LECTURE 5-B
RELATED TECHNOLOGIES

CEEN 4800/6965 - Special Topics
Geographic Information Systems and Hydrologic & Hydraulic Modeling
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Department of Civil / Environmental & Chemical Engineering

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OUTLINE

- GIS Related Technologies
  - Remote sensing (satellite imagery)
  - Global Positioning System (GPS)
    - Mobile GIS
  - Internet GIS

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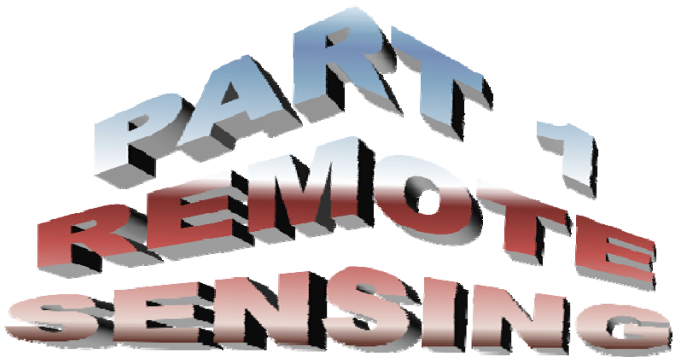

REMOTE SENSING APPLICATIONS

- Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device called sensor that is not in contact with the object, area or phenomenon under investigation.
- Remote sensing data examples
  - Aerial photos
  - Satellite imagery
- Applications
  - High resolution satellite imagery for base maps
  - Creation of land use / land cover maps
  - Master planning
    - Watershed stormwater management plans
    - Regional water resources studies

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EXAMPLES OF REMOTE SENSING

- As you read these words you are employing Remote Sensing
  - your eyes : sensors
  - light reflected from the page: data
  - understanding the meaning: analysis
- Photography
  - film: sensor
  - light reflected from the scene: data
  - film processing: analysis
- Electromagnetic Remote Sensing (satellite imagery)
  - electromagnetic energy detectors: sensors
  - light reflected and emitted from the ground objects: data
  - extracting the useful information: analysis

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REMOTE SENSING DATA

Type	Alt. (mi)	Res. (ft/m)	Scale	Scene size mi^2
Low alt. aerial photo	1	5	1:20,000	8
High alt. aerial photo	7	10	1:120,000	300
SPOT Satellite	517	33/10	1:555,000	1,370 (37 x 37)
LANDSAT 7	438	100/30	1:1,000,000	13,225 (115 x 115)

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SAMPLE AERIAL PHOTO

1. WHITE HOUSE 2. US CAPITOL 3. LINCOLN MEMORIAL 4. POTOMAC RIVER

- Washington DC, color infrared film, altitude = 4 mi,
- Blue objects (water, wetlands, river) appear green
- Green objects (trees, parks, playground) appear red
- Infrared objects (emitting heat) appear white

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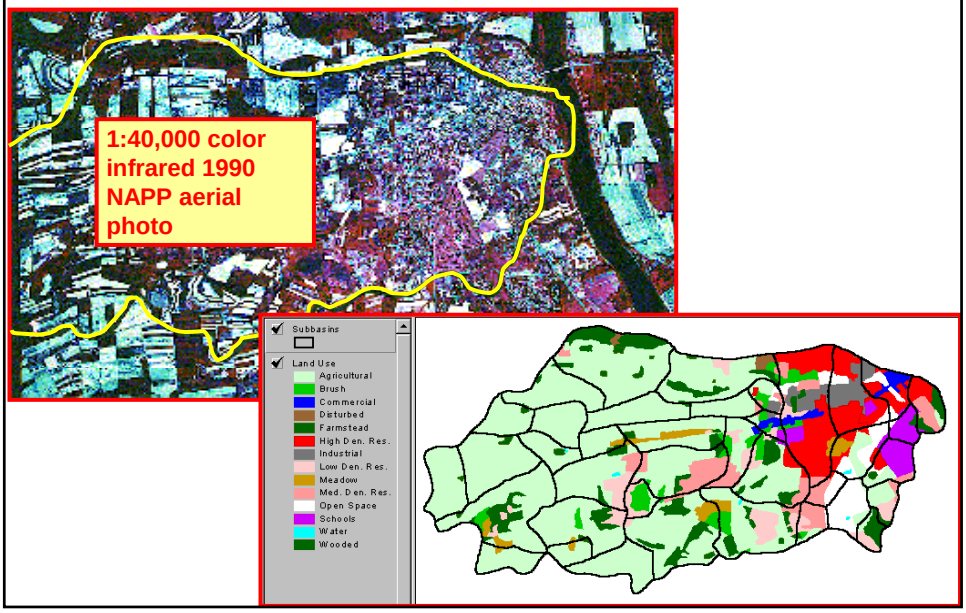
LAND USE MAPPING USING AERIAL PHOTOS



