3-Dimensional Visualization and Analysis at Mine Sites – an Example from French Gulch

Office of Science Policy's Contaminated Sediments
Virtual Workshop
October 23, 2019

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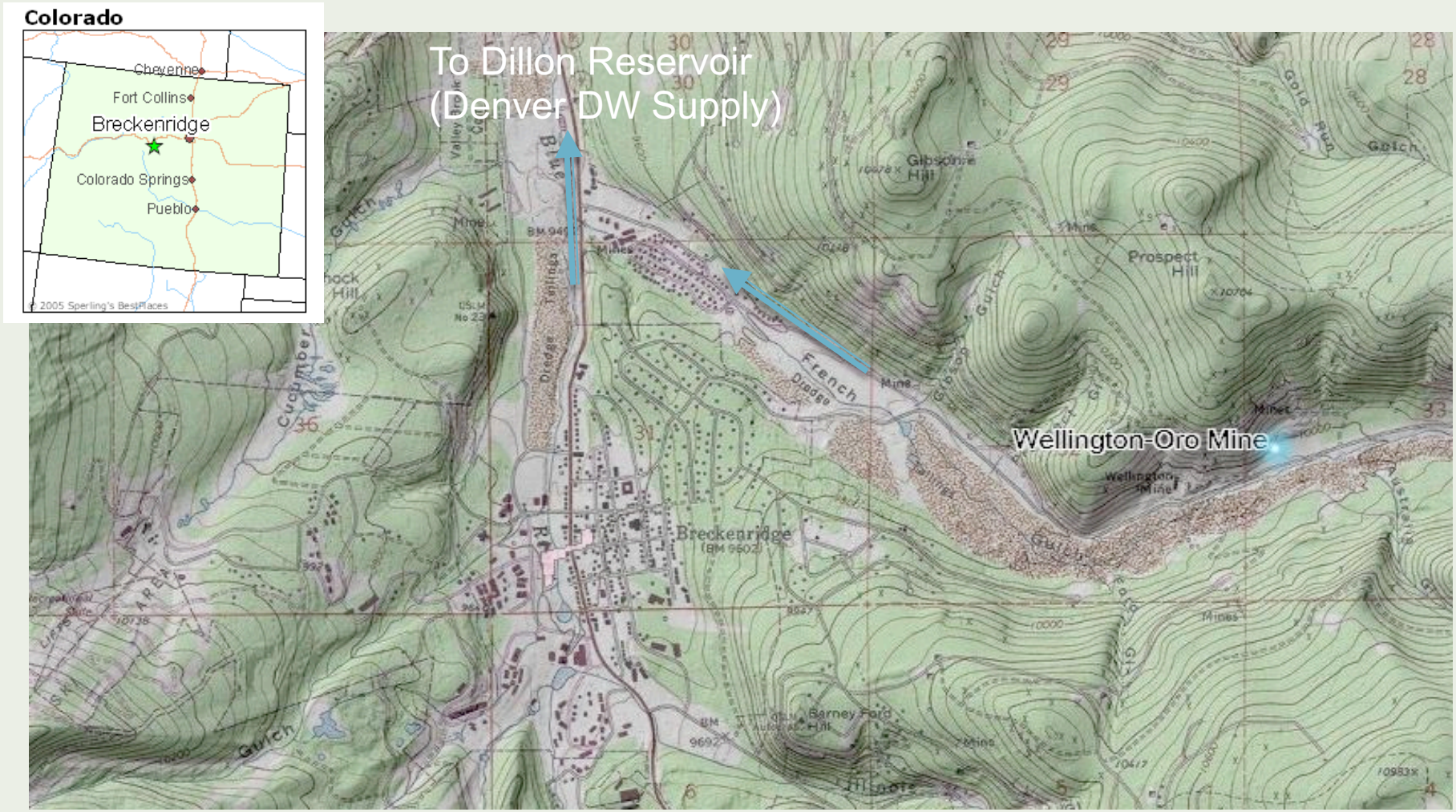
Topics

- **Site background and project needs**
- **Available data sets**
  - Site layout and features
  - Geology
  - Mine workings
  - Hydrology
  - Contaminant chemistry
- **Challenges and solutions**
- **The final product**

Note: All visualization products were prepared by Cascade Technical Services using C-Tech Studio EVS software.

Site Location and Setting

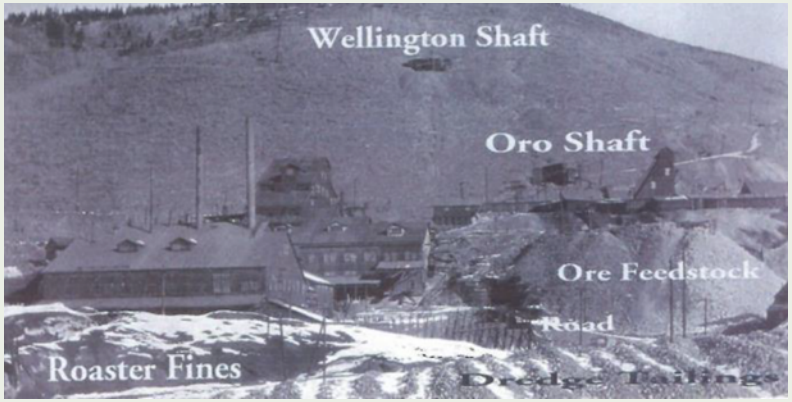


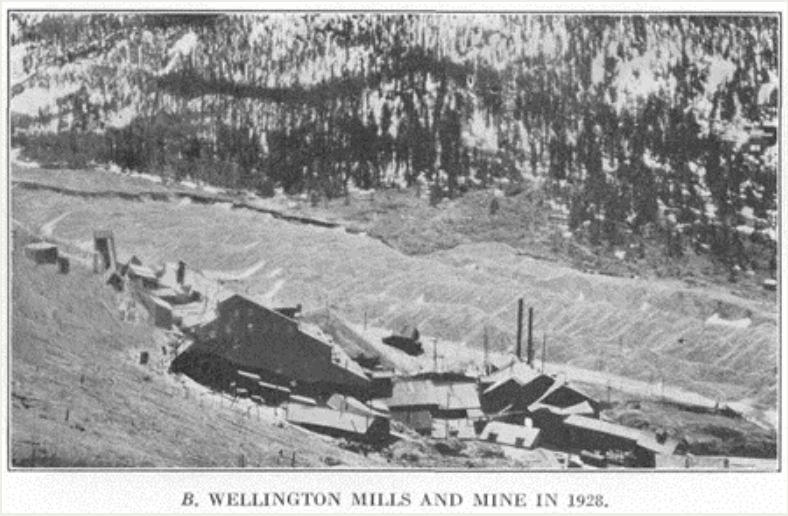
Site Location and Setting

Site Location and Setting

Site Overview

- **Wellington and Oro Mines – 1880's to 1970's**
- **12-miles of mine workings extending 800-feet in elevation, nearly 80% below valley floor**
- **Lode and placer (dredge) mining, Pb and Zn ore also produced Cu, Ag and Au**
- **Mine Influenced Water:**
  French Creek → Blue River → Dillon Reservoir
- **Previous investigations conclude mine pool is primary source**
- **Numerous seeps identified and sampled**
- **Water treatment plant treats acid rock drainage collected at the site by pumping a natural seep named FG-6C**
- **Fractured bedrock, faults, mine workings and connectivity with surface and groundwater**
- **Faults = mineralized zones = ore bodies = sources = transport pathways**

