Geographic Information Systems & Critical Infrastructure Protection

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CT 8330: Critical Infrastructure Protection (CIP)
Technological Leadership Institute, University of Minnesota

Session on Geographic Information Systems & CIP


Tu, October 18th, 2022, Alumni Center Rm 235
Tu, October 26th, 2021, Alumni Center Rm 235
Th., Sept. 24th, 2020, [https://umn.zoom.us/my/tli.msst](https://umn.zoom.us/my/tli.msst)
Tu, June 20th, 2019, Alumni Center Rm 235
Tu, June 19th, 2018, Alumni Center Rm 235
Tu, June 27th, 2017, Alumni Center Rm. 235
Tu, June 28th, 2016, Alumni Center Rm. 235
Tu. June 23rd, 2015, Alumni Center Rm.235
Tu. June 17th, 2014, Alumni Center Rm. 235
Tu. June 18th, 2013
Tu. June 19th, 2012
Fr. June 17th, 2011
Th. July 22nd, 2010
Introductions

- Round-table Introductions
  - Name, Affiliation
  - Background in GIS, GIS for CIP
  - Objective for session on GIS and CIP
Learning Objectives

We should be able to answer the following questions after this session:

1. What is a Geographic Information System (GIS)?
   - What are GIS Data-layers?
   - What are common GIS Operations? What are their inputs and outputs?
   - What are Geo-referencing systems? Data transfer standards?

2. How may GIS help?
   - Critical Infrastructure Protection (CIP)?
   - Emergency Management (EM)?
<table>
<thead>
<tr>
<th>Hour</th>
<th>Topics</th>
<th>Lecture</th>
<th>Exercise</th>
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<tr>
<td>0:00-0:30</td>
<td>Introductions</td>
<td>30 minutes</td>
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<tr>
<td>0:30-1:00</td>
<td>Motivation</td>
<td>9 slides, 15 minutes</td>
<td>15 minutes</td>
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<tr>
<td>1:00-1:30</td>
<td>GIS: Data, Standards</td>
<td>16 slides, 15 minutes</td>
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<tr>
<td>1:30-2:00</td>
<td>GIS: Analytic Tools</td>
<td>18 slides, 15 minutes</td>
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<td>2:00-2:15</td>
<td>Break</td>
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<td>15 minutes</td>
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<tr>
<td>2:15-2:45</td>
<td>GIS for CIP - I</td>
<td>13 slides, 15 minutes</td>
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<td>2:45-3:15</td>
<td>GIS for CIP - II</td>
<td>10 slides, 15 minutes</td>
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<tr>
<td>3:15-3:30</td>
<td>Case Study</td>
<td>6 slides, 10 minutes</td>
<td>Video (5-min)</td>
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<tr>
<td>3:30-3:45</td>
<td>Wrap-up</td>
<td>2 slides (5 minutes)</td>
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Outline

- Motivation
  - GIS & London Cholera (1854)
  - GIS & WTC (2001)
  - GIS & DHS/CIP
- Basics of GIS
- How can GIS help CIP?
- Case Study
- Next
1854 London Cholera

1854: What causes Cholera?

Collect & Curate Data

Discover Patterns, Generate Hypothesis

? water pump

Test Hypothesis (Experiments)

Remove pump handle

Develop Theory

Germ Theory

Impact on cities & infrastructure:
Health & well-being, parks,
Separate drinking & waste water
sewage system,
drinking water supply, …

Q? What are Choleras of today?
cancer, crime, accidents, …

Q? How may GIS help?
GIS and COVID-19

Sources:
(a) Coronavirus World Map: Tracking the Global Outbreak, nytimes.com, updated on Oct. 18, 2022

- Forecast hospital impact
- SIR Model simulation
- social distancing => later peak

Another recent use-case

Motivation:
- Reduce delays
- Example: Tornado outbreak (2012)

Approach:
- Monitor Tweets
- Filter on disaster keywords
- Color maps by keyword frequency

Even before cable news outlets began reporting the tornadoes that ripped through Texas on Tuesday, a map of the state began blinking red on a screen in the Red Cross' new social media monitoring center, alerting weather watchers that something was happening in the hard-hit area. (AP)

A tornado moves through the Dallas-Fort Worth area on Tuesday, April 3, 2012 in this still image taken from video. (Reuters TV/Reuters)
GIS & World Trade Center

- NYC GIS center destroyed
- CUNY supported firefighters, rescue workers, utility crews
- 50+ GIS professionals for 2+ months

Source: Sean C. Ahern, Hunter College - CUNY
World Trade Center Area
USGS/NASA/JPL

Core Zone: orange/red areas are thermal hot spots
Sept. 16, 2001 mid-day
Example DHS Scenario & GIS

- Preparation of response to attacks
- Help public officials to make important decisions
- Guide affected population to safety
- Ex. Chemical Leak

PLANNING SCENARIOS
Executive Summaries

Created for Use in National, Federal, State, and Local Homeland Security Preparedness Activities

The Homeland Security Council
David Howe, Senior Director for Response and Planning

July 2004

Images from www.fortune.com
NIMS & GIS

- Concepts and Principles
  - A Common Operational Picture accessible across agencies
- Interoperability Standards
  - Geospatial Information (item 4)

Hurricane Isaac monitoring @ Mississippi State Emergency Operations Center,
(Source: The Role of the EOC: Special Operations, B. Moeller, 1/31/2014,
DHS & GIS

  - 6 Missions: Intelligence/Warning, Protect Key Infrastructure, ...
  - 4 Foundations: Information Sharing and Systems, Law, ...

  - National Planning Scenarios
  - Universal Task List (UTL), Target Capability List (TCL)
  - National Response Plan

- National Incident Management System (NIMS), 2004
  - Incident Command System
  - Common Operational Picture
Role of GIS in Critical Infrastructure Protection

- **Determine Risk**
  - *Types of Crisis Faced by location*

- **Track event progression**
  - Ex.: [2004 Tsunami Video](https://www.youtube.com/watch?v=8-F_pSCzpaA)
  - Situation Awareness,
  - Common Operational Picture (NIMS 2004)

- **(Nearby) Resource Availability**
  - Hospitals near I-35W bridge collapse
  - Fire-stations, Shelters, Roads, …

- **Geospatial Infrastructure Interdependency**
  - WTC debris damaged Water Main & Telecom
  - Water flooded Train tunnels
  - Telecom outage halted Stock Trading, …
**Active Learning Exercise**

- **Learning Objectives:** What is a Geographic Information System (GIS)?

