

# DIGGS DATA SCHEMA, DICTIONARY AND ~~DEVELOPMENT TOOLS~~ PHASE II PILOT TESTING

TRB Workshop – January 10, 2016  
Dan Ponti, USGS



# Overview

- DIGGS Genesis – Pre FHWA Pooled-Fund Efforts
- What is DIGGS?
  - DIGGS Characteristics
  - DIGGS Data Model Overview
  - DIGGS Examples

# Background for Geotechnical Data Dissemination

- 1992      NSF/FHWA sponsors the National Geotechnical Experiment Sites.
- 1996      The ROSRINE project pioneers web dissemination of geotechnical data.
- 1998      USC Workshop highlights growing need for geotechnical data management and exchange.
- 1999      PEER Lifelines initiates Project 2L01.**
- 2001      Project 2L01 – Held a workshop to assess user needs and build consensus to develop a Geotechnical Virtual Data Center (GVDC).**
- 2004      Project 2L02 – Unveiled a pilot GVDC that demonstrated the feasibility of the technology.  
----- FHWA Pooled-Fund Study -----**
- 2005      Project 2L03 – Expanded GVDC capabilities and web tools, using DIGGS**

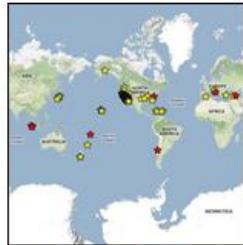


# STRONG-MOTION VIRTUAL DATA CENTER (VDC)

Global Component of the Center for Engineering Strong Motion Data

Home · Login/Logout · Download · AboutUs · Contact  
Earthquakes · Stations · Search · Map · Adv. Search

## Welcome to the Updated VDC Your Portal to Worldwide Strong Ground Motion Data



[Earthquakes by Region](#)



[Stations by Region](#)



[Data Search](#)

### Data Contributors:

Armenian Strong-Motion Network  
Bogazici Univ., Kandilli Observatory, Turkey  
California Geological Survey\*  
California Inst. of Technology  
Centro de Investigaciones Geotecnicas, El Salvador  
Dept. of Geophysics and Geodesy, Santiago, Chile  
Dept. of Natural Resources, Wash.  
Dept. of Water and Power, Los Angeles, Calif.  
Geological Survey of Canada  
Indian Inst. for Techology, Roorkee, India  
Inst. of Geological & Nuclear Sciences Ltd, NZ  
Inst. de Ingenieria , UNAM, Mexico  
IRIGM: Univ. Joseph Fourier, Grenoble, France  
Kiban-Kyoshin Network, Japan  
Kyoshin Net, Japan  
Los Angeles Flood Control, Los Angeles, Calif.  
Metropolitan Water District, Los Angeles, Calif.  
MCEER, Buffalo, New York

Nat. Survey for Seismic Protection, Armenia  
Puerto Rico SM Network  
Seattle Light and Power, Seattle, Wash.  
Seismology Center, CWB, Taipei, Taiwan  
Southern California Earthquake Center  
Southern California Edison  
Tacoma Public Utilities  
Univ. of Alaska, Geophysical Inst., Anchorage  
Univ. of California at Los Angeles  
Univ. CentroAmericana, San Salvador, El Salvador  
Univ. of Nevada, Reno  
Univ. of Southern California, Dept. of Civil Engineering  
Univ. of Washington, Geophysics Program  
U.S. Army Corps of Engineers\*  
U.S. Bureau of Reclamation\*  
U.S. Geological Survey\*  
Washington Dept. of Natural Resources

\* CORE Member of COSMOS

# STRONG-MOTION VIRTUAL DATA CENTER (VDC)

Global Component of the Center for Engineering Strong Motion Data

Home · Login/Logout · Download · AboutUs · Contact  
Earthquakes · Stations · Search · Map · Adv. Search

## Basic Search

To search on database parameters not found on this page, use the [advanced search](#).  
[Search Help](#)

Note: Leave blank any fields that do not apply to your search.

**Event Name:**  (e.g. North Palm Springs)

**Station Identifier:**  (Station location or number assigned by the station owner.)

### Mechanism

- Unknown
- Thrust
- Strike-slip
- Reverse-Oblique
- Reverse
- Normal-Oblique
- Normal

### Structure

- Unknown
- Ground
- Building
- Bridge
- Dam
- Geotechnical array

### Site Conditions

- Unknown
- Hard Rock
- Rock
- Very dense soil and soft rock
- Stiff soil
- Soft soil

Enter minimum and/or maximum values:

**Magnitude:** from  to

**Date:** Start Year Month Day End Year Month Day  
1933  1  1  2015  12  31

**Peak Ground Accel. (cm/s/s):** from  to

**Hypocentral Distance (km):** from  to

- Return earthquake, station, and accelerogram information
- Return station information only
- Return earthquake information only



# COSMOS VDC

- Data portal NOT a data repository
- Each data provider maintains data in their own *database server in a standard schema*
- VDC queries data providers to extract metadata that is stored in the VDC database (data “harvester”)
- Users access data by querying the VDC metadata, select data they desire
- VDC extracts data from data provider servers and sends to user in *a standardized format*

# A Geotechnical Virtual Data Center

- COSMOS motivation
  - Geotechnical data is critical in evaluating strong ground motion site response
  - Why not do the same for geotechnical data as for strong motion data?
- Challenge
  - Most archived geotechnical data is “information” not “data”
  - No enterprise-level centralized database for most organizations (with some limited exceptions)
  - Diverse domain: there has been no standardized way of storing/organizing geotechnical data

# A Geotechnical Virtual Data Center

- COSMOS GVDC Goals
  - Develop a standard data dictionary and schema for a limited number of common geotechnical data types
  - How to implement schema, store/query/transfer such data?
    - A RDBMS?
      - All data produced by various sources that matches extraction
      - Then what?
    - Answer:



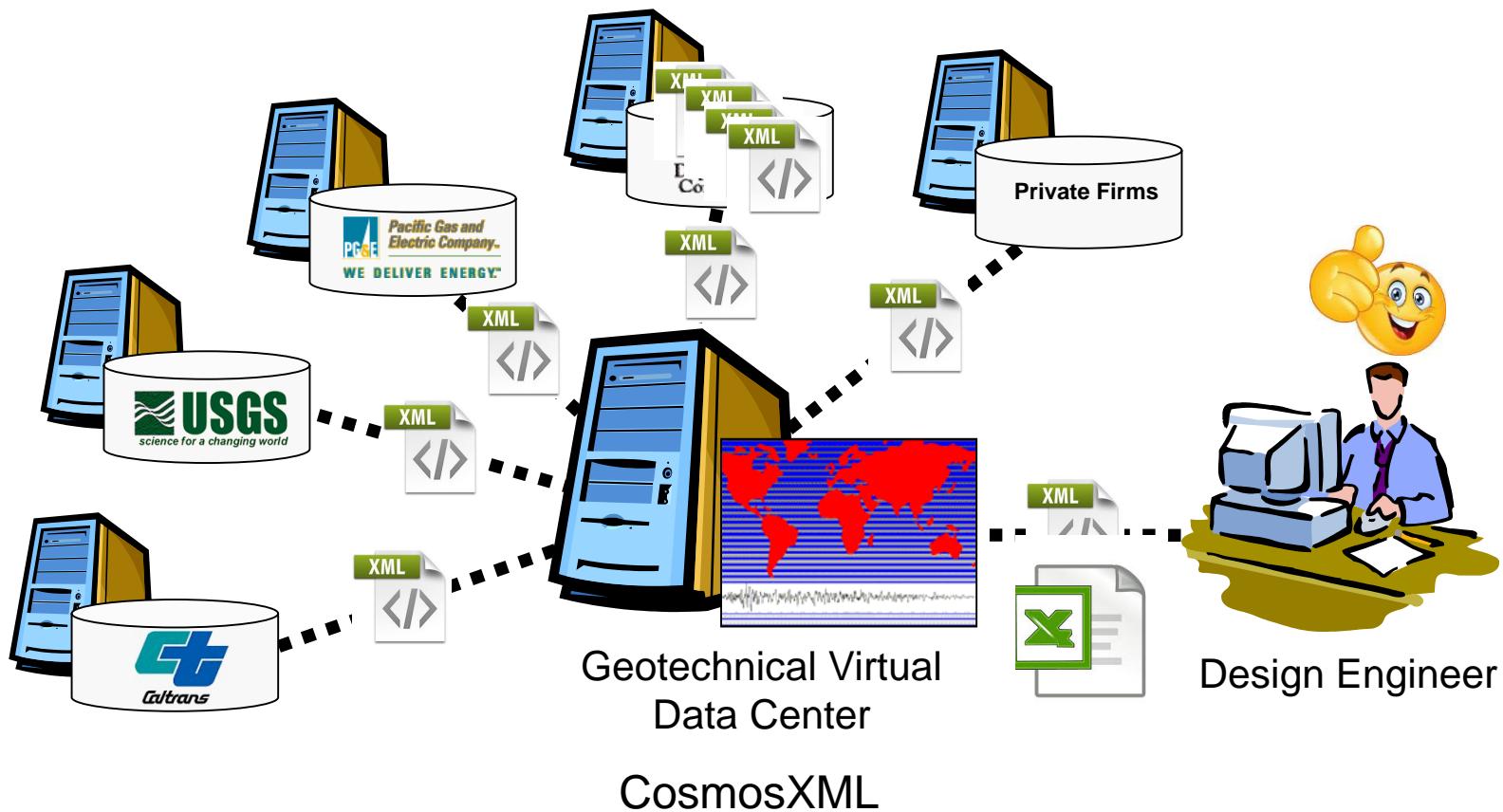
end up a database server  
data harvesting and  
end user?

# Why XML?

- XML is the de facto standard for internet data transfer
  - Platform/software independent
  - Text-based (eg. human readable); self-describing schema
  - Ubiquitous and open-source tools available for validating, querying, processing, displaying, and transforming data



# Data Sharing Across Multiple Organizations



# IDENTIFY THE SEARCH AREA BY MAP

Use the ARROW tool (cursor) to click and drag a rectangular search area, or enter the boundaries of the search area in the form to the right. Use ZOOM and PAN tools for navigation.

**COSMOS - Data Types - Microsoft Internet Explorer**

File Edit View Favorites Tools Help

Check the data types you wish to filter by:

- AGE - Age
- AQI - Aquifer
- ATL - Atterberg Limits
- BLG - Basic
- BHE - Borehole Electric Logs
- BHG - Borehole Gamma
- BHI - Borehole Imaging
- BPW - Borehole P-Wave
- BSW - Borehole S-Wave
- CPT - Cone Penetration Testing
- CON - Consolidation
- CAD - Correlation Age Dating
- DGC - Detailed
- FLL - Fluid Level
- FRS - Formations
- MIN - Mineralogy/Petrology
- MSC - Moisture Content
- NAD - Numerical Age Dating
- OCT - Other Chemical Test
- OET - Other Engineering Test
- OIE - Other In-Situ Engineering Test
- OIG - Other In-Situ Geophysical Test
- OIH - Other In-Situ Hydrologic Test
- OST - Other Stratigraphic Test
- PLM - Paleomagnetics
- PLT - Paleontology
- PSA - Particle-Size Analysis
- PHC - pH
- PPD - Pore Pressure Dissipation
- PWC - Pore Water Chemistry
- PMT - Pressuremeter Testing
- ROP - Reduction-Oxidation Potential

**Filter Search**

**DATA TYPES**

Find all data sets

Specify data sets to search

**Done**

Scale: 4,748,192

SEARCH

Longitude Boundaries  
(decimal degrees)

**COSMOS/PEER-LL - Microsoft Internet Explorer**

File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites History Mail Print Edit

Address <http://216.132.254.225/CustomerDocSearchResult.asp>

HOME PROJECT INFO ABOUT CALENDAR USER SURVEY FORUM NEWS AND EVENTS

Home Interactive Map Document Search Account Help Logout

## Document Search Results

This page displays the results of your search of our geotechnical documentation database.