LANDSAT PROGRAM

- The Landsat program is the longest running enterprise for acquisition of imagery of Earth from space.
- The first Landsat satellite was launched in 1972; the most recent, Landsat 7, was launched on April 15, 1999.
  - Landsat 6 exploded before launch in 1993
- NASA: Design and launch
- NOAA: Data collection

LANDSAT 7

NASA: National Aeronautics and Space Administration
NOAA: National Oceanic and Atmospheric Administration

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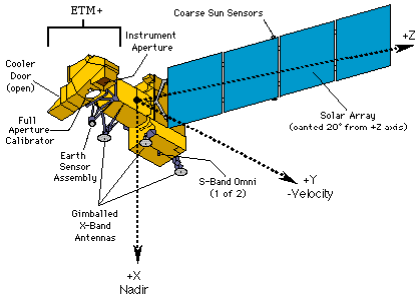
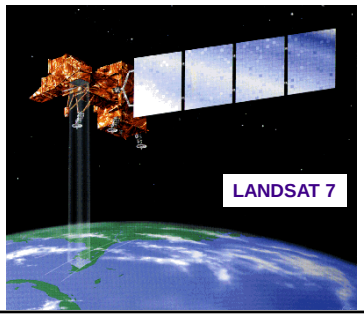
LANDSAT CONFIGURATION

- Diameter = 108 in (2.7 m)
- Length = 108 in (4m)
- Weight: 2200 kg
- Design Life: 5 years
- Sensor:
  - Landsat 7: Enhanced Thematic Mapper Plus (ETM+)
  - Landsat 4 & 5: Thematic Mapper (TM)





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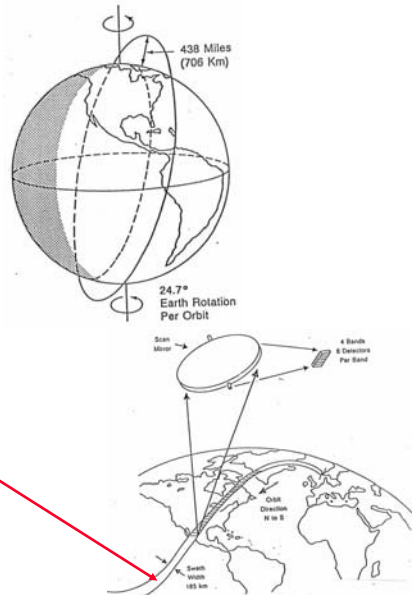
LANDSAT ORBIT CHARACTERISTICS

- Altitude = 705 km (435 miles)
- Orbit type: near polar, sun-synchronous
  - (versus geo-synchronous)
- Orbit period: 98.9 minutes (14 orbits/day)
- 233 fixed orbital paths spaced equally around earth with each path being covered in 16 days
- Longitudinal separation of adjacent orbits = 24.7 degrees = 503 miles
- swath width = 185 km (115 mi)



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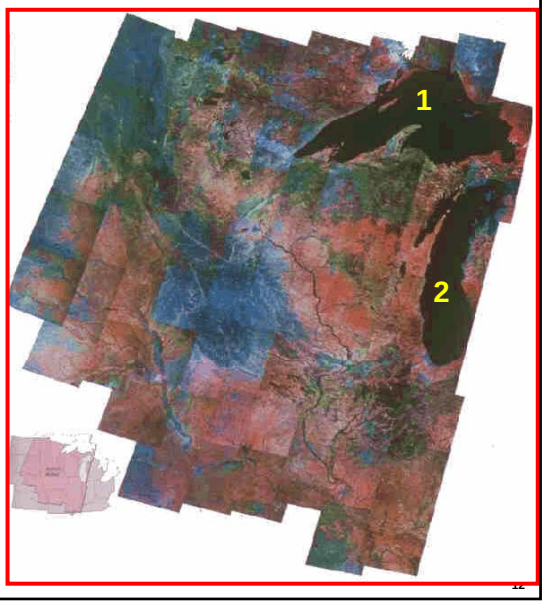
LANDSAT SCENE MOSAIC

- Source: Landsat 1,2
- Resolution = 30m
- Manual mosaic of 75 images (each 115 mi^2)
- 10 orbital paths
- Consecutive scenes provide continuous coverage
- Overlap between adjacent tracks
- Lake Superior (1) and Lake Michigan (2)



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LIST OF HIGH RESOLUTION SATELLITES

Feature	*QuickBird-2*	*IKONOS*	*OrbView-3*
Company	DigitalGlobe	Space Imaging	ORBIMAGE
Launch Date	October 18, 2001	September 24, 1999	June 26, 2003
Black &White Resolution (m)	0.61	1	1
Color Resolution (m)	2.5	4	4
Swath Width (km)	16.5	12	8
Global Cover Repeat Days	148	247	3
Standard scene size	40 km x 40 km	13 km x 13 km	User defined
Web Site	digitalglobe.com	spaceimaging.com	orbimage.com