- **Activity:** Review the following document:
  

- Answer the following questions using the congressional report:
  
1. Provide a definition of GIS based on this report.
2. Name two GIS applications used in daily lives of millions of people.
3. The report lists examples of why and how geospatial information is used. Which two examples are relevant to Emergency Management?
4. Name two CIP related federal agencies, which are members of Federal Geographic Data Committee.
Active Learning Exercise (Extra)

- **Learning Objectives:** What is a Geographic Information System (GIS)?


- Answer the following questions using the above paper:
  1. Name a few transformative spatial computing ideas beyond GIS.
  2. List a few recent changes in the field of Spatial Computing.
  3. List a short opportunity, which may help in CIP or Emergency Management.
Outline

- Motivation
- **GIS: An Overview**
  - Basics of GIS
  - Transfer Standards
  - Analytical Tools
- How can GIS help CIP ?
- Case Study
- Next
Defining GIS

Sample definitions

- “… a computer data system capable of capturing, storing, analyzing, and displaying geographically referenced information—information attached to a location, such as latitude and longitude, or street location” (USGS.gov)
- “… It allows you to analyze data visually and see patterns, trends, and relationships that might not be visible in tabular or written form.” (EPA.gov)

Key: Spatial data are unique because they are linked to maps (location matters!)

A GIS at least consists of

- a database
- map information
- a link between them

Source: www.epa.gov/region5fields/gis.html
What’s special about spatial?

- Everything happens in geographic space
- A map shows phenomena as a function location & time
- Geographical relations, e.g., distance
  - Powerful search and query
- Tobler’s law
- Basics
  - Coordinate Systems, e.g., latitude, longitude
  - Spatial Data Genres, e.g., raster, vector
Geographic Mistakes - Coordinate Systems

- Q. What is wrong with circular ranges of missiles (left bottom map)?
- Correction: North Korea’s missiles (www.economist.com/node/1788311)
Basics I: Coordinate Systems

- Coordinate systems
  - Codes locations as numbers
  - Ex.: (East-ing, North-ing), (latitude, longitude)

- Taxonomy
  - Relative, e.g., units of map’s paper sheet
  - Absolute
    - Geographic: Latitude, longitude, elevation
    - Projected: Mercator, military grid, state plane

- Coordinate Systems matter in:
  - Map Comparison
  - Distance, area, or direction over large areas
  - Video (https://www.youtube.com/watch?v=kIId5FDi2JQ)
Alternative georeferencing

- **Symbolic Geo-referencing**
  - Place names (e.g., Dinkytown, Eyjafjallajökull,)
  - Street address (200 Union St. SE, MN 55455)
  - Internet URLs

- **Geo-code symbolic to numerical geo-reference**
  - Ex.: street address to latitude-longitude on map
  - Reverse Geo-code: GPS reading to place-name

- **A GIS package should be able to move between**
  - map projections
  - coordinate systems
  - datums, and Ellipsoids
  - And do geocoding
Quiz: Coordinate Systems

1. Which is preferred by privacy advocates for contact-tracing apps?
   A. Absolute position, e.g., (latitude, longitude)
   B. Relative position, e.g., distance between two smartphones

2. Which positioning systems provides Relative position?
   A. Global Positioning System (GPS)
   B. Bluetooth
   C. Wi-fi based indoor positioning

3. Which absolute coordinate system is used by Google Maps?
   A. Geographic: (Latitude, longitude, elevation)
   B. Projected: Mercator (or webMercator), military grid, state plane

4. Which model of Earth is used by GPS?
   A. Sphere
   B. Ellipse
   C. Geoid

5. Which model of Earth is used for water flow models?
   A. Sphere
   B. Ellipse
   C. Geoid
Basics II: Spatial Data-Genres

- **Raster**: geo-images e.g., Google Earth
- **Vector**: point, line, polygons
- **Graph**: e.g., roadmap: node, edge, path
- **Others**: Terrain, Spatio-temporal, …

Raster Data for UMN Campus
Courtesy: UMN

Graph Data for UMN Campus
Courtesy: Bing

Vector Data for UMN Campus
Courtesy: MapQuest
Raster Representation as fields

- Space divided into regular grid
  - Pixel = Cell of the grid
  - Each pixel assigned a gray value to represent local intensity
  - Resolution = pixel size
- Issues:
  - Approximation
  - Mixed pixels
  - Drop out
  - Interpolation
  - Multi-resolution
Geometry: Arc/node data structure

- **Primitives:** Node, Arc, Area
- **Constraints:** Topology Matters
  - Some GIS operations may be performed without accessing the point files.
  - Example: Is USA a neighbor of Canada?
3D Terrain Models, e.g., Elevation

- **Raster Representation**
  - Regularly Spaced **Grid**, e.g., 50m to 500m
  - Pixel value represents local elevation

- **Vector Representations**
  - Triangulated Irregular Networks (**TIN**)  
    - use optimal Delaunay triangulation of a set of irregularly distributed points.
  - Contours

Source for 5 pictures: SpatialSys.com
Terrain Analysis-2

- Terrain analysis: Slope/aspect, catchment, drainage, Floods

![Diagram showing DEM, Flow path, Flow direction, and Flow accumulation matrices]
4D: Adding Time to GIS

- The missing $t$ in $(x, y, z, t)$
- Much interest in spatio-temporal dynamics, models
  - GPS trajectories
  - Seasonal variation
- Only a few methods as yet, still research
- Spatial modeling tools in few GIS, e.g. CA in IDRISI
- Transaction-based problem solved in 2D e.g. Oracle Spatial

Source:
http://upload.wikimedia.org/wikipedia/commons/1/12/2004_Indonesia_Tsunami_100px.gif
Quiz

Background: distance(Washington D.C., USA) = 0 is zero, as USA contains Washington DC.

Experiment:
1. Google Search on “distance between Washington DC and USA”
2. Explain Google search result by answering the following question:

Question: Which Geometric Data-Type is used by Google to Model USA?