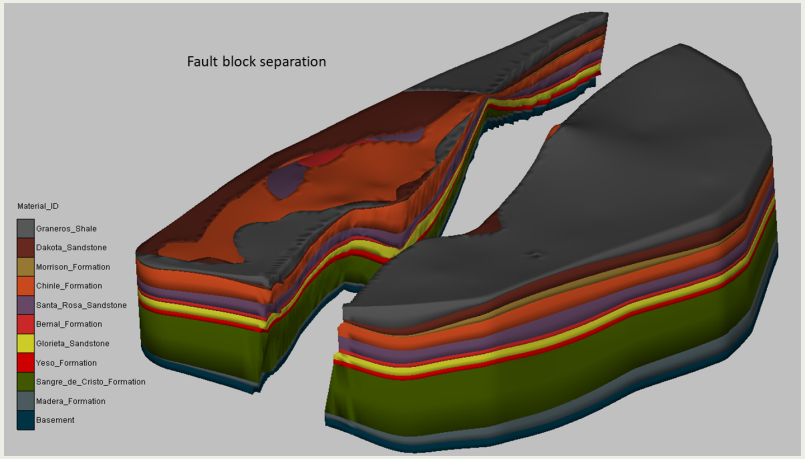


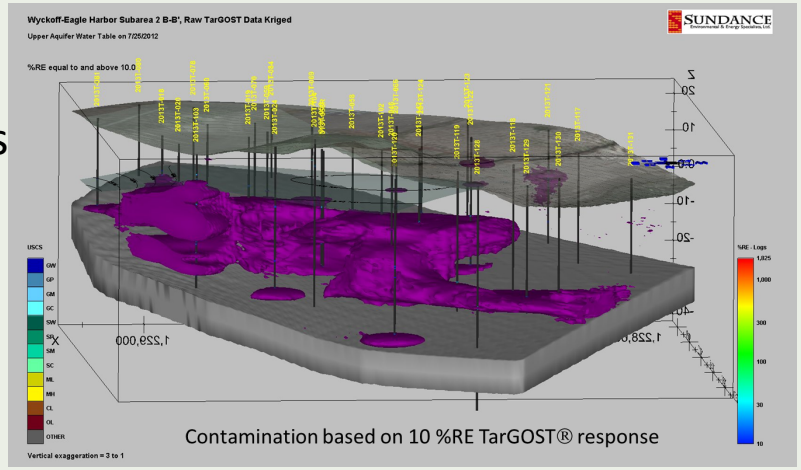


B. WELLINGTON MILLS AND MINE IN 1928.

Project Objectives

- **Construct a 3DVA to include**
  - Mine site features: mine pool(s), mine workings, dredge mining operations, stream channels, fractures
  - Geology
  - Hydrogeology
  - Contaminant distribution
- **Use the 3DVA to enable a more complete conceptualization of interconnecting parts (CSM)**
  - Help make more informed decisions about where and how to investigate loading sources
  - Help identify and determine the feasibility of remedial alternatives
- **Provide an additional tool for communicating site issues to stakeholders**





3-D Visualization and Analysis Process

- **Clarify Project Goals**
  - » Identify specific questions to be answered
- **Manage Data**
  - » Address acquiring, reviewing, processing, importing
- **Develop Component Databases and Visualizations**
  - » Components include geologic, hydrogeologic, and chemical
- **Develop Integrated Visualizations**
  - » Integration of components with calibration and outlier checks
- **Analyze Visualizations**
  - » Assess what 3-D visualizations depict
- **Present Conclusions and Recommendations**
  - » Inform stakeholders and recommend next steps

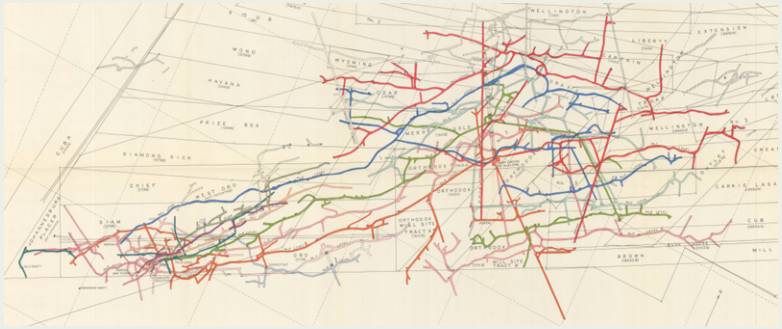
Available Data

- **Mine features and geology**
  - Primarily from 1934 USGS paper on the Breckenridge Mining District
  - No digital mine data
  - LiDAR data became available during project
- **Hydrology**
  - EPA and USGS investigations beginning 1980s; sporadic water level data
- **Chemistry (groundwater and surface water)**
  - Like the hydrology data somewhat sporadic
  - Focused on surface water data

