Jet Grouting and Deep Mixing Extensions to DIGGS

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ABSTRACT

The issue of data management is not unknown to the geotechnical engineering industry. In some instances, the storage of data includes an outdated file room cluttered with thousands of files haphazardly shuffled away. In others, data has been digitized to some extent, but the transfer of these files is not as efficient as it could be. Countless resources are wasted every year as data from previous explorations or construction activities are searched for or individually manipulated to fit the needs of current projects. In some instances, data are lost altogether and repeat explorations are required to be performed. Additionally, as data are produced even today, time and money are wasted on manipulating data as they are shared between different members of the geotechnical community. Two parties using different applications or formatting techniques makes transferring and processing data difficult and time consuming. To combat these issues, the Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) project was created. This project was initially introduced to manage data from geotechnical explorations, but the ASCE Geo-Institute has been making a push in recent years to expand DIGGS to include data from construction activities as well. Work on DIGGS to expand its capacity to be able to organize data from grouting-related ground improvement activities began in 2021. The initial phase of this expansion was a success, and funding was granted by the Geo-Institute Special Projects Committee to continue this expansion in 2022.

The efforts of this project were to extend the DIGGS grouting schema to accommodate jet grouting and deep mixing ground improvement methods. The ContinuousGrouting object was a paramount addition of this expansion, and the successful testing of this object among others is confirmed. Other objects added to the schema include those pertaining to fluid additives and data recorded over time series. Finally, objects were created to carry information about the equipment used in jet grouting and deep soil mixing projects. Sample data sets were used to test the new objects and the instance documents generated from these sample data sets verified the successful extension of the DIGGS schema for jet grouting and deep mixing projects.

INTRODUCTION

To combat the issue of wasted time in the geotechnical industry due to outdated data management practices, the Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) project was created. The aim of this project is to construct a data schema that defines a standard way for contractors, consultants, and geotechnical applications to transfer geotechnical data. This standardization intuitively organizes data from geotechnical projects so that industry practitioners can import and export data about the ground conditions in a consistent, standardized format.

DIGGS was initially created to include data from geotechnical explorations but has recently been expanded to include data from geotechnical construction activities as well. There has been a recent push in the DIGGS community to expand the schema to handle data generated during grouting activities. Initial DIGGS grouting extensions were made in 2021 and included support for rock, compaction, and permeation grouting projects. To further expand DIGGS to support jet grouting and deep soil mixing, funding was approved and granted by the ASCE Geo-Institute Grouting Committee in 2022. The results of this expansion are included in this report.

The latest version of the DIGGS schema and corresponding documentation that includes the latest grouting extensions are incorporated into the DIGGS development release 2.6-dev, and can be found on the DIGGS GitHub site at https://github.com/DIGGSml/diggs-schema/tree/2.6-dev/. DIGGS is a living standard, such that it will be continuously added to and updated as it is used and as the geotechnical industry evolves.

GROUTING TYPES TO BE IMPLEMENTED

This project involves extending the DIGGS schema to support storage and transfer of data collected from jet grouting and deep mixing ground improvement projects. This section summarizes the ground improvement methods that are supported by these new extensions.

Jet Grouting

Jet grouting is the process by which a wide column of grouted soil is produced by highly pressurized expulsion of grout in the horizontal direction over a specified depth range within a single borehole. This specific process, shown on the left-hand side in Figure 1 below, is referred to as single fluid jet grouting.

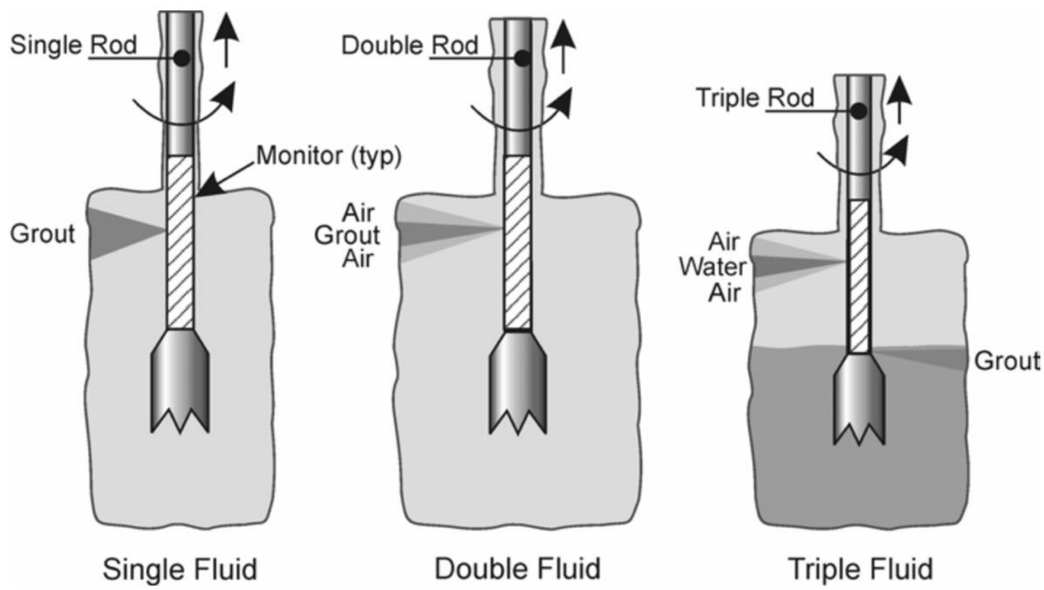

Figure 1: Most common jet grouting systems (Burke, 2004).

Beyond varying fluid injection parameters, the efficiency of the soil-cutting action in jet grouting can be significantly improved using alternative jet grouting methods. The two most common of these alternative methods are referred to as double fluid and triple fluid jet grouting (Figure 1). Double fluid jet grouting includes a shroud of air surrounding the pressurized grout exiting the monitor. This shroud protects the grout jet from friction as it enters the material and allows the grout jet to maintain its high pressure much further into the soil layer.

