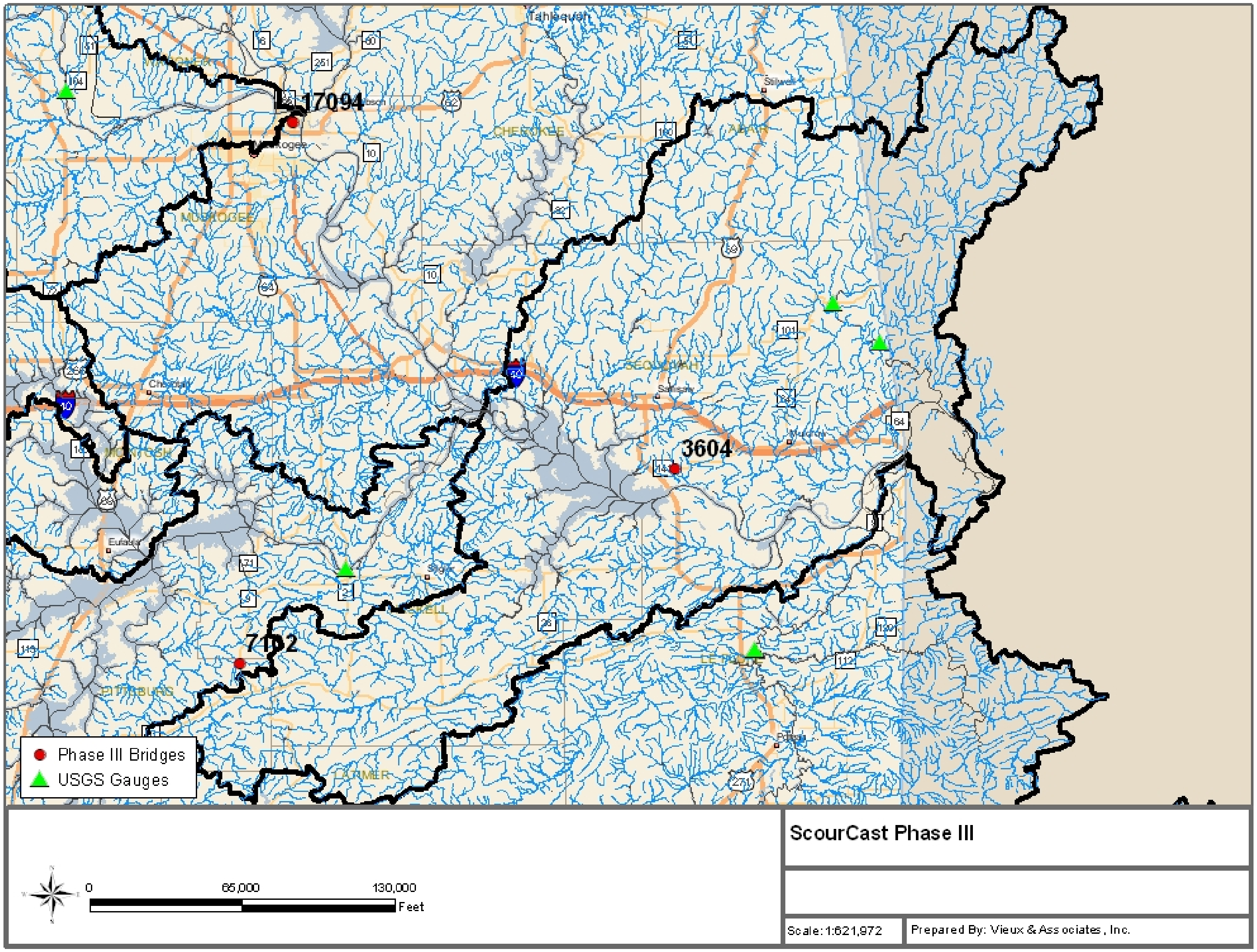


Figure A-18 Bridges in HUC 11110101



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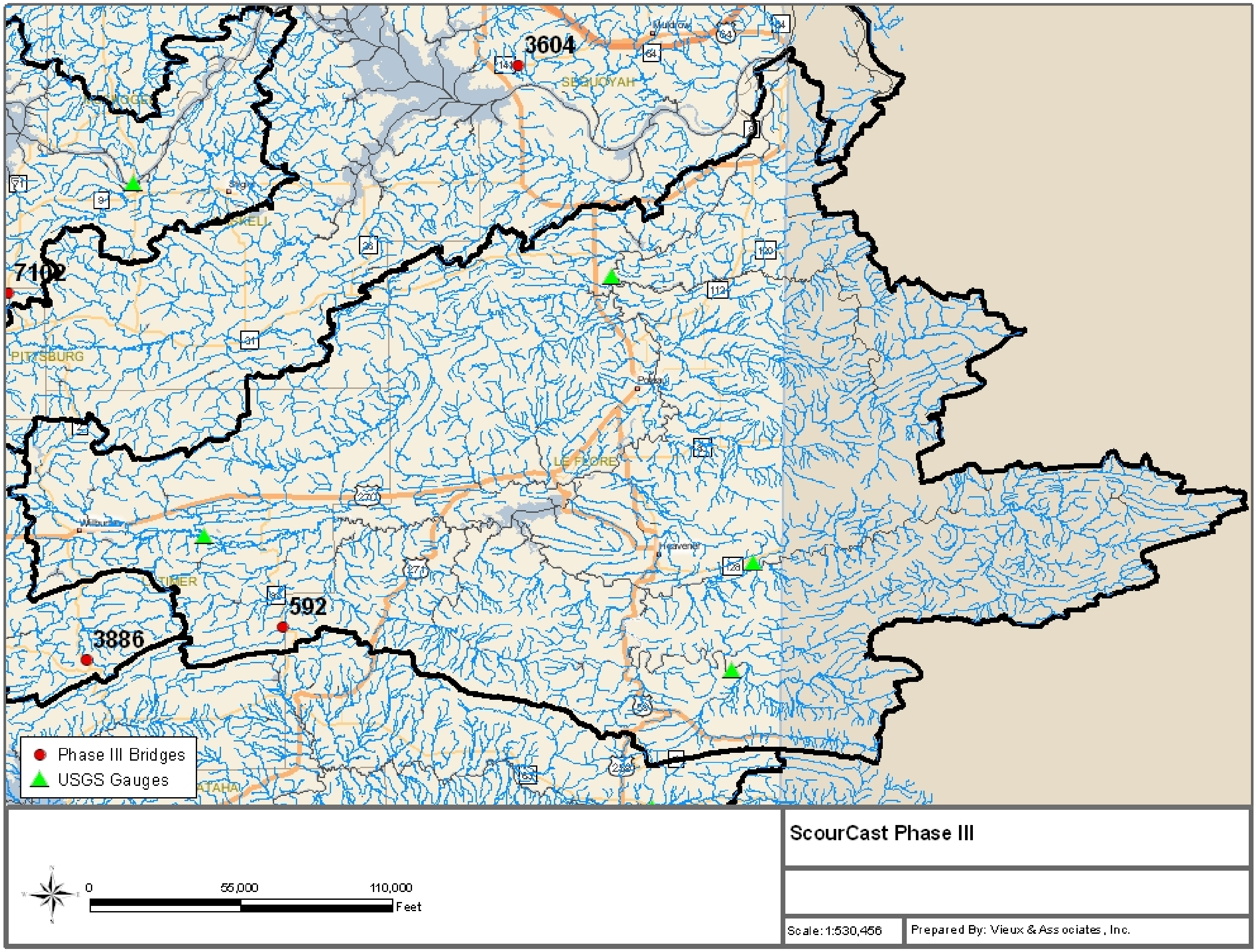

