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Flash Flood Event Assessment (FFEA): Terrestrial and Satellite Remote Sensing for Flash Flood Assessment.

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Introduction

Flash floods threaten life and property and as such have been the focus of efforts by the US National Weather Service (NWS) to predict and monitor their occurrence. However, these efforts are focused principally on monitoring conditions conducive to flash flood prediction. Information on flash floods usually takes the form of broad areas identified as likely to experience flooding. More detailed models allowing assessment at the basin level are not readily available to the general public or the private sector responsible for post-event cleanup and mitigation. While prediction is critical for early warning, post-event assessment is required by the public and private sector to address the impacts to life and infrastructure. These assessments are most critical in urban environments where extensive areas of impermeable surfaces create conditions more susceptible to flash flooding. Integrating hydrologic basins, estimates of permeability and runoff potential with rainfall accumulations, rates, and precursor surface moisture allows the development of more localized assessments and provides information of importance to individuals and organizations responsible for event response and recovery.

This paper discusses a prototype Flash Flood Event Assessment model (FFEA) designed to meet the need for localized assessment. FFEA uses rainfall rates and accumulations derived from NEXRAD weather radar coupled with information on topographic and runoff potential in a distributed physics-based GIS model to generate near real-time assessments of flash flooding conditions (Vallabhaneni et al. 2003; Vieux 2003; Vieux et al. 2005; Vieux and Vieux 2004). FFEA generates automated assessments incorporating hourly precipitation with daily summaries including maps of basins with associated flash flood probabilities and level estimates as GIS layers and graphic displays.

Flash Flood Event Assessment Model (FFEA)

The Flash Flood Event Assessment model is a near real-time model designed to provide information on location specific effects and limits of flash floods. FFEA assessment data are provided via a web-based interface and delivery system. Formatted to meet the needs of the user, data are provided in a GIS format on an as needed basis or automatically by scheduled downloads to client servers. Developed using Open Source software linked to web-based map and image services, FFEA provides a low-cost and efficient means to monitor local scale impacts of flash floods. The FFEA web interface integrates satellite imagery and aerial photography from web-based services, e.g. Google Earth or Virtual Earth, to display results in a readily interpreted image format and to facilitate post-event assessment and response.

Model Requirements

To effectively meet the needs of agencies, both public and private, FFEA must provide local information in a timely and readily accessible fashion. To meet these requirements the model must: 1) ingest a variety of near real-time datasets from disparate sources, 2) integrate them into coherent geospatially referenced format, 3) process these data using a distributed physics-based hydrological model into meaningful products, and 4) deliver

the products to the end clients within one day or less following the event. Figure 1 presents a schematic of the FFEA model data, processing, and product delivery.

Data Ingestion

To accomplish near real-time analysis requires the monitoring of conditions likely to lead to a flash flood event in the area of interest. This is accomplished by timed queries of NWS weather and flood warning sites to identify storm events and issued warnings. The NWS maintains an Internet data service that provides weather-related warnings in GIS (shapefile) format for all fifty states. Warnings provided in shapefile format are Tornado Warnings, Severe Thunderstorm Warnings, Flash Flood Warnings, and Special Marine Warnings. These warnings are updated every one to two minutes, twenty-four hours a day, seven days a week (National Weather Service 2007b). In addition to the shapefile format, these warnings also are available in RSS XML and as a text-based Common Alertings Protocol (CAP) XML formats (National Weather Service 2007c). These data provide important additional information beyond that provided by the shapefiles and are used to populate additional fields in the shapefile attribute tables. The shapefile and XML data serve to provide an alert that initiates an automated download of precipitation data from the NWS NEXRAD Station(s) covering the area of the warning (Xie et al. 2005). Additional data on prior precipitation can also be acquired for inclusion in the analysis of runoff.

Automated data requests are scheduled to access the NWS sites to identify and initiate download and processing of precipitation data. Data queries can be scheduled to access the warnings site at any desired frequency. Precipitation data are available from the NWS in several formats. The most readily accessible and spatially contiguous data are derived from the NEXRAD weather radar. Precipitation data are available as hourly, daily and storm totals for the entire US. Where prior precipitation has affected soil permeability and may contribute to runoff rates, historical data from the last 7 and 14 days are also available (National Weather Service 2007a).