A. Node, e.g., point
B. Arc, e.g., Line
C. Area, e.g., polygon
D. Terrain
GIS >> Google Maps

- Extended Geometry, e.g., Polygons
- Spatial Relationships
  - Ex. Topological, Metric, …
  - OGC Simple Features Standards
- Help feature selection for machine learning & modeling
  - Ex. Distance to key geographic features
  - Ex. Neighbor relationships
Large Constellations of Small Satellites

- Hi-frequency (e.g., daily or hourly) time-series of imagery of entire earth
  - Monitor illegal fishing, forest fires, crops (2017 DARPA Geospatial Cloud Analytics)
- Large Constellations
  - 2017: Planet Labs: 100 satellites: daily scan of Earth at 1m resolution in visible band

Cheap (or free) Geo-data on cloud computers

- 2008: USGS gave away 35-year Landsat satellite imagery archive
  - Analog of public availability of GPS signal in late 1980s
- 2017: Many cloud-based Virtual collaboration environment
  - Explosion in machine learning on satellite imagery to map crops, water, buildings, roads, …

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Google Earth Engines</th>
<th>NEX</th>
<th>AWS Earth</th>
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</thead>
<tbody>
<tr>
<td>Elevation, Landsat, LOCA, MODIS, NAIP</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>NOAA</td>
<td>X</td>
<td>Χ</td>
<td></td>
</tr>
<tr>
<td>AVHRR, FIA, GIMMM, GlobCover, NARR, TRIMM, Sentinel-1</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>IARPA, GDELT, MOGREPS, OpenStreetMap, Sentinel-2, SpaceNet</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>(building/road labels for ML)</td>
<td></td>
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<tr>
<td>CHIRPS, GeoScience Australia, GSMap, NASS, Oxford Map, PSDI, WHRC, WorldClim, WorldPop, WWF, BCCA, FLUXNET</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Outline

- Motivation
- **GIS: An Overview**
  - Basics of GIS
  - Transfer Standards
  - Analytical Tools
- How can GIS help CIP?
- Case Study
- Next
Data resources and Formats

Data Formats
- SHP, E00
- DXF
- GeoTIFF
- Img
- VPF
- DRG, DEM, DOQQ
- TIGER/SDTS

Data Sources
- MN Geospatial Commons
- NSDI clearinghouses
- Geospatial One Stop
- National Map
- GDT, ESRI etc.
- Geography network
- Alexandria www.alexandria.ucsb.edu

Look ahead at Exercise
- Review MN Geospatial Commons (https://gisdata.mn.gov/)
- What kinds of critical infrastructure are covered by these datasets?
  - Hint: Look under Resource tab
- Which data formats are used?
Approach: Interoperability via Standards

• SDTS
  • terminology, set of references, list of features, transfer mechanism, accuracy standard.
  • Includes DLG and TIGER data formats
  • FGDC – standards for metadata and selected feature (e.g., raster profile)
  • Other standards efforts are DIGEST, DX-90, the Tri-Service Spatial Data Standards, …

• OGC
  • Open GIS Consortium, Inc. ([www.opengis.org](http://www.opengis.org)) with 256 members worldwide
  • Develops standards, Test Compliance
  • Simple feature model, WCS, WML, Sensor ML…

• ISO TC 211
  • 19129 : GIS - Imagery, Gridded and Coverage Data
  • 19130 : GIS-Sensor data model

• Agreement between OGC and ISO
OGC Initiatives

- Open Geospatial Consortium (www.opengeospatial.org)
  - Standard cover many domains such as
    - Emergency Response & Disaster Management
    - Defense & Intelligence; IoT & Sensor Webs, the 3D & Built Environment, ...

- Recent
  - Disasters Resilience 2019 & GEOSS Architecture Implementation Pilot
  - Earth Observation Big Data Architecture and a planned Earth Observation Big Data Analytics Market Enablement Initiative

- Past
  - Critical Infrastructure Protection Initiative, Phase 1.2 (CIPI 1.2) In Progress
  - Emergency Mapping Symbology, Phase 1 (EMS 1) In Progress
  - Multihazard Mapping Initiative, Phase 1 (MMI -1)

- Ex. Dev. of Disaster Spatial Data Infrastructures for Disaster Res. (‘18)
  - Standards (Section 5.1.1, pp. 34-38)
  - Disaster management data requirements (Section 5.2, pp. 38-40)
  - Data Sources (Appendix A & B, pp. 54-63)
Active Learning Exercise

**Learning Objectives:** What are Geo-referencing systems? Data transfer standards?

**Activity 1:** Review [MN Geospatial Commons](https://gisdata.mn.gov/) > Resource tab
- Identify 3 data layers (and their data formats) for estimating CIP.
- What kinds of critical infrastructure are covered by these datasets?
- How up-to-date and complete are these datasets?
- Which data transfer standards are supported?


OMB Circular A-16 was issued to ensure that federal surveying and mapping activities met the needs of federal and state agencies and the general public and to avoid duplication of effort.

Name a federal GIS initiatives relevant to CIP and its contribution for data transfer standards.
Outline

- Motivation
- **GIS: An Overview**
  - Basics of GIS
  - Transfer Standards
  - Analytical Tools
- How can GIS help CIP?
- Case Studies
Analytic Tools and GIS

Functionality:
- Searches based on spatial relationships, e.g. distance
- Spatial Statistics
- Spatial Models, e.g. plume simulation
- Spatio-temporal

Example Tools
- ESRI ArcGIS, ArcView
- AutoCAD Map
- GRASS
- IDRISI (Clark University, Worcester, MA)
### GIS Analytical Functions: A Taxonomy

