Using GPS for GIS and Asset Management

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What is GPS?

GPS - Global Positioning System

Diagram Source
www.geog.okstate.edu/gpstools/overview1.htm

- **29 GPS Satellites** continuously transmit digital radio signals, which contains data on the satellite's location and the exact time, to earth-bound receivers (GPS measuring devices). They orbit every 12 hrs at 20,200 km.
- **Radio Signals travel** at the speed of light, the length of time it takes the receiver to get the signal, determines how far it is away from the satellite. **Distance = Velocity x Time.**
- **Knowing how far away a satellite is,** the GPS receiver knows that it is located somewhere on the surface of an imaginary sphere that has the satellite at it's center.
- **Three satellites,** can calculate the location of the receiver, based on where the three spheres surfaces intersect.
- **Four satellites,** for GPS to determine location on Earth's surface, need very accurate time. 4th works as atomic clock for user's GPS receiver (clock error of 1 nanosecond = 0.3 meter Dist error).

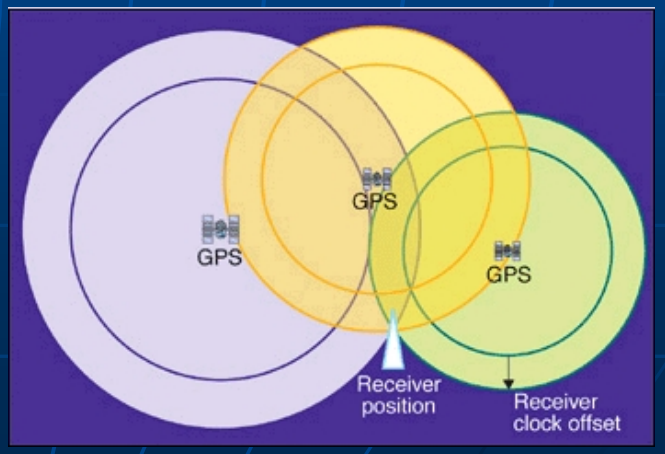


Diagram source: www.aero.org/publications/crosslink/summer2002/02.html

GPS Data Collection

- **Collect Spatial - with other Attributes:**
  Current GPS technology can be ideal for the collection of spatial data along with other attribute information.

- **Hundreds of Points Collected:**
  Hundreds of GPS data points can be collected each day in the field.

- **Exact location – Rich with Attribute info:**
  Accurate Horizontal and Vertical positions can be collected, along with any important attribute data. Both collected rapidly using GPS data-collector during field surveys.

GPS and Asset Management

- **Need location to Manage:**

  We all know, you can't manage an asset it if you don't know where it is. Using GPS helps solidify the location.

- **The Foundation of Asset Management:**

  Having an accurate spatial location of assets, along with their other attributes in a database, can be the foundation of a Asset Management System.

- **GPS - Start or Augment:**

  For organizations without one, GPS data collection can be a good initial start to developing an Asset Management Database. Or one can add spatial data to an existing Asset Management Database using GPS.

Current GPS- Varying Accuracy

- **Centimeter Accurate GPS**
  larger GPS units mounted on range poles,
  cost 20-30k approx. (Hardware+Software)

- **Sub-meter Accurate GPS**
  Small hand held units, cost 7-11k approx. (Hardware+Software)

- **Sub-foot Accurate GPS**
  became available in January 2006
  Small hand held units, cost 7-11k approx. (Hardware+Software)

- **Rule of Thumb:**
  Accuracy - Vertical ½ of Horizontal
  E.g. if using a Centimeter Accurate GPS:
  Horizontal Accuracy - 1cm
  Vertical Accuracy – 2cm
  *See manufacturer's Specs and Field Test yourself

