Flood Plain Modeling/Mapping at DuPage County, IL Requires GIS

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Abstract
Modern flood plain modeling and mapping is done at the County of DuPage, IL, using ESRI software products. GIS methodology is applied to DuPage's hydrology/hydraulic/statistical/mapping approach which creates reproducible, defensible flood study models and digital map products. This paper presents an overview of the workflow process from raw data to flood maps. The analytical modeling approach was established in the early 1990s. What was needed was GIS to organize the spatial data progression and to establish routine map making capabilities. All work to date uses Workstation ArcInfo except for the map making, which relies upon Desktop ArcGIS. This approach has earned DuPage the Cooperating Technical Partner status with FEMA, which recognizes its Digital Flood Insurance Rate Map and its Regulatory Flood Map. This case study will help other governments consider other approaches for producing all digital flood plain maps.

Introduction

DuPage County, Illinois is located directly west of the City of Chicago and encompasses an area of 336 square miles, or about 1/5th of that City's surburban fringe. There are 39 municipalities wholly or partially in the County and about 29% of it is unincorporated. The 2002 U.S. Census total population estimate is about 924,600.

The County has undergone rapid urbanization over the last forty-five years and much of that occurred with disregard to stormwater and flood plain impacts. Although the Federal Emergency Management Agency (FEMA) developed Flood Plain Maps for the County in the late 1970s and early 1980s, urbanization has reduced the accuracy of these maps dramatically. The level of man-made change in the County is due not solely to residential construction but also to large industrial and commercial development. While many of these developments avoided the flood plains, they did have a profound impact on the hydrology and hydraulics of the streams in the County. The level of development, number of communities, degree of stormwater and flood plain issues, and piece-wise development and other inadequacies of the FEMA maps all contributed to the need for a regional approach to stormwater and flood plain management.

The development of regional stormwater planning within the County began in 1983 with the Winfield Creek Pilot Study, representing the first use of a continuous simulation hydrologic and dynamic routing watershed modeling effort by means of the Hydrologic Information Package. In 1986, the County organized a joint committee of County and Municipal representatives to address stormwater issues, and during the same year, the State of Illinois passed legislation that authorized northeastern Illinois counties to develop their own regional stormwater management programs. Coincidentally, in August 1987, severe flooding caused $150 million in damage in the County. The following year, the still current County-Municipal Stormwater Management Committee was formed under the State Legislation authorization guidelines to oversee the new Department of Development & Environmental Concerns - Stormwater Management Division (DEC-SMD). In September 1989, the Stormwater Management Committee and the DuPage County Board adopted the *DuPage County Stormwater Management Plan (PLAN)*, which provides the goals, policies and standards under which DEC-SMD operates. The *County-wide Stormwater and Flood Plain Ordinance (ORDINANCE)* was adopted in 1991. It established the regulatory mechanism to address flood plain management, stormwater drainage and detention, wetland impact, soil erosion and sediment control issues, and enforces riparian and stream protection resulting from development activities.

Among other DEC governing activities, the PLAN and the ORDINANCE are administrated via a collection of Watershed Plans. These Plans serve to identify existing problems and assess remediation, as well as to develop updated modeling and mapping, for each tributary watershed unit of DEC's Watershed Planning Areas (WPA). The WPAs are a hierarchy of watershed areas defined by physical watersheds and the County boundary. The primary areal level is the riverbasin watershed, which is then portioned into tributary watersheds, or 'tribsheds', as the secondary level. A tribshed is portioned into catchment watersheds, also called sub-basins, as the final, tertiary level, which serve as the smallest unit for analytical modeling. Since almost all modeling, mapping, and project management work at DEC revolves around the tribshed areal unit, this paper will hereafter most often use the more common word 'watershed' for it.

Originally, DEC sought to matriculate directly from the older FEMA Flood Plain Maps to its own WPA model/mapping products, but after the County entered into a Cooperating Technical Community Agreement with FEMA in 1998 to re-delineate the many existing Flood Insurance Study flood profiles onto the County's two-foot contour interval topographic maps, an interim, transitional map product has been realized instead. This flood plain map, called the DuPage Regulatory Flood Map (RFM), to be approved by FEMA in June 2004 for all County purposes except insurance rating, will be the basis of the first Digital Flood Insurance Rate Map (DFIRM) for the County by December 2004. The advent of the RFM is advantageous to all parties since it incorporates the older flood plain mapping, but more accurately expressed, and provides a framework for the County to update entire watersheds with WPA model/mapping products and to perform piece-wise updating per FEMA Letters of Map Change. As a FEMA Cooperating Technical Partner (CTP), the County will maintain the continuous, County-wide RFM by housing an up-to-date version on the DEC-SMD GIS data stores and provide it on Compact Disk formats, including Environmental Systems Research Institute (ESRI) ArcReader Published Map Files (PMF).

Modeling Methodology

DuPage County has seven Watershed Planning Areas, which are East Branch of the DuPage River, West Branch of the DuPage River, DuPage River Tributaries, Salt Creek and Sawmill Creek and other Des Plaines River Tributaries, and Fox River Tributaries. All of these drain to the Illinois River and thence to the Mississippi River. Watershed Plans are used to identify structural and nonstructural improvement projects to alleviate current and anticipated flooding problems, to index significant natural areas, storage areas, and wetlands, and to update and revise flood plain maps.

DuPage County is unique in its choice of the hydrologic and hydraulic models used for watershed planning and flood plain mapping. Rather than using single event, steady state models such as HEC1 and HEC2 for hydrology and hydraulics, the DEC-SMD utilizes continuous simulation and dynamic routing models. The models were selected for the following reasons. First, the continuous simulation hydrologic model is used to capture the effects of antecedent moisture on runoff volumes and peaks and to account for non-uniform precipitation distributions over the watersheds. It is difficult to deal with these factors using the typical design storm approach. Second, the effects of backwater, flood plain storage, and complex urban stream systems have a significant impact on the hydraulics of County streams. Thus, an unsteady flow model has been adopted for use in County Watershed Plans.

DEC-SMD produces continuous flow and stream stage information based on historical precipitation records. From this data, flow and stage duration is readily available for not only large events, but also for dry times and small runoff events. The continuous simulation approach allows the County to properly implement stormwater programs such as flood plain mapping, flood forecasting, water quality protection and enhancements, wetland creation, and project analysis.

Hydrologic information, by means of the Hydrologic Simulation Program - FORTRAN (HSPF) developed by Hydrocomp International, Inc. and currently maintained by the USEPA, creates the data needed for the hydraulic analysis. This model simulates continuous runoff for various land cover types for a continuous period of precipitation record. The model incorporates infiltration, interflow, depressional storage, soil storage, snowmelt, overland flow, evapotranspiration, and changes in antecedent soil moisture in determining rainfall runoff. Seven long-term precipitation gages are utilized to develop a forty-five year continuous time series meteorology input file, with six of these gages maintained by National Oceanic and Atmospheric Administration (NOAA) and one by USDOE Argonne National Laboratory (ANL). Six land cover categories defined as impervious, flat grass, medium grass, steep grass, forest, and agricultural have been developed and calibrated throughout the County to match observed flows recorded at stream flow gages operated by the United States Geological Survey (USGS). The resulting output from the HSPF is a continuous time series file (TSF) of runoff for each land cover type and each rain gage.

Hydraulic analyses are achieved using the dynamic flood routing model known as Full Equations (FEQ). FEQ is used for both project analysis and flood plain mapping. FEQ was developed by Dr. Delbert Franz of Linsley, Kraeger Associates, Ltd., and is verified and supported by the USGS. The FEQ model represents unsteady type flows in channels and reservoirs and is based on the numerical solution of the Saint-Venant equations describing one-dimensional flow in open channels. FEQ uses the TSFs created from the HSPF output and can represent the effects of flood plain encroachment, on-line and off-line storage, diversions, channel improvements, bridges, culverts, dams, weirs, and other flow impediments. Complex hydraulic structures such as time or stage dependent gates, and complicated flow paths such as split flow, can be represented readily in FEQ model, all of which occur in the County's streams.

Historical rainfall and stream flow data along with computer modeling are used to evaluate the flood control needs of each watershed. All models are calibrated with reported "high water" marks. In order to better model the watersheds, the County has developed a network of precipitation and stream flow gages: in addition to the NOAA and ANL precipitation gages (1949-present), DEC-SMD has developed a network of precipitation gages throughout the County. These gages are used for both flood forecasting and model calibration. In addition to these gages, SMD has identified more than forty precipitation gages maintained by local communities. In all, ninety six precipitation gages have been identified in and around DuPage County. There are nineteen stream flow gages recording stage and/or flow on streams located in or upstream of the County. Twelve of these gages are operated cooperatively by the County and the USGS. The remaining ones are operated by either the USGS or the Illinois Department of Natural Resources - Office of Water Resources. In addition, high water marks have been recorded and surveyed for several recent flood events. With this variety and density of hydrologic data, the models can be calibrated very accurately.

Currently, more than 80% of the County's 59 watershed areas have models developed. These models will project stream flows and alternative flood heights under various land use and storm conditions. Depending on the complexities of the watershed, it takes, the average, up to two years to complete a Watershed Plan. The Stormwater Management Committee and County Board have approved Plans for more than 50% of the County. These are the areas of documented flood damages and losses where capital measures were needed to address the problems. The remaining Plans exist primarily for flood plain mapping.

For flood stage predictions, SMD employs a statistical computer program called Peak-to-Volume Statistics (PVSTATS) to determine the 1% Annual Chance (100 Year) and other frequency flood elevations. The PVSTATS model was chosen due to problems incurred by the Water Resource Council's Bulletin 17B (LP-III) technique, which includes the postulates that there are typically no significant changes in a watershed that would affect its hydrology over a period of record, total flows are not typically regulated or modified by control structures, and an area's climatic record is typically homogeneous. As stated before, DuPage County has gone through rapid urbanization, severely impacting the land's hydrologic response for the period of record. The County's essentially flat topography, coupled with the number of control structures on the streams such as detention facilities, causes many backwater situations and severe flow regulation.

The PVSTATS "peak-to-volume" approach was developed for use with the continuous simulation approach employed by the County. The basis for the method is to estimate both the probability distribution of flood volumes and the regression relationship between their flood peaks. At sites of interest, say at all stream cross section points, flood volumes are developed and a probability distribution is fit to a series to yield a frequency estimate of volumes, exploiting the fact these series often conform to commonly assumed probability distributions, even when their peaks are affected by flood control projects. Many local historical storms are used to define the regression relationship between the flood peaks and volumes, and additional major American Midwest storm events are used to fill in the upper end of the relationship series. The peak-to-volume curve is then interpreted to produce stages and/or flows at the sites of interest for different recurrence intervals. Since flow information exists for many cross-section locations for forty-five years of record, accurate recurrence intervals can be developed for them in the model. This better continuity leads to a better flood plain map.

Floodway encroachments into flood plains are determined by using the NRCS's SCS floodway program. They are imported to the FEQ model to insure that maximum depth and velocity increase requirements are not exceeded. FEMA and the State, which has statutory requirements for monitoring floodway limits as the permitting authority, has agreed to this method to augment SMD's HSPF/FEQ/PVSTATS methodology.

GIS Applications

The hydrologic/hydraulic/statistical modeling approach taken by DuPage County's DEC-SMD group was well established by the mid-1990s. Although the enterprise is inherently geographical, the modeling preparation, processing, and visual reporting, if any, was performed manually. While this is not necessarily poor practice for small or few watersheds, it does not accommodate long term workloads with personnel turnover, several score of watershed modeling exercises, and integrated visual feedback. At worse, it does not follow a defensible, repeatable workflow pattern that can be part of an overall business plan. Therefore, starting at that time, DEC-SMD began to explore and develop the use of GIS to augment its modeling approach.

ESRI software and customized applications upon them were chosen to automate, without forfeiting the models, any part of the modeling preparation and post-processing steps that could be made rigorous. Since the HSPF, FEQ, and PVSTATS analysis programs were developed more-or-less independently of each other, their outputs-to-become-inputs require modification or repackaging when put into a workflow sequence. Workstation ArcInfo Arc Macro Language (AML) menus and scripts, DOS batch and UNIX operating system shell commands, PERL scripts, and Visual Basic for Application (VBA) forms and scripts were fashioned into customized programs and applications for the various automatable modeling steps.

The first figure, DuPage County Flood Plain Modeling/Mapping Workflow, shows the overall work flow path for the modeling process as supplemented by the GIS applications. Table 1, Major GIS Applications in DuPage Flood Plain Modeling/Mapping, outlines the five major applications used by DEC-SMD and amplifies the descriptors in Figure 1. The Table lists the basic modeling workflow support function or role, primary geodatasets as source data, primary geodatasets products, and the software basis for each GIS application. About half of the program coding was developed by the author and the more complex parts were developed by the able assistance of various workers at GeoAnalytics, Inc., Madison, Wisconsin. There are many other helper programs and utilities that have been constructed at SMD to complete the constellation of modeling activities that have evolved over the past decade.

RGFAC

The Rain Gage Factors (RGFAC) application produces rainfall adjustment factors for catchment watersheds in the DPC WPA territory, which extends beyond the County boundary in some tributary watershed cases. Whether the user chooses to use results from a subset of physical rain gages or the NEXRAD grid pattern, the application develops a rainfall distribution isohyetal surface for a given recorded rainfall event. From this continuous surface, a table of rainfall adjustment factors is interpolated. A given catchment's centroid location is tagged with a multiplier, usually nearly 1.0, to be applied to the nearest rain gage total value. In this way, the collection of catchment centroids becomes a representative point sampling for the isohyetal surface.

The Rain Gage Factors (RGFAC) figure sequence shows the gist of the user experience for the application. First, the user is presented a basic parameters form. After choosing a recorded, significant storm event and watershed, the user requests a network of rain gages to exercise. The network may be either all physical rain gages used by the County, or the NEXRAD pseudo-rain gage network formed by its grid cell centers. The user must then elect to use all rain gages in a network or to winnow the full set from a minimum subset to some larger subset in an Area-of-Interest (AOI), a circle centered on the watershed. Finally, the user must preview the recorded rain gage values (or estimates in the case of NEXRAD cells) for establishing a minimum number of useful rainfall reports. Once a valid set of parameters is established, the isohyetal development work can commence. When done, the user is presented with a series of views of the isohyetal surface as a contour map, which he/she may elect to save as an ArcPlot map composition. The application ends with the creation of a simple text file enumerating the selected rain gages and catchment centroid multiplier factors.

The basic processing steps for the analysis part of the application are as follows:
1) From the parameters form, create a parameters text file to both support the current exercise and to provide an alternative starting point for subsequent, alternative batch processing runs.
2) Development a surface grid cell size as being at least the size of the least cardinal dimension of the smallest catchment extent; reset grid cell size if necessary depending on available computer memory.
3) Create point coverages for AOI rain gages and catchment centroids.
4) Develop an isohyetal surface grid from the AOI rain gages and develop thiessen polygons from the AOI catchment centroids.
5) Assign rainfall depths to catchment centroids from the isohyetal surface grid.
6) Intersect catchment polygons with rain gage thiessen polygons to associate each catchment's isohyetal depth with the thiessen's depths. Compute the rainfall factors as the ratio of these depths.
7) Generate output files.
As stated in processing step 1, the parameters text file can be reused by simple editing in subsequent isohyetal analysis runs. This is often the case since many storm events and rain gage combinations are typically used as input to the HSPF program for one or more watersheds.

