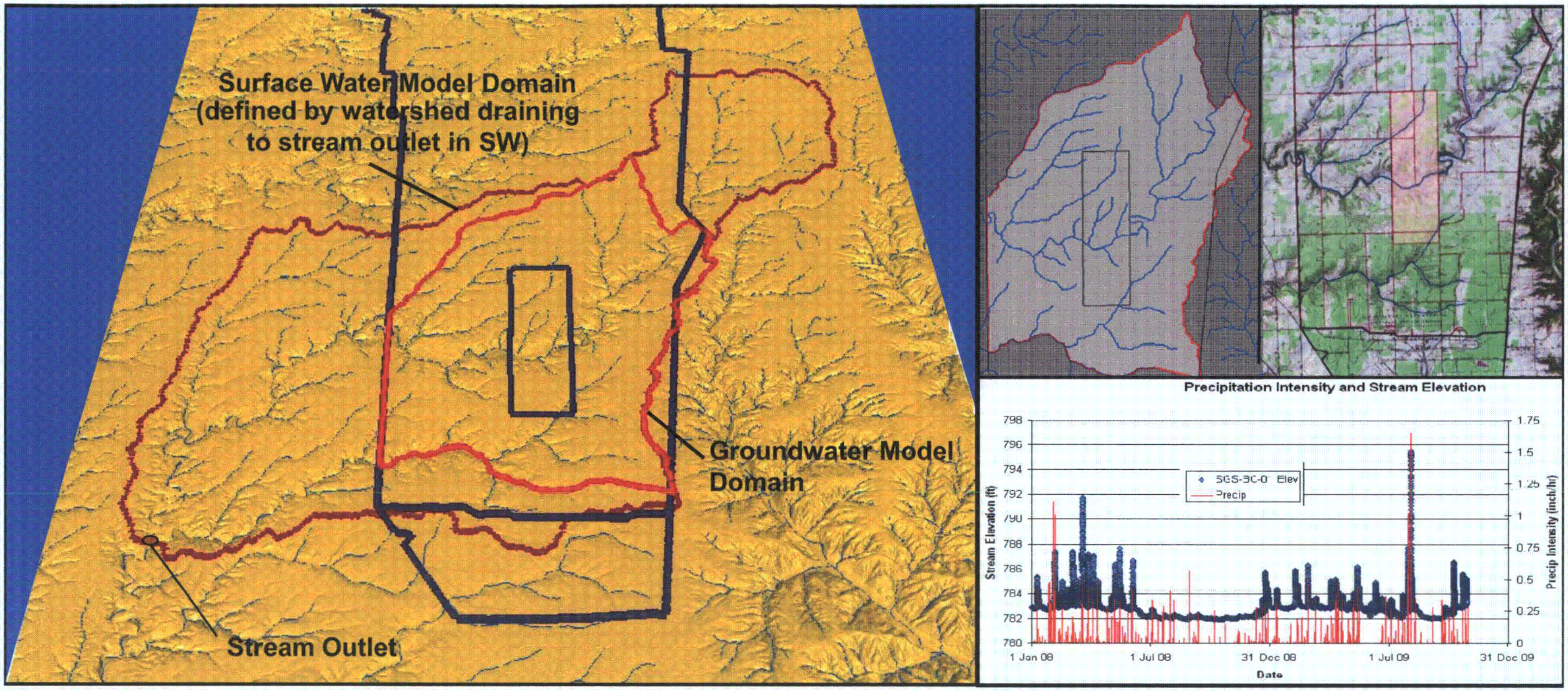

JPG Surface and Groundwater Modeling Status

March 18, 2010

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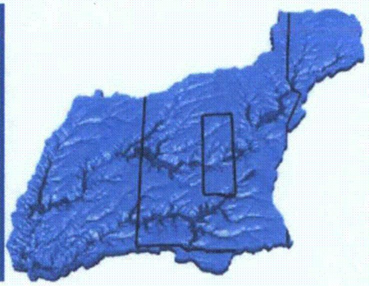
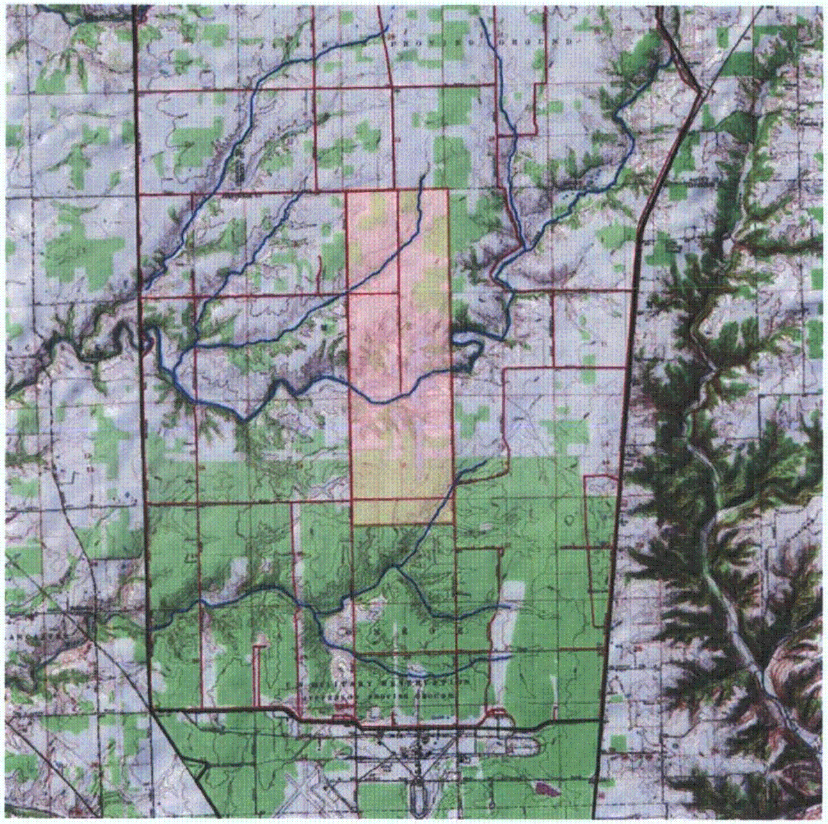
Objectives of Presentation

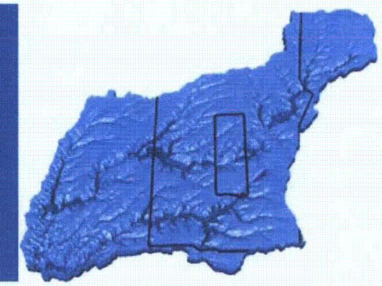


- Present objectives & approach (including task schedule)
- Present current status
  - Focus on surface water modeling effort
- Define next steps



***Note:* Information presented here is a work in progress and will be updated as appropriate as the work is completed.**

Modeling Objectives and Approach



- Predict the fate and transport of depleted uranium (DU) via the surface and groundwater pathways over the next 1,000 years to support risk-based assessment of potential future impacts
- Approach:
  - Calibrate surface and groundwater models to observed site conditions
    - Flow
    - Transport
  - Perform predictive simulations
- Surface Water
  - Hydrologic Simulation Program – Fortran (HSPF) http://www.epa.gov/ceampubl/swater/hspf/index.html
  - Storm Water Management Model (SWMM) http://www.epa.gov/ednnrmrl/models/swmm/index.htm
- Groundwater
  - MODFLOW SurFACT http://www.hglsoftware.com/Modflow_Surfact.cfm
  - Finite Element Heat and Mass Transfer Model (FEHM) http://fehm.lanl.gov/

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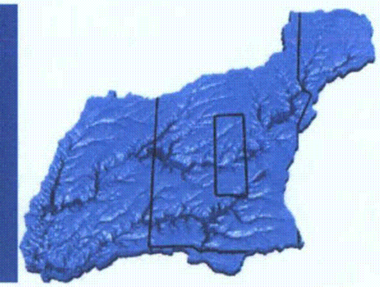
Surface Water Modeling

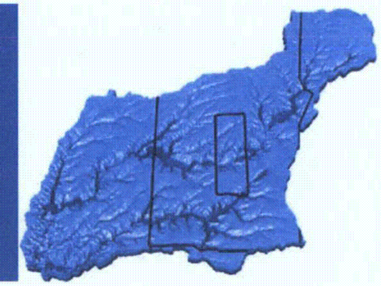


- Task 1: Data Collection and Formatting (1/29/2010)
- Task 2: Model Setup (2/26/2010)
- Task 3: Runoff Calibration (4/2/2010)
- Task 4: Sediment Transport Calibration (4/30/2010)
- Task 5: DU Transport Calibration (6/2/2010)*
- Task 6: Predictive Modeling (7/2/2010)
- Task 7: Reporting (8/2/2010)

* Completion date dependent on Kd study results

Note: Above are internal deadlines for modeling project team and may be adjusted as project moves forward.

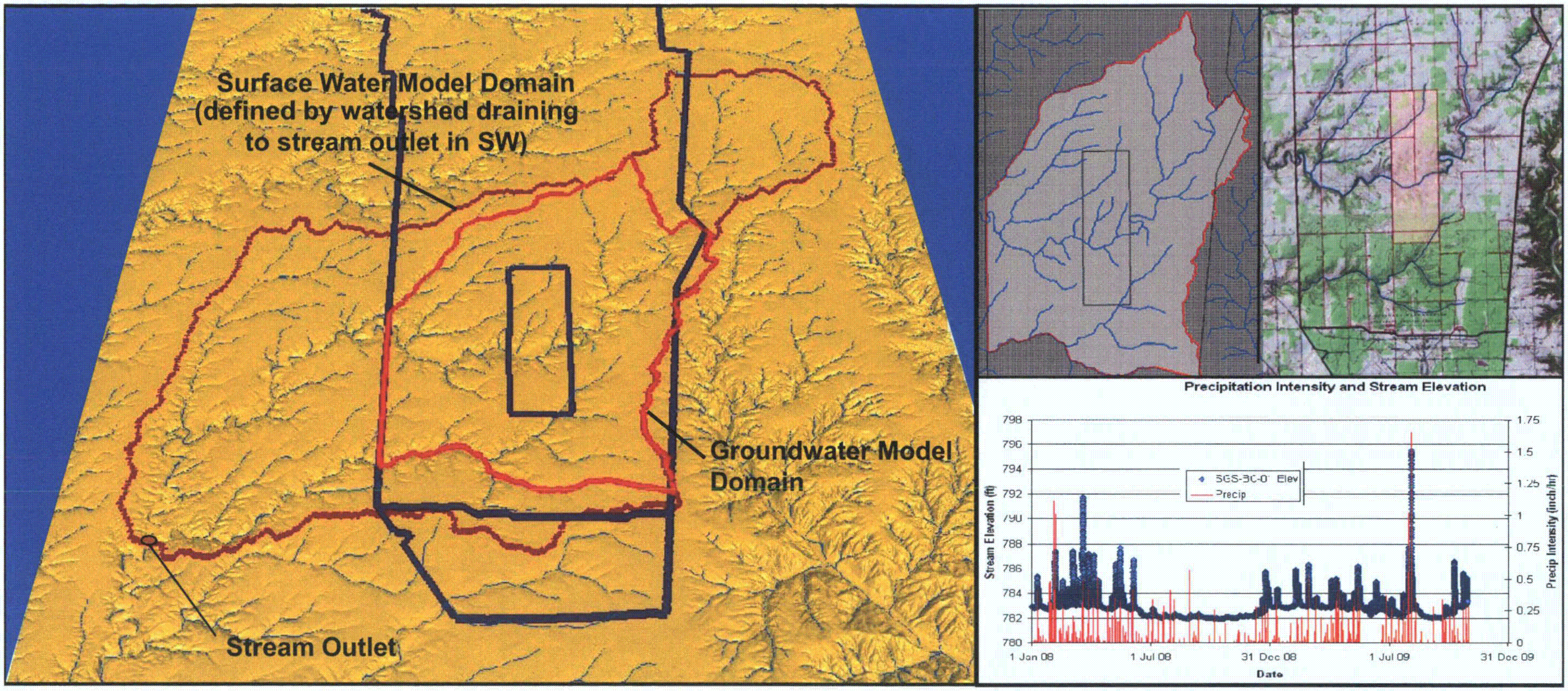
Groundwater Modeling Task



- Task 1: Conceptual Model (1/15/2010)
- Task 2: Calibrate Groundwater Flow Model (3/26/2010)
- Task 3: Discrete Fracture Flow Evaluation (3/26/2010)*
- Task 4: DU Transport Through Soil Column (3/26/2010)*
- Task 5: DU Transport in Groundwater (6/4/2010)*
- Task 6: Sensitivity/Uncertainty Analysis (6/4/2010)
- Task 7: Reporting (7/2/2010)

* Completion date dependent on Kd study results

Note: Above are internal deadlines for modeling project team and may be adjusted as project moves forward.