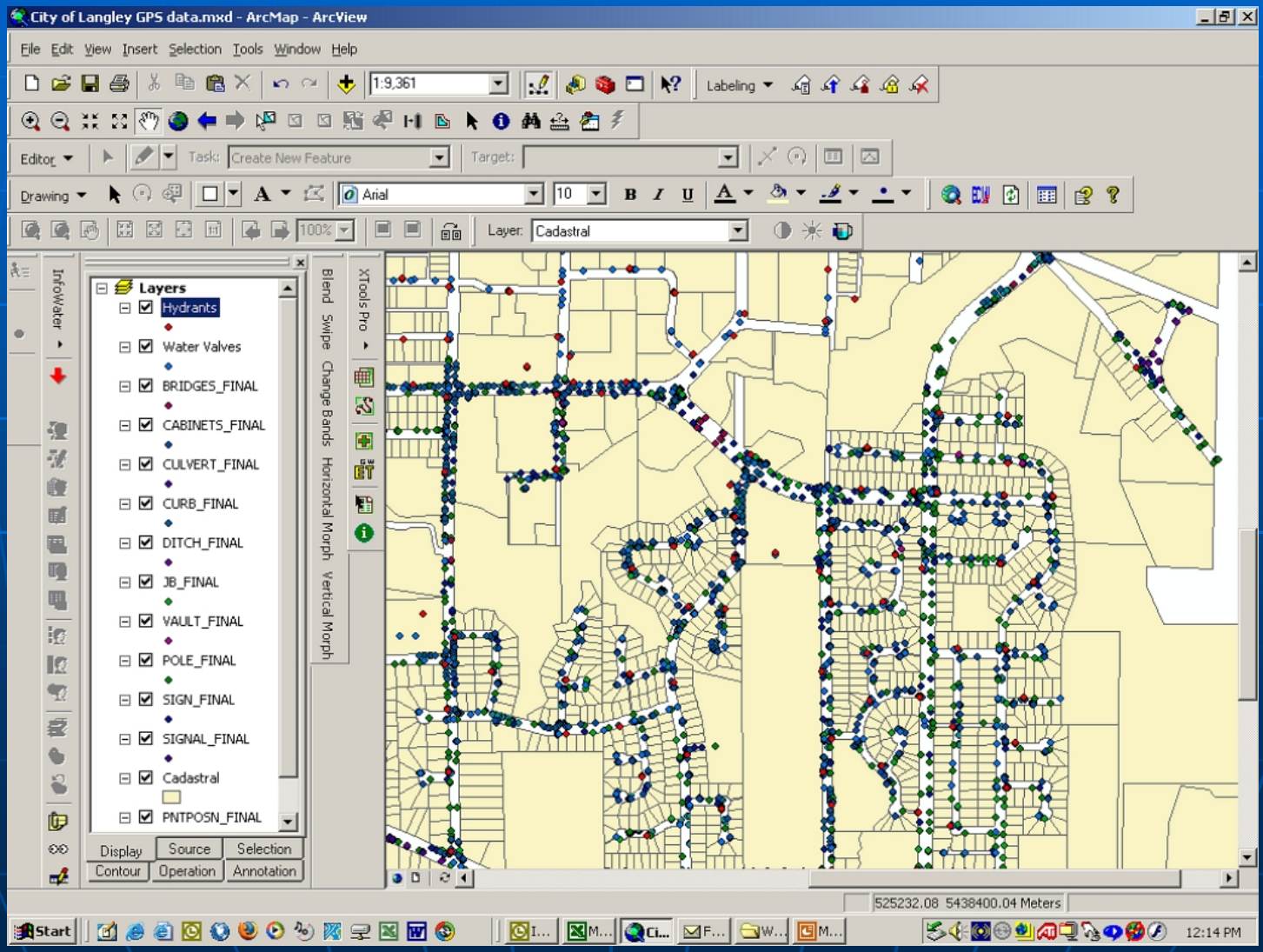
Current GPS Units

Centimeter Accuracy
"Survey Grade"- GPS

Sub-Foot Accuracy
"Mapping Grade" - GPS

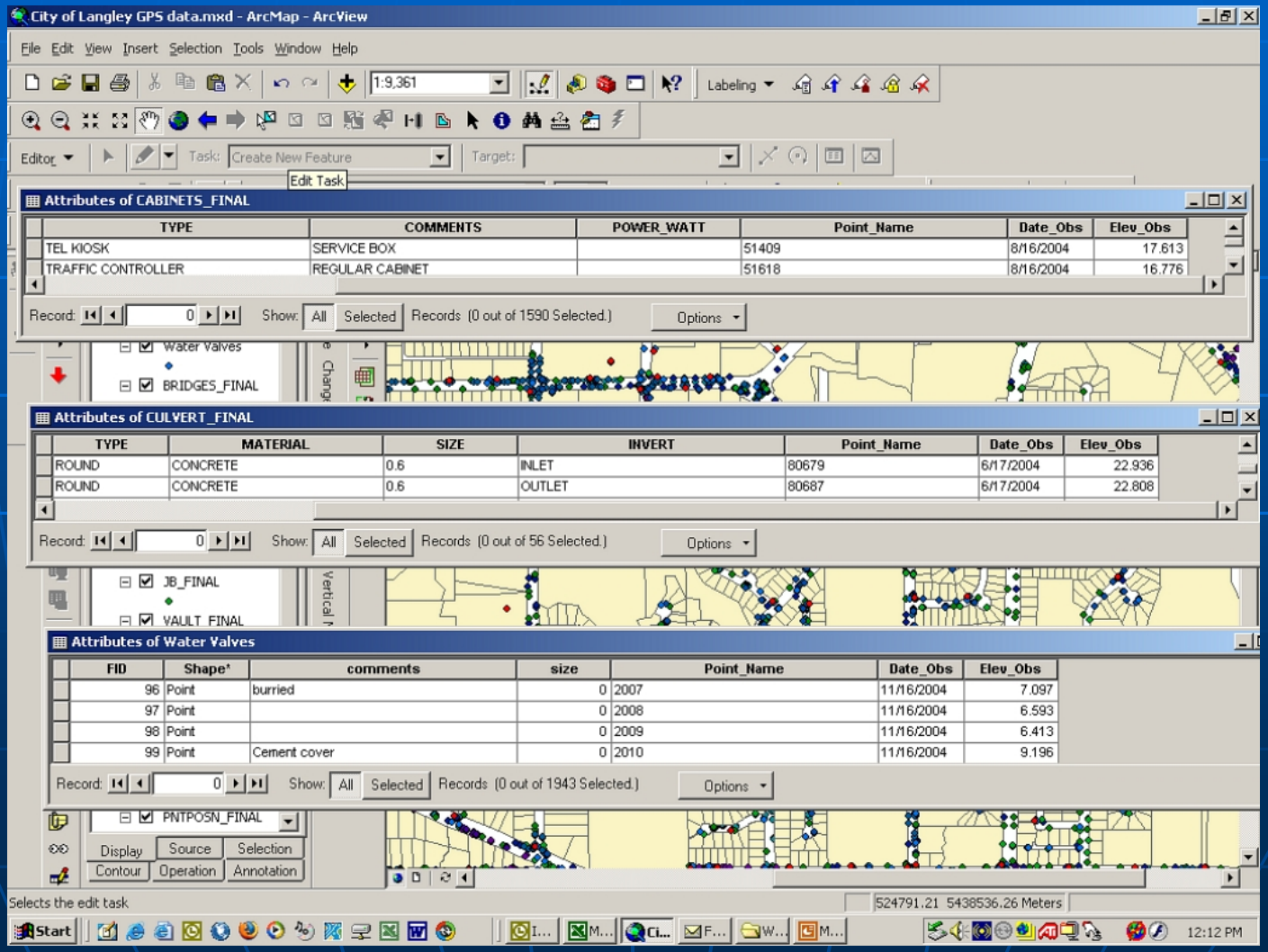
Images source: www.trimble.com/

In 3 months, entire water system (100km) City mapped with Centimeter Accurate GPS (Average 200+ points/day)