LCTOTS

Besides utilizing the more realistic, recorded rainfall distributions repackaged by the RGFAC application instead of a typical uniform rainfall pattern, the HSPF program must also account for the land cover types for each catchment watershed (denoted by the curved arrow in the Workflow figure). Specific land cover facts are developed by the Land Cover Totals (LCTOTS) application. It pursues a multi-tiered map overlay process, where each map is a relevant geographic theme to a site's hydrologic response. These themes include catchment watershed areas within a chosen tributary watershed, land use types including types of open spaces and hydrographic features, physical rain gage networks, both local and NOAA, soil units, and topographic slope classes. The intersection of all these themes makes for a highly partitioned watershed, where each area part is assigned tailored land cover characteristics. The LCTOTS application then tallies all of the parts per land cover classifications and slope classes and prepares data text files for use in both the HSPF and FEQ modeling programs. The tallying, or totaling, reports include two pairs of data files as standard output. One pair is for the local rain gage network and the other is for the NOAA network. In each pair, one data file lists acreages of four basic land cover types, {impervious, grass, forest, and agriculture}, per one of three slope classes, {flat, moderate, and steep}. This file is used in the HSPF program. The other data file summarizes the HSPF input data file per catchment area, expressing the land cover types as percentages. This file is used in the FEQ program. The LCTOTS application can also produce customized totals files.

The Land Cover Totals (LCTOTS) figure sequence shows the gist of the user experience for the application. First, the user is presented a basic procedure form. This allows a choice between setting up parameters and exercising all processing steps in toto or setting up parameters and electing to manually driving each processing step in turn. The reason for the latter procedure is to track and debug difficult processing scenarios if desired or to progress only to some desired point. Second, the parameters form is presented offering all application choice scenarios. This form is immediately followed by a confirmation menu from which the user may backtrack or launch the theme overlay processing. The application finishes with generated data files for standard runs, but also presents dialogues for custom INFO table construction(s) if initially requested.

The basic processing steps for the analysis part of the application are as follows:
1) Clip out the applicable tributary watershed, with its sub-basin (catchment) watersheds, from the master WPA geodatasets.
2) Use the hull of the watershed to clip out parcels from a land use tagged version of the County's parcel geodatasets. Dissolve per FEQ hydrologic land use code.
3) Use the watershed hull to clip out open space areas from the parcel geodatasets and combine these with the dissolved land use areas to create an overall land use coverage.
4) Use the wateshed hull to clip out hydrographic patterns, soil units, and rain gages from their respective master geodatasets.
5) Buffer the wateshed hull and apply the buffer shape to a clipped subset of the County's topography. Create a TIN geodatasets from this and classify into slope categories.
6) Progressively overlay the prepared geographic themes into an overall combined land use coverage.
7) Generate a master INFO data table, thence create standard or custom text data files by a fixed naming convention.
Although the goal is often just the use of the generated data files to support hydrologic modeling, the set of derived coverages can be used for many other purposes.

XSEC

The Stream Cross Section Construction, Manipulation, and Output (XSEC) application produces and maintains all stream cross sections (X-secs) and some other kinds of transects for SMD's hydraulics, flood statistics, and mapping models and mapping applications. These X-secs and transects are maintained as Arc coverages, where each one holds all developed X-secs for a routed stream reach within a tributary watershed. By convention, a watershed's mainstem reach, usually the stream bearing the place name for a watershed, is tagged as Reach #1, but all others are enumerated as they were originally utilized. By construction, the X-secs are defined as directed, contingous chains of simple arcs, where a simple arc is one having no intervening vertices. This construction allows each terminating vertex, which is topologically termed a node, to hold attributes corresponding to its exact location, which SMD calls 'station points' after surveying parlance. The arcs themselves are tagged with attributes as well. In fact, the entire arrangement is componentized so that GIS and user attributes are developed for minor parts as well as various collections of parts, all based more-or-less on the processing needs of the FEQ modeler via its pre-processing program called FEQUTL.

The XSEC application is large enough to have been broken into two main activities. The first is termed Bulk Processing since its goal is to digest text data files and convert their intelligence into juvenile X-sec coverages. The XSEC application has been built to process (SMD-wise) pre-GIS FEQUTL data files and SMD formatted GPS survey point data files, and can be extended to digest other kinds of transect representations. Bulk processing itself proceeds through two basic steps: first, source text data is inducted and fashioned into raw X-secs; second, these are spatially adjusted, if necessary, to fit and orient with respect to their declared stream station (distance) locations.

The second main XSEC activity is public enough to be given its own name, Cross-Section Database Interface (XDI). It is the application allowing users to manipulate the juvenile X-secs in any way they wish to prepare them into mature ones for their several intended uses: direct input into the FEQ modeling program, indirect input into the PVSTATS modeling program, and direct input into the Flood Plain Delineator application. Once users have thoroughly developed all X-secs for all modeled reaches in a given watershed, then the reach-wide X-sec coverages are consolidated into a single tributary watershed-wide one for mapping purposes. Because all watershed-wide X-sec coverages will be further combined into a single County-wide one for the Flood Plain Mapper application, it follows that each X-sec within the County must have a unique identifier. This fact and similar component constraints are enforced by the XSEC application. Besides unique identifiers as a characteristic of SMD developed X-secs, the XDI coverage database is intended to be a growing repository of them, to help reduce the difficulties of personnel tenure and project work often spanning many years. Each watershed can accommodate up to 10,000 X-secs.

The Cross Sections (XSEC) figure sequence shows some of the aspects of the Bulk Processing steps. First, typical data 'flat', or text, files are shown to contrast the principal X-sec data sources to-date for SMD. FEQUTL files, for which the XSEC application was originally exclusively intended, can range considerably in terms of map intelligence but will still easily satisfy their purpose of supplying an FEQ model exercise. GPS files are rich in coordinates, but lack almost all of the usual information needed in an FEQ model run. For either source, Bulk Processing creates the same kind of componentized, juvenile set of X-secs with all source data permanently recorded to permit a 'paper trail'.

The X-Sec Database Interface (XDI) figure sequence shows the gist of the XDI user experience with the form menu operation mode (the other is the pull-down menu mode, which is functionally identical). There are several groupings of tools including Selection Status, Component

Manipulation Tools, Reporting Tools, Control Tools, and System Tools. Only a few of the several tools are illustrated. The Move a Station Point is representative of the modus operandi of the Component Manipulation tools. Presuming a single X-sec has been selected, a user invokes the Move Station tool and then fills out a parameter form of which station point to move, indicates its new location, and applies the exercise as stated in the form's mini-report. The geometric change is performed, thence a series of component attribute table updates are made in synchrony, except for creating a new elevation from County topography – this is done to force the user to exercise caution and judgment with presumably superior survey data. One of the most important XDI tools is for (re)creating an FEQUTL data file to directly support FEQ model runs. An XDI generated data file guarantees a consistent, complete format for such files. More importantly, it includes precise coordinates and GIS identifiers which are needed to track a given X-sec through the FEQ/PVSTATS modeling and XDI/FPD/FPM mapping processes.

The basic processing steps for the Bulk Processing part of the XSEC application are as follows:
1) Prepare reference coverages, namely a routed, dendritic network of stream reaches, a buffer area around the routed network, and a clipped portion of the County topography from the stream buffer.
2) Segregate X-sec source data files into files per stream reach. Induct each source file into a raw X-sec coverage (Type A).
3) Manually segregate FEQ commentary, if applicable, since component membership is inherently ambiguous in sequential record processing.
4) Spatially adjust X-sec station points without valid coordinate values. Complete the component attribution tables to form juvenile X-sec coverages (Type B).

The basic processing steps for the XDI part of the XSEC application are as follows:
1) Request a particular stream reach Type B X-sec coverage within a given watershed. Request desired background mapping and imagery to assist geometric manipulations.
2) Choose a particular X-sec and manipulate it for geometric changes and/or attribute changes. Repeat process for any other existing or XDI created X-secs.
3) Create new FEQUTL data file, regardless of source data (model-only intended FEQUTL file or GPS survey file).
4) Repeat steps 1-3 for every other X-sec populated stream reach (up to 999 reaches, max).

There are several ancillary AML programs that supplement the overall SMD modeling/mapping process that involve the XDI X-sec coverage 'database'. One is to create a consolidated X-sec coverage (Type C) for an entire watershed with County-wide unique attribution, used for mapping purposes. Another is to create profile graphs for individual watershed reaches. Others are to take receipt of some of the output of the FEQ and the PVSTATS programs. The former provides channel encroachment measures from which Floodway zones are built and the latter provides return period flood elevations from which Flood zones are built.

FPD

The Flood Plain Delineator (FPD) application is the point in the work flow process, provided no modeling/mapping iteration occurs, where modeling activities cease and mapping ones dominate. The FPD compares a continuous surface grid of topography with one of a flood surface to produce an elevation difference grid. All grid cell difference values, representing depths, of like arithmetic sign indicate locations where a flood surface is either above or below the topographic surface. Of course, where they coincide at depth zero is the trace of a flood zone boundary. The FPD uses the same topography grid already developed for a given watershed for the XSEC application. The flood surface is developed from the elevation attributed station points of a set of stream reach X-secs, or from all reach X-sec sets in the consolidated watershed X-sec coverage. When processing is done in the most detailed mode – a single reach set and smallest reasonable grid cell size – the FPD application will generate morphing sets of temporary, intermediate X-secs in order to densify the station point coordinate set. Generally, the unit areal density of available topographic points is at least an order of magnitude greater than from XDI produced X-sec station points sampling a flood surface, hence densifying the flood surface is required to compare 'apples-to-apples'. After a flood surface is generated, it is used primarily for computing the depth grid and secondarily for creating flood surface contours, known in the flood mapping trade for the 1% annual chance (100-Year) flood as Base Flood Elevation (BFE) lines.

The Flood Plain Delineator (FPD) figure sequence shows a most detailed mode exercise. Other modes, called draft modes, allow for more rapid exercises to catch mistakes since grid processing is resource and time consuming. First, the theory of the application is shown as a series of source data to grid operations with the result of simple grid algebra being a difference grid per flood scenario. Next, a series of views of the appearance of the application for a single reach exercise is shown, all involving a Workstation ArcInfo GRID display with divided panes. The first view shows that the topography grid must be readily available, since FPD does not develop it. The next views shows the FPD developed flood surface and flood depth grids in their initial state and then after gross editing is done with a customized editor. The last view also shows a close up of the flood boundary, created by splining along the zero depth cells, and flood surface contours interpolated from the flood surface and bounded by the new flood boundary.

The basic processing steps for the FPD application are as follows:
1) Estimate the computer memory requirements for the session and request it before starting the session, since it cannot be adjusted on-the-fly.
2) Choose session parameters including watershed, X-sec set, return period, and processing mode. The modes for reach-wide sets of X-secs permits two levels of draft mode and a final mode (grid cell sizes of 20, 10, and 5 feet, respectively).
3) Develop the flood surface grid, choosing to keep morphed, intermediate X-secs if desired, then develop the flood depth grid.
4) Inspect the extent of the flood depth grid and edit, if desired, the flood surface grid to remove extraneous flooded areas due to a) useless extrapolations of the flood surface beyond the X-sec envelope of station points and b) excessive flooding in stream confluence areas.
5) Create the flood boundary and flood contour coverages.

FPM

While the use of the previous GIS applications is punctuated by the use of analysis modeling programs and procedures, the workflow span between the use of the applications FPD and Flood Plain Mapper (FPM) is entirely the GIS development of five principal themes comprising a County flood map and two principal base map themes to support such maps. The five flood map themes are {1% annual chance flood zones (also known as the Base Flood), floodway zones as a direct function of the Base Flood, miscellaneous descriptive information such as flood zone annotation and stream names, Base Flood Elevation flood surface contour lines, and modeled stream X-secs}. The two base map themes are {roadway (street, highway, railroad) names and principal place names, municipal boundaries and names}. Other typical planimetric base map information is presented as being self-evident in a grayscale orthoimage background, which is the primary reason the application was ported from Workstation ArcInfo ArcPlot to Desktop ArcGIS ArcMap – ArcMap can show flood zones translucently over an image.

Whereas original FEMA flood hazard mapping in the County is based on the municipal and unincorporated community boundary as its referential geographic unit, an agreement between FEMA and the County as a CTP allows it to use the tributary watershed as its referential geographic unit for flood modeling and mapping. However, the FPM application creates products based on a geographic unit of the Public Land Survey System (PLSS), specifically an informal one called the tetrasection (four sections of a PLSS township that share a common corner). Each map product, called a Map Panel, contains tables in their map surrounds that indicate the unit membership from both of the other tiling schemes. The Map Index of the Map Panels also demonstrates the overlap of these three tiling schemes.

For the flood zone theme, there are two stages of consolidation work before a County-wide theme is available for FPM exercises. First, within each watershed, all of the reach-wide flood zone FPD products must be merged and overlaps manually rectified. Also the unavoidably labor intensive work of refining the FPD flood boundaries must be done by an experienced editor, preferably a staff engineer. Refinements are needed for several reasons: FPD products are only as good as the data provided (X-sec station point density cannot be as great as terrain point density and X-secs are created principally for 1-D analysis models, not 2-D maps representing 3-D geography), the resolution of the surface grids, although reduced to the resolution of the base topography, still forfeits detailed locales, X-sec layout often obscures the existence of split flood flows and backwater areas. Second, each manually refined watershed flood zone is collected with others to form a County-wide flood zone coverage from which FPM mapping can be made. Likewise for the floodway and base flood elevation line themes, manual refinement is performed and then County-wide collected. Likewise, the miscellaneous information theme is constructed for each watershed and then also County-wide collected. Finally, the FPM X-secs theme is the collection of all watershed-wide sets of X-secs in the County, but winnowed down to those X-secs actually used in FEQ/PVSTATS analysis modeling (the rest are generally supplementary for FPD work).

The in-house modeling and mapping work that this paper describes replaces previous older watershed mapping, one watershed at a time. Although the older flood mapping was community boundary based, FEMA sanctioned SMD's work of re-expressing all of it into a County-wide map on the watershed basis using the County's topography base and known site topography updates. It is into this matrix of consistent mapping that the current, in-house work is deposited. DuPage County SMD has been awarded the 2004 James Lee Witt Local Award for Excellence for this Digital FIRM and RFM Project from the Association of State Flood Plain Managers.

The Flood Plain Mapper (FPM) figure sequence shows some aspects of using the application and related products. The key to Countywide-map set, be it a DFIRM look-alike, in-house work map, or the usual RFM, is a set's Map Index sheet. Here a user can recognize several concurrent geographic themes and use them to navigate to appropriate Map Panels for more detail. Each kind of sheet is set for an E sized plot, with actual plot area dimensions, dictated by FEMA standards, of 26”**x**36”, creating a map scale of 1:60000 and 1:6000 for the Map Index and Map Panels, respectively. Since the RFM atlas is a new appearance of flood maps for the County constituency, SMD has made Interpretation Guides for each type of sheet, where each type builds upon an actual atlas example. The next figure shows how the FPM is used in interactive mode. A single dialogue form collects the requisite parameters to build a complete plot layout. The following figure is a collage of two possible appearances an RFM Map Panel map, the left shows topographic contours as the base map for in-house review only while the right show an orthoimagery base for public use. The last figure provides a detail view of the confluence of the two modeled reaches of the Armitage Creek watershed as part of the finished flood map product.