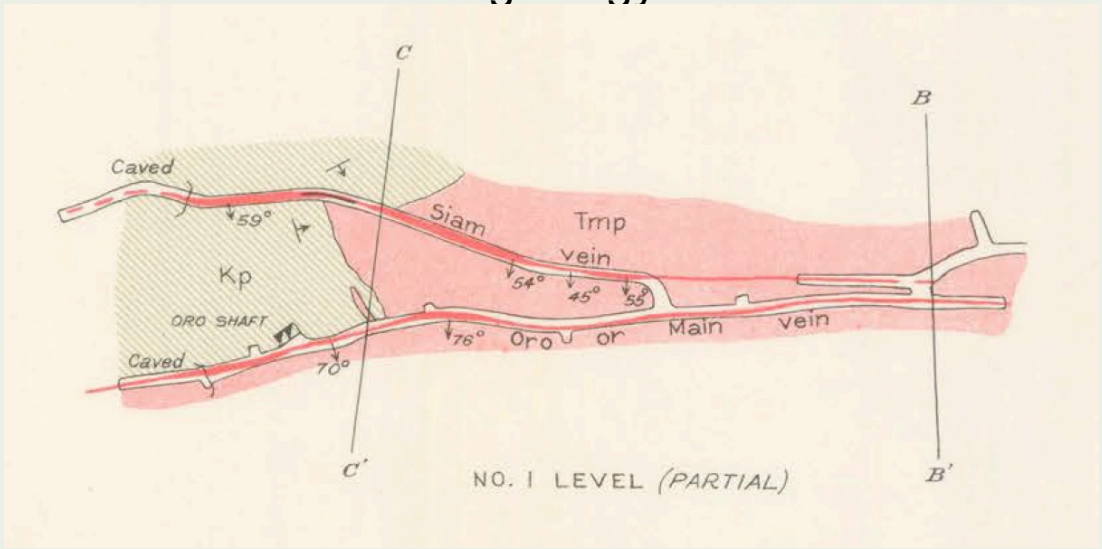
Digitizing Mine Workings and Geology

Using 5 Plates from 1934 USGS paper

"Spaghetti" mine levels map

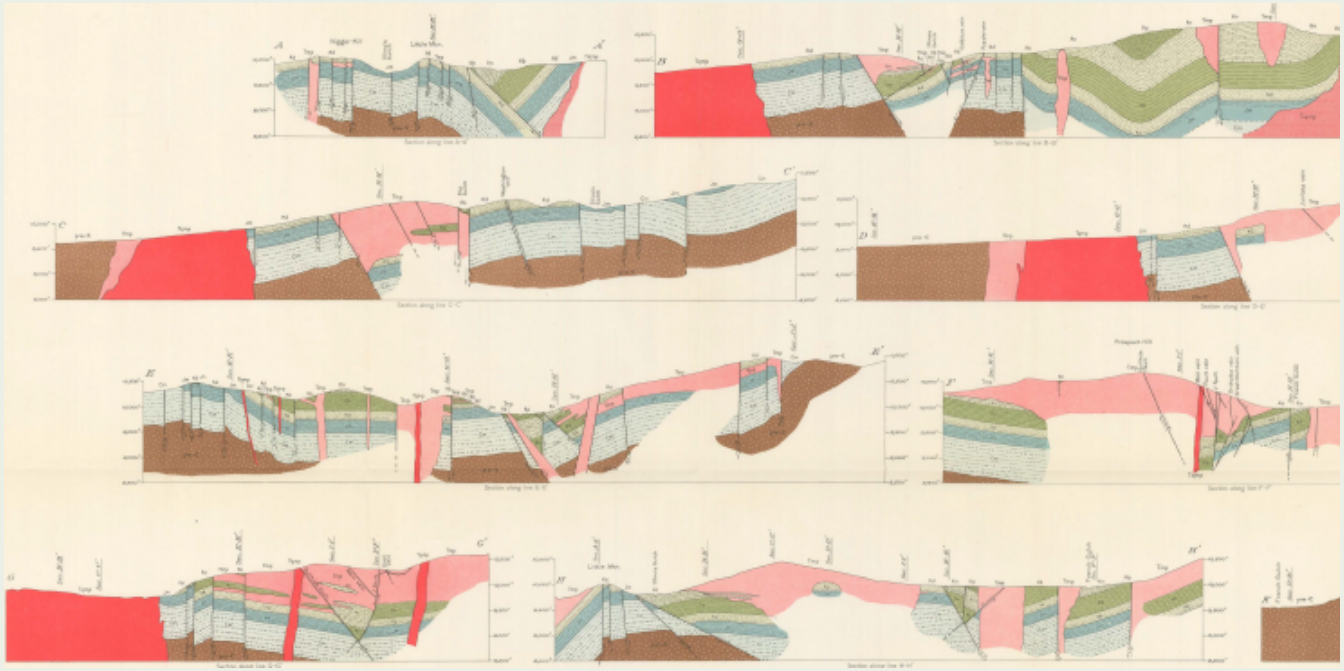


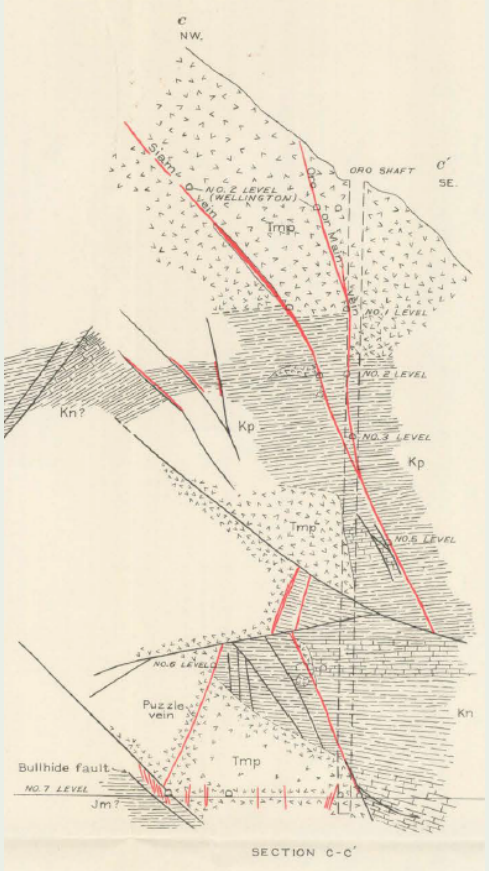
Mine levels and geology



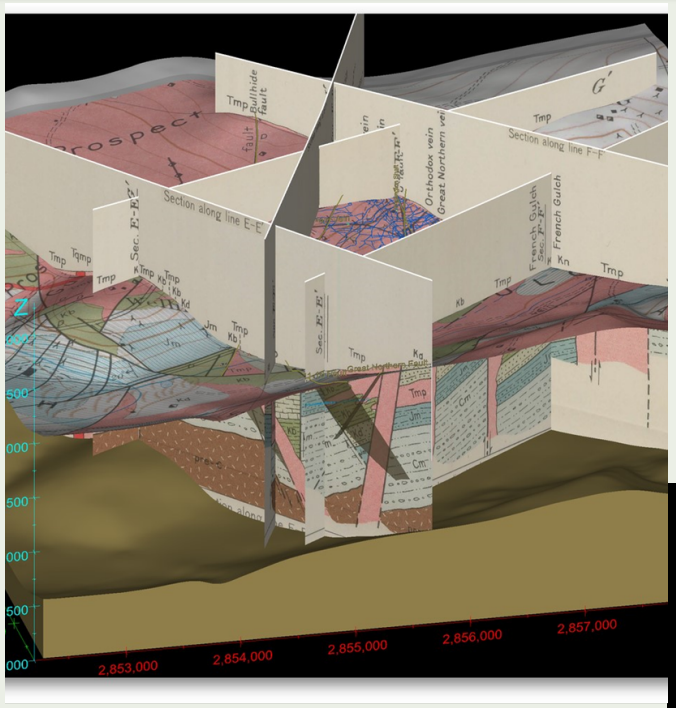