Triple fluid jet grouting introduces a third fluid to the process: water. The configuration in these systems includes a pressurized grout jet near the bottom of the monitor, with a water jet surrounded by an air shroud near the top of the monitor. This highly pressurized expulsion of a water jet, used in conjunction with the friction-blocking air shroud, is exclusively used for cutting; and provides the highest power cutting action of the three standard jet grouting methods (Burke, 2004).

Deep Soil Mixing/Cutter Soil Mixing

Conventional deep mixing, sometimes referred to as deep soil mixing, is a general term used to describe ground improvement practices in which, like jet grouting, columns of soil are treated in situ to achieve desired strength or permeability properties. Deep soil mixing differs from jet grouting in that it relies on a mixing tool to perform the cutting action in the soil as opposed to relying solely on the action of injected fluids. As such, fluids are injected into the soil at a much lower pressure in deep soil mixing than with jet grouting.

With deep soil mixing, a laboratory procedure is often required as a prerequisite to the grouting activity. Soil from the site to be improved is sampled and mixed in the lab with varying amounts of cementitious binder, often simply consisting of a cement and water slurry. Each of the samples generated from the variation of these ratios is tested for strength using an unconfined compressive strength test. Through a trial-and-error process, the optimum mixture producing the largest compressive strength is often selected for the mix design. This mix design then governs the rates of grout injection and cutting tool advancement speeds that are chosen for the job. The testing process is done for deep mixing because field conditions can be simulated more easily than in jet grouting, due to the guaranteed mixing diameter characteristic of deep mixing.

Once the optimum soil-cement mixture has been selected, construction can begin. In this process, a drill advances the mixing tool to a target depth, and a cementitious binder is injected into the soil either as the mixing tool continues rotation downward or as it is lifted out from the hole. The binder used in deep mixing often consists of lime, cement, fly ash or any combination of these and other soil stabilizers (Archeewa et. al, 2011). The binder can be injected with air in what is referred to as “dry soil mixing”, or with water in what is called “wet soil mixing”.

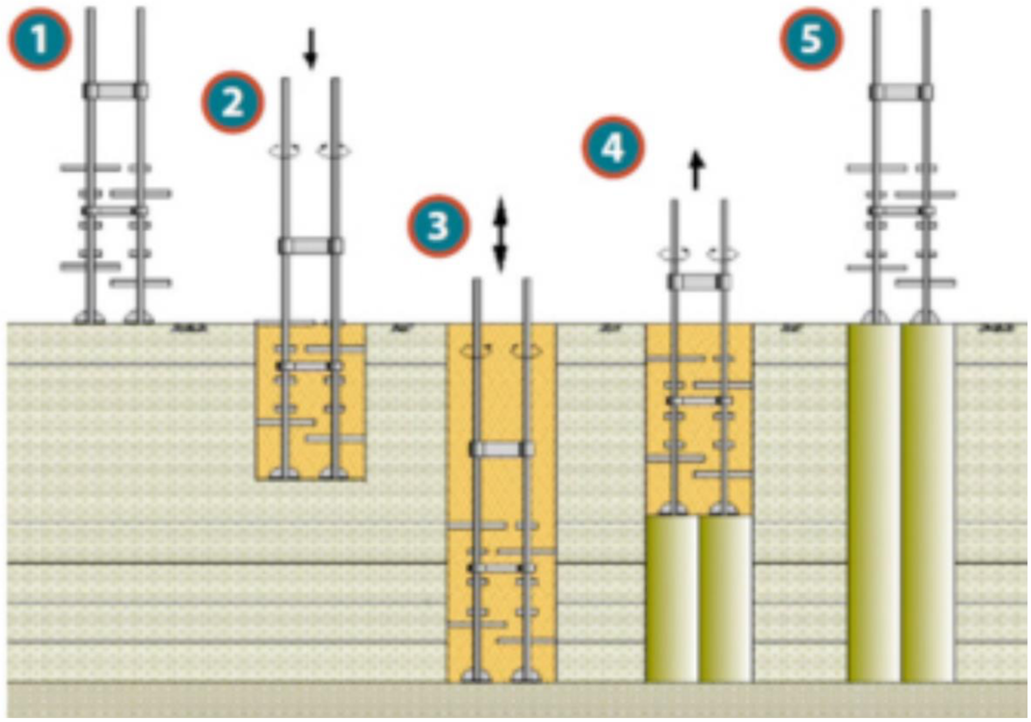

Figure 2: Numbered illustration of deep soil mixing method. 1) Alignment of mixing tool at ground surface. 2) Insertion of rotating tool. 3) Insert rotating tool to target treatment depth. 4) As rotation continues, inject cementitious binder at bottom of treatment depth and slowly withdraw rotating tool. 5) Working the mixing tool throughout the treatment depth range, the mixing of the soil and binder creates a soilcrete column. Remove mixing tool from the product column (JAFEC USA, Inc., n.d.).

Another common soil mixing type that falls within the deep mixing family is cutter soil mixing (CSM). A wet mixing method, CSM operates similarly to the deep mixing method previously discussed, but rather than the mixing tool rotating around the vertical axis, it consists of two mixing tools positioned alongside one another that rotate along the horizontal axis (Bellato et. al., 2017). An image of the mixing tool used in CSM is displayed in Figure 3.

Figure 3: Image of the cutter soil mixing tool (Bellato et. al., 2017).

This configuration allows for a rectangular panel to be produced in situ rather than a cylindrical column as produced in the standard deep mixing method. CSM is preferred in some applications due to its high degree of verticality. It also is more suitable for harder soil formations than conventional deep mixing might be (Gerressen & Vohs, 2012).

DEVELOPMENT PROCESS FOR THE JET GROUTING/DSM SCHEMA

The following numbered list briefly summarizes the body of work performed in this project to bring about the jet grouting and deep mixing extensions to DIGGS.