The FPM application can be driven in batch processing mode by AML and DOS batch scripts or interactively via a parameters menu. The basic processing steps for the application are as follows:
1) Read the parameter arguments file and set working variables such as geographic extent of the applicable Map Panel.
2) Generate the various data frames (maps) within the Map Panel layout document including PLSS key maps, agency logos, and the geographic map.
3) Based on the chosen map scheme, create the variable graphics in the map surround including the legend, the text bodies with variable character strings in the DuPage and FEMA sub-panels, the membership tables of the concurrent tiling schemes, and the title sub-panel fixed and variable text.
4) Generate ancillary location information for the geographic map including adjacent Panel callouts and corner coordinates.
5) If pursuing batch processing, export the completed map layout into plot files and/or perform plot printing.
A similar procedure is followed when making the single sheet Map Index. There are 87 sheets for the body of Map Panels. Both procedures are essentially replicated for the FPM operations mode of producing distribution Compact Disks (CD). The difference is that the products are either ESRI ArcReader PMF files or Adobe Acrobat PDF files.

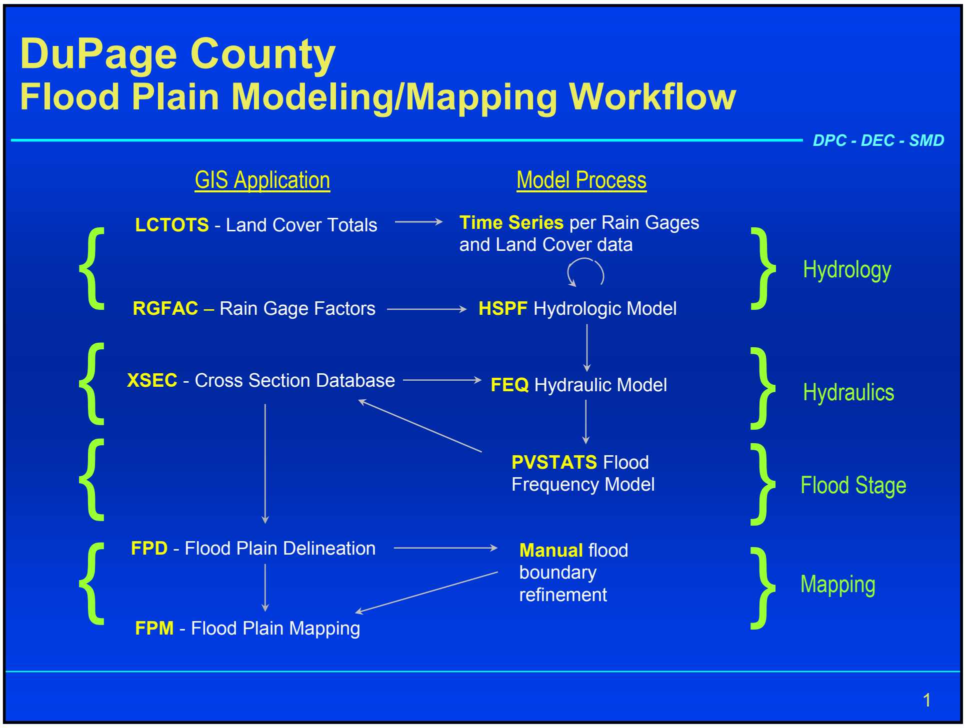
Conclusion

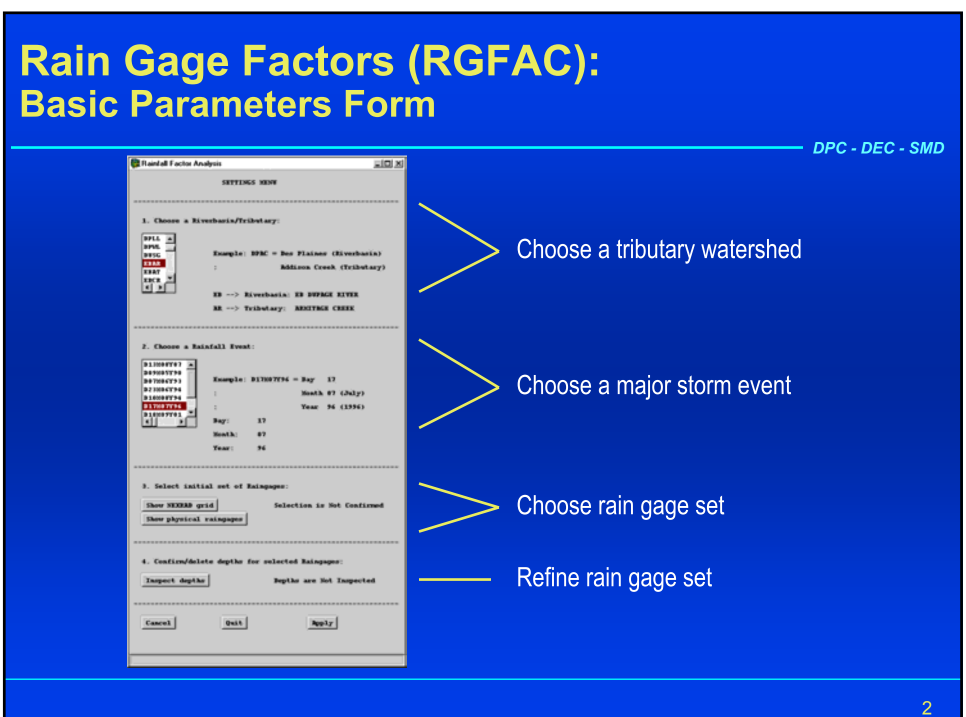
Out of necessity, DuPage County’s Stormwater Management Division has developed its own program of hydrology and hydraulics methodology for determining flood hazard areas with the HSPF/FEQ/PVSTATS suite of analysis programs. Initially the approach was almost strictly a manual workflow process, supported only by limited CAD capability. In the past decade, SMD has actively pursued GIS technology to expedite the process, attempting to automate any part susceptible to it. While in the strictest sense, the workflow process could still be done manually, in any practical sense with limited budgets, personnel, and workload demands, GIS technology with ESRI products has proven to be invaluable. Considering that an average size watershed can take about two years to develop to State and Federal approval, that there are 59 candidate watersheds in the County, that reference datasets are rapidly out-of-date, and that the urban landscape is changing yearly, any reasonable means to hasten the program is pursued. Thus far and will be, the best means of support is GIS technology. The toolkit approach provided by ESRI has been instrumental in enabling GIS application and program development, along with a strong working relationship with one of its business partners, GeoAnalytics, Inc., who has provided support throughout the spectrum of the GIS business function: hardware, software, organization, personnel, and implementation. The logical next step in the evolving GIS development at SMD is to consider how to retool the successful Workstation ArcInfo file-centric approach into perhaps a more successful Desktop ArcGIS geodatabase approach. Better yet, the modeling side of the workflow process might be better integrated with the spatial support side of it.

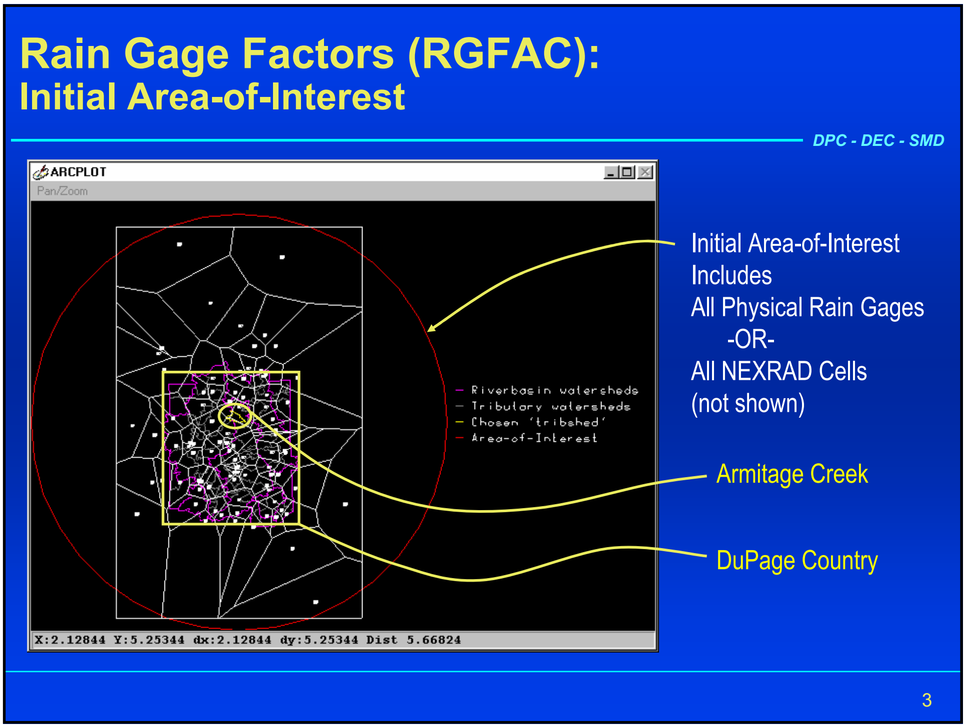
Table 1 – Major GIS Applications in DuPage Flood Plain Modeling/Mapping

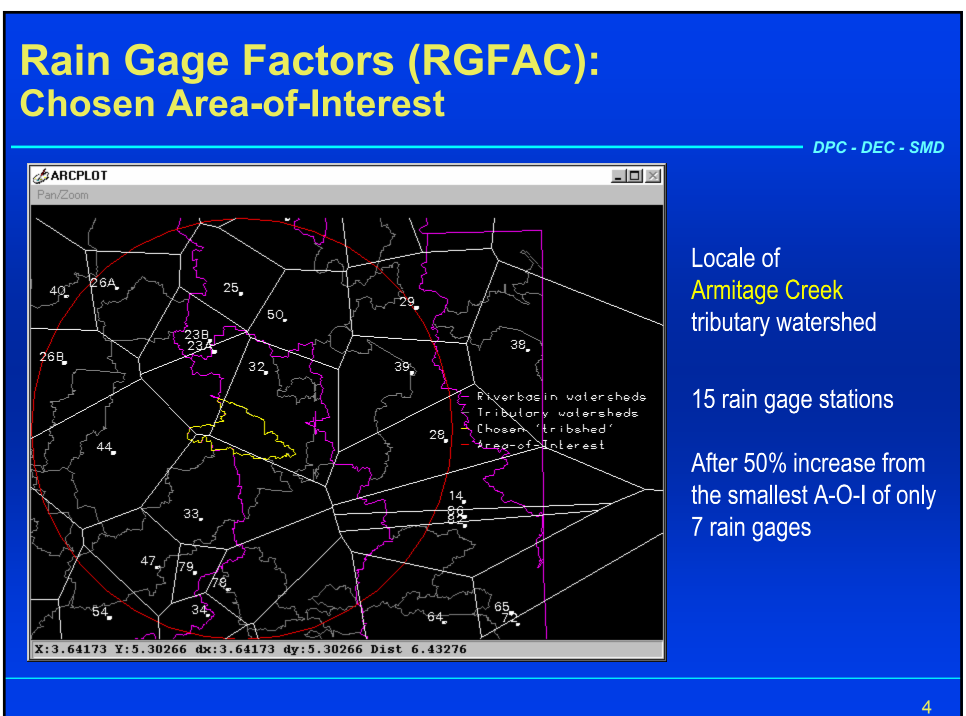
GIS Application	Workflow Support or Role	Primary Data Sources	Primary Data Products	Software Basis
LCTOTS Land Cover Totals Analysis	Hydrology: Produce runoff potential factors for catchment watersheds	1. INFO table of FEQ land use codes 2. Point coverage of Raingages 3. Arc/point coverage of Topography 4. Polygon coverage of FEQ characterized Parcels 5. Polygon coverage of Soils 6. Polygon coverage of Hydrography	1. Text files of Runoff Characteristics per catchment watershed	1. AML scripts in Workstation ArcInfo: **Arc**
RGFAC Raingage Factor Analysis	Hydrology: Produce rainfall adjustment factors for catchment watersheds	1. Point coverage of Raingages 2. Polygon coverage of Watersheds	1. Text file of Rainfall Adjustment Factors per catchment watershed	1. AML scripts in Workstation ArcInfo: Arc, ArcEdit, ArcPlot, **Grid** 2. UNIX shell commands
XSEC Stream Cross-section Development: Bulk Processing	Hydraulics, Flood Stage, and Mapping: Create and maintain cross-sections and transects for all purposes	1. FEQUTL or GPS survey stream cross-section text files 2. Route coverage of Stream Network	1.Raw Stream Cross Section arc coverages and preliminary attribute tables per tributary watershed stream reach	1. AML scripts in Workstation ArcInfo: **Arc**, ArcEdit, ArcPlot 2. UNIX shell commands 3. PERL scripts
XSEC Stream Cross-section Development: XDI Adjustment	Hydraulics, Flood Stage, and Mapping: Create and maintain cross-sections and transects for all purposes	1. Arc coverages of raw Stream Cross Sections or transects 2. Route coverage of Stream Network 3. Modeling program output for flood elevations and floodway encroachments	1. Refined Stream Cross Section arc coverages and populated attribute tables per tributary watershed stream reach 2. Consolidated Stream Cross Section arc coverage per tributary watershed 3. Arc coverage of raw Floodway path	1. AML scripts in Workstation ArcInfo: Arc, **ArcEdit**, ArcPlot, Librarian 2. UNIX shell commands 3. PERL scripts
FPD Flood Plain Delineator	Mapping: Produce estimate of flood boundaries	1. Arc coverages of refined Stream Cross Sections 2. Route coverage of Stream Network 3. DEM grid of Topography	1. Estimated DEM Flood Depth and Surface Grids 2. Estimated Flood Boundary polygon coverages 3. Estimated flood surface contour arc coverages, as Base Flood Elevation lines	1. AML scripts in Workstation ArcInfo: Arc, ArcEdit, ArcPlot, **Grid** 2. UNIX shell commands
FPM Flood Plain Mapper	Mapping: Produce flood plain maps	1. Revised Flood Boundary polygon coverages 2. Revised Floodway polygon coverages 3. Revised Base Flood Elevation contours arc coverage 4. Miscellaneous Info. for Flood Zones annotation and arc coverage 5. Modeled only subset of Consolidated Stream Cross Section arc coverages 6. Municipal Boundaries arc coverage 7. MrSID Orthoimagery of DuPage County	1. Plot files of flood zones in tailored layouts	1. AML scripts in Workstation ArcInfo: Arc 2. UNIX shell commands 3. VBA scripts in Desktop **ArcMap**

Note: **Bold** entries in the Software Basis column indicate the principal ESRI software package for the GIS Application


DuPage County
Flood Plain Modeling/Mapping Workflow
DPC - DEC - SMD
GIS Application
Model Process
LCTOTS - Land Cover Totals
Time Series per Rain Gages and Land Cover data
RGFAC – Rain Gage Factors
HSPF Hydrologic Model
Hydrology
XSEC - Cross Section Database
FEQ Hydraulic Model
Hydraulics
PVSTATS Flood Frequency Model
Flood Stage
FPD - Flood Plain Delineation
Manual flood boundary refinement
FPM - Flood Plain Mapping
Mapping
1


Rain Gage Factors (RGFAC):
Basic Parameters Form
DPC - DEC - SMD
Choose a tributary watershed
Choose a major storm event
Choose rain gage set
Refine rain gage set
2

