U.S. NRC Staff Experience with Conceptual Site Models from Development and Testing to Lessons Learned

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Definition and Development of Conceptual Site Models

Adapted from ASTM E1689.6648

Conceptual Site Model - a written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system.

Adapted from NUREG 1757 Vol 2. Rev.1

Development of conceptual models is a subjective process based on interpretation of often limited site data. Key issues in developing the conceptual site model:

(a) identifying the important site features, events, and processes that need to be included in the conceptual model;

(b) deciding among possible competing interpretations of the site data; and

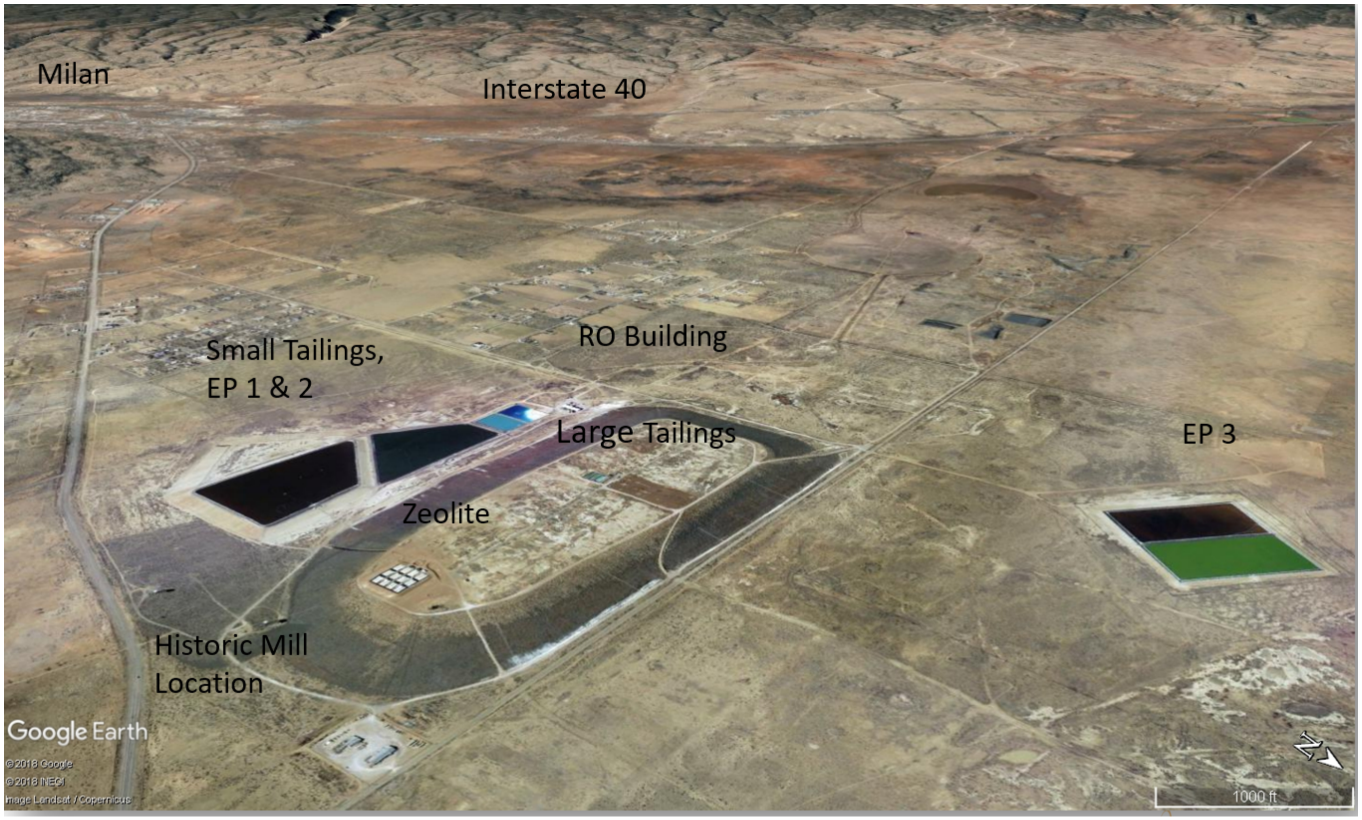
(c) determining the level of detail needed to describe those features and processes