1. Literary review of jet grouting and deep soil mixing was conducted to familiarize the project team with the procedures, equipment, and applications of these ground improvement methods.

2. Meetings with experts of the grouting industry were held to broaden the knowledge-base in these ground improvement methods and determine what parameters need to be accounted for in each grouting method.

3. Combining knowledge obtained through literary review and discussions with the grouting community, discussions were held to finalize what additions/modifications would be made to DIGGS.

4. The discussed additions/modifications were made to the schema and example data sets were used to develop example DIGGS instance documents to test the schema's ability to capture the collected data.

5. The updated schema was shared with the geotechnical community through workshops, presentations, and publications.

Throughout this process, meetings with the grouting community were frequently taking place to help in the completion of this project. Industry experts from the consulting side, the contracting side, and from academia were all utilized to ensure the work completed was rigorous and inclusive.

HOW JET GROUTING AND DEEP MIXNG FITS INTO DIGGS

DIGGS defines a structure that describes real-world objects and activities and their relations within the geotechnical discipline. Data are stored as ASCII text in eXtensible Markup Language (XML) format that conforms to Geographic Markup Language (GML) standards for defining objects, properties, and geometries for location-based geotechnical data, and that defines data objects, object properties, and their associations.

The data objects are represented within a DIGGS instance document as XML elements of complex type – meaning that they contain nested XML elements within them; these nested elements are the object properties. DIGGS properties may themselves also contain nested component objects in accordance with GML's object-property rule (Ponti, 2016).

The extensions to the DIGGS schema made for this project consisted of the addition of the ContinuousGrouting object, which required the addition of some component objects as well. In addition, objects were added to describe the equipment used during these ground improvement jobs. Finally, parameters were added to the DIGGS data dictionary to allow for DIGGS to report the parameters that might be recorded during jet or deep spoil mixing operations.

Figure 4 is a Unified Modeling Language (UML) diagram that serves as a visual aid in presenting the objects used for jet grouting and deep soil mixing and their associations. In this diagram, each box represents an object within the schema. The purple boxes represent pre-existing objects, while the tan objects are newly added for this project. Within the primary grouting activity object (LinearGroutingActivity), the ContinuousGrouting object has been added for use for jet grouting and deep soil mixing instead of the GroutStage object used for rock, permeation, and compaction grouting (not shown in Figure 4).