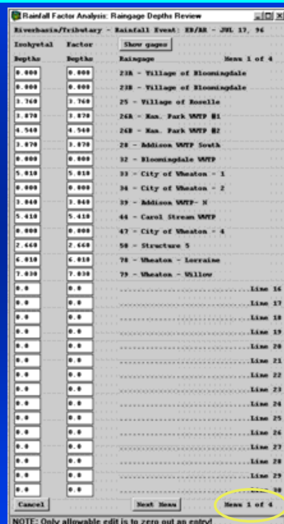

Rain Gage Factors (RGFAC):
Initial Area-of-Interest
DPC - DEC - SMD
ARCPLOT
Pan/Zoom
Riverbasin watersheds
Tributary watersheds
Chosen 'tribshed'
Area-of-Interest
X:2.12844 Y:5.25344 dx:2.12844 dy:5.25344 Dist 5.66824
Initial Area-of-Interest
Includes
All Physical Rain Gages
-OR-
All NEXRAD Cells
(not shown)
Armitage Creek
DuPage Country
3


Rain Gage Factors (RGFAC):
Chosen Area-of-Interest
DPC - DEC - SMD
ARCPLOT
Pan/Zoom
Riverbasin watersheds
Tributary watersheds
Chosen 'tribshed'
Area-of-Interest
X:3.64173 Y:5.30266 dx:3.64173 dy:5.30266 Dist 6.43276
Locale of
Armitage Creek
tributary watershed
15 rain gage stations
After 50% increase from
the smallest A-O-I of only
7 rain gages
4

Figures

Rain Gage Factors (RGFAC):
Rain Gage Depths Review

DPC - DEC - SMD



15 nearest physical rain gages to Armitage Creek

- •Check for zero entries (incomplete report)
- •Edit to make zero entries (forfeit a report)

Chain of review menus…

5

Rain Gage Factors (RGFAC):
Completed Settings Menu

DPC - DEC - SMD

Confirmations of user review

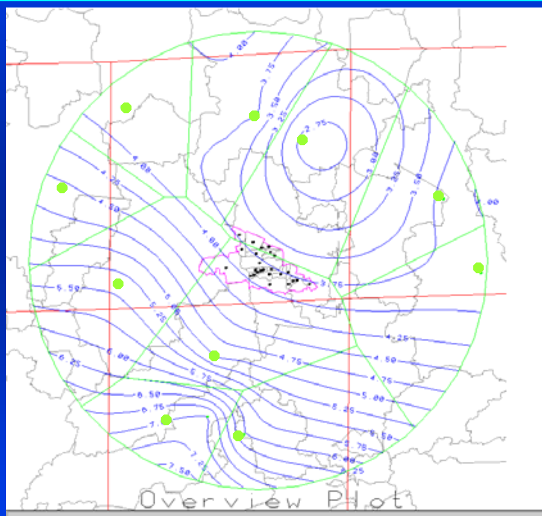
Launch GIS analysis interactively

6

Figures

Rain Gage Factors (RGFAC):
Isohyetal Overview Plot

DPC - DEC - SMD



Overview Plot

Green points – Rain Gage stations

Green lines – Thiessen polygons for stations

Blue lines – Rainfall isohyetals

Magenta line – Armitage Creek watershed boundary

Black points – Catchment centroids

7

Rain Gage Factors (RGFAC):
Factors Output File

DPC - DEC - SMD

ARC

Rainfall Factors Analysis
Tributary: EBAR
Rain Event: D17M07Y96
Grid cell size: 260 ft sq
FACtors calculated on: April 14, 2004

Catchment Name	Catchment Depth	Raingage Name	Raingage Depth	Depth Ratio	Northing	Easting
ARF19A	3.720	50	2.660	1.399	1916091.683	567802.458
ARF17	3.670	50	2.660	1.379	1915156.963	569546.034
AR53B	3.600	50	2.660	1.354	1914537.093	571567.805
AR56	3.650	50	2.660	1.373	1914423.960	570683.008
ARF19B	3.800	33	5.010	0.759	1914262.690	568119.371
AR53A	3.630	50	2.660	1.365	1913910.339	571806.981
AR35	3.730	33	5.010	0.745	1913685.167	569941.617
AR33	3.640	50	2.660	1.369	1913394.472	572346.422
AR29	3.790	33	5.010	0.756	1912494.648	570407.746
ARF15	4.080	33	5.010	0.815	1911853.692	566061.767
AR39	3.770	33	5.010	0.753	1911699.266	571924.290
AR45	3.820	33	5.010	0.763	1911607.084	570886.570
AR44	3.870	33	5.010	0.773	1911595.470	569831.889
AR46	3.850	33	5.010	0.768	1911473.683	570565.801
AR19	3.720	33	5.010	0.743	1911333.860	574062.048
AR47	3.880	33	5.010	0.774	1911333.272	570119.470
AR21	3.770	33	5.010	0.753	1911049.527	573116.753
AR24	3.830	33	5.010	0.764	1911035.936	571671.731
AR49	3.920	33	5.010	0.783	1910944.991	569684.350
AR52	3.950	33	5.010	0.789	1910823.039	569260.368
AR14	3.770	33	5.010	0.753	1910236.773	575225.478
AR16	3.790	33	5.010	0.757	1910189.537	574683.727
AR9B	3.780	33	5.010	0.754	1909767.150	576799.271
AR18A	3.840	33	5.010	0.766	1909761.336	574133.333
AR18B	3.920	33	5.010	0.783	1909696.956	571700.385

Continue Pause Quit

Rainfall amount at each Catchment centroid =

Nearest rain gage depth

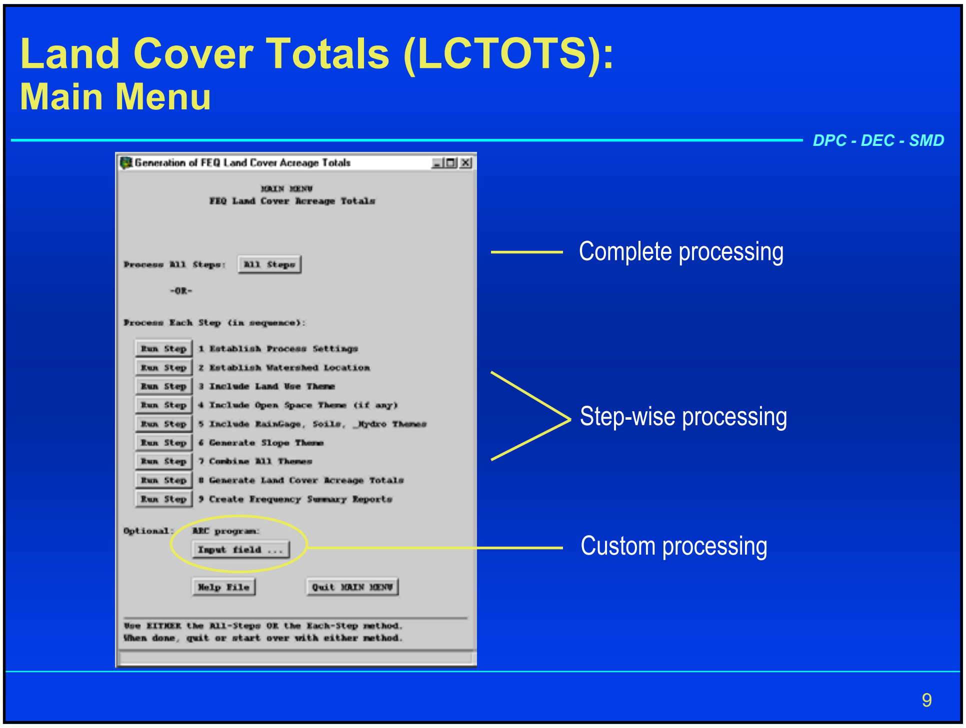
X

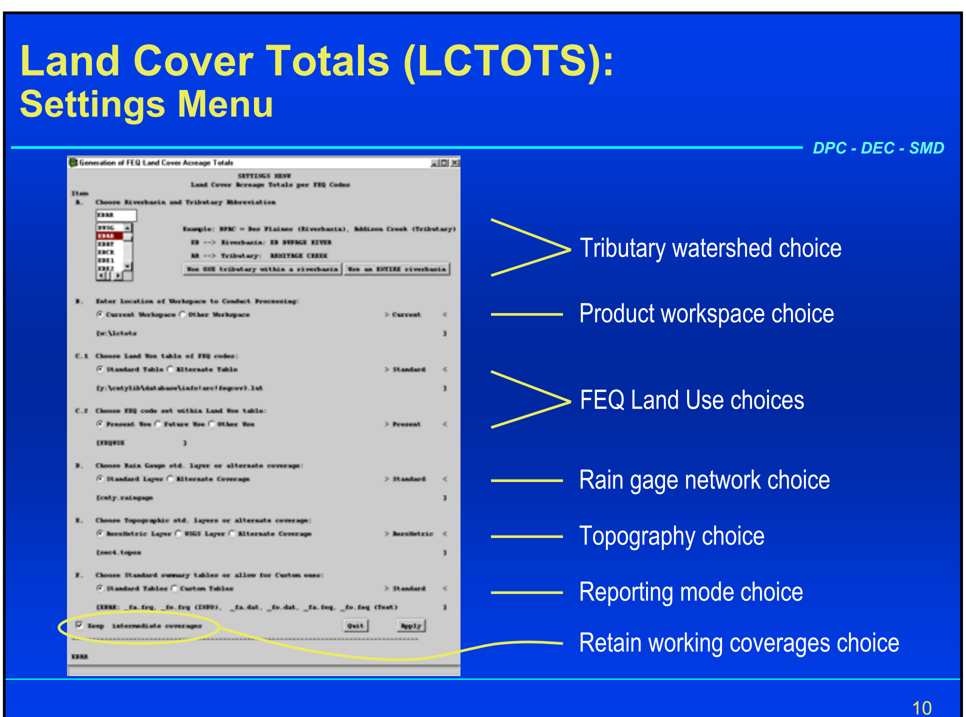
Interpolated Depth Ratio

Output for a single Storm event only

8

Figures


Land Cover Totals (LCTOTS):
Main Menu
DPC - DEC - SMD
Generation of FEQ Land Cover Acreage Totals
MAIN MENU
FEQ Land Cover Acreage Totals
Process All Steps: All Steps
-OR-
Process Each Step (in sequence):
Run Step 1 Establish Process Settings
Run Step 2 Establish Watershed Location
Run Step 3 Include Land Use Theme
Run Step 4 Include Open Space Theme (if any)
Run Step 5 Include RainGage, Soils, _Hydro Themes
Run Step 6 Generate Slope Theme
Run Step 7 Combine All Themes
Run Step 8 Generate Land Cover Acreage Totals
Run Step 9 Create Frequency Summary Reports
Optional: ARC program:
Input field ...
Help File
Quit MAIN MENU
Use EITHER the All-Steps OR the Each-Step method.
When done, quit or start over with either method.
Complete processing
Step-wise processing
Custom processing
9


Land Cover Totals (LCTOTS):
Settings Menu
DPC - DEC - SMD
Tributary watershed choice
Product workspace choice
FEQ Land Use choices
Rain gage network choice
Topography choice
Reporting mode choice
Retain working coverages choice
10

Land Cover Totals (LCTOTS): Confirmation Menu

DPC - DEC - SMD

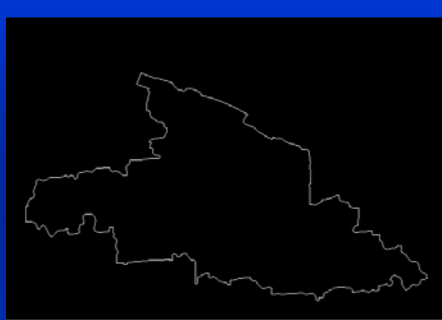
Roster of choices made

Redo choices

11

Land Cover Totals (LCTOTS): Overlay Progression Part 1

DPC - DEC - SMD



Armitage Creek watershed area …….

Overlain by ……
- Land Use characterized parcels (red)
- Open Space areas (white)

12

Figures

Land Cover Totals (LCTOTS):
Overlay Progression Part 2

DPC - DEC - SMD

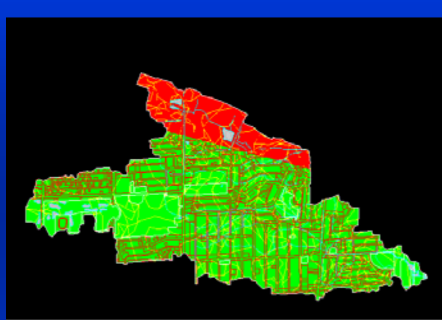
Overlain by …….
• Hydrographic areas (cyan)

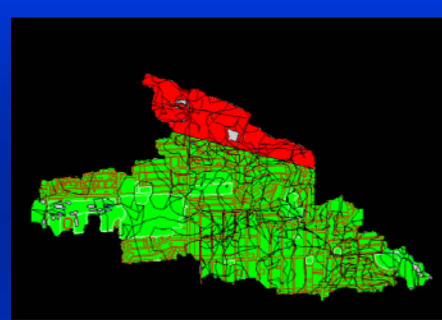
Overlain by ……
• Terrain slope groups (orange)

13

Land Cover Totals (LCTOTS):
Overlay Progression Part 3

DPC - DEC - SMD





Overlain by …….
• Rain gage regions (red/green shades)

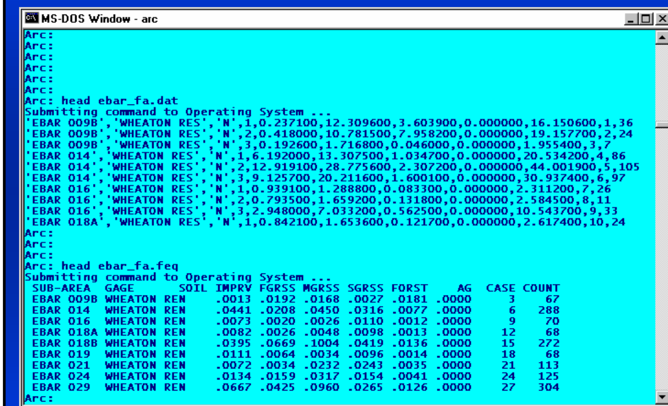
Overlain by
• Soil units (black)