JPG Modeling

Conceptual Site Model – Supports Task 1 for Both Groundwater and Surface Water Modeling Efforts

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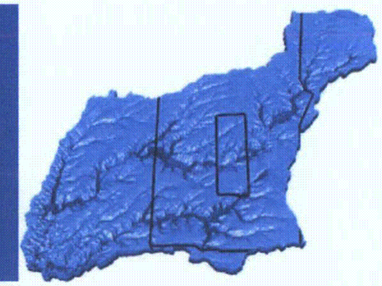
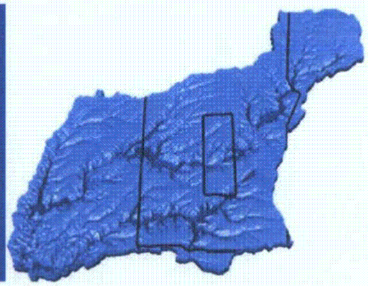
Conceptual Site Model

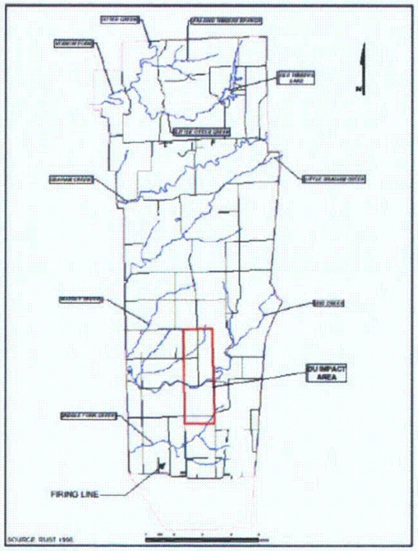


- Generally first task associated with any model development
  - Collection/assembly of information for incorporation into numerical model
  - Parameters to describe flow conditions
    - Within each stratigraphic unit of interest (extent, thickness, hydraulic properties)
      - » Overburden
      - » Shallow bedrock
    - Within each watershed/subwatershed for surface water modeling (land use, soil type, slope, area)
    - Water budget (precipitation, runoff, infiltration, evapotranspiration)
  - Parameters to describe transport conditions
    - Nature and extent of DU (soil, groundwater, surface water, sediment)
    - Timeline (operational history)
    - Mass release mechanisms (Corrosion study)
    - Transport mechanisms and chemical properties (Kd studies)

DU Impact Area

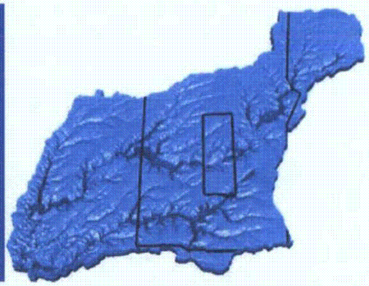


- 1983 to 1994: depleted uranium (DU) projectiles were tested at JPG
  - Three fixed-gun positions on the firing line at four soft targets placed at intervals of 3,280ft from the firing line
  - Projectiles impact in similar location, creating a trench roughly 3 ft deep by 16 to 26 ft wide extending for 3,940 ft.
  - Secondary impact locations developed when the projectile skipped, either whole or in fragments
  - Approximately 100,000 kg of DU projectiles were fired in the 2,080 acre DU Impact Area.
  - Approximately 30,000 kg of DU projectiles were recovered, leaving approximately 70,000 kg of DU remaining within the DU Impact Area.

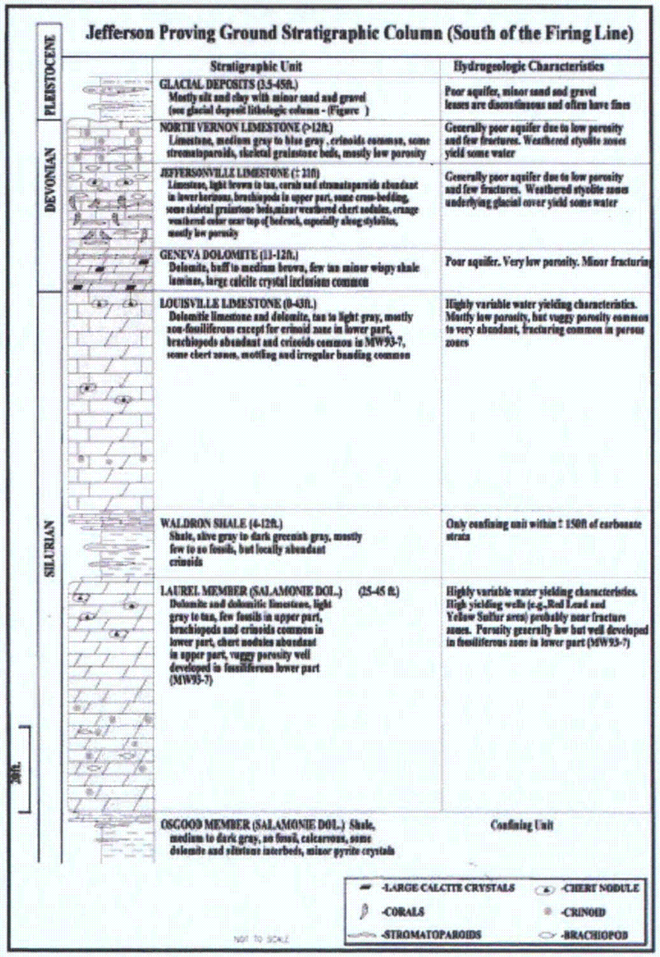


Source: MWH (2002)

DU Impact Area Stratigraphy



- General Stratigraphy (From Final Well Const Report, SAIC March 2008)
  - Overburden
    - Consists of 0.5 to ~3ft of silty loam surface soil followed by glacial tills and loess – mostly fine-grained materials (described as silty clay) which appear to have a low permeability
    - Thickness ranges from 0.65 to 72.5 ft with an average depth to bedrock of 20.8 ft
    - Sand lenses within till
  - Shallow Bedrock
    - Consists of nearly horizontally bedded limestone, shaley interbedded limestone, dolostone and shaley interbedded dolostone
    - There is limited secondary porosity consisting of weathering near bedrock surface, fractures and very limited solution features
    - Thickness is the top 40 to 60 ft of bedrock
  - Deep Bedrock
    - Consists of the same bedrock type as the shallow, though with little to no fracturing and no evidence of solution features



Source: MWH 2002.

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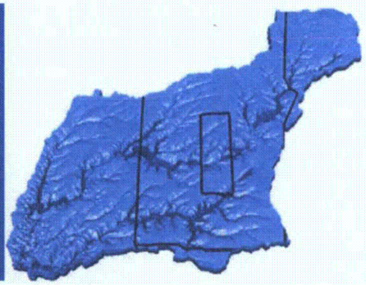
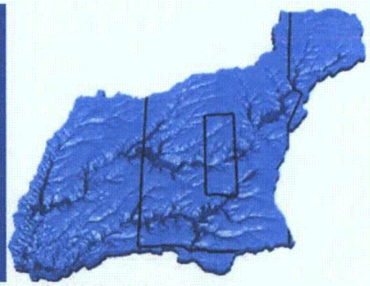


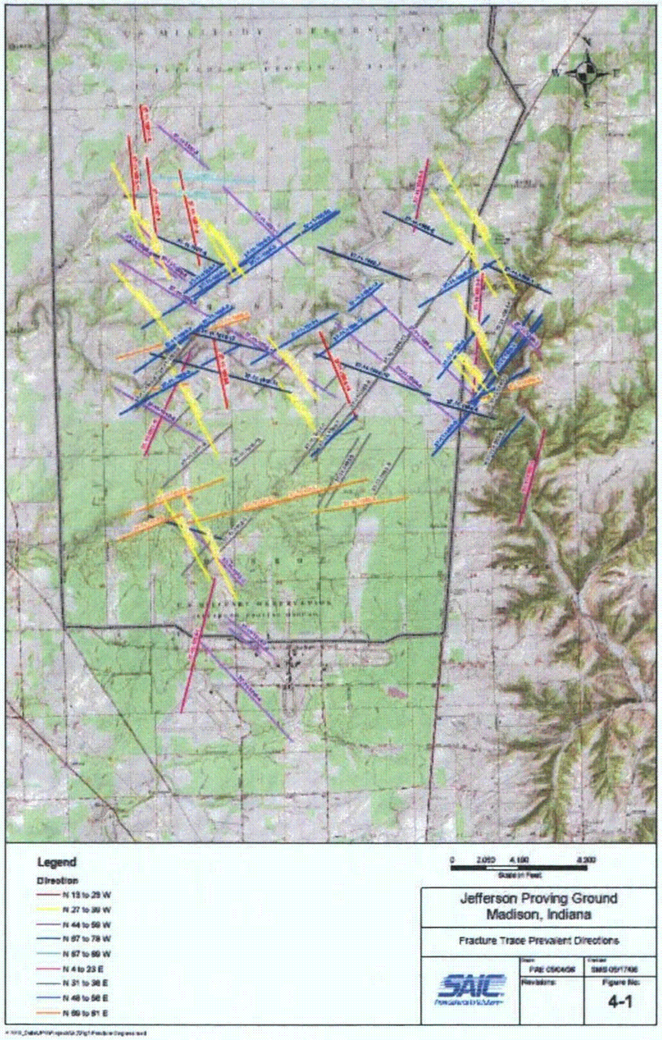
Surface Soils

- Cobbsfork-Avonsburg
  - Covers most of the DU Impact area with the exception of the stream locations
  - Consists primarily of silty loam material approximately 1 ft thick
- Cincinnati-Rossmoyne
  - Located in drainage areas along streams
  - Consists primarily of silt loam and silty clay loam approximately 3 ft thick

DU Impact Area Stratigraphy



- Karst Features (From Final Well Const Report)
  - Have been observed within the DU Impact area as surface expressions of sinkholes, caves along Big Creek, and weathered jointing of bedrock observed at outcrops along Big Creek
  - Appears to be limited in depth and lateral extent
  - Located within the narrow erosional plain along Big Creek and offsite along lower sections of Middle Fork Creek
  - Caves and solution features appear to be most commonly above the groundwater table and above the elevation of Big Creek and limited to depths of less than 50ft below the land surface
- Fracture Picture (at right) from Well Locations Report