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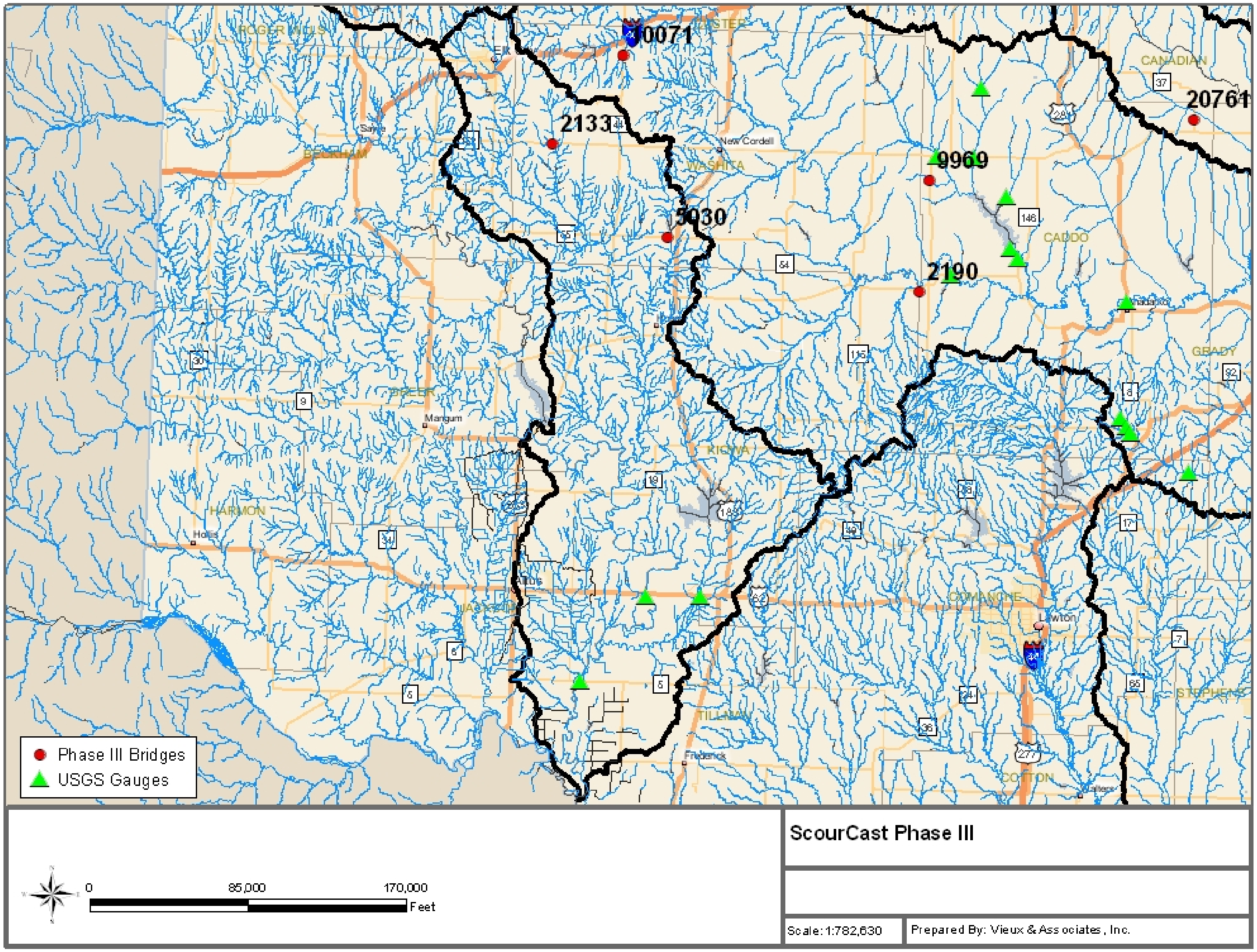
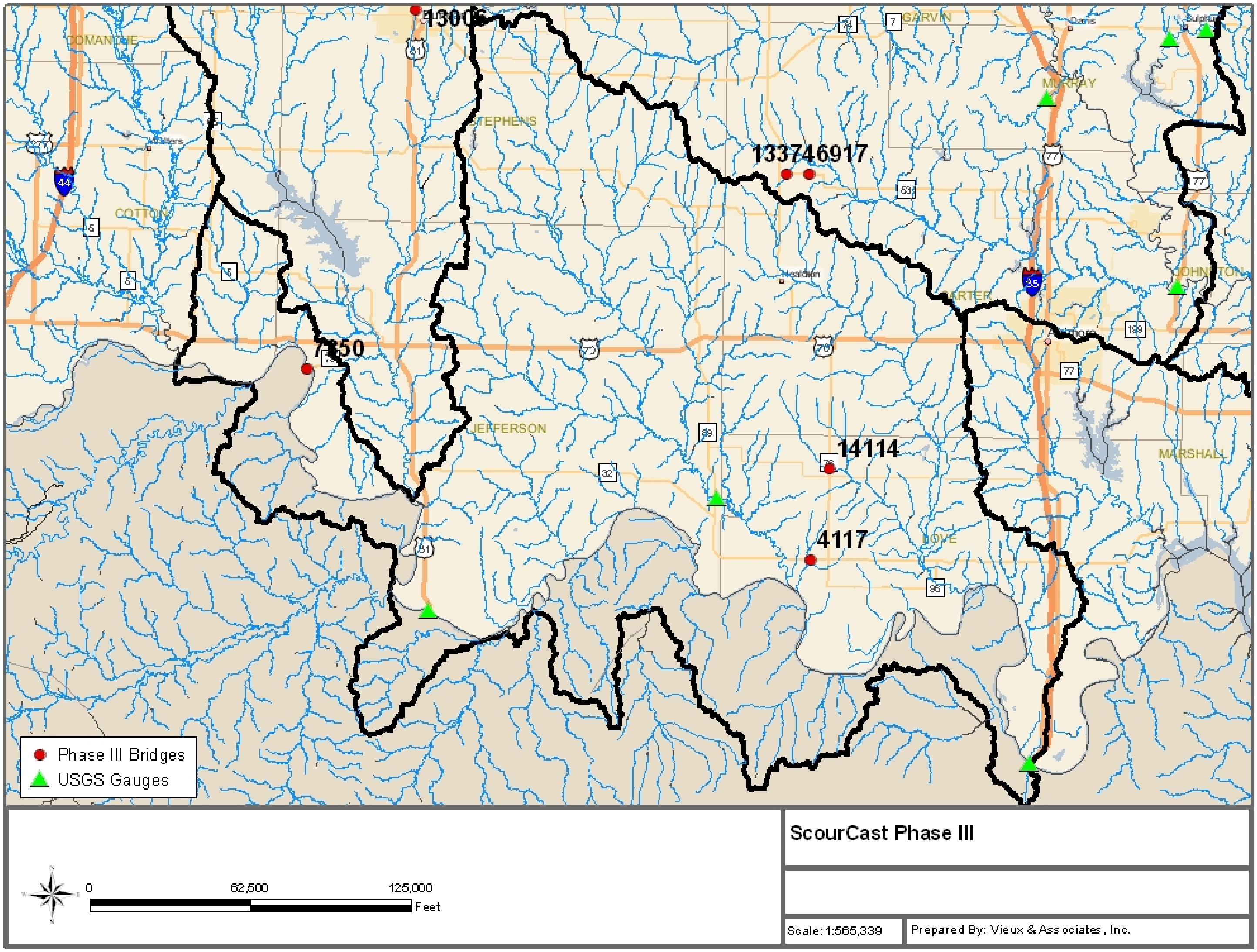


