Learning Unit Curriculum Support Document

Analysis of Potential Flood Elevations and Economic Losses in the Event of a Catastrophic Dam Breach, Using GIS and ENVI, with an Introduction to HAZUS-MH

Focus Topic
Disaster Management

Problem Statement
Whether Geographic Information Systems (GIS) and Remote Sensing (RS) can analyze potential flood elevations and economic losses in the event of a catastrophic failure of a large, multipurpose dam for a specific community and the surrounding area.

Description/Overview
The community of Williston, North Dakota is located on the Missouri River, between two large, multi-purpose dams, Fort Peck Dam located upstream near Fort Peck, Montana, and Garrison Dam located downstream near Garrison, ND.

Local city and county officials have requested an analysis of potential flood elevations and economic losses for the city of Williston, ND, in the event of a catastrophic dam breach of the upstream Fort Peck Dam. Objective: To demonstrate the use of Geographic Information Systems (GIS), ENVI Remote Sensing, and HAZUS-MH technology to assess potential risks for flood inundation in the event of a catastrophic dam breech and assist city officials with their disaster management planning.

Dams and their reservoirs provide important benefits such as water storage during times of drought, assist with flood control, hydroelectric production, irrigation projects, navigation, recreation, etc. However, along with those benefits, dams pose serious risk for the downstream river basin, agricultural land, historical sites, ecological habitat and communities should the dam fail. Dam failures happen. Whether caused by natural forces or terrorist attack, catastrophic events are a great concern in terms of community preparedness and response.

Skill Level
GIS: Intermediate; Remote Sensing: Intermediate

Outline of Content

Week 1

- PreQuiz
- Lecture
  - Focus Topic
  - Overview and Objective
  - Study Project Area
  - Brief Historical Background
  - Student Outcomes
  - Student Evaluations
  - Introduction to Topics of Research
  - Assign Student 'Teams', Topics and Due Dates
- Lab Begin Study Project (much of this lab consists of reading or examining of data)
  - Important Notes
  - Preparations Prior to Analysis of Data
  - Download Data and Make Copy
  - Make Direct Connection to Study Project
  - Become Familiar with File Structure
  - Examine Project Subfolders
  - Set ArcMap Document Properties
  - Set Options and Output Variables and Rules
  - Create Base Maps
  - Examine FEMA Flood Maps and Data

Week 2

- Lecture
  - Student 'team' presentation #1 and class discussion,
  - Any additional information instructor can add to student presentations,
- Lab: Instructor demonstrates GIS and ENVI skills used this week.
  - Create 1891 ft Flood Elevation Polygon
  - Begin GIS Analysis of Flood Inundation
  - Determine Flooded Areas
  - Emergency Services Availability
  - Possible Evacuation Routes
  - Possible Evacuation Shelters
  - Safety of Critical Facilities
  - Hazardous Sites/Structures
  - High Risk Groups
  - Use Census Data to Analyze Population Demographics

Week 3

- Lecture
  - Student 'team' presentation #2 and class discussion,
  - Any additional information instructor can add to student presentations,
- Lab: Instructor demonstrates GIS and ENVI skills used this week.
  - Use City Parcels to Analyze Market of Flood Property
  - Use Extrusion Too to Visualize Market Value in 3D
  - Additional 3D Analysis of Study Project

Use CLU data to Calculate Acres of Flooded Ag Land
Analyze Land Use Land Cover of Flooded Area
Isolate Flooded LULC using Extract by Mask tool
Locate NLCD2001 data on Internet and print classification definitions
Adding LULC definitions to attributes table
Reclassifying LULC data
Determine percentage of flooded LULC types
Determine frequency of distribution of each LULC type
Create graphs and reports

Week 4

Lecture

Student 'team' presentation #3 and class discussion,
Any additional information instructor can add to student presentations,

Lab: Instructor demonstrates GIS and ENVI skills used this week.

Use ArcToolbox Tools to analyze Williston Study Project
Determine percentage of LULC types
Determine frequency of distribution of each LULC type
Create graphs and reports
Compare to Extract by Mask Tool results
Download and unzip Landsat-7 Imagery from Internet
Open ENVI and Load Bands
Create grayscale and color satellite images
Use Layer Stacking and re-name bands
Link Images
Use Pixel Locator
Use Cursor Location/Value Tool
Use Display Information Window
Use Window Finder

Week 5

Lecture

Student 'team' presentation #4 and class discussion,
Any additional information instructor can add to student presentations,

Lab: Instructor demonstrates GIS and ENVI skills used this week.

Save Satellite Imagery as TIFF/GeoTIFF
Subset Satellite Image
Import and Overlay Satellite Imagery with Vector Data
Re-project Satellite Imagery
Perform Unsupervised Classification on Satellite Imagery
Use Post Classification Tools
Preparations prior to using ENVI Zoom Extraction Tool

Week 6

Lecture

Student 'team' presentation #5 and class discussion,
Any additional information instructor can add to student presentations,

Lab: Instructor demonstrates GIS and ENVI skills used this week.