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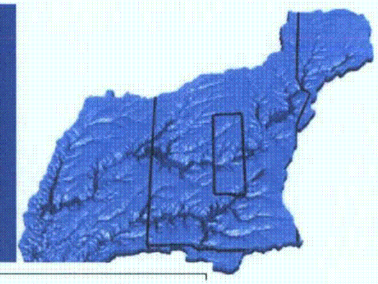
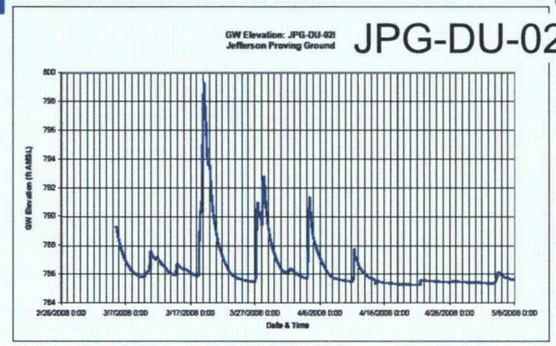
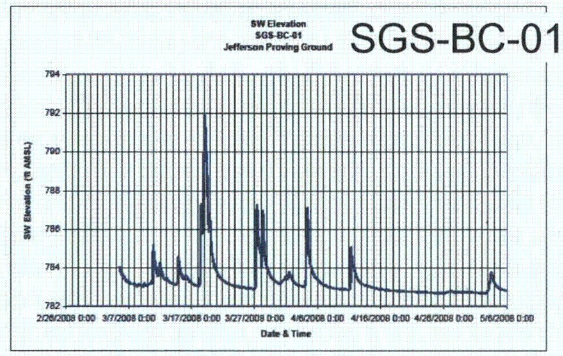
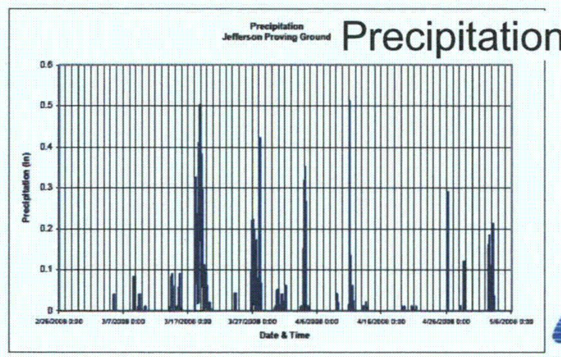
Groundwater/Surface Water/Precipitation



- Well JPG-DU-02I near Big Creek, SW gauging station SGS-BC-01, and on-site weather station precipitation.
  - JPG-DU-02I had ~6" void open to the screen interval at 23-23.5 feet below grade
  - Elevation of groundwater higher than stream water elevation (April 2008)
  - Response to precipitation very quick in both the stream and the well, but larger in the well
- Areas of thick overburden
  - Show slower response to precipitation events
- Deep Bedrock
  - Shows very limited response to precipitation events







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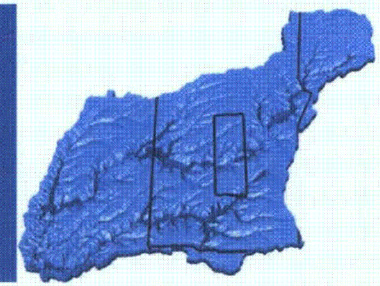
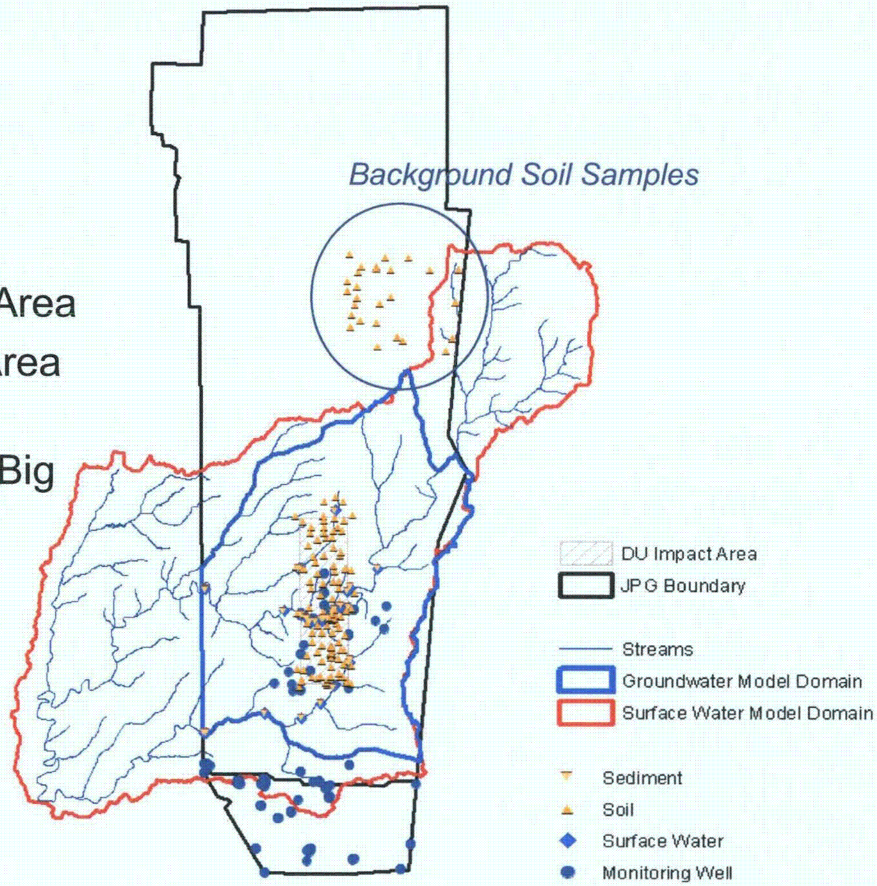
Sampling Locations



Analytical Data

- Background Soil Samples
- Soil Samples in/around the DU Impact Area
- Groundwater Data around DU Impact Area and South of the Firing Line
- Surface Water & Sediment Samples in Big Creek and Middle Fork Creek



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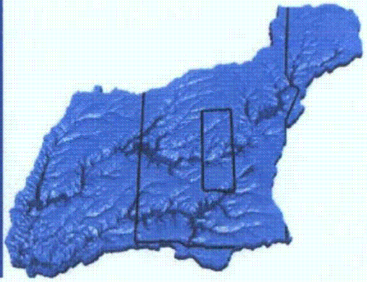
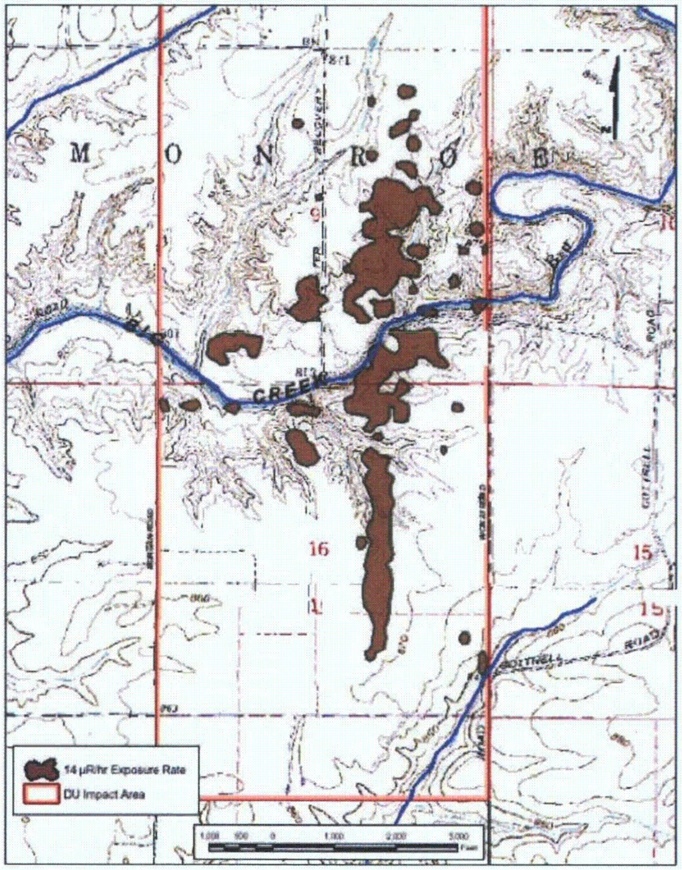
Approximate DU Distribution in Soils



- Source info
  - In 1994/1995, the DU Impact Area was characterized to determine possible location of DU penetrators. The map to the right shows areas where the exposure rate was higher than background values and therefore considered high concentration areas where penetrators may be present.
  - Estimated that 70,000 kg of DU remain within the Impact Area
- Integrate more recent data as part of the DU transport modeling effort for surface and groundwater
  - Ongoing as part of source term for surface and groundwater pathways



Source: SEG 1996.

Figure 4-3. Exposure Rate of 14 µR/hr from Soil at Jefferson Proving Ground

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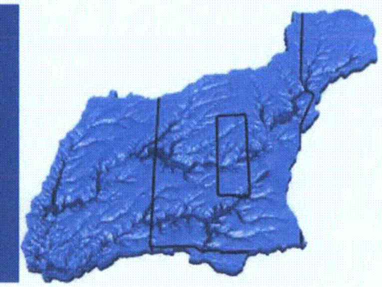
Surface Water/Sediment Sampling



- Characterization Sampling: April 2008, July 2008, October 2008, and February 2009
  - 20 Surface water samples (locations based on stream survey)
  - 20 Sediment samples (locations based on gamma walkover survey and stream survey)
  - Entrance, midpoint, and exit of Big Creek with respect to the DU Impact Area
  - Cave entrances in Big Creek
  - Entrance and exit of Middle Fork Creek with respect to the DU Impact Area
  - Big Creek and Middle Fork Creek near the exit of the JPG facility
  - 4 Upgradient samples collected to establish background

- Analyses
  - Total Uranium
  - Anion/Cation signature in comparison with surface/groundwater
  - Spatial Distribution, proximity to trench, etc.
  - Variability with flows, sampled features (fine sediment vs. tributaries, etc.)
  - Seasonal variations

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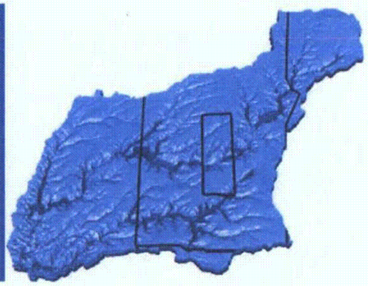
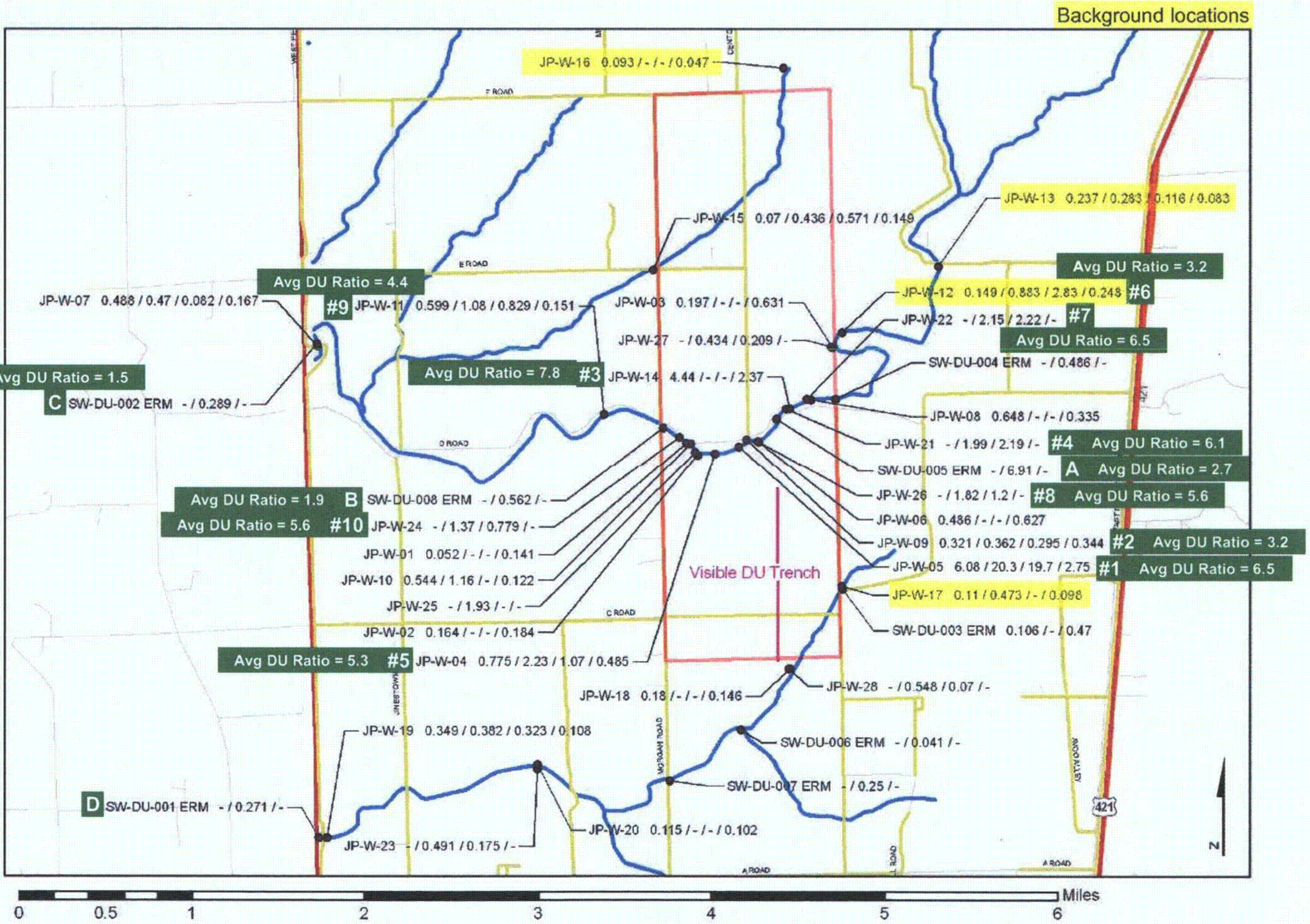
Quarterly Surface Water Sampling

Collected 80 surface water samples from 20 locations in April 2008, July 2008, October 2008, and February 2009





	Unfiltered	Filtered	ERM
n	75	75	77
Min	0.031	0.047	0
Max	63.8	20.3	6.91
Average	2.17	1.29	0.50
Std. Dev.	7.94	3.29	0.46

Surface Water Action Level for ERM Samples: If < 150 pCi/L, no corrective action.