Figure A-21 Bridges in HUC 11120303



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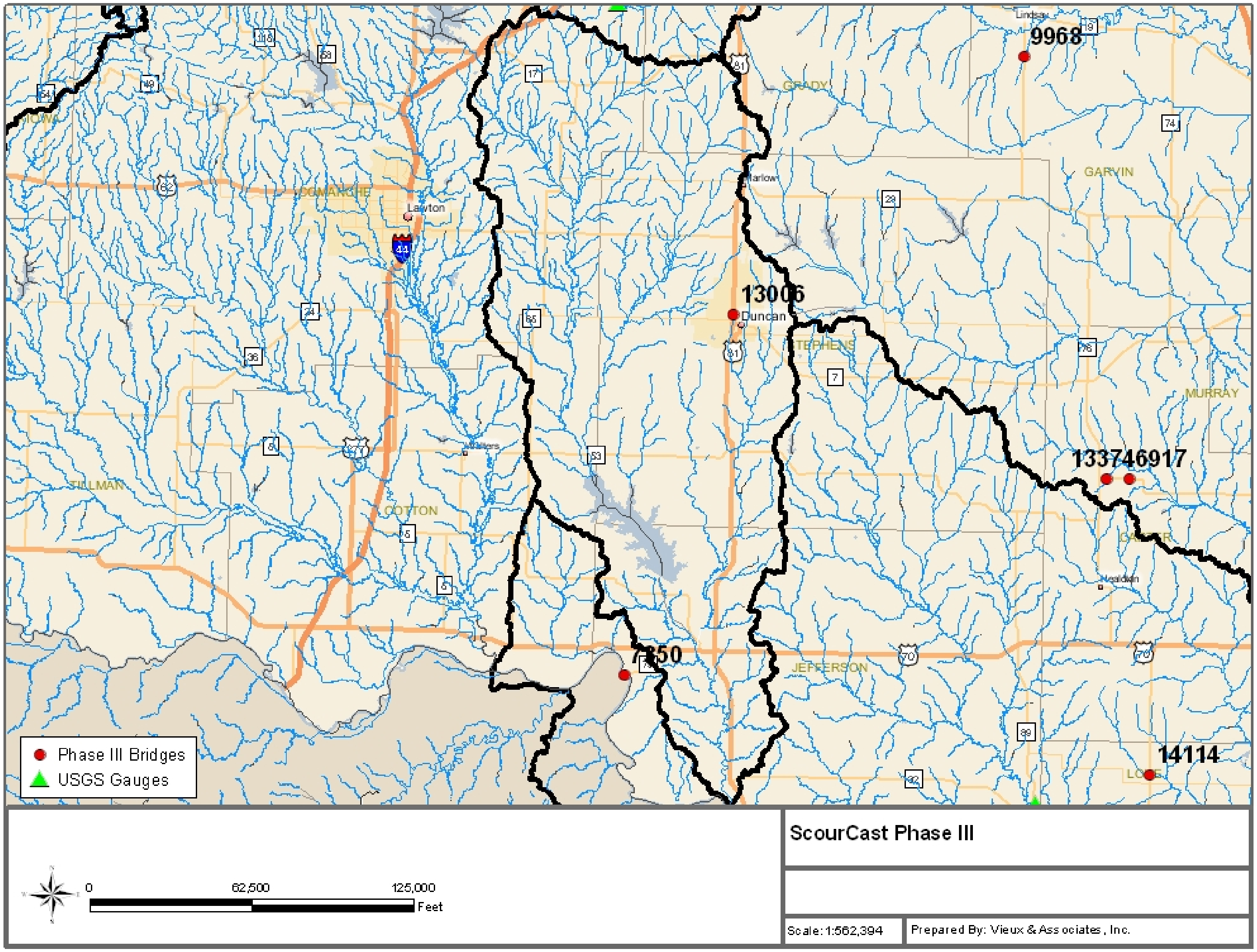