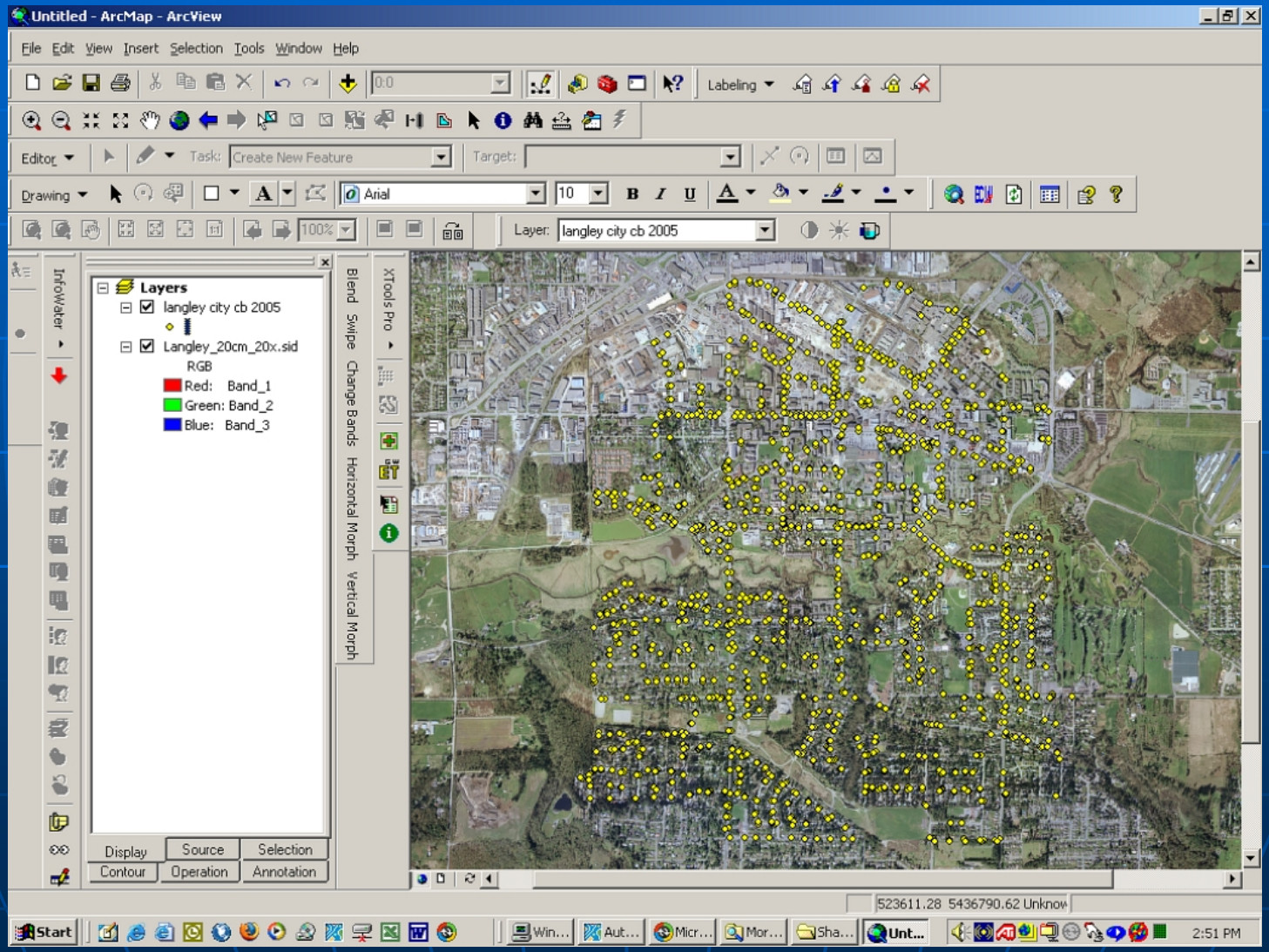


CoL Attribute data

Collected with Centimeter Accurate GPS

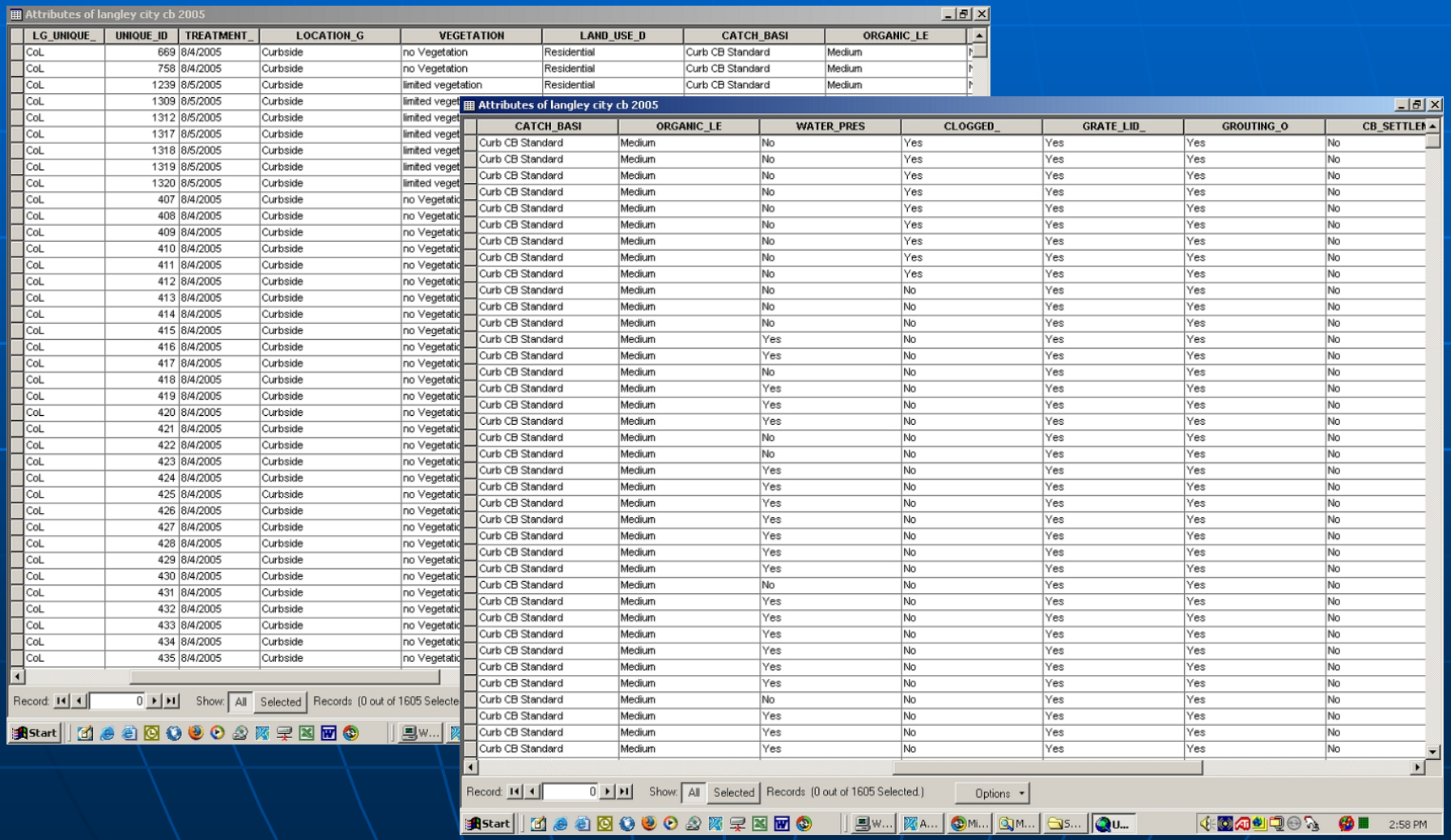


1600 Catch Basins - GPS mapped in 4 days, using Hand-held GPS (400+ points/day)



Catch Basin GIS Attribute Data

Built "On-the-Fly" using hand-held GPS unit



Field GPS use is Simple

- 1) POSITION

  GPS "Surveyor" needs to POSITION the GPS unit over the feature

  - Centimeter accurate GPS: place range pole point on asset, level bubble
  - Hand-held GPS units: hold GPS over feature at chest height