14

Figures

Land Cover Totals (LCTOTS):
Standard Reports

DPC - DEC - SMD



```
MS-DOS Window - arc
Arc:
Arc:
Arc:
Arc:
Arc:
Arc:
Arc: head ebar_fa.dat
Submitting command to Operating System ...
'EBAR 009B','WHEATON RES','N',1,0.237100,12.309600,3.603900,0.000000,16.150600,1,36
'EBAR 009B','WHEATON RES','N',2,0.418000,10.781500,7.958200,0.000000,19.157700,2,24
'EBAR 009B','WHEATON RES','N',3,0.192600,1.716800,0.046000,0.000000,1.955400,3,7
'EBAR 014','WHEATON RES','N',1,6.192000,13.307500,1.034700,0.000000,20.534200,4,86
'EBAR 014','WHEATON RES','N',2,12.919100,28.775600,2.307200,0.000000,44.001900,5,105
'EBAR 014','WHEATON RES','N',3,9.125700,20.211600,1.600100,0.000000,30.937400,6,97
'EBAR 016','WHEATON RES','N',1,0.939100,1.288800,0.083300,0.000000,2.311200,7,26
'EBAR 016','WHEATON RES','N',2,0.793500,1.659200,0.131800,0.000000,2.584500,8,11
'EBAR 016','WHEATON RES','N',3,2.948000,7.033200,0.562500,0.000000,10.543700,9,33
'EBAR 018A','WHEATON RES','N',1,0.842100,1.653600,0.121700,0.000000,2.617400,10,24
Arc:
Arc:
Arc:
Arc: head ebar_fa.feq
Submitting command to Operating System ...
 SUB-AREA  GAGE       SOIL IMPRV FGRSS MGRSS SGRSS FORST    AG  CASE COUNT
 EBAR 009B WHEATON REN     .0013 .0192 .0168 .0027 .0181 .0000     3    67
 EBAR 014  WHEATON REN     .0441 .0208 .0450 .0316 .0077 .0000     6   288
 EBAR 016  WHEATON REN     .0073 .0020 .0026 .0110 .0012 .0000     9    70
 EBAR 018A WHEATON REN     .0082 .0026 .0048 .0098 .0013 .0000    12    68
 EBAR 018B WHEATON REN     .0395 .0669 .1004 .0419 .0136 .0000    15   272
 EBAR 019  WHEATON REN     .0111 .0064 .0034 .0096 .0014 .0000    18    68
 EBAR 021  WHEATON REN     .0072 .0034 .0232 .0243 .0035 .0000    21   113
 EBAR 024  WHEATON REN     .0134 .0159 .0317 .0154 .0041 .0000    24   125
 EBAR 029  WHEATON REN     .0667 .0425 .0960 .0265 .0126 .0000    27   304
Arc:
```

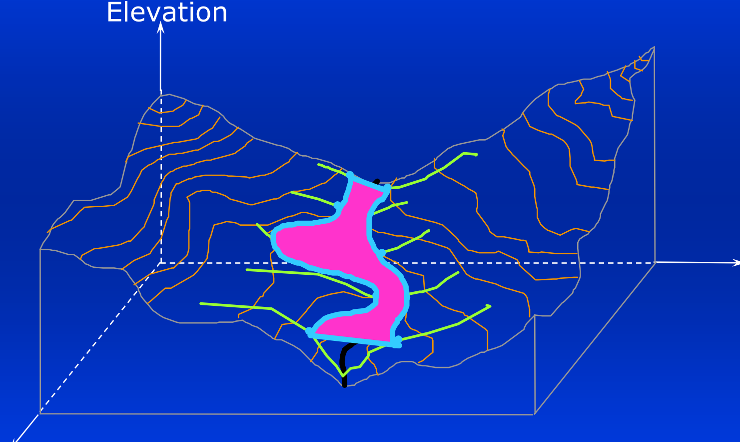
Armitage Creek reports per local rain gage network

- Raw data for HSPF analysis
- Summarized data for FEQ analysis

15

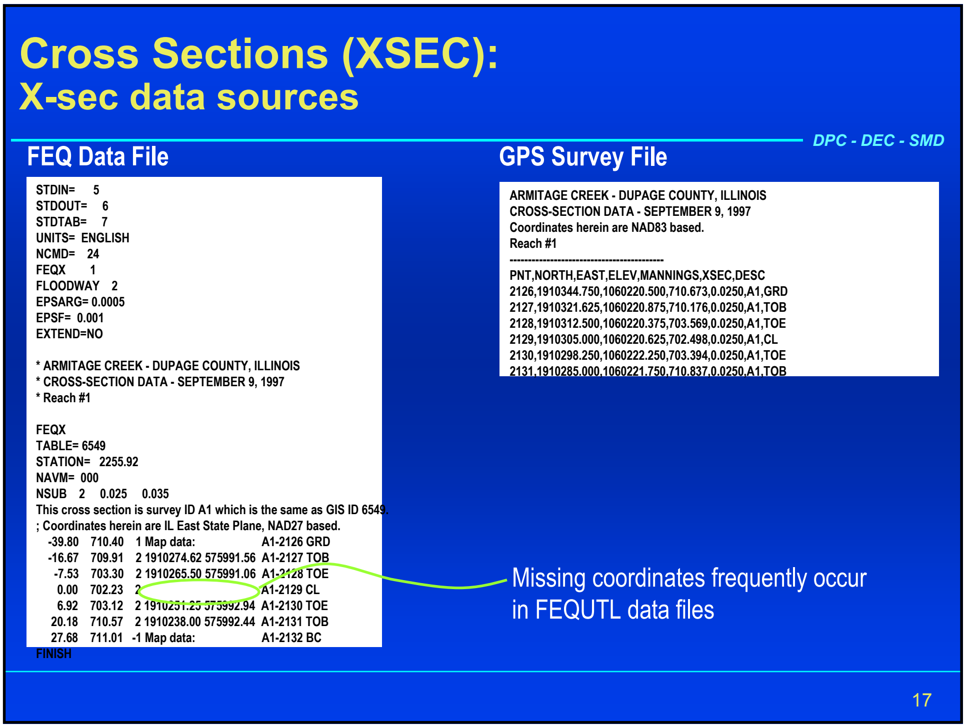
Cross Sections (XSEC):
Flood Surface Development

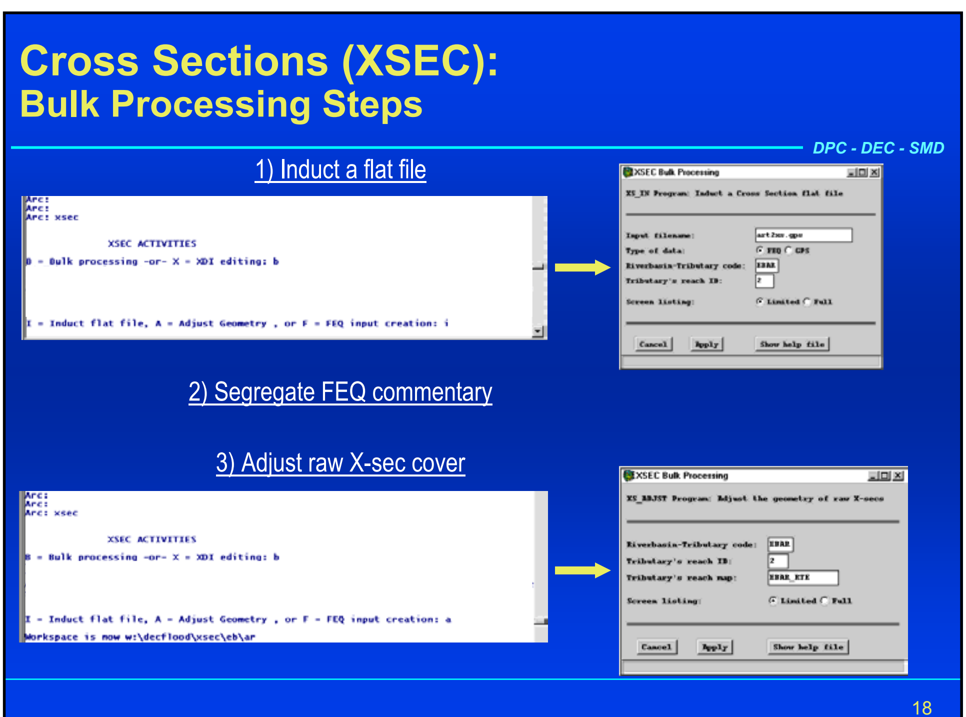
DPC - DEC - SMD



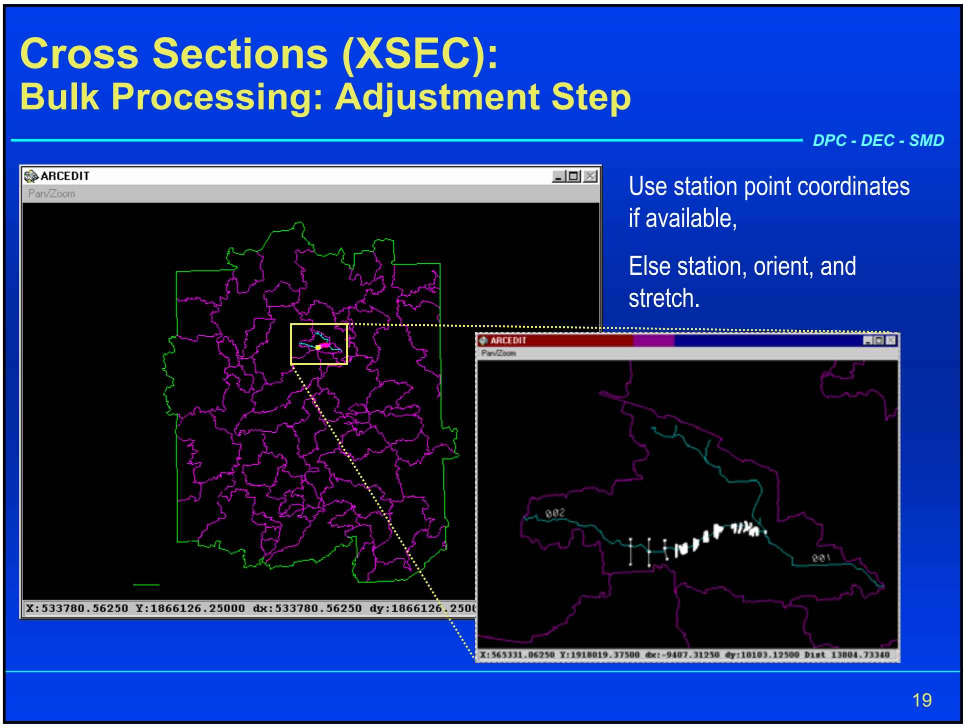
16

Figures

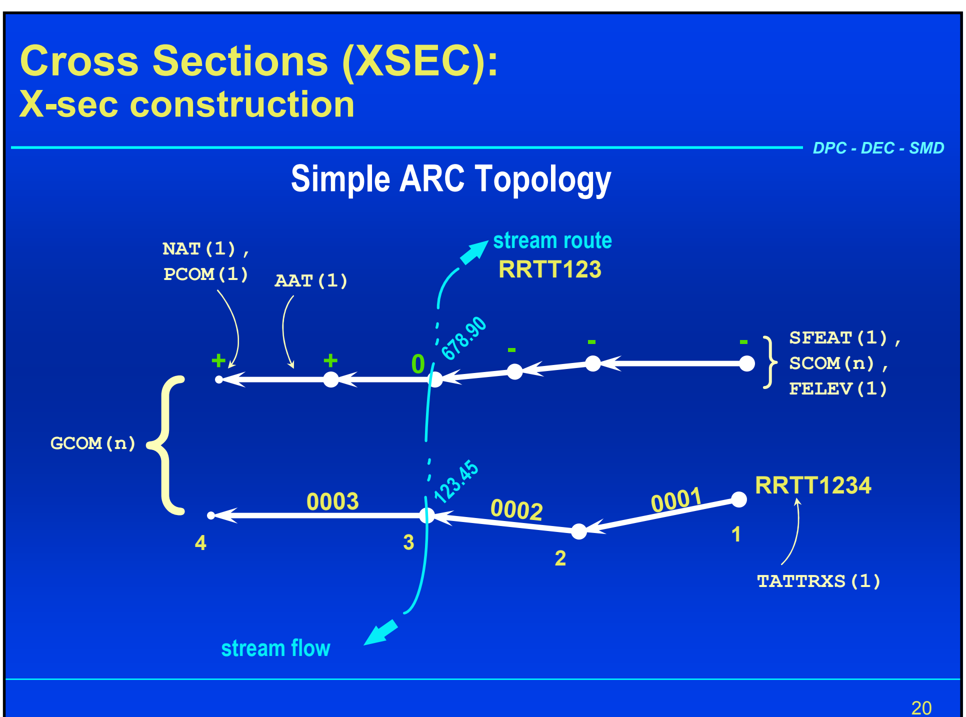

Cross Sections (XSEC):
X-sec data sources
DPC - DEC - SMD
FEQ Data File
STDIN= 5
STDOUT= 6
STDTAB= 7
UNITS= ENGLISH
NCMD= 24
FEQX 1
FLOODWAY 2
EPSARG= 0.0005
EPSF= 0.001
EXTEND=NO
* ARMITAGE CREEK - DUPAGE COUNTY, ILLINOIS
* CROSS-SECTION DATA - SEPTEMBER 9, 1997
* Reach #1
FEQX
TABLE= 6549
STATION= 2255.92
NAVM= 000
NSUB 2 0.025 0.035
This cross section is survey ID A1 which is the same as GIS ID 6549.
; Coordinates herein are IL East State Plane, NAD27 based.
-39.80 710.40 1 Map data: A1-2126 GRD
-16.67 709.91 2 1910274.62 575991.56 A1-2127 TOB
-7.53 703.30 2 1910265.50 575991.06 A1-2128 TOE
0.00 702.23 2 A1-2129 CL
6.92 703.12 2 1910251.25 575992.94 A1-2130 TOE
20.18 710.57 2 1910238.00 575992.44 A1-2131 TOB
27.68 711.01 -1 Map data: A1-2132 BC
FINISH
GPS Survey File
ARMITAGE CREEK - DUPAGE COUNTY, ILLINOIS
CROSS-SECTION DATA - SEPTEMBER 9, 1997
Coordinates herein are NAD83 based.
Reach #1
PNT,NORTH,EAST,ELEV,MANNINGS,XSEC,DESC
2126,1910344.750,1060220.500,710.673,0.0250,A1,GRD
2127,1910321.625,1060220.875,710.176,0.0250,A1,TOB
2128,1910312.500,1060220.375,703.569,0.0250,A1,TOE
2129,1910305.000,1060220.625,702.498,0.0250,A1,CL
2130,1910298.250,1060222.250,703.394,0.0250,A1,TOE
2131,1910285.000,1060221.750,710.837,0.0250,A1,TOB
Missing coordinates frequently occur in FEQUTL data files
17


Cross Sections (XSEC):
Bulk Processing Steps
DPC - DEC - SMD
1) Induct a flat file
Arc: xsec
XSEC ACTIVITIES
B = Bulk processing -or- X = XDI editing: b
I = Induct flat file, A = Adjust Geometry , or F = FEQ input creation: i
XSEC Bulk Processing
Cancel
Apply
Show help file
2) Segregate FEQ commentary
3) Adjust raw X-sec cover
Arc: xsec
XSEC ACTIVITIES
B = Bulk processing -or- X = XDI editing: b
I = Induct flat file, A = Adjust Geometry , or F = FEQ input creation: a
Workspace is now w:\decflood\xsec\eb\ar
XSEC Bulk Processing
Cancel
Apply
Show help file
18

Figures



Cross Sections (XSEC):
Bulk Processing: Adjustment Step
DPC - DEC - SMD
ARCEDIT
Pan/Zoom
X:533780.56250 Y:1866126.25000 dx:533780.56250 dy:1866126.250
Use station point coordinates if available,
Else station, orient, and stretch.
ARCEDIT
002
001
19



Cross Sections (XSEC):
X-sec construction
DPC - DEC - SMD
Simple ARC Topology
NAT(1),
PCOM(1)
AAT(1)
stream route
RRTT123
678.90
+
+
0
-
-
-
SFEAT(1),
SCOM(n),
FELEV(1)
GCOM(n)
123.45
0003
0002
0001
RRTT1234
4
3
2
1
TATTRXS(1)
stream flow
20

Cross Sections (XSEC):
X-sec construction - attribution

DPC - DEC - SMD

Concept: Componentize a cross section so that any part can be attributed using required Feature Attribute Tables (FAT) and related User Attribute Tables (UAT).