**California Department of Transportation**

VDC Record ID	Project	Hole	Data Type	Project Date	Updated	Contact	Downloads
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML

**Download Selected**

**California Geologic Survey**

VDC Record ID	Project	Hole	Data Type	Project Date	Updated	Contact	Downloads
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML
2321-03928221-0948	Mace Rahon O.C.	97-092	CPT	12-08-1998	2-5-2000	M. Tyler	<input type="checkbox"/> Excel <input type="checkbox"/> XML

**Download Selected**

Page: <1> - 2 - 3

Internet GIS by [Parallon Geographics](#)

ASCE TS

File Edit View Favorites Tools Help

Back Search Favorites Media Print Address https://geodata.cosmos-data.org/CustomerDocSearchResult.aspx#

**COSMOS/PEER-LL**

HOME PROJECT INFO ABOUT CALENDAR USER SURVEY FORUM NEWS

Home Interactive Map Document Search Account Help

## Document Search Results

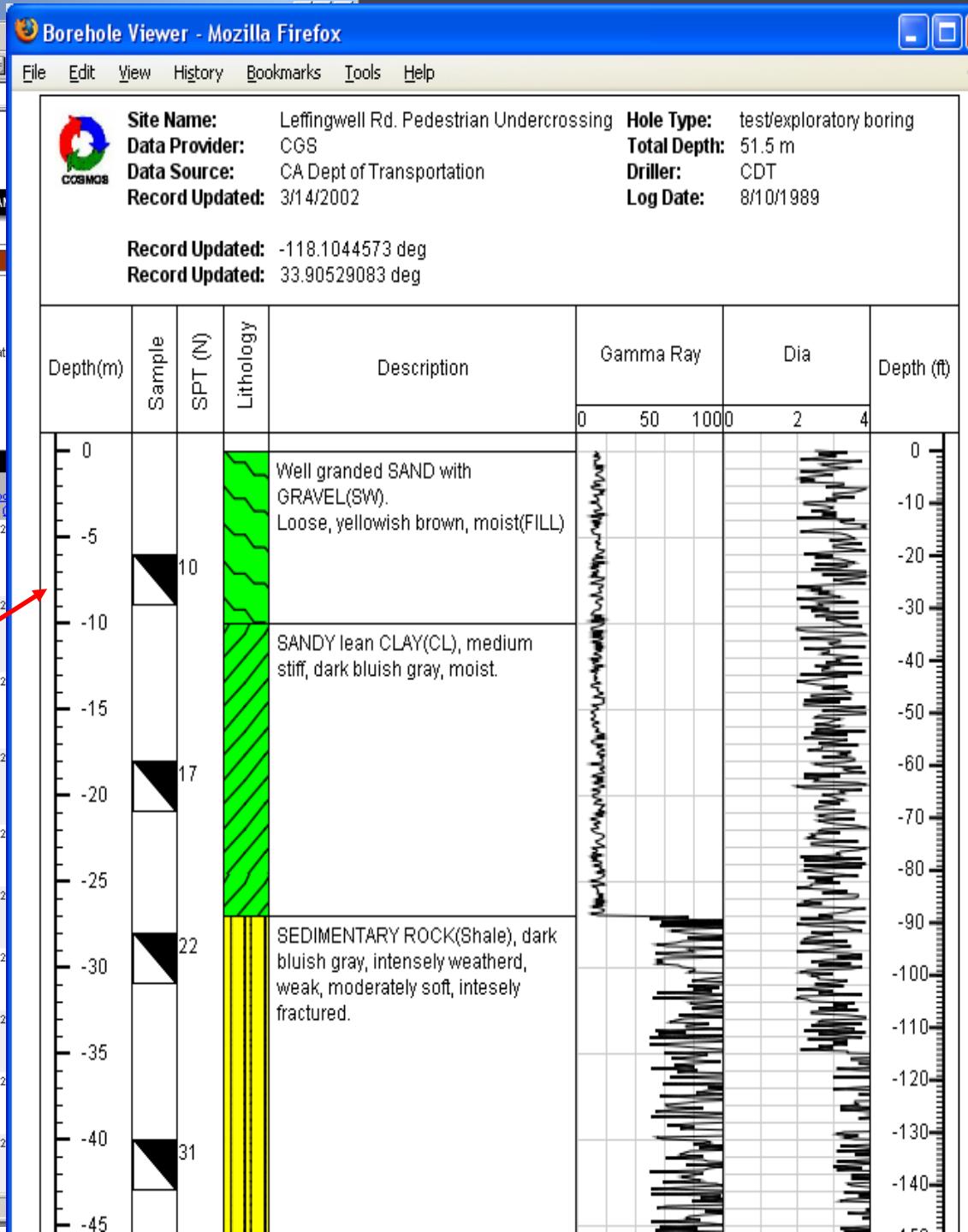
This page displays the results of your search of our geotechnical documentation database.

Your search returned data sets from the following data providers:

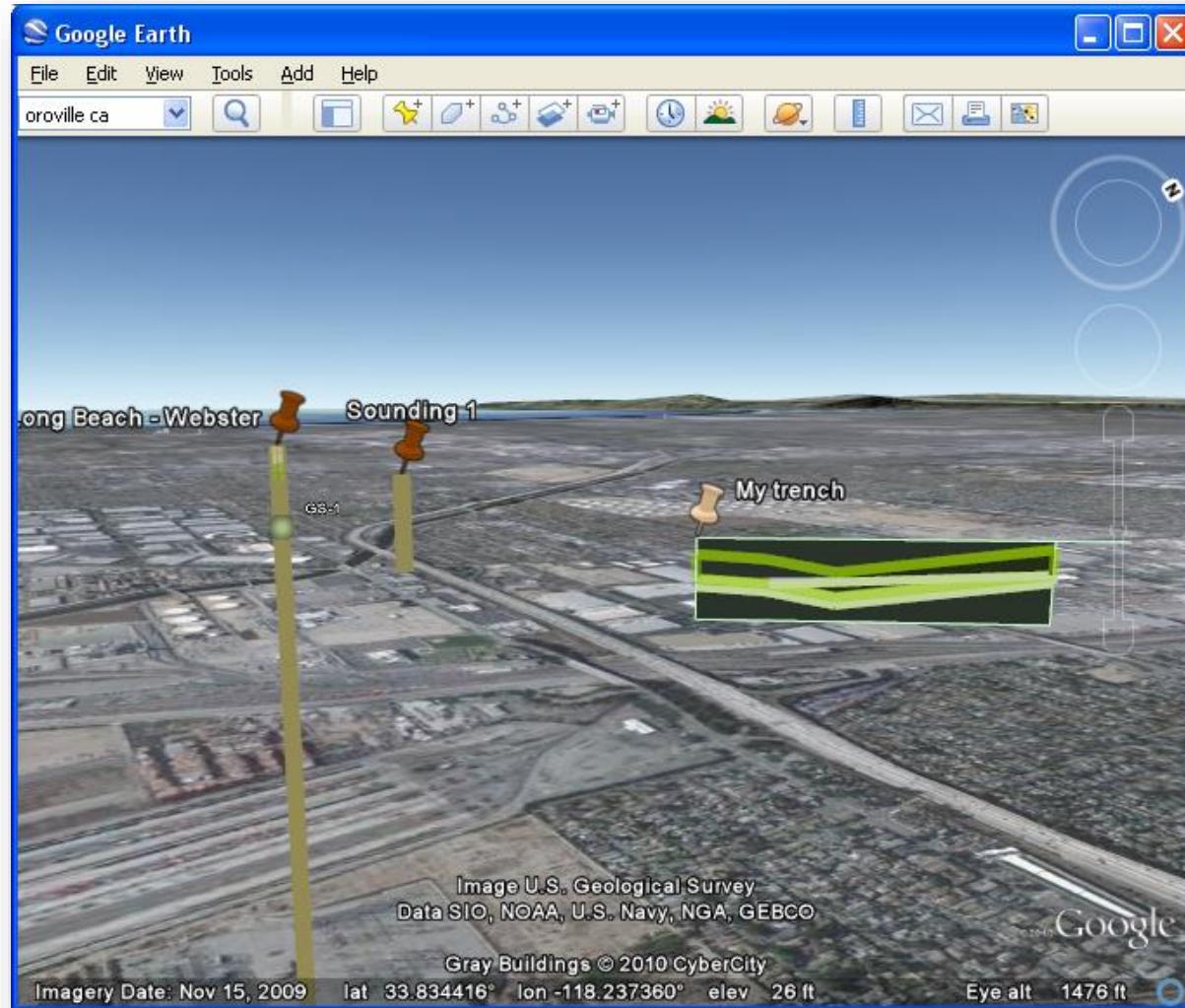
- California Geological Survey (1271)