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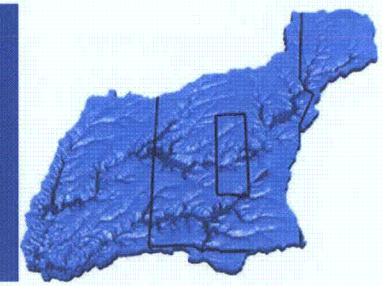
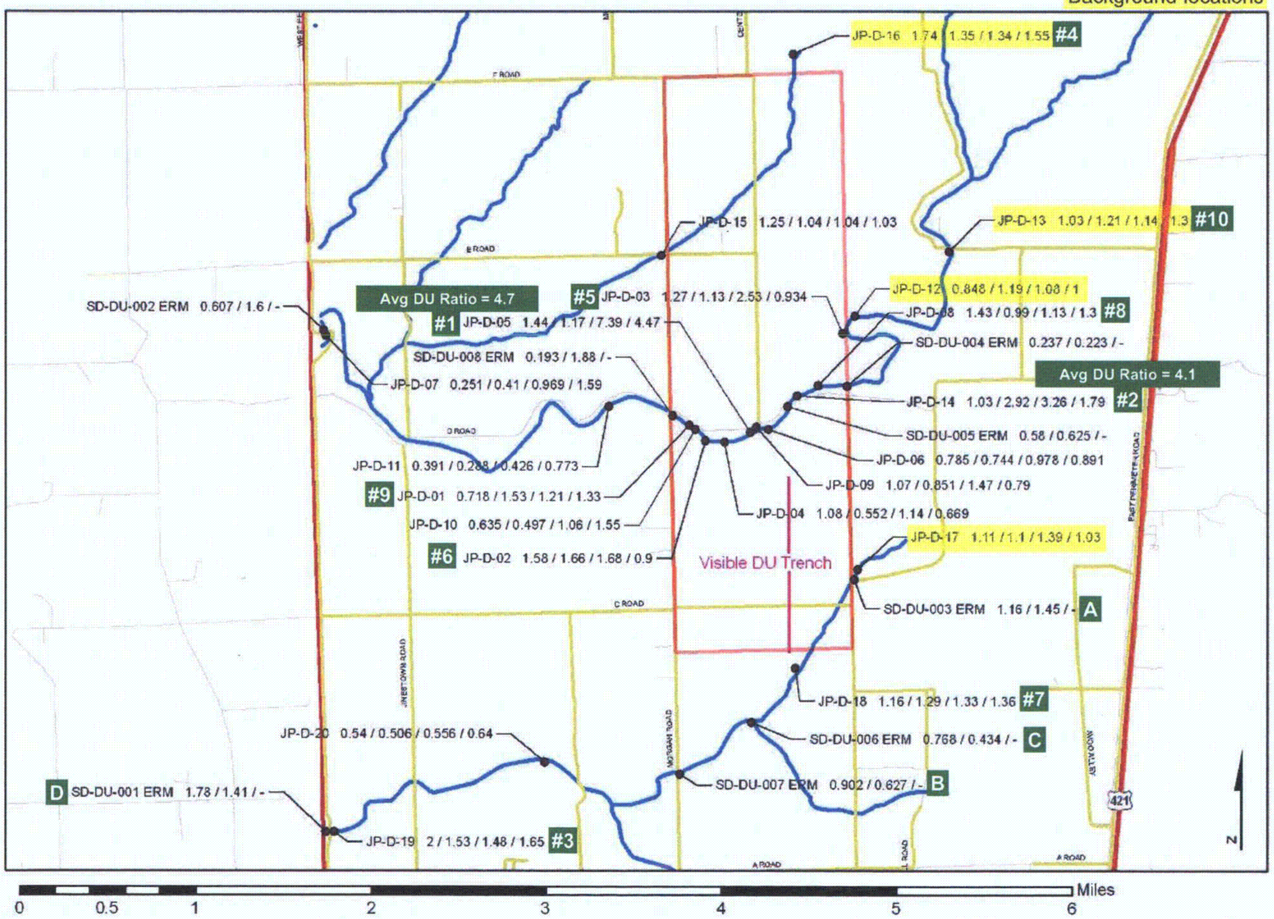
Quarterly Sediment Sampling

Collected 80 sediment samples from 20 locations in April 2008, July 2008, October 2008, and February 2009



Background locations

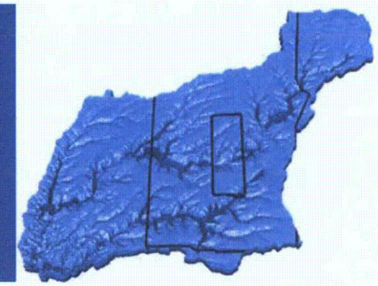


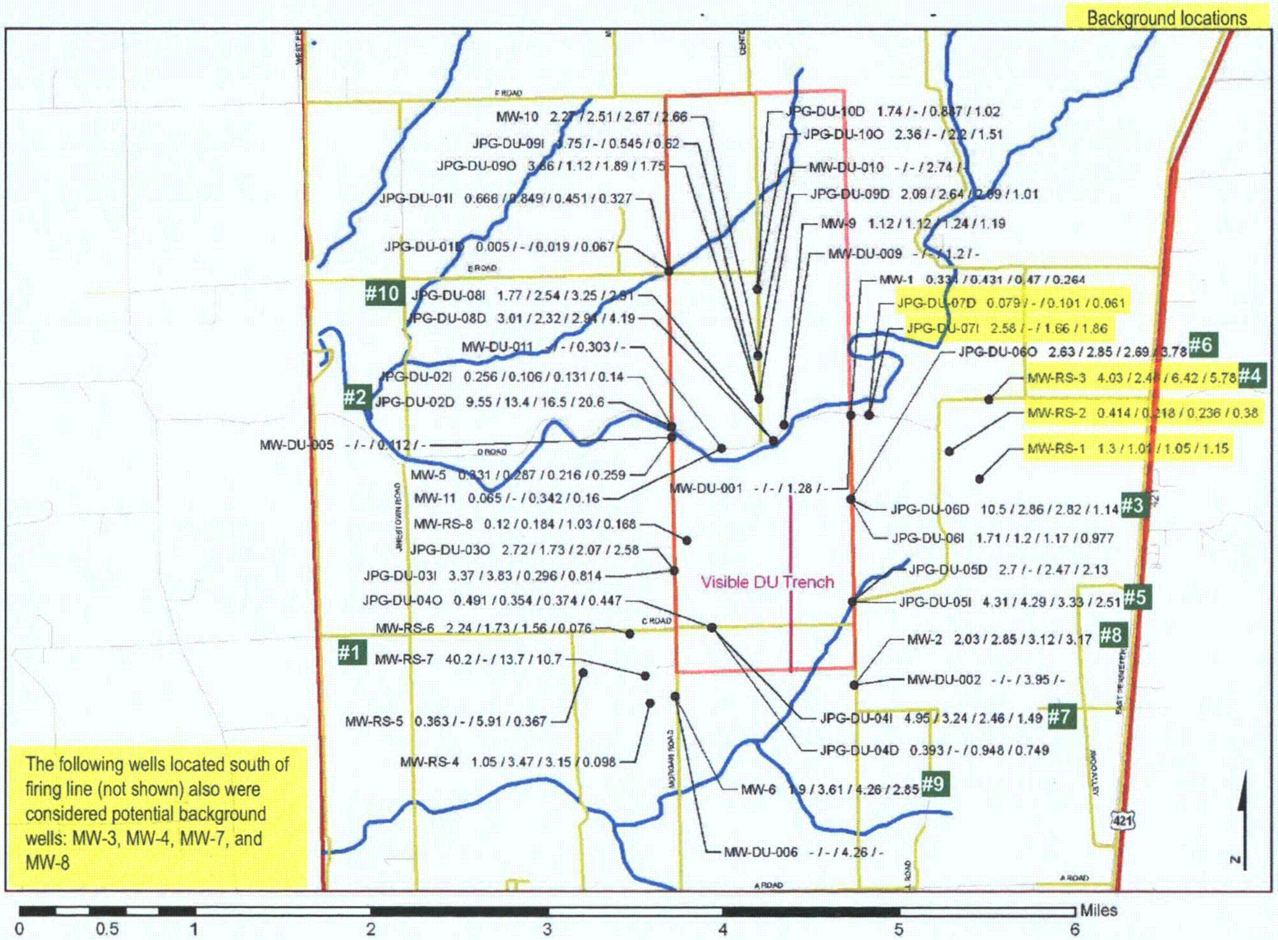
	Site Char.	ERM
n	80	160
Min	0.251	0.193
Max	7.39	2.801
Average	1.28	0.99
Std. Dev.	0.94	0.56

Sediment Action Level for ERM Samples: If < 35 pCi/g, no corrective action.

Quarterly Groundwater Sampling

Collected 328 groundwater samples from 42 wells in April 2008, July 2008, October 2008, and February 2009





	Unfiltered	Filtered
n	160	168
Min	0.028	0.032
Max	47.1	40.2
Average	2.19	2.03
Std. Dev.	4.42	4.00

Groundwater Action Level for ERM Samples: If < 150 pCi/L, no corrective action.