<table>
<thead>
<tr>
<th>GIS Analytical Functions</th>
<th>CIP Use Case Example</th>
</tr>
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<tbody>
<tr>
<td>1. Measure, e.g., distance, area</td>
<td>A. How far is a derailed train from tunnel entrance?</td>
</tr>
<tr>
<td>2a. Search, e.g., nearest neighbor</td>
<td>B. List hospitals closest to I-35W bridge</td>
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<tr>
<td>2b. Search, e.g., Thematic</td>
<td>C. How many people live in the path of a wildfire?</td>
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<tr>
<td>3. Location analysis, e.g., buffer</td>
<td>D. Secure areas within a mile of Super Bowl 2018</td>
</tr>
<tr>
<td>4. Terrain analysis, e.g., visibility</td>
<td>E. Which windows &amp; rooftops need to be secured to protect a presidential route?</td>
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<tr>
<td>5. Flow analysis, e.g., shortest path</td>
<td>F. Send ASAP ambulance from HCMC to I-35W bridge</td>
</tr>
<tr>
<td>6. Spatial Patterns, e.g., hotspots</td>
<td>G. Geographic concentrations of critical infrastructure</td>
</tr>
<tr>
<td>7. Create new maps</td>
<td>H. Common Operational Picture, e.g., track first responder locations</td>
</tr>
</tbody>
</table>
1. **Measurements**, e.g., **Distance**, perimeter, adjacency, direction

1. **A.** How far is a derailed train from tunnel entrance?
   - Ex.: Open [Google Maps](https://www.google.com/maps) (not in Lite mode)
   - Right-click on starting point. Choose **Measure distance**.
   - Click anywhere on map to create a path to measure.

![Google Maps screenshot showing distance measurement](image-url)
2. Search

- Search:
  - Thematic search, e.g., people in path of a fire
  - Search by region or proximity

2. Search : CIP Example

- Search :
  - Thematic search, e.g., people in path of a fire
  - Search by region or proximity

- CIP Example:
  - What is near a planned electric transmission line (red)?
  - Result: A gas pipeline (yellow) Source: (Abdalla 2010)
  - Mitigation: Protect gas line during construction
  Or relocate to avoid spatial interdependency
3. Location Analysis

- Location analysis: Buffer, corridor, overlay,
  - Ex. My location => Area with a specific distance (ArcGIS)
  - Use Case: Secure areas within a mile of Super Bowl 2018
- CIP Example: Circular Buffer around a Point location
  - Ex. 2: Source: (Abdalla 2010)
    - Defective (yellow) power station (Point location) => outage area (circle)
    - Affects backup (red) communication line between data centers
    - Mitigation: Establish alternative communication
3. Location Analysis

- Location analysis: Buffer, corridor, overlay,

- Ex.: South Portland's City Council on 3/22/2016 approved a buffer between important public facilities and liquefied natural gas distribution plants. The buffers are shown on the map as light blue shaded circles around important public facilities. [Courtesy city of South Portland](#)
Q. Which GIS Analytical Function is illustrated below?

1. Measure, e.g., distance, area
2a. Search, e.g., nearest neighbor
2b. Search, e.g., Thematic
3. Location analysis, e.g., buffer

For example, Cobb County, Georgia, a longtime, innovative user of GIS, added a web app to its ArcGIS Hub site dedicated to COVID-19 resources. It supplied up-to-date information on grocery inventories of essential items, special hours for at-risk people, how crowded stores were, and how well social distancing practices were being followed for area stores. Current data was fed into the app by crowdsourcing data from residents who used Survey123 for ArcGIS to fill out surveys on stores. A story map on the site contained information on area food pantries and government assistance.

4. Terrain Analysis: Visibility

- Terrain analysis: Visibility, Slope/aspect, catchment, drainage, Floods
4. Terrain Analysis

- Terrain analysis: Visibility, Slope/aspect, catchment, drainage, Floods
- CIP Example: Flood prediction using Terrain contours and predicted precipitation
  - Includes a transmission line powering a air traffic radio beacon
  - Mitigation: protect beacon by sandbags, backup generator at beacon
- Source: (Abdalla 2010)
Ex. Mixing Terrain Operations with Flow Analysis

**Goal:** Estimate accumulated water map, from Rainfall and elevation maps.

**Approach:** Elevation Map $\rightarrow$ Gradient Map $\rightarrow$ Water Flow $\rightarrow$ Flow Accumulation

**Assume:** Surface water flows down steepest slope (Gradient). No ground absorption.

1. Draw the gradient graph by adding directed edges along gradient (flow direction).
2. Compute map of accumulated water flow.
3. Which Terrain operation is relevant? Choices: Visibility, Slope/Aspect
4. Which graph operation is relevant? Choices: Transitive closure, shortest path

**Inputs:**

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Rainfall map

<table>
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<td>60</td>
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Elevation map

**Output:**

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Accumulated Flow
5. Flow Analysis

- Flow analysis: Connectivity, shortest path, travel-time map
- CIP Example: A flood shuts down a power substation (!)
  - serving an air traffic control (tower) and a chemical plant (triangle)
- Source: (Abdalla 2010)
## 5. Flow Analysis - 2

- **Flow analysis**
  - Connectivity
  - Shortest path
  - Travel-time map
  - Evacuation Route Selection

### Static

<table>
<thead>
<tr>
<th>Question</th>
<th>Time-Variant</th>
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<tbody>
<tr>
<td>Which is the shortest travel time path from downtown Minneapolis to airport?</td>
<td>Which is the shortest travel time path from downtown Minneapolis to airport at different times of a work day?</td>
</tr>
<tr>
<td>What is the capacity of Twin-Cities freeway network to evacuate downtown Minneapolis?</td>
<td>What is the capacity of Twin-Cities freeway network to evacuate downtown Minneapolis at different times in a work day?</td>
</tr>
</tbody>
</table>
**Quiz (GIS Analytical Functions & COVID-19)**

- **Q.** Which GIS Analytical Function is illustrated below?

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<tbody>
<tr>
<td>1.</td>
<td><strong>Measure</strong>, e.g., distance, area</td>
</tr>
<tr>
<td>2a.</td>
<td><strong>Search</strong>, e.g., nearest neighbor</td>
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</tr>
<tr>
<td>6.</td>
<td><strong>Spatial Patterns</strong>, e.g., hotspots</td>
</tr>
<tr>
<td>7.</td>
<td>Create new maps</td>
</tr>
</tbody>
</table>

---

6. Spatial Patterns: Hotspots

- Hotspot of a disease, disturbance, accidents,
- The 1854 Asiatic Cholera in London
  - Near Broad St. water pump except a brewery

![Map of Soho with cholera cases and SaTScan software advertisement](image-url)
6. Spatial Patterns: **Hotspots**

- **Hotspot of critical infrastructure** or facilities

  (Source: [Geographic Hotspots of Critical National Infrastructure](https://doi.org/10.1111/risa.13042), S. Thacker et al., Risk Analysis, 37(12):2490-2505, 2017.)