Total data sets returned: 1271

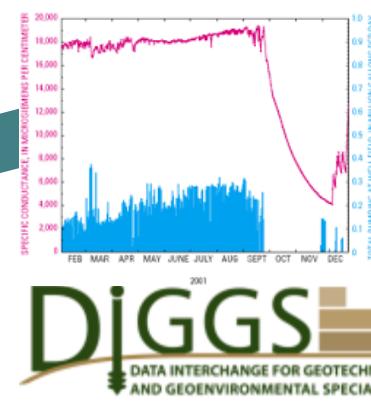
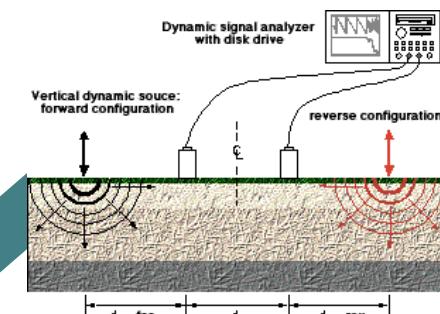
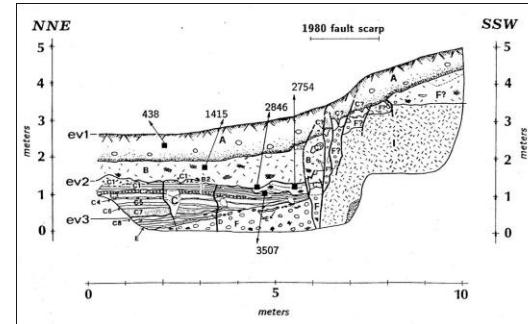
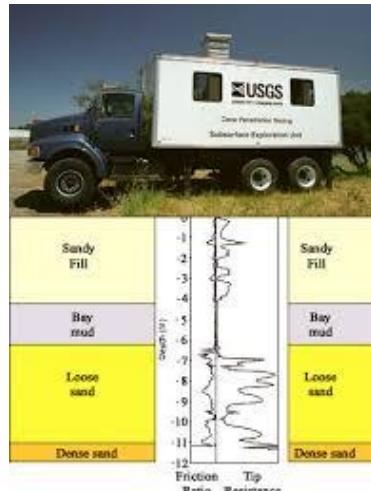
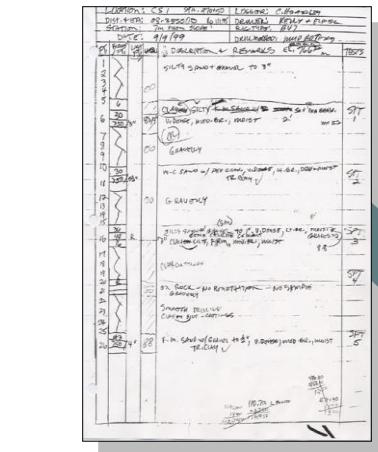
California Geological Survey						
VDC Record ID (1)	Project (2)	Hole (3)	Data Type (4)	Project Date (5)	Updated (6)	Upd
000002_00039_33117H8	ORANGE FWY	CGS_000002_00039_33117H8	FLL	1989-08-10	2002	
	57 AND TONNER CANYON BRIDGE					
000002_00039_33117H8	ORANGE FWY	CGS_000002_00039_33117H8	SPT	1989-08-10	2002	
	57 AND TONNER CANYON BRIDGE					
000002_00039_33117H8	ORANGE FWY	CGS_000002_00039_33117H8	BLG	1989-08-10	2002	
	57 AND TONNER CANYON BRIDGE					
000002_00039_33117H8	ORANGE FWY	CGS_000002_00039_33117H8	DGC	1989-08-10	2002	
	57 AND TONNER CANYON BRIDGE					
000002_00041_33117H8	ORANGE FWY	CGS_000002_00041_33117H8	FLL	1989-08-10	2002	
	57 and TONNER CANYON BRIDGE					
000002_00041_33117H8	ORANGE FWY	CGS_000002_00041_33117H8	SPT	1989-08-10	2002	
	57 and TONNER CANYON BRIDGE					
000002_00041_33117H8	ORANGE FWY	CGS_000002_00041_33117H8	BLG	1989-08-10	2002	
	57 and TONNER CANYON BRIDGE					
000002_00041_33117H8	ORANGE FWY	CGS_000002_00041_33117H8	DGC	1989-08-10	2002	
	57 and TONNER CANYON BRIDGE					
000002_00042_33117H8	ORANGE FWY	CGS_000002_00042_33117H8	DGC	1989-08-10	2002	
	57 and TONNER CANYON BRIDGE					
000002_00042_33117H8	ORANGE FWY	CGS_000002_00042_33117H8	FLL	1989-08-10	2002	
	57 and TONNER CANYON BRIDGE					



# DIGGS-to-KML Tool



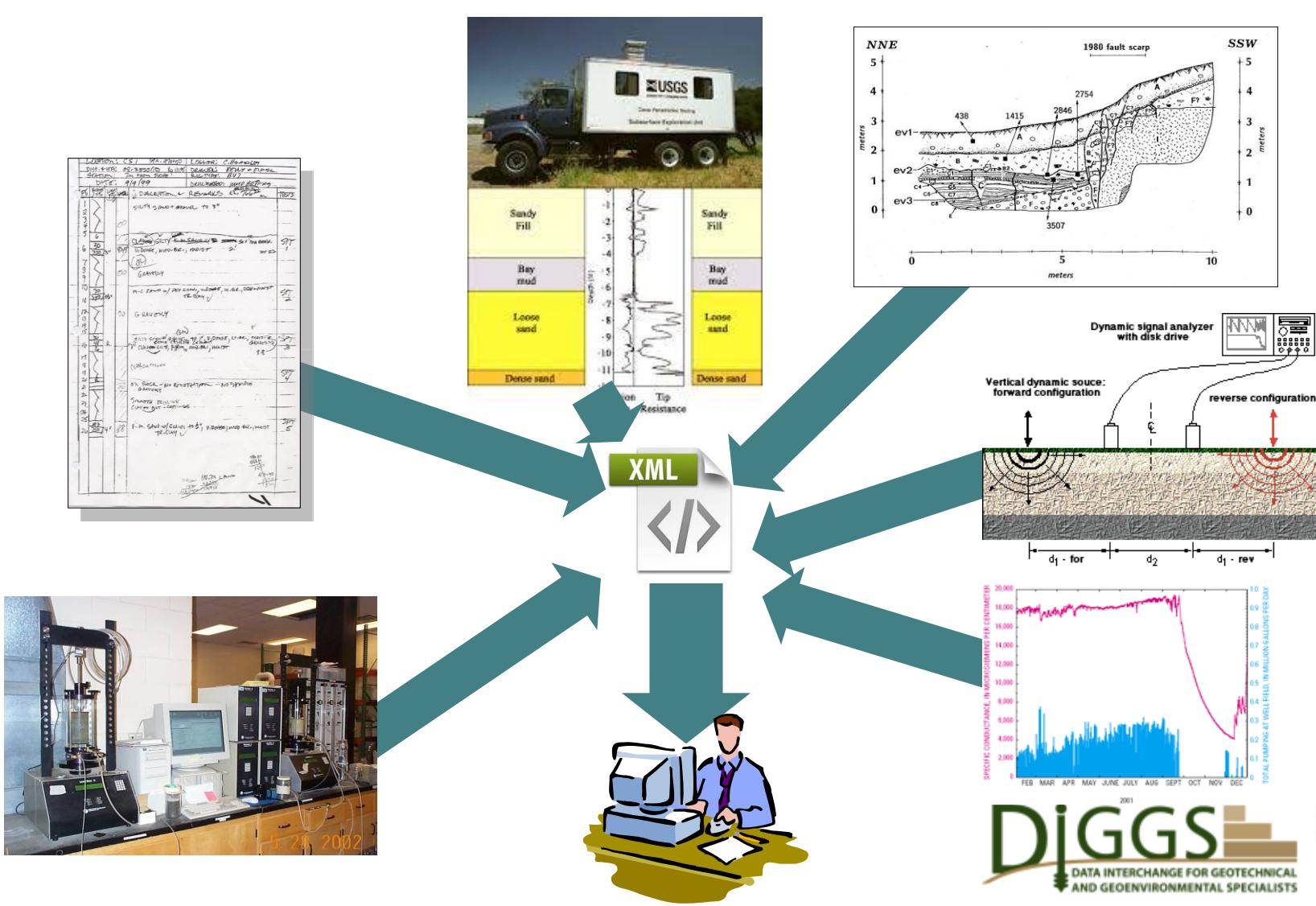
# Integration of Data Types and Formats



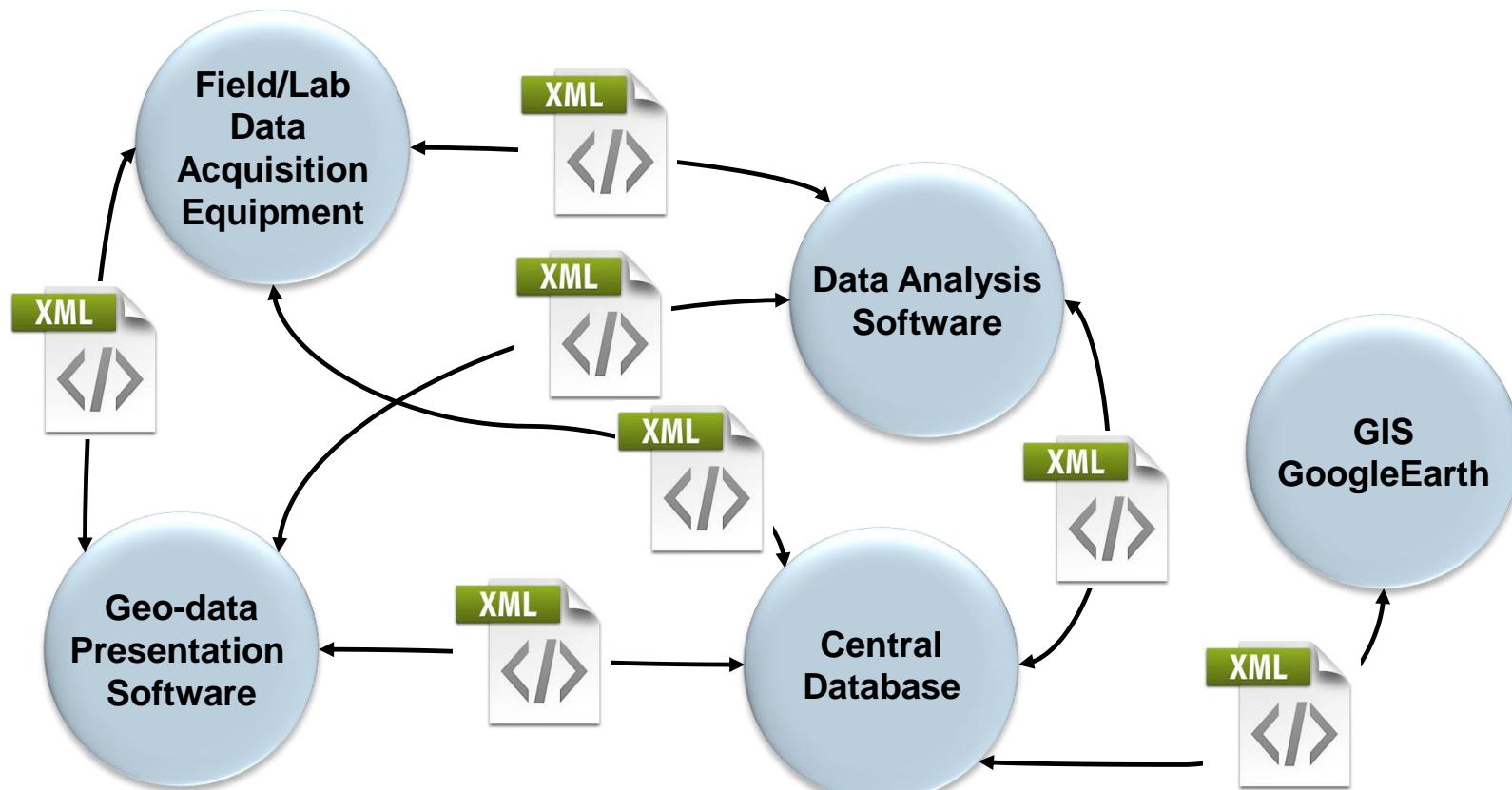
**DIGGS**  
DATA INTERCHANGE FOR GEOTECHNICAL  
AND GEOENVIRONMENTAL SPECIALISTS