- 2) COLLECT

  GPS "Surveyor" needs to COLLECT attribute data and measure location

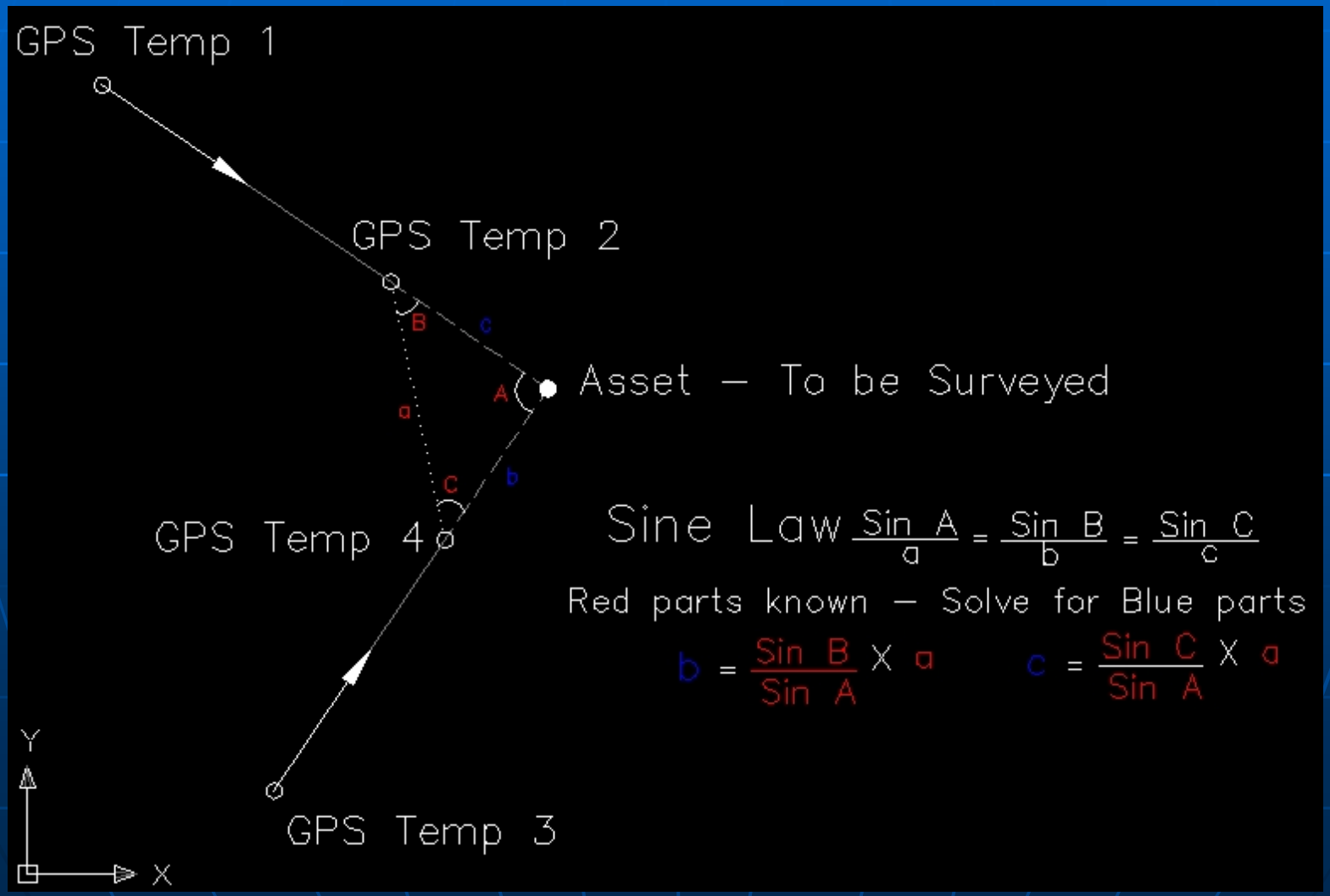
  - Attribute data "keyed-in" with key pad on the GPS unit
  - Location collected at the same time, by pressing simple function like "measure"

Note: Using Centimeter GPS
4 Point "intersection"
function very useful

Four Point Intersection

- Intersection using 4 temp GPS points (a Brg-Brg Int)

  "Done on the Fly" Simple, Rapid, and SAFE (Avoid Traffic)



Training Required to use GPS in Field

- **Centimeter Accurate GPS** used effectively at CoL by BCIT (Geomatics) and UBC (GIS) students (typically using GPS after 2 hours of "hands-on" training)

- **Sub-meter Accurate GPS** used effectively at CoL by Foreman, Gardeners, and Laborers (typically using GPS after 2 hour of "hands-on" training)

Training Required to Reduce GPS Data in Office

- **Recommend Employing Mapping (Geomatics) Technologist or University Graduate**

  comfortable with datum and coordinate conversions, and with a good understanding of map projections and GPS.

- **BCIT has offered a 3 day GPS course,**

  which was an excellent "how-to" or "refresher" course for a Mapping Tech or a University GIS Grad.

- **On-line Info:**

  www.colorado.edu/geography/gcraft/notes/gps/gps.html
  www.spatial.maine.edu/~leick/alpha.htm
  www.gisdevelopment.net/technology/gps/pdf/ma04123.pdf
  www.leica-geosystems.com/corporate/en/lgs_405.htm
  www.ga.gov.au/geodesy/gps/gpsoverview.jsp
  www.products.thalesnavigation.com/en/
  www.geod.nrcan.gc.ca/geodesy/reference/reference04_e.php
  www.topcongps.com/
  www.trimble.com/gps/
  www.geneq.com/frames.html
  www.gpsworld.com/gpsworld/
  www.kowoma.de/en/gps/errors.htm