Digitizing Mine Workings and Geology

Cross sections

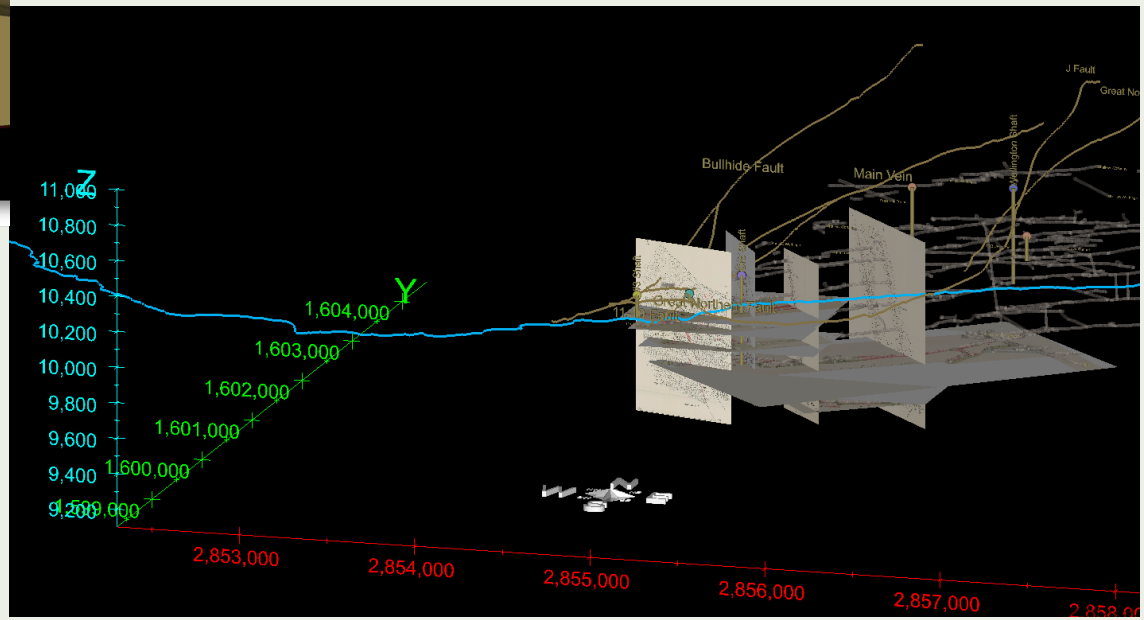




Digitizing Mine Workings and Geology

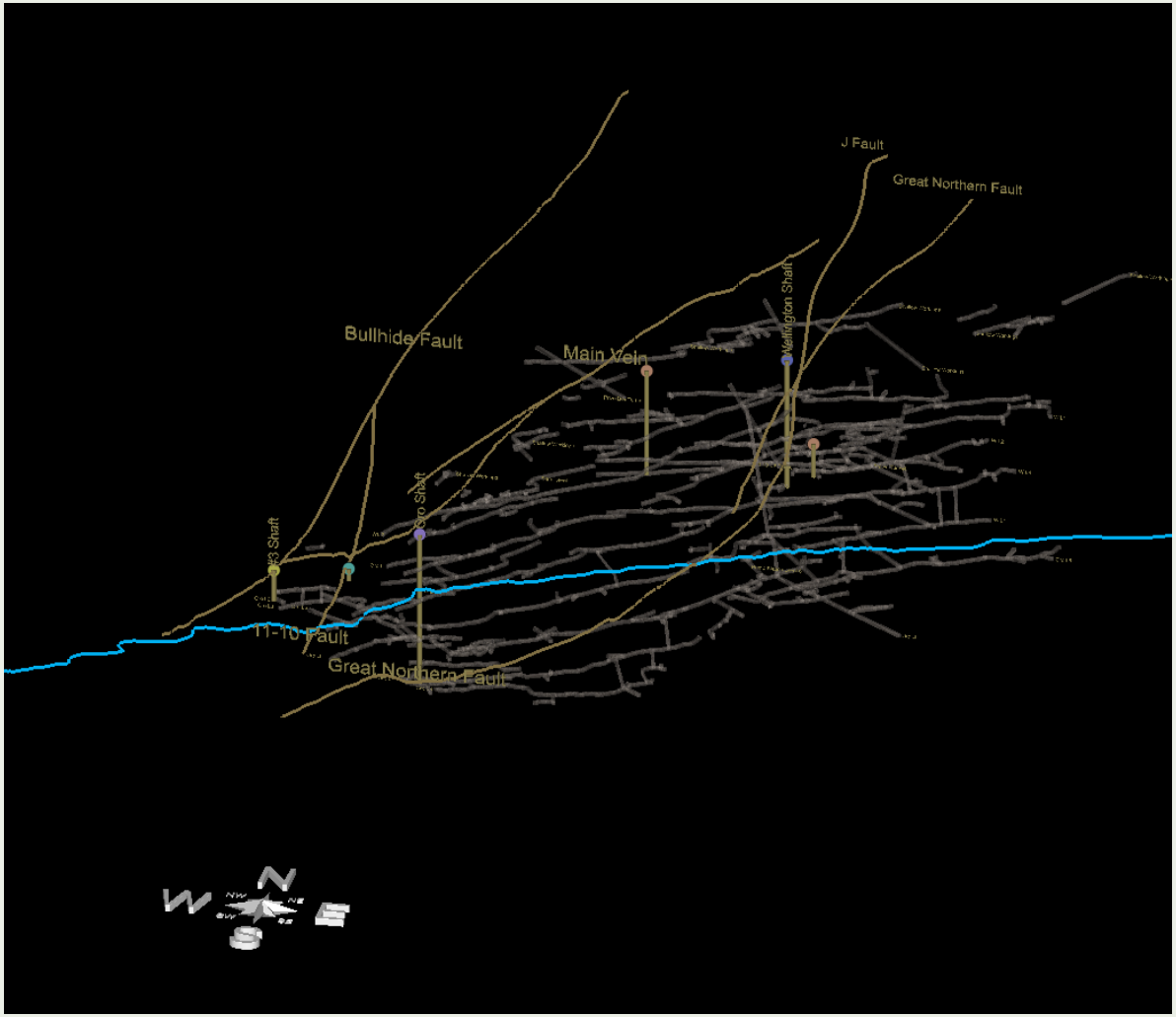


Placing cross sections and mine level maps in correct orientations



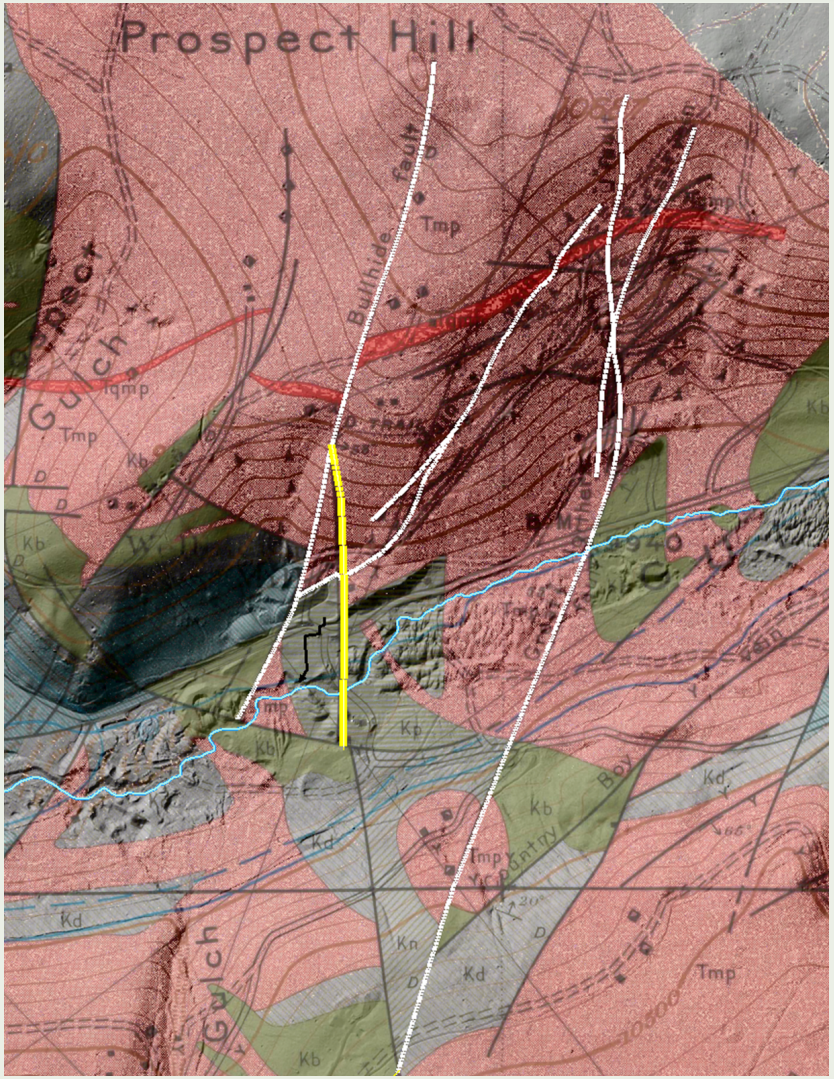