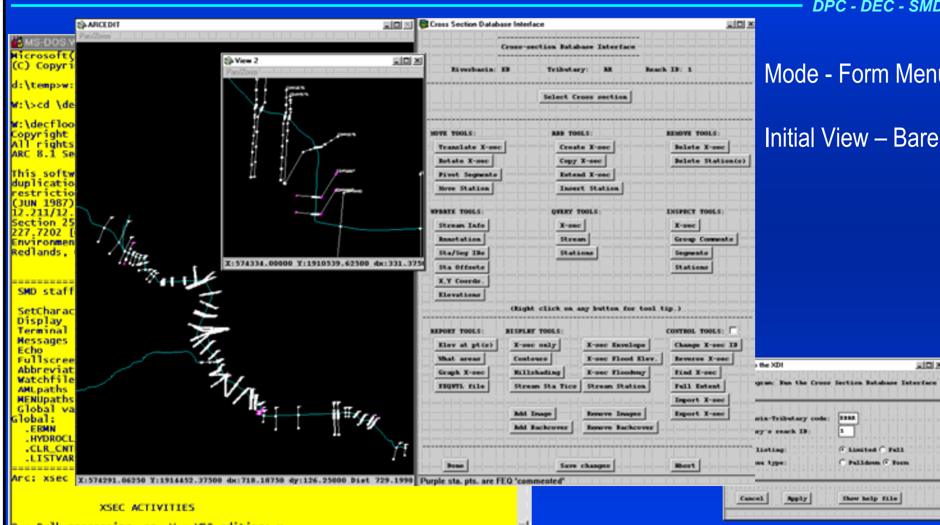
Component	Topological Entity	INFO table	Table type	
Station Point	Node	.NAT(1)	FAT	GIS required
Segment	Simple Arc	.AAT(1)	FAT	
Cross Section	Arc Chain	.TATTRXS(1)	FAT	
		.SFEAT(1)	UAT	Application supplied
Cross Sec. Flood Elevations	Arc Chain	.FELEV(1)	UAT	
Station Pt. Commentary	Node	.PCOM(1)	UAT	
Cross Sec. Commentary	Arc Chain	.SCOM(n)	UAT	
Group X-sec Commentary	Arc Chains	.GCOM(n)	UAT	

Note: (1) means one record per component, (n) means many records per component

21

X-Sec Database Interface (XDI):
Typical Launch Appearance

DPC - DEC - SMD

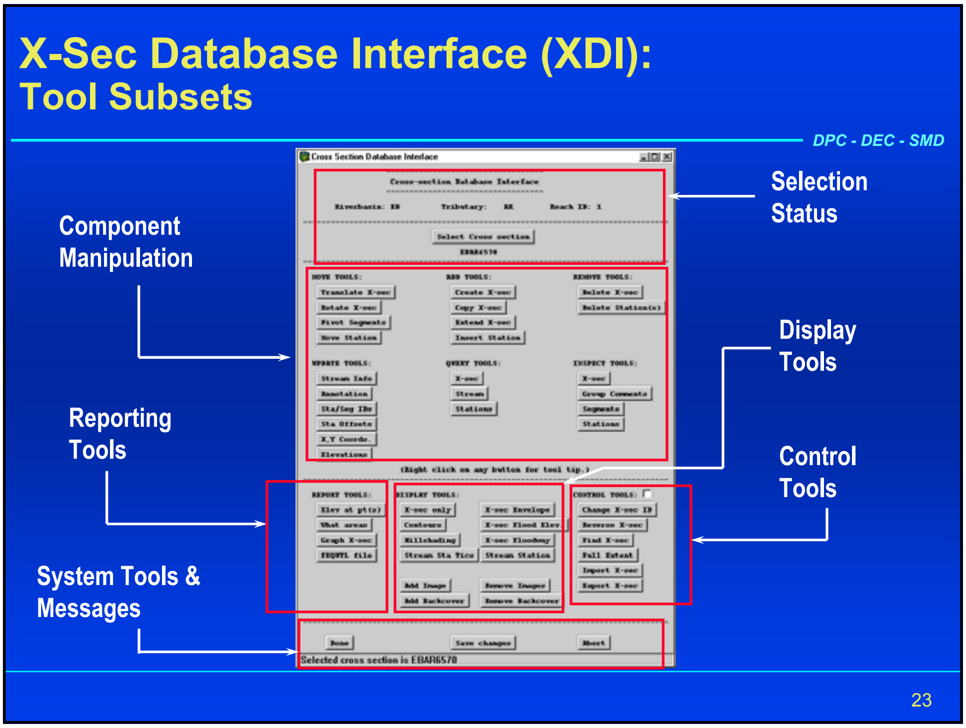


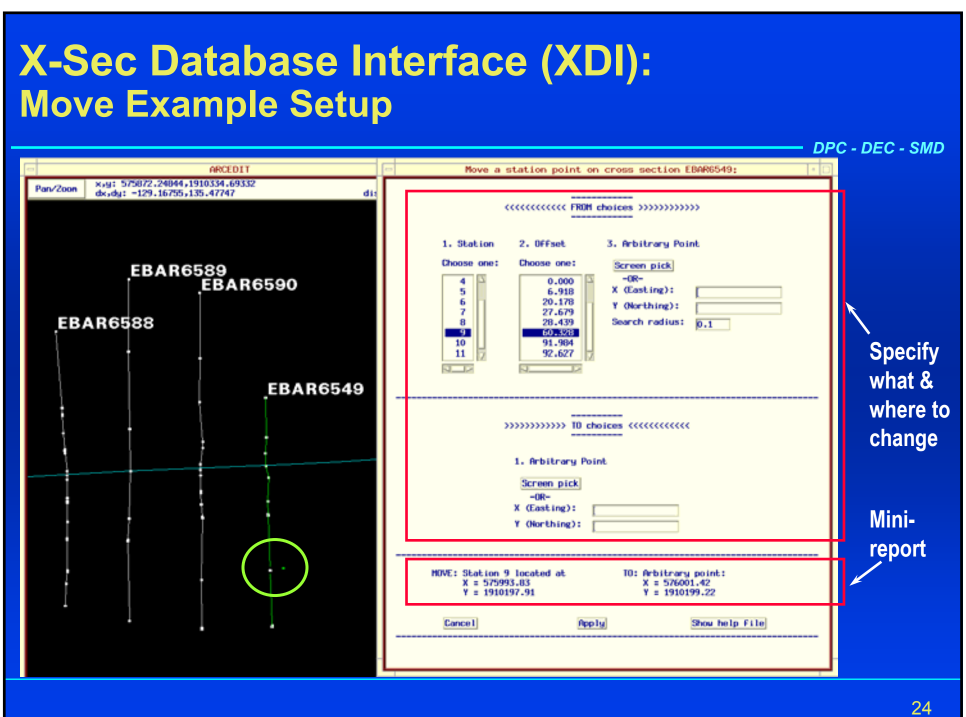
Mode - Form Menu

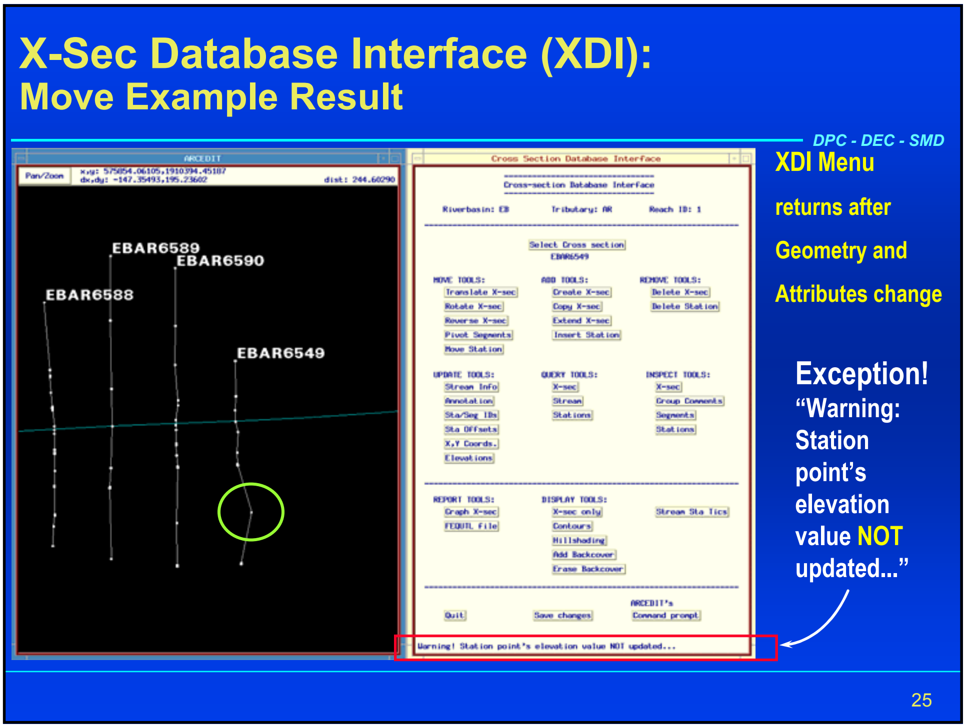
Initial View – Bare

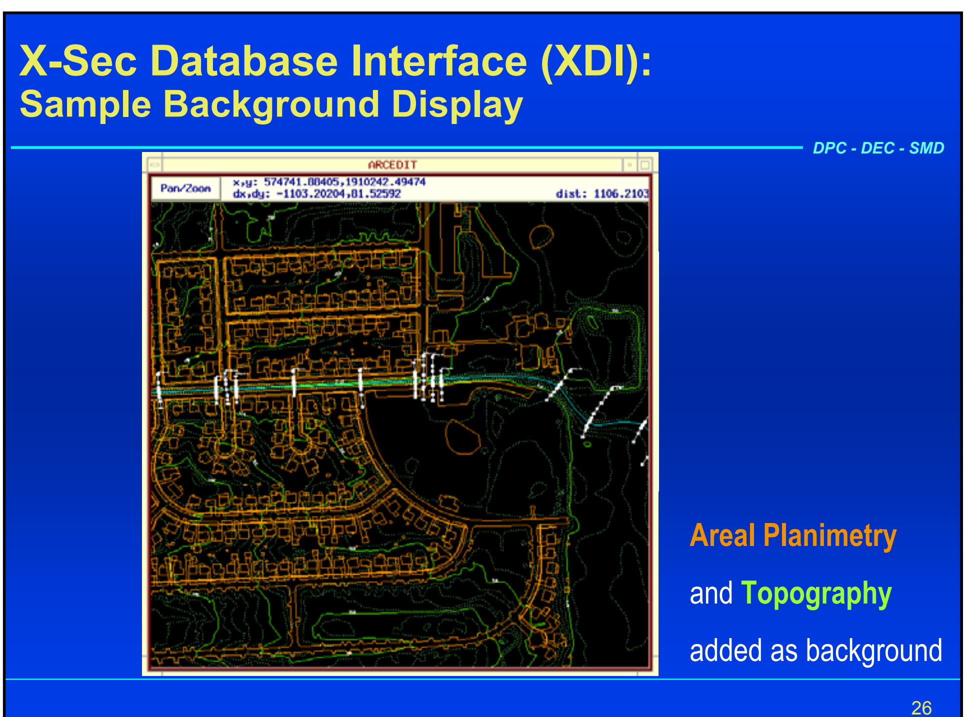
22

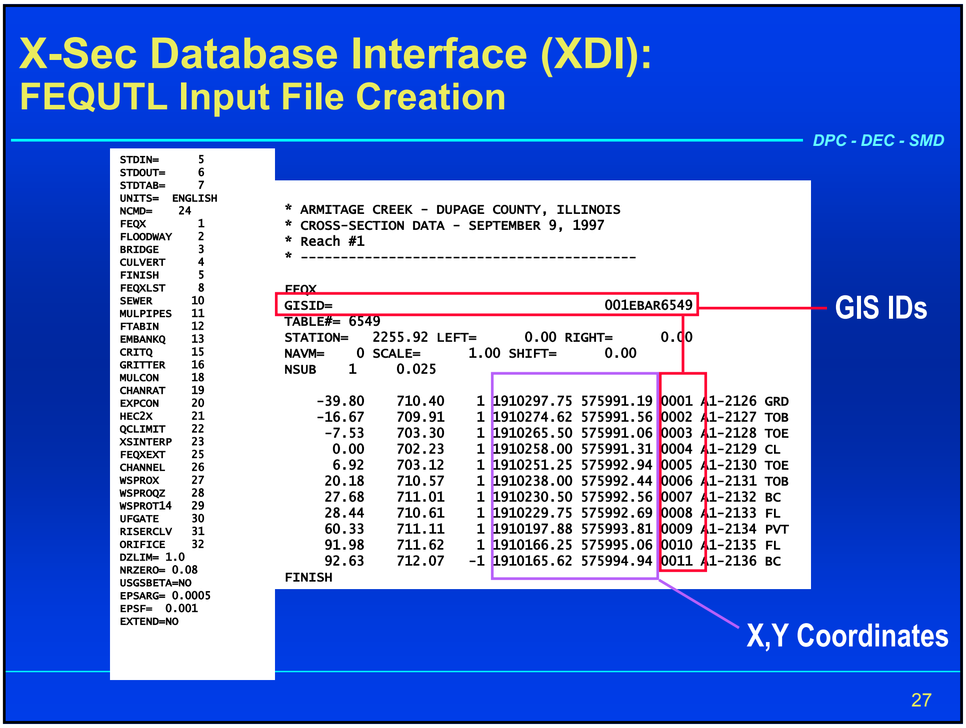
Figures

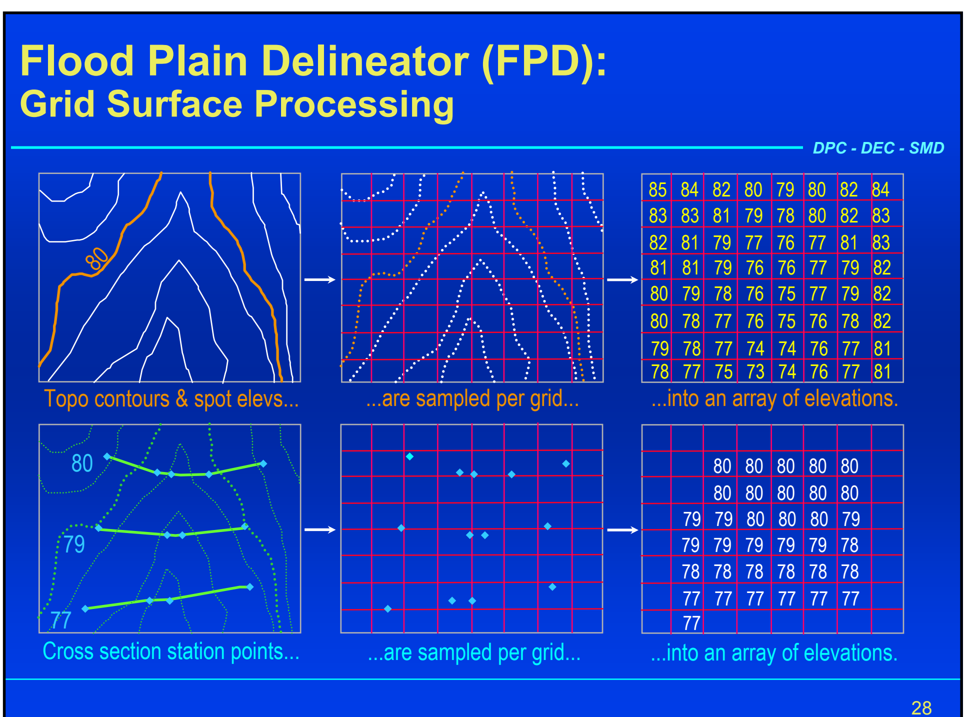

X-Sec Database Interface (XDI):
Tool Subsets
DPC - DEC - SMD
Selection Status
Component Manipulation
Display Tools
Reporting Tools
Control Tools
System Tools & Messages
Selected cross section is EBAR6570
23


