

# GPS/GIS Inspection and Analysis Tools for Highway Construction



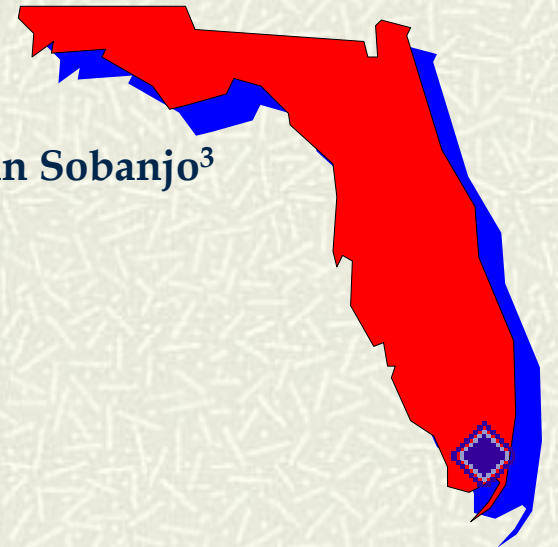
*By*  
Sastry Putcha<sup>1</sup>, Dean Bowman<sup>2</sup>, and John Sobanjo<sup>3</sup>

<sup>1</sup> FDOT Construction Office

<sup>2</sup> Bentley Systems, Inc.

<sup>3</sup> Florida State University

March 2, 2005



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Project Motivation: The Construction Inspection Process*



- # *Manual Methods Currently Being Used for Field Data Entry and Measurement of Pay Item's Quantities*
- # *Spatial (Location) Attributes of Constructed Items Not Effectively Documented (Except as Final As-Built Drawing) - Planned vs. Actual Location*
- # *Field Inspection Typically Done Based on Hardcopy Print of Drawings and Specifications*
- # *No Electronic Documentation of Inspection History*



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

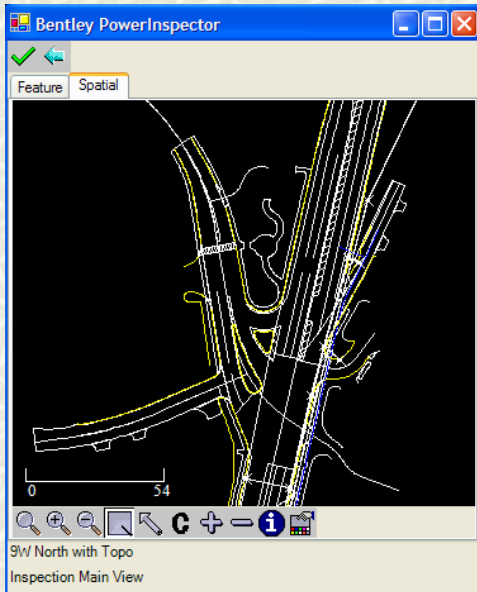
*Proposed Solutions: The Construction Inspection Process*



- *Integrated GPS/GIS Application for Inspection and Analysis*
  - *FDOT's Microstation drawings converted into Geographical Information System (GIS) Basemaps, with correction to the proper projections; Specifications; and Pay Items' Original Quantities.*
  - *Global Positioning System (GPS) Receivers Capture Pay Item Locations and Pertinent Dimensions for Quantities.*
  - *Database to Store Inspection Results: Observed Quality of Construction, Lab. Test Results, etc. and Digital Images*
  - *GIS Analyses and Database Queries Provide Monthly Display of Construction Progress and Estimate of Quantities, including As-Built Final Drawings and Quantities.*

# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Proposed Solutions: The Construction Inspection Process*



## # Customization of the Bentley® Construction Handheld for Florida DOT Pay Items

- Access to Design Data While the Inspector Observations Are Recorded at the Most Convenient Time and Location - in the Field While Construction Is Occurring
- Subsequent Manual Calculations in the Office Are Often Not Longer Necessary.
- Incessant Filling Out of Forms and Transcribing Is Reduced.
- A Complete Compendium of All Previous Inspection Activities Is Readily Available to Inspectors While in the Field. Reviews Can Be Stratified by One or More Inspectors, Date Ranges and Type of Inspection Activity.



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Project Objectives*

**Develop tools, based on modern technologies that can be used by the FDOT for inspection of ongoing roadway and bridge construction projects**

- *Integration of Global Positioning System (GPS) and Geographic Information System (GIS) to Model Temporal Spatial Data and Pay Item Attributes on the Construction Site; GIS-Based Analyses to Estimate Quantities, Display As-Builts and Digital Images.*
- *A Pilot Study Using the Bentley Construction Handheld Software to Perform Certain Specialty Inspections Such As Bituminous Materials, Concrete Placement and Pile Driving Information.*

# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Project Tasks:*

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- # *Project Kickoff and Literature Review*
  - # *Develop Framework and Methodology of GPS/GIS Tools*
  - # *Data Review and Preparation for the Pilot Study*
  - # *Develop Computer Programs for Bentley Construction Handheld*
  - # *Develop Computer Programs for GPS/GIS Tools*
  - # *Conduct Pilot Study*
  - # *Analyses of Data and Results*
  - # *Final Report*
-



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Project Tasks: Details*

---

- *Project Kickoff and Literature Review*
    - *Identify State-of the Art.*
    - *Visit Project Pilot Site and Collect Preliminary Data.*
    - *Identify Pertinent Pay Items for Study.*
  - *Develop Framework and Methodology of GPS/GIS Tools*
    - *Selection of GPS Receivers and Accuracy Enhancement (Correction) Methods.*
    - *Establish Interoperability Between CAD (Bentley's Microstation) and ESRI's GIS Formats.*
    - *Database Structure Based on FDOT Pay Items and Pertinent Attributes: Method of Construction; Unit and Method of Measurement; and Basis of Payment.*
-

# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Project Tasks: Details*

---

- *Data Review and Preparation for the Pilot Study*
    - *SR 817 University Drive Project.*
    - *Request for Project Contract Documents (Drawings and Specifications).*
    - *Review and Transfer of Project Data Files: Microstation Files, GEOPAK Geometry File (GPK), Drainage Database, and Quantity Manager Database.*
  - *Develop Computer Programs for Bentley Construction Handheld*
    - *Custom VB.NET Applications for Standard FDOT Report and Specialty Inspections.*
-



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Project Tasks: Details*

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- # *Develop Computer Programs for GPS/GIS Tools*
    - *Computer Programs to Customize the GIS Software, Enabling Both Data Capture With the GPS Receivers and Also Conducting Analyses to Generate Tabular and Graphic Reports .*
  - # *Conduct Pilot Study*
    - *GPS Data Capture of Constructed Pay Items.*
    - *Use of Bentley's Construction Handheld to Inspect Constructed Pay items.*
  - # *Analyses of Data and Results*
    - *Processing of GPS Data and GIS Analyses.*
    - *Integration of GPS/GIS Tools and Bentley's Construction Handheld.*
  - # *Final Report*
-



# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Pilot Project Site:*



- # **State Road: 817 (University Drive)**
- # **Financial Project: ID 228079-1-52-01**
- # **County/Section: Broward / 86220**
- # **Limits: North of SR-84 to just South of Broward Blvd (SR-842)**
- # **Description: Milling and Resurfacing**



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*





# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*1-Day Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*

- *Meeting with Resident Engineer:*
  - *Project Overview, and Overall Progress Update.*
  - *Review of Resident Engineer's Diaries: Measurement of Pay Item Quantities.*
  - *Resident Engineer's Opinions and Needs Regarding Proposed Research: Review of Pertinent Pay Items.*
  - *Site Tour With Resident Engineer.*
- *Collection of GPS Data at Broward Blvd. End of Project*
  - *FDOT Survey Control Point; Point Feature Pay Item; Line Feature Pay Item; and Area Feature Pay Item.*
- *Preliminary Data Transfer and Display*
  - *Microstation - GIS Basemap Conversion; GPS Data Correction Process; Integration of GPS Data with GIS Basemap; Observed Accuracies and Discrepancies.*



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

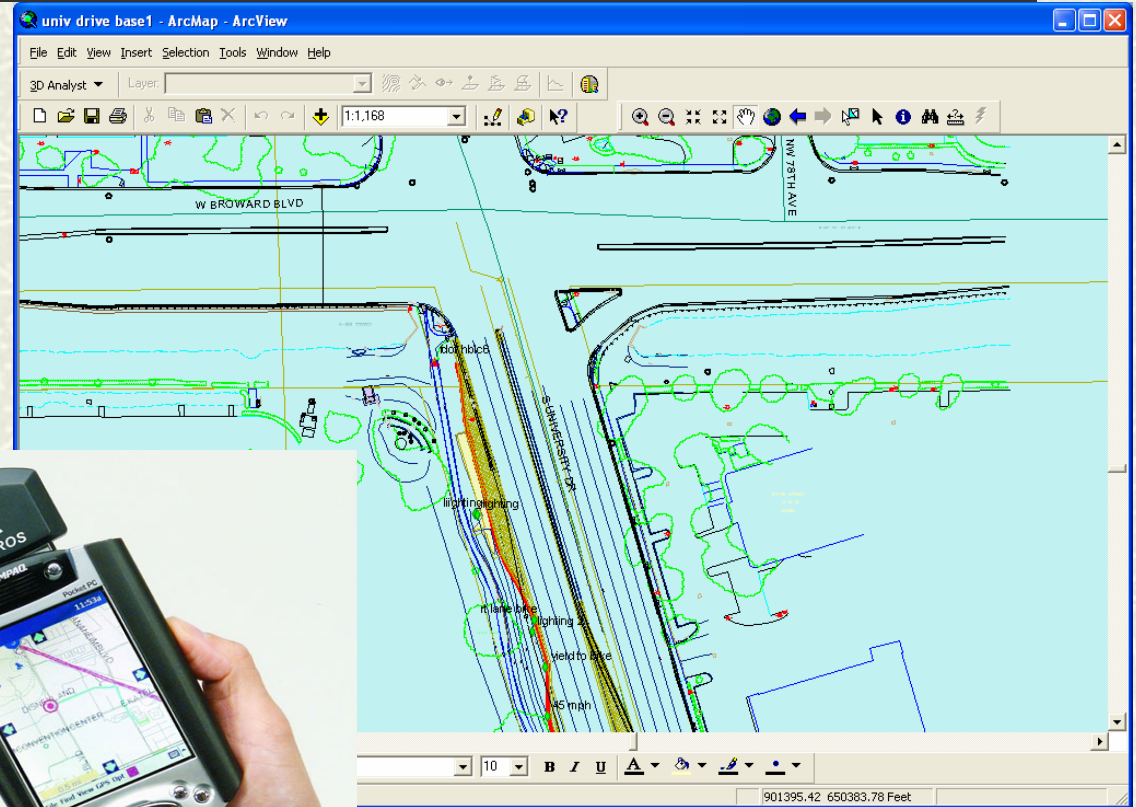
*Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*



**Trimble GeoXT GPS Receiver (\$4,000)**



**Compaq Pocket PC (\$300) with Pharos GPS Receiver (\$150)**



**Project Drawing Converted to GIS Basemap**

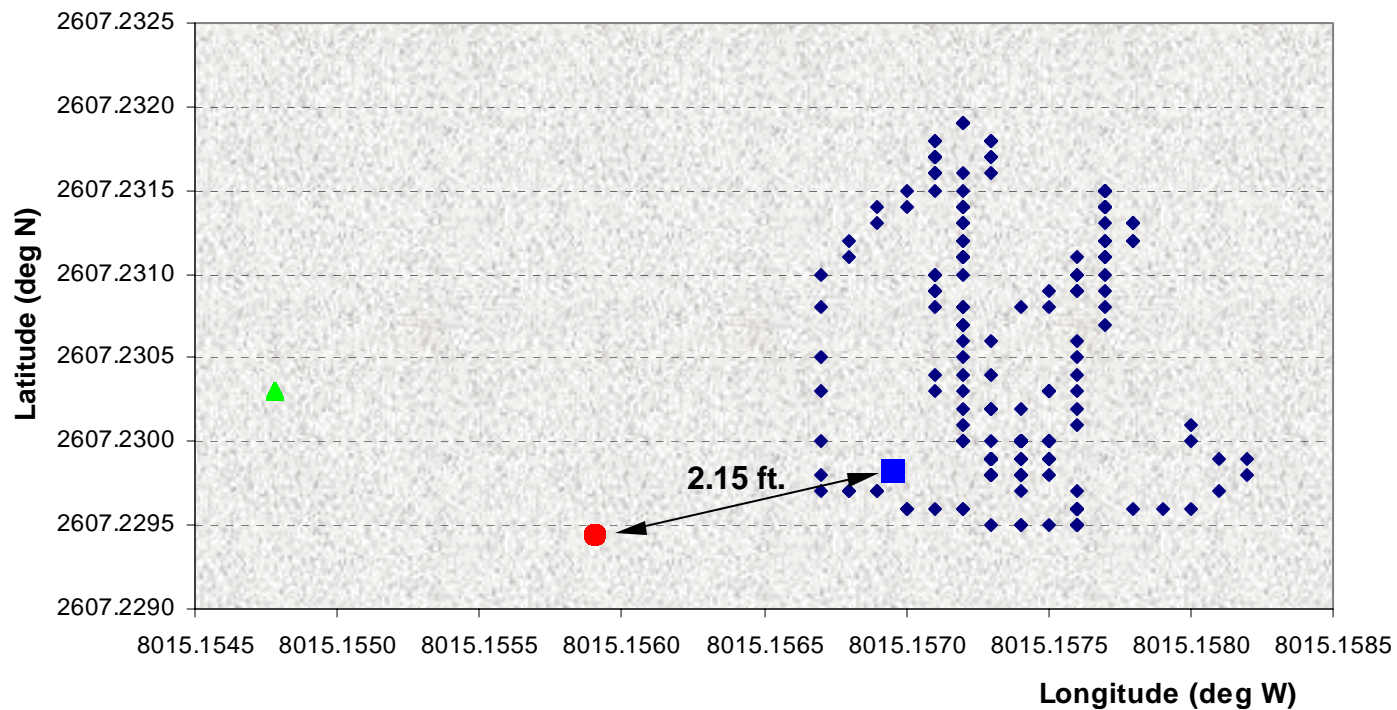
# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at*