# Integration of Data Types and Formats



# XML for Software Interoperability



# What is DIGGS?

- XML Schema (XSD) plus XML dictionaries defining controlled terms and coordinate systems
  - Normative document
  - Defines data structure, objects and properties within the geotechnical engineering, geology, environmental and hydrology domains
  - Enforces rules for data organization
- Data stored/transferred as XML (structured text) instance documents (files) that follow DIGGS schema structure

# What is DIGGS?

- DIGGS is the extension/replacement for CosmosXML
- DIGGS is a Geography Markup Language (GML) application schema
  - Geologic/geotechnical data is inherently geographic data
  - GML is an international standard (ISO/OGC)
  - GML has standardized Feature, Geometry data types
  - Allows for processing by GIS applications
  - Allows for display and of data over the Internet using web map services



# What is DIGGS?

- DIGGS defines a structure that describes real-world objects and activities and their relations, that define the geotechnical/geoenvironmental domain
- DIGGS is extensible
  - Framework for adding additional sampling features, test procedures and measurement results not already included in the standard
  - Able to reference non-textual data (photos, docs, etc.) as part of the transfer
- DIGGS does not specify procedures or reporting requirements, but instead is a framework that allows test specifications, procedures, etc. to be documented as part of the data transfer/storage.
- DIGGS is profileable
  - Can restrict the schema to enforce business rules for specific use cases



# DIGGS Data Model

- A DIGGS instance document consists of a collection of related GML features and objects.
- GML Object – a declared XML element with “identity” that is described by properties and their values, and derived from a base “abstract” GML type
  - <Road gml:id="r1">
    - <gml:name>Main St.</gml:name>
    - <numLanes>4</numLanes>
    - <pavementType>concrete</pavementType>
  - </Road>

Object instance →

	A	B	C	D
1	id	name	numLanes	pavementType
2	r1	Main St.	4	concrete
3	r2	Broadway Ave.	4	asphalt
4	r3	Rural Rd.	2	gravel

Property values

Properties

# DIGGS Data Model

- GML Feature – A GML object that also can contain geospatial information within its properties .

```
<Road gml:id="r1">
  • <gml:name>Main St.</gml:name>
  • <numLanes>4</numLanes>
  • <pavementType>concrete</pavement>
  • <centerLine>
    • <gml:LineString srsDimension="2" srsName="urn:diggs:def:crs:DIGGS:0.1:4269">
      □ <gml:posList> -117.394 33.243 -117.307 33.344</gml:posList>
    • </gml:LineString>
  • </centerLine>
</Road>
```

# What kinds of features and objects are in DIGGS?

- The success of DIGGS' adoption depends on whether its structure and content holds/carries the necessary data objects (eg data tables) and object properties ("data fields") necessary to serve the use cases of the geotechnical and geoenvironmental community NOW and into the future.
  - Too restrictive – few will be able to use it
  - Too extensive – too cumbersome to manage
- This is the key issue we are now in the testing phases for:
  - Phase II – do DIGGS objects and properties adequately model geotechnical data?
  - Phase III – can DIGGS data be readily transformed to/from existing geotechnical software and data systems to ensure adoption?

# Types of DIGGS Features

- Projects
  - a business activity that produces sampling features, sampling activities, samples, and measurements.
- Sampling Features
  - Features from which all data, in the form of observations, descriptions, and measurements, are obtained
- Sampling Activities
  - the action taken to obtain or produce a physical sample, although the activity itself may not be successful in producing a sample
- Samples
  - a specimen of earth material, liquid or gas that is obtained as a result of a sampling activity, for the purpose of testing and/or observation



# Types of DIGGS Features

- Field Descriptions
  - Systems of visual/manual descriptions of earth material properties from a sampling feature
- Measurements
  - An act, whose results are estimates of the values of properties of the target of investigation. Measurements include lab and in-situ test results, and monitoring activities

## Metadata Objects

- Document Information      ▫ Business Associates
- Groups                        ▫ Equipment
- Associated Files            ▫ Specifications

A DIGGS instance can contain any number of these objects/features



# Common DIGGS Object Properties

- Attributes
  - **gml:id** (NCNAME)
  - **xml:lang** (language code)
- Properties
  - **gml:description**
  - **status** (for QA/QC)
  - **remark**
    - **Remark**
      - **content** (string)
      - **authorRef** or **author** (string)
      - **remarkDateTime**

# Common DIGGS Feature Properties

- Adds to Object:
- Properties
  - `associatedFile` (reference)
  - `role`
    - Role
      - `content` (codeType)
      - `timePerformed` (TimeInterval – start, end or duration)
      - `remark`
      - `businessAssociateRef` or `businessAssociate` (string)
- DIGGS features and objects all build off of these base types

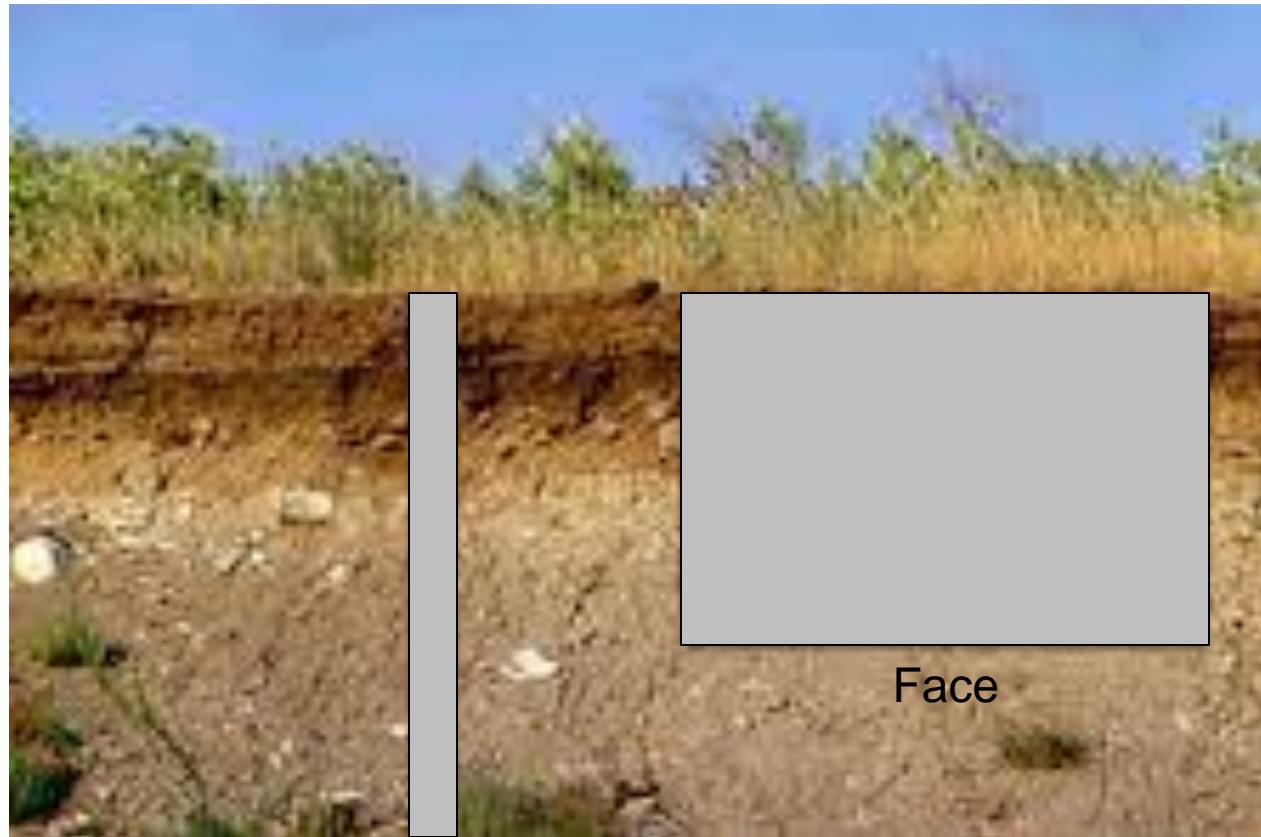
# Project Properties

- Adds to Base Feature type:
- Properties
  - References to sampling features, sampling activities, and groups contained within the project
  - Geometry information
    - referencePoint, linearExtent, arealExtent
  - projectDateTimeSpan (**TimeInterval – start, end or duration**)
  - location (string)
  - purpose (codeType)
  - contract
    - **Contract**
      - associatedFile (reference)
      - type (codeType)
      - clientRef or client (string)
      - contractorRef or contractor (string)

# What are we investigating?



We observe/measure properties of the investigation target via a *sampling feature*



Borehole

Face

# Current Diggs Sampling Features

1D (modeled by a GML LineString)

- Borehole
- Sounding
- Transect
- Trial Pit (AGS Legacy)
- Well

2D (modeled by a GML Polygon)

- Face
- TrenchWall

0D (modeled by a GML Point)

- Station



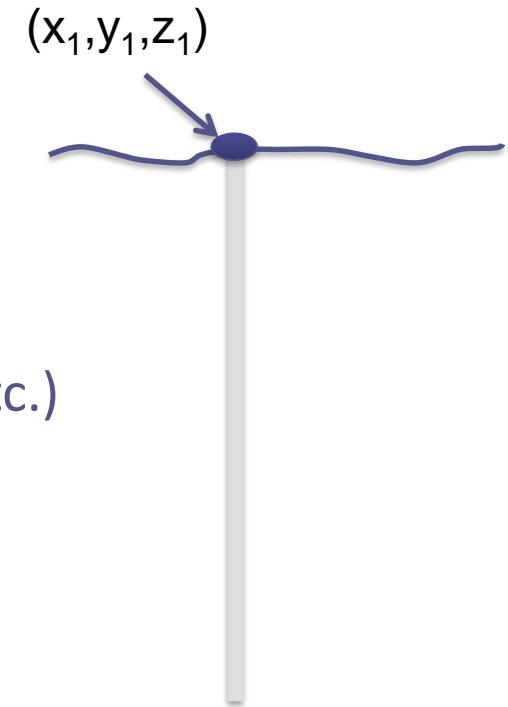
Borehole



Face

# Sampling Features define the geographic and geometric context of the data we obtain

- Borehole Geometry
  - referencePoint (GML point)
    - Usually at one end of the borehole path
      - Eg. top of hole at land surface, rig table, etc.)
    - Represented in 3 dimensions (x, y, z)
    - Useful for map view representations

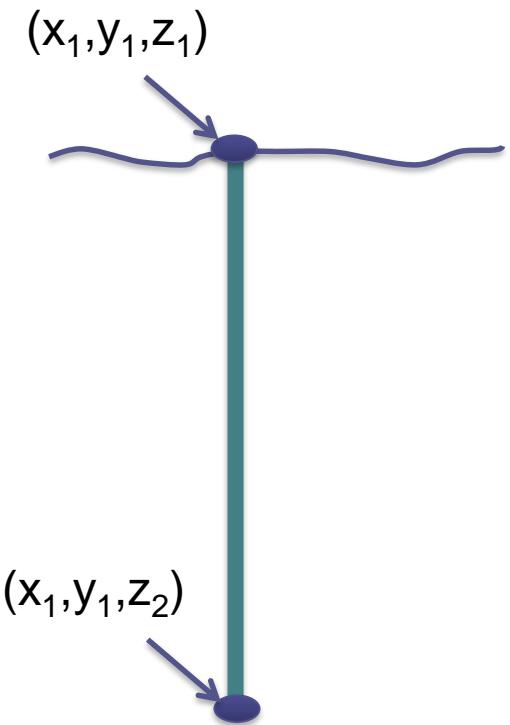


```
<referencePoint>
  <PointLocation gml:id="cpt1" srsName="urn:diggs:def:crs:DIGGS:0.1:26911_5703" srsDimension="3">
    <gml:pos>387416.665116977 3742645.12297961 6</gml:pos>
  </PointLocation>
</referencePoint>
```