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SAMPLE IKONOS IMAGERY

- **IKONOS 1-m satellite imagery**
- **Launched in September 1999**
- **Starting at $12/sq.km. (Min. order $1000)**
- **Downtown San Francisco-Oct21, 1999**

http://www.spaceimaging.com - Click on Carterra Digital Snapshots

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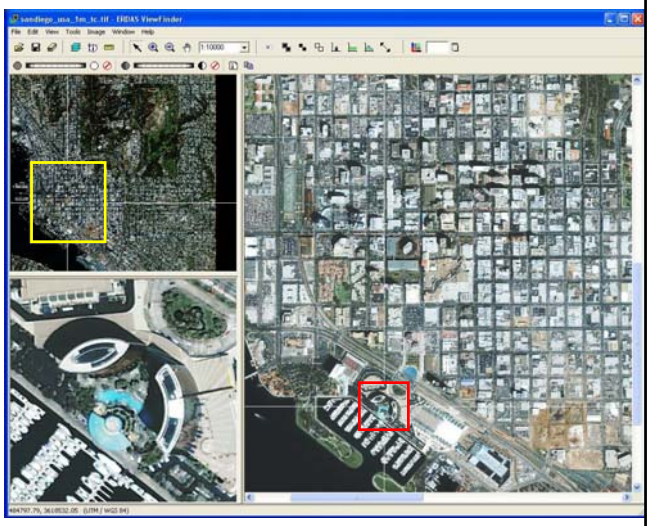
SAMPLE IKONOS IMAGERY

- San Diego, California
- Processed Jan 2002
- Resolution: 1 meter
- Used by Space Imaging Solutions to create
  - Land use land cover map
  - Pervious / Impervious map
- Screenshot created using ERDAS ViewFinder 2.0 (free viewer software)



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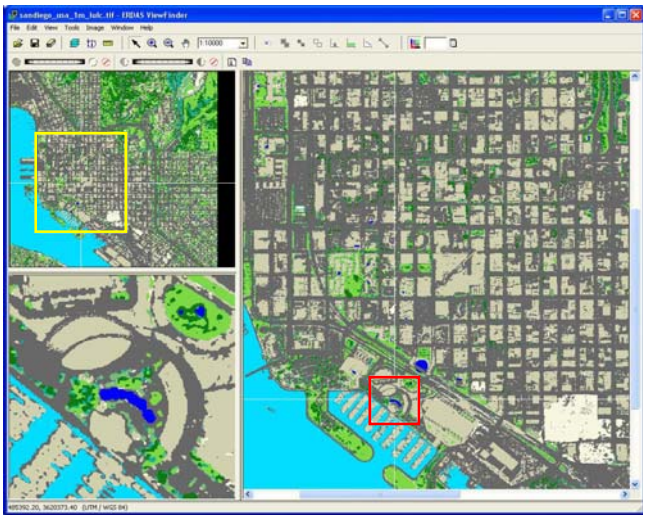
SAMPLE LAND USE / LAND COVER

- San Diego, California
- Land use land cover map derived from 1m IKONOS imagery

Legend
Open Water
Landscaped Water
Bare Ground
Pavement
Building
Irrigated Grass
Dry Grass
Shrub
Tree



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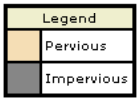
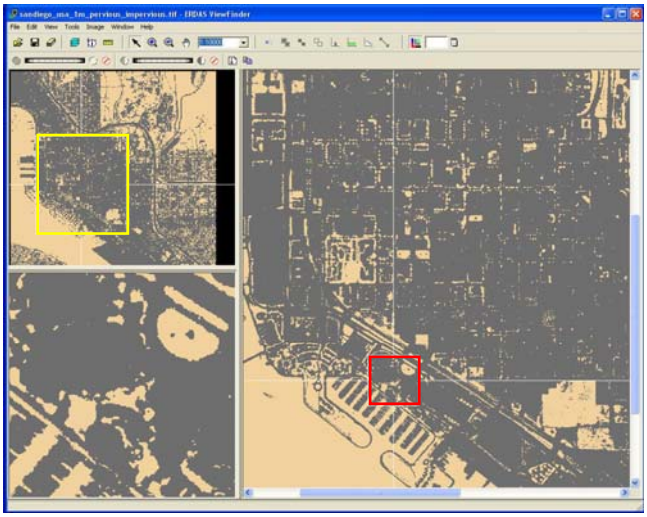
SAMPLE PERVIOUS / IMPERVIOUS MAP