---

**Fig. 6.** (a) Kernel density estimated infrastructure asset spatial density (GSP, gas, telecoms, water, and water treatment assets). (b) Kernel density estimated infrastructure asset user demand (GSP, gas, telecoms, water, and water treatment assets).

---

**Fig. 4.** Stages in assigning users to assets. (a) Introduces a set of asset footprints. (b) Provides a view onto ward-level population data. (c) Represents the union of both the asset footprint and the bounded population data. (d) Gives user estimates transferred to asset footprints. (e-h) Provide user assignments, with user magnitude highlighted on a color scale derived for wastewater treatment works, gas off-take points, telecom masts, and water towers, respectively.
6. Spatial Patterns - continued

- Spatial Patterns
  - Spatial autocorrelation, Distribution Change detection, …
  - Hotspot, Colocation, …
- CIP Example:
6. Spatial Patterns – **Ring-Shaped Hotspot**

(a) Legionnaire’s in New York (2015)

(b) Output of SaTScan

(c) Output of RHD

<table>
<thead>
<tr>
<th>Id</th>
<th>Log LR</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.84</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>13.87</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>6.99</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Log LR = 34.55
p-value = 0.001

RHD Source: Ring-Shaped Hotspot Detection: A Summary of Results, IEEE Intl. Conf. on Data Mining, 2014 (w/ E. Eftelioglu et al.)
Spatiotemporal Forecast for Scenario Planning

- **Data-Driven Forecast**
  - Fit a curve to past data to project future values

- **Process-Driven Forecast**
  - Physical (process-based) model: calibrate with past data, then project future
  - Examples:
    - Plume simulation using gas/particle dispersion
    - Climate change projections
    - Flood projection using scenarios of weather etc.
**Quiz (GIS Analytical Functions & COVID-19)**

Q. Which GIS Analytical Function is illustrated below?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Measure</strong>, e.g., distance, area</td>
<td>4. <strong>Terrain analysis</strong>, e.g., visibility</td>
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</tr>
<tr>
<td>3. <strong>Location analysis</strong>, e.g., buffer</td>
<td>7. Create new maps</td>
</tr>
</tbody>
</table>

As the pandemic has unfolded, Esri has developed tools that incorporate mathematical models used by epidemiologists such as the COVID-19 Hospital Impact Model for Epidemics (CHIME) model. At the outset of the pandemic, Esri developed an implementation of CHIME for use in ArcGIS Pro that leverages Susceptible, Infected, Recovered (SIR) modeling and can be used to forecast the curve of the epidemic in terms of its impact on hospitals and visualize those impacts spatially.

Visualization of these inputs illustrates exactly what it means to flatten the curve. With greater social distancing, the peak comes later, lessening the burden on medical care providers and the healthcare system.

7. Create new Maps

- Create new maps: map visualization, map overlay, re-classification, ...
- CIP Example: No fly zones for UAVs
  - Overlays airports, military bases, national parks, temporary restrictions (e.g., events)
  - Another Example: Hurricane trajectory projection
7. Create new Maps: Global Crop Monitor

- Create new maps from remote sensing data
- Global Crop Monitor
7. Create new Maps

map visualization, map overlay, re-classification, ...

Hospitals, Water Tanks, Critical Dams, Fire/Police Stations, City EOC, Comm.

Telecom tower, Transportation, ...

Source: Nevada’s approach to CIP (publicintelligence.info/nevadasilvershield.pdf)
**Quiz (GIS Analytical Functions & COVID-19)**

**Q.** Which GIS Analytical Function is illustrated below?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td>1. <strong>Measure</strong>, e.g., distance, area</td>
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</tr>
<tr>
<td>3. <strong>Location analysis</strong>, e.g., buffer</td>
<td>7. <strong>Create new maps</strong></td>
</tr>
</tbody>
</table>

As the COVID-19 outbreak grew to an epidemic and fears of its metamorphosing into a pandemic began to be considered seriously, Johns Hopkins University (JHU) launched its COVID-19 dashboard. A team led by Lauren Gardner, an epidemiologist and

**Source:** GIS Systems Lead Response to COVID-19, [(pdf), (html)](ArcUser magazine, Sp. 2020).
# Active Learning Exercise

## Learning Objectives
- What are GIS Data-layers?
- What are common GIS Operations? What are their inputs and outputs?

## Learning Objectives: Why and how GIS is use in CIP?

## Activity: Match GIS Analytical Functions to CIP Use Case

<table>
<thead>
<tr>
<th>GIS Analytical Functions</th>
<th>CIP Use Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Measure, e.g., distance, area</td>
<td>A. Common Operational Picture, e.g., track first responder locations</td>
</tr>
<tr>
<td>2a. Search, e.g., nearest neighbor</td>
<td>B. Which windows &amp; rooftops need to be secured to protect a presidential route?</td>
</tr>
<tr>
<td>2b. Search, e.g., Thematic</td>
<td>C. How far is a derailed train from tunnel entrance?</td>
</tr>
<tr>
<td>3. Location analysis, e.g., buffer</td>
<td>D. Dispatch ambulance from HCMC to I-35W bridge</td>
</tr>
<tr>
<td>4. Terrain analysis, e.g., visibility</td>
<td>E. Geographic concentrations of critical infrastructure</td>
</tr>
<tr>
<td>5. Flow analysis, e.g., shortest path</td>
<td>F. List hospitals closest to I-35W bridge</td>
</tr>
<tr>
<td>6. Spatial Patterns, e.g., hotspots</td>
<td>G. How many people live in the path of a wildfire?</td>
</tr>
<tr>
<td>7. Create new maps</td>
<td>H. Secure areas within a mile of Super Bowl 2018</td>
</tr>
</tbody>
</table>
Active Learning Exercise

Learning Objectives
- What are GIS Data-layers?
- What are common GIS Operations? What are their inputs and outputs?

Learning Objectives: Why and how GIS is use in CIP?

Activity: Use Google Maps to find
- (a) Hospitals near I-35 bridge collapse incident
- (b) (straight line and driving) distance between MSP airport & University of Minnesota.