Digitizing Mine Workings and Geology

Initial mine infrastructure component developed from plates

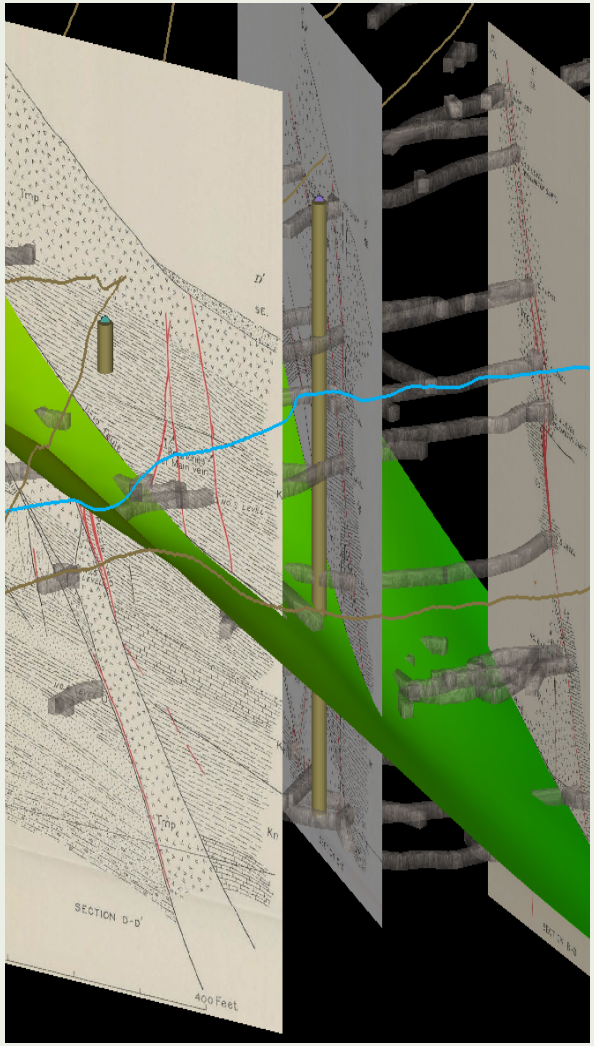


Digitizing Mine Workings and Geology

- **Faults were an important component to the CSM**
- **Lots of faults at the site!**
- **Could they be visualized in a useful manner?**