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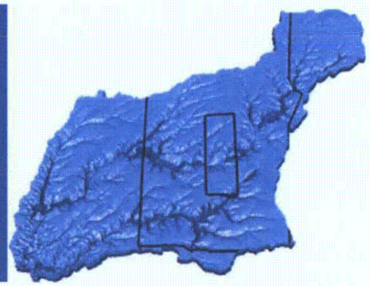
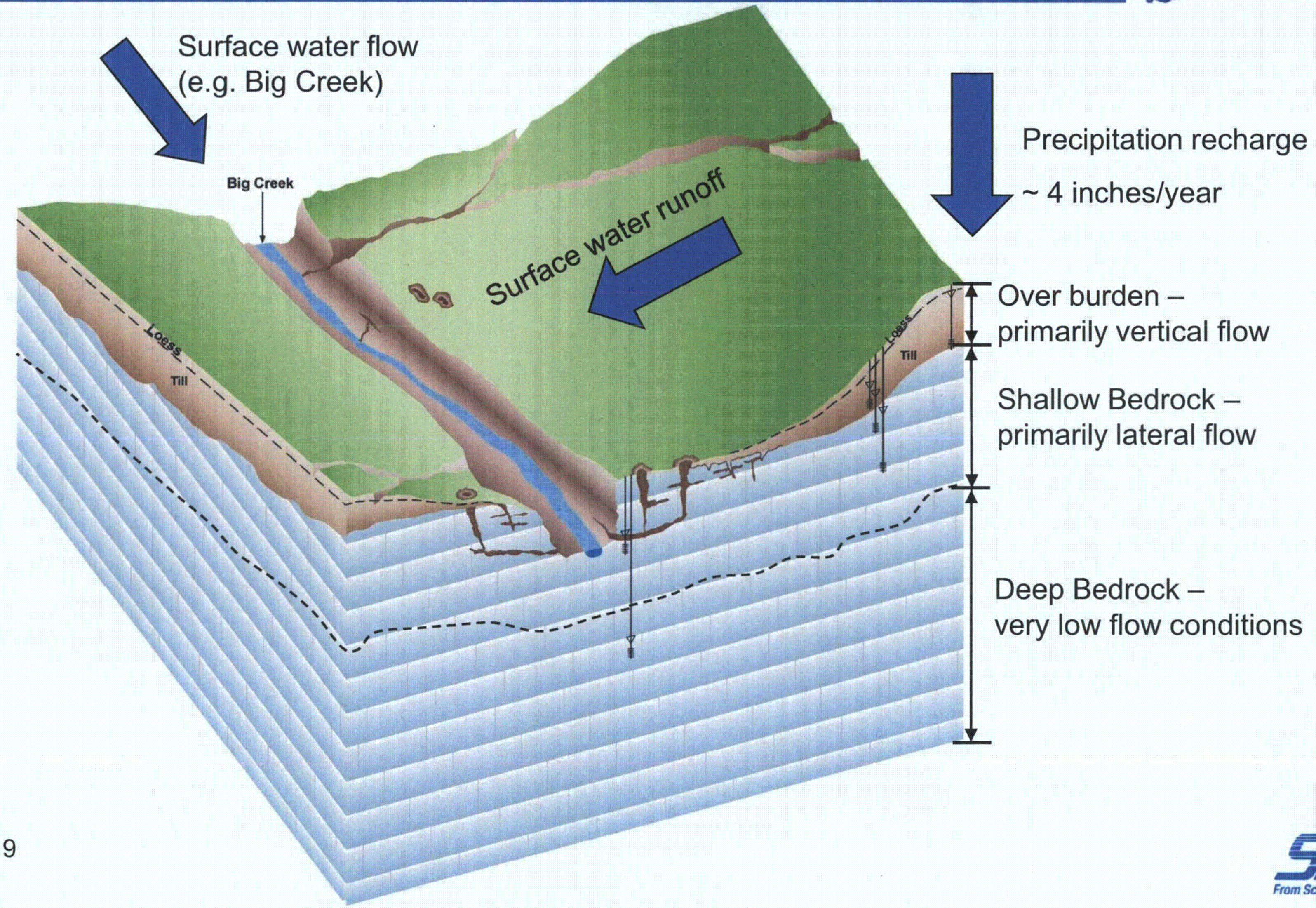
Conceptual Site Model





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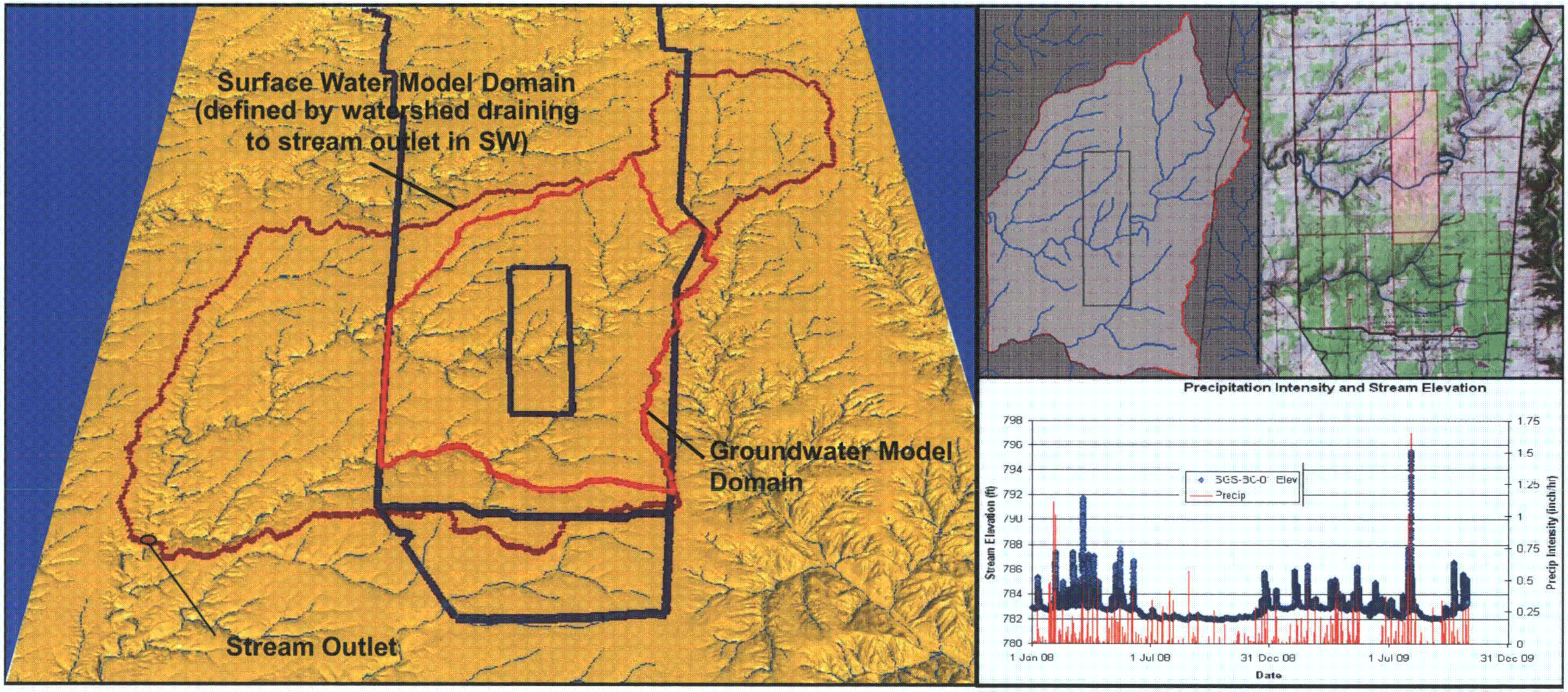

JPG Surface Water Modeling

Model Setup and Initial Calibration Efforts

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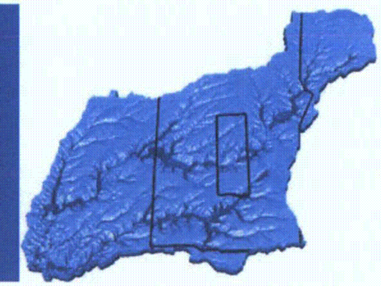
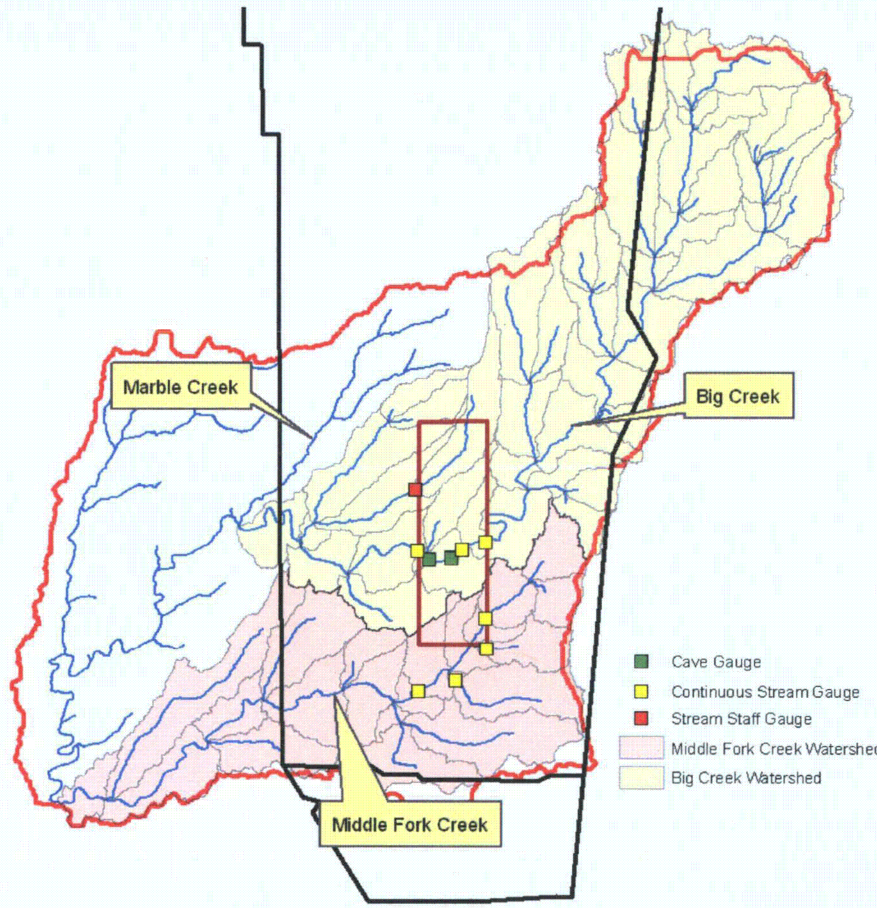
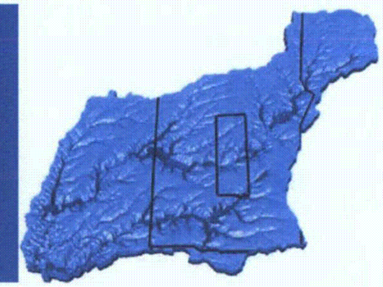
Surface Water Flow



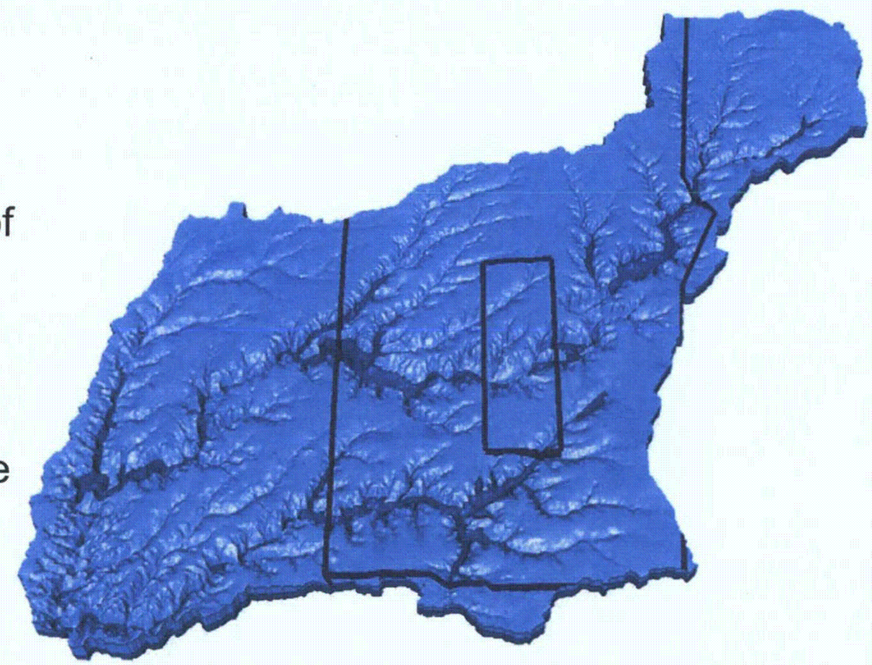
- Site Flow
  - The surface water flow is in roughly parallel streams to the southwest of the site (DP Final 2002)
  - Middle Fork Creek and Big Creek drain the DU Impact Area, and Marble Creek is a tributary to Big Creek that joins the main trunk shortly after crossing the western site boundary (DP Final 2002)
  - Evidence for a significant shallow groundwater contribution to stream flow is supported by several cave stream gauges installed and monitored since 2007 (Final Well Const Report 2008)



Conceptual Model



- Runoff
  - Rainfall/snowmelt in each catchment generates a quantity of flow based on the amount of precipitation, the slope and soil characteristics of the catchment, the area of the catchment, and the overland flow path. A portion of the water will evaporate, while another portion will infiltrate and contribute to the shallow groundwater. The remainder runs off into the stream channels and is transported through the model.