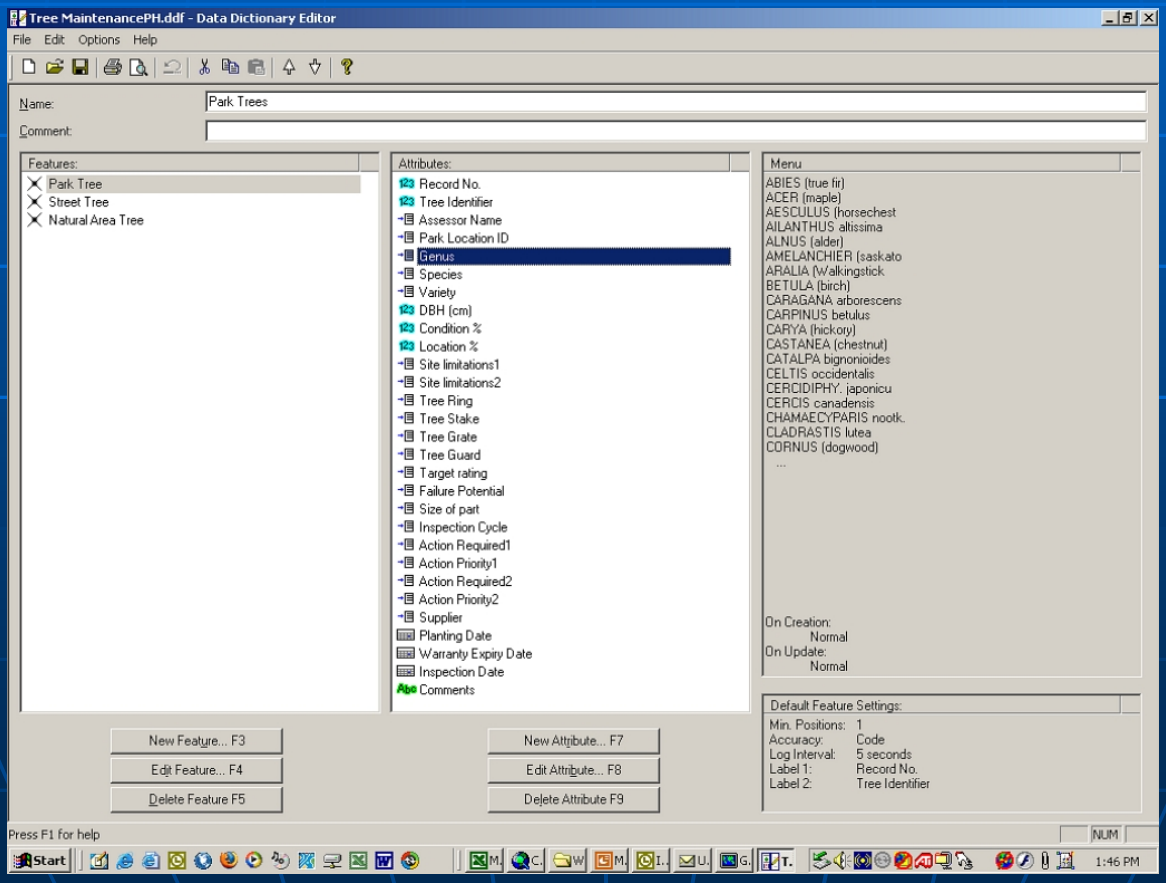
  Plus many many others on-line

Typical Office-Worker GPS Tasks

- **Build Data Dictionary:** with "canned software" and upload to GPS data collector for field survey attribute collection.
- **Apply Differential Corrections:** either during field GPS survey (RTK) or after field GPS survey completed (post-process), to obtain accuracy levels noted earlier.
- **Down load GPS data to PC, and refine:** simply connect GPS to cradle with active sync, down load data, convert data to desired datum and coordinate system, convert data to useful data type (Shape file or DWG), and possibly place data in database for storage and use.

Data Dictionary

- **Building and uploading Data Dictionary is simple** with canned software (example of "Tree-Dictionary" used by CoL Parks dept)



Differential Corrections

- **GPS Differential Correction,** use to correct the inaccuracies caused by the physics involved in sending radio signals through the earth's atmosphere. Separated into two classifications: RTK, and Post Processed Differential Corrections. Using the know location of the Base, one can calculated corrections for atmospheric delay, clock errors, and orbital errors etc., and then apply this correction to the Rover.

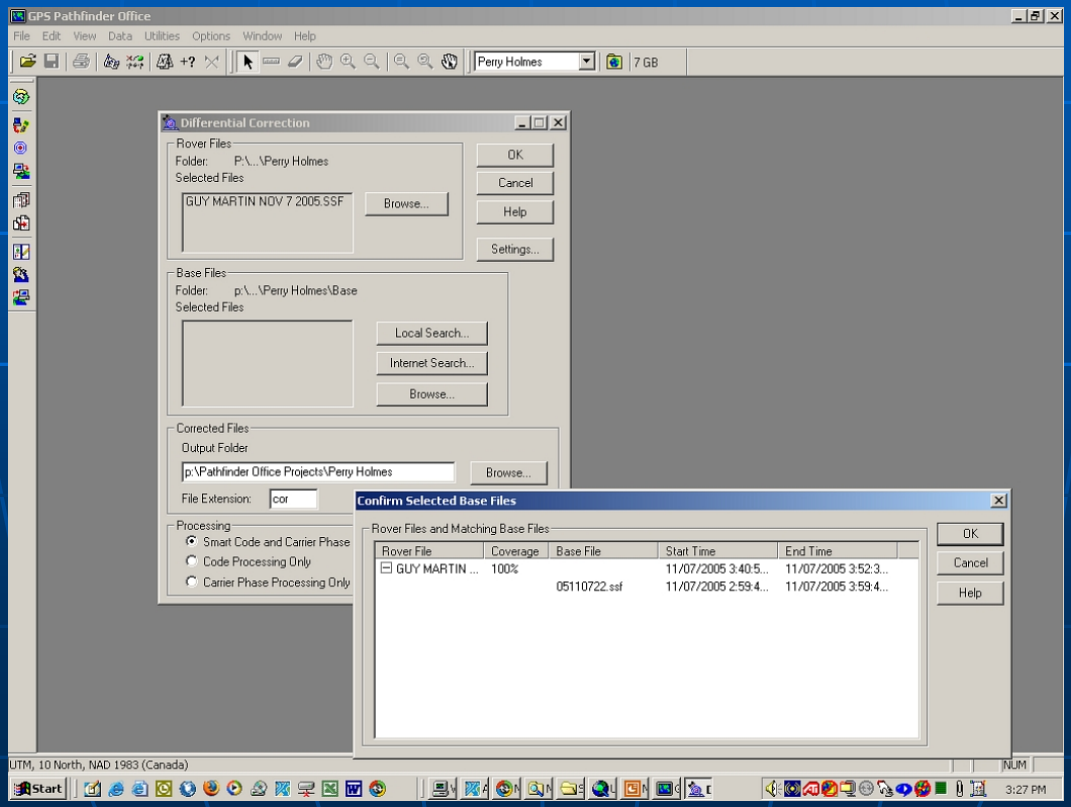
- **Post Processing,** is Differential Correction that takes place after the fact; the GPS data collected in the field is saved, and the Differential Correction is applied later.

