



TECHNICAL SUMMARY NOTEBOOK

FLOOD-WARNING SYSTEM AND
FLOOD-INUNDATION MAPPING IN
FT. WAYNE, INDIANA

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Center

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Purpose of this Technical Summary Notebook template:

This template's purpose is to serve as a resource for the creation of technical documentation for USGS flood-warning and flood-inundation studies that are intended to be used for the development of a National Weather Service (NWS) Advanced Hydrologic Prediction Service's forecast site.

It is assumed for some USGS study efforts, the only product(s) will be a Scientific Investigations Map. Therefore, a "Technical Summary Notebook" can accompany the data delivered to the NWS and other interested parties. This document is not intended to serve as a formal USGS published document, rather it is intended to provide a technical overview of the study that will aid future users of the data and models developed/used for the study.

The format of the headings and sub-headings (and some example text for selected sections), are provided as suggestions and as an initial guidance to the author.

*Comments and suggestions to the project chief/author have been italicized and are in blue. Locations of text to be filled in have been **italicized and are in red**.*

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GENERAL DOCUMENTATION

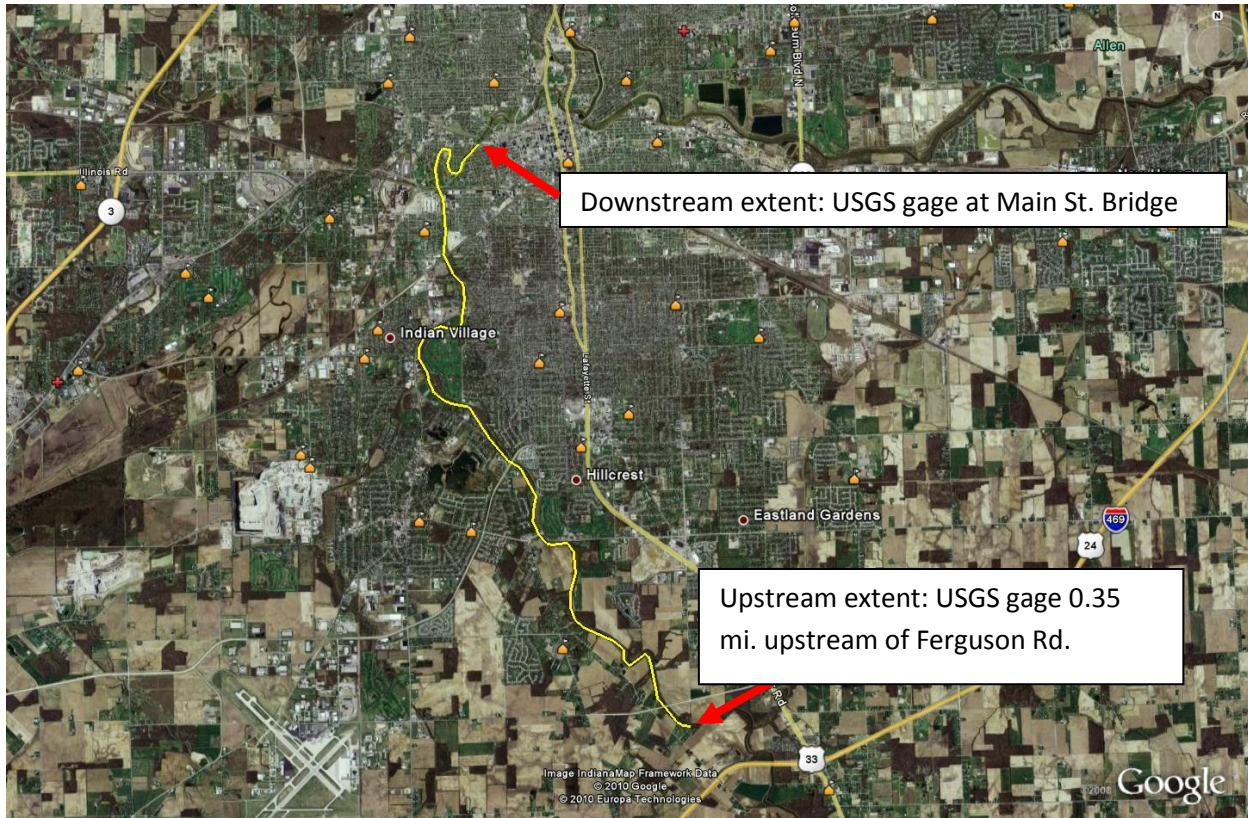
BACKGROUND AND PURPOSE

The City of Fort Wayne, Allen County, Indiana lies at the confluence of three major rivers – the St. Mary’s, St. Joseph, and Maumee – and is thus prone to damaging flooding. The City of Fort Wayne, through progressive and proactive flood damage mitigation activities such as the installation of flood warning systems and active floodplain management, has increased the resilience of its neighborhoods, services, and infrastructure to flooding. New technologies developed by the U.S. Geological Survey (USGS) and National Weather Service (NWS) can provide Fort Wayne with real-time flood information and flood information forecasted up to 5 days out for as yet unprotected portions of the community along the St. Mary’s River.

The National Weather Service (NWS) is responsible for issuing river forecasts and flood warnings as authorized in the Organic Act of 1890. NWS provides flood forecasts for over 4000 stream locations; often collocated at USGS stream gages. NWS disseminates flood forecasts through the Advanced Hydrologic Prediction Service (AHPS), a Web-based suite of forecast products that includes forecasts of the magnitude of floods or droughts, from hours to days in advance. A recent addition to AHPS is flood inundation map libraries for selected NWS flood forecast points (figure 1). These inundation libraries provide information on the spatial extent and depth of flood waters in the vicinity of NWS river forecast points for river levels ranging from minor flooding through the largest observed flood on record. Combined with near-real time and historic river data from USGS streamgages and NWS flood forecasts, these maps enhance the communication of flood risk and provide users additional information needed to better mitigate the impacts of flooding and build more resilient communities.