1. What are critical transportation infrastructures (CTI)? Provide two examples.
2. Review sample CTI disaster information needs (pp. 4). Which of these are geo-spatial?
3. What is remote sensing? How may it help assess infrastructure damage?
4. Match GIS benefits in disaster management (pp. 6) with GIS Analytic Tools, e.g., measurements, search, location analysis, terrain analysis, flow analysis, spatial patterns, …
Active Learning Exercise (Extra)

- **Learning Objectives**
  - What are GIS Data-layers?
  - What are common GIS Operations? What are their inputs and outputs?


(a) The attributes of different types of geospatial data - such as roads and bridges, buildings, lakes and rivers, counties - can each constitute a layer or theme in GIS. List three layers of geospatial information relevant to CIP.

(b) The power of GIS is the ability to combine geospatial information in unique ways - by layers or themes - and extract something new. List two possible use of such power in context of emergency management using specific GIS operations discussed in last slide.
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
  - Critical Infrastructure
  - Role of GIS in CIP
- Next
Critical Infrastructure

- **Infrastructure**: Basic physical and organizational structures and facilities
  - Ex. Buildings, Transportation (e.g., Roads), Water (e.g., Dams), Internet, Power, ...

- **Critical Infrastructure**: Extremely important to operation of civilized society
  - Patriot Act (2001): “systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters”

- Presidential Decision Directive 63 (Clinton 1998, pp. 1-2)
  Critical infrastructures are those physical and cyber-based systems essential to the minimum operations of the economy and government. They include, but are not limited to, telecommunications, energy, banking and finance, transportation, water systems and emergency services,

“The framework of **interdependent** networks and systems comprising identifiable industries, institutions and distribution capabilities that provide a **reliable** flow of products and services **essential to the defense and economic security** of the US, the smooth functioning of government at all levels, and society as a whole.” - President's Commission on Critical Infrastructure Protection, Critical Foundations Protecting America's Infrastructure, 1997
Critical Infrastructure (CI) Types


- Chemical
- Commercial facilities
- Communications
- Critical manufacturing
- Dams
- Defense industrial base
- Emergency services
- Energy
- Financial services
- Food and agriculture
- Government facilities
- Healthcare and public health
- Information technology
- Nuclear reactors, materials, and waste
- Transportation systems
- Water and wastewater systems

Q? Which CIs are geo-spatial?

Q? Is GPS (positioning) CI?
Which category may cover it?
Quiz on Critical Infrastructure (CI) Types

Q? Which are not identified among 16 CIP types listed in previous slide?
Positioning (e.g., GPS) is a Critical Infrastructure Today!

- 2 billion GPS receivers in use, will hit 7 billion by 2022.
- Besides location, it reference time for many critical infrastructure
  - Telecommunications industry
  - Banks
  - Airlines...
- GPS is the single point of failure for the entire modern economy.
- 50,000 incidents of deliberate (GPS) jamming last two years
  - Against Ubers, Waymo’s self-driving cars, delivery drones from Amazon

Why are CIs critical?

- Provide **basic support** for life, livelihood, and communities
- Disruption **affects all sectors**: businesses, households, other CIs
- CIs are vulnerable to physical damage in **disasters**
  - 1993 Midwest Floods, 1994 Northridge Earthquake, 2003 Northeast Blackout,
Economic impacts

- **1993 Midwest floods**: Des Moines (IA) suffered more loss from infrastructure outage than from physical flooding.

- **1994 Northridge EQ** highway damage accounted for 27% (US$1.5 billion) of regional business loss.

- **1995 Kobe EQ**: massive failures of virtually all major infrastructures essentially lead to cessation of urban economic functions.

- **2003 Northeast blackout** estimated to have cost US$4.5~$10.0 billion in economic loss.

Highway bridge damage in Northridge earthquake (photo: EERI)
Household impacts

- Infrastructure outages can affect households in complex ways
  - Public safety dangers from utility loss and traffic delays for first responders
  - Infrastructure outage could force households to seek emergency shelter
  - Infrastructure loss may compound or even cause health problems and injuries
  - Business disruption may cause job loss or financial hardship; etc.

- Some socio-economic groups (e.g., elderly) are especially vulnerable

- One survey found that households gave highest priority in disaster policy to
  - Electric power
  - Water
  - Hospitals
Infrastructure Interdependencies

“bidirectional relationship between two infrastructures through which the state of each infrastructure influences or is correlated to the state of the other” (Rinaldi et al., 2001)

**Figure 1.1.** Interdependence among four lifelines in an urban setting. Four lifeline sectors—energy, water, transportation, and communications—are top priorities for strengthening resilience in all regions as they provide essential products and services that underpin the continued operation of nearly every sector.

Source: Partially inspired by Siemens Creating Resilient Cities.
Infrastructure Interdependencies

“bidirectional relationship between two infrastructures through which the state of each infrastructure influences or is correlated to the state of the other” (Rinaldi et al., 2001)
A Taxonomy of Infrastructure Interdependencies

- Geographic Interdependence due to proximity
  - Fires, Floods, Explosions affect geographic neighborhoods
  - Puerto Rico Hurricane Maria 2017: [Hurricane Maria damages Houses, Roads, Electric Grid, …](#)
  - Tunnel Train fire breaks water main above, melts fiber-optic cable in tunnel, disrupts power line

- Functional
  - Many infrastructure use electric power, telecommunication & Internet for control
  - Puerto Rico 2017: [Electricity outage disrupts water, hospitals, …](#)

- Cyber-Interdependence
  - Many infrastructure use computers and Internet for control and communications

- Logical Interdependence
  - Economic (e.g., market) or political dependence
  - 1973 Oil Embargo reduced vehicle transportation
Geographic Interdependence Example

- **Harvard Street Tunnel Fire** (https://en.wikipedia.org/wiki/Howard_Street_Tunnel_fire)
  - 1-minute ABC News clip: https://www.youtube.com/watch?v=6SrFQigzw6s