- **RTK (Real Time Kinetics),** is Differential Correction where signals are received from the differential provider (Base), and used by the receiver (Rover) at the same time as signals from the GPS satellite are received (Rover), to calculate a much more precise position instantaneously.

- **If Differential Corrections are not applied,** then I understand accuracy will drop to +/-8 meters 95% of the time for both centimeter and sub-meter units (atmospheric, clock and orbital errors etc.), plus specific receiver inaccuracy (e.g. submeter unit add another meter, centimeter unit add 1 cm).

Post-Processing can be Simple

- **For Sub-Meter GPS, a free private Post-Processing service** is available on the internet, for users who purchase equipment from a particular Survey Equipment Supply Company.



RTK System Diagram

- **Must have a "live" communication link** (radio or cell-phone/internet) between Base Station & Rover

- **Limit distance** between Base Station and Rover:

  Approx Error = 0.1 meter for 100 km separation dist

  Rule of thumb- 40 km max for Centimeter GPS, and 200 km max for hand-held

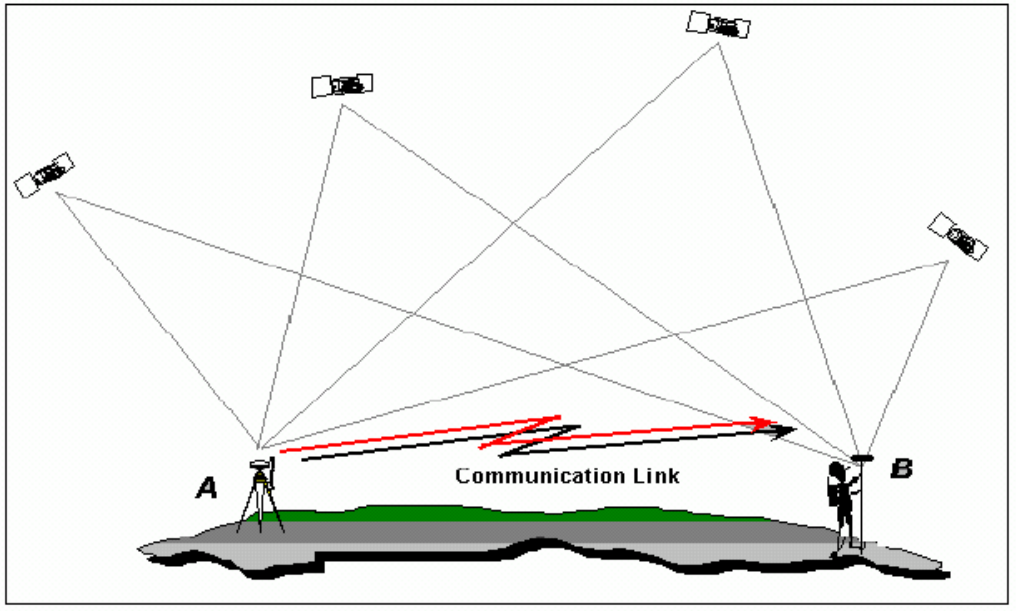


Figure 1: "Classic" RTK system diagram…A is RTK Base Station, B is RTK rover(s)

Diagram Source: srmwww.gov.bc.ca/bmgs/gsr/british_columbia_guidelines_for_rtk_gps_surveys_ver1-0.pdf

Some RTK Options

- **GVRD provides a Cell-Internet link** to GVRD Base Stations (member municipalities must pay for own internet/cell connection); Organizations that are not a member municipality, can also apply for service as an user pay system. Contact is Global Minds Inc. Application forms for this service on line at: http://srmwww.gov.bc.ca/bmgs/bcacsm/gvrd/support.htm

- **Municipal/Regional District Base Stations** (internet/cell solution) are set up or being set up on the Island (Campbell River) and Interior (Kelowna, Kamloops, and Prince George). More are investigating.

- **Survey Equipment Supplier** (Cansel 604-299-5794) offers internet/cell connection to their Base Stations for an RTK solution (user pay system)

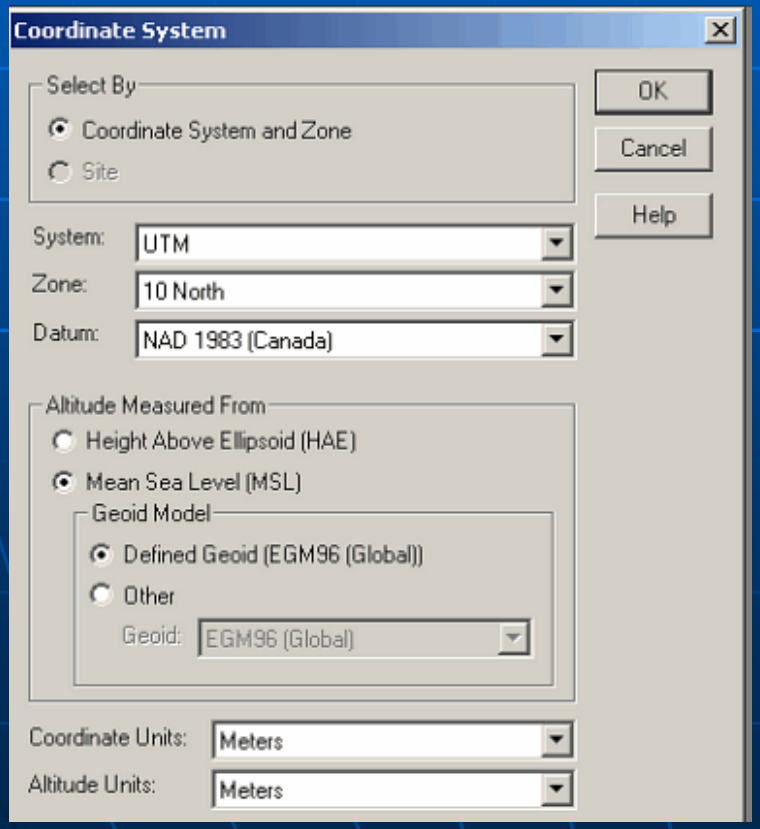
- **Set up your own GPS Base Station** need another GPS receiver, a computer, and Base software with radio link system. Antennae can be located by convention survey methods (e.g. using a Survey Total Station).