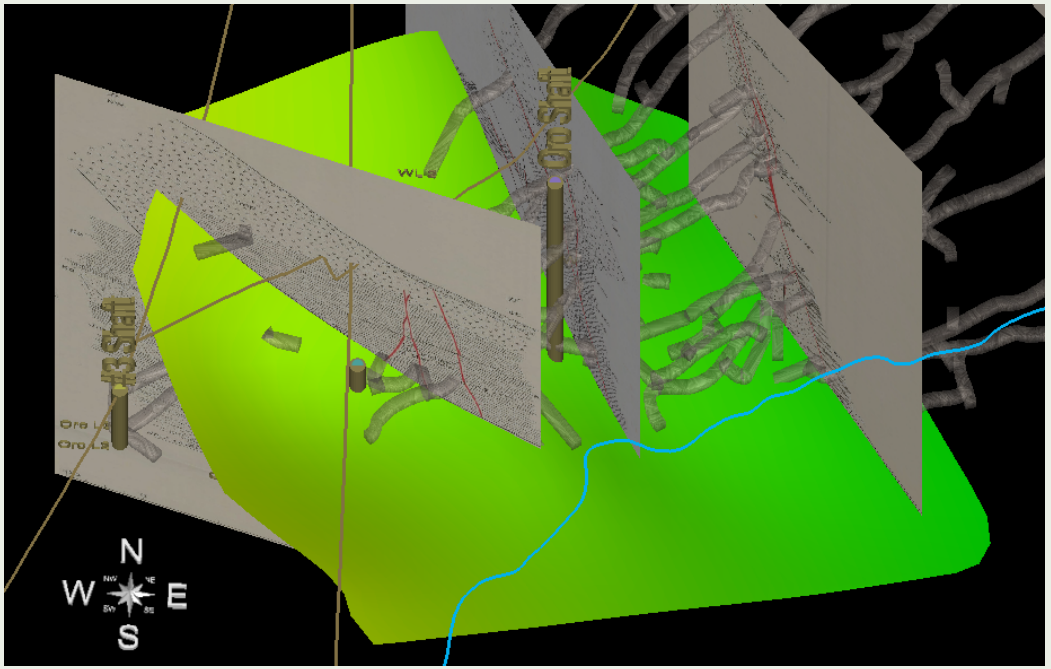


Digitizing Mine Workings and Geology



Creating fault planes

Example shows construction of the 11-10 fault from cross section data

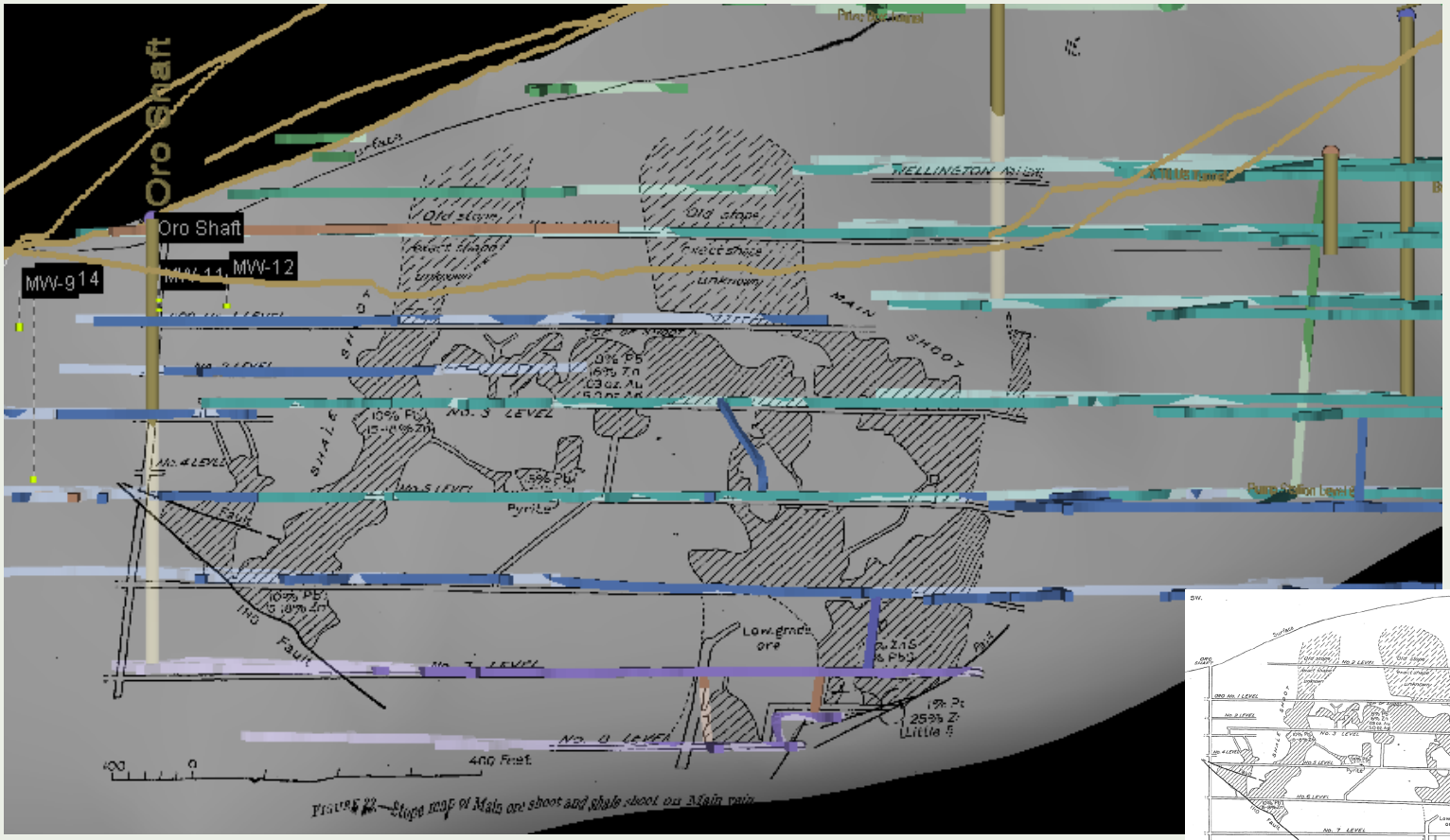


USGS fault map showed a different surface location of the 11-10 fault from the interpreted subsurface data

Digitizing Mine Workings and Geology

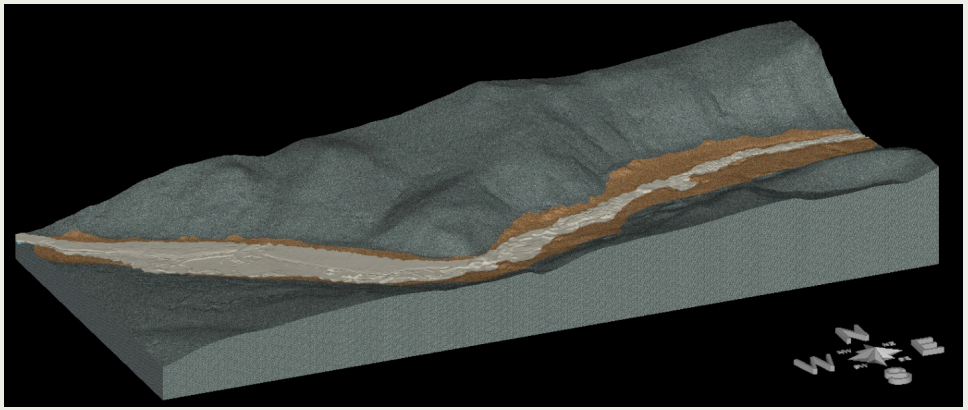
Adding Stopes

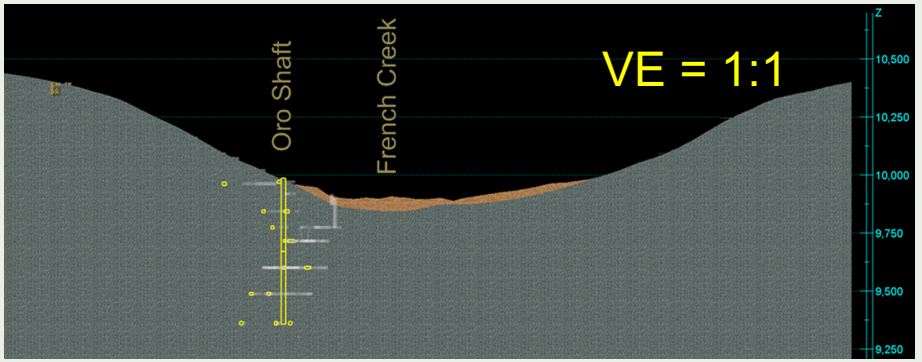
After initial review of the CSM, team thought that mined out areas would be helpful to see in the CSM



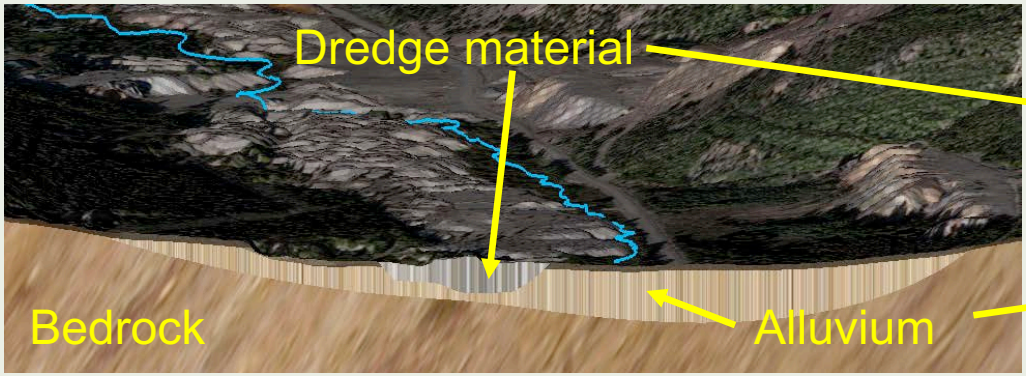
Stope Maps from 1934 Paper and 1950 USGS Papers