- San Diego, California
- Pervious / impervious derived from 1m IKONOS imagery





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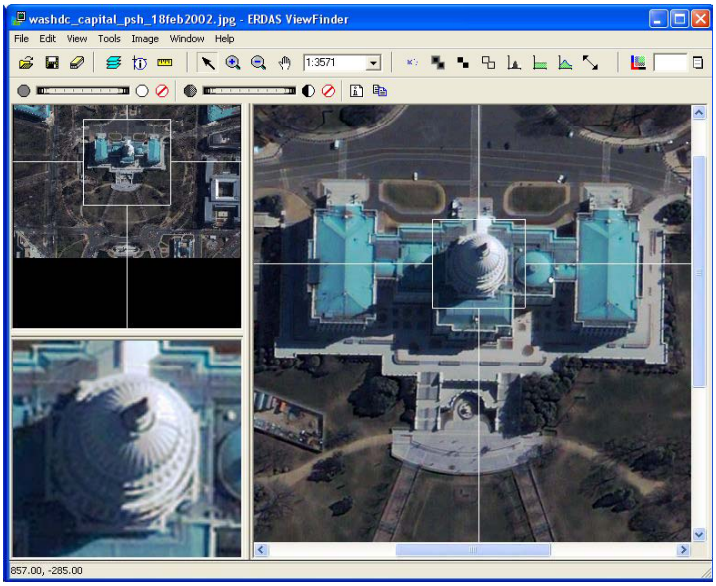
SAMPLE QUICKBIRD IMAGERY

- Washington, DC
- The Capitol
- From DigitalGlobe (digitalglobe.com)
- Collected February 18, 2002.



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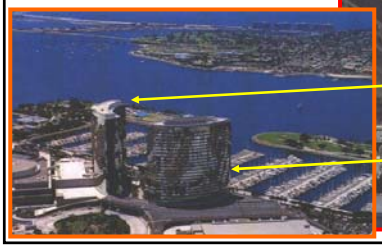
SAMPLE QUICKBIRD IMAGERY

- Resolution: 61-cm
- San Diego Convention Center, Marriott Hotel and Marina
- March 9, 2002



PART 2 GPS

GLOBAL POSITIONING SYSTEM (GPS)

- GPS (1980) is a constellation of 24 satellites orbiting the earth 12,500 miles above the Earth twice daily transmitting precise time and position signals
- GPS receivers read signals from orbiting satellites to calculate the exact spot of the receiver on the Earth by comparing the time taken by signals from three or four different GPS satellites to reach the receiver.

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WHY USE GPS?

- Verify and correct locations of existing map features
- Map new features (never mapped before)
- Traditional geodetic survey is expensive
- GPS is 10 to 20 times faster than the traditional methods
- Traditional transit survey
  - Traverse between a known point to the point of interest
  - Generally 5-20 points per day
- GPS survey
  - Generally 100-200 points per day
  - A two-man crew with bicycle mounted equipment can survey up to 500 points (non-RTK) per day

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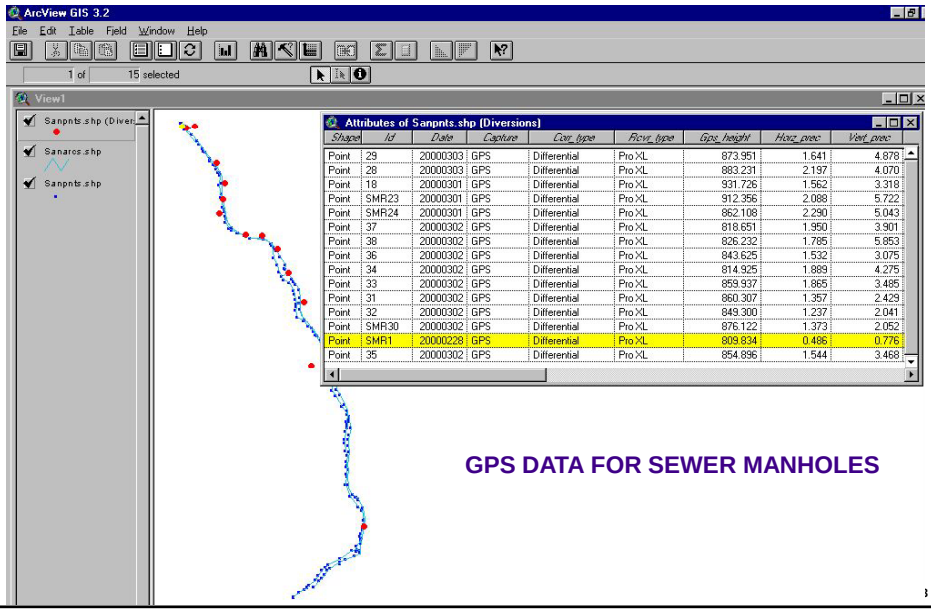
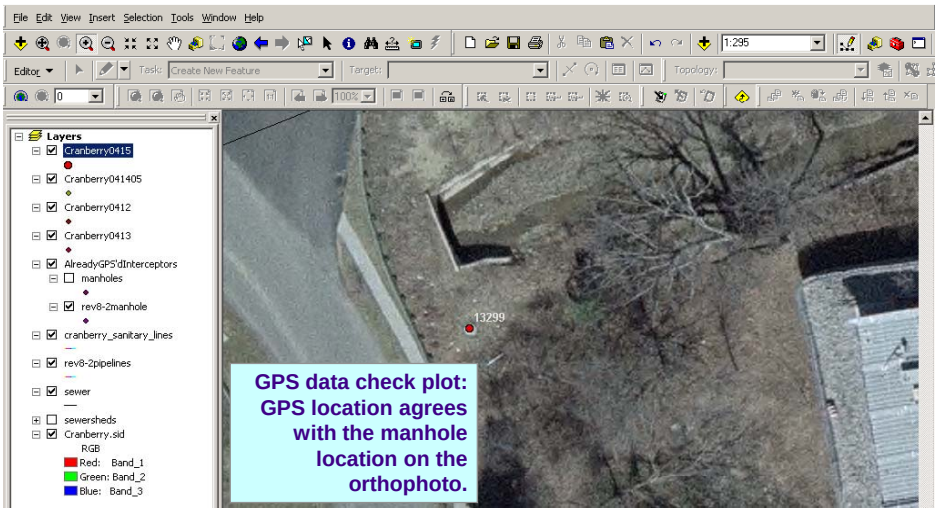
GIS/GPS INTEGRATION