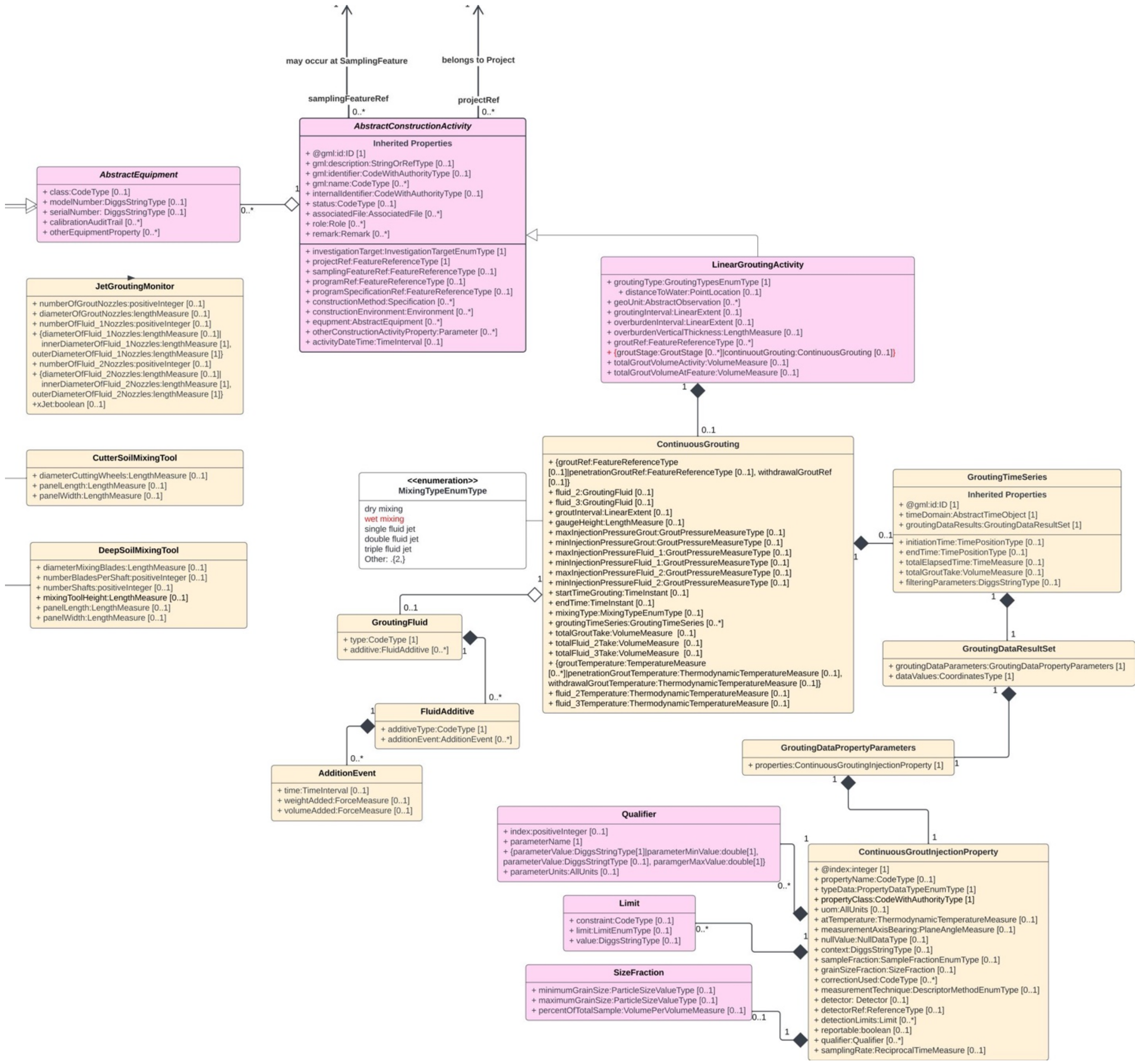

Figure 4: Generalized UML diagram of the ConstructionActivity objects relevant to jet grouting and deep soil mixing. Objects in tan are those that have been added for this extension; those in purple are pre-existing; although some have modified properties to accommodate this extension. Some pre-existing and unmodified component objects have been omitted from the diagram for visual clarity. Explanation of association symbology: open triangle=inheritance/generalization, triangle points to the parent (generalized) object; open diamond=aggregation, diamond points to the parent object, child object is a component of the parent object, but its existence does not depend on the existence of the parent; closed diamond=composition, diamond points to the parent object, child object is a component of the parent object, and its existence depends on the existence of the parent.

The ContinuousGrouting Object

The principal new object created to accommodate jet grouting and deep mixing practices is the ContinuousGrouting object. It became apparent early in the project that the existing GroutStage object could not be used for these soil mixing job types because of the nature of how the borehole is created and grouted in these jobs. The GroutStage object was created for rock, permeation, and compaction grouting methods where the hole is drilled prior to grouting and grout is injected into the hole in one or more depth intervals, or "stages", while holding the grout head stationary. However, jet and deep soil mixing techniques typically involve grouting over a depth interval in one continuous activity that involves moving the grouting head along the path of the hole as grout is expelled into the soil. Thus, the ContinuousGrouting object was created to accommodate properties being collected by jet grouting and deep soil mixing methods that are unique to these methods. ContinuousGrouting is a component object contained within the main object that describes the grouting activity (LinearGroutingActivity) and substitutes for the GroutStage object where the groutingType property of the LinearGroutingActivity has the values "Deep Soil Mixing", "Cutter Soil Mixing" or "Jet".

Contained in the ContinuousGrouting object are properties holding summary information about the grouting performed, such as maximum and minimum pressures, the fluids used, the time over which the grouting took place, and the mixing type. Data recorded continuously during grout injection as a time series, such as depth, rotary pressure, crowd pressure, grout, and fluid flow are recorded in the GroutingTimeSeries object. This object is a component object incorporated under the groutingTimeSeries property of the ContinuousGrouting object.

Accounting for Time Series Data Recorded During Grouting

The GroutingTimeSeries object is a component object contained within the ContinuousGrouting object that is used to record continuous data collected with time as grouting is occurring. The object contains two primary properties: a timeDomain property, which records the absolute or elapsed time index value for each data record, and a groutingDataResults property (and its contained GroutingDataResultSet object), where the recorded parameters are defined and the parameter values for each data record are reported. The GroutingDataResultSet object defines the parameters recorded and the order in which the parameters are reported (groutingDataParameters property and its component GroutingDataPropertyParameters object), whereas the actual data points (the results for each parameter recorded) are contained within the dataValues property as a single text block. This encoding pattern allows for the compact reporting of the potentially thousands of data points that are recorded during jet grouting and deep soil mixing activities. An example of this encoding pattern is given in Appendix A, using an example data set from a jet grouting job.

DIGGS Data Dictionary

The list of parameter codes reported as part of a grouting time series (propertyClass property), the parameter names, and the parameter definitions are not hard-coded into the schema; but are stored within an online dictionary file. Consuming applications can then look up the parameter codes within the dictionary to ensure that parameters recorded are "known" to the application. DIGGS provides a series of standard parameter dictionaries, but other dictionaries can be used and referred to in a DIGGS instance document. By storing the list of controlled parameter terms in an external dictionary, it is easy to expand the parameter list, if necessary, without having to update the schema each time a new parameter is added

For this project, the DIGGS data dictionary for grouting parameters has been expanded beyond those parameters recorded for rock, compaction, and permeation grouting to account for those recorded during jet grouting and deep soil mixing. The following list of parameters represents the list of parameters found in the DIGGS data dictionary to support jet and deep soil mixing grouting activities:

- Advance Rate
- Binder Content
- Binder Factor in Place
- Blade Rotation Number
- Crowd Pressure
- Drilling Index
- Elapsed Time
- Elevation
- Fluid 2 Flow
- Fluid 2 Pressure
- Fluid 2 Stroke
- Fluid 2 Temperature
- Fluid 3 Flow
- Fluid 3 Pressure
- Fluid 3 Stroke
- Fluid 3 Temperature
- Gauge Pressure
- Grout Flow
- Grout Pressure
- Grout Specific Energy
- Grout Temperature
- Grout Trench Cutoff Wall Depth
- Grout Volume
- Header Pressure
- Mass Flow Meter (MFM) Mass Flow
- MFM Temperature
- MFM Volume
- MFM Volume Flow
- MFM Specific Gravity
- Masthead Deviation X
- Masthead Deviation Y
- Measured Distance
- Rotary Pressure
- Rotation Speed
- Specific Energy
- Stroke Count
- Take
- Thrust
- Torque
- Total Tool Revolutions
- Withdrawal Rate

Accounting for Fluid Additives

The grout used in any grouting job is a combination of any number of cementitious materials, admixtures, chemicals, binders, and fillers. Because this is not unique to the grouting types being accounted for in this project, the schema structure to accommodate complex grout mixtures and designs had already been completed and implemented into DIGGS. What is unique to the grouting methods focused on in this project is the potential to have multiple fluids being separately injected into the ground at the same time. Occasionally, the air and/or water used in double and triple fluid grouting jobs can include additives to enhance the engineering properties of the soilcrete column. Most often in current practice, the addition of additives to fluids in double and triple fluid systems is not a continuous time series measurement. Instead, a given weight or volume of an additive is introduced to the fluid over some time interval while the grouting is taking place.