ENVI Zoom Feature Extraction Tool

Using ENVI QuickMap
Optional ENVI procedures and tools
Optional ArcGIS procedures and tools

Week 7

Lecture

Student 'team' presentation #6 and class discussion,
Any additional information instructor can add to student presentations,

Lab: Instructor demonstrates HAZUS-MH skills used this week.

Introduction to FEMA HAZUS-MH
Complete free HAZUS-MH online ESRI courses
Ground Truthing
Questions Following Successful Completion
Students Begin Creating Portfolio of their Study Project Maps
Optional Challenge Activity

Week 8

Lecture

Student 'team' presentation #7 and class discussion,
Any additional information instructor can add to student presentations,

Lab: Instructor demonstrates GIS and ENVI skills used this week.

Students finish Study Project
Students Create Portfolio of their Study Project Maps
Student Collaboration to Prepare Presentation for city officials

Timeline

The focus of this study project is a catastrophic breach of a specific dam and the impacts that would have on a specific community. Data (or directions where to find necessary data on the Internet) is provided. This study project was written at the request of city and county officials. The study project is long and involves many steps to insure it included as many areas of concern as possible for that community's flood study analysis. It is intended to not only to be a GIS and Remote Sensing learning experience for students, but also a guide to help other communities analyze their potential risks for a catastrophic dam breach event.

The complete study project is long, 159 pages, and will require many hours for students to complete. The first 60% of the study project consists of ArcGIS exercises and the last 40% of ENVI remote sensing exercises. It was written to be completed in eight weeks, using a combination of brief lectures, student out-of-class research, hands-on geospatial labs, student collaboration and 'team' presentations, and class discussion.
Because class time varies at each institution and level (high school, college, etc.) and student skill level varies, it may take your students more time than eight weeks. Some instructors may feel the length of this study project would work best, completed over an entire semester.

The study project was written to be completed as written with Chapters 1-26 in order, as data and maps from earlier chapters may be needed for later chapter analysis. Options:

1) Divide the study project into smaller subunits: Chapters 1-8, and 21 use ArcGIS, Chapters 9-20 use ENVI, and Chapters 22-26 involve ground truthing, final essay questions, challenge activity and final presentation by students. Either of the GIS or

ENVI subunits could be omitted or the two could be reversed, followed by the final chapters 22-26.

2) Divide the study project into two sections 1) ArcGIS, and 2) ENVI with students completing the GIS exercises during one semester and the ENVI exercises during a later semester.
3) Select only specific chapters or steps. A Table of Contents is located at the end of both the Student Guide and this Instructor Guide. Review the contents and use only those chapters or parts of chapters of interest.
4) If you wish to use the entire study project but time runs short, Chapter 3, Creating Base Maps, is a review of GIS spatial analyst skills and could be briefly reviewed or omitted.
5) For those students who fly through GIS exercises and want additional challenges, Chapters 20 and 21 provide optional ENVI and GIS procedures and tools not used in the study project and could be used for extra credit.

Testing of this study project will be completed during the spring 2009 semester and adjustments in the time line will be made to the iGETT posting of the study project if testing determines it is needed. Instructors who use this study guide are encouraged to contact the author with suggestions and comments. This project will be used as a community service project by the spring 2009 GIS students and the final presentation to local officials is planned during the end of that semester.

List of Possible Disciplines or Existing Courses where LU may be included:

- Math/Science Dept
- Applied Sciences (Nursing, PT, Massage Therapy because of human health and emergency response issues related to catastrophic flood events)
- Geography/History Dept
- Agriculture Dept
- GIS and Remote Sensing

Entrance Skills and Competencies

The LU is targeted for students with current knowledge of GIS concepts and software. It is for use in a remote sensing course, or at the end of an intermediate course in GIS.

Pre-requisite skills:

- Basic PC skills using Windows, MS Office and applications (PPT)
- Intermediate ArcGIS
- Basic to intermediate ENVI knowledge
- Basic understanding of principles of remote sensing
- Basic mapping and projection
- File management
- Internet searching skills and file downloading
- Basic collaboration skills to work in teams
- Basic communication skills to present results

Course Materials and Resources

Learning unit support resources

Hardware

- Computer with sufficient RAM and storage space for data, software and image calculations
- Hardcopy output with printer or plotter (color is preferred)

Software

- MS Office suite: Excel, Word, PowerPoint
- ArcGIS 9.2 with Spatial and 3D Analyst Extensions
- ENVI 4.4

Data

- Access to Internet and capacity to download Landsat-7 image and DEM
- Ability to disseminate data to individual lab stations (CD burner, common network drive, USB drive)
- 2005 satellite image, free Internet download after February 2008
- DEM, free Internet download
- HAZUS-MH3 (v1.3 or newer) software, available free from FEMA, www.fema.gov

Learning Objectives

This learning unit will apply ArcGIS, ENVI and HAZUS-MH3 tools to analyze satellite imagery, DEMs and vector data to understand the impacts of a catastrophic dam breech for the city of Williston, ND.