MANAGE YOUR GPS DATA IN GIS



GIS/GPS INTEGRATION

SEE YOUR GPS DATA IN GIS



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GPS APPLICATIONS

- Sub-meter survey
  - Use mapping grade GPS: code-based receivers
- Centimeter level survey
  - Use survey grade (RTK – Real Time Kinematic) GPS: carrier phase receivers
- GIS data collection
  - GIS feature attributes using GPS
  - GPS data collection is no longer limited to point features
    - Lines: Bike along a channel
    - Polygons: Walk around a detention pond

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ACCURACY

- The closeness of results, computations, or estimates to TRUE values.
- How closely (accurately) map features reflect real-world objects.
- Maps are accurate to roughly one line width (0.5 mm)
  - Equivalent to 12 m on 1:24,000 map
    (0.5/1000) x 24000 = 12 m

Map scale	Ground distance corresponding to 0.5 mm map distance
1:1250	62.5 cm
1:2500	1.25 m
1:5000	2.5 m
1:10,000	5 m
1:24,000	12 m
1:50,000	25 m
1:100,000	50 m
1:250,000	125 m
1:1,000,000	500 m
1:10,000,000	5 km

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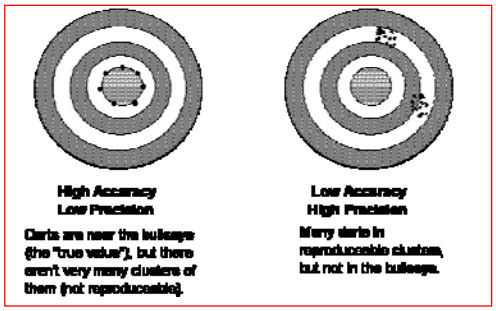
PRECISION

- Precise = consistent and reproducible
- Not the same as accuracy!
- A basic GPS equipment is less accurate but quite precise because it consistently gives inaccurate coordinates.



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GPS ACCURACY

- Varies from millimeters to meters (20 m)
- Utility standard: cm to sub-meter accuracy
- Varies with
  - *GPS equipment*
  - Time of occupation
  - Location: vegetation, obstructions (tall buildings), reflection
- Cost increases with accuracy
- Desired accuracy depends on the project-specific requirements

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GPS EQUIPMENT

- **Four types of GPS equipment:**
  1. **Navigation / Recreation**
  2. **Basic**
  3. **Advance (Asset/Mapping Grade)**
  4. **Survey Grade**

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GPS EQUIPMENT

Receiver Type	*Horizontal Accuracy (meters)*	*Price (US$)*
Recreation	5-20	50-350
Basic	1-5	3,500-6,000
Advance	< 1	8,000-10,000
Survey and geodetic	<0.2	25,000 and up

- Only survey-grade RTK equipment can provide vertical accuracy of ±1-3 cm (important for manhole rim elevations used in hydraulic modeling)

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GPS EQUIPMENT COMPANIES

Ashtech	Dark Blue	www.ashtech.com
Leica Geosystems	Red	www.leica.com
Magellan Corporation	Various	www.magellangps.com
Sokkia Corporation	White	www.sokkia.com
Topcon (GPS/GLONASS)	Green	www.topconps.com
Tripod Data Systems	Light Blue	www.tdsway.com
Trimble Navigation	Yellow	www.trimble.com

- **Magellan provides consumer oriented products**
- **Tripod is a Trimble Company**
- **Ashtech (blue) acquired by Magellan**
- **Javad Positioning Systems (JPS) (green) acquired by Topcon**