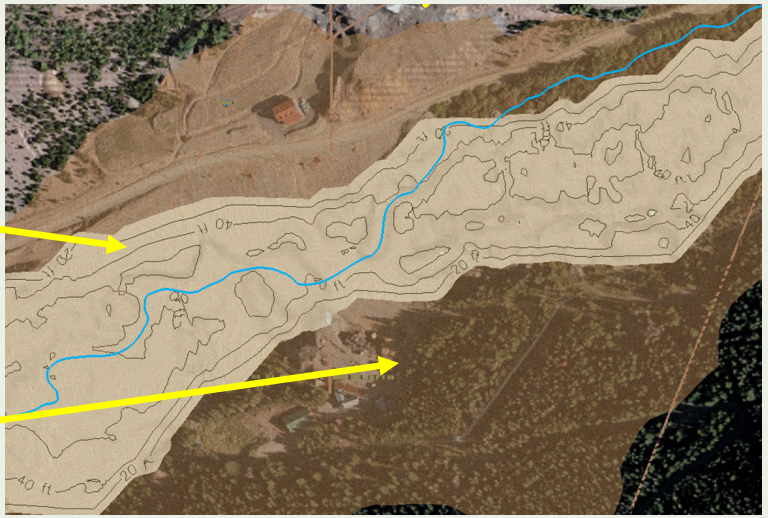
Developing Overburden Geology Layer





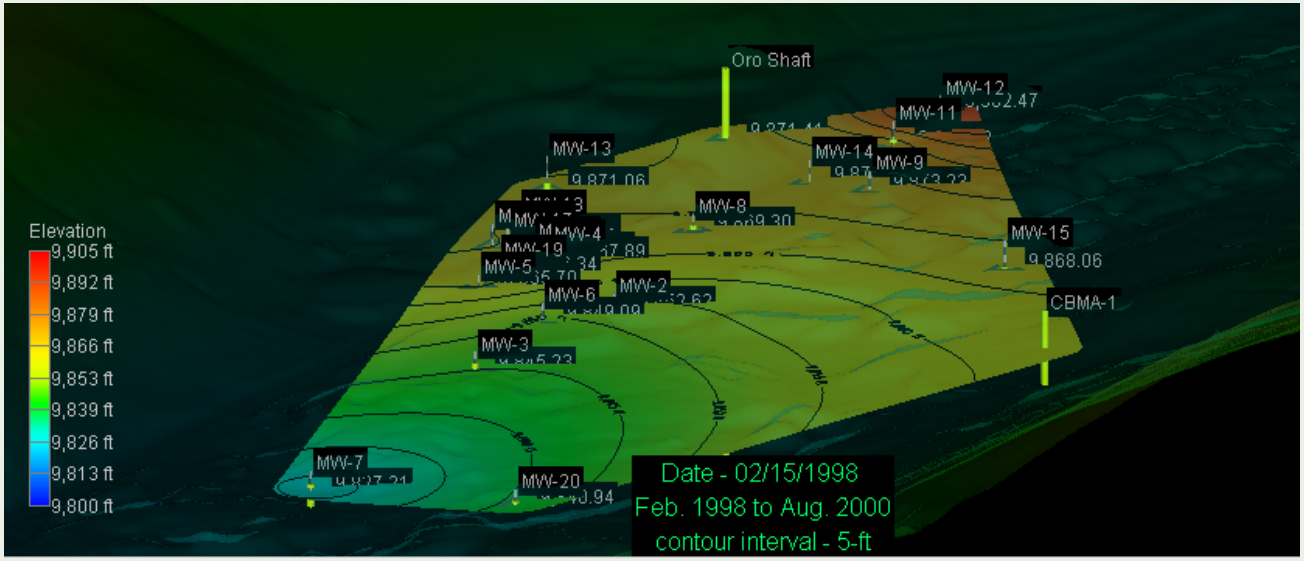
Alluvium depth/extent based on boring logs and USGS top and geologic maps





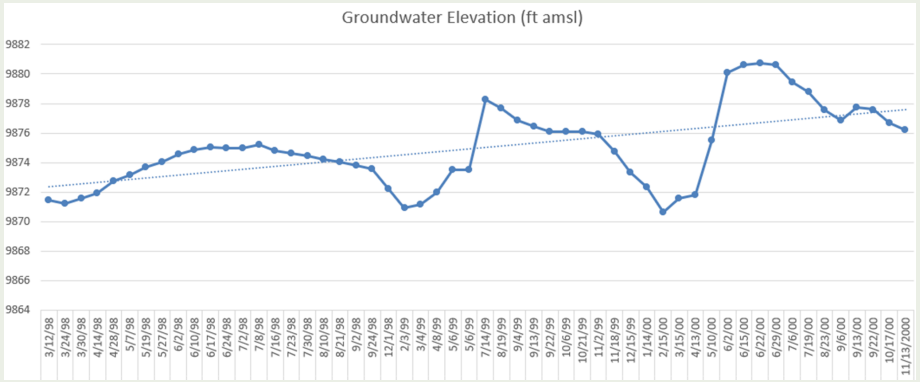
Hydrology

Potentiometric surface mapping



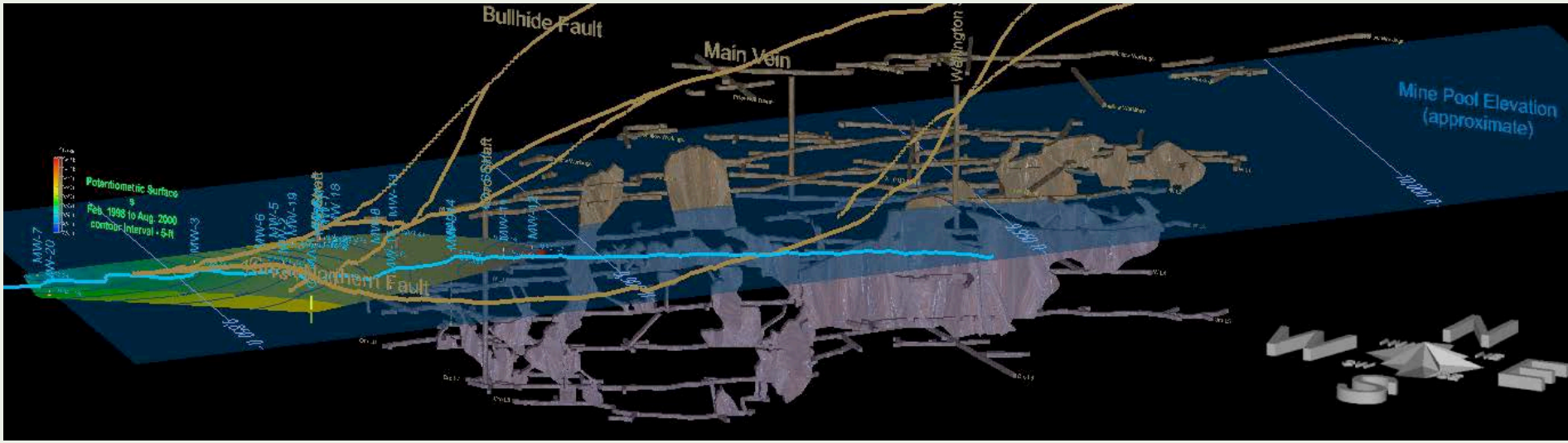
Regular synoptic water readings February 1998 – August 2000

Water levels in the ORO mine appear to be rising?