# Sampling Features define the geographic and geometric context of the data we obtain

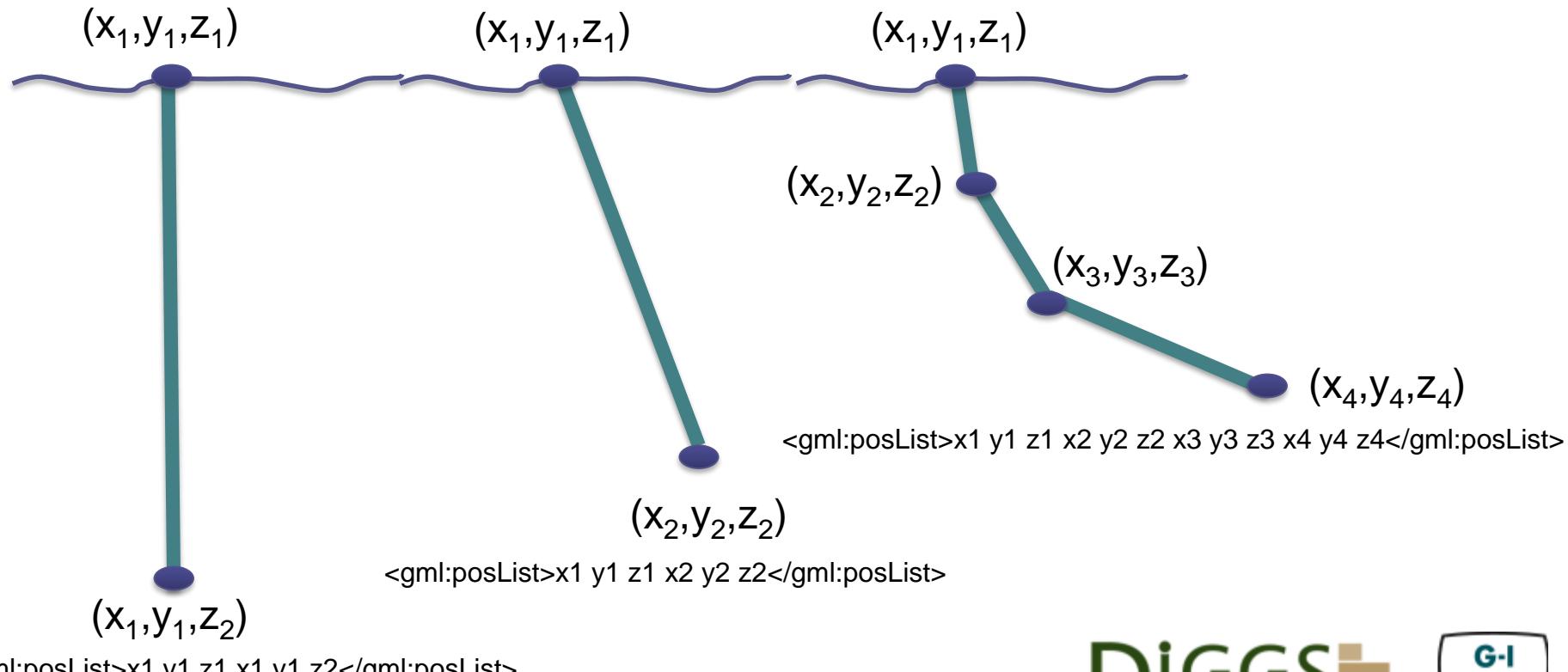
- Borehole Geometry
  - centerLine (GML LineString)
    - A connected set of vertices that define the borehole path
    - Represented in 3 dimensions
    - A borehole can have more than one centerLine property

```
<centerLine>
  <LinearExtent gml:id="ls1" srsDimension="3" srsName="urn:diggs:def:crs:DIGGS:0.1:26911_5703">
    <gml:posList>387416 3742645 6 387416 3742645 1.44</gml:posList>
  </LinearExtent>
</centerLine>
```



# Can DIGGS represent inclined or deviated boreholes?

- YES!! (it's all in the `gml:posList` property)

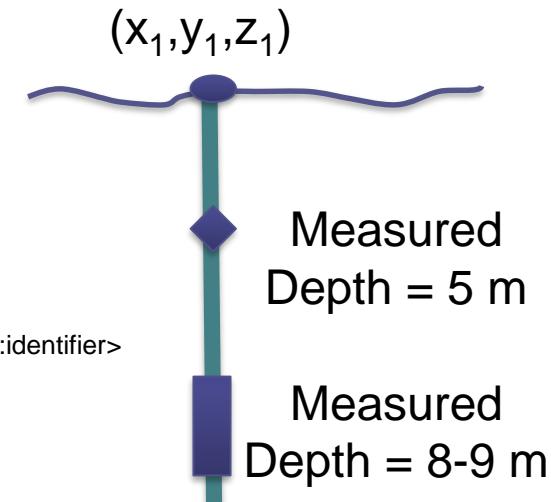


# How do we represent the position of samples/measurements within a borehole?

- Linear referencing (GML 3.3)

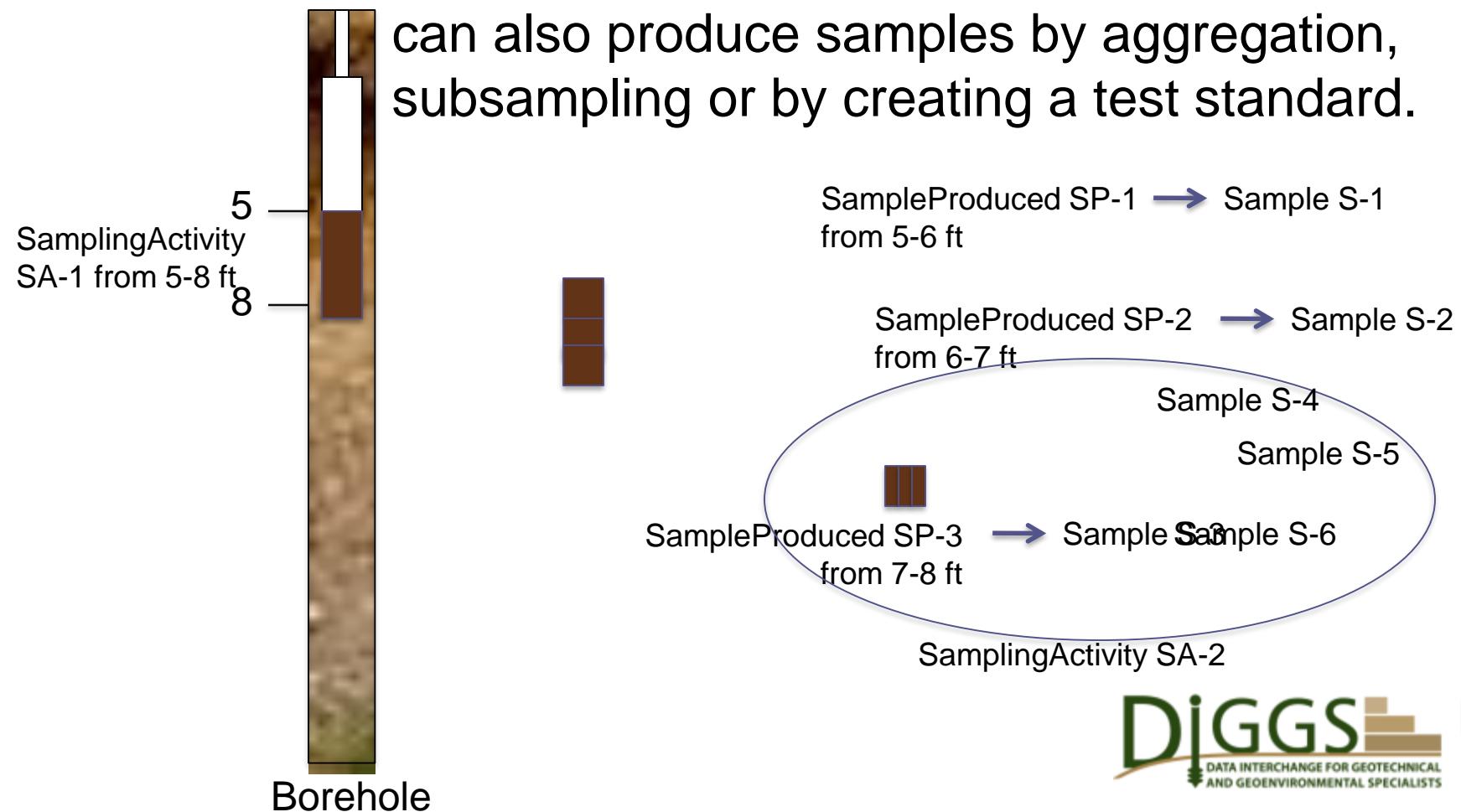
```
<linearReferencing>
  <LinearSpatialReferenceSystem gml:id="cptsr1">
    <gml:identifier codeSpace="urn:x-diggs:def:authority:DIGGSINC">urn:diggs:def:fi:DIGGSINC:cptsr1</gml:identifier>
    <glr:linearElement xlink:href="#ls1"/>
    <glr:lrm>
      <glr:LinearReferencingMethod gml:id="lrcpt1">
        <glr:name>chainage</glr:name>
        <glr:type>absolute</glr:type>
        <glr:units>m</glr:units>
      </glr:LinearReferencingMethod>
    </glr:lrm>
  </LinearSpatialReferenceSystem>
</linearReferencing>
```

```
<sampleLocation>
  <PointExtraction gml:id="pt122" srsName="#ppst1" srid="1">
    <gml:posList>51.09</gml:posList>
  </PointExtraction>
</sampleLocation>
```