Data Integration

In addition to the dynamic precipitation data, the GIS-based hydrological model requires additional static geospatial data. Table 1 summarizes the input data requirements of the model. All of these data are registered to the WGS-84 geographic datum and are in an unprojected geographic format. The base model data consists of Elevation, Hydrological Connectivity, Channel Cross-Sections, Permeable/Impermeable Surfaces, Soils/Permeability, and Drainage Channels and are summarized in Table 1.

The ingested precipitation files are shapefiles in geographic format with nominal 4-km grid spacing. The 24-hour precipitation totals are attached as attributes to the center point of the Hydrologic Rainfall Analysis Project (HRAP) grid coordinate system. HRAP is a gridded polar stereographic projection true at 60°N / 105°W. All precipitation data are reprojected to match the model base data (WGS-84, geographic) in accordance with procedures described by the National Weather Service (2002).

Processing and Product Generation

The analysis of the precipitation data is accomplished using a distributed physics-based hydrological model. Three models are currently under consideration: two commercial products, vFlo™ by Vieux, Inc. and the hydrologic tools in the Spatial Analyst Extension of ArcGIS by ESRI, and a suite of hydrological analysis tools (r.water.fea) in the Open Source Geographic Resources Analysis Support System (GRASS). All of these models require the same data inputs and generate the same kinds of outputs. Using the base model data in conjunction with the near real-time precipitation data, these models produce estimates of runoff associated with a particular storm event. Products include flooding extent and depth, and with the inclusion of an economic valuation data layer (e.g. zoning, taxation valuation) can even be extended to estimate associated losses. Processing of flash flood potential and warnings is accomplished as an automated process immediately following the event using calibrated precipitation data where they are available.