Figure A-23 Bridges in HUC 11130208

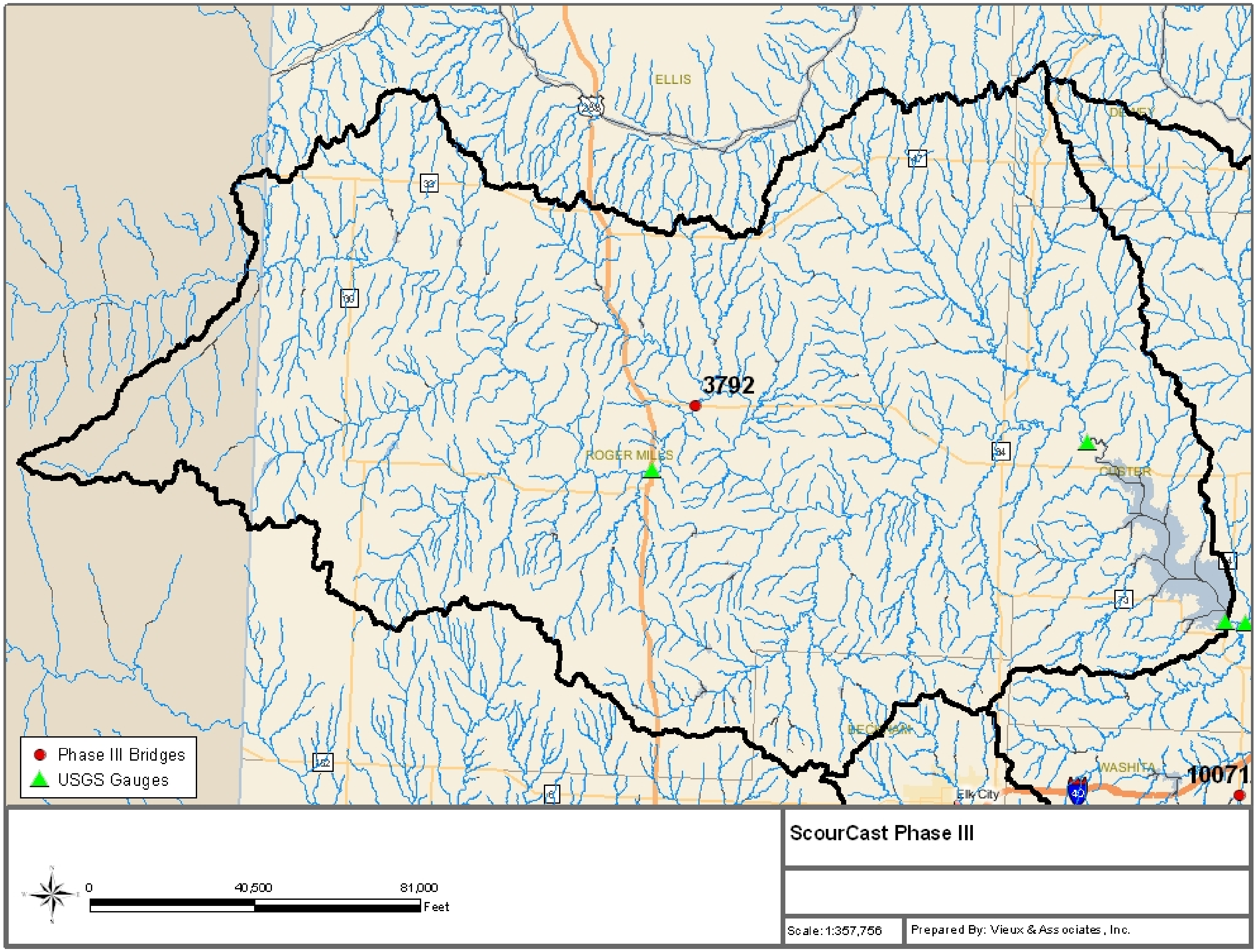
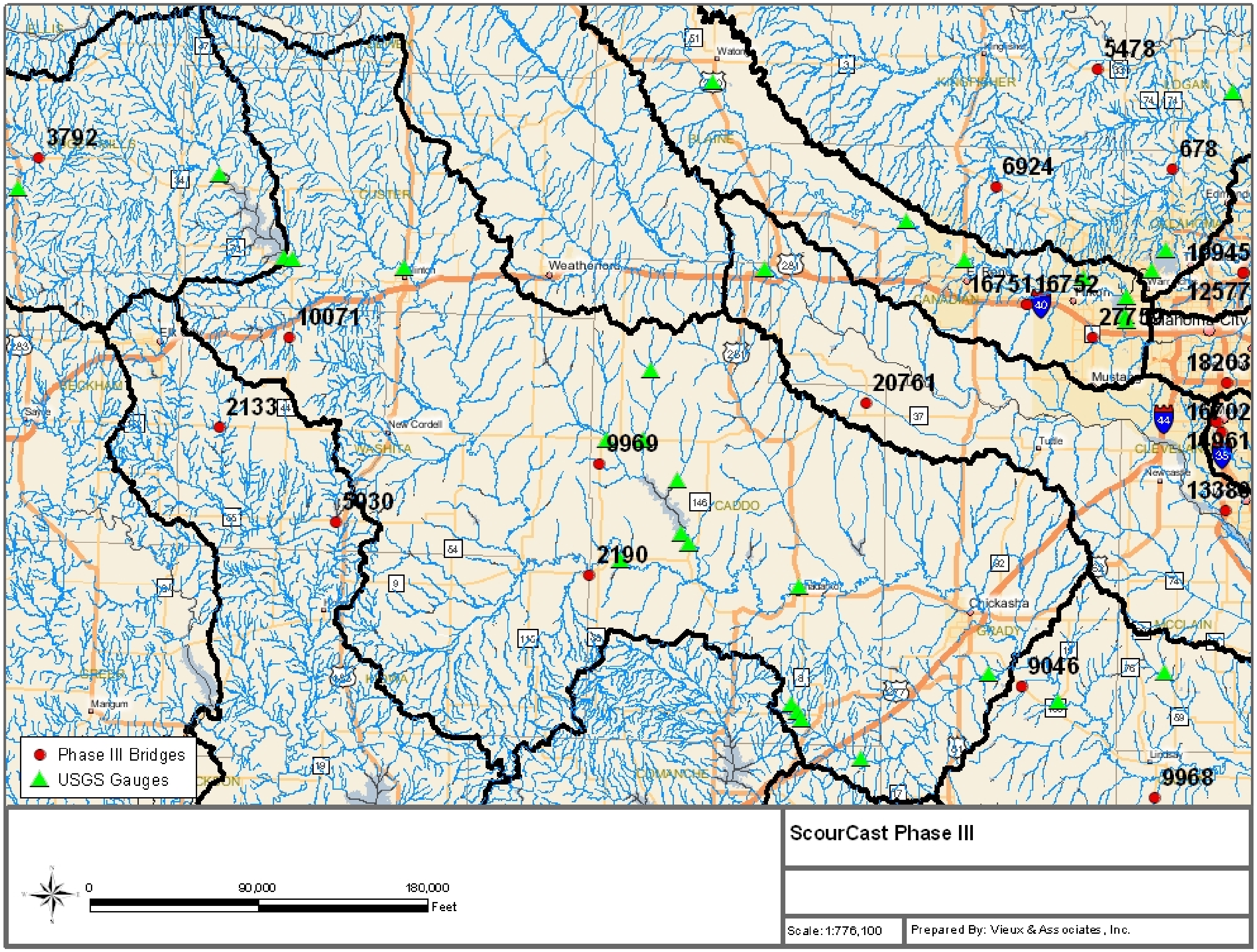