Scope of Work of Study Effort

The purpose of project component is to develop a library of flood inundation maps for an approximate 9-mile reach of the St. Mary’s River in Fort Wayne (fig 2). The project reach will extend upstream from USGS streamgage 04182769, St. Mary’s River at Main St. at Fort Wayne to USGS streamgage 04182000, St. Mary’s River near Fort Wayne (about 0.35 miles upstream of Ferguson Road Bridge). This project will produce, using the most recent science and information technologies, a flood library that can be viewed interactively through the NWS’ Advanced AHPS Web pages and also used in GIS applications by Fort Wayne. The library will consist of a set of flood extent and depth maps at set water-level (stage) intervals (for example, a map for each one foot of stage). The maps will be created such that users will be able to view each map in reference to base features such as streets.



The St. Mary's River flows generally north throughout the study area.) The downstream study limit is the *USGS gage 04182769*). The upstream study limit is the *USGS gage 04182000* This stream reach is approximately *9 miles* in length.

Figure 1. Map of study area.

ENGINEERING ANALYSES

MODELING APPROACH

A 1-D HEC-RAS model (Version 4.1) was used with the steady flow computation. The St. Mary's River has a slowly changing slope in a rather flat topography. The bridge geometry was provided by the previous FEMA FIS model completed in August 3, 2009. All but three bridges were used from this model and were verified as unchanged with current photographs and observations taken during this projects field collection. The three bridges that were not used were Hale, Airport Expressway and Ferguson Road. The most recent bridge plans were provided by INDOT and entered as bridge geometry data into the HEC-RAS model . The previous FIS did not include the two most recent levee installations in the model. All of the current levees were put into the model directly from the plans without use of any existing model information. HWM data was collected in previous years before the new levees went in so there were no HWM's to calibrate to for this study.

HYDROLOGIC ANALYSES

A known water surface was used as the boundary condition on the downstream reach to compute and calibrate to the upstream gage height and discharge from the gage rating. The known water surfaces were picked off using differences in stage from downstream reach to upstream reach from the old FIS profile. A model was created for stages ranging from 10.0 ft to 22.0 ft in stage. The most recent rating to streamgage 0334182000 was used in making sure gage height at that location matched discharge when calibrating the model.