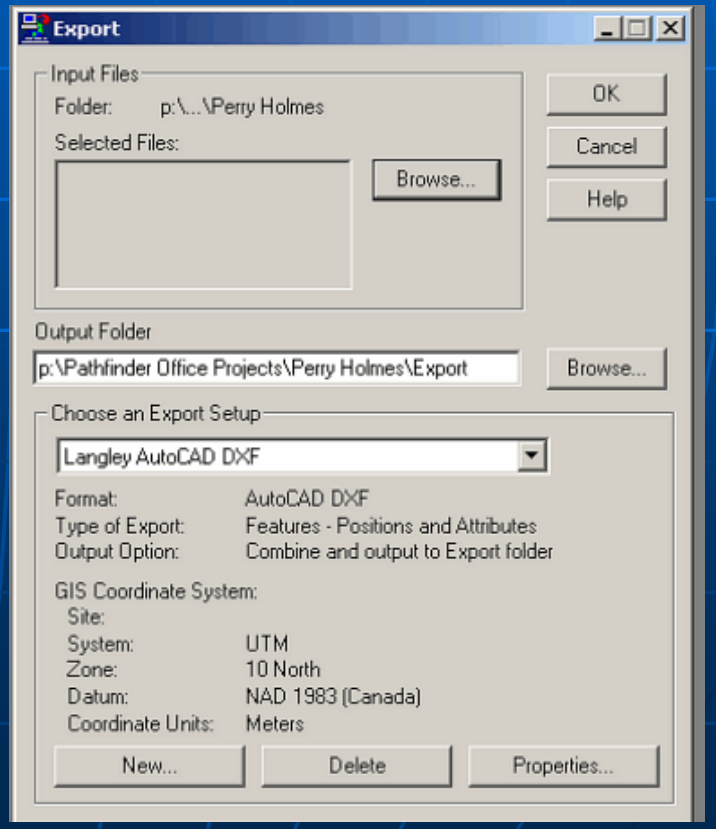
- **WAAS** (Wide Area Augmentation System) consists of approx 25 ground reference stations positioned across the USA that monitor GPS satellite data, in order to create a GPS correction message. Any WAAS-enabled GPS receiver can read this free signal in North America. Obtain < 3 meter accuracy using mapping grade GPS.

Convert GPS data collected in Lat/Long-WGS84-HAE to UTM-Nad83-MSL

- Using Vendor software, converted easily

to UTM-Nad83-MSL(EGM96-World, HT2000-Canada, HTGVRDBC00-GVRD Geoid Models), or other Coordinates/Datum/Geoid-Models, by Setting GIS-User Coordinate System & Datum & Geoid "As Defaults" . Also, easily converted to AutoCAD or Shape Files, in another step.





How City of Langley has used GPS

- **Used RTK and Post Process:** CoL used own base station and internet/cell RTK solutions, and has post-processed data.

- **Data Collected:**

  - with Centimeter GPS

  Entire Municipal Water System, ½ of City's (Electrical Utilities and Signs, Curbs, and Culverts)

  - with Sub-meter GPS

  Catch Basins, Trees, and Garbage Cans

- **GPS Data at CoL Used to:** update City Utility As-built Drawings, build Asset Data Files, create maps for contracts, and start the initial planning/review for building Enterprise Asset Management Database System

GPS Accuracy Issues

- **Precision Indicators - Standard Deviation** and others (e.g. RMS -Root Mean Square, CEP - Circular Error Probable, SEP - Spherical Error Probable etc.) stored as attributes in GPS data files.

- **Minimum Occupancy Time** (e.g. 15 seconds get 15 recordings), effectively deals with random errors of receiver, and helps with other errors.

- **PDOP - Poor Geometry (Position Dilution of Precision)**

  All satellites are at the same elevation, or satellites appear in a line, or the satellites are all close together. Set-up GPS not to collect with poor (high) PDOP. Refer to manufacturer suggested settings.

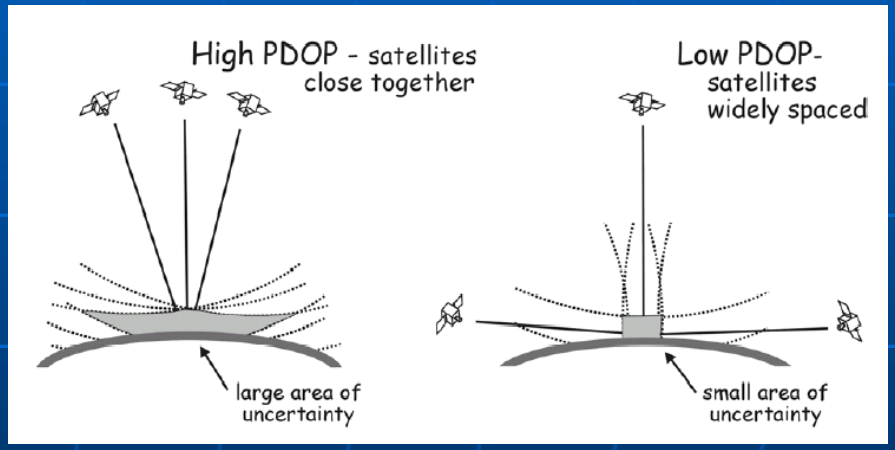


Diagram Source: www.usyd.edu.au/su/agric/acpa/GRDC/GPS%20webpage.pdf

- **SNR and Elevation Mask**

  - SNR = Signal Noise Ratio - Relationship between the usable intended signal and extraneously present noise.
  - Elevation Mask = Minimum angle the satellites are above the horizon, for a GPS measurement to occur.

  (do not set either too low – Refer to manufacturer suggested settings)

More GPS Accuracy Issues

- **Multipath (Reflected Signals)**
  Centimeter unit may not get a solution (no converges), for sub-meter unit errors tend to be filtered out (firmware), avoid low altitude satellites (Elevation Mask), id and clean with software, can use specialized antenna, perform 4 point intersection or offset as check, or can return to site to re-occupy.

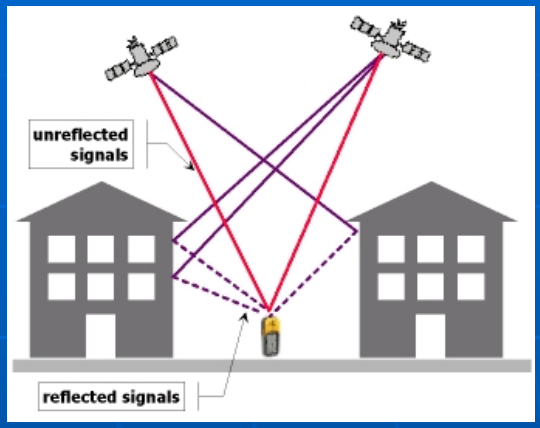


Diagram Source:www.kowoma.de/en/gps/errors.htm

- **Daily Data-Cleaning using Ortho-Photos**
  Field staff reviews the GPS data they have collected using mapping software (AutoCAD, ArcMap ect) on a PC with high resolution (10cm) ortho-photos as a background.