Outline of Conceptual Site Model

- Site Information - Historical and Current Site-Related Activities
- Determination of Background Concentrations for Contaminants of Concern
- Characterization of Source Term
- Transport pathways to the accessible environment
- Potential Receptors

Adapted from ASTM E1689.6648 Standard Guide for Developing Conceptual Site Models for Contaminated Sites

Site Information: Site Layout



- Site history
  - Mill operated from 1958-1990
  - Groundwater restoration began in 1977
- Large and small tailings piles
- Network of injection and extraction wells
- Three Evaporation Ponds (EP1, EP2, EP3)
- Two collection ponds
- Reverse Osmosis (RO) and Zeolite groundwater treatment facilities
- Adjacent communities

Adapted from Google Earth

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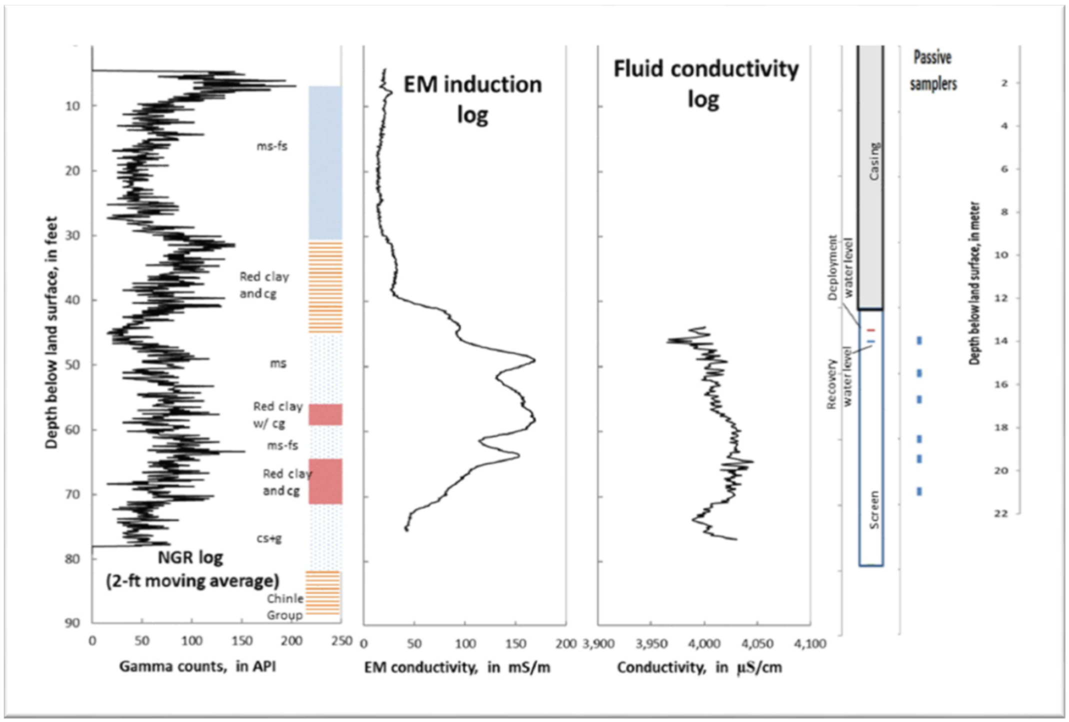
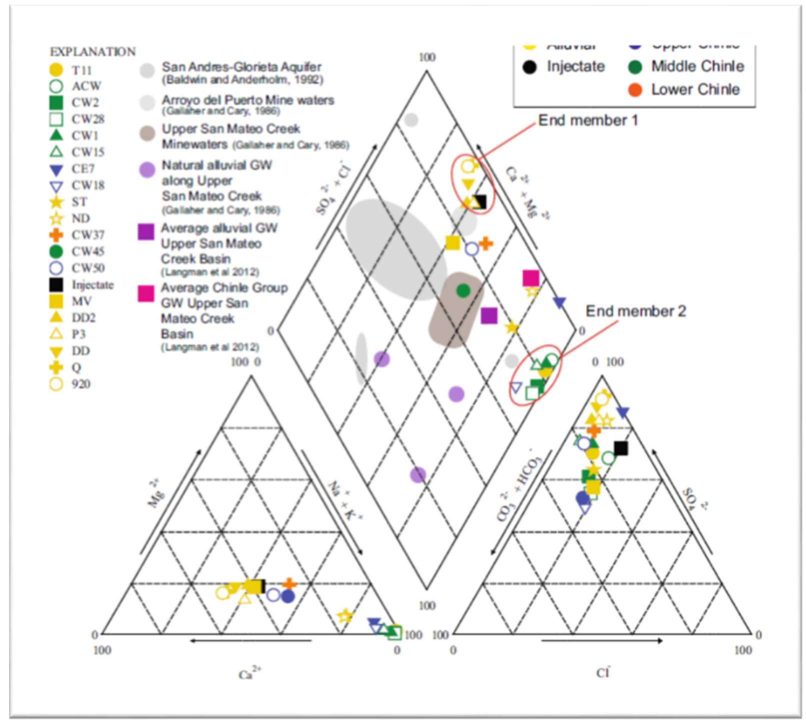
Determination of Background