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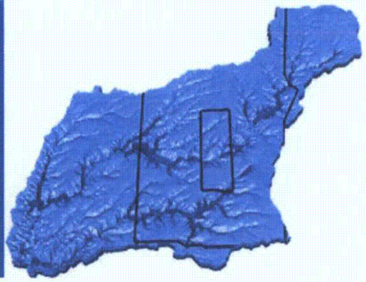
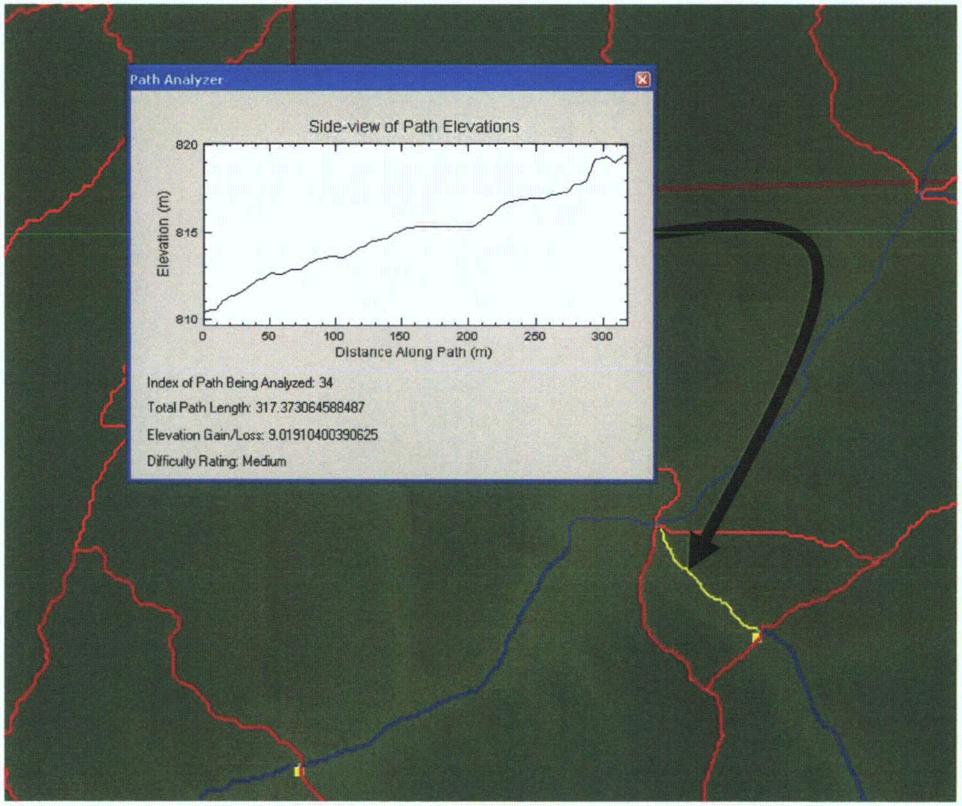
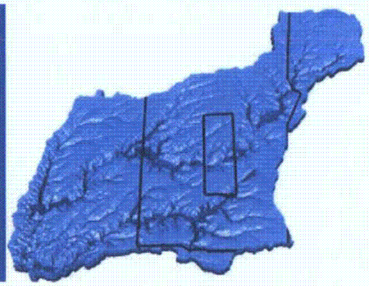
Conceptual Model



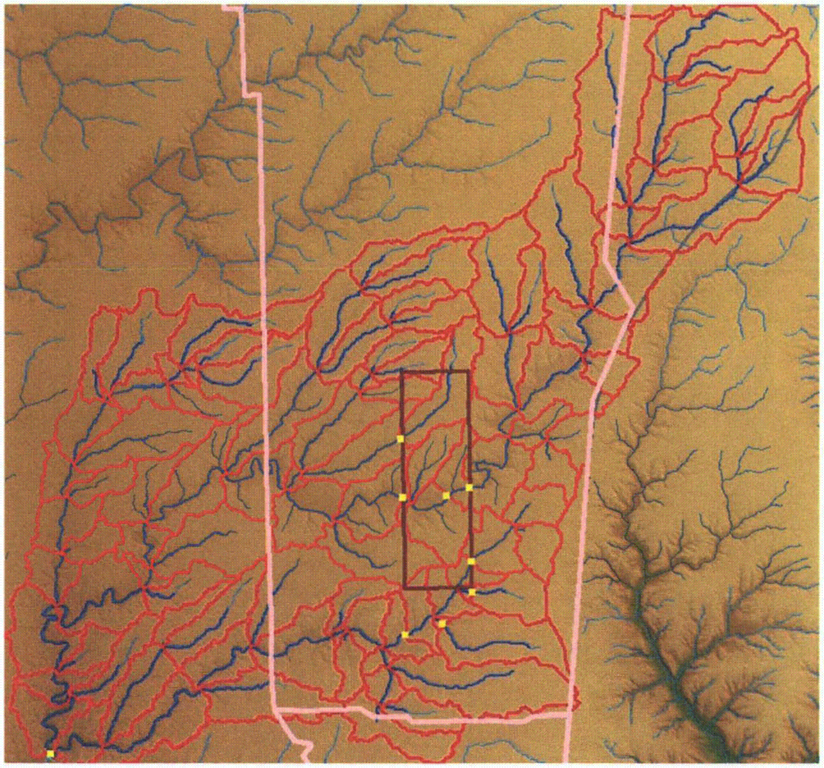
- Transport
  - The runoff from each segment is routed either to another catchment or to a junction of the stream channel.
  - Junctions receive runoff from the catchments, any assigned upstream flows from unmodeled portions of the stream, and inflows/outflows from the shallow groundwater.
  - Stream channels can be defined by shape, roughness, and slope to transport the captured water forward in sequence.
  - Pictured to the left, a plug-in named Path Analyzer is used to analyze the slope of the yellow-highlighted stream link.



Surface Water Data and Model Setup



- Catchment Data
  - BASINS 4 (pre-processor for HSPF) is capable of using provided DEM information and delineating catchments.
    - Average slopes of both streams and catchments to be calculated.
    - Other GIS layers such as land use, soil types, and vegetation cover to to calculate runoff characteristics
  - Delineation tool can provide the level of detail required to meet project objectives
    - DU Impact Area may be further refined into several catchments to provide better resolution
    - Upstream and downstream areas with fewer/larger catchments will be sufficient



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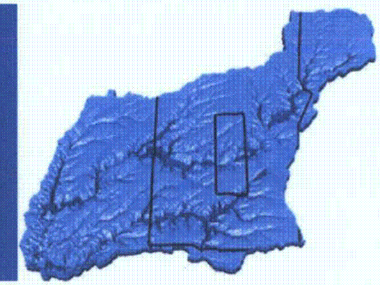
Surface Water Data – Runoff
Precipitation and Water Budget



- Meteorological Data
  - A USFWS weather station is located on the eastern portion of JPG, northeast of the DU Impact Area
    - This data has been augmented with historical data from nearby Butlerville, IN, to generate a longer timeline of meteorological data coinciding with stream gauge data on site
  - Historical Data is available from several surrounding weather stations
    - This data will be used to help construct plausible 1000-yr meteorological scenarios for predictive modeling.
  - Preliminary water budget based on 47 inches of annual precipitation
    - 56% (26 inches) were lost to Evapotranspiration
    - 36% (17 inches) were available as surface runoff
    - 8% (4 inches) were allocated to groundwater.

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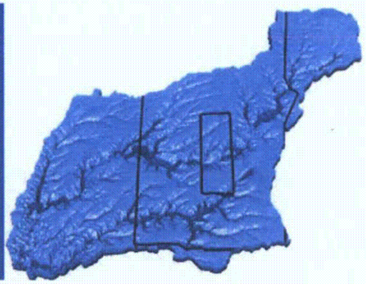
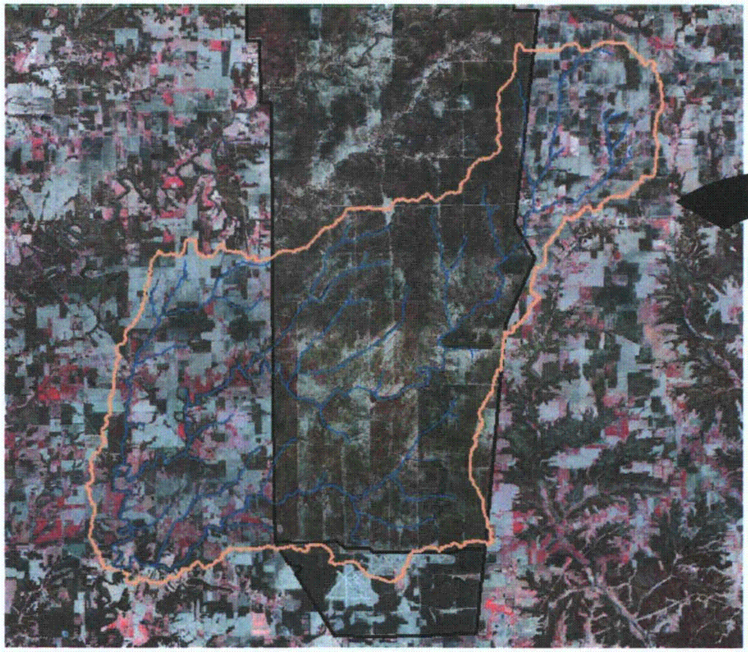
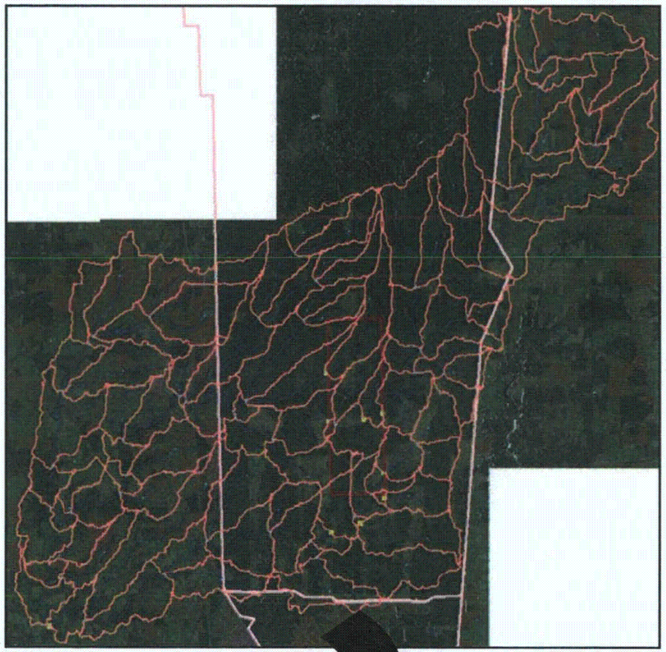
Surface Water Calibration – Land Use Classification



Infrared Coverage for (2008) was proceesed to produce a detailed 6 meter Land Use Classification, Providing better resolution than the 30 meter grid available from Purdue