A. Stream Gage Selection and Rating Suitability

The St. Mary's River near Ft. Wayne gage was used to calibrate this model. This stream gage was installed November 7, 1930 and has been active since. This site is a NWS forecast point and has a very stable history providing stable rating knowledge for this study. The stage range used for the modeling was selected by the NWS and the City of Ft. Wayne. The downstream gage St. Mary's River at Ft. Wayne was not used for calibration purposes due to the fact that it was new and non-relating gage-heights half the period of record due to work between the gages and non-established rating. A long enough history with both gages collecting hydrologic data to show a consistent hydrologic relation to calibrate was not available during the modeling.

B. Stream Gage Datum

The datum of St. Mary's River near Ft. Wayne is 748.97 NGVD (Levels from Indiana Flood Control and Water Resources Commision). Vertcon computes an elevation of 748.458 ft in NAVD for the datum.

HYDRAULIC ANALYSES

Provide a discussion of the hydraulic analyses and an overview of the general framework of the modeling technique employed for the study.

Example –

HEC-RAS (version 4.1), using the HEC-2 conveyance computations option, was used to model flood profiles for all streams analyzed in this study effort. After the initial hydraulic models calculations were completed, warnings presented by the HEC-RAS model were reviewed. The results were assessed for validity, accuracy, and appropriate engineering practices. Some of the areas of concern included: 1) critical water-surface calculations, 2) water-surface elevation differences between adjacent cross-sections, and 3) correct usage of ineffective flow areas.

After the initial areas of concern were addressed, the HEC-RAS models were recalculated. All remaining warnings generated by HEC-RAS were reviewed and judged acceptable for the final models presented in this study. Table (#) shows the models used and the model analysis date for each stream submitted in this project.

Table (X).
Summary of the hydraulic model version and analysis date for each of the studied stream reaches.

Flooding Source	Hydraulic Model Version	Model Analysis Date
<i>St. Mary's River nr Ft. Wayne</i>	<i>HEC-RAS 4.1</i>	<i>11/25/2010</i>
<i>St. Marv's River nr Ft. Wavne</i>	<i>HEC-RAS 4.1</i>	<i>09/12/2011</i>

Special Hydraulic Considerations

Provide more in-depth discussions of various modeling techniques in this section and include pertinent assumptions and reasoning behind modeling decisions to handle unique hydraulic situations.

Examples of these more in-depth discussions are provided for each heading below –

Solution Check at Bridges

During high flow conditions, it is possible for pressure flow to occur at a bridge or culvert. Pressure flow occurs when the water surface on the upstream side of a bridge equals or exceeds the low chord elevation. The validity of this type of solution was checked at all bridges where the water-surface elevation derived from the energy equation was found to be within 1.0 foot of the low chord elevation of a bridge.

The standard-step method (energy equation) is applicable to the widest range of hydraulic problems (U.S. Army Corps of Engineers, 2002a). However, if flow conditions are such that the bridge opening may act like a pressurized orifice, (flow comes in contact with the low chord) pressure flow computations are warranted.

Submergence Check at Culverts

During high flow conditions, it is also possible for road overflow to occur. Road overflow may result in weir flow if; there is sufficient drop in channel/overbank elevation on the downstream

side of the structure and, the structure is not submerged. Submergence is determined as a function of the ratio of the downstream flow depth to the upstream energy grade line, as measured from the minimum high chord of the deck (U.S. Army Corps of Engineers, 2010). The HEC-RAS model uses a default maximum submergence ratio of 0.95 for weir flow calculations. The HEC-RAS Applications Guide states: "When this ratio is exceeded for a bridge analysis, the program will switch from the weir-flow equation to the energy method to determine the upstream flow depth. For a culvert analysis, this ratio is not used because the program cannot perform a backwater analysis through a culvert flowing full. Therefore, a weir analysis will always be used when overflow occurs". As a result, when road overflow occurs at a culvert and a weir flow computation is determined to be invalid, other modeling techniques must be used to account for an energy based solution. For situations in which road grades do not act like weirs, Shearman and others (1986) recommend abandoning culvert and weir hydraulics in favor of composite sections (the combination of the road and culvert cross-section geometries) to reflect pseudo-open-channel conditions.