*SR 817 University Drive, Fort Lauderdale, Florida*

## Variation in (X,Y) Data at FDOT Survey Control Point (HBLC6)\*

\*To be used for Vertical Control Only



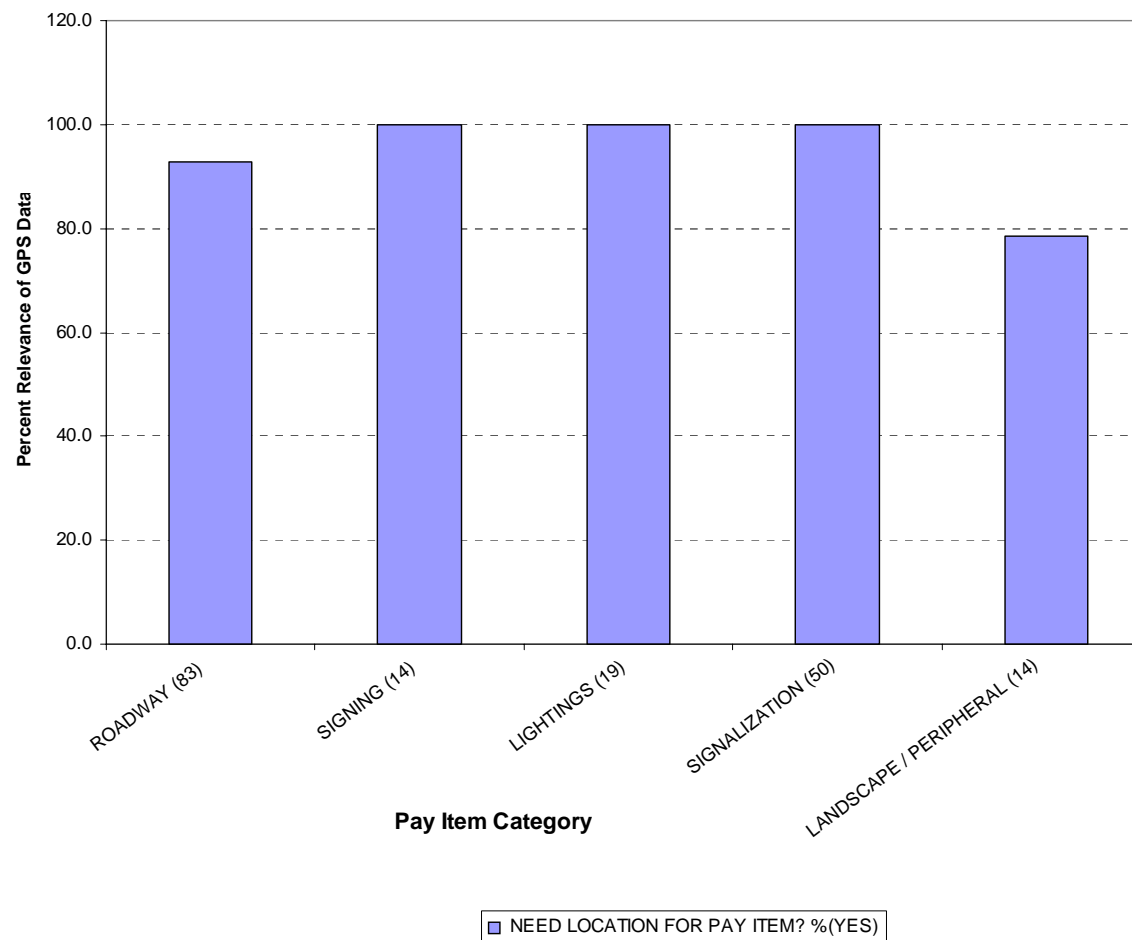
◆ Raw Teletype 'Cheap' GPS   ● FDOT Survey Reference Control Point   ▲ Trimble GPS Uncorrected   ■ Trimble GPS Corrected



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*

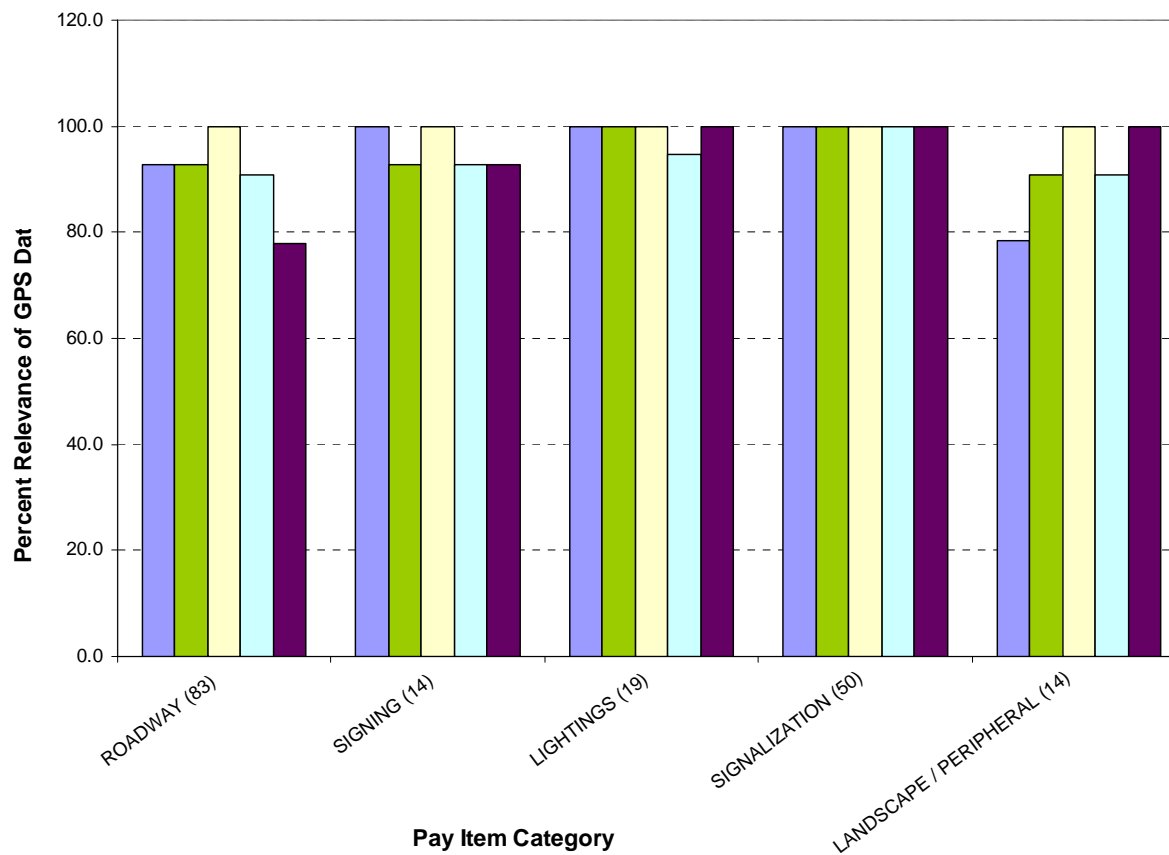
Evaluation of Pay Items for Spatial Location Data Relevance



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*

**Evaluation of Pay Items for Spatial Data Relevance**



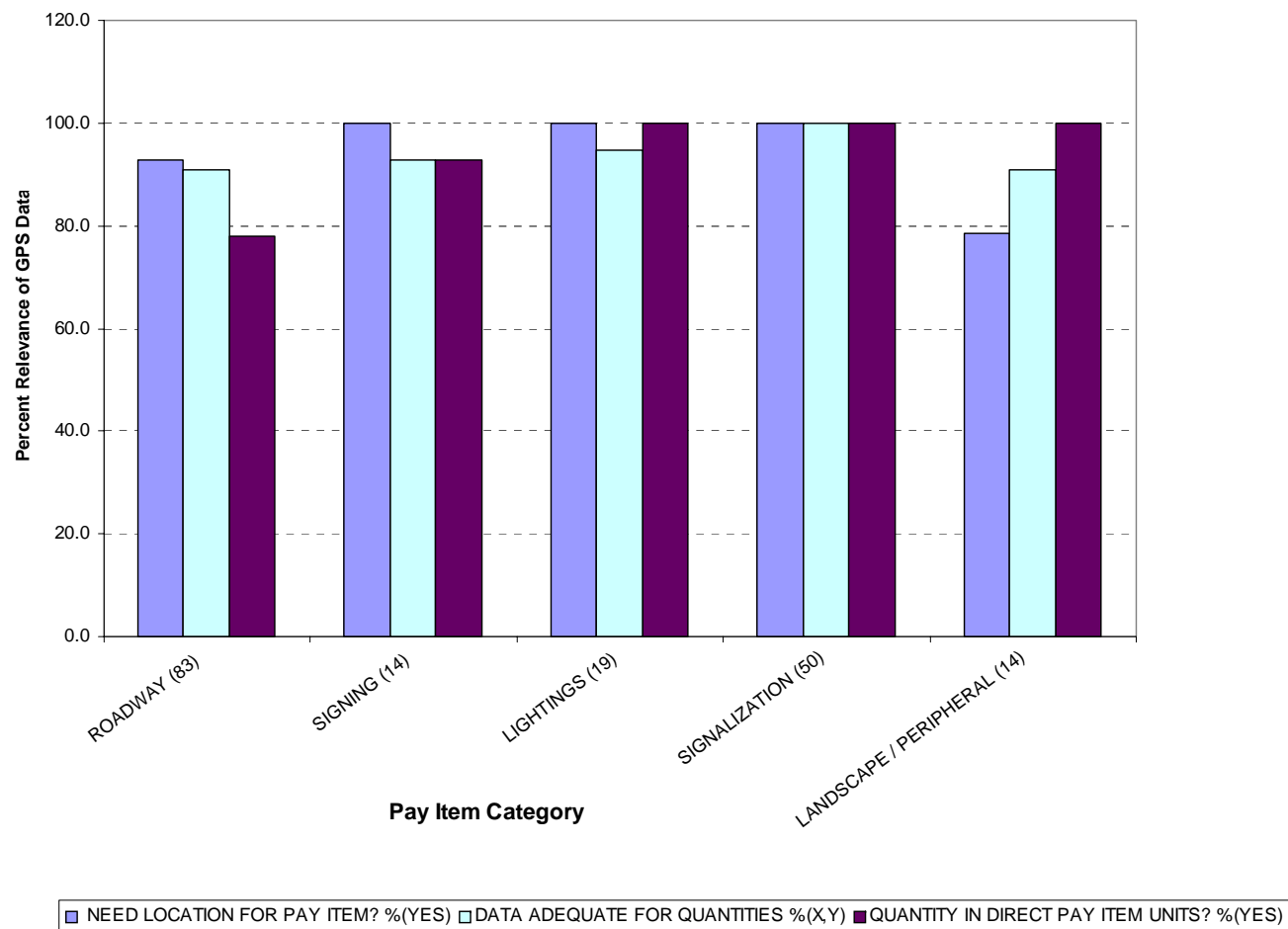
■ NEED LOCATION FOR PAY ITEM? %(YES)     
 ■ SPATIAL DATA NEEDED FOR QUANTITIES? %(YES)     
 ■ DATA NEEDED FOR LOCATION %(X,Y)  
■ DATA ADEQUATE FOR QUANTITIES %(X,Y)     
 ■ QUANTITY IN DIRECT PAY ITEM UNITS? %(YES)



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*

Evaluation of Pay Items for Spatial Data Relevance



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida*

	<b>SPATIAL DATA RELEVANT FOR LOCATION? %(YES/NO)</b>	<b>SPATIAL DATA NEED FOR LOCATION %(X,Y)/(X,Y,Z)</b>	<b>SPATIAL DATA RELEVANT FOR QUANTITIES? %(YES/NO)</b>	<b>SPATIAL DATA NEED FOR QUANTITIES %(X,Y)/(X,Y,Z)</b>	<b>DIRECT PAY ITEM UNITS %(YES/NO)</b>
0001 SUMMARY OF ROADWAY (83)	92.8 7.2	100.0 0.0	92.8 7.2	90.9 9.1	77.9 22.1
0002 SUMMARY OF SIGNING (14)	100.0 0.0	100.0 0.0	92.9 7.1	92.9 7.1	92.9 7.1
0003 SUMMARY OF LIGHTINGS (19)	100.0 0.0	100.0 0.0	100.0 0.0	94.7 5.3	100.0 0.0
0004 SUMMARY OF SIGNALIZATION (50)	100.0 0.0	100.0 0.0	100.0 0.0	100.0 0.0	100.0 0.0
0005 SUMMARY OF LANDSCAPE / PERIPHERAL (14)	78.6 21.4	100.0 0.0	90.9 9.1	90.9 9.1	100.0 0.0



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at  
SR 817 University Drive, Fort Lauderdale, Florida*

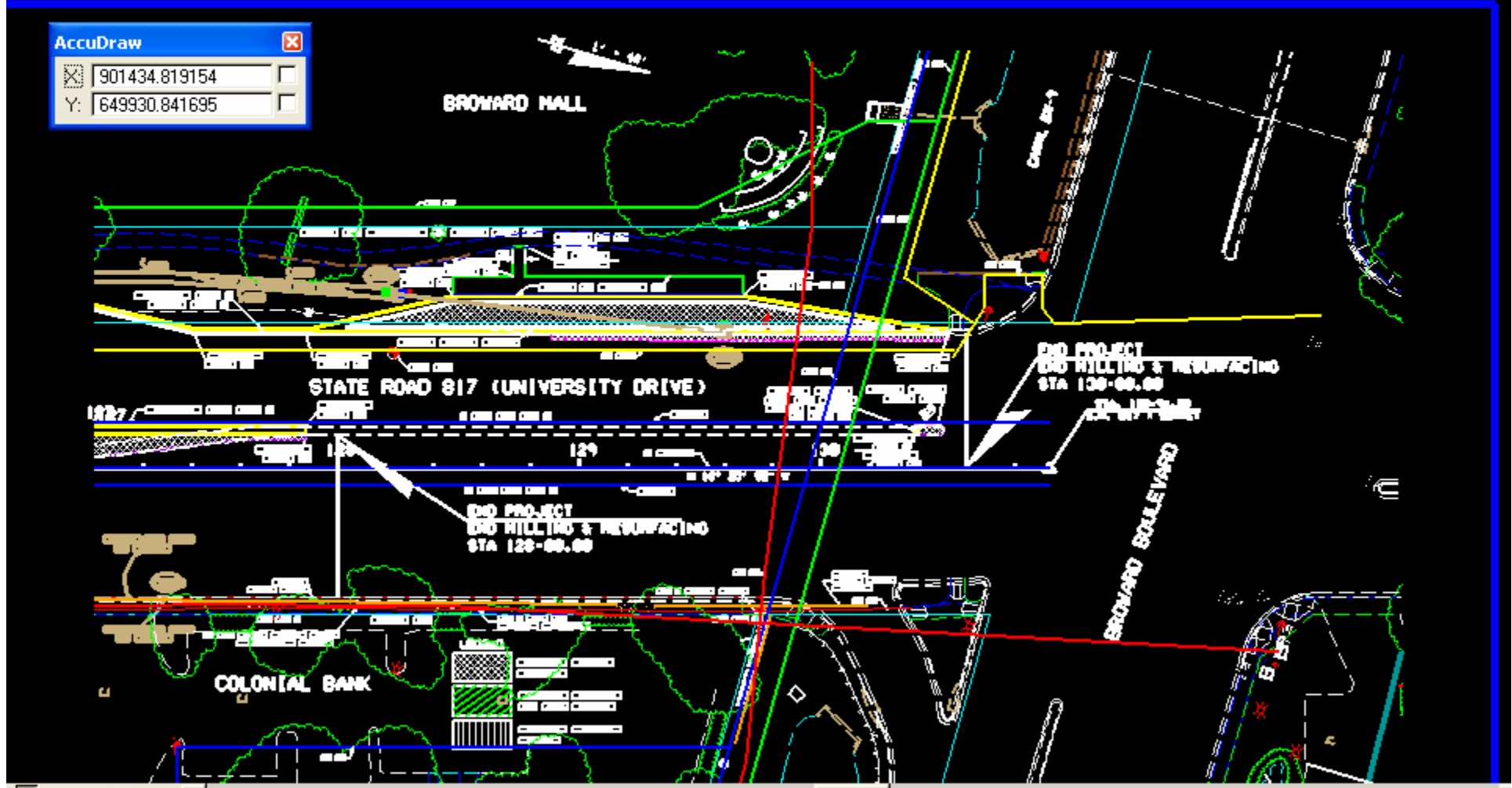
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*Following Slides Show Microstation Drawings  
for Some Pay Item Locations*