Defines Land Use Percentages in HSPF PERLND and IMPLND Modules

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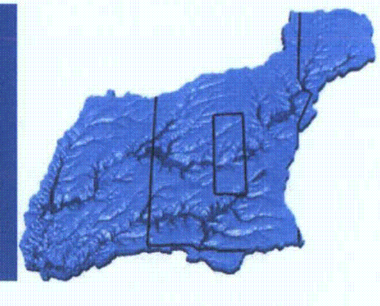
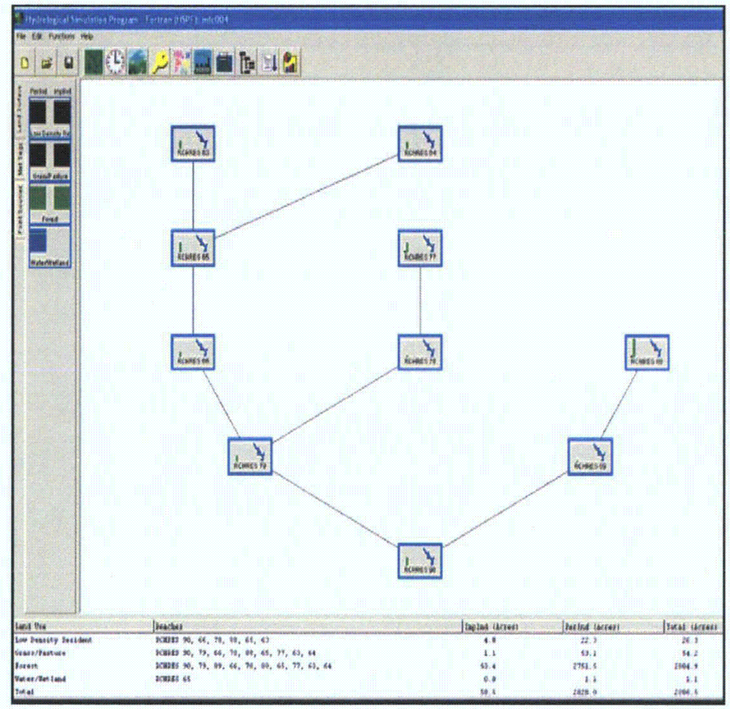
Surface Water Data – Runoff
Catchment Data



- Catchment Data
  - Land Use data was obtained from a Purdue University website
  - This data allows us to define Land-use types and associated acreage
    - Commercial
    - Agricultural
    - Surface water
    - Residential (low density and high density)
    - Grass/ pasture
    - Forest
    - Industrial
  - Data is currently being refined by use of IR imaging to break down the large forested regions

HSPF Submodel for Middle Fork Creek



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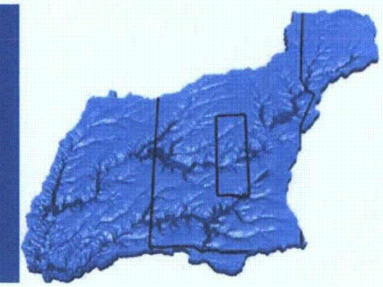
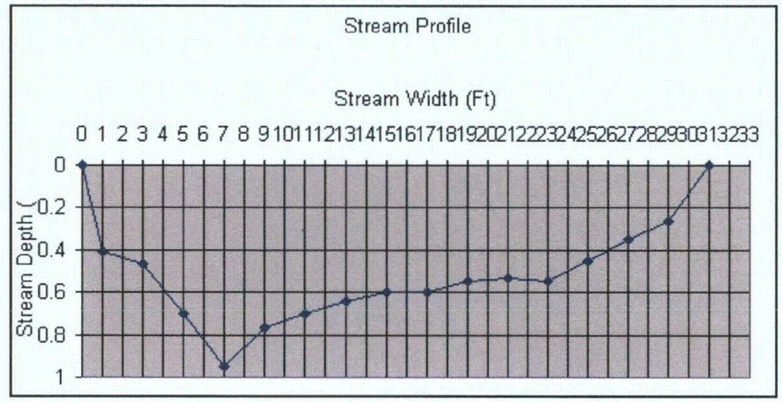
Surface Water Data – Runoff
Stream Profiles



- Stream Profiles
  - Stream profile data measured at the site
  - In HSPF, this contributes to the Ftables that define stream flow as a function of depth for each reach (flow calibration)
  - Support transport calculation (sediment and surface water)



Depth (ft)	SA (acres)	Vol (ac*ft)	Q (cfs)
0	0.34435125	0	
0.05	0.367308	0.0183654	0.17045
0.2	0.43617825	0.08723565	1.786223
1	0.80348625	0.80348625	33.00966
2	1.26262125	2.5252425	135.7741
5	2.64002625	13.20013125	1072.41
10	4.93570125	49.3570125	5805.072
30	14.11840125	423.5520375	96384.66

Wide bottom , shallow-sided, vegetated, steep slope

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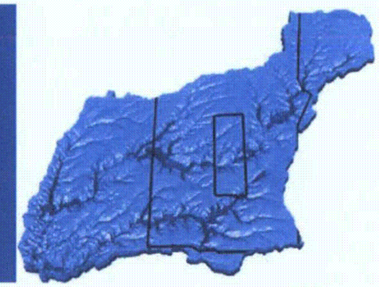
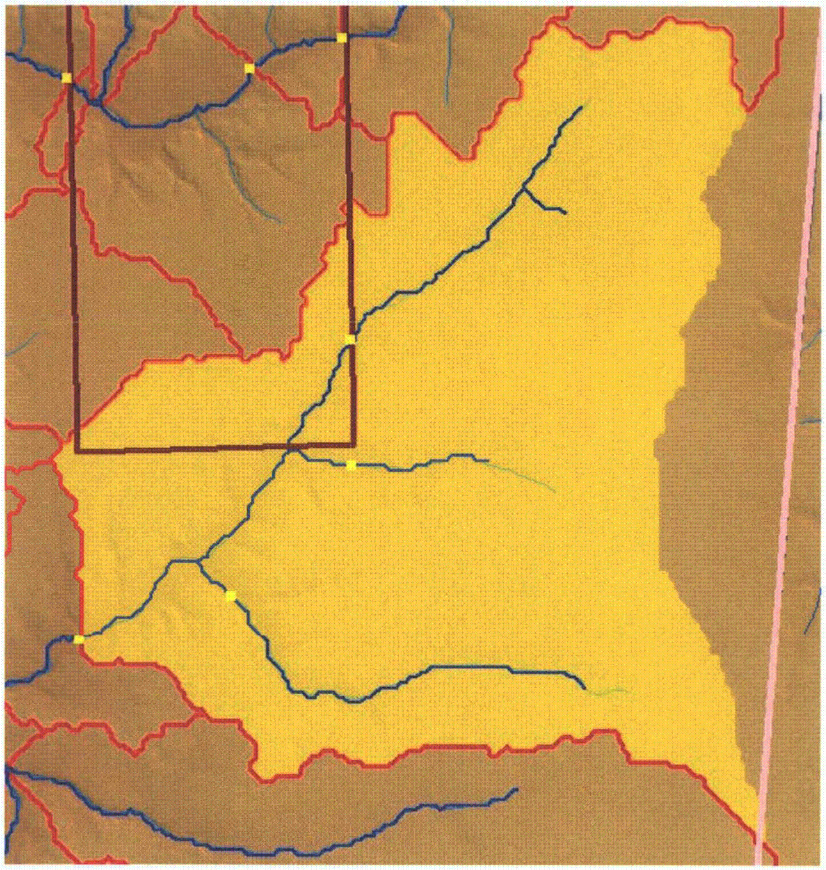
Surface Water Calibration - Flow





- Middle Fork Creek
  - Sub-model consisting of 10 catchments
  - Can be calibrated to 4 continuous stream gauges (pressure transducers.)
  - Calibration runs are currently ongoing

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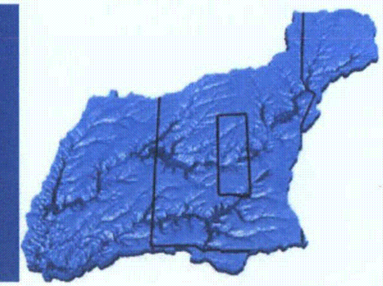
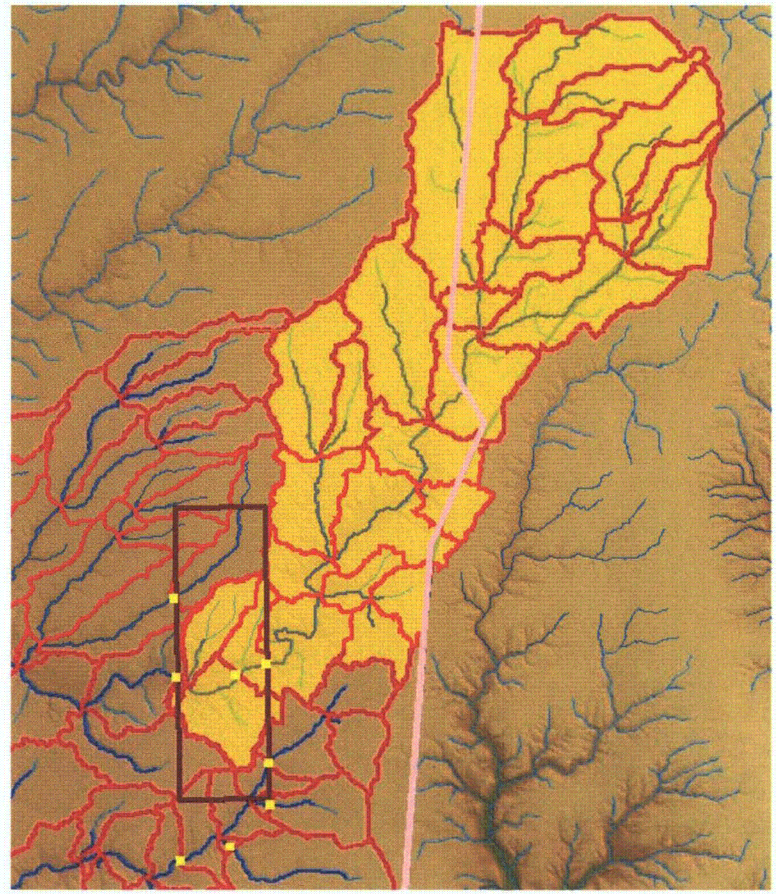
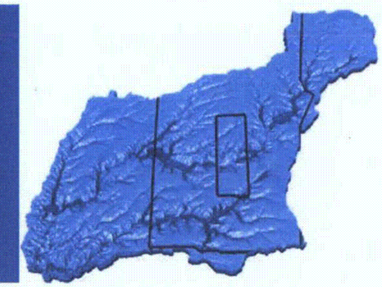
Surface Water Calibration - Flow



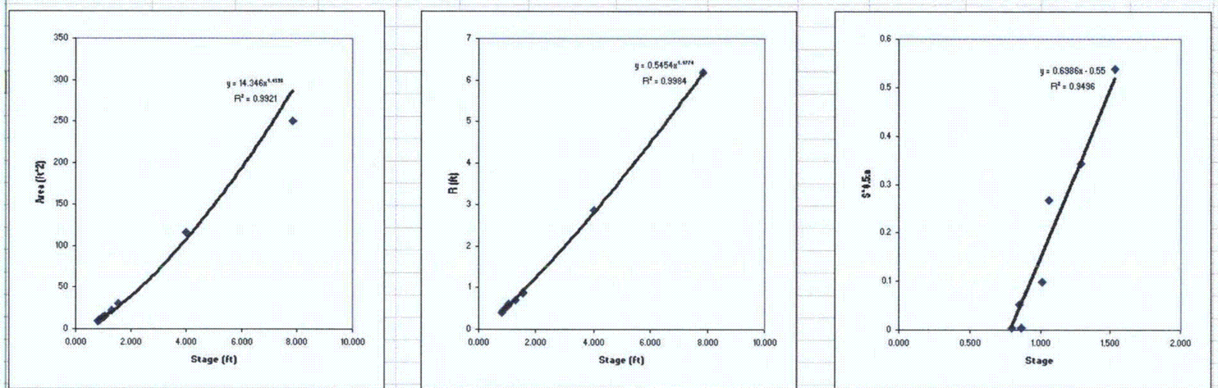
- Big Creek
  - Sub-model consisting of 29 catchments
  - Can be calibrated to 3 continuous stream gauges (pressure transducers.)
  - Calibration runs are ongoing