# DIGGS Data Model

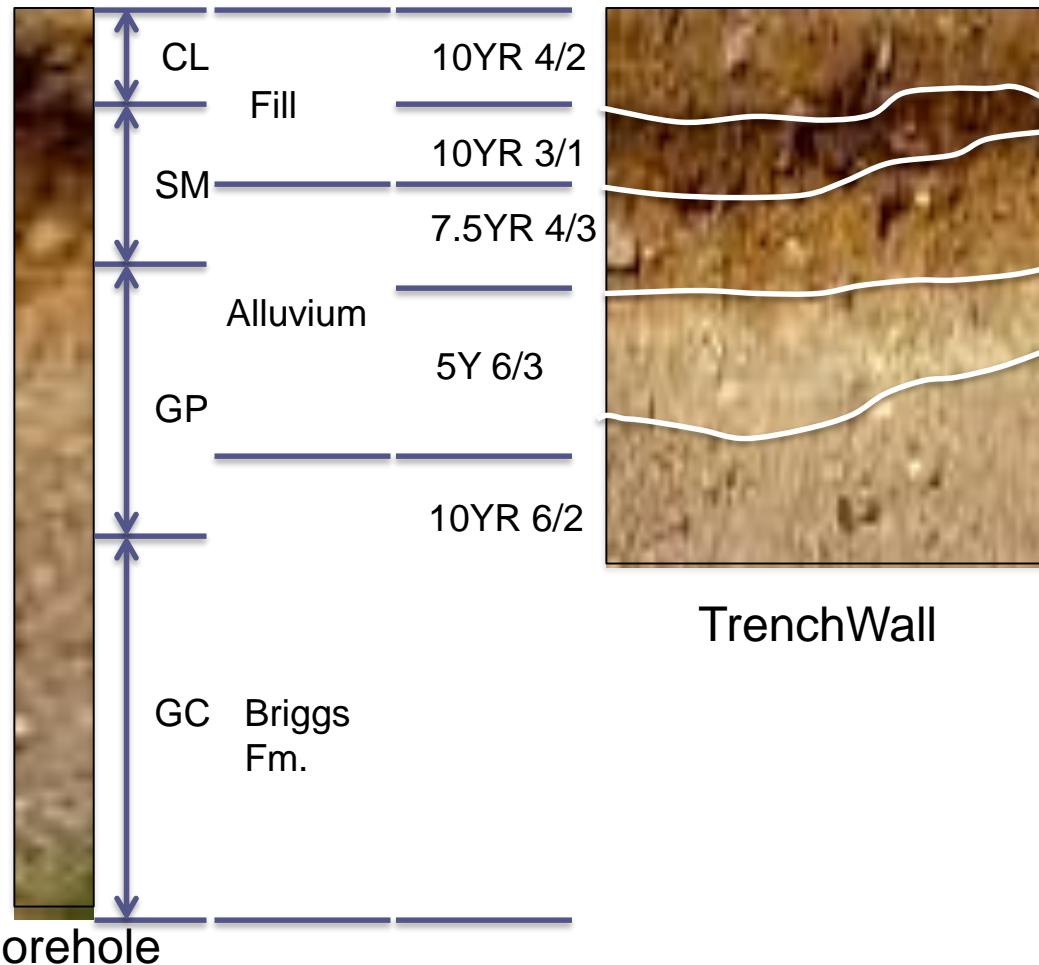
*Samples* are collected from sampling features as a result of *sampling activities*. *Sampling activities* can also produce samples by aggregation, subsampling or by creating a test standard.



# DIGGS Data Model

- Sampling Activity Properties
  - references to source sampling features, projects, samples
  - activity location
  - activity type
  - samples produced
  - date
  - environment
  - sampling equipment and procedures
- Sample Properties
  - references to source sampling features, projects, sampling activities
  - classification
  - container type, medium, matrix, condition
  - sample dimensions
  - lithology and component descriptions
  - chain of custody activities

# *Field Descriptions* hold systems of descriptive properties assigned to regions of a sampling feature



- LithologySystem
- ColorSystem
- StratigraphySystem
- ConstituentSystem
- DiscontinuitySystem
- OrientationSystem
- OtherDescriptionSystem

# Lithology Descriptions

```
<description>
  <LithologyDescription gml:id="l1">
    <location>
      <LinearExtent gml:id="i1" srsName="#sr123" srsDimension="1">
        <gml:posList>0 5</gml:posList>
      </LinearExtent>
    </location>
    <trueBaseObserved>true</trueBaseObserved>
    <primaryLithology>
      <Lithology gml:id="l1" diggs:technique="visual">
        <gml:description>silty sand with clay; brown, loose, moist</gml:description>
        <classificationCode codeSpace="USCS">SM</classificationCode>
        <fieldProperties>
          <FieldProperties gml:id="dp-3">
            <apparentDensity>loose</apparentDensity>
            <beddingSpacing>varved</beddingSpacing>
            <cementation>medium</cementation>
            <consistency>soft</consistency>
            <dryStrength>medium</dryStrength>
            <moistureCondition>moist</moistureCondition>
            <odor>none</odor>
            <particleAngularity>subrounded</particleAngularity>
            <particleShape>elongated</particleShape>
            <particleSize>fine sand to silt</particleSize>
            <particleSorting codeSpace="AGI">well-sorted</particleSorting>
            <plasticity>medium</plasticity>
            <reactionToHCl>violent</reactionToHCl>
            <soilStructure>stratified</soilStructure>
            <toughness>medium</toughness>
          </FieldProperties>
        </fieldProperties>
      </Lithology>
    </primaryLithology>
    <componentLithology>
      <ComponentLithology gml:id="sl1" association="interbedded with the primary lithology">
        <lithology>
          <Lithology gml:id="l11">
            <gml:description>clay</gml:description>
            <classificationCode codeSpace="USCS">CL</classificationCode>
          </Lithology>
        </lithology>
        <abundancePercent uom "%">20</abundancePercent>
      </ComponentLithology>
    </componentLithology>
    <baseBoundary>
      <Boundary gml:id="b1">
        <dipAngle uom="ddeg">10.2</dipAngle>
        <dipDirection uom="ddeg">230</dipDirection>
        <distinctness>sharp</distinctness>
        <origin>depositional</origin>
        <topography>wavy</topography>
      </Boundary>
    </baseBoundary>
  </LithologyDescription>
</description>
```

# Measurements

- A measurement is an act or event whose results are estimates of the values of properties of the target of investigation (eg. natural ground).
- Two measurement features in DIGGS
  - Test – measurements over a spatial domain (lab and in-situ tests)
  - Monitor – measurements over a temporal domain (monitoring activities)
- Both features are structured very similarly and results are reported in a self-describing fashion (based on OGC O&M structure) in order to support extensibility and the wide range of measurement results and procedures in the geotechnical and geoenvironmental community.
- Measurements do NOT carry RAW or solely procedural data (eg. tare weights, machine voltages, container ID's)

# Tests

- Components of a Test Feature
  - References to project, samplingFeature(s), samples, measurements
  - Temporal properties (samplingTime, resultTime, validTime) (optional)
  - Test results (mandatory)
    - Spatial domain (location(s) where measurements occur)
    - Property descriptions
      - Controlled terms that define WHAT is being measured/interpreted (terms held in a standard dictionary NOT as elements within the schema)
    - Property values
      - The reported results – values of the properties described above
  - Test procedure(s) (optional)
    - Metadata about the procedure(s) followed in making the measurements
    - Measurements bound directly to the specific procedure and used to obtain the reportable results of the test
    - Equipment used, calibration dates, specifications followed
- Challenge:
  - The distinction between reportable test results, intermediate results that lead to reported results, and raw data or procedural information is sometimes difficult to discern

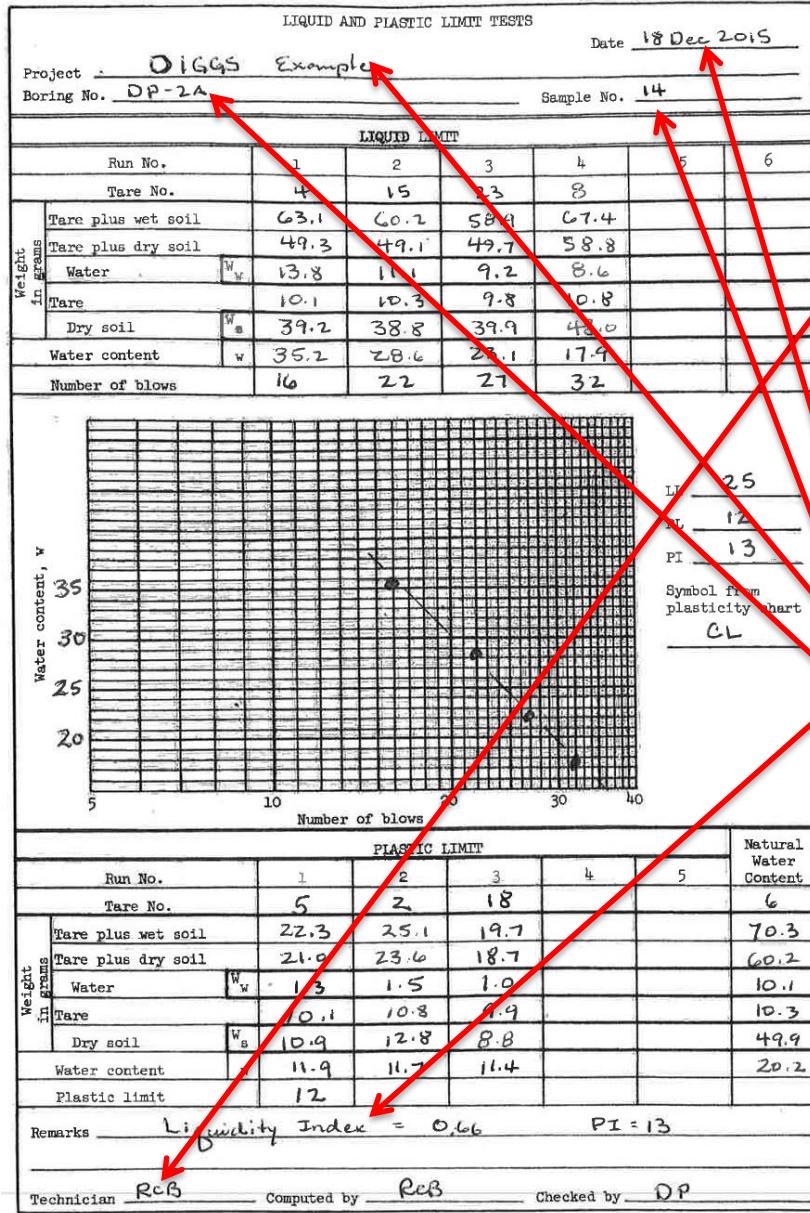
# Monitor

- Components of a Monitor Feature
  - Readings (1 or more) – each reading is from one response zone
    - Response zone location
    - Time domain (list of time instants)
    - Property descriptions
      - Controlled terms that define WHAT is being monitored (terms held in a standard dictionary NOT as elements within the schema)
    - Property values
      - The reported results – values of the properties described above
  - Sensors (optional)
    - Reference point
    - Date installed
    - Detectors
      - Detector location
      - Measurand
      - Type
      - Measurement axis bearing
      - Measurement axis inclination

# Result Properties

- propertyName
- typeData (eg. string, integer, double etc.)
- propertyClass (controlled term – must be defined in an external dictionary)
- unit of measure
- measurementAxisBearing
- measurementAxisInclination
- nullValue
- context
- sampleFraction (eg. dissolved, total, vapor, etc. – controlled list)
- correctionUsed
- measurementTechnique (eg. measured, assigned, estimated – controlled list)
- reference to detector object
- detection limits
- reportable (boolean)
- qualifiers (name-value pairs)
- curve state (eg. processed, raw, depth adjusted, etc. – controlled list from WITSML)