- **Events**
  - 7/18/2001: 3pm: 60-car CSX train derailed :: 4pm: multi-day Fire & Smoke
  - 545pm: Civil defense sirens, shelter in place resident & evacuate pedestrians
  - 615pm: Water main above tunnel (Howard & Lombard) broke releasing 1.4M gallons
    - Water did not put out fire, instead flowed in a different direction in to an electric substation
  - **Transportation:**
    - Rail: Disruption to CSX freight, MARC commuter
    - Road: Howard & Lombard (I-395, Downtown) & Water: Inner harbor closed to boats
  - **Electric Power:** Power cable damage left 1,200 Baltimore buildings without electricity.
    - Water knocked out phone service to 2 office towers (250 & 300 W. Pratt St.)
    - Fire destroyed Worldcom Fiberoptic cables in tunnel => affected email and web in NYC

- **Lesson Learned:** CIP planning must include Geography
Geospatial Interdependencies

- Geographic proximity of infrastructure components
  - Common corridor
  - Transmission lines, water pipelines, gas pipelines, telecommunications
- Geographic catastrophe impacts multiple infrastructures
  - Electric fire may ignite gas pipelines

Functional Infrastructure Interdependencies

Example: Power outage in Kobe led to:

- Loss of water filtration plants & pump stations
- Fire ignitions from natural gas leaks and electricity sparks
- Malfunction of traffic signals
- Loss of satellite emergency communications
- Hospital shutdowns
- Loss of water and elevators in high-rises
- Lack of heating at emergency shelters

Urban fires in 1995 Kobe Earthquake
(Source: Nojima and Kameda, 1996)
Active Learning Exercise

- **Learning Objectives:** Why and how GIS is used in CIP?


1. What is a geospatial interdependency? Which GIS operations may be used to identify *geospatial interdependencies* among critical infrastructures such as transportation, energy, water, etc.?

2. Flag geospatial interdependencies in list below:
   1. After Hurricane Katrina, the supply of crude oil and refined petroleum products was interrupted because of a loss of electric power at the pumping stations for three major transmission pipelines.
   2. When the twin towers collapsed, water mains servicing the WTC complex were ruptured by falling debris, which also severed 70,000 Verizon copper pairs and additional fiber optic-lines at 140 West Street.
   3. Water from the ruptured underground pipelines flooded train tunnels beneath the Hudson River, and the cable vault of the Verizon building at 140 West Street critical for block trades on the stock exchange.
   4. Ruptured WTC water mains and flooding of Verizon building were linked directly with the interruption of securities trading and the restoration of international financial stability.


1. What is an important lesson learned from July 2011 Baltimore Harvard Tunnel Fire?
2. Which GIS operations may Baltimore have used to note that many infrastructures intersect at one location?
3. List four GIS use cases for protection of water distribution infrastructure as per the article.
Active Learning Exercise (Extra)

- **Learning Objectives:** Why and how GIS is used in CIP?


1. What is a geographic or spatial interdependency? (Section 3.2, pp. 5 & sc. 5.3.1, p. 13).
2. What is location-based Critical Infrastructure Interdependency (LBCII)? List 6 steps of LBCII. List 3 components of LBCII. (Section 4, pp. 8-11).
3. List a few GIS analytical tools used in the Vancouver case study in Section 5.3. Recall GIS Analytic tools include measurements, search, location analysis, terrain analysis, flow analysis, spatial patterns, etc.
Notes: GEOINT and CIP Resilience

- Water Utility Example from East Bay, SF
  - X. Irias, The Underlying Fabric of Our Society: Critical Infrastructure Resilience Relies Upon GEOINT, USGIF Report on Building Resilient Communities Through Geospatial Intelligence, pp. 10-12, Sept., 2018

- Harvard Tunnel Fire, Baltimore, MD, July 2011
  - “Among the important lessons learned was that resiliency efforts must consider not just system age and design, but also geography. Had Baltimore realized that all of these systems intersected at one location, mitigation efforts would have prevented such cascading failures.”

- GIS Use Cases for Water Utility in East Bay
  - Resilience planning for maximum survivability when possible
    - avoid geo-hazards, e.g., earthquakes, landslides, and flood zone
    - Use more robust pipes in direction of quick repair in geo-hazard zones
  - Assess impact of draughts and floods
  - Identify critical links in an water infrastructure network
    - Low-reliability links
    - Reducing community impact during replacement of low-reliability links
    - Strategic placement of isolation values to reduce impact of a break
    - Highest priority links
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
  - Critical Infrastructure
  - Role of GIS in CIP
- Next
Disasters

- **Natural**
  - Weather: Wildfire, Heatwave, Flood, Storm, Tornado, Hurricane, Winter Storm,
  - Other: Tsunami, Earthquake, Volcano, Landslide, Fire,

- **Man-made, Technological**
  - Terrorism, Nuclear Power Plant Emergency
  - Dam Failure, Chemical Emergencies, Hazardous Material
Disaster Resilience

- **Resilience**
  - Survival through natural & man-made disasters
  - Needs never exceed resources & ability to respond
  - Physical, Emotional, Relationship and Spiritual

- **Disaster life-cycle phases**
  1. Risk Assessment
  2. Risk Reduction & Mitigation
  3. Prevention & Preparedness
  4. Response
  5. Recovery

- Disaster Resilience for critical infrastructure
- Critical infrastructure for Disaster Resilience
1. Risk Assessment: Risk Maps
2. Risk Reduction: Map & Protect Critical Assets
2. Risk Reduction: Perimeter Management

Downtown Minneapolis
Traffic Restrictions
- Road Closure
- Road Closure (Gameday Weekend Only)
- Local Traffic Only
- Area of Restricted Roadways

Traffic Command
- Traffic Signals

SUPER BOWL LII GAMEDAY
3. Prevention & Preparedness

- Delay an adversary from gaining access to critical infrastructure is paramount
  - such as *Pumping Stations*, *Substations*, *Regulator Stations*, *Switching Centers*

- Equipment or technology to delay entry or access is based on
  - its spatial relationship to the critical facility or infrastructure

- GIS uses include:
  - *Perimeter Management*
  - *Barrier Management*
  - *Patrol route planning*
  - *Persistence Surveillance*
3. Preparedness: ModelingScenarios

- GIS for Scenario based planning
  - Specify incident location
  - Map impact footprint using a model, e.g., plume simulation
  - Assess vulnerable population using demographic maps
  - Plan response, e.g., evacuation routes or shelter in place
  - …
4. Response: Situation Awareness