The GroutingFluid, FluidAdditive, and AdditionEvent objects were developed to hold information about the fluids and additives used in double and triple fluid jet grouting jobs. These objects are component objects of the ContinuousGrouting object, as shown in Figure 4. The GroutingFluid object identifies the type of fluid injected (air or water) along with an additive property that identifies any additives used in the fluid. The additive property's component GroutingFluidAdditive object contains an additiveType property that identifies the additive (eg. sodium silicate or other additives intended to come from a controlled list of terms) and any number of additionEvent properties. The additionEvent property's component AdditionEvent object contains information on the time interval during which the additive was introduced to the fluid, along with the volume and or weight of product introduced as it is recorded in the field.

Equipment Objects

Other extensions made to DIGGS to accommodate jet grouting and deep soil mixing activities include adding specialized equipment objects to describe properties specific to the equipment used with these methods. For jet grouting, a JetGroutingMonitor object was added to record the number and diameter of grout and fluid nozzles installed on the equipment. This is done to evaluate the cutting/mixing energy transmitted to the soil. For deep mixing methods, two equipment-related objects were created. The DeepSoilMixingTool object was created for conventional deep mixing method projects. This object contains properties to describe the diameter of the mixing blades, the number of blades per shaft, the number of shafts, and the mixing tool height; as well as properties to describe the dimensions of the panel created during the deep mixing process. The CutterSoilMixingTool object includes properties for the diameter of the cutting wheels as well as the length and width of the panel created by the tool.

VERIFICATION

The proposed objects created for this schema extension were tested using real data sets obtained from contracting firms that perform these types of work. Data sets collected from jet grouting and deep soil mixing jobs were used to test the new schema additions, and all of the data from these data sets were successfully mapped into validated DIGGS instance documents. These example data files are available on the GitHub site (https://github.com/DIGGSml/diggs-schema/tree/2.6-dev/) and an abridged version of the jet grouting instance is provided in Appendix A.

NEXT STEPS

Further enhancements to DIGGS to support grouting and other construction activities include development of objects to record pre-construction design information and post-construction performance testing; as well as to extend the grouting schema to support other grouting techniques. As the schema is further tested and utilized in practice, it is likely that other refinements will be added in future releases.

The biggest test of the extensions to DIGGS for grouting is how well the grouting industry accepts and utilizes the standard. DIGGS is now rapidly being incorporated by DOTs and industry practitioners for exploration data, but that adoption has taken several years to evolve, and it is anticipated that the same is likely for construction projects.

The use of DIGGS opens the door to optimized data management and transfer and will become more readily adopted as its benefits become more widely recognized. Workshops, seminars, and use-case presentations at conferences should all be used to educate the community about DIGGS and explain the ways in which it will benefit the geotechnical engineering industry. DIGGS is a valuable tool that will serve the industry well as it is fully embraced and becomes a mainstream means for data management and transfer within geotechnical engineering.

SUMMARY

Through literature review and meetings with members of the industry and grouting academia, this project successfully implemented schema extensions into DIGGS to support jet grouting and deep mixing ground activities. This expansion introduced the ContinuousGrouting object; along with component objects to record time-series data collected during grouting and other objects to record information on fluid additives and grouting equipment. In addition, the DIGGS data dictionary was expanded to accommodate specific time-series parameters recorded during jet grouting and deep mixing jobs.

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Appendix A: Abridged Example Jet Grouting DIGGS File

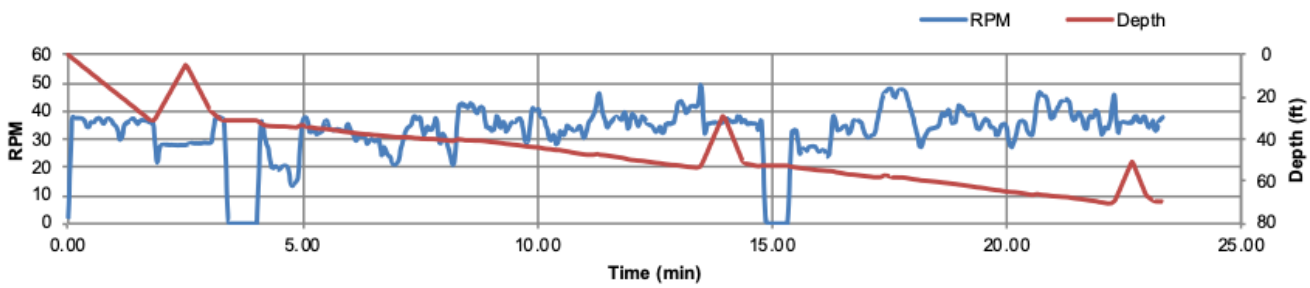
The sets of plots shown below are time series collected for an actual jet grouting job, and the subsequent XML example shows how these data are encoded in a DIGGS instance file. The first set of plots show the revolutions per minute, depth, drilling speed, crowd pressure, and rotary pressure measured while the monitor tool is being inserted into the soil column. A portion of these data is shown in the example DIGGS XML file in the first GroutingTimeSeries object with id = ”cg_ts1”. Note that the XML example contains data for some parameters that are not shown on the plots.