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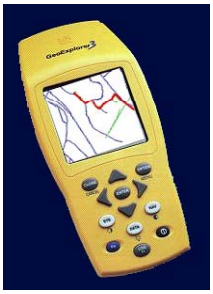
BASIC GPS EQUIPMENT

- **Example: Geoexplorer III**
- **Hand-held GIS data collection system**
- **ArcGIS, AutoCAD, and Intergraph compatible**
- **GIS export using Pathfinder Office software**
- **Cheap ($3,500) but less accurate:**
  - **2-5 m accuracy (worst in woods), not allowed in NJ, educational use)**



GEOEXPLORER III

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STEPS FOR FIELD DATA COLLECTION

- Using basic GPS (Geoexplorer II)
- Install Pathfinder Office software on your PC
- Create a data dictionary: define attributes for each feature type
- Transfer data dictionary from PC to receiver (serial or USB cables)
- Enter attributes during GPS survey
- After the GPS survey, transfer location and attribute data from receiver back to Pathfinder Office on your PC
- From Pathfinder Office export data to your GIS
  - ArcView Shapefile, Map Info

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DATA DICTIONARY EXAMPLE

- Sanitary Features
  - San_mh
    - Lid_size
    - Lid_type
    - Condition
    - ID
- Storm Features
  - Catchbasin
    - Size
    - Type
    - Condition
    - ID
  - Endwall
    - Condition
    - ID

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ADVANCE GPS EQUIPMENT

- Pathfinder Pro XR/XRS
- Enter attributes using
  - Hand-held Asset Surveyor, Tablet PC, Pocket PC, or Windows CE devices
- Expensive ($10.5K for receiver + $4.5k for asset surveyor) but more accurate
- Real-time sub-meter accuracy


Asset Surveyor

Pocket PC


Windows CE Field Device

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SURVEY GRADE GPS

- GPS Total Stations
- Integrated real-time kinematic (RTK) survey technique
- Dual frequency receivers can give ±1 cm accuracy in real time
- Trimble's Model 4800 starting at $25,500 (need two receivers: base station and rover)

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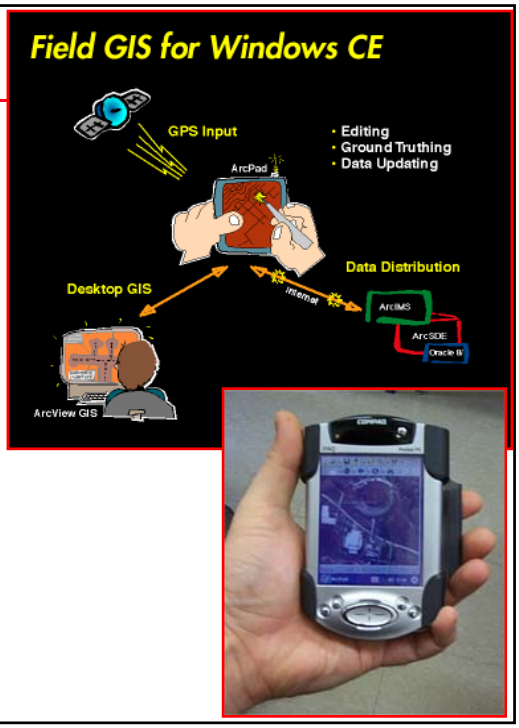
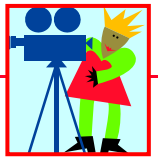
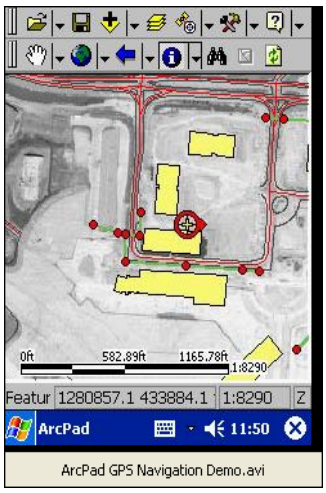
MOBILE GIS

- **ESRI ArcPad**
- Handheld GIS software for Windows CE computers
- Reduces the steps from GPS to GIS
- User-defined form-filling capability
- Real-time positioning using an optional GPS receiver.
- Mark features on the map and enter information about them.
- Upload these features into your desktop GIS.