- Understand basic causes of dam failure
- Understand potential risks that may exist for communities located below a dam
- Use GIS and RS (including raster and vector analysis) to analyze potential downstream risks for flood inundation for a specific location.
- Create 2-D and 3-D animations and maps of analysis results
- Optional – work in teams and develop critical thinking skills to determine data needs and analytic processes for dam breech risks at a different location.
- Use oral and written communication skills to present data in a clear and concise manner to local government officials

Student Outcomes

At the end of this learning unit, the student should be able to

- Understand basic causes and the potential risks of dam failures;
- Examine digital data structure and metadata for the Dam_Breach project;
- Examine FEMA Flood Insurance Rate Maps (FIRM) and create a 100-year/500-year flood map for the study area;
- Examine federal estimates for peak flood elevations and arrival times in the event of a catastrophic breach of the Fort Peck Dam;
- Learn how to find, download and use remote sensing and vector data in ENVI and ArcGIS and perform the following:
    - Create flood elevation contour lines using a DEM, close flood contour lines and convert to a polygon;

    - Learn how to find and use U.S. Census data and analyze location of housing units and high-risk populations within the flood elevations;
    - Analyze location of emergency facilities, safety of critical facilities, location of hazardous/toxic sites, possible evacuation routes and shelters, etc. within the flood elevation;
    - Learn how to find and use municipal parcel data to determine market value of property within the flood elevation;
    - Learn how to find and analyze land use land cover data for the study area;
    - Learn how to find and use CLU (common land unit) data to determine market value of agricultural land within the flood elevation;
- Use 3D and Spatial Analyst in their analyses of geospatial data;
- Learn where to order and how to use the FEMA HAZUS-MH Flood software program, and how it can help analyze social and economic losses resulting from disasters;
- Work in teams to develop critical thinking skills;
- Develop reports, charts, and PowerPoint presentations;
- Use oral and written communication to present what they learned to local elected public officials, disaster management officials, local law enforcement agencies, state health officials.

National Geography Standards That Correlate to the Study Project

1. How to Use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective
3. How to analyze the spatial organization of people, places, and environment
14. How human actions modify the physical environment
15. How physical systems affect human systems
18. How to apply geography to interpret the present and plan for the future

National Education Technology Standards (NETS) and Performance Indicators for Students

1. Creativity and Innovation. Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students:
    a. apply existing knowledge to generate new ideas, products, or processes.
2. Communication and Collaboration. Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students:
    b. communicate information and ideas effectively to multiple audiences using a variety of media and formats.
3. Research and Information Fluency. Students apply digital tools to gather, evaluate, and use information.

Students:

b. locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.

4. Critical Thinking, Problem Solving, and Decision Making. Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.
   Students:
   c. collect and analyze data to identify solutions and/or make informed decisions.
5. Digital Citizenship. Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.
   Students:
   a. advocate and practice safe, legal, and responsible use of information and technology.
6. Technology Operations and Concepts. Students demonstrate a sound understanding of technology concepts, systems, and operations.
   Students:
   a. understand and use technology systems.

Science, Technology, Engineering, Mathematics (STEM) or Other National K-12 Standards

- Scientific literacy: Understand economic and environmental impact of catastrophic dam breech,
- Technology literacy: Understand and use GIS and remote sensing technology, remote sensing data, data storage, overlaying and other analyses tools to create maps for better visualization of flood inundation due to a catastrophic dam breech,

Mathematical literacy: Ability to analyze, reason, and communicate ideas effectively to pose, formulate, evaluate potential losses from catastrophic dam breeching and resulting flood inundation.

Brief Description of the Methods

- Short introductory lectures by Instructor.
- Student 'team' presentations on assigned topics with instructor adding as needed.
- Brief instructor-led software demonstrations.
- Hands on ArcGIS software labs. Most data is provided, but students are expected to practice download and saving data to their computer. Students will be provided with a Study Guide.
- Students will be required to work in teams to present what they learn to local city officials.
- Optional: Complete this LU to another geographical site.

Method of Evaluation of Student Mastery

- Short pre-quiz to assess student knowledge of Missouri River history, Pick-Sloan Plan, construction of dams, remote sensing and its applications to the problem. Questions will target general history, economic impact of dams and dam breeches.

- Students will be required to answer milestone questions as they progress through the lab. Study guides will be provided to guide the student learning of concepts.
- Generate GIS maps:
  - Part – 2 to demonstrate flood inundation in the event of a dam breech.
  - Instructor grading of maps generated by the analyses.
- Optional – Instructor grading of presentation on independent student project.

Contact Information for Questions Related to the Learning Unit

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