Figure A-24 Bridges in HUC 11130301



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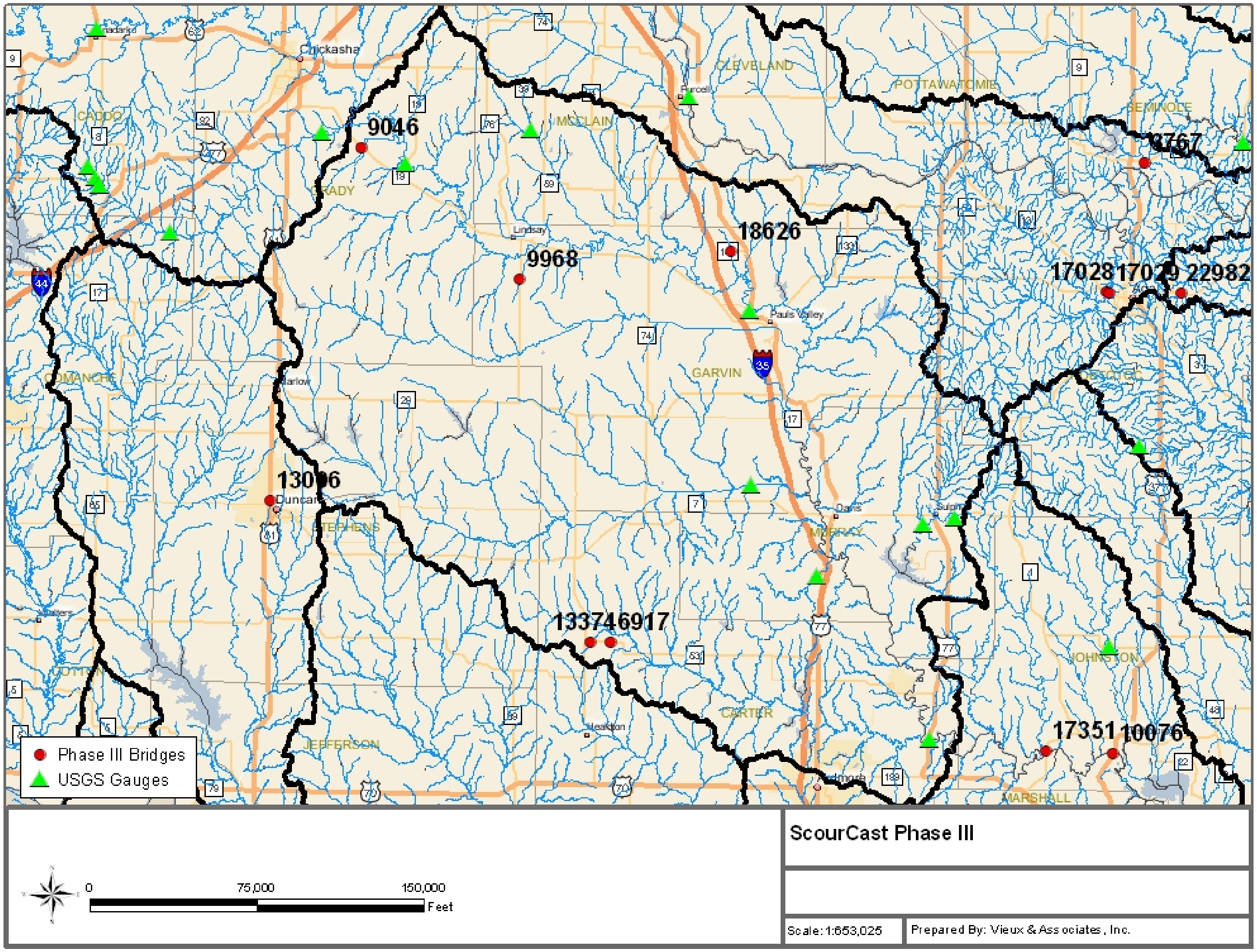