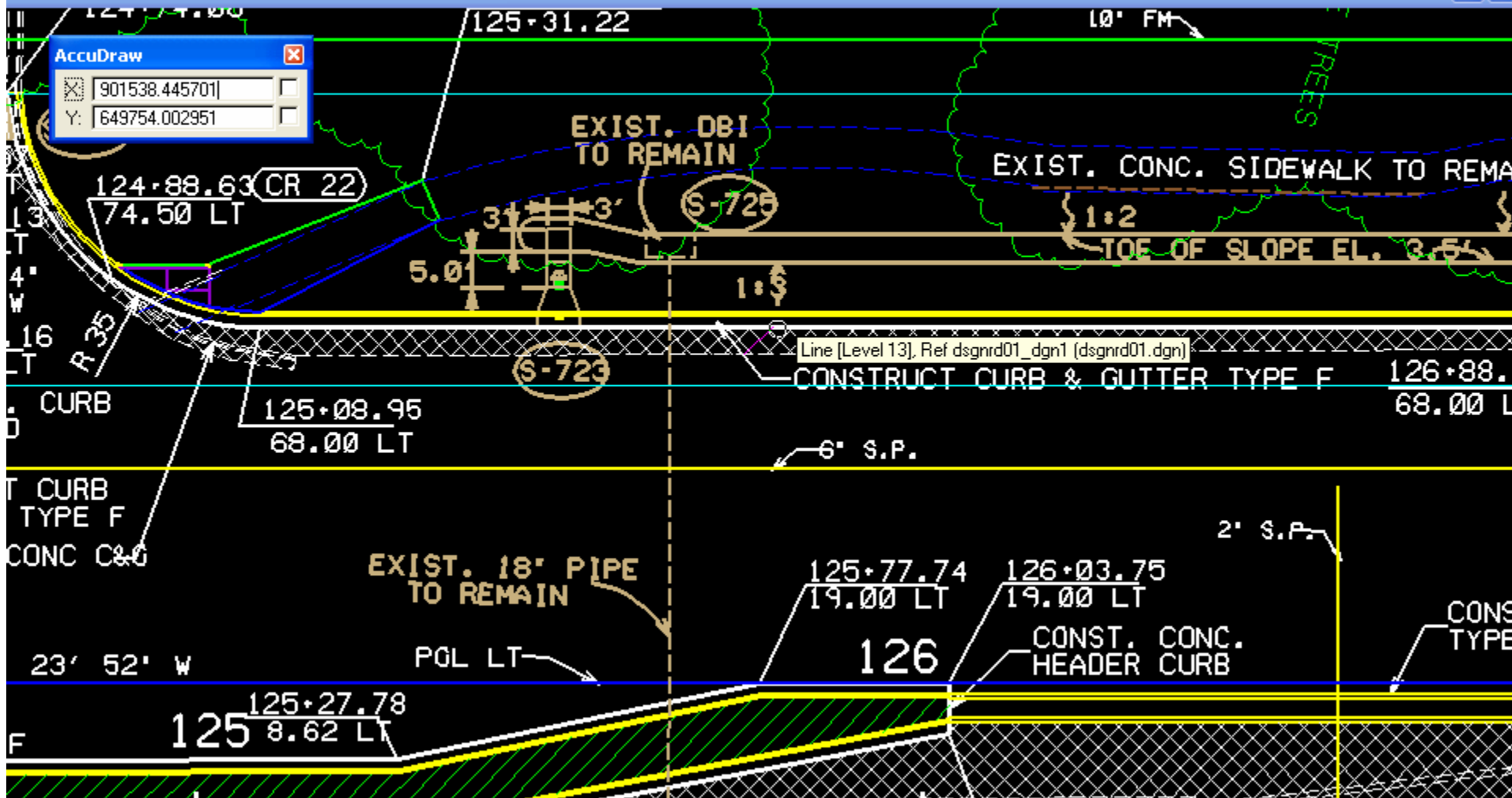
- \* Sidewalk/Bus Stop Concrete Slab*
  - \* Traffic Signs*
  - \* Curb and Gutter*
-

**AccuDraw**

X:	901434.819154	<input type="checkbox"/>
Y:	649930.841695	<input type="checkbox"/>





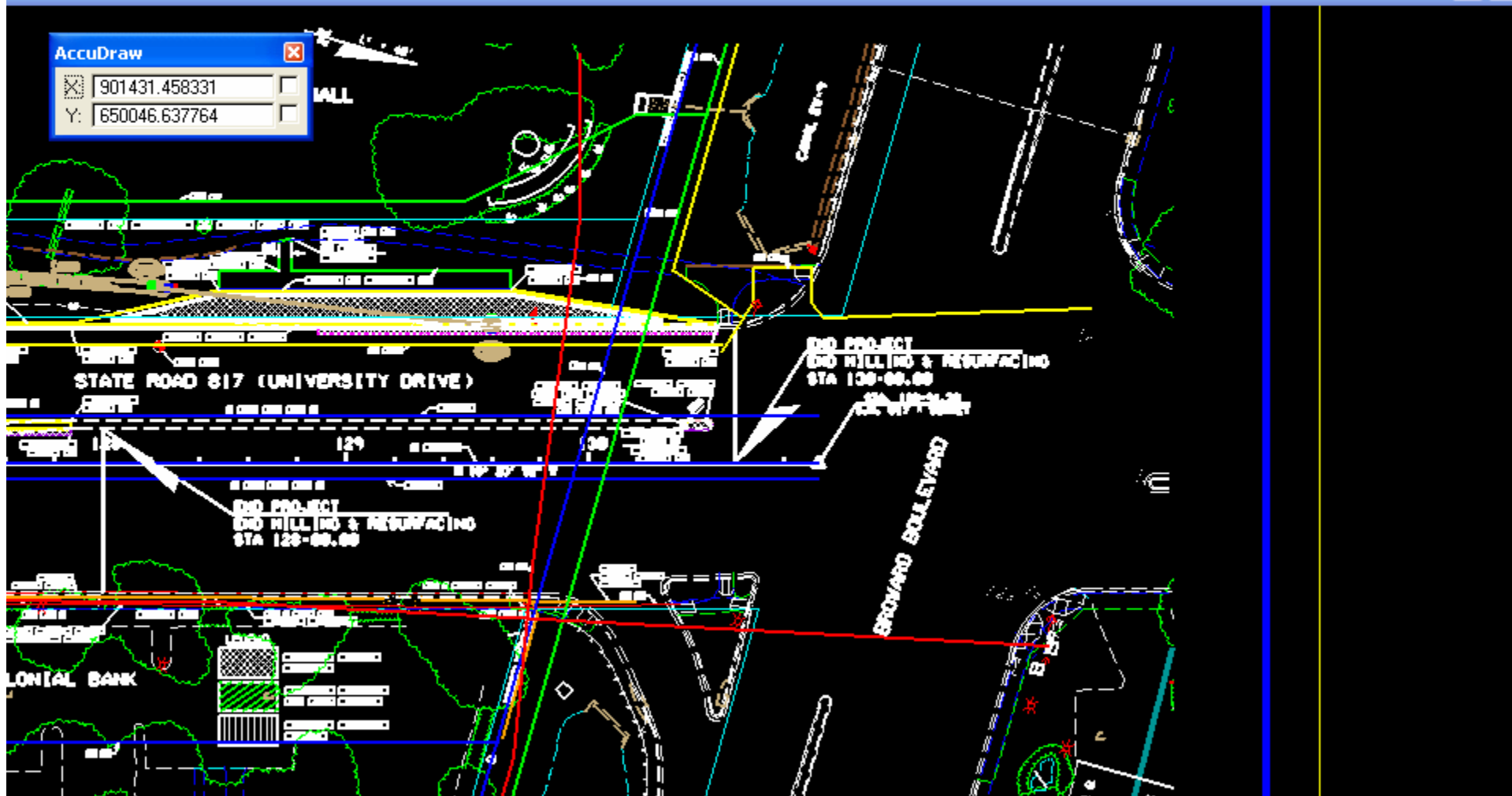








View 1







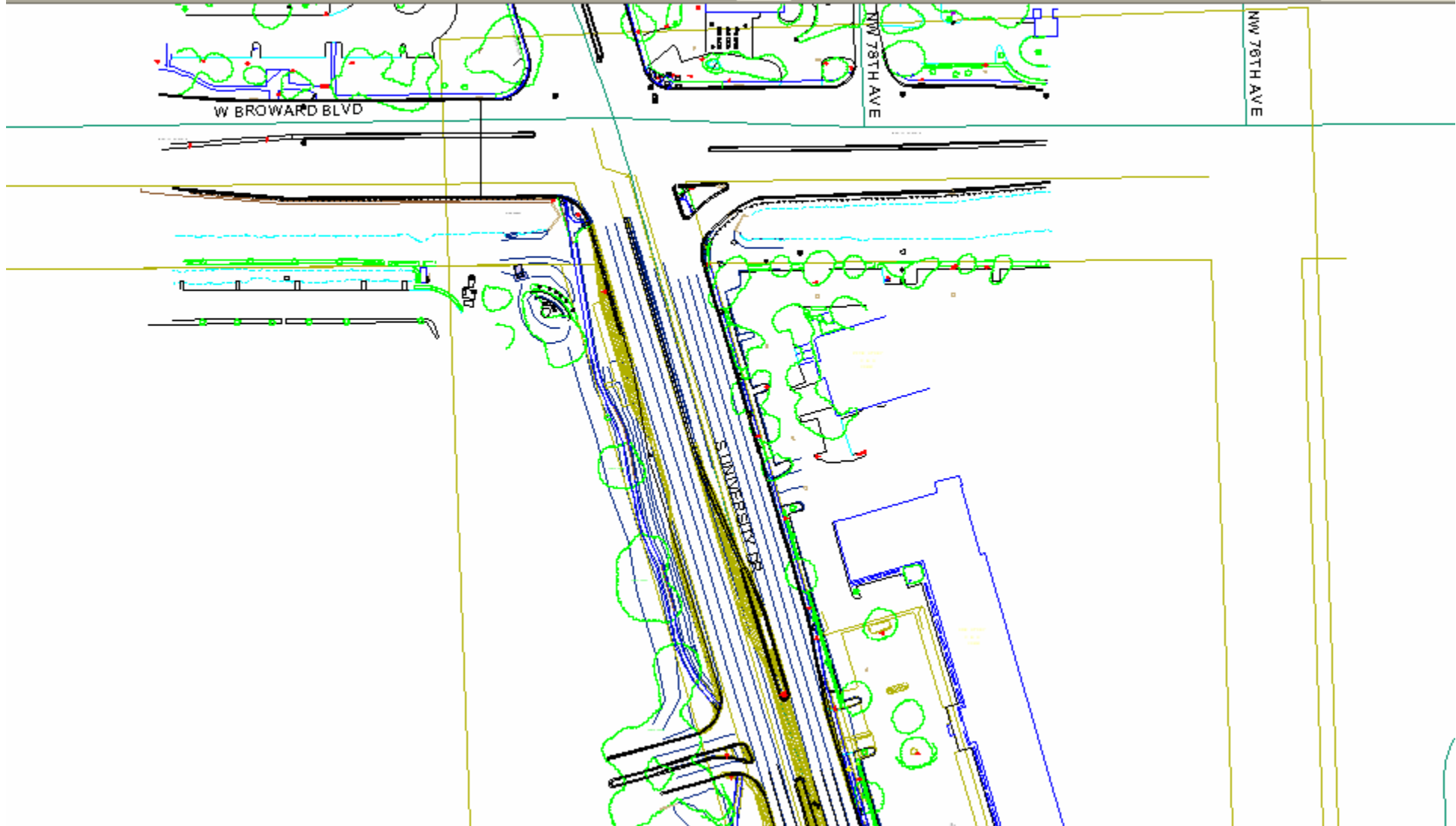
# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at  
SR 817 University Drive, Fort Lauderdale, Florida*

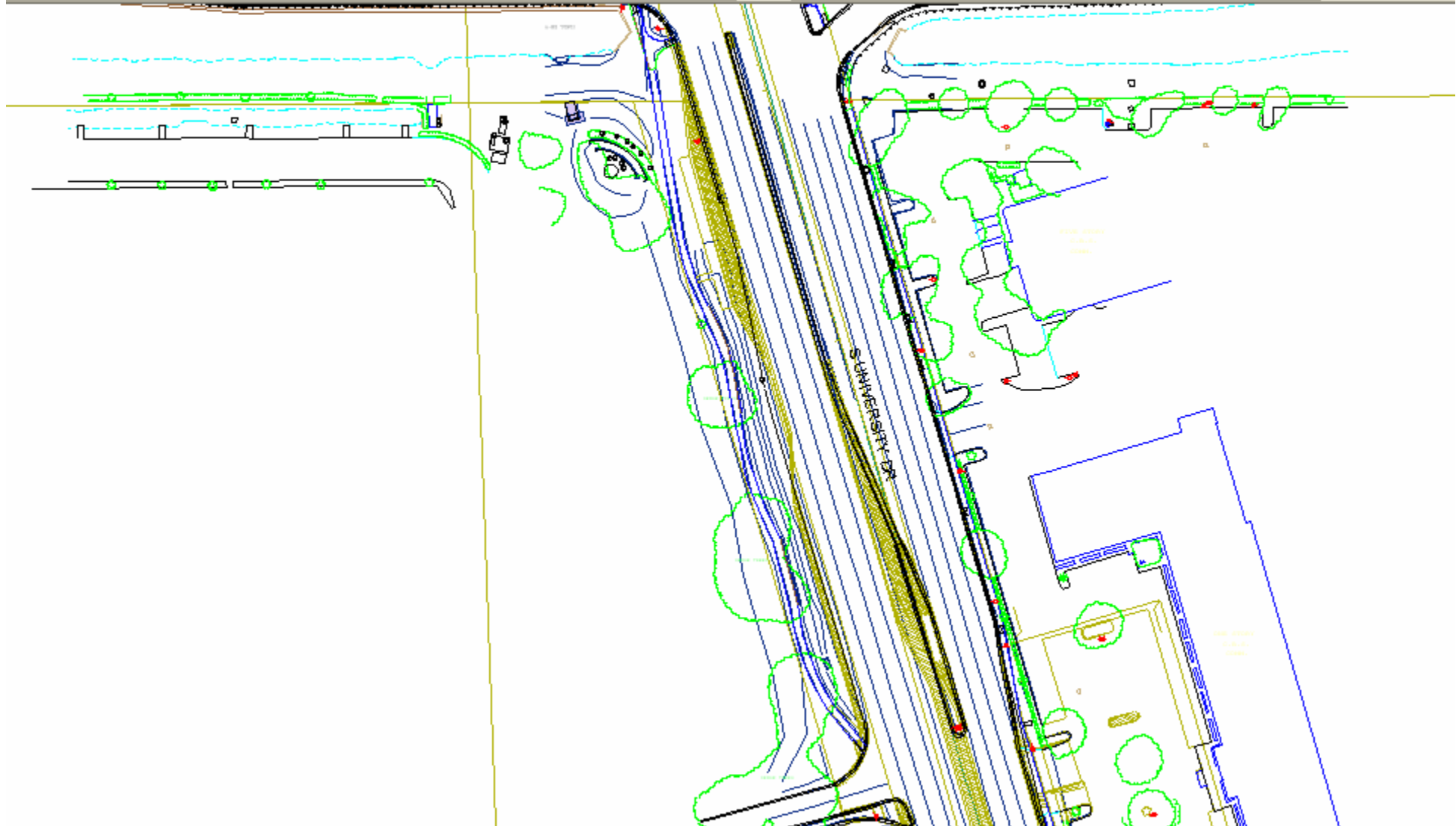
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*Following Slides Show Some Pay Item Locations  
on the GIS Basemaps, Including Trimble  
GeoXT GPS Differential-Corrected Locations  
Relative to the Original Drawings' Locations*