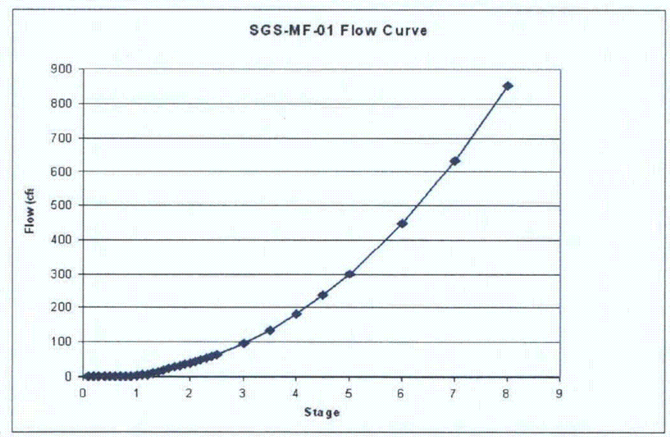


Flow Calibration



Q=1.49*(14.346*D^1.4536)*(0.5454*D^1.1774)^(2/3)*(0.6986*D-0.55)





- Physical measurements used to construct a flow curve to calculate flows based on stage measurements from transducers at stream gauges

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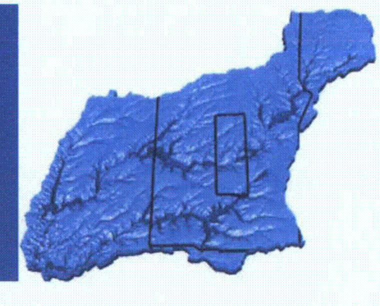
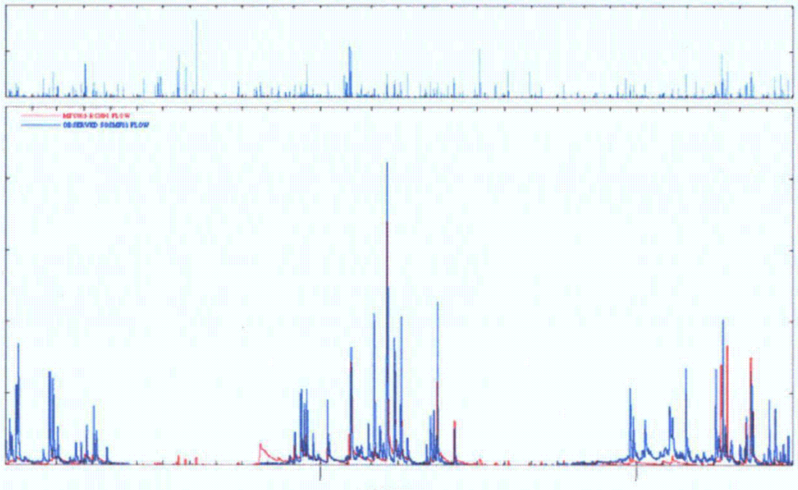
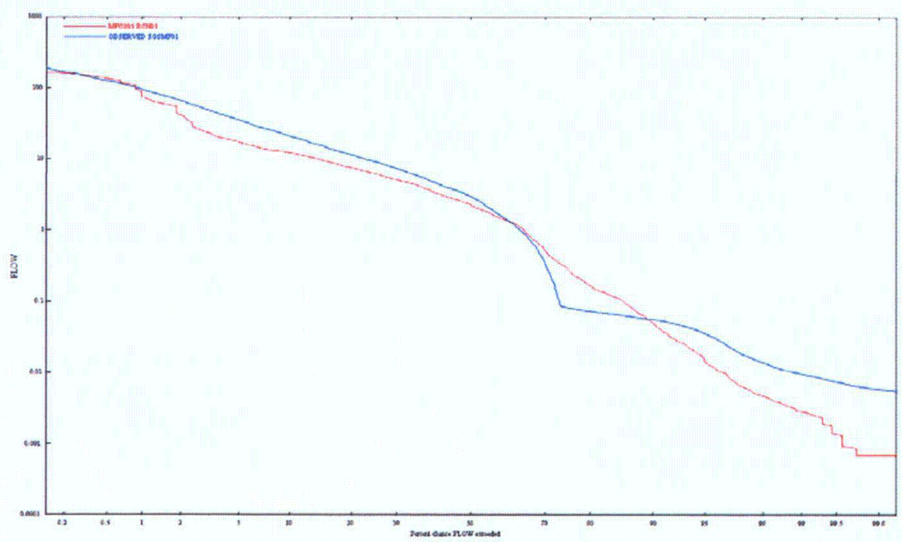
Preliminary Flow Calibration Results
Middle Fork Creek

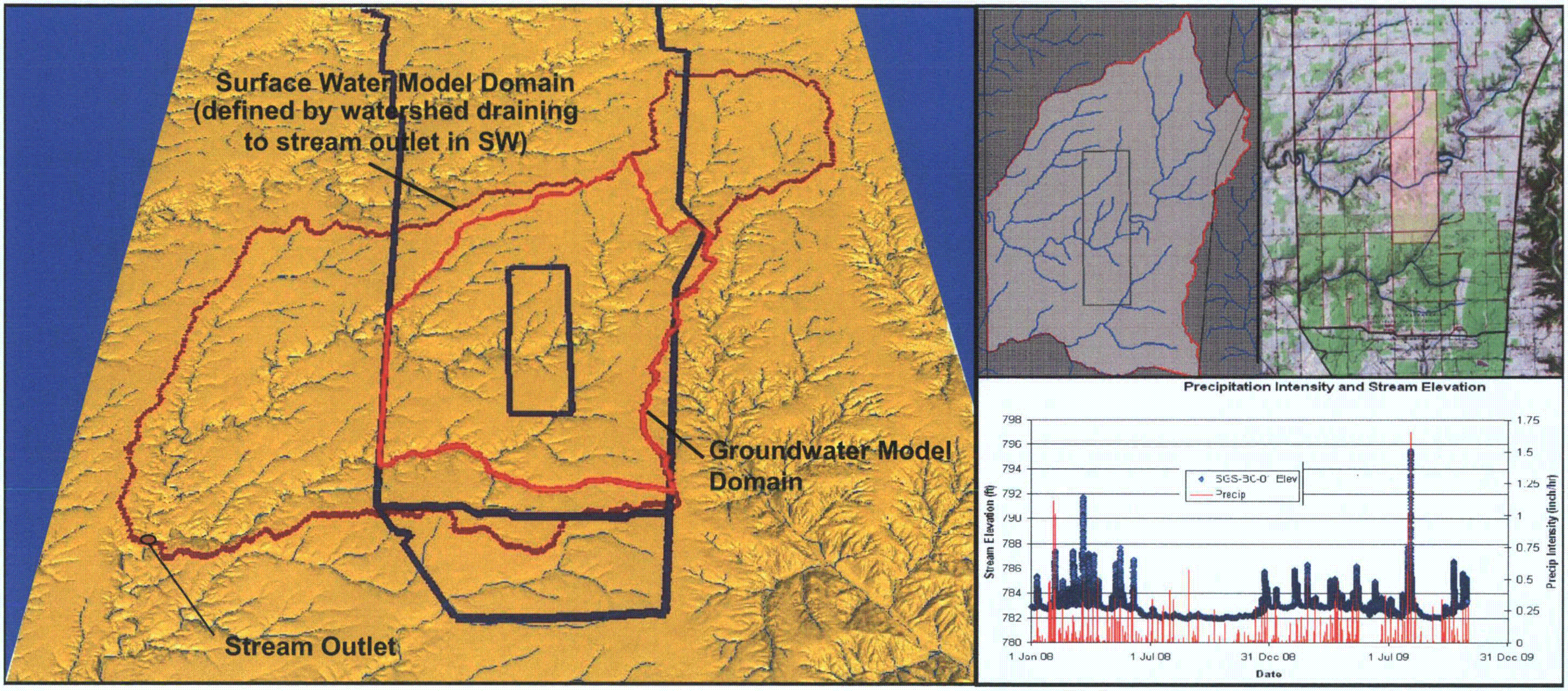




- Preliminary model output for Middle Fork Creek Calibration runs.
- Precipitation shown on top graph
- Modeled flow (red) and observed flow (blue) on bottom graph
  - Good peak matches (timing and magnitude)
  - Low flow results in winter appear to be under-predicted

- Preliminary results for flow duration (logarithmic scale).
- Peak values match well; additional calibration is needed at lower flows
  - One source of error could be in converting observed stream stage to flows, especially at the lower stages (more observed relative error)





JPG Groundwater Water Modeling

Model Setup and Initial Calibration Efforts

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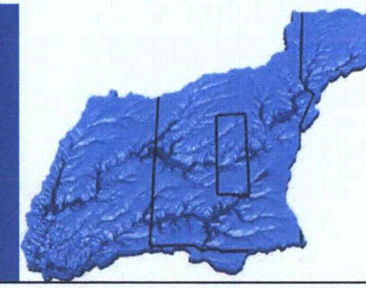
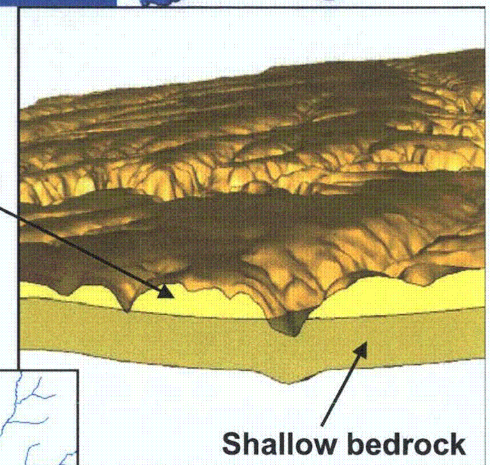
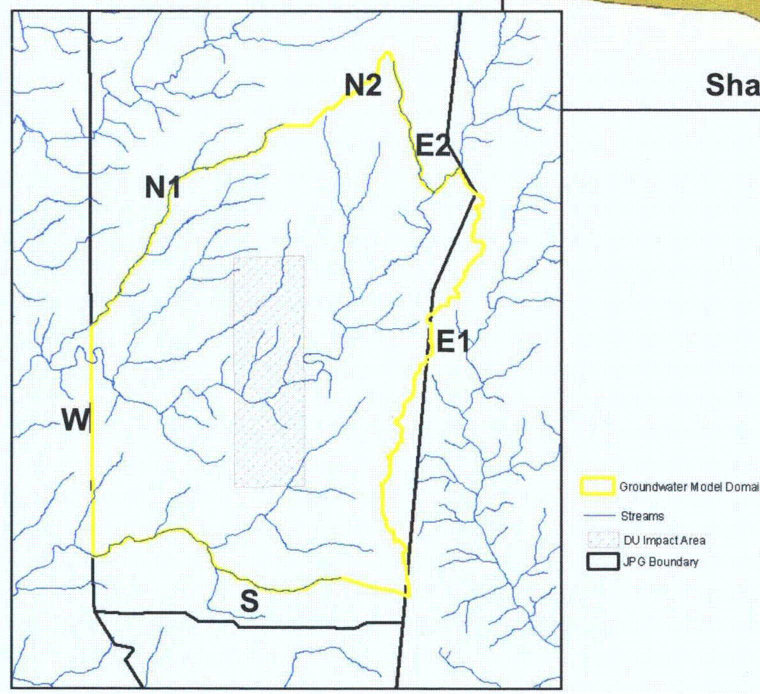
Groundwater Model Task 2: Calibration Domain and Discretization



- Two Layer Model
  - Overburden
  - Shallow (Weathered) Bedrock



- Lateral Model Boundaries
  - Eastern boundary follows watershed boundaries (E1) and a portion of Big Creek (E2)
  - Southern boundary is primarily on Middle Fork Creek (S)
  - Western boundary lies at JPG boundary
  - Northern boundary lies on a combination of a tributaries to Big Creek (N1) and a portion following a watershed boundary (N2)



- Discretization
  - Currently set up with uniform 100ft by 100ft grid spacing
  - Grid refinement is expected in the area of contamination

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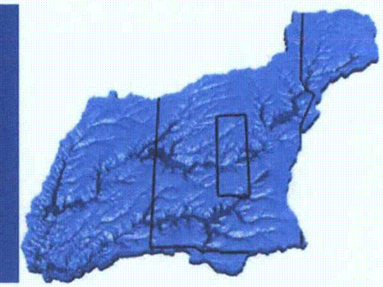
Next Steps



- Questions/Key Issues
- For Next Meeting:
  - Surface Water Flow
    - Big Creek Flow Calibration
  - Groundwater Flow
    - Column Modeling Results
    - Flow Model Setup and Calibration

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