**OBJECTIVES**
- Real-time situation awareness
- Where are affected people?
- Which roads and sites are usable?
- Structural health and performance, …

**GIS Technologies**
- Field deployable in an ad-hoc environment
  - Flood
  - Partial Infrastructure loss (e.g. electricity, cell towers, Internet, …)
- Remote sensing: air, satellite, …
- VGI, e.g. OpenStreetMap
- Citizens as sensors, e.g. Tweets
- In-situ sensing
  - Reestablish within 12-24 hours
  - Despite poor infrastructure
5. Recovery

- Map recovery sites and hazards.
  - Ex. World Trade Center

- Ex. Electric Grid Recovery
  - Customer Reliability
  - Emergency Vehicle Dispatch and Tracking
  - System Restoration Monitoring
  - Damage Assessment
Climate Change

- Climate Change increases Frequency and Severity of weather extremes
- Ex. Heatwaves, Storms, Landslides, …
- Stresses Infrastructure, e.g.,
- Ex. 2022 CA Power grid and heatwave

CALIFORNIA’S HIGH ELECTRIC DEMAND

From 4:10 to 9 p.m. on Tuesday, the state’s electrical usage reached a “demand response event” — when demand is close to supply limits and triggers emergency measures.

Demand response event

Peak

Around 5 p.m.

52,061 MW

Demand drops

after state sends

text message to

conserve at around 6 p.m.

Megawatts

50,000

45,000

40,000

35,000

30,000

25,000

12 2 4 6 8 10 12 Noon

2 4 6 8 10 12 P.M.

Midnight Tuesday

Midnight Wednesday

Source: Calif. Independent System Operator

BAY AREA NEWS GROUP
Active Learning Exercise

Learning Objectives
- Why and how GIS is used in Critical Infrastructure Protection (CIP)?


1. Name two GIS layers used in this case study.
2. Name two kinds of GIS analysis used in this case study.
3. Did the case study address the issue of interoperability across data sources?
4. Did it address the issue of data accuracy?
5. Is their system capable of addressing multiple incident?
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
- Case Study
- Next
Scenario - Nuclear Power Plant Accident

Nuclear Power Plants in Minnesota
Buffer (10-miles) Around a Nuclear Power Plant

- Monticello Power Plant
- Affected Cities
- Evacuation Destination
- U of M
A Scenario: Monticello Emergency Planning Zone

Emergency Planning Zone (EPZ) is a 10-mile radius around the plant divided into sub areas.

### Monticello EPZ

<table>
<thead>
<tr>
<th>Subarea</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4,675</td>
</tr>
<tr>
<td>5N</td>
<td>3,994</td>
</tr>
<tr>
<td>5E</td>
<td>9,645</td>
</tr>
<tr>
<td>5S</td>
<td>6,749</td>
</tr>
<tr>
<td>5W</td>
<td>2,236</td>
</tr>
<tr>
<td>10N</td>
<td>391</td>
</tr>
<tr>
<td>10E</td>
<td>1,785</td>
</tr>
<tr>
<td>10SE</td>
<td>1,390</td>
</tr>
<tr>
<td>10S</td>
<td>4,616</td>
</tr>
<tr>
<td>10SW</td>
<td>3,408</td>
</tr>
<tr>
<td>10W</td>
<td>2,354</td>
</tr>
<tr>
<td>10NW</td>
<td>707</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>41,950</strong></td>
</tr>
</tbody>
</table>

Data source: Minnesota DPS & DHS
Web site:  [http://www.dps.state.mn.us](http://www.dps.state.mn.us)
[http://www.dhs.state.mn.us](http://www.dhs.state.mn.us)
Evacuation Routes

Estimate EPZ evacuation time:
Summer/Winter (good weather):
3 hours, 30 minutes
Winter (adverse weather):
5 hours, 40 minutes
# Scenarios for Metro Evacuation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Evacuation Zone</th>
<th>Possible Event Locations</th>
<th>Evacuation Population</th>
<th>Evacuation Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Detonation – 10-Kiloton Improvised Nuclear Device</td>
<td>Large (50 m.)</td>
<td>Entire Metro</td>
<td>Over 2 million.</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Blister Agent</td>
<td>Medium (2-5 m.)</td>
<td>CBD (Mpls, St. Paul)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Toxic Industrial Chemicals</td>
<td>Medium (2-5 m.)</td>
<td>Refinery (Newport)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Nerve Agent</td>
<td>Medium (2-5 m.)</td>
<td>CBD (Mpls, St. Paul)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Chlorine Tank Explosion</td>
<td>Medium (2-5 m.)</td>
<td>Rail yards</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Radiological Attack – Radiological Dispersal Devices</td>
<td>Medium (2-5 m.)</td>
<td>CBD (Mpls, St. Paul)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Explosives Attack – Improvised Explosive Device</td>
<td>Small (1-2 m.)</td>
<td>Mall of America, U of M sports event</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
</tbody>
</table>
Evacuation Route Planning

- **Only in old plan**
- **Only in new plan**
- **In both plans**

FoxTV newsclip:
- quicktime H.264 - 128Mb
- avi - 65Mb
- youtube

youtube video (5 min.)
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
- Case Study
- Next
  - Courses: Csci 5715: Spatial Computing
  - GIS Service: Uspatial (https://research.umn.edu/units/usspatial/)
Csci 5715: From GPS and Google Earth to Spatial Data Science
  - Fall 2022: Tu., Th. 1115am-1230pm, MechEng. 212

Topics: Positioning, Remote Sensing, Spatial Statistics and Data Mining, Spatial Databases (SQL3/OGIS), data-structures (e.g., R-tree, Vornoi diagram), algorithms (e.g., routing), Geo-visualization (e.g., cartography).

Recent Syllabus: [http://www.spatial.cs.umn.edu/Courses/Fall21/5715/](http://www.spatial.cs.umn.edu/Courses/Fall21/5715/)
Spatial Resources at UMN

Library

- Spatial Computing, The MIT Press Essential Knowledge series, 2020 (via UMN library)

USpatial: https://uspatial.umn.edu/

- Provides training on spatial tools and data-sets

Training:

- Geospatial Skills Badge – Storytelling
- Workshops
  - ArcGIS Notebooks: The Basics (Online)
  - Web GIS 101: Introduction to ArcGIS Online, (Online)

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