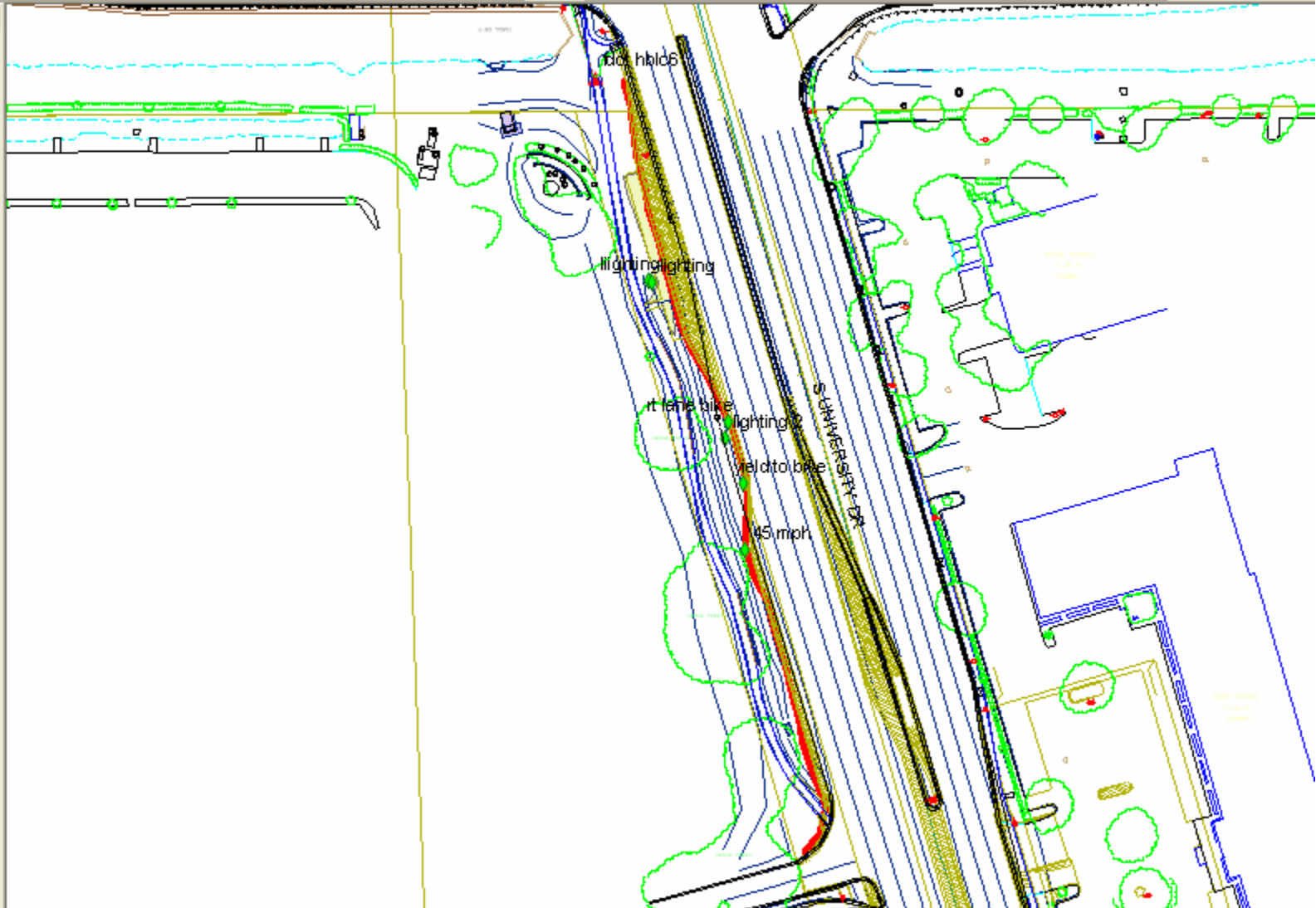
- \* Sidewalk/Bus Stop Concrete Slab*
  - \* Traffic Signs*
  - \* Curb and Gutter*
-



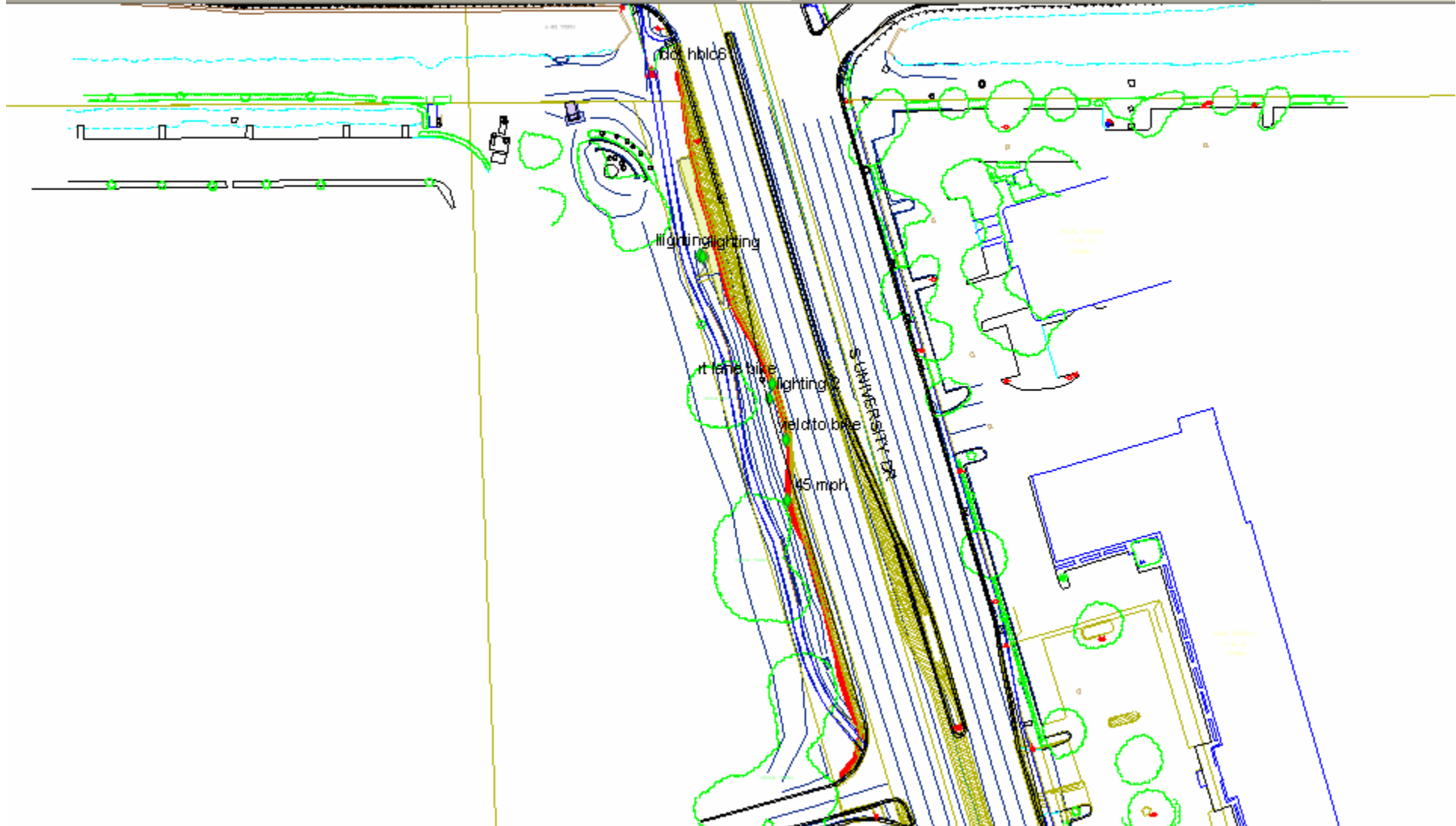




- Layers
- planrd09.dgn Annotat
- 817topor.dgn Annotat
- topogra.dgn
- Point\_ge2
- 102-61\_B
- planrd09.dgn Point
- 817topor.dgn Point
- dsgnrd01
- 520-2-4\_
- planrd09.dgn Polyline
- 817topor.dgn Polyline
- streets
- Area\_gen2
- Area\_gen
- planrd09.dgn Polygon
- 817topor.dgn Polygon
- sectgrid