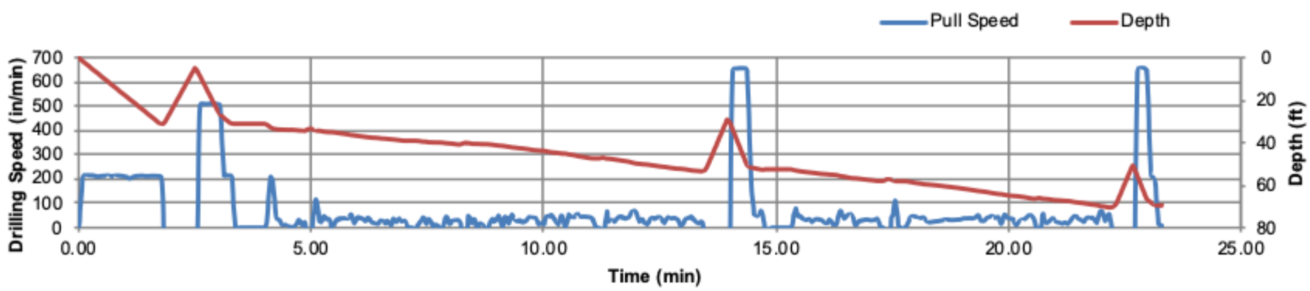
In the second set of plots, data recorded during the time that grout and air are being injected into the soil column while the monitor is being retrieved from the soil column are shown. These data are shown in the XML example in the second GroutingTimeSeries object with id = ”cg_ts2”.

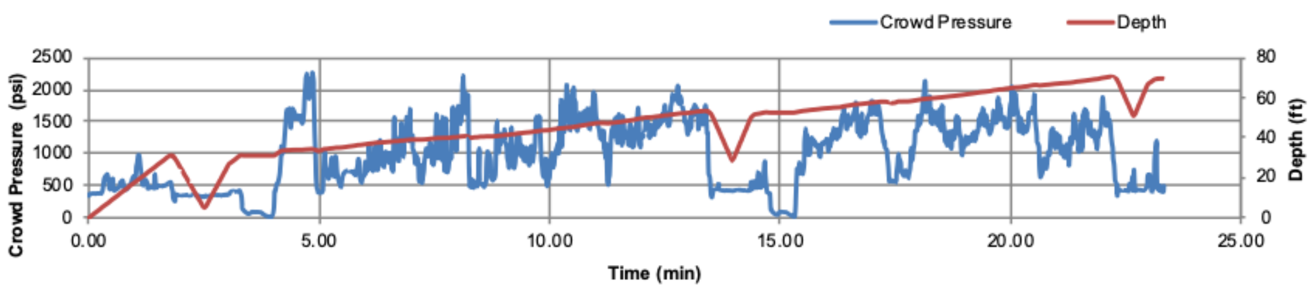
The instance document shown has intermediate time steps and data values omitted for brevity as the full data set contains thousands of data records. However, the unabridged example instance document in its entirety is available on the DIGGS GitHub site. Also, although these data sets are from a real grouting job, name and location information in the instance document has been changed to protect the proprietary nature of the projects from which they came.

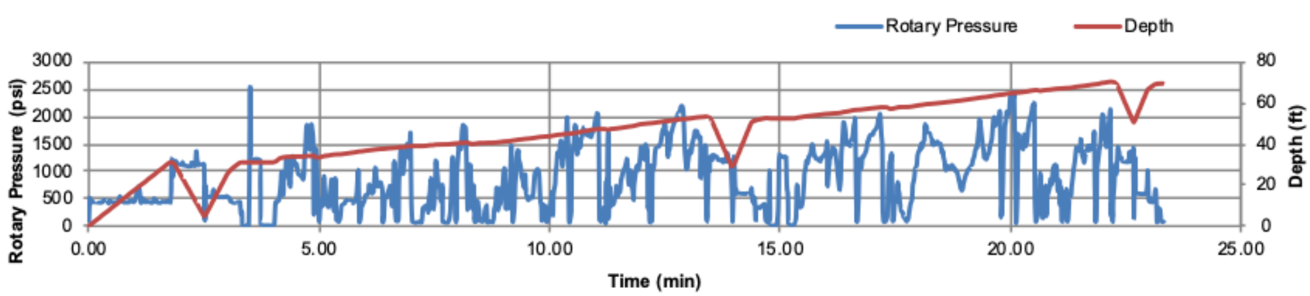
Jet Grout Drilling Report
Highway 1 Lane Widening

Column Number:	1-39	**Date:**	10/9/2015
Drilled Depth:	70.50 ft	**Start Time:**	10:19 PM
Inclination (X, Y):	0.0600, -0.6400	**End Time:**	10:42 PM
		Duration:	00:23:20