# Example – Atterberg Limits



```

<measurement>
  <Test gml:id="atterberg">
    <gml:name>Atterberg Limits Test</gml:name>
    <role>
      <Role>
        <rolePerformed>Technician</rolePerformed>
        <businessAssociate>RCB</businessAssociate>
      </Role>
    </role>
    <role>
      <Role>
        <rolePerformed>Computed by</rolePerformed>
        <businessAssociate>RCB</businessAssociate>
      </Role>
    </role>
    <role>
      <Role>
        <rolePerformed>Checked by</rolePerformed>
        <businessAssociate>DP</businessAssociate>
      </Role>
    </role>
    <remark>
      <Remark>
        <content>Liquidity Index = 0.66; PI = 13</content>
      </Remark>
    </remark>
    <investigationTarget>Natural Ground</investigationTarget>
    <projectRef xlink:href="#DiggsExample"/>
    <relatedSamplingFeatureRef xlink:href="#DP-2A"/>
    <sampleRef xlink:href="#s14"/>
    <resultTime>
      <TimeInterval gml:id="t3">
        <start>2015-12-18</start>
      </TimeInterval>
    </resultTime>
    <outcome>
  </Test>
</measurement>

```

# Example – Atterberg Limits

LIQUID AND PLASTIC LIMIT TESTS														
Project : DIGGS Example			Date 18 Dec 2015											
Boring No. DP-2A			Sample No. 14											
<b>LIQUID LIMIT</b>														
Run No.	1	2	3	4	5	6								
Tare No.	4	15	23	8										
Weight in grams	63.1	60.2	58.9	67.4										
Tare plus wet soil	49.3	49.1	49.7	58.8										
Water	W <sub>w</sub>	13.8	11.1	9.2	8.6									
Tare		10.1	10.3	9.8	10.8									
Dry soil	W <sub>s</sub>	39.2	38.8	39.9	48.0									
Water content	W	35.2	28.6	23.1	17.9									
Number of blows	16	22	27	32										
<table border="1"> <tr> <td>LL</td><td>25</td> </tr> <tr> <td>PL</td><td>12</td> </tr> <tr> <td>PI</td><td>13</td> </tr> <tr> <td>Symbol from plasticity chart</td><td>CL</td> </tr> </table>							LL	25	PL	12	PI	13	Symbol from plasticity chart	CL
LL	25													
PL	12													
PI	13													
Symbol from plasticity chart	CL													
Run No.	1	2	3	4	5	Natural Water Content								
Tare No.	5	2	18			6								
Weight in grams	27.3	25.1	19.1			70.3								
Tare plus wet soil	21.0	23.6	18.7			60.2								
Water	W <sub>w</sub>	1.3	1.5	1.0		10.1								
Tare		10.1	10.8	9.9		10.3								
Dry soil	W <sub>s</sub>	10.9	12.8	8.8		49.9								
Water content	W	11.9	11.7	11.4		20.2								
Plastic limit		12												
Remarks	Liquidity Index = 0.66			PI = 13										
Technician	RcB	Computed by	RcB	Checked by	DP									

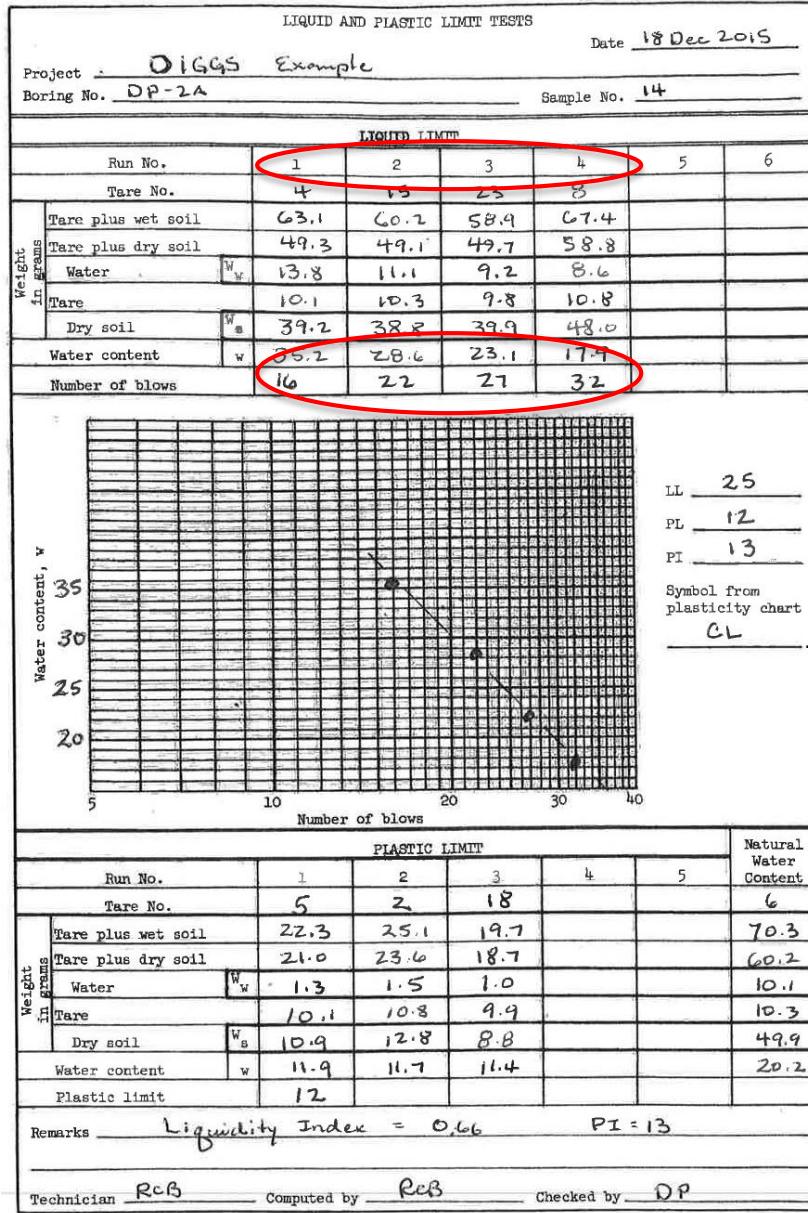
## Test Result Properties

[liquid\\_limit](#)  
[liquid\\_limit\\_oven\\_dried](#)  
[liquidity\\_index](#)  
[consistency\\_index](#)  
[natural\\_water\\_content](#)  
[plastic\\_limit](#)  
[plasticity\\_index](#)  
[shrinkage\\_limit](#)  
[shrinkage\\_ratio](#)  
[volumetric\\_shrinkage](#)  
[uscs\\_symbol](#)

liquid\_limit  
plastic\_limit  
plasticity\_index  
uscs\_symbol  
liquidity\_index  
natural\_water\_content

```
<outcome>
  <TestResult gml:id="altr1">
    <location>
      <PointLocation gml:id="pl2" srsDimension="1" srsName="#sr123">
        <gml:pos>32</gml:pos>
      </PointLocation>
    </location>
    <results>
      <ResultSet>
        <parameters>
          <PropertyParameters gml:id="pp">
            <properties>
              <Property index="1" gml:id="p1">
                <propertyName>LL</propertyName>
                <typeData>integer</typeData>
                <propertyClass codeSpace="urn:x-diggs:def:code-list:property">liquid_limit</propertyClass>
              </Property>
              <Property index="2" gml:id="p2">
                <propertyName>PL</propertyName>
                <typeData>integer</typeData>
                <propertyClass codeSpace="urn:x-diggs:def:code-list:property">plastic_limit</propertyClass>
              </Property>
              <Property index="3" gml:id="p3">
                <propertyName>PI</propertyName>
                <typeData>integer</typeData>
                <propertyClass codeSpace="urn:x-diggs:def:code-list:property">plasticity_index</propertyClass>
              </Property>
              <Property index="4" gml:id="p4">
                <propertyName>Symbol from plasticity chart</propertyName>
                <typeData>string</typeData>
                <propertyClass codeSpace="urn:x-diggs:def:code-list:property">uscs_symbol</propertyClass>
              </Property>
              <Property index="5" gml:id="p2">
                <propertyName>LI</propertyName>
                <typeData>double</typeData>
                <propertyClass codeSpace="urn:x-diggs:def:code-list:property">liquidity_index</propertyClass>
              </Property>
              <Property index="6" gml:id="p6">
                <propertyName>Natural M/C</propertyName>
                <typeData>double</typeData>
                <propertyClass codeSpace="urn:x-diggs:def:code-list:property">natural_water_content</propertyClass>
                < uom>%</uom>
              </Property>
            </properties>
          </PropertyParameters>
        </parameters>
        <dataValues cs="," decimal=". " ts=" ">25,12,13,"CL",0.66,20.2</dataValues>
      </ResultSet>
    </results>
  </TestResult>
</outcome>
```

# Example – Atterberg Limits



<procedures>

```

<diggs_geo:AtterbergLimitsTest gml:id="atterberg-procedure">
  <diggs_geo:liquidLimitTrial>
    <diggs_geo:CasagrandeTrial gml:id="tr1">
      <diggs_geo:trialNo>1</diggs_geo:trialNo>
      <diggs_geo:isManual>true</diggs_geo:isManual>
      <diggs_geo:blowCount>16</diggs_geo:blowCount>
      <diggs_geo:waterContent uom "%">35.2</diggs_geo:waterContent>
    </diggs_geo:CasagrandeTrial>
  </diggs_geo:liquidLimitTrial>
  <diggs_geo:liquidLimitTrial>
    <diggs_geo:CasagrandeTrial gml:id="tr2">
      <diggs_geo:trialNo>2</diggs_geo:trialNo>
      <diggs_geo:isManual>true</diggs_geo:isManual>
      <diggs_geo:blowCount>22</diggs_geo:blowCount>
      <diggs_geo:waterContent uom "%">28.6</diggs_geo:waterContent>
    </diggs_geo:CasagrandeTrial>
  </diggs_geo:liquidLimitTrial>
  ....
<diggs_geo:AtterbergLimitsTest>

```

# Example – Atterberg Limits

LIQUID AND PLASTIC LIMIT TESTS						
Project : DIGGS Example			Date 18 Dec 2015			
Boring No. DP-2A			Sample No. 14			
<b>LIQUID LIMIT</b>						
Run No.	1	2	3	4	5	6
Tare No.	4	15	23	8		
Weight in grams	63.1	60.2	58.9	67.4		
Tare plus wet soil	49.3	49.1	49.7	58.8		
Water	W <sub>w</sub>	13.8	11.1	9.2	8.6	
Tare		10.1	10.3	9.8	10.8	
Dry soil	W <sub>s</sub>	39.2	38.8	39.9	48.0	
Water content	W	35.2	28.6	23.1	17.9	
Number of blows	16	22	27	32		
<b>PLASTIC LIMIT</b>						
Run No.	1	2	3	4	5	Natural Water Content
Tare No.	5	2	18			6
Weight in grams	22.3	25.1	19.1			70.3
Tare plus wet soil	21.0	23.6	18.7			60.2
Water	W <sub>w</sub>	1.3	1.5	1.0		10.1
Tare		10.1	10.8	9.9		10.3
Dry soil	W <sub>s</sub>	10.9	12.0	8.9		49.9
Water content	W	11.9	11.7	11.4		20.2
Plastic limit		12				
Remarks	Liquidity Index = 0.66			PI = 13		
Technician	RcB	Computed by	RcB	Checked by	DP	