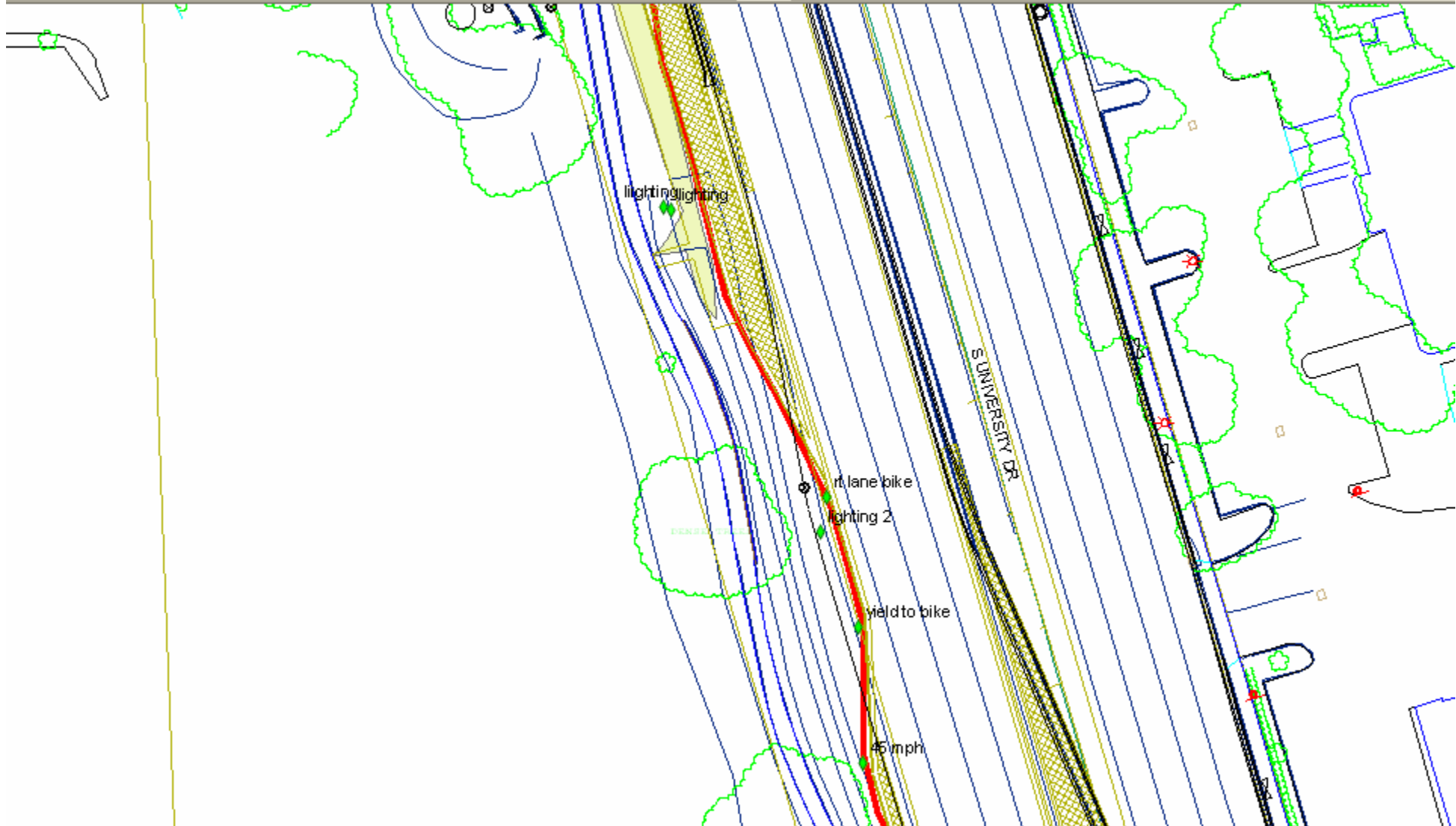


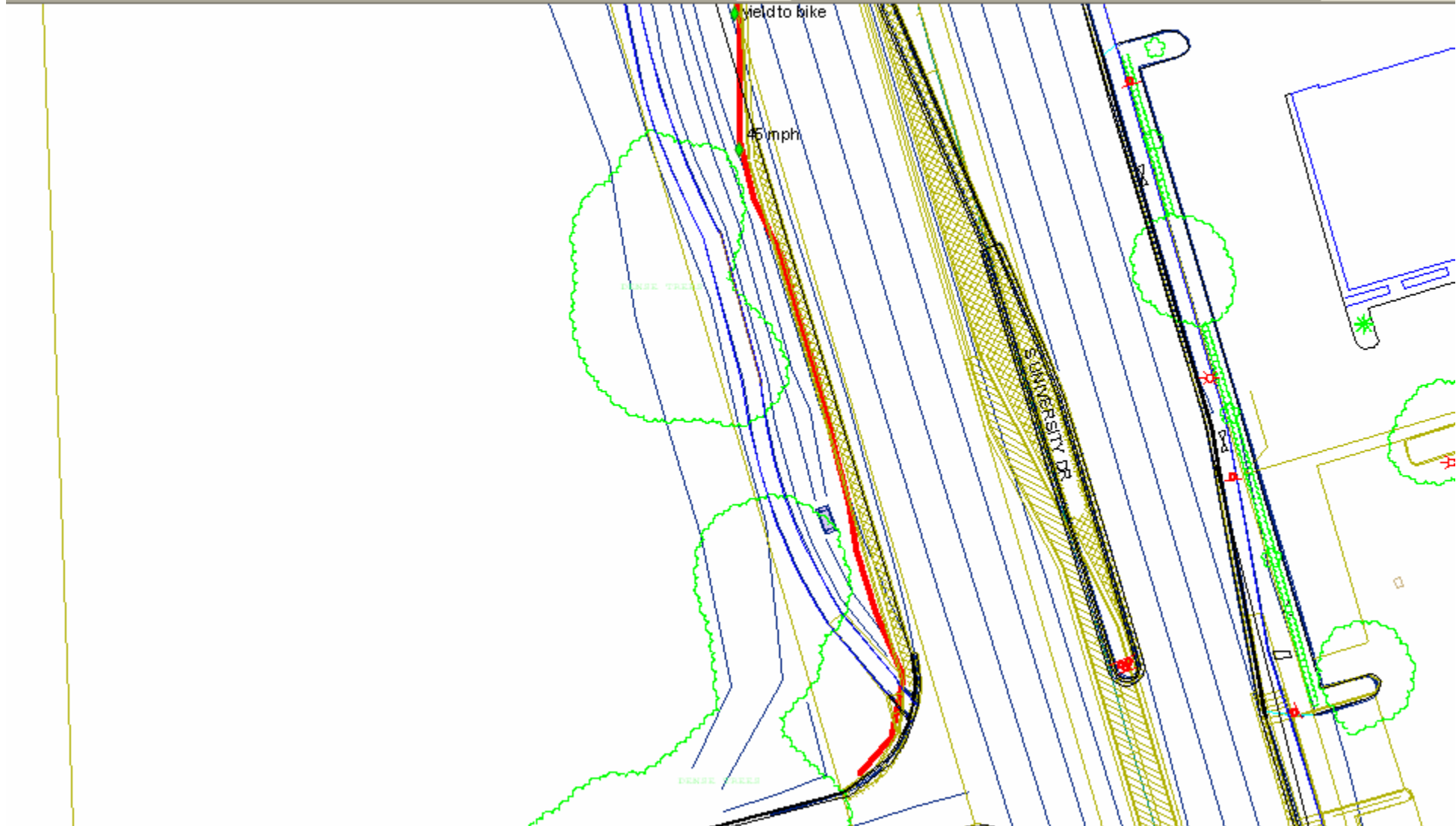




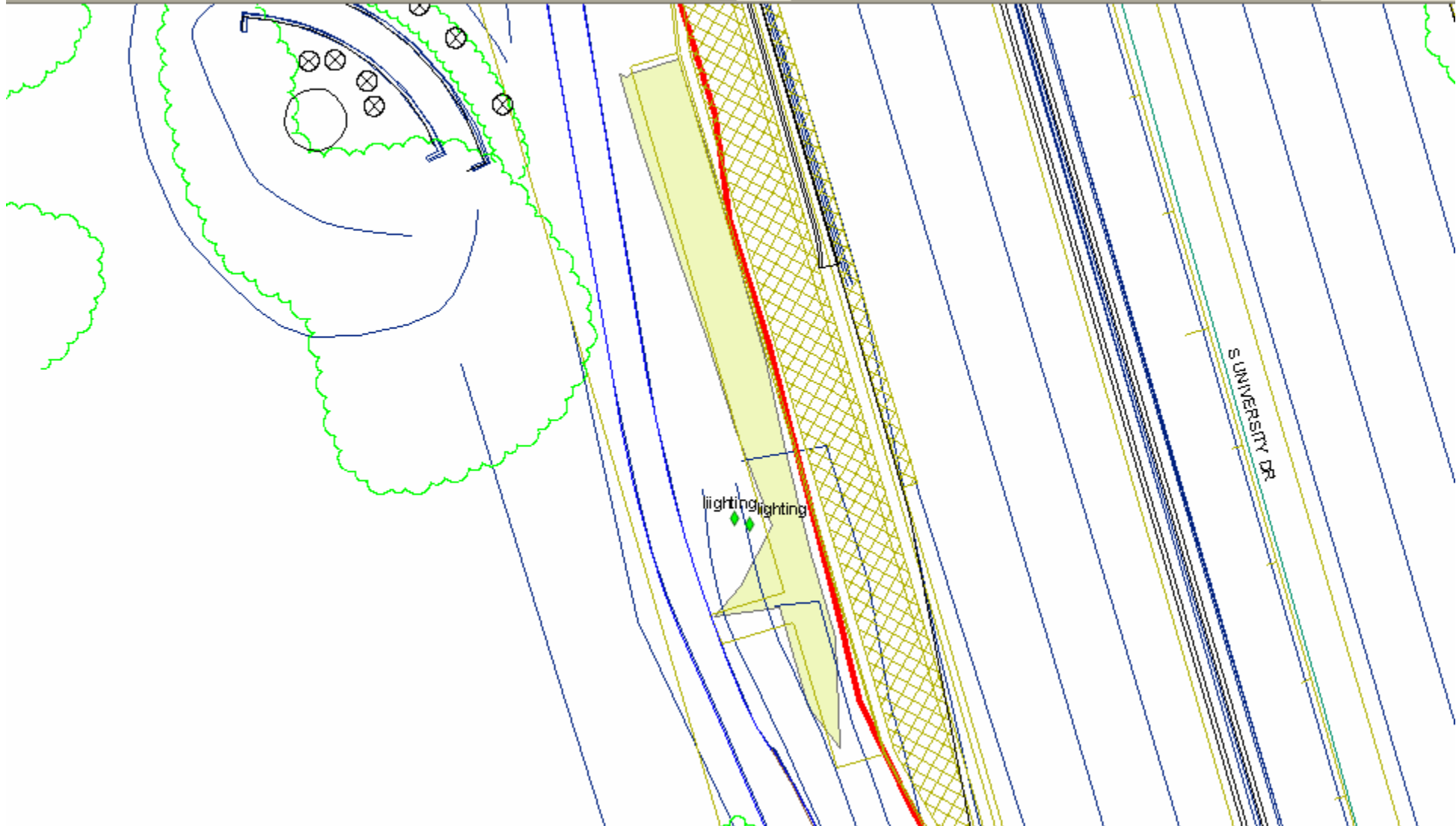


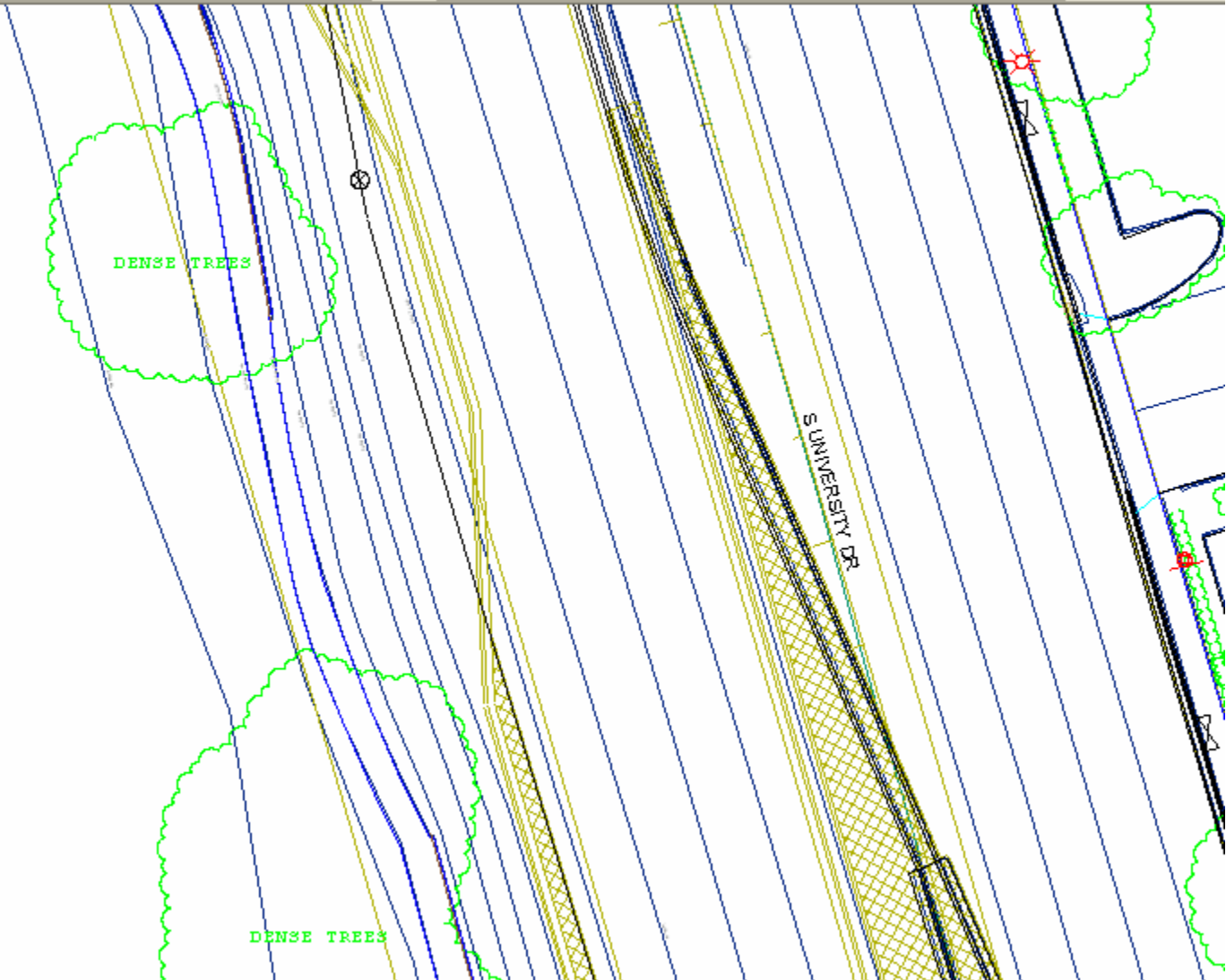


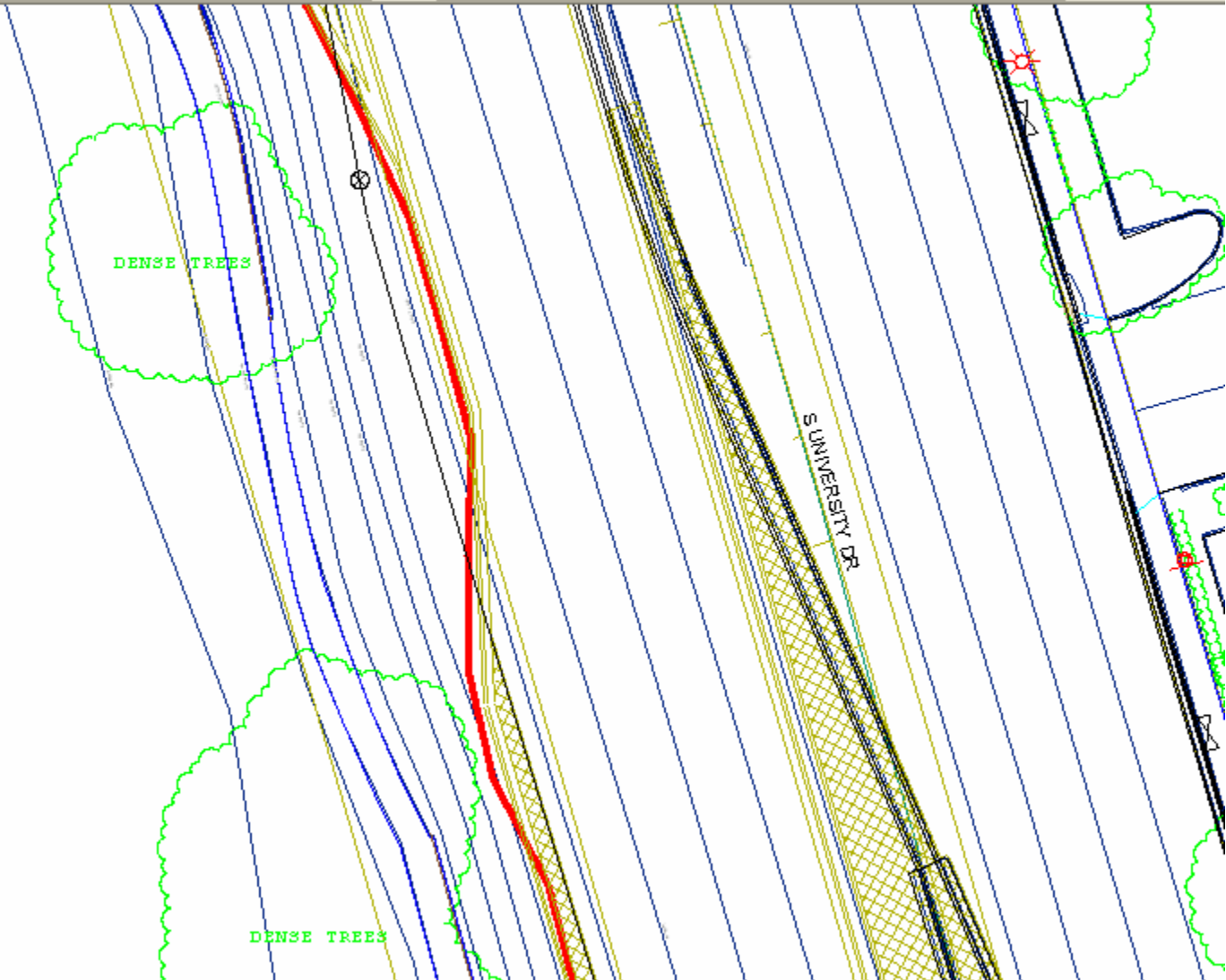




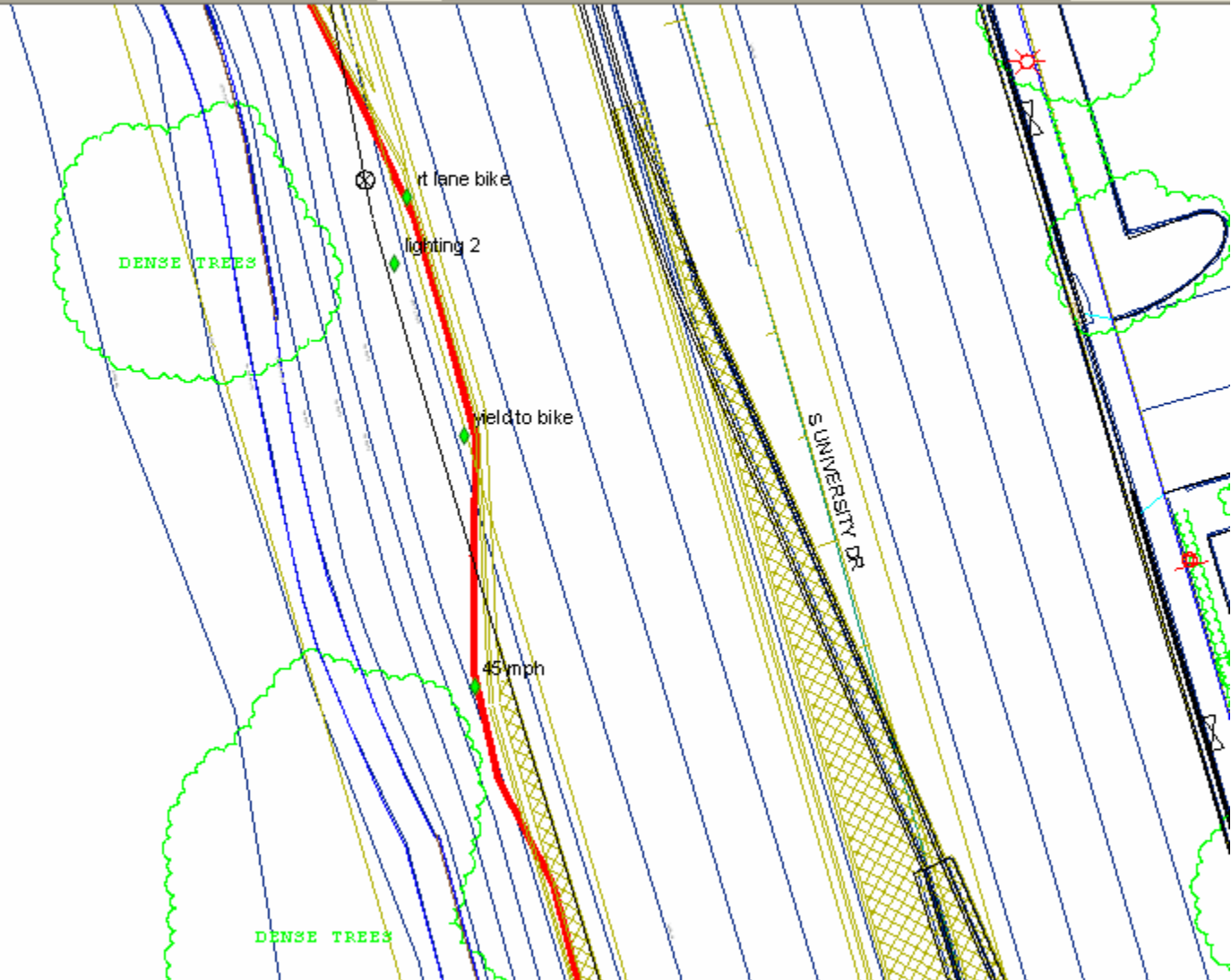


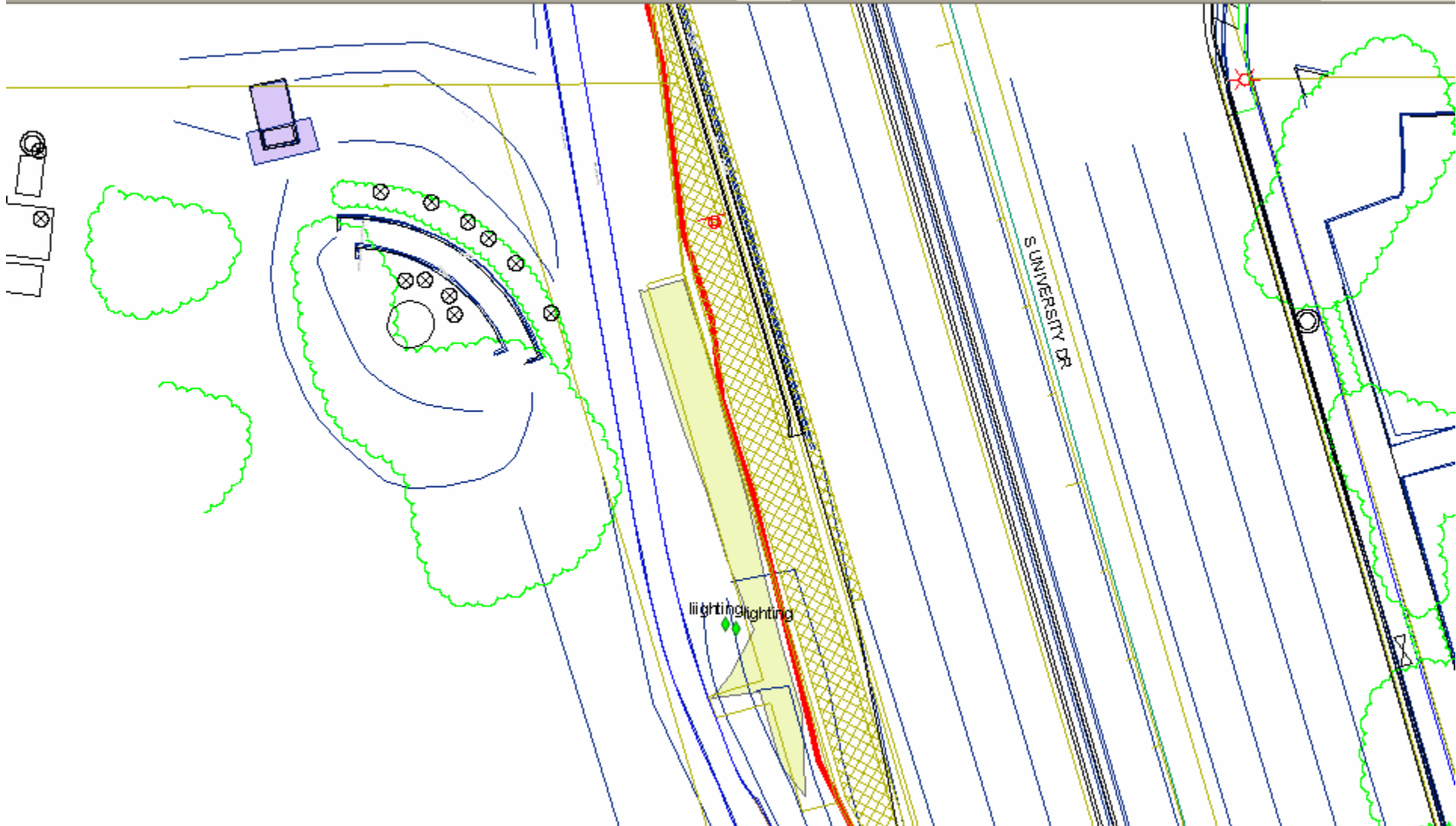


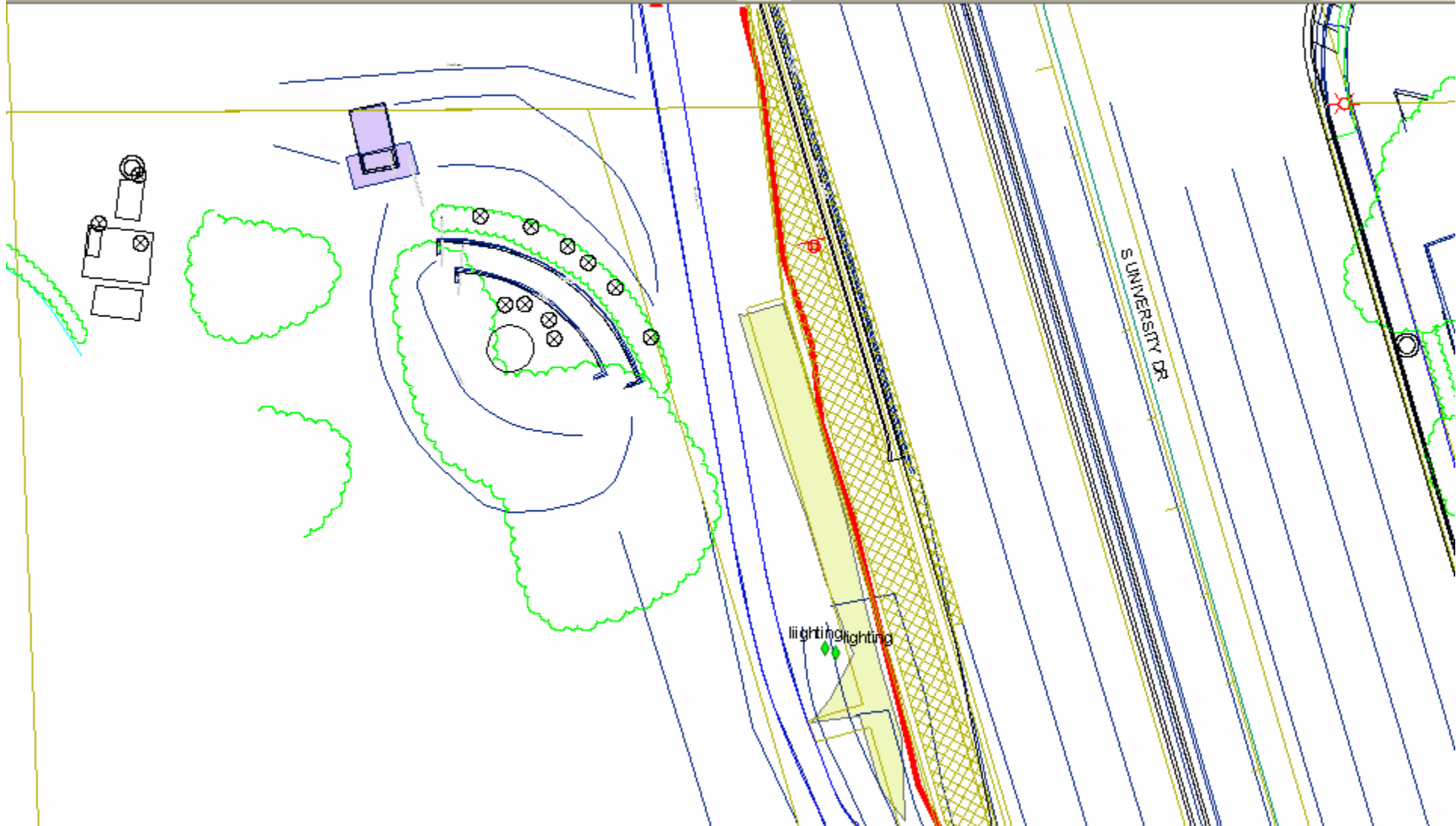




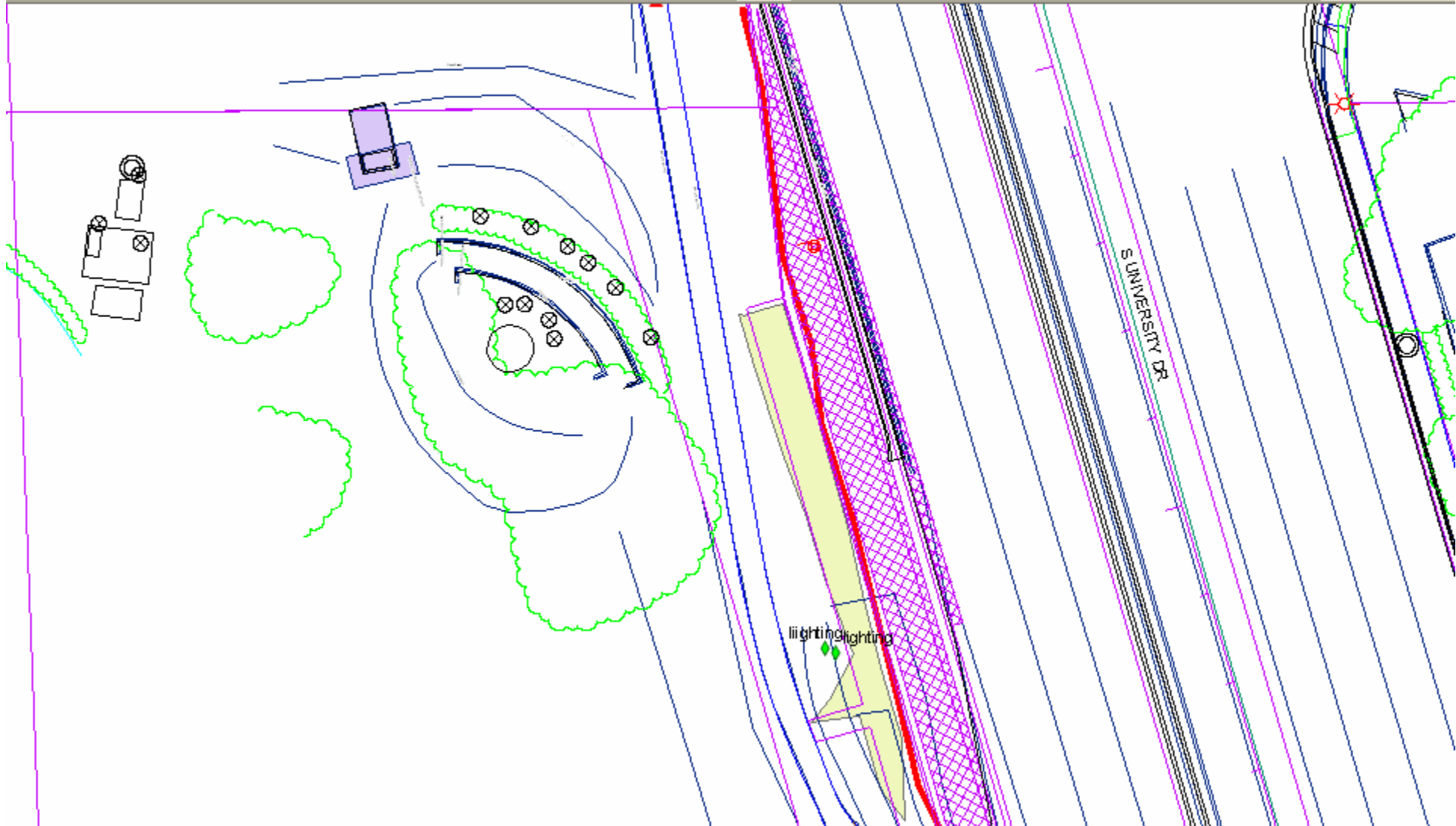












# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at  
SR 817 University Drive, Fort Lauderdale, Florida*

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*Following Slides Show Site Photographs of Some  
Pay Item Locations Indicated on the GIS  