A set of brief discussions are presented, based upon the stream(s) studied, which provide specific details related to the topic headings, if applicable, to the study. Example discussions are provided for each topic heading for a hypothetical (Stream Name 1).

A. *St. Mary's River*

Work conducted by the USGS

Cross sections surveyed in the field and synthetic cross sections derived from a digital 2-foot contour map obtained from *Allen County* (refer to the mapping section of this documentation for a discussion on the digital contour maps) were used to develop a step-backwater model to establish the selected flood profiles for *St. Mary's River*.

Scope of Work

The St. Mary's River flows generally *north*. The downstream study limit is *St. Mary's River at Ft. Wayne gage (04182769)*. The upstream study limit is the *St. Mary's River near Ft. Wayne gage (04182000)*. This stream reach is approximately *9 miles* in length.

Hydraulic Baseline

Stationing used for the hydraulic baseline for this stream is referenced to *feet* upstream from the *St. Mary's River at Ft. Wayne gage on Main St.*

Cross-Section and Contracted Opening Geometry Data Surveyed in the Field

The USGS surveyed *4* cross sections at 10 hydraulic structures and 38 open channel sections for this reach of *the St. Mary's River*. All surveys were referenced to the North American Vertical Datum of 1988 (NAVD 88) and the North American Datum of 1983 (NAD83).

Synthetic Cross-Sectional Geometry Data

Using a geographic information system (GIS), the USGS generated a triangular irregular network (TIN) from contours, breaklines, and spot elevations to obtain supplemental cross-sectional data for *the St. Mary's River*. A total of 135 synthetic cross-sectional profiles were generated by use of the TIN at desired locations along the stream reach. In-channel data for all synthetic cross sections were estimated by interpolation from cross-sectional data surveyed in the field.

Starting Water-Surface Elevations

The starting water-surface elevation at the initial section for the *11* stage profile for *St. Mary's River near Ft. Wayne* was obtained by the use of the most current (discharge measurement verified) stream gage stage-discharge rating. All starting water-surface elevations for all the profiles were confirmed using shifted rating number *32.0* dated *03/16/2011*.

Manning's Roughness Coefficients

Manning's roughness coefficients (*n*) for the main channel and overbank areas of *St. Mary's River* were determined from field observation and aerial photographs by experienced personnel. Estimates of Manning's roughness coefficients range in value from *0.03 to 0.05* for the main channel, and from *0.05 to 0.08* for the overbank areas.

Flow Lengths

Main channel and overbank flow lengths were computed through the use of HEC-GeoRAS (U.S. Army Corps of Engineers, 2009). Flow paths are drawn in the GIS by the user for both the main channel and overbanks. HEC-GeoRAS computes all flow lengths based on the flow paths estimated by the user.

Hydraulic Structure Solution Reviews

For this study, all hydraulic structure computations were reviewed for the appropriate modeling solutions (see Special Hydraulic Considerations section of Hydraulic Analyses). Initial reviews focused on the type of solution computed at each structure (energy equation based or based on pressure and/or weir-flow equations). In the cases where road overflow occurred at a culvert, a submergence check was made. In the cases where the hydraulic model computed weir flow at a culvert that was determined to be submerged, the culvert was replaced with composite sections. Table A1-A3 shows the river station, a location description, the type of structure, the presence of road overflow, and the solution type of all structures affecting the 11 stage profile for the *St. Mary's River*. (Excel Table A1-A4 lists summary of hydraulic structure solutions per stage.)

Profile Verification (or Calibration)

Old high-water marks could not be used to calibrate too since two levees were put in afterwards. The old FIS could also not be used due to new Levees in place. If high-water mark or historical gage data were available, discuss how they used to verify or calibrate modeling runs. If a FEMA Flood Insurance Study is available and current, was a check performed with model derived water-surface elevations and the FEMA flood profile.

Backwater Elevation

Discuss if there is a potential for any backwater effects to occur.

St. Mary's River backwater does cause flooding on Junk Ditch and Fairfield Ditch.