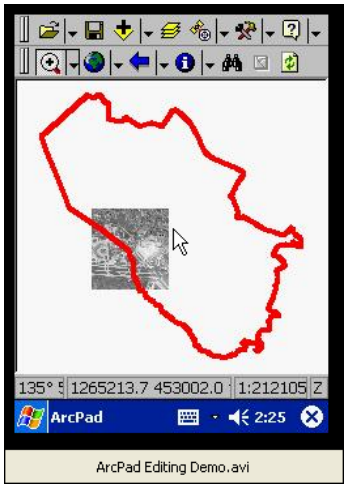


ARCPAD DEMOS





Navigating for field inspections



Manhole inspections

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GPS CASE STUDY

Application	**GPS survey of sanitary and stormwater manholes, catch basins, and stormwater outfalls for NPDES Permit compliance**
Study area	**City of Rock Island, Illinois, 15 mi^2, 40,000 residents**
Year Published	**2004**
Reference	**T. Johnson (2004)**
GPS Software	• **ESRI ArcPad 6 and Application Builder for creating custom attribute collection forms** • **Leica Geosystems DataPro software for transferring GPS data to office computer**
GPS Equipment	• **One base station: Leica receiver with a 35-watt radio repeater for broadcasting to rovers** • **Two rovers: Leica GS50+** • **Two data collectors: MicroSlate MSL-3800 ruggedized pen-tablet PCs**
GPS Accuracy	• **Horizontal: 0.01 ft (0.31 cm)** • **Vertical: 0.035 ft (1.1 cm)**
Coverage	• **12 miles radius from base station** • **22 miles radius from the base station with additional mobile repeaters**
Capture rate	• **12,750 points in 4 months (800 pints per week)**
GPS Data	• **Manholes: size, depth, material, and condition** • **Sewers: size, material, direction** • **Catch basins: Size, material, grate type, bike safe, gas trap** • **Outfalls: Pipe size, material, erosion control, and type (head wall, flared end, or straight pipe)**
Benefits	**Started with conventional traverse survey using total stations @ 60+ points/week. GPS survey @800 points/week translates into *1300%* time savings. *Savings Factor = 13.***

Reference: T. Johnson (2004). "Sharing The Wealth." Point of Beginning Magazine, June 2004.

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GPS CONCLUSIONS

- **A mapping-grade GPS which can provide sub-meter horizontal accuracy is generally adequate for mapping a water, wastewater, or stormwater system.**
- **Vertical accuracy of mapping-grade GPS is poor (1-3 meters)**
- **Only a survey-grade RTK GPS can provide centimeter level vertical accuracy**
- **GIS attributes can be captured from a GPS survey using field computers, hand held devices, or data collectors.**

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SOURCES OF DATA

Based on the source of their availability, there are three main sources of GIS data:

1. **Custom data**
   - **Data conversion**
     - **Digitization**
     - **Scanning**
   - **GPS**
2. **Public domain data**
   - **Internet**
3. **Commercial data**
   - **Data vendors**

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WEB GIS SOFTWARE

Internet GIS uses a client-server architecture. Therefore, two types of software is required to Web enable a GIS:

- Client-side software, and
- Server-side software.

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CLIENT-SIDE SOFTWARE

- Data browsing tools
- Very easy to use
- No data creation or editing capability
- Usually available for free
- Examples :
  - ArcExplorer, ESRI
  - GeoMedia Viewer, Intergraph
  - MapGuide Viewer, Autodesk

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SERVER-SIDE SOFTWARE

- Accessible through browsers
- Makes GIS usable over the Web
- Based on the capabilities, the cost ranges from $5,000 to $25,000.
- Examples:
  - ArcGIS Server, ArcIMS and RouteMap IMS, ESRI
  - GeoMedia Web Map, Intergraph
  - MapXtreme (NT or Java), a server-side Java GIS package from MapInfo
  - MapGuide, Autodesk
  - MapXsite from MapInfo

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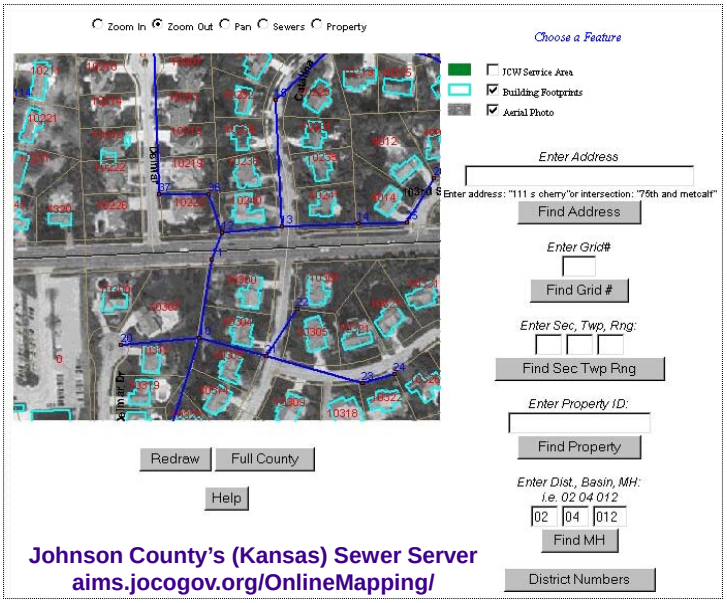
ArcIMS EXAMPLE