Basemap.*

- \* Sidewalk/Bus Stop Concrete Slab*
  - \* Traffic Signs*
  - \* Curb and Gutter*
-

















BEGIN  
RIGHT TURN LANE  
←  
YIELD TO BIKES

SPEED  
LIMIT  
45

















# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Site Visit and Preliminary Data Collection at  
SR 817 University Drive, Fort Lauderdale, Florida*

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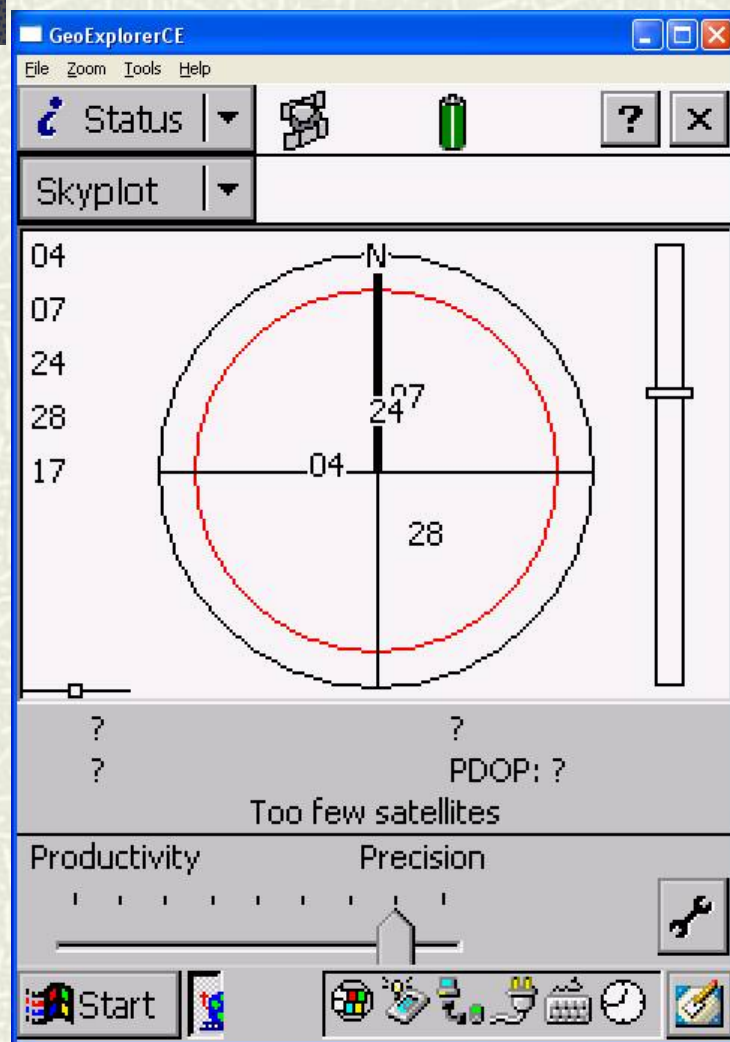
*Following Slides Show Screen Captures of the  
Trimble GeoXT GPS Receiver*

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# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *GPS Receiver Data Collection*