B. Junk Ditch is a contributing tributary that flows into the St. Mary's. This stream was not surveyed for conventional modeling. A discharge was estimated per stage using a discharge computed by using rating discharge at St. Mary's River near Ft. Wayne gage per stage and multiply it by the St. Mary's drainage area computing the cfsm (cubic square feet per square mile). The cfsm was then multiplied by drainage area of Junk ditch giving an estimated discharge contributing to the St. Mary's River at that location per stage.

C. Fairfield Ditch is a contributing tributary that flows into the St. Mary's. This stream was not surveyed for conventional modeling. A discharge was estimated per stage using a discharge computed by using rating discharge at St. Mary's River near Ft. Wayne gage per stage and multiply it by the St. Mary's drainage area computing the cfsm (cubic square feet per square mile). The cfsm was then multiplied by drainage area of Junk ditch giving an estimated discharge contributing to the St. Mary's River at that location per stage.

D. Snyder Ditch is a contributing tributary that flows into the St. Mary's. This stream was not surveyed for conventional modeling. A discharge was estimated per stage using a discharge computed by using rating discharge at St. Mary's River near Ft. Wayne gage per stage and multiply it by the St. Mary's drainage area computing the cfsm (cubic square feet per square mile). The cfsm was then multiplied by drainage area of Junk ditch giving an estimated discharge contributing to the St. Mary's River at that location per stage.

Tables showing the computation of discharges for each trib at each stage is in excel file TribQsTablefin_mhk3.xlsx.

MAPPING INFORMATION

GEOSPATIAL MAP DOCUMENTATION

The following information will be provided with the inundation maps as they are created.

Section 1: Identification information

This includes the **title, creator or originator of the data**, and **abstract** describing the content of the dataset, **time period, keywords, contact information** for a person or organization for questions

Section 2: Data Quality Information Contains information about the **resolution or scale of the data, accuracy of the data, processing steps, and sources of the data** (if source data were used).

Section 3: Spatial Data Organization Specifies **data type** as vector or raster.

Section 4: Spatial Reference Information Details the **projection or coordinate system**.

Section 5: Entity Attribute Information Provides a **definition and description of the attributes** in the tables or fields in a dataset.

Section 6: Distribution information

Gives information about how the data are available

Section 7: Metadata Reference Information about the format and **contact information** for the creator of the metadata.

A useful reference that provides more detail is "FGDC Don't Duck Metadata. Metadata Quick Guide", April 2006 version.

It is available online at <http://www.fgdc.gov/metadata/documents/MetadataQuickGuide.pdf>

Surveys conducted by the USGS

Example text-

The USGS conducted both Global Positioning System (GPS) and conventional surveys for this study. The GPS surveys were conducted to establish a control network at pertinent locations along each of the streams studied. Conventional surveys were conducted to obtain stream and hydraulic-structure geometry. Third order accuracy (horizontal and vertical) was maintained for all conventional survey data collected (Federal Geodetic Control Committee, 1984).

The horizontal datum for the survey is the North American Datum of 1983 (NAD83), Ohio State Plane (Ohio North) coordinates. The vertical datum for the survey is the North American Vertical Datum of 1988 (NAVD 88).

GPS surveys were conducted by the USGS using both Real-Time Kinematic (RTK) and static surveying techniques. Control for the USGS survey was established using a U.S. Geological Survey benchmark and streamgage water surface elevations with known vertical coordinates. A comparison of the published coordinates and surveyed coordinates are shown in the Table 1 below.

Table 1. Comparison of published coordinates to USGS surveyed coordinates. All data shown in feet, NAD83, and NAVD88. (Excel file Table 1)

MISCELLANEOUS REFERENCES

REFERENCES AND BIBLIOGRAPHY

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Federal Geodetic Control Committee, 1984, Standards and Specifications for Geodetic Control Networks, 34 p.

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Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model—Research report: Federal Highway Administration Publication FHWA-RD-86- 198, 112 p.

Army Corps of Engineers, Hydrologic Engineering Center, January 2010: HEC-RAS River Analysis System, User's Manual, Version 4.1 790 p.

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Army Corps of Engineers, Hydrologic Engineering Center, 2009, HEC-GeoRAS, GIS Tools for Support of HEC-RAS using ArcGIS, Version 4.2, 246 p.