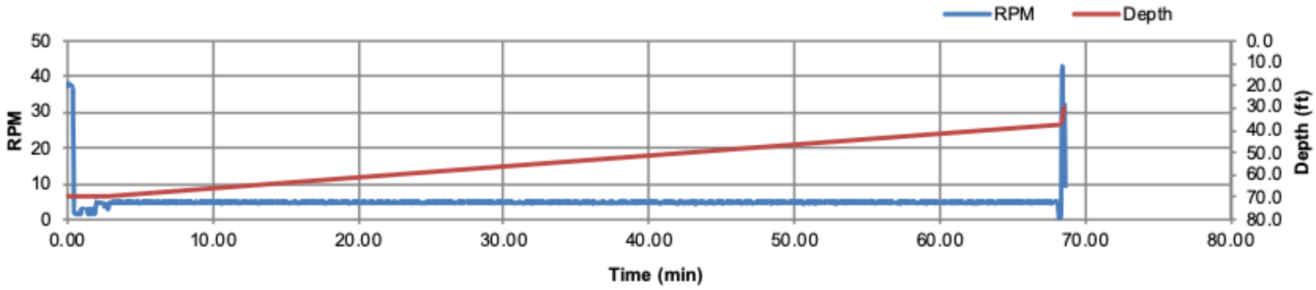


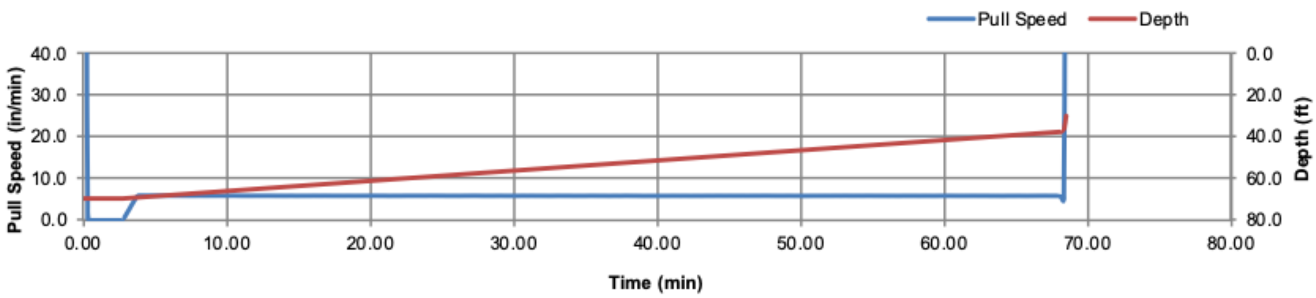


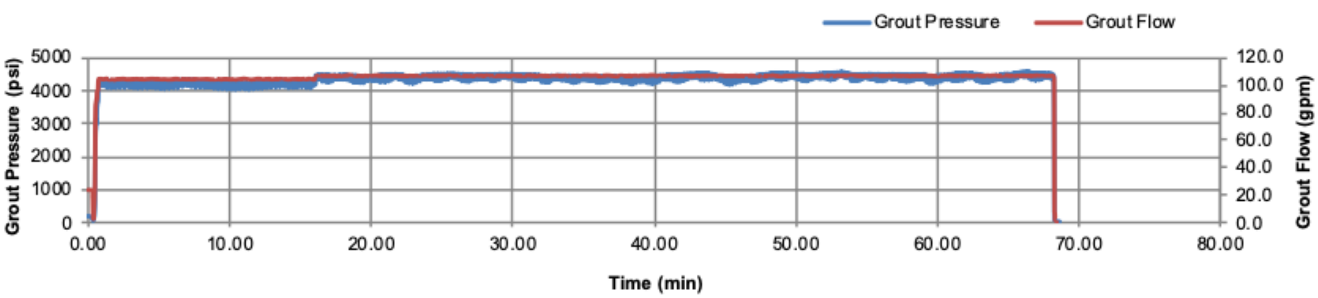


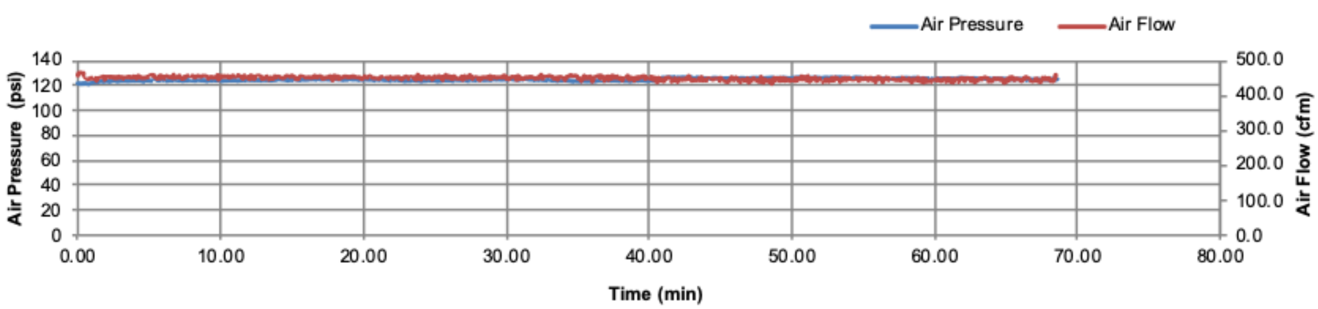
Jet Grouting Report
Highway 1 Lane Widening

Column Number:	1-39	**Date:**	10/9/2015
Total Grout Volume:	7221 gal	**Start Time:**	10:42 PM
Treatment Length:	32.05 ft	**End Time:**	11:51 PM
		Duration:	01:08:38
		Avg. S.G.:	1.43