<procedures>

```

<diggs_geo:AtterbergLimitsTest gml:id="atterberg-procedure">
    ...
    <diggs_geo:plasticLimitTrial>
        <diggs_geo:PlasticLimitTrial gml:id="pl1">
            <diggs_geo:trialNo>1</diggs_geo:trialNo>
            <diggs_geo:isManual>true</diggs_geo:isManual>
            <diggs_geo:waterContent uom "%">11.9</diggs_geo:waterContent>
        </diggs_geo:PlasticLimitTrial>
    </diggs_geo:plasticLimitTrial>
    <diggs_geo:plasticLimitTrial>
        <diggs_geo:PlasticLimitTrial gml:id="pl2">
            <diggs_geo:trialNo>2</diggs_geo:trialNo>
            <diggs_geo:isManual>true</diggs_geo:isManual>
            <diggs_geo:waterContent uom "%">11.7</diggs_geo:waterContent>
        </diggs_geo:PlasticLimitTrial>
    </diggs_geo:plasticLimitTrial>
    <diggs_geo:plasticLimitTrial>
        <diggs_geo:PlasticLimitTrial gml:id="pl3">
            <diggs_geo:trialNo>3</diggs_geo:trialNo>
            <diggs_geo:isManual>true</diggs_geo:isManual>
            <diggs_geo:waterContent uom "%">11.4</diggs_geo:waterContent>
        </diggs_geo:PlasticLimitTrial>
    </diggs_geo:plasticLimitTrial>
</diggs_geo:AtterbergLimitsTest>
</procedures>
<procedures>
    <diggs_geo:MoistureContentTest gml:id="natural_moisture1">
        <specification codeSpace="ASTM">D2216</specification>
    </diggs_geo:MoistureContentTest>
</procedures>
</Test>
</measurements>

```

Client:	USACE	Project Name:	Dewey Dam
Project Number:	TestProject	Project Location:	Some location, Norcross
Date Started:	Jun 04 2015	Completed:	Jun 04 2015
Drilling Contractor:	ABC Drilling	Logged By:	Shaoshuai Gong
Drilling Method:	4-1/4" Hollow stem auger	Latitude:	33.942901
Equipment:	CME 1100	Longitude:	-84.237488
Hammer Type:	Automatic hammer	Elevation:	325.00
Notes:	Notes go here		

Depth	Sample Type	Number	Blow Counts (N Value)	Environmental Data	Graphic	Water Depth	Material Description	Well Details
1								
2								
3								
4								
5	AUGER....							
6								
7	SPT-2							
8								
9	SPT-3							
10								
11	SPT-4							
12								
13	SPT-5							
14								
15	SPT-6							
16								
17	SH-7							
18								
19	SPT-8							
20								
21	SPT-9							
22								
23	SPT-10							
24								
25								
26								
27								
28								
29								
30								

(continued on next page)

## &lt;projects&gt;

&lt;Project gml:id="TestProject"/&gt;

## &lt;projects&gt;

## &lt;samplingFeature&gt;

&lt;Borehole gml:id="BH-38"/&gt;

## &lt;/samplingFeature&gt;

## &lt;samplingActivity&gt;

&lt;SamplingActivity gml:id="SA-AUGER"/&gt;

## &lt;/samplingActivity&gt;

## &lt;samplingActivity&gt;

&lt;SamplingActivity gml:id="SA-SPT-2"/&gt;

## &lt;/samplingActivity&gt;

.....

## &lt;sample&gt;

&lt;Sample gml:id="AUGER"/&gt;

## &lt;/sample&gt;

## &lt;sample&gt;

&lt;Sample gml:id="SPT-2"/&gt;

## &lt;/sample&gt;

.....

Client:	USACE	Project Name:	Dewey Dam
Project Number:	TestProject	Project Location:	Some location, Norcross
Date Started:	Jun 04 2015	Completed:	Jun 04 2015
Logged By:	Shaoshuai Gong	Checked By:	
Drilling Contractor:	ABC Drilling	Latitude:	33.942901
Drilling Method:	4-1/4" Hollow stem auger	Longitude:	-84.237488
Equipment:	CME 1100	Elevation:	325.00
Hammer Type:	Automatic hammer		
Notes:	Notes go here		

Depth	Sample Type	Number	Blow Counts (N Values)	Environmental Data	Graphic	Water Depth	Material Description	Well Details
1								
2								
3								
4								
5	AUGER...							
6								
7								
8	SPT-2							
9								
10	SPT-3							
11								
12	SPT-4							
13								
14	SPT-5							
15								
16	SPT-6							
17								
18	SPT-7							
19								
20								
21								
22								
23	SH-7							
24								
25	SPT-8							
26								
27	SPT-9	9-12-50/0...						
28	SPT-10	15-50/0.2' 50/0.1'						
29								
30								

(continued on next page)

&lt;fieldDescriptions&gt;

&lt;LithologySystem gml:id="USCS"&gt;

...

&lt;descriptions&gt;

&lt;LithologyDescription gml:id="ls1-1"/&gt;

&lt;/descriptions&gt;

&lt;descriptions&gt;

&lt;LithologyDescription gml:id="ls1-2"/&gt;

&lt;/descriptions&gt;

...

&lt;/LithologySystem&gt;

&lt;fieldDescriptions&gt;

&lt;measurements&gt;

&lt;Test gml:id="t-SPT-2"&gt;

...

&lt;outcome&gt;

&lt;TestResult gml:id="tr-1"/&gt;

&lt;location/&gt;

&lt;results/&gt; (n\_value)

&lt;/outcome&gt;

&lt;procedures&gt;

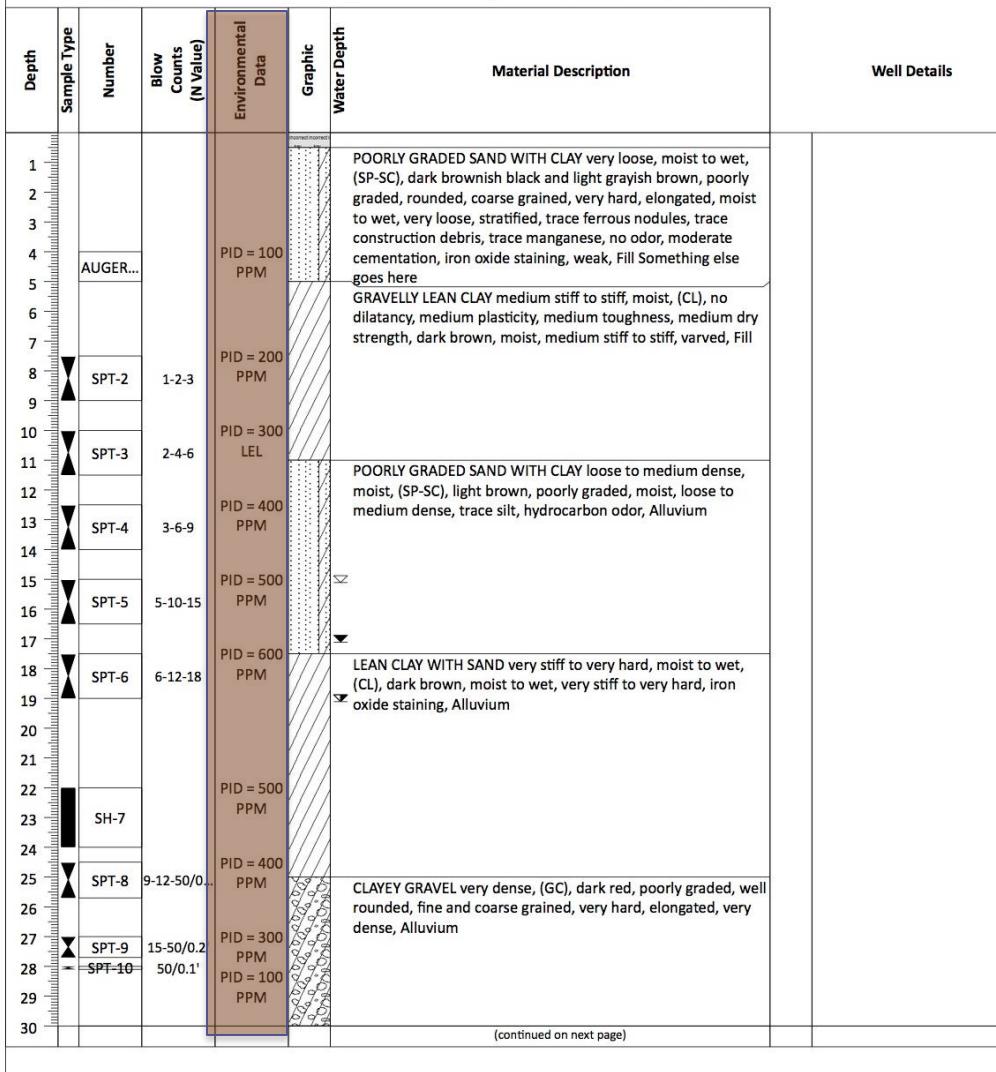
&lt;diggs\_geo:DrivenPenetrationTest gml:id="t1-p1"&gt;

&lt;procedures/&gt;

&lt;/Test&gt;

&lt;/measurements&gt;

Client:	USACE	Project Name:	Dewey Dam
Project Number:	TestProject	Project Location:	Some location, Norcross
Date Started:	Jun 04 2015	Completed:	Jun 04 2015
Logged By:	Shaoshuai Gong	Checked By:	
Drilling Contractor:	ABC Drilling	Latitude:	33.942901
Drilling Method:	4-1/4" Hollow stem auger	Longitude:	-84.237488
Equipment:	CME 1100	Elevation:	325.00
Hammer Type:	Automatic hammer		
Notes:	Notes go here		



&lt;measurements&gt;

&lt;Test gml:id="t-SPT-2"&gt;

...

&lt;outcome&gt;

&lt;TestResult gml:id="tr-2"/&gt;

&lt;location/&gt;

&lt;results/&gt; (photo\_ionization\_measurement)

&lt;/outcome&gt;

&lt;procedures&gt;

<diggs\_geo:PhotolonizationDetectorTest  
gml:id="pid1"/>

&lt;procedures/&gt;

&lt;/Test&gt;

&lt;/measurements&gt;

# Phase II Pilot Testing

- Priority Test Procedures for Review

- AtterbergLimitsTest
- CationExchangeTest
- CompactionTest
- CompressiveStrengthTest
- ConsolidationTest
- DensityTest
- DirectShearTest
- DrivenPenetrationTest
- FlatDilatometerTest
- FrostSusceptibilityTest
- HandVaneTest
- InsituCBRTTest
- StaticConePenetrationTest
- InsituDensityTest
- InSituPenetrometerTest
- InsituPermeabilityTest
- InsituVaneTest
- LabCBRTTest
- LabPenetrometerTest
- LabPermeabilityTest
- LosAngelesAbrasionTest
- MoistureContentTest
- ParticleSizeTest
- PointLoadTest
- PressuremeterTest
- PumpingTest (monitoring)
- RelativeDensityTest
- SuctionTest
- TriaxialTest

# Thank you!

# Questions?

