Managing 1,000,000 Tons of Soil for the Green Line Extension Project
(Using 3D time-enabled GIS)
Boston, Mass.

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The Green Line Extension

- MassDOT + MBTA
- Green Line Extension (Cambridge to Medford)
  - 5 miles of new track
  - 7 New Stations
  - Vehicle Maintenance Facility
Kleinfelder’s Role

- Part of the HDR/Gilbane JV for Program Management & Construction Management
- Environmental Design and Construction Lead
- Site Characterization
- Management of all excavated soil
Environmental Soil Mgt. Requirements

Requirements:

- Quantify soil excavation
- Classify soil contamination
- Update estimates with new data
- 2-feet intervals by depth
- Conservative “interpolation” methodology
- Soil Tracking - “Cradle to Grave”
- Easy QAQC
- Share data with team
- Use iPads and mobile devices!
Environmental Soil Mgt. Requirements

Considerations:
- Design still in progress
- Continuous soil data collection program
- State and Federal regulations subject to change
  - Soil reuse and disposal options
GIS Plan

<table>
<thead>
<tr>
<th>BRANCH</th>
<th>STATION</th>
<th>POSITION</th>
<th>GROUP</th>
<th>ZONEID</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB</td>
<td>251</td>
<td>L</td>
<td>MB-L</td>
<td>MB-L-251</td>
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</tbody>
</table>

SMU
GIS Plan - Conceptual

$V_{tot}, V_{0-2}, V_{2-4}, \ldots V_{24}, \text{Class}(0-2), \text{Class}(2-4), \ldots$

$\text{Class}(24\text{-bottom}), \text{É Zone’s “MAKE-UP”}$
GIS Plan - Architecture

VOLs
Alignment
ROW
Walls
Surface info.
Bottom Contours
“Neat Line”

Soil Class
Boring Info.
Soil Class @ boring

V_{SMU}, [V_{SMU i}]

[Class_{SMU i}]

Project

SMU

PUB

ArcGIS Online

QAQC

Summaries
Total Volume Calculations

Input Data

- LiDAR for existing conditions
- CAD data for track alignment (alignment stations)
- Civil 3D custom-built sub-assemblies (walls)
- Bentley “in Roads” bottom contours
Total Volume Calculations

Pilot

- Tin:
  - Extrude between
  - Surface Difference

- Vector:
  - Multipatch-features
  - Polygon Volume

- Raster
  - Raster Math
  - Cut-fill

- CAD (comparison)
Total Volume Calculations – Pilot results

- **Tin Method:**
  - Difficult to work with and replicate workflow effectively
  - Rough edges induced gaps
  - Inefficient processing

- **Vector Method:**
  - Too many additional processing steps
  - Conversion left open Multipatch features

- **Raster**
  - Workflow integrates multiple concurrent calculations with same Cut Fill tool calculation
  - Inherent error
  - Efficient and routine processing

<table>
<thead>
<tr>
<th>Method</th>
<th>Vol (cu yd)</th>
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<tbody>
<tr>
<td>CAD - Tin math</td>
<td>10,000</td>
</tr>
<tr>
<td>Raster Analysis (3 ft res)</td>
<td>17,000</td>
</tr>
<tr>
<td>Raster Analysis (1 ft res)</td>
<td>10,849</td>
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<tr>
<td>GIS - Tin math</td>
<td>10,800</td>
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</table>
Soil Classification Process

- 60 analytes — Data stored in EQuIS
- GIS/Env. Professional creates “classified” FC
- Uploads soil class FC to eGIS
- Calculate “SMU make up” for the zones that have borings (.mdb)
- Import back to eGIS
- Geoprocessing (Model Builder) to assign make-up of closest SMU to SMUs that don’t have data of the same GROUP.

![Diagram of Soil Classification Process](image)
Filling-in the Gaps

- Now, all the zones that have a boring have a make-up.
- Zones with no boring get the make-up from the closest zone that has one.
- Need to do this automatically over time, and overwrite as data is QAQC’d.

- With this step: Total volume per zone, and soil class by depth, every 2 ft.
Making “The Cake”

- Need to calculate Volumes per at 2 feet intervals per zone, and summarize by soil classification through the corridor (and by project area – future request)

- Slicing the 3D model in 2-ft intervals and assigning the soil classifications

Interval Vol. = \((\text{Elev.}^{(\text{Upper})} - \text{Elev.}^{(\text{Lower})}) \times \text{Cell Size}\)

SMU Vol. = \(\sum \text{“Cut” Cell Vol.}\)
What raster values really represent in 3D.

- Each raster cell contains one value
  - Values can be anything
  - Commonly: Elevation, Concentration, Color
Calculate Interval Surfaces

Calculate surface intervals between existing and proposed bottom
Calculation Setup

- Calculations:
- Elevations for each interval raster
- Surface Delta \( (\text{Elev.}^{\text{Upper}} - \text{Elev.}^{\text{Lower}}) \)
Potential Limitations:

- Select resolution
- Cell values represent the avg. value
- Consider resolution of source data
- Acceptable error vs. Efficiency
Calculations Beyond the Raster

- Calculations:
- Convert raster values to another format
- Interval Vol. = (Surface Delta) x (Cell Size) + Unit Convert
- Integrate SMU attributes for statistics and filtering
Modeling “The Cake”

1. Create Interval Surface Rasters
2. Calculate Interval thickness and manage “fill” areas
3. Convert to points, calculate volumes, convert units
Making “The Cake” – Slicing the layers
Results

~500,000 yd³
~700,000 tons
Results

Join Outputs:
1. SMUs with Estimated Borings
2. Volume Calculation Results
3. Soil Classification Results
Results

- Symbology
- Statistics and Filters
- Trend Analysis
- Report Output
- Dynamic Graphs
QAQC tool
Next Steps

- Data Dashboard
- Planning viewer
- Soil tracker app
- Stock-pile mgt.(?)

- Update model with improved/new source data
- Include excavation from utilities
- Integrate EQuIS into eGIS and automatize boring classification
- Enable time
- Produce dynamic summaries for project areas
Questions?