Figure A-26 Bridges in HUC 11130303

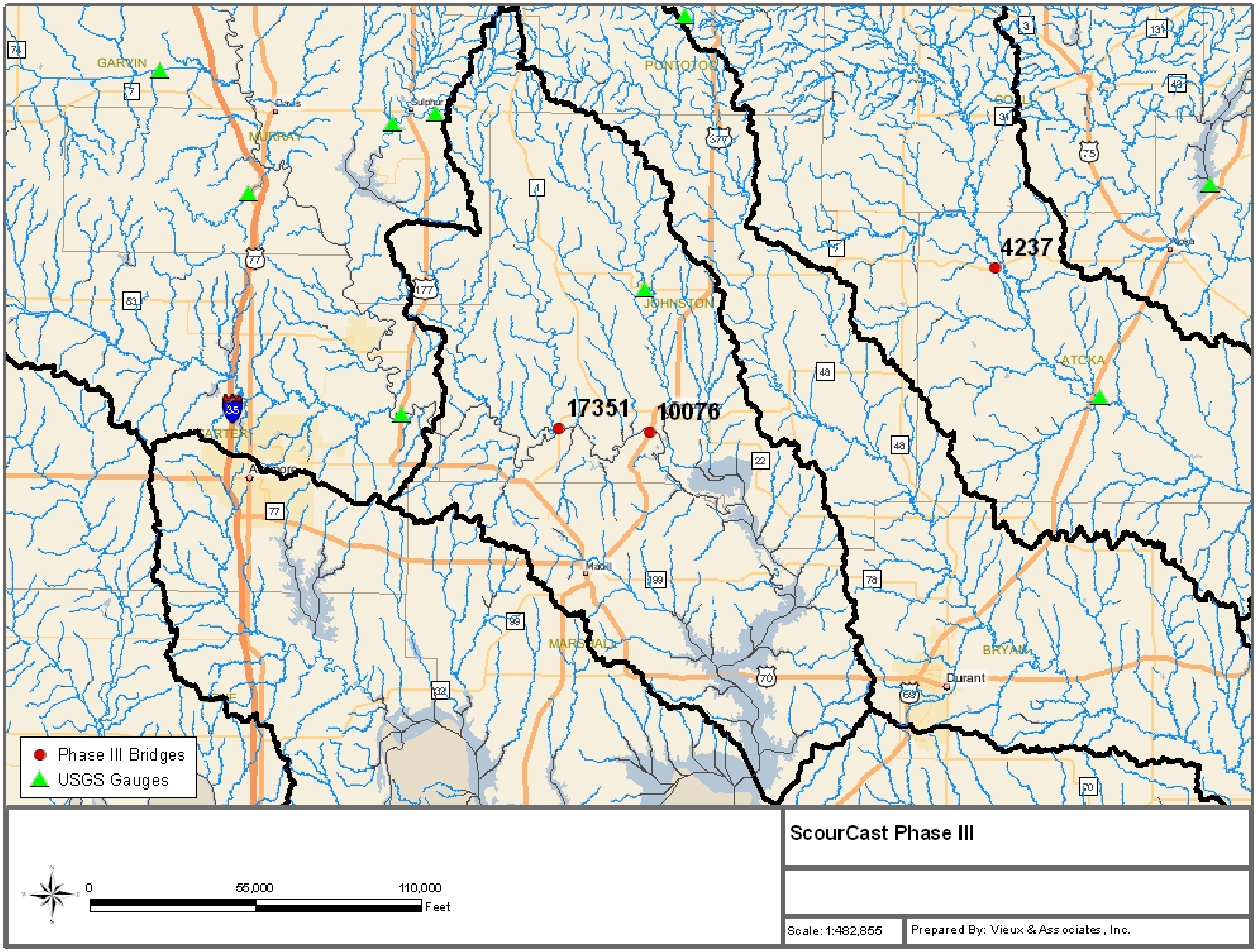


Figure A-27 Bridges in HUC 11130304

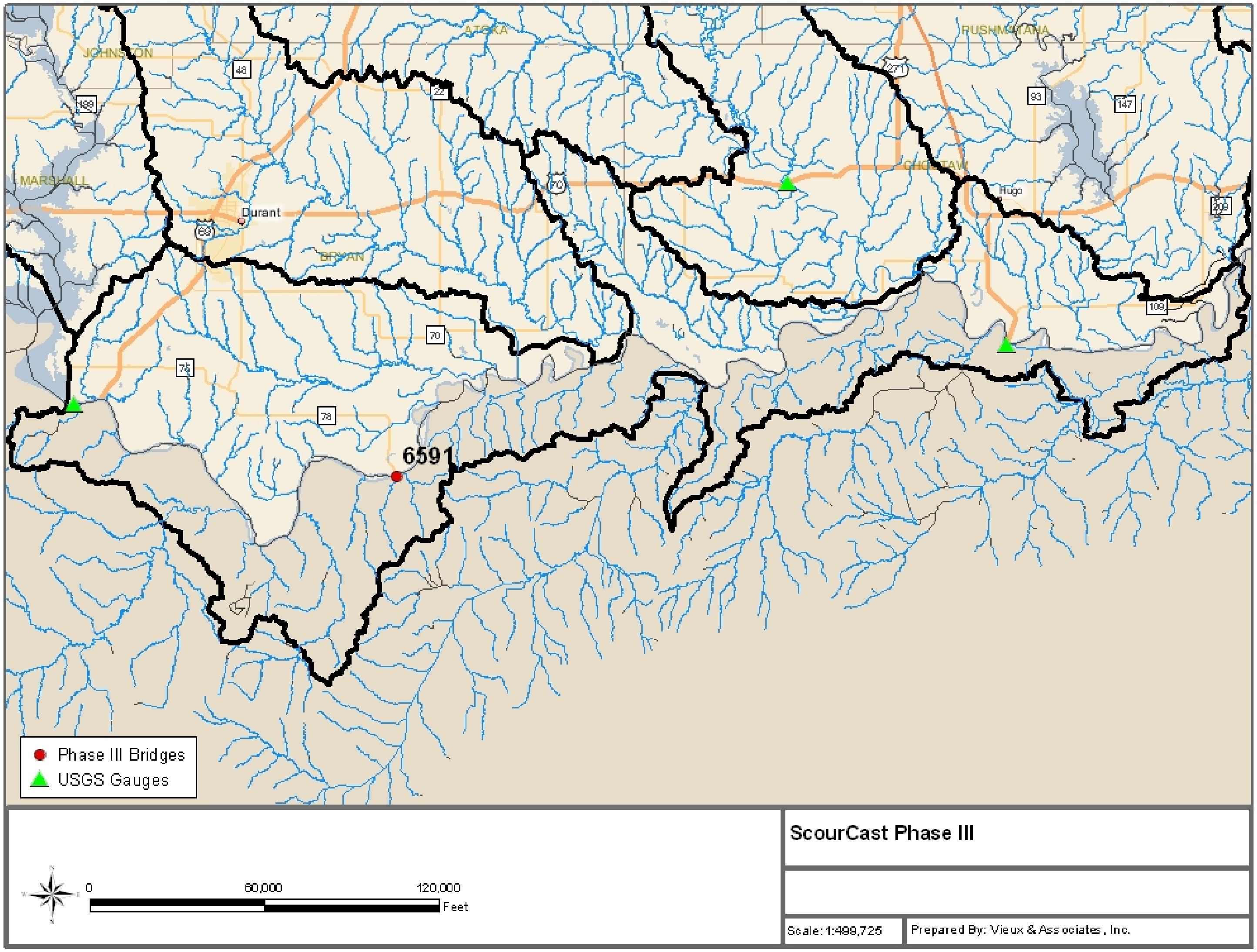