- **Accuracy - Occupy Integrated Survey Monuments**, if possible, a number or times throughout the day. CoL has found difference in GPS UTM coordinates to published UTM coordinates, range of 0.008 to 0.035 meters for centimeter GPS, and 0.5 to 1.1 meters for sub-meter GPS (horizontal).

- **GPS Specialist on Staff (Geomatics Tech)** that is aware of potential GPS accuracy issues and the preventative steps to take to mitigate them (e.g. settings for SNR, Elevation Mask, PDOP, number of SVs used etc.). May want to do "Site Calibration"- Establish Relationship between WGS-84 and Local Coordinates.

Other Issues

- **Do not "Water-Down" Accuracy** keep spatial precision as collected by GPS (no dropping of significant figures). Computer memory cheap now

- **Do not use Arbitrary Coordinate System**
  Makes it difficult to exchange data with other staff members/ departments and other agencies

- **Use same Cadastral Base**
  with same Datum and UTM Coordinates (or same Ground Coordinate System) through out organization (e.g. Engineering, Planning, Parks, Fire Department, etc.)

- **Collect Metadata** attributes like "operator name", "date collected", "precision attributes", "GPS-Receiver Type" etc.
  Keep all Field GPS Survey Files (may want to re-process at later date).

Down-side of GPS

- **Much More Data to Manage,**

  because of efficiency of collecting GIS data with GPS systems, one now needs to use, store, and update a lot more data.

- **Can Spend Significant Office Time (Analyze)**

  Points – Easy; Lines – Harder; Polygons - Hardest

  May need to analyze field data to correctly represent features you are mapping (e.g. "connecting-the-dots" of mapped features like water valves surveyed, to create as-built of water line system).

- **Integrate with Legacy Data - More Time**

  (Cad drawings, Modeling Software, Databases etc.)

  Legacy data is likely very important; and it may require significant effort to integrate the GPS data with Legacy Data. Evaluate if GPS is the best tool to get needed spatial data for existing modeling software or database.

GPS and Asset Management Summary

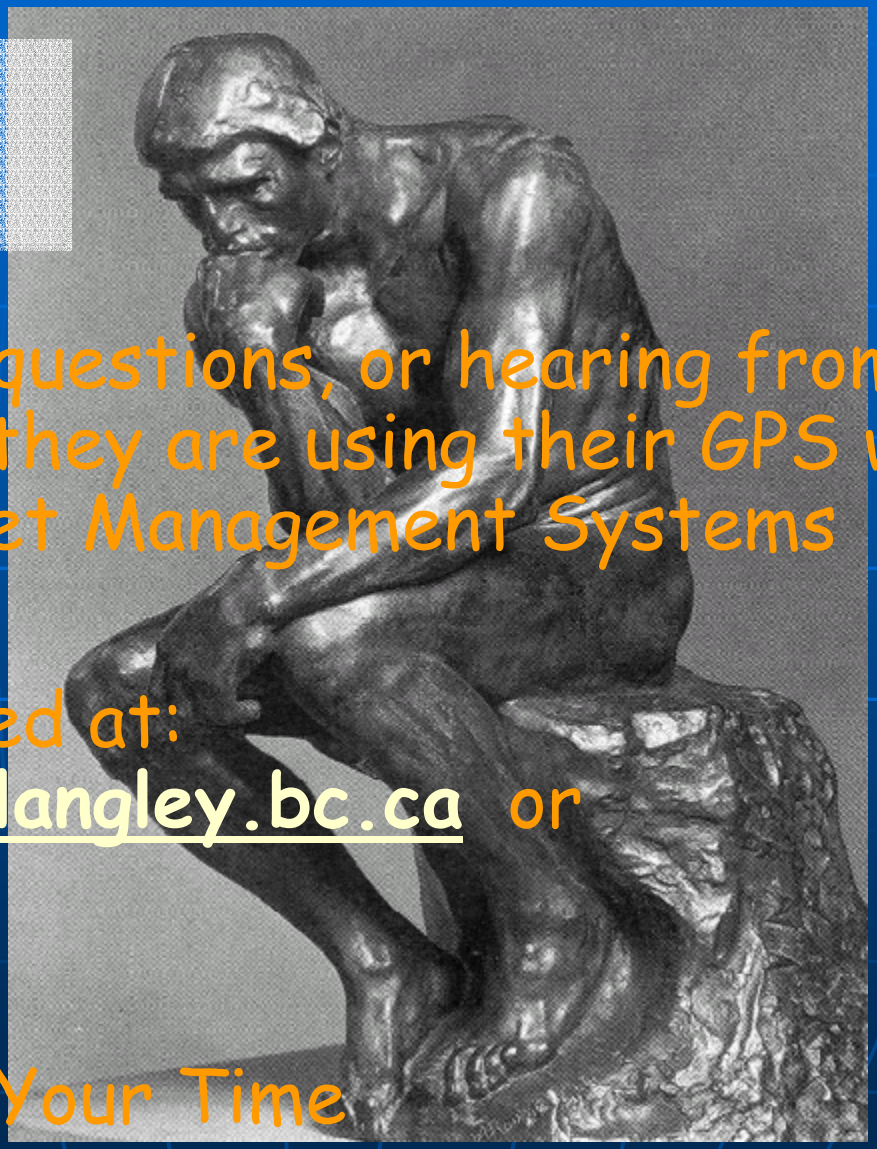
- Good Start or Augment Existing Asset Mgmt Database

- GPS Use:
  - Accurate, Fast, and Easy – Attribute Rich
  - Training: Field-limited Office-Geomatics Tech etc.
  - Do Differential Corrections (RTK or Post-Process)
  - Do Conversions (Datum & Coordinate & Geoid)
  - Use Proper Settings (PDOP, Elev. Mask, SNR etc.)
  - Do Accuracy Checks (Tie Monuments & Ortho etc.)
  - Analysis & Integration can be Time Consuming

- GPS - a GREAT Tool for GIS and Asset Management

Contact Info

GPS – "Heck… What is it Good for Again…" ?



- I welcome any questions, or hearing from others on how they are using their GPS with their GIS/Asset Management Systems
- I can be reached at: pholmes@city.langley.bc.ca or 604-514-2821
- Thank You for Your Time