bridged Example Jet Grouting DIGGS Instance

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           </glr:lrm>
        </LinearSpatialReferenceSystem>
     </linearReferencing>
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     <bearing uom="dega">174.6</bearing>
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/samplingFeature>
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     <projectRef xlink:href="#acme_820081"/>
     <samplingFeatureRef xlink:href="#sf_1-39"/>
     <equipment>
        <JetGroutingMonitor gml:id="jgm">
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           <numberOfFluid_2Nozzles>2</numberOfFluid_2Nozzles>
           <xJet>false</xJet>
        </JetGroutingMonitor>
     </equipment>
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           <start>2015-10-09T22:19:37</start>
           <end>2015-10-09T23:51:56</end>
        </TimeInterval>
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    </activityDateTime>
    <groutingType>Jet</groutingType>
    <groutingInterval>
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        <gml:posList srsDimension="1" srsName="#lsrs_sf_1-39">29.17 69.54</gml:posList>
      </LinearExtent>
    </groutingInterval>
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        <fluid_2>
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            <gml:name>Air</gml:name>
          </GroutingFluid>
        </fluid_2>
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          >4590.67</maxInjectionPressureGrout>
        <minInjectionPressureGrout type="gauge" uom="psi"
          >19.30</minInjectionPressureGrout>
        <maxInjectionPressureFluid_2 uom="psi">192.76</maxInjectionPressureFluid_1>
        <minInjectionPressureFluid_2 uom="psi">119.51</minInjectionPressureFluid_1>
        <startTimeGrouting>
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          </gml:TimeInstant>
        </startTimeGrouting>
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—Only first five and last two data records shown for brevity →
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                  2015-10-09T22:19:39 2015-10-09T22:19:40 2015-10-09T22:19:41
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                                    .
                                    .
                  2015-10-09T22:41:46 2015-10-09T22:41:47 </timePositionList>
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            </timeDomain>
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                       <uom>min</uom>
                      </ContinuousGroutInjectionProperty>
                     <ContinuousGroutInjectionProperty index="2"
                       gml:id="cgip-2">
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                        <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">rotation_speed</propertyClass>
                       <uom>rpm</uom>
                      </ContinuousGroutInjectionProperty>
                     <ContinuousGroutInjectionProperty index="3"
                       gml:id="cgip-3">
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                        <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">advance_rate</propertyClass>
                       <uom>in/min</uom>
                      </ContinuousGroutInjectionProperty>
                     <ContinuousGroutInjectionProperty index="4"
                       gml:id="cgip-4">
                       <typeData>double</typeData>
                        <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">measured_distance</propertyClass>
                       <uom>ft</uom>
                      </ContinuousGroutInjectionProperty>
                     <ContinuousGroutInjectionProperty index="5"
                       gml:id="cgip-5">
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                        <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">rotary_pressure</propertyClass>
                       <uom>psi</uom>
                      </ContinuousGroutInjectionProperty>
                     <ContinuousGroutInjectionProperty index="6"
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                              gml:id="cgip-6">
                              <typeData>double</typeData>
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                              <uom>psi</uom>
                            </ContinuousGroutInjectionProperty>
                          <ContinuousGroutInjectionProperty index="7"
                              gml:id="cgip-7">
                              <typeData>double</typeData>
                                <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">drilling_index</propertyClass>
                            </ContinuousGroutInjectionProperty>
                          <ContinuousGroutInjectionProperty index="8"
                              gml:id="cgip-8">
                              <typeData>double</typeData>
                                <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">grout_flow</propertyClass>
                              <uom>gal[US]/min</uom>
                            </ContinuousGroutInjectionProperty>
                          <ContinuousGroutInjectionProperty index="9"
                              gml:id="cgip-9">
                              <typeData>double</typeData>
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                              <uom>psi</uom>
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                          <ContinuousGroutInjectionProperty index="10"
                              gml:id="cgip-10">
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                                <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">fluid_2_flow</propertyClass>
                              <uom>ft3/min</uom>
                            </ContinuousGroutInjectionProperty>
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                              gml:id="cgip-11">
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                              <uom>psi</uom>
                            </ContinuousGroutInjectionProperty>
                          </properties>
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2,9.00,26.48,0.33,527.79,377.68,7.27,23.76,234.67,265.92,192.76
3,16.50,69.84,0.62,428.44,390.44,3.05,23.76,177.38,265.92,192.76
5,24.00,112.90,0.92,426.41,394.21,2.01,23.79,224.08,265.92,192.76
',32.25,156.01,1.21,455.85,380.00,1.53,23.80,218.86,265.92,192.76
                                  .
                                  .
                                  .
5,33.75,54.89,70.47,1967.44,1519.13,10.28,23.76,203.20,466.51,121.83
17,33.90,59.67,70.50,2122.05,1491.14,9.97,23.78,192.61,466.16,121.83
                    </dataValues>
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-Only first three and last four data records shown for brevity →
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                                                   .
                                                   .
                                                   .
                        2015-10-09T23:51:33 2015-10-09T23:51:34 2015-10-09T23:51:35
                        2015-10-09T23:51:36 </timePositionList>
                    </TimePositionList>
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                          <properties>
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                              gml:id="cgip2-1">
                              <typeData>double</typeData>
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<propertyClass codeSpace="https://www.diggsml.org/dictionaries DIGGSGroutInjectionPropertyDefinitions.xml">elapsed_time</propertyClass>
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  <uom>rpm</uom>
</ContinuousGroutInjectionProperty>
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  <uom>in/min</uom>
</ContinuousGroutInjectionProperty>
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  <uom>ft</uom>
</ContinuousGroutInjectionProperty>
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  gml:id="cgip2-5">
  <typeData>double</typeData>
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  <uom>ft3/min</uom>
</ContinuousGroutInjectionProperty>
<ContinuousGroutInjectionProperty index="6"
  gml:id="cgip2-6">
  <typeData>double</typeData>
    <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">fluid_2_pressure</propertyClass>
  <uom>psi</uom>
</ContinuousGroutInjectionProperty>
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  <uom>gal[US]/min</uom>
</ContinuousGroutInjectionProperty>
<ContinuousGroutInjectionProperty index="8"
  gml:id="cgip2-8">
  <typeData>double</typeData>
    <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">grout_pressure</propertyClass>
  <uom>psi</uom>
</ContinuousGroutInjectionProperty>
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  gml:id="cgip2-9">
  <typeData>double</typeData>
    <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">grout volume</propertyClass>
    <uom>psi</uom>
</ContinuousGroutInjectionProperty>
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  gml:id="cgip2-10">
  <typeData>double</typeData>
    <propertyClass codeSpace="https://www.diggsml.org/dictionaries/DIGGSGroutInjectionPropertyDefinitions.xml">specific_gravity</propertyClass>
  <measurementTechnique>assigned</measurementTechnique>
</ContinuousGroutInjectionProperty>
</properties>
</GroutingDataPropertyParameters>
</groutingDataParameters>
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,37.35,193.60,69.54,464.22,121.88,23.72,206.14,0.51,1.43
,37.20,183.27,69.54,463.97,121.86,23.71,211.83,0.91,1.43
.
.
.
8,28.36,103.18,29.17,460.97,124.91,0.00,27.56,7220.82,1.43
0,22.06,103.08,29.17,460.15,125.11,0.00,27.09,7220.82,1.43
2,15.46,102.98,29.17,461.25,125.14,0.00,26.86,7220.82,1.43
3,9.15,102.88,29.17,461.28,125.15,0.00,27.33,7220.82,1.43
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</groutingDataResults>
</GroutingTimeSeries>
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</groutingTimeSeries>
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</LinearGroutingActivity>
/constructionActivity>
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