GeoExplorerCE

File Zoom Tools Help

Data

New Create

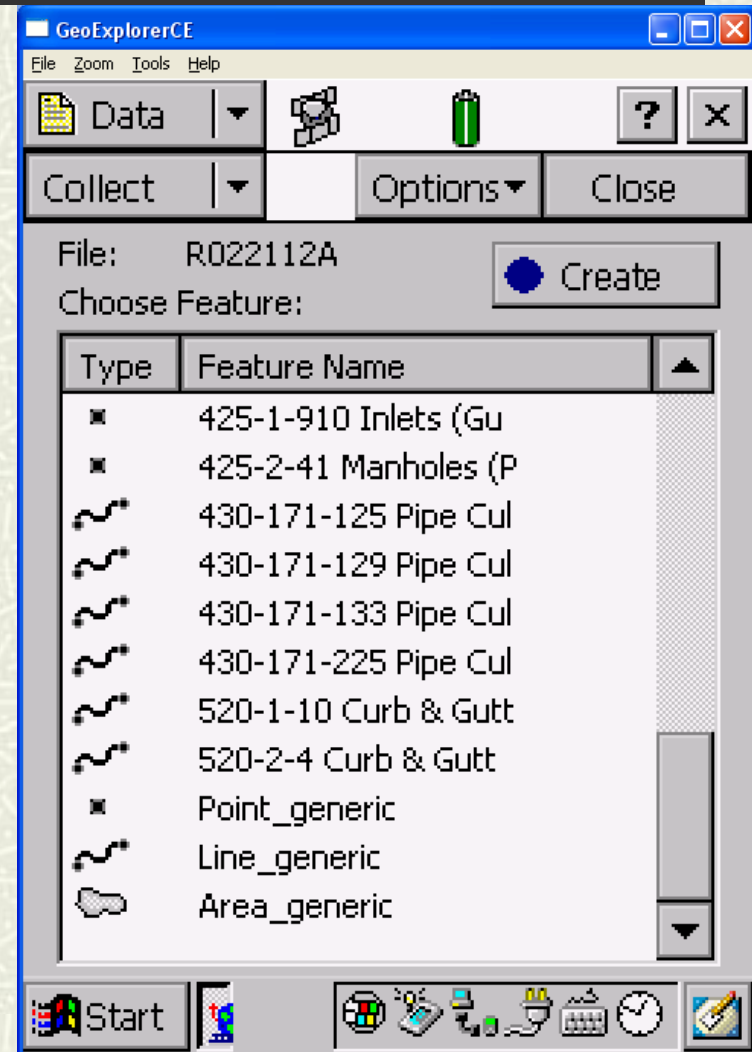
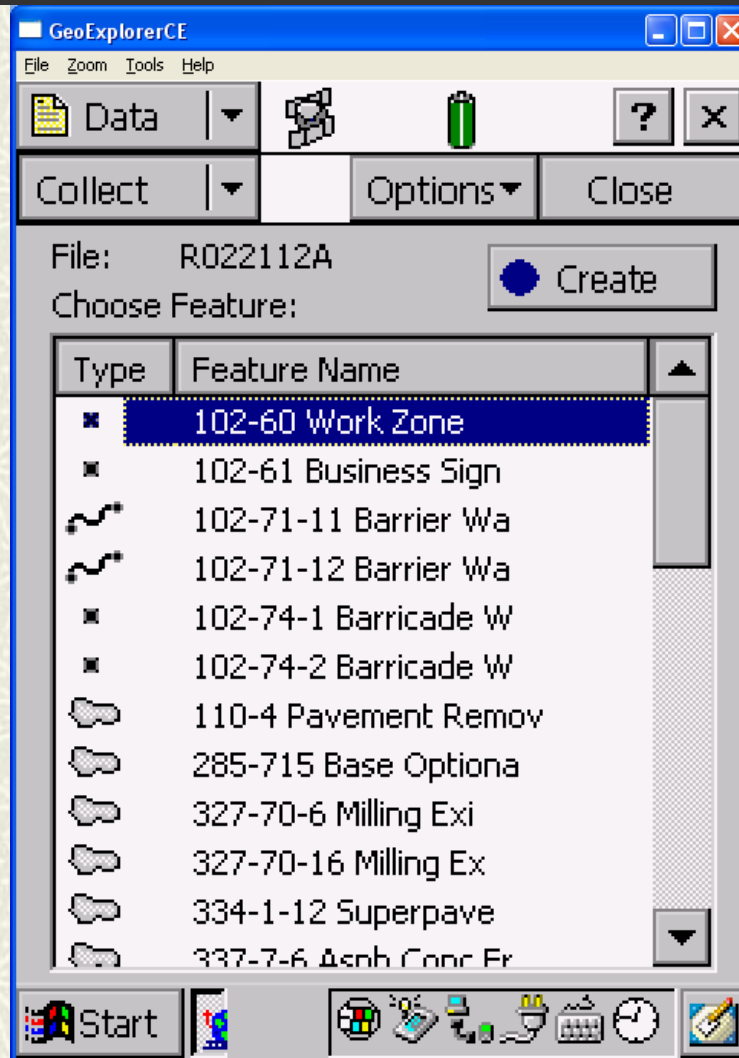
Create New Data File:

File Name: R022112A

Dictionary Name: 5R 817 Univ

Start

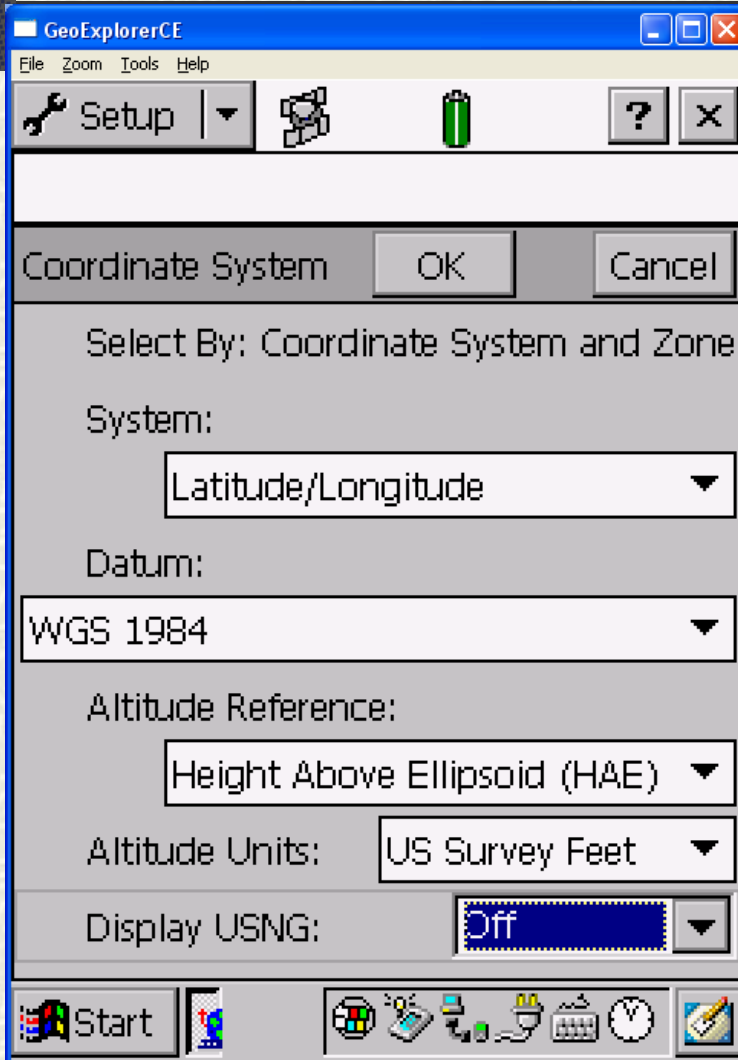
# GPS/GIS Inspection and Analysis Tools for Highway Construction: *GPS Receiver Data Collection*





# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *GPS Receiver Data Collection*



GeoExplorerCE

File Zoom Tools Help

Setup

Coordinate System OK Cancel

Select By: Coordinate System and Zone

System:  
Latitude/Longitude

Datum:  
WGS 1984

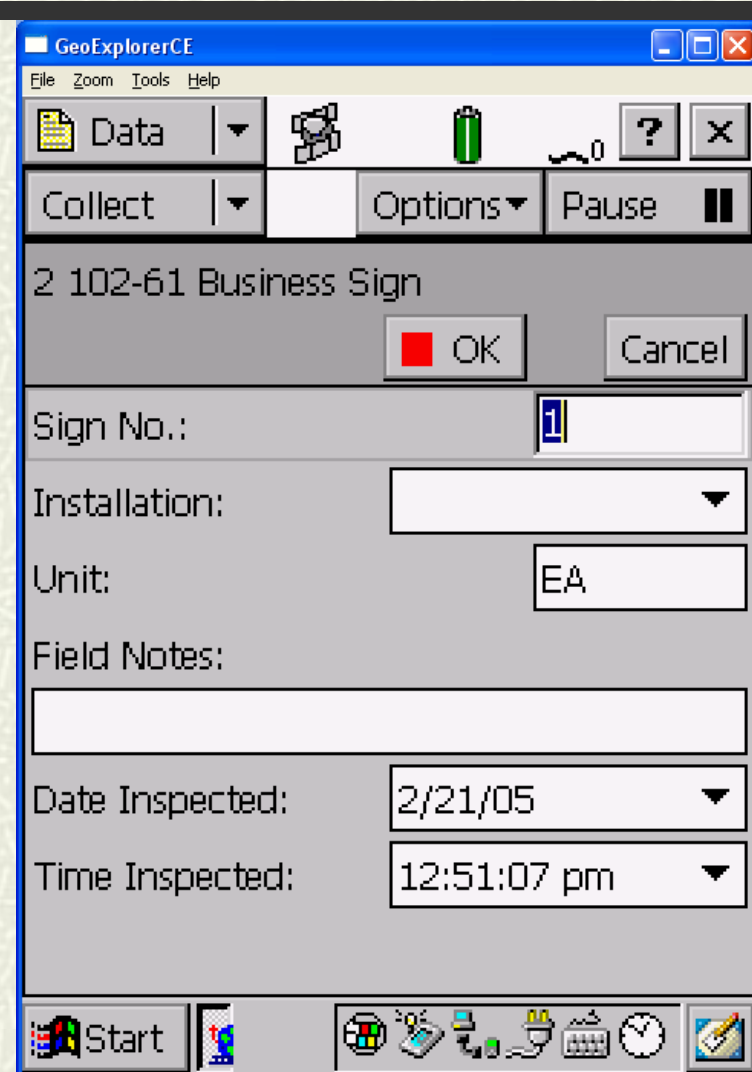
Altitude Reference:  
Height Above Ellipsoid (HAE)

Altitude Units: US Survey Feet

Display USNG: Off

Start

Detailed description: This is a screenshot of the 'Setup' dialog box in GeoExplorerCE. The window title is 'GeoExplorerCE'. The menu bar includes 'File', 'Zoom', 'Tools', and 'Help'. The toolbar contains a wrench icon, a dropdown menu labeled 'Setup', a 3D globe icon, a battery icon, a question mark icon, and a close icon. The dialog box has 'OK' and 'Cancel' buttons. The main area contains several settings: 'Select By: Coordinate System and Zone', 'System:' with a dropdown menu showing 'Latitude/Longitude', 'Datum:' with a dropdown menu showing 'WGS 1984', 'Altitude Reference:' with a dropdown menu showing 'Height Above Ellipsoid (HAE)', 'Altitude Units:' with a dropdown menu showing 'US Survey Feet', and 'Display USNG:' with a dropdown menu showing 'Off'. The Windows taskbar at the bottom shows the 'Start' button and several system icons.



GeoExplorerCE

File Zoom Tools Help

Data

Collect Options Pause

2 102-61 Business Sign

OK Cancel

Sign No.: 1

Installation:

Unit: EA

Field Notes:

Date Inspected: 2/21/05

Time Inspected: 12:51:07 pm

Start

Detailed description: This is a screenshot of the 'Data' dialog box in GeoExplorerCE. The window title is 'GeoExplorerCE'. The menu bar includes 'File', 'Zoom', 'Tools', and 'Help'. The toolbar contains a document icon, a dropdown menu labeled 'Data', a 3D globe icon, a battery icon, a question mark icon, and a close icon. The dialog box has 'Collect', 'Options', and 'Pause' buttons. The main area contains several fields: '2 102-61 Business Sign' with a red square icon and 'OK' and 'Cancel' buttons, 'Sign No.:' with a text input field containing '1', 'Installation:' with a dropdown menu, 'Unit:' with a text input field containing 'EA', 'Field Notes:' with a text input field, 'Date Inspected:' with a dropdown menu showing '2/21/05', and 'Time Inspected:' with a dropdown menu showing '12:51:07 pm'. The Windows taskbar at the bottom shows the 'Start' button and several system icons.

# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *GPS Receiver Data Collection*

GeoExplorerCE

File Zoom Tools Help

Data | [Icons]

Collect | Options | Pause

3 285-715 Base Optiona

OK Cancel

Location: [Text Box]

Unit: SY

Estimated Work: 0.00

Measured Work: 0.00

Field Notes:

Date Inspected: 2/21/05

Time Inspected: 12:52:17 pm

Start [Icons]

Detailed description: This screenshot shows the GeoExplorerCE software interface. The title bar reads 'GeoExplorerCE'. The menu bar includes 'File', 'Zoom', 'Tools', and 'Help'. Below the menu bar is a toolbar with a 'Data' dropdown menu and several icons. The main interface has a 'Collect' dropdown menu, an 'Options' dropdown menu, and a 'Pause' button. The current location is '3 285-715 Base Optiona'. There are 'OK' and 'Cancel' buttons. The 'Location' field is a text box with a blue border. The 'Unit' is set to 'SY'. 'Estimated Work' and 'Measured Work' are both 0.00. There is a 'Field Notes' section with a text area. 'Date Inspected' is 2/21/05 and 'Time Inspected' is 12:52:17 pm. The bottom of the window shows a 'Start' button and a row of icons.

GeoExplorerCE

File Zoom Tools Help

Data | [Icons]

Collect | Options | Pause

7 520-1-10 Curb Gutt

OK Cancel

Location: [Text Box]

Unit: LF

Estimated Work: 0.00

Measured Work: 0.00

Filed Notes:

Date Inspected: 2/21/05

Time Inspected: 12:53:57 pm

Start [Icons]

Detailed description: This screenshot shows the GeoExplorerCE software interface. The title bar reads 'GeoExplorerCE'. The menu bar includes 'File', 'Zoom', 'Tools', and 'Help'. Below the menu bar is a toolbar with a 'Data' dropdown menu and several icons. The main interface has a 'Collect' dropdown menu, an 'Options' dropdown menu, and a 'Pause' button. The current location is '7 520-1-10 Curb Gutt'. There are 'OK' and 'Cancel' buttons. The 'Location' field is a text box with a blue border. The 'Unit' is set to 'LF'. 'Estimated Work' and 'Measured Work' are both 0.00. There is a 'Filed Notes' section with a text area. 'Date Inspected' is 2/21/05 and 'Time Inspected' is 12:53:57 pm. The bottom of the window shows a 'Start' button and a row of icons.