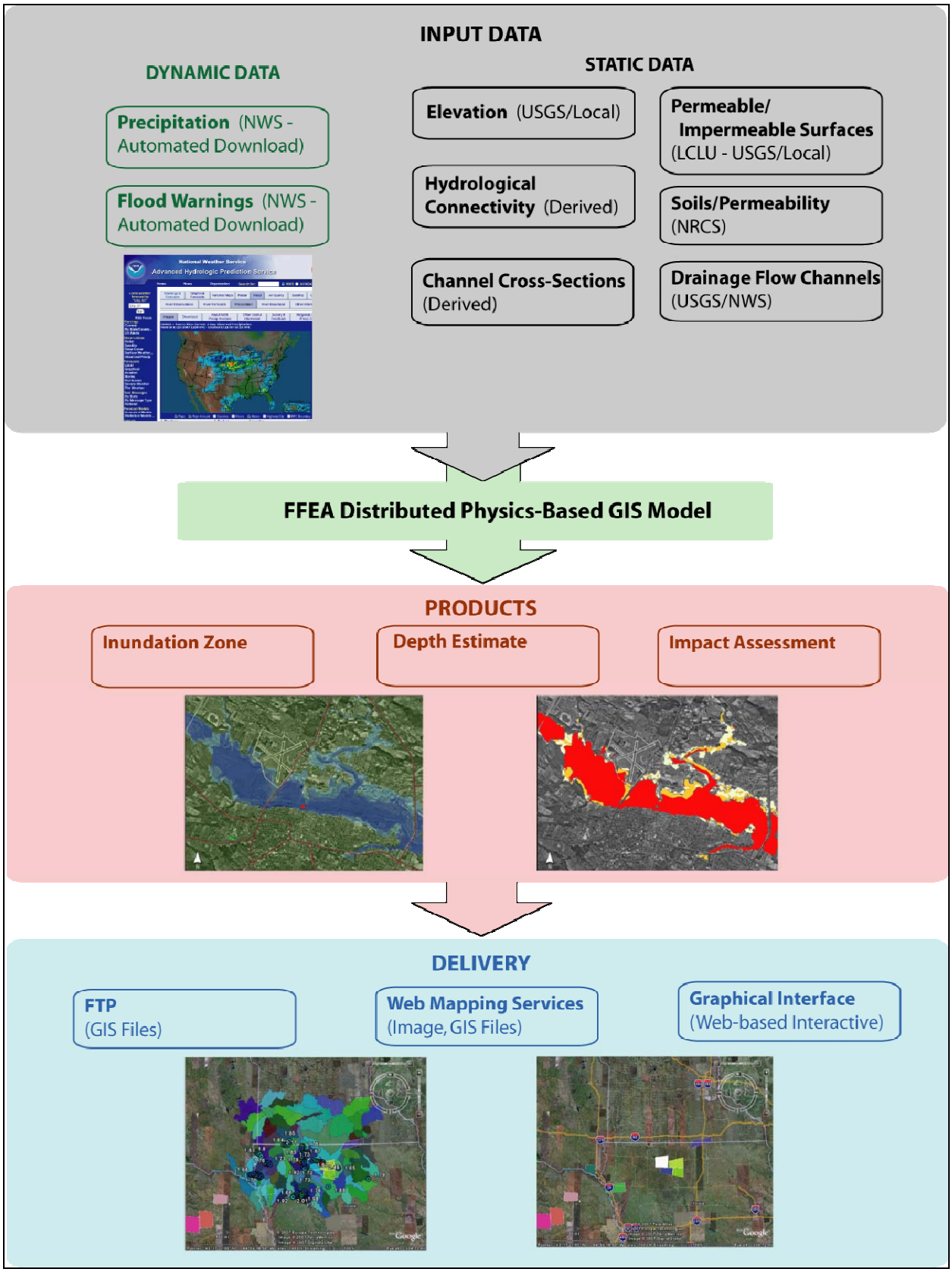

Figure 1: Schematic of the FFEA Model.

Table 1: FFEA Model Inputs

Data	Source	Status	Processing
Elevation	USGS/Local	Static – periodic updates as new data become available	DEM
Hydrological Connectivity	Derived	Static – periodic updates as new DEM data become available	Derived from DEM/Slope
Channel Cross-Sections	Derived	Static – periodic updates as new DEM data become available	Derived from DEM/Slope
Permeable/Impermeable Surfaces	LCLU – USGS/Local	Static - periodic updates as new imagery becomes available	Estimated from LCLU data and/or derived from aerial or satellite imagery
Soils/Permeability	NRCS	Static - periodic updates as new data become available	Can be approximated for large areas from Soil Surveys.
Drainage Channels	USGS/NWS	Static – periodic updates as new data become available	Available as vector drainages or can be derived from DEM data.
Precipitation	NWS – Automated Download	Dynamic – Hourly to Daily Total updates	Provides basis for runoff model in GIS (*Vflo*™, GRASS, ArcGIS)

The FFEA model is intended to provide local area assessments of the impacts of flash flooding. Nationally available real-time data for severe weather events provides a valuable resource that, coupled with advances in hydrological analysis that allow the integration of spatially distributed precipitation inputs and physics-based finite element analysis, provides reliable, near real-time mapping of flash flood events at a local scale (Table 2). While the predictive models of NWS (Flash Flood Monitoring and Prediction – FFMP) are designed to provide real–time predictions of flash flooding, FFEA uses similar algorithms to provide post-event analysis. Data are provided as maps and spatially explicit information on flash flood extents and intensities. These products are not provided by the NWS Advanced Weather Interactive Processing System (AWIPS), of which the FFMP is a part, and are not readily available to the general public or the private sector.

Table 2: FFEA Products

Product	Description
Inundation zone	Map and associated attribute table for total inundation area.
Depth Estimate	Map and associated attribute table for depth estimates of the inundated area.
Impact Assessment	Map and tabular summary of economic affects.

Output Data Delivery

The FFEA model provides outputs as GIS data layers, and map-based graphics over the Internet for integration into a GIS. Alternatively, these data can be provided as dynamic maps and data delivered through an Internet browser via a Web Mapping Service (WMS). These data and information can even be presented using a web-mapping program such as Google Earth (Figure 1 & Table 3).

Table 3: FFEA Data and Product Delivery

Mechanism	Format	Software
FTP	GIS files (Shape File, Grid, etc.)	FTP Client or Browser
Web Mapping Services (WMS)	Image, GIS files	Internet Browser
Graphical Interface	Web-Based Interactive Map	Internet Browser, Google Earth,

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