X-Sec Database Interface (XDI):
Move Example Setup
DPC - DEC - SMD
EBAR6589
EBAR6590
EBAR6588
EBAR6549
Specify what & where to change
Mini-report
24


X-Sec Database Interface (XDI):
Move Example Result
DPC - DEC - SMD
EBAR6589
EBAR6590
EBAR6588
EBAR6549
XDI Menu
returns after
Geometry and
Attributes change
Exception!
"Warning: Station point's elevation value NOT updated..."
25


X-Sec Database Interface (XDI):
Sample Background Display
DPC - DEC - SMD
ARCEDIT
Pan/Zoom
x,y: 574741.88405,1910242.49474
dx,dy: -1103.20204,81.52592
dist: 1106.2103
Areal Planimetry
and Topography
added as background
26


X-Sec Database Interface (XDI):
FEQUTL Input File Creation
DPC - DEC - SMD
STDIN= 5
STDOUT= 6
STDTAB= 7
UNITS= ENGLISH
NCMD= 24
FEQX 1
FLOODWAY 2
BRIDGE 3
CULVERT 4
FINISH 5
FEQXLST 8
SEWER 10
MULPIPES 11
FTABIN 12
EMBANKQ 13
CRITQ 15
GRITTER 16
MULCON 18
CHANRAT 19
EXPCON 20
HEC2X 21
QCLIMIT 22
XSINTERP 23
FEQXEXT 25
CHANNEL 26
WSPROX 27
WSPROQZ 28
WSPROT14 29
UFGATE 30
RISERCLV 31
ORIFICE 32
DZLIM= 1.0
NRZERO= 0.08
USGSBETA=NO
EPSARG= 0.0005
EPSF= 0.001
EXTEND=NO
* ARMITAGE CREEK - DUPAGE COUNTY, ILLINOIS
* CROSS-SECTION DATA - SEPTEMBER 9, 1997
* Reach #1
* ---
FEQX
GISID= 001EBAR6549
TABLE#= 6549
STATION= 2255.92 LEFT= 0.00 RIGHT= 0.00
NAVM= 0 SCALE= 1.00 SHIFT= 0.00
NSUB 1 0.025
-39.80 710.40 1 1910297.75 575991.19 0001 A1-2126 GRD
-16.67 709.91 1 1910274.62 575991.56 0002 A1-2127 TOB
-7.53 703.30 1 1910265.50 575991.06 0003 A1-2128 TOE
0.00 702.23 1 1910258.00 575991.31 0004 A1-2129 CL
6.92 703.12 1 1910251.25 575992.94 0005 A1-2130 TOE
20.18 710.57 1 1910238.00 575992.44 0006 A1-2131 TOB
27.68 711.01 1 1910230.50 575992.56 0007 A1-2132 BC
28.44 710.61 1 1910229.75 575992.69 0008 A1-2133 FL
60.33 711.11 1 1910197.88 575993.81 0009 A1-2134 PVT
91.98 711.62 1 1910166.25 575995.06 0010 A1-2135 FL
92.63 712.07 -1 1910165.62 575994.94 0011 A1-2136 BC
FINISH
GIS IDs
X,Y Coordinates
27


Flood Plain Delineator (FPD):
Grid Surface Processing
DPC - DEC - SMD
80
85 84 82 80 79 80 82 84
83 83 81 79 78 80 82 83
82 81 79 77 76 77 81 83
81 81 79 76 76 77 79 82
80 79 78 76 75 77 79 82
80 78 77 76 75 76 78 82
79 78 77 74 74 76 77 81
78 77 75 73 74 76 77 81
Topo contours & spot elevs...
...are sampled per grid...
...into an array of elevations.
80
79
77
80 80 80 80 80
80 80 80 80 80
79 79 80 80 80 79
79 79 79 79 79 78
78 78 78 78 78 78
77 77 77 77 77 77
77
Cross section station points...
...are sampled per grid...
...into an array of elevations.
28

Flood Plain Delineator (FPD):
Grid Surface Processing Results

DPC - DEC - SMD

Topography grid
--- Flood Surface grid

Flood Depth grid

-5	-4	-2	+0	+1	+0	-2	-4
-3	-3	-1	+1	+2	+0	-2	-3
-2	-1	+1	+3	+4	+3	-1	-3
-2	-2	+0	+4	+4	+3	+0	-3
-1	+0	+1	+3	+4	+2	+1	-3
-2	+0	+1	+2	+3	+2	+0	-3
-2	-1	+0	+3	+3	+1	+0	-4
-1	+0	+2	+4	+3	+1	+0	-4

… an array of depths.

…Interpreted as…

-5	-4	-2	**+0**	**+1**	**+0**	-2	-4
-3	-3	-1	**+1**	**+2**	**+0**	-2	-3
-2	-1	**+1**	**+3**	**+4**	**+3**	-1	-3
-2	-2	**+0**	**+4**	**+4**	**+3**	**+0**	-3
-1	**+0**	**+1**	**+3**	**+4**	**+2**	**+1**	-3
-2	**+0**	**+1**	**+2**	**+3**	**+2**	**+0**	-3
-2	-1	**+0**	**+3**	**+3**	**+1**	**+0**	-4
-1	**+0**	**+2**	**+4**	**+3**	**+1**	**+0**	-4

Flood zones and **boundaries**

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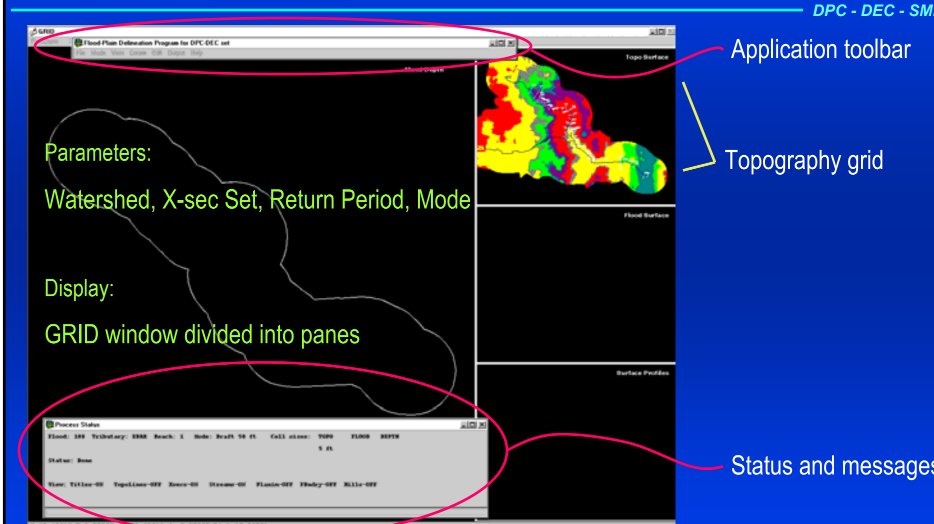
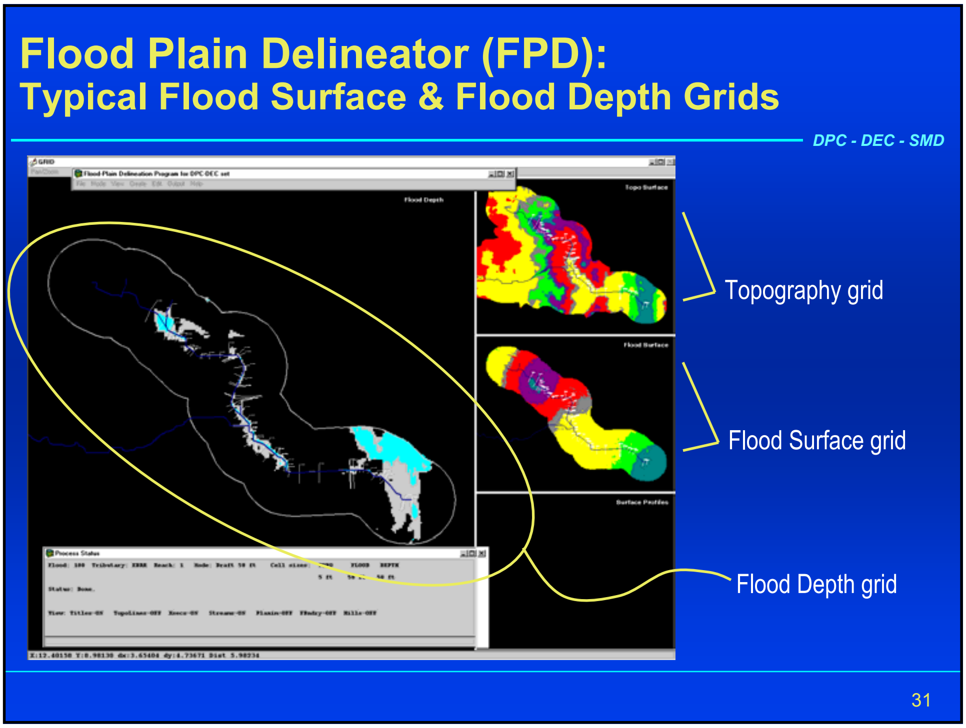
Flood Plain Delineator (FPD):
Typical Initial View

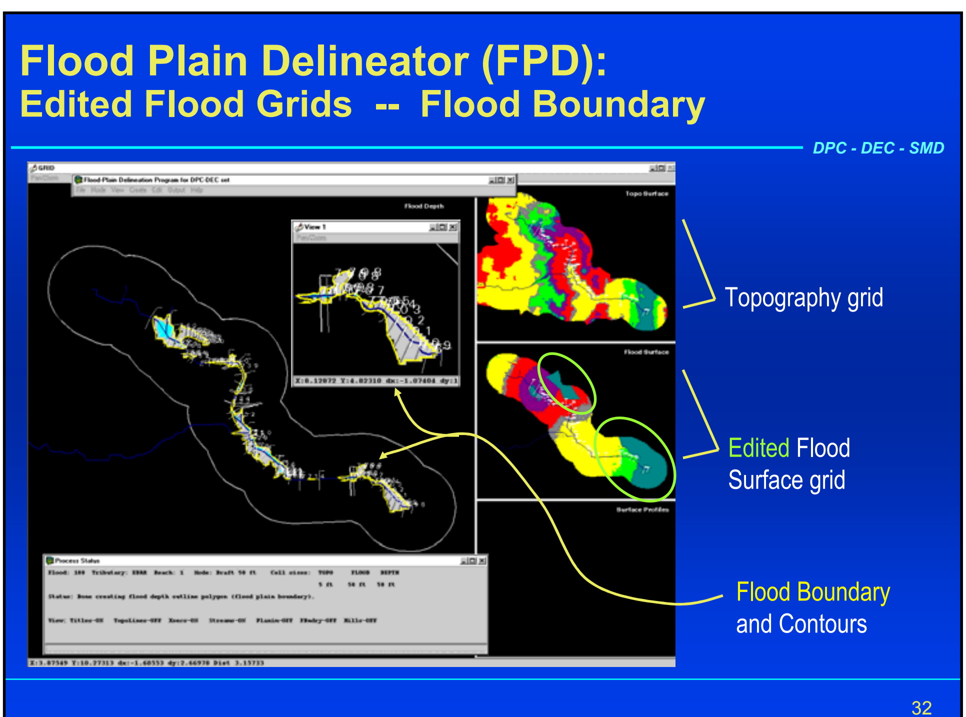
DPC - DEC - SMD



30

Figures

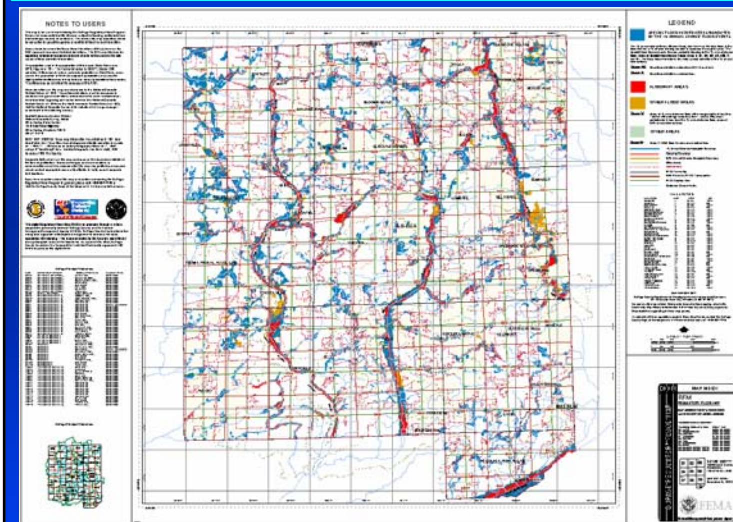

Flood Plain Delineator (FPD):
Typical Flood Surface & Flood Depth Grids
DPC - DEC - SMD
Topography grid
Flood Surface grid
Flood Depth grid
31


Flood Plain Delineator (FPD):
Edited Flood Grids -- Flood Boundary
DPC - DEC - SMD
Topography grid
Edited Flood Surface grid
Flood Boundary and Contours
32

Figures

Flood Plain Mapper (FPM):
Map Index

DPC - DEC - SMD



Features:

- Map Panel index, PLSS townships
- County-wide flood map
- Tables of Watersheds, Communities
- Keymap of Watersheds
- General notes

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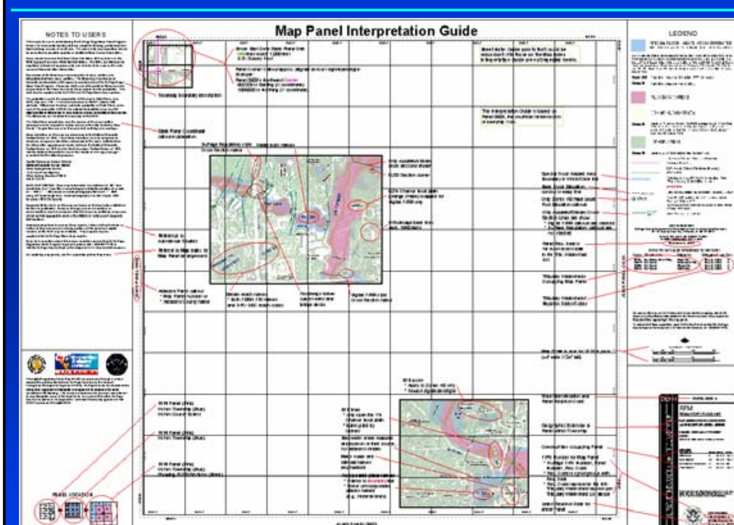
Flood Plain Mapper (FPM):
Map Panel Interpretation Guide

DPC - DEC - SMD



Guide based on actual product layout:

- E sized sheet
- Fixed scale

Map Index Interpretation Guide is similar

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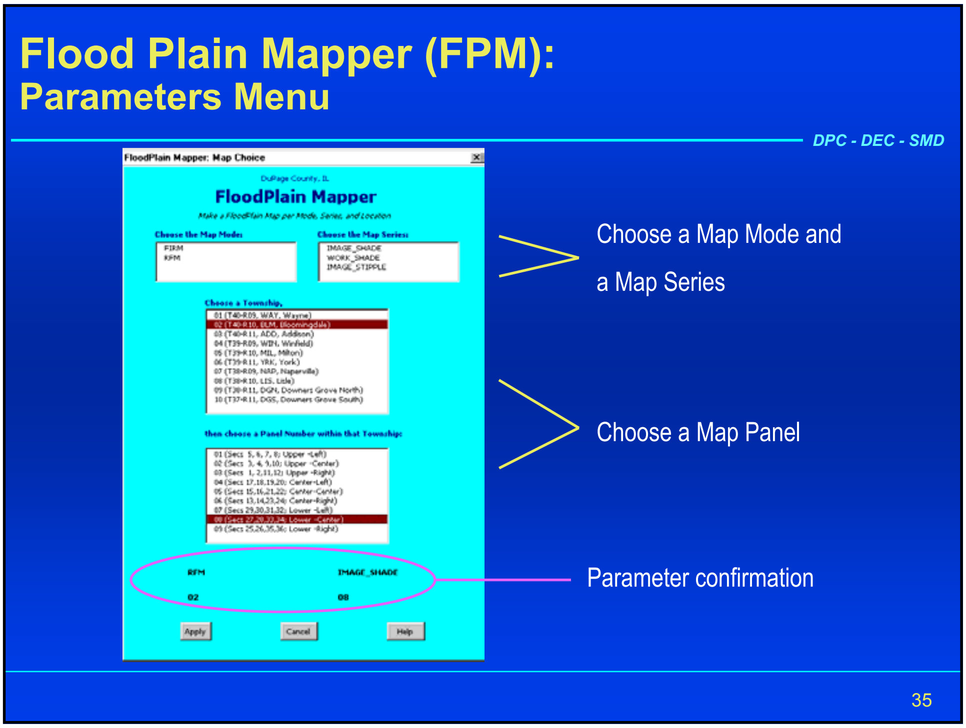
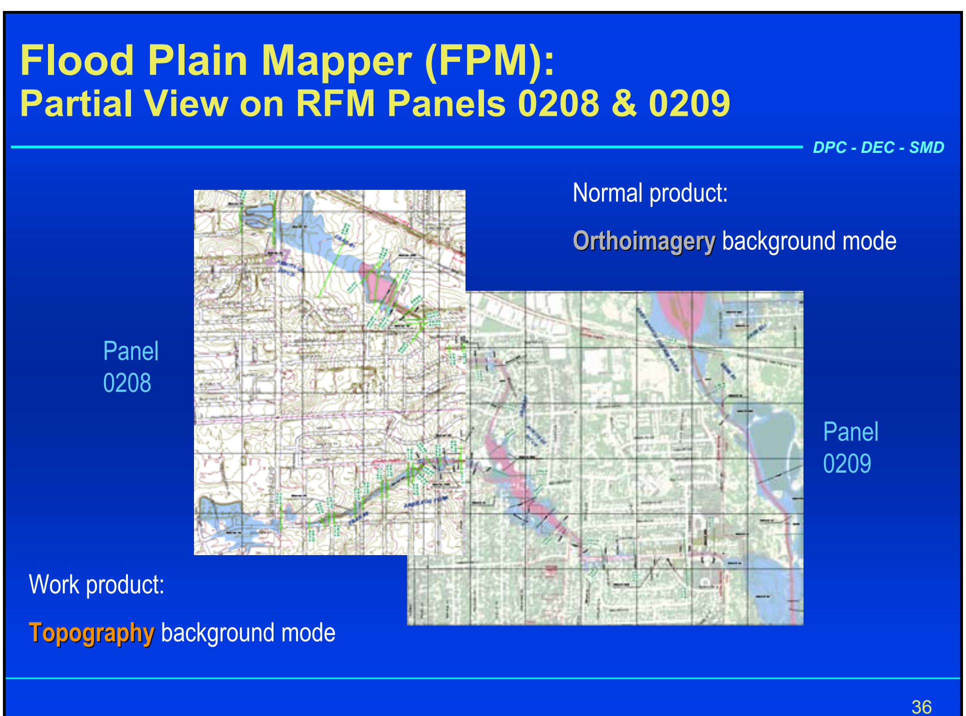
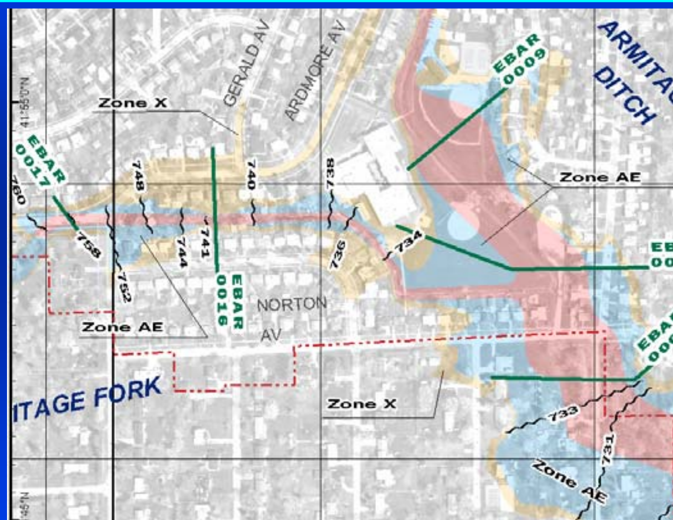

Flood Plain Mapper (FPM):
Parameters Menu
DPC - DEC - SMD
FloodPlain Mapper: Map Choice
FloodPlain Mapper
Choose a Map Mode and
a Map Series
Choose a Map Panel
Parameter confirmation
Apply
Cancel
Help
35


Flood Plain Mapper (FPM):
Partial View on RFM Panels 0208 & 0209
DPC - DEC - SMD
Normal product:
Orthoimagery background mode
Panel
0208
Panel
0209
Work product:
Topography background mode
36

Flood Plain Mapper (FPM): Detail View on RFM Panel 0209

DPC - DEC - SMD



Translucent flood zones over grayscale orthoimagery

Pink = Floodway

Blue = Base Flood

Orange = 500Yr flood

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Acknowledgements

The following individuals contributed to the construction of the various GIS softwares described in this paper.

GIS application or programs	**Author/Contributor**	**Firm**
LCTOTS	John McLaughlin Pamela Brooks	DPC-DEC-SMD Formerly with DPC-DEC-SMD
RGFAC	John McLaughlin Pamela Brooks Peter Thum	DPC-DEC-SMD Formerly with DPC-DEC-SMD GeoAnalytics, Inc.
XSEC – Bulk Processing	John McLaughlin	DPC-DEC-SMD
XSEC – XDI	John McLaughlin Steve Denowski Peter Thum	DPC-DEC-SMD GeoAnalytics, Inc. GeoAnalytics, Inc.
FPD	John McLaughlin Chuang-chang Chiang Steve Denowski Paul Braun	DPC-DEC-SMD GeoAnalytics, Inc. GeoAnalytics, Inc. GeoAnalytics, Inc. (now with VarionSystems, Inc.)
FPD to FPM preprocessing	John McLaughlin	DPC-DEC-SMD
FPM	John McLaughlin Becky Cummings Hossam Abdel Sayed	DPC-DEC-SMD GeoAnalytics, Inc. GeoAnalytics, Inc.

During the course to the GIS application workflow development, Dr. Delbert Franz of Linsley, Kraeger Associates, a principal author of the FEQ analysis programs, graciously modified the FEQ programs to accommodate some of the GIS identifiers used by SMD. Likewise, Dr. Allen Bradley of the College of Engineering at the University of Iowa, graciously modified the PVSTATS programs to do the same.

Appendixes

The following table details the ArcInfo coverage structure of those themes that collectively constitute the current flood maps for DuPage County. This is the recipe used by the FPM application.

DFIRM and RFM coverages structure for DuPage County flood maps

Drawing Order	Precedence Order	Flood Theme	Floodset	Feature Class	Subclass	Description	Attributes	Notes
8th	2	**_m100**	IDF, DDF	anno	zon	Flood zone callouts	TEXT	Formerly anno.msc level 1, height = 50'
	8			anno	nms	Stream and place names	TEXT	Formerly anno.msc level 2, height = 90'
	3			anno	pnd	BFE pools and ponds	TEXT	Formerly anno.bfe, height = 40'
	9			arc		Callout leader lines		
				point				Reserved for future use
7th	1	**_c100**	IDF,DDF	anno	bfe	Base flood elevation callouts	TEXT	
	1			arc		Base flood elevation contours	BFE	BFE={whole foot elevation}, height = 40'
6th		**_xsf**	IDF	anno	trxs	FEMA X-sec ID callout	TEXT	Non-plot set; stacked text, height = 25'
	4	(subset of _xs)		anno	xsec	FEMA X-sec ID callout	TEXT	Plot set; stacked text, height = 50'
				arc		FEMA X-sec	XSEC	XSEC={RRTT####} where ####<5000 = FEMA X-sec, otherwise fabricated
6th		**_xsm**	DDF	anno	trxs	Modeled X-sec ID callout	TEXT	Non-plot set; non-stacked text, height = 25'
	4	(subset of _xs)		anno	xsec	Modeled X-sec ID callout	TEXT	Plot set; non-stacked text, height = 50'
				arc		Modeled X-sec	XSEC	XSEC={RRTT####} where modeled if SOURCE = {1(if CASE ne D),2,3}
5th		**_fw**	IDF,DDF	anno	zone	Flood zone anno	TEXT	No members
	5			arc		Floodway boundary	BOUNDARY	BOUNDARY={99}
				label		100Yr floodway zone tag	CODE	CODE={FW,0=island}
4th		**_p100**	IDF,DDF	anno	zone	100 Yr flood zone anno	TEXT	Height = 50'
	6			arc		100Yr flood boundary	BOUNDARY	BOUNDARY={100,101=gutter line}
				label		100Yr flood zone tag	CODE	CODE={A=unmodeled or estimated,AE=modeled,0=island}
3rd		**_p500**	IDF	anno	zone	500 Yr flood zone anno	TEXT	Height = 50'
	7			arc		500Yr flood boundary	BOUNDARY	BOUNDARY={500}
				label		500Yr flood zone tag	CODE	CODE={X,0=island}

Drawing Order	Precedence Order	Base Theme	Floodset	Feature Class	Subclass	Description	Attributes	Notes
2nd	10	**roadnms**	IDF,DDF	anno	dxf	Road and major place names	TEXT	Only three heights should be used, height = {60', 100', 150'}
1st	12	**munic03**	IDF,DDF	anno	mun	Municipal names	TEXT	Border names (requires italic font expression), height = 60'
				anno	dxf	Municipal names	TEXT	Area names (***not** used in flood maps*)
	11			arc		Municipal boundaries		

<u>**Relationships**</u>

Inter (between feature classes among several coverages):
1) _p100 polys always nest within _p500 polys
2) _fw polys nest within _p100 polys except at unseen (from above) passages
3) _c100 arcs span _p100 polys only
4) _m100 arcs terminate within _p100 or _p500 polys
5) Annos from any theme should not overlap if possible

Intra (among feature classes within a given coverage)
1) _m100 arc and anno have a preferred arrangement: anno.zon above leader line, anno.pnd (if applicable) below it, these two left aligned, offset from leader line about half text height, leader line horiz. or vert.
2) _m100 anno.nms should be aligned with stream trend
3) _m100 ann.pnd elev. to most significant digits only [e.g. (EL 123), not (EL 123.0)]. PND anno is for AE zone ponds <u>only</u>.
4)_m100 anno.zon string to be within cited poly if wholly contained and readable, and exterior to floodway poly
5) All annos must have read-normal vector pointing to southern hemi-circle (bottom of page)
6) _c100 anno.bfe string should be centered on a bfe arc if arc length < 180', else should be end aligned
7) _xs (and _xsf, _xsm) anno.xsec and anno.trxs should be (preferably) end aligned with cited x-sec
8) _xs (and _xsf, _xsm) anno.xsec and anno.trxs to cite a X-sec only once
9) _p100, _p500 anno.zone should be within cited poly if wholly contained, else not at all
10) _500 anno.zone should never appear under the _p100 poly
11) _fw, _p100, p500 arcs form closed polys only, no dangles at all
12) _fw, _p100, _p500, munic03 polys to have 1-to-1 correspondence with tagging label points
13) _p100 arcs between differing flood zone polys to take special boundary value of '101'
14) roadnms anno.dxf to be generally aligned with cited streets and places
15) munic03 anno.mun to be aligned with poly edge, if possible, and to pair off generally

Notes:
1) Floodsets: IDF = Interim DFIRM data, DDF = DuPage digital flood data.
2) Precedence Order applies to appearance overposting control.

End Notes

1. Acronyms, mnemonics, and placeholders used in this paper are expanded as follows:

1-D – one dimension
2-D – two dimensional
3-D – three dimensional
AML – Arc Macro Language
ANL – Argonne National Laboratory
AOI – Area-of-Interest
BFE – Base Flood Elevation
CAD – Computer Aided Drawing/Drafting/Design
CD – Compact Disk
CTP – Cooperating Technical Partner
DDF – DuPage digital flood
DEC- Department of Development & Environmental Concerns
DFIRM – Digital Flood Insurance Rate Map
DOS – Disk Operating System
DPC – DuPage County
ESRI - Environmental Systems Research Institute
FEMA – Federal Emergency Management Division
FEQ – Full Equations
FEQUTL – Full Equation Utility
FIRM – Flood Insurance Rate Map
FPD – Flood Plain Delineator
FPM – Flood Plain Mapper
GIS – geographic information system
HEC – U. S. Army Hydrologic Engineering Center
HSPF – Hydrologic Simulation Program – FORTRAN
IDF –Interim DFIRM
IL – Illinois
INFO – The name of the simple relational database within the Workstation ArcInfo GIS
LCTOTS – Land Cover Totals
LP-III – Log Pearson Type III probability distribution
NEXRAD – Next Generation Weather Radar
NOAA – National Oceanic and Atmospheric Administration
NRCS – U. S. Department of Agriculture's Natural Resources Conservation Service
ORDINANCE – DuPage County County-wide Stormwater and Flood Plain Ordinance
PDF – Portable Document File
PERL – Practical Extraction and Reporting Language
PLAN – DuPage Stormwater Management Plan
PLSS – U. S. Public Land Survey System
PMF – Published Map File
PVSTATS - Peak-to-Volume Statistics
RFM – Regulatory Flood Map
RGFAC – Rain Gage Factors
SCS – Natural Resources Conservation Service (formerly Soil Conservation Service)
SMD – Stormwater Management Division
tetrasection – an informal unit of a PLSS township's sections as four PLSS sections sharing a common corner
TIN – triangulated irregular network
tribshed – tributary watershed
TSF – time series file
UNIX – A weak pun on the Bell Labs 'Multics' project, an interactive time-sharing operating system developed by K. Thompson and D. Ritchie
USDOE – U. S. Department of Energy
USEPA – U. S. Environmental Protection Agency
USGS – U. S. Geological Survey
VBA – Visual Basic for Applications
WPA –Watershed Planning Area
XDI – Cross-section Database Interface
XSEC – Cross Section
X-sec – Cross-section

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