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

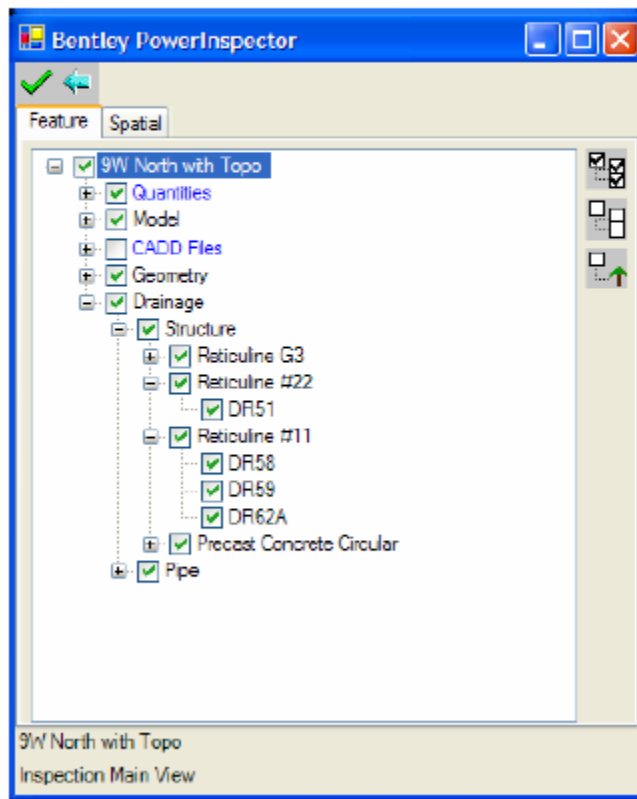
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*Following Slides Show Proposed Applications of the Bentley's Construction Handheld*

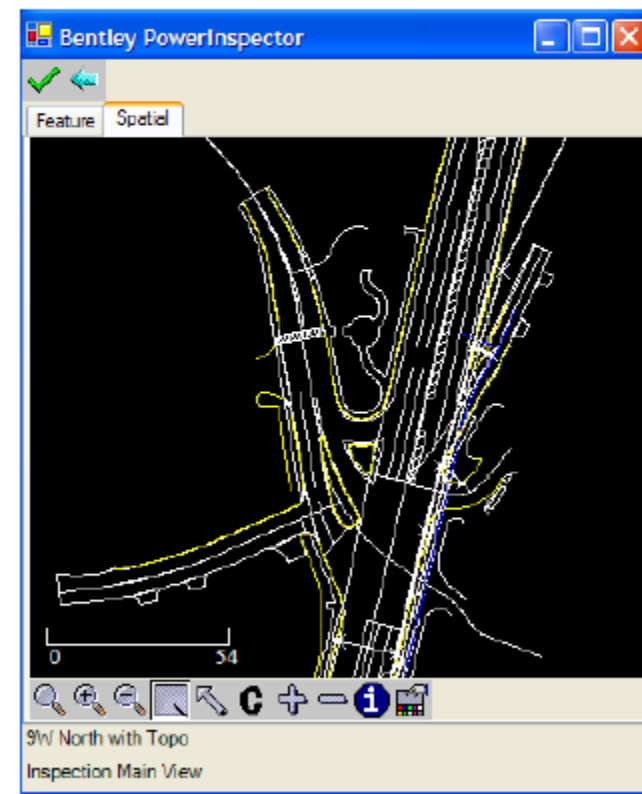
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# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Bentley's Construction Handheld*

## In-field Automation via Handheld Devices – Easy to Use



Feature Query



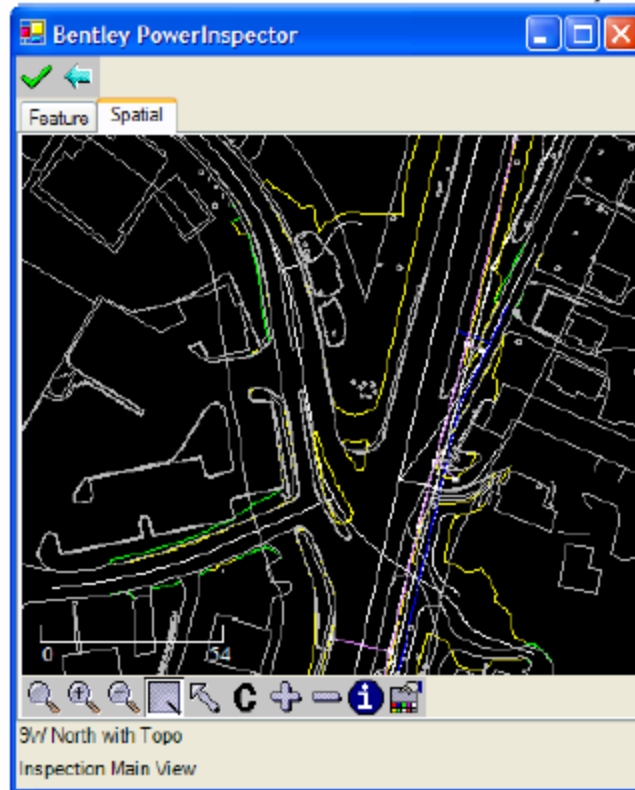
Spatial Query



# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Bentley's Construction Handheld*

## **In-field Automation via Handheld Devices – Location Assistance**

This is what's there now; this is what I want to build

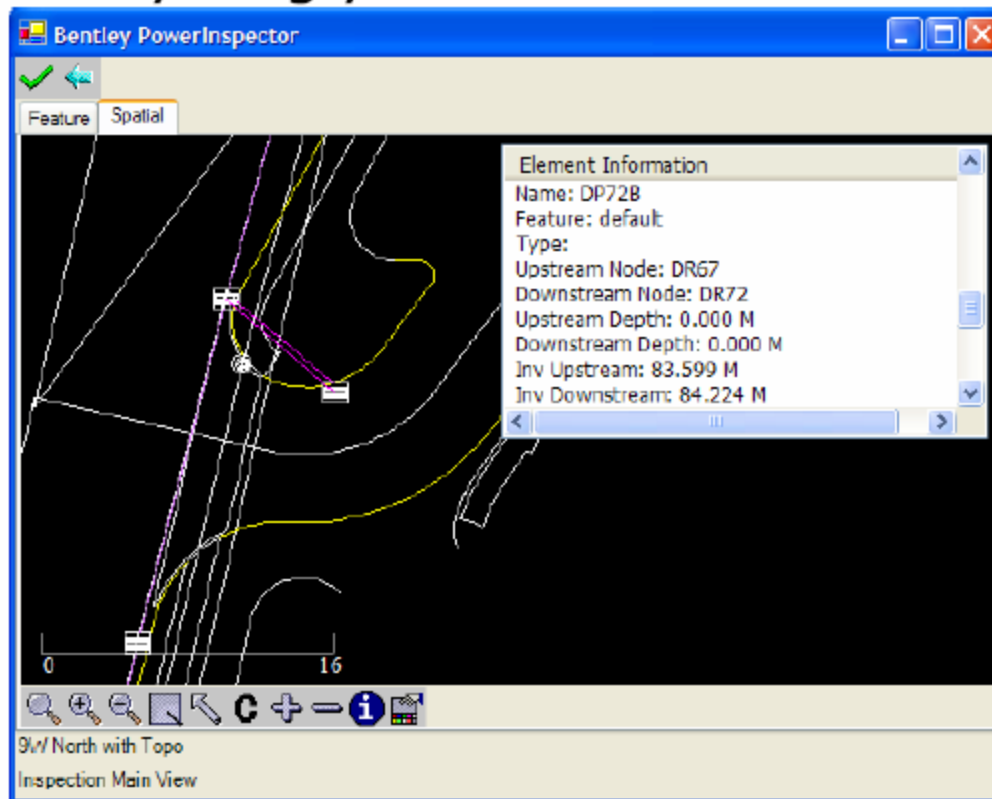


Background graphics  
added to graphical display

# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Bentley's Construction Handheld*

## In-field Automation via Handheld Devices – Info Feature

Everything you want to know about the design



Drainage structure data provided by Info Command



# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Bentley's Construction Handheld*

### Construction Inspection

Inspect by selecting graphical entities

- Graphical reference to all inspection activities
- Final project rectification easier

Support for wide range of automated measuring techniques: GPS, Atlanta Laser...

Paperwork reduction: Keep inspectors in field rather than in office filling out forms

Spec Book, Special Provisions, Standard Drawings and Standard Inspection

Procedures Accessible on Handheld

- Tied directly to graphics/pay items

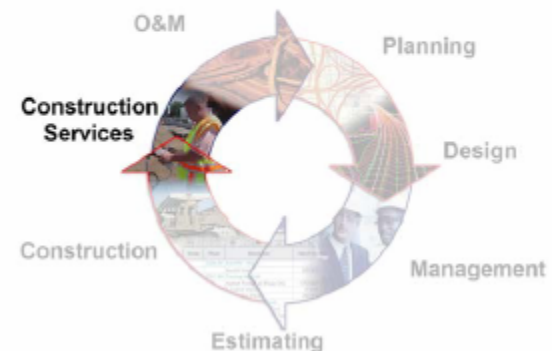
Support for Visual Basic to customize for specific agency procedures and output formats

- Summary Reports
- Specialized Inspections

Feeds Business-side systems such as AASHTO

SiteManager

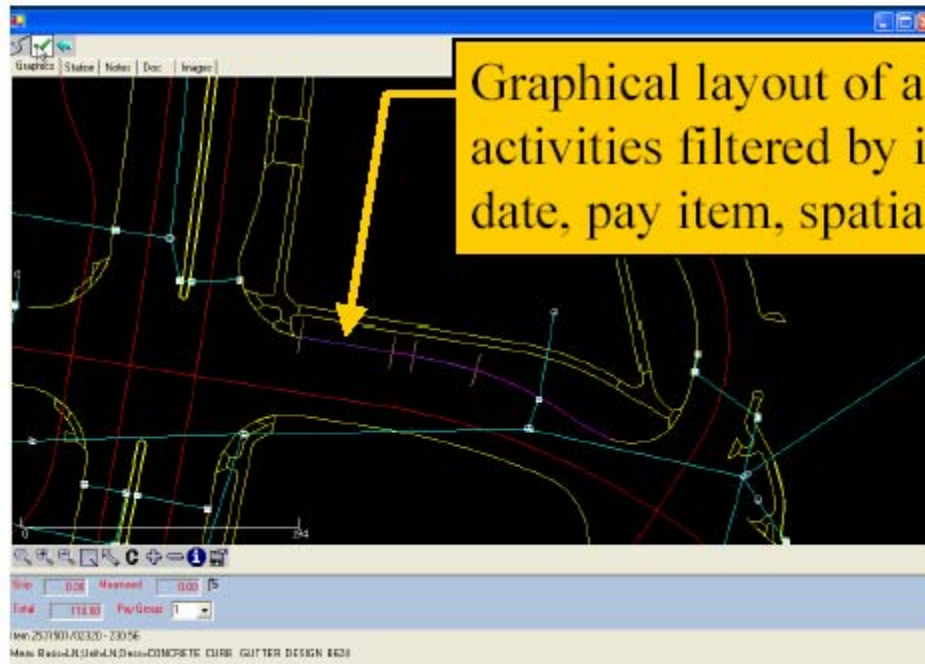
As-builts will be created during typical Inspection measurements with emergence of VRS/CORS



# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Bentley's Construction Handheld*

## Inspection

Graphical based: If a picture is worth a thousand words...



Graphical layout of all inspection activities filtered by inspector, date, pay item, spatial area

=





# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Bentley's Construction Handheld*

### **Construction Inspection**

Spec Book, Special Provisions, Standard Drawings and Standard Inspection Procedures Accessible on Handheld

- Tied directly to graphics/pay items



# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Bentley's Construction Handheld*

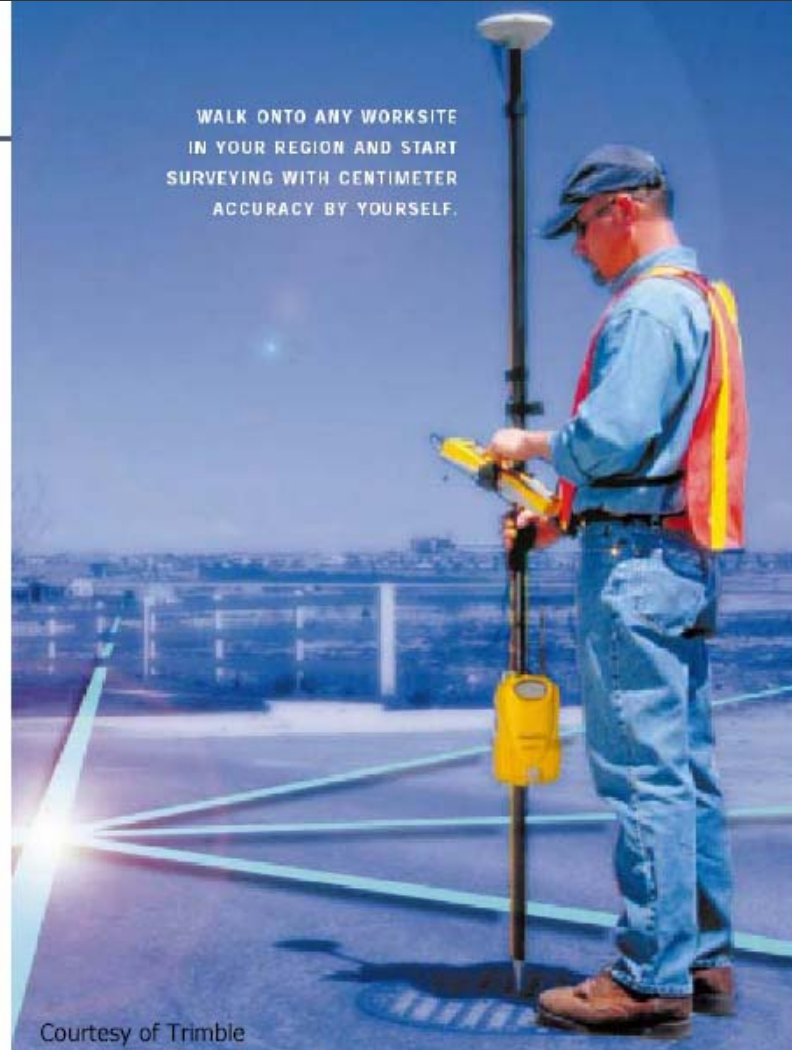


## Creating As-builts with a Future

As-builts via  
Inspector-ready  
Rovers:

- Trimble – VRS
- Leica - CORS

WALK ONTO ANY WORKSITE  
IN YOUR REGION AND START  
SURVEYING WITH CENTIMETER  
ACCURACY BY YOURSELF.



Courtesy of Trimble



# GPS/GIS Inspection and Analysis Tools for Highway Construction: *Bentley's Construction Handheld*

## Input to Business Systems

Streamline Input to Business Systems: Graphical identification of the project component negates the need to manually transcribe onto forms.

The screenshot displays the 'FieldPad' software interface. At the top, the title bar shows 'FieldPad' and the date '12/06' with time '3:38'. Below the title bar is a 'View Posting' window with a question mark and close button. The form contains the following fields:

Quantity:	9.110	SQYD	Price:	45.55	
Remarks:	[Empty text box]				
From:	[Empty text box]	To:	[Empty text box]		
Breakdown:	[Dropdown menu]	Location:	On site		
<input type="checkbox"/> Attention		<input type="checkbox"/> All Materials Reviewed			
Item:	SODDING TYPE LAWN		Code:	2575 505/0030	
Project:	00001A	Category:	0001	Prop. Line #:	0085

At the bottom right of the form, there is a small icon and an upward-pointing arrow.

# GPS/GIS Inspection and Analysis Tools for Highway Construction:

## *Bentley's Construction Handheld*

### **Construction Management**

Summary of all inspection and stake out activities:

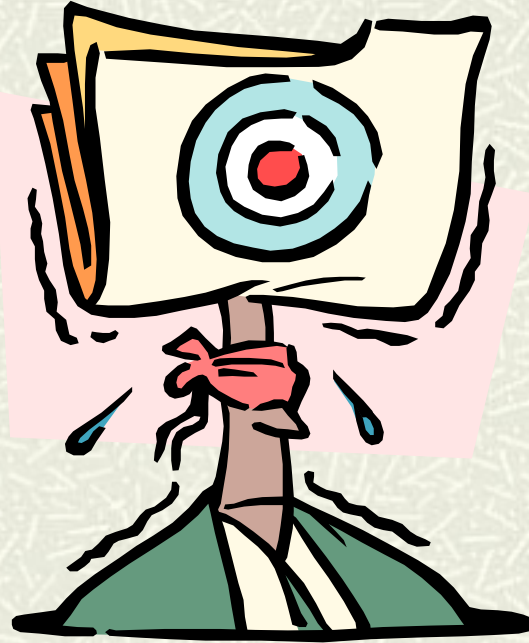
- Maintained in comprehensive database that acts like an electronic field book
- Graphical overlays provide comprehensive summary on current inspection and stake out status
- Queries:
  - » By date range, personnel, activity
  - » Review field generated RFIs, ordered services
- Any type of customized report available
- For Resident Engineers, District Construction Engineer, etc.





# GPS/GIS Inspection and Analysis Tools for Highway Construction:

*THANK YOU!*



*ANY QUESTIONS?*