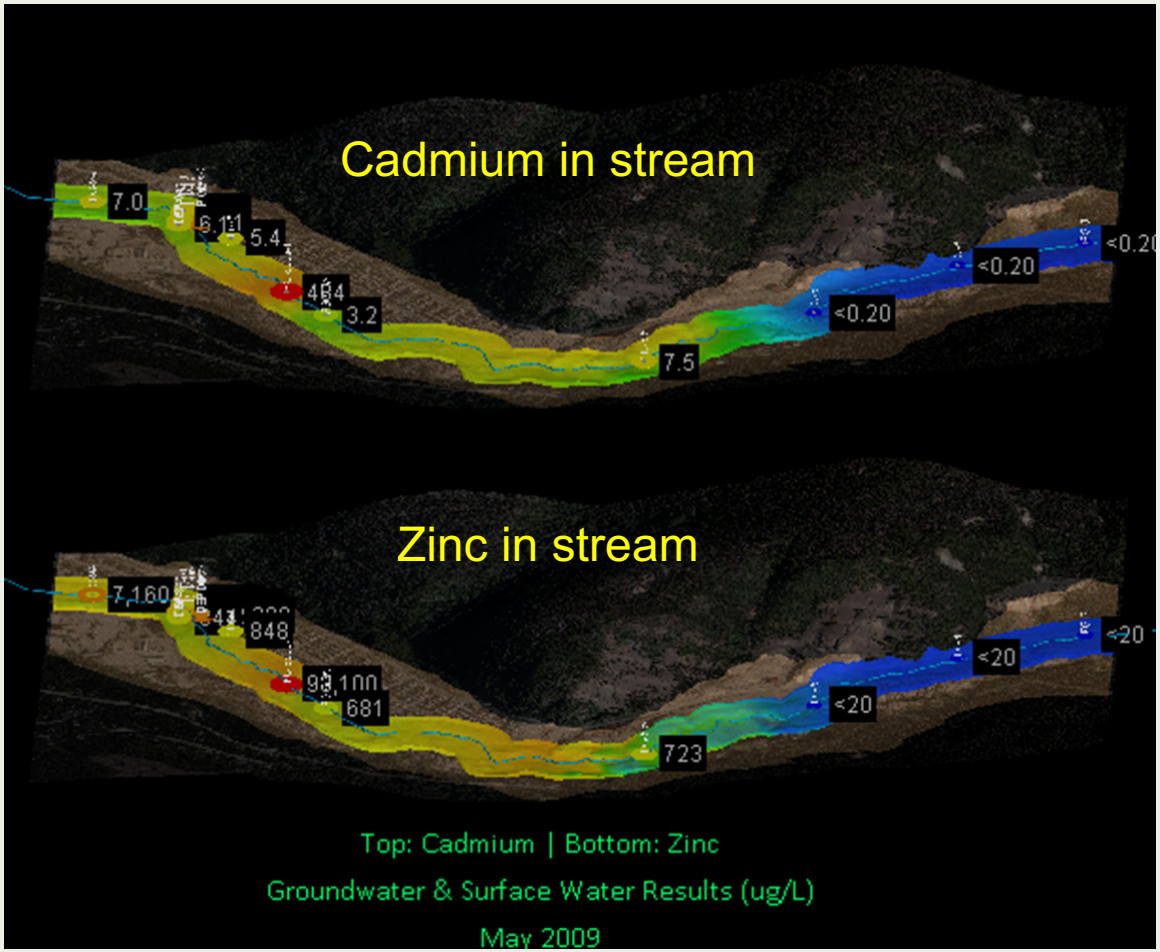
Hydrology

Question to be answered – What levels of the mine are flooded?



Surface Water Chemistry

Seeps and surface water measurements over time



Using Non-digital Data in the 3DVA

Mine level elevation

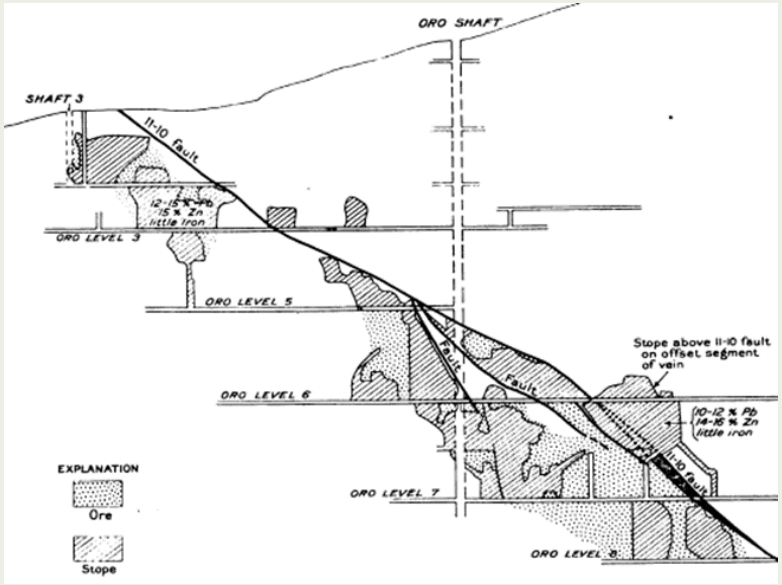
	Extent (feet)	Altitude at shaft (feet)
Wellington levels:		
First	8, 090	10, 048
Second	6, 590	9, 962
Third	6, 480	9, 863
Fourth	5, 700	9, 730
Fifth	8, 220	9, 601
Sixth	6, 720	9, 470
Oro tunnel	1, 020	----------
Oro levels:		
First	2, 020	9, 844
Second	1, 320	9, 774
Third	1, 480	9, 715
Fourth	420	9, 637
Fifth	(8, 220)	9, 612
Sixth	(6, 720)	9, 488
Seventh	2, 990	9, 361
Eighth	2, 200	9, 260
Siam tunnel	1, 150	----------
Prize Box tunnel	1, 610	----------
Brown tunnel	1, 410	----------
Other surface workings	9, 150	----------
Drifts and crosscuts, total	66, 570	----------
Shafts	1, 346	----------

"Along French creek the depth to bedrock in the main channel…is 45 to 50 ft." (Janin 1919 - January 25, 1919 mining journal documenting dredging operations in the valley).

Fault location and orientation

Great Northern vein.—The Great Northern vein is cut by the no. 1 level 140 feet south of the Orthodox vein and about 550 feet east-southeast of the Wellington shaft. The general strike of the vein is N. 65° E., and its dip is 30°–55° S., the steeper dips occurring below the third level. It has been explored a maximum

In the Oro fault block the most notable vein is the Siam vein, or Main vein, as it is now called. It strikes N. 45° E. and dips about 62° SE. It can be clearly traced from the Oro shaft to a point about 1,500 feet northeast, where it is cut by the eastward-trending Fault vein. The Iron vein, which strikes northeast and dips 65° SE. leaves the Fault vein on the north at



Data Not Included in the 3DVA

Some important data for the CSM was not included in this visualization

- **Hydrogeology**
  - » USGS tracer test studies (how to depict routes?)
  - » Temperature data (limited spatial and temporal)
  - » Flow and hydraulic conductivity data
- **Geology**
  - » Extensive complex mineralogy could not be reasonably correlated between data points on cross sections
  - » Level of detail not needed at this time
  - » Monitoring well geologic data limited (depth and spatial)

But some interpretations were used to support the visualization

from 1995 report,
"… pumping tests indicated… that the mine, shale, and alluvium are hydraulically connected, and they have similar head elevations."
and,
"…there was drawdown in wells across the 11-10 fault…"
08-401469GW 4.1995 - Characterization FG Mine Pool Vol.1.pdf

Final Product

- **Visualization package**
  - Component models (mine workings, geology, hydrology and contaminants) in 4DIM format (free viewer)
  - Integrated visualization with key data from each component
  - Technical Memorandum to describe process and product
- **Other useful products**
  - Presentation to external stakeholders as a common platform of current site understanding
  - “Clean” database of well information and chemistry data to support EPA and USGS studies
  - 3D PDF for use in meetings, reports other communications

Final Product

Switch to C-Tech Studio 4DIM Viewer to display integrated 4DIM