Figure A-28 Bridges in HUC 11140101

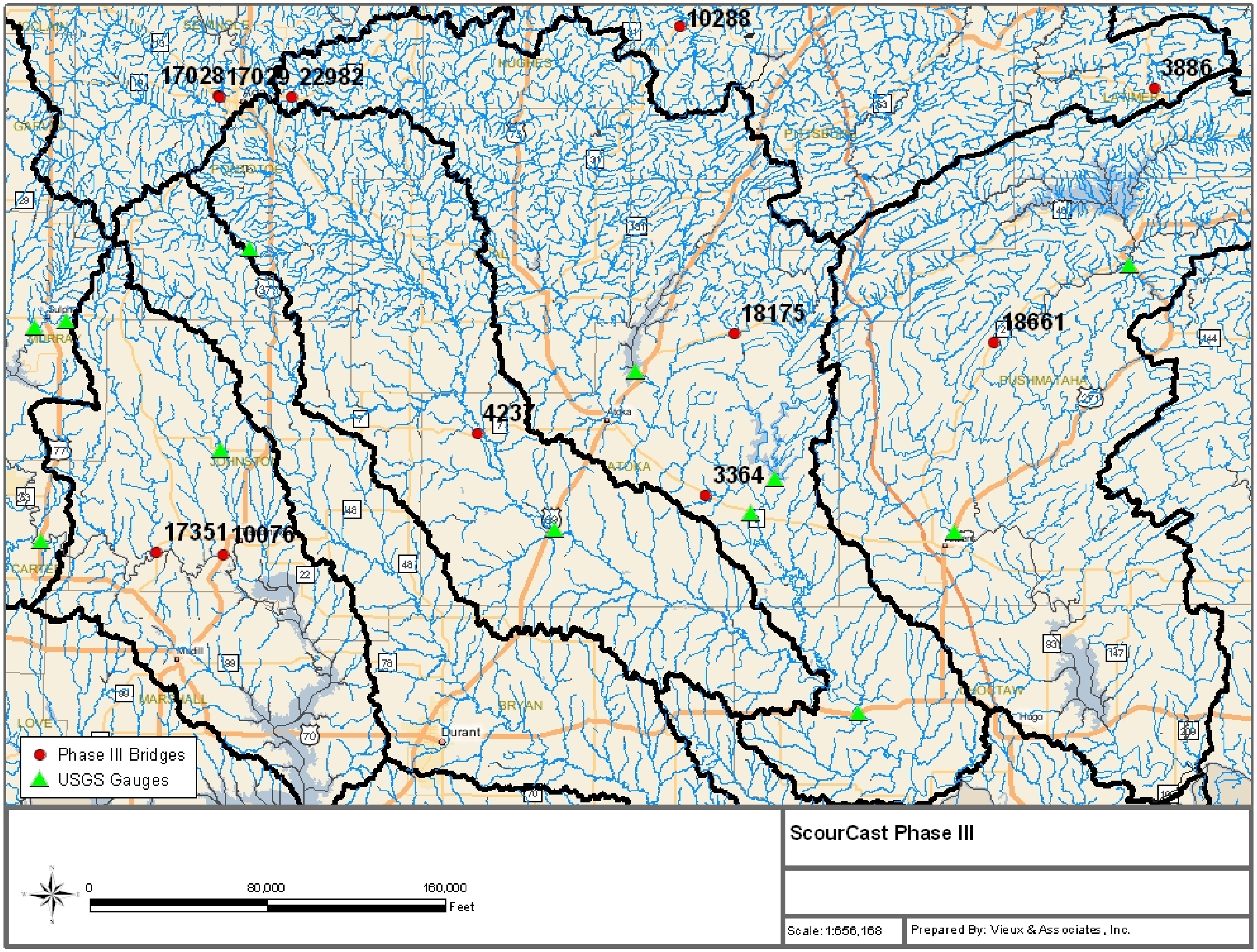
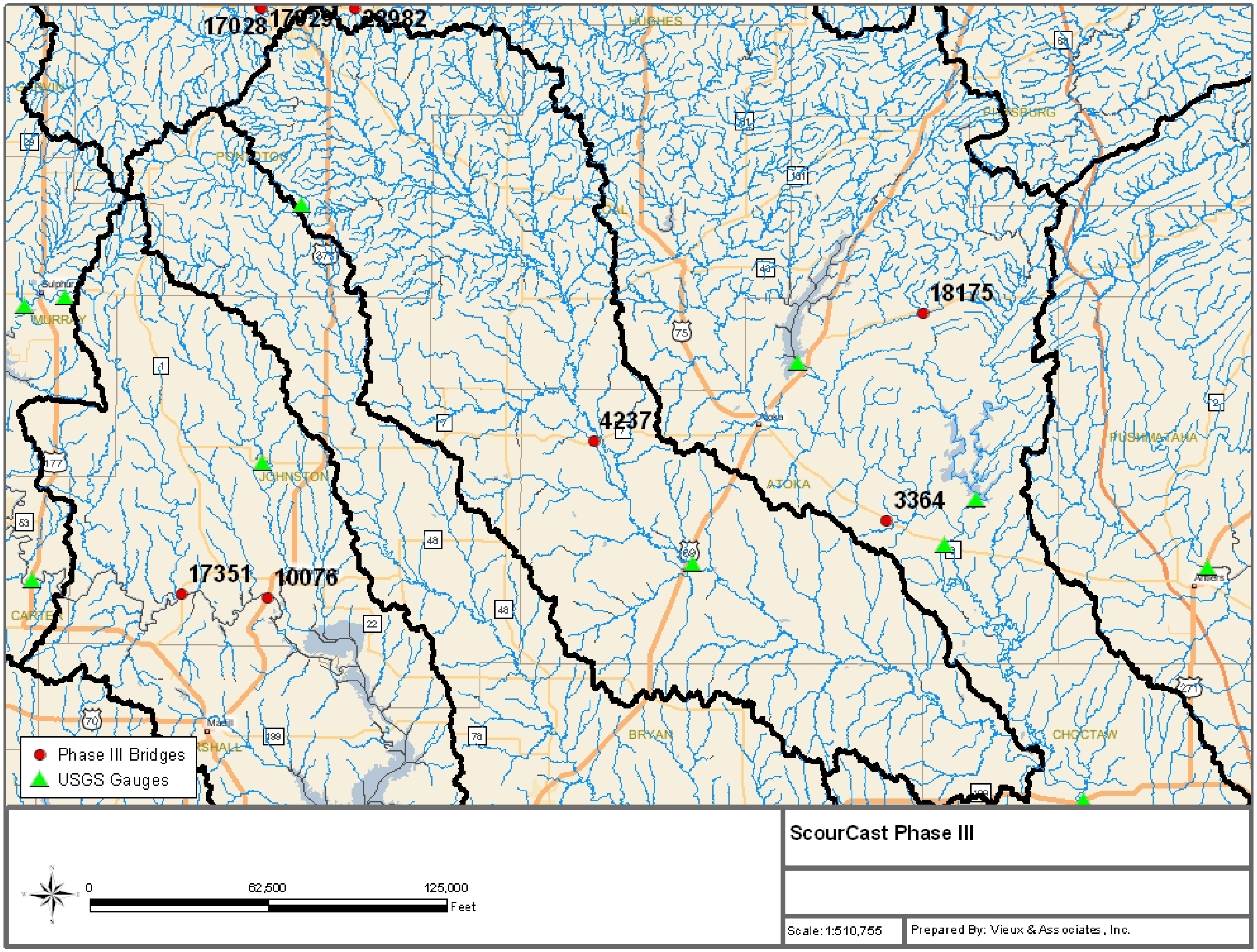