Johnson County's (Kansas) Sewer Server
aims.jocogov.org/OnlineMapping/

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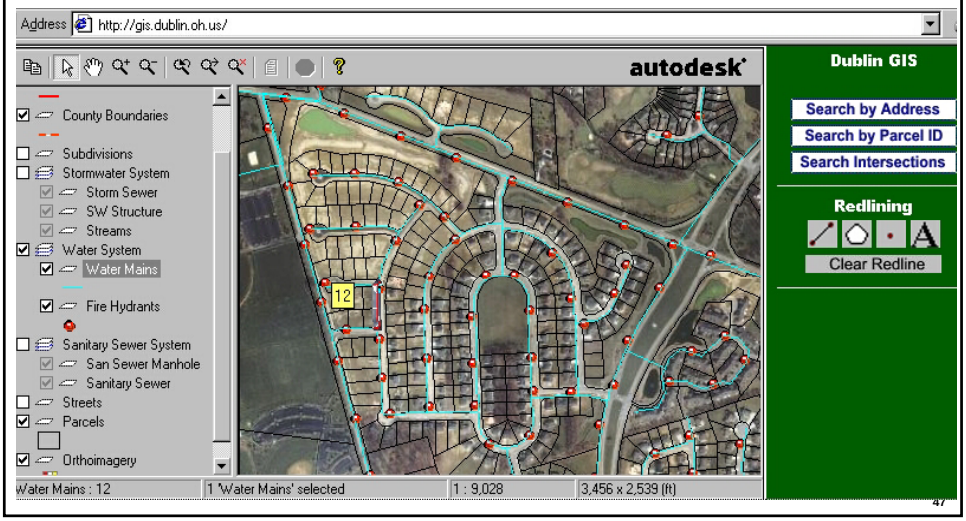
MAPGUIDE EXAMPLE

DUBLIN, OHIO
GIS.DUBLIN.OH.US

Dublin (Ohio) water, wastewater, and stormwater system Internet GIS created using Autodesk's MapGuide software.



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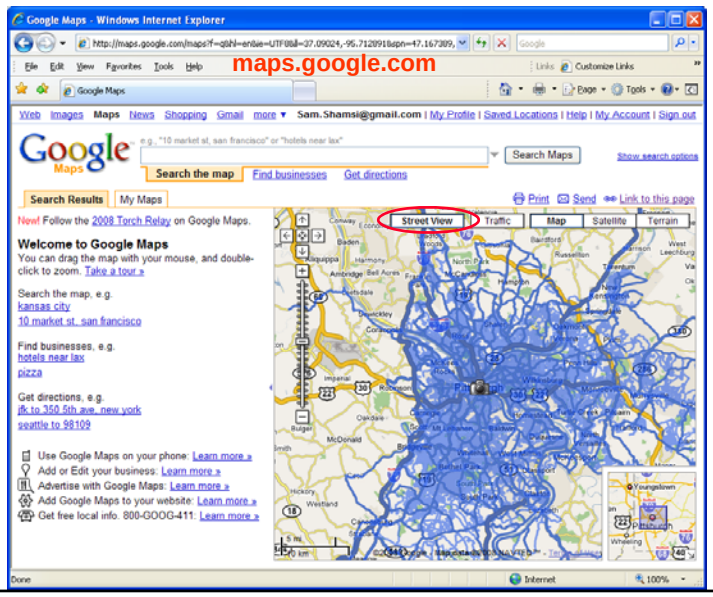
GOOGLE STREET VIEW

Video Mapping: Combination of GIS, GPS, and Video



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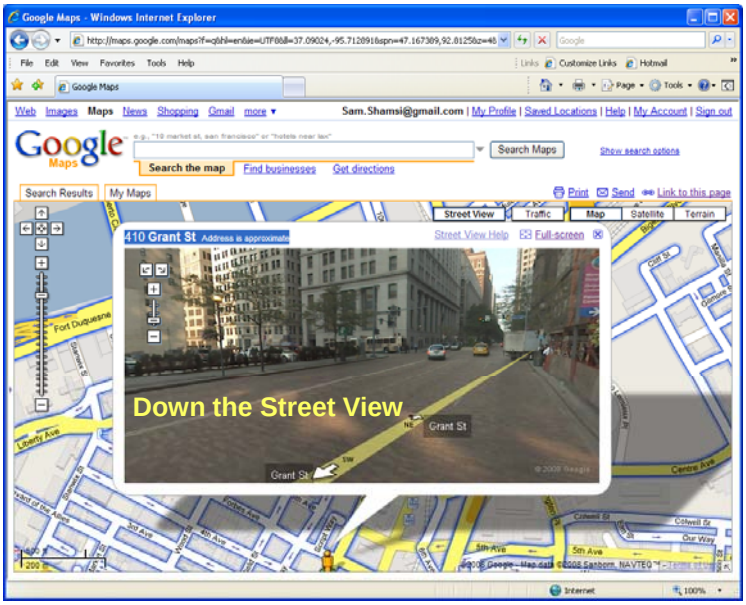
GOOGLE STREET VIEW



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GOOGLE STREET VIEW