- Often limited historical data (i.e., pre-operational)
- Natural variability of hydrogeologic parameters and geochemistry
- Collection of information

- Review of background concentrations by EPA with USGS field studies & analyses
- Concurrent review by Homestake of the data
- Geophysical and geochemical analyses by USGS
- Upgradient sources





Adapted from USGS Publications:
Harte et al., 2019 (ADAMS Accession No. ML19050A424)
Blake et al., 2019 (ADAMS Accession NO. ML19289C422)

Determination of Background

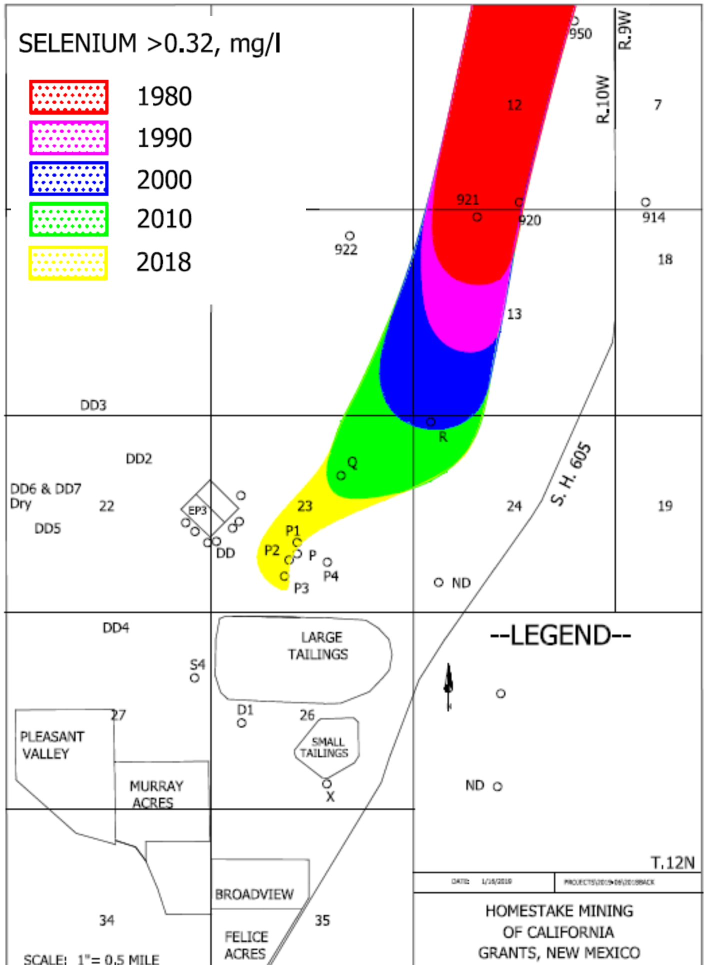


FIGURE 4.3-1A. EXTENT OF ALLUVIAL SELENIUM CONCENTRATIONS ABOVE BACKGROUND, BY YEAR