Figure A-29 Bridges in HUC 11140103



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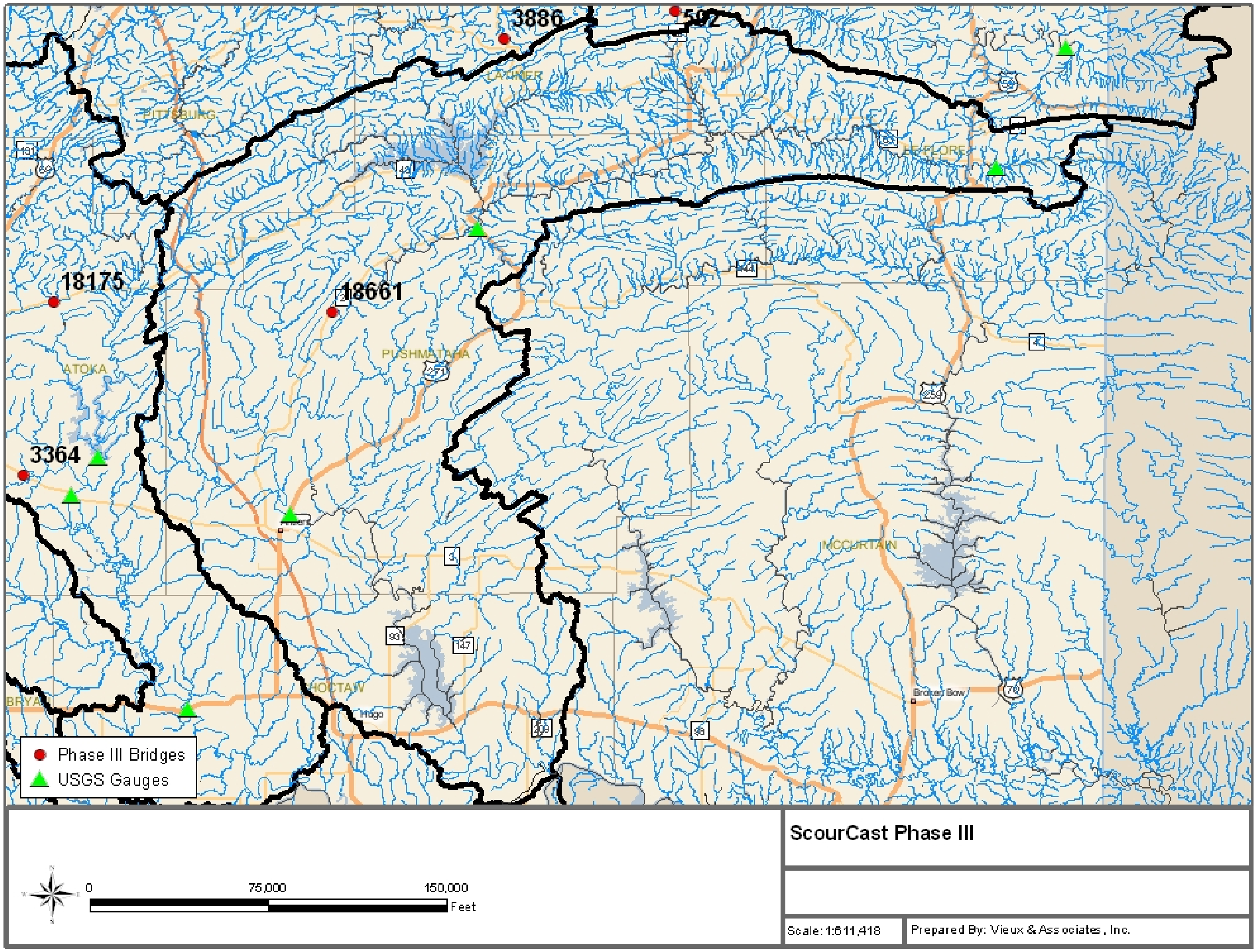

Figure A-31 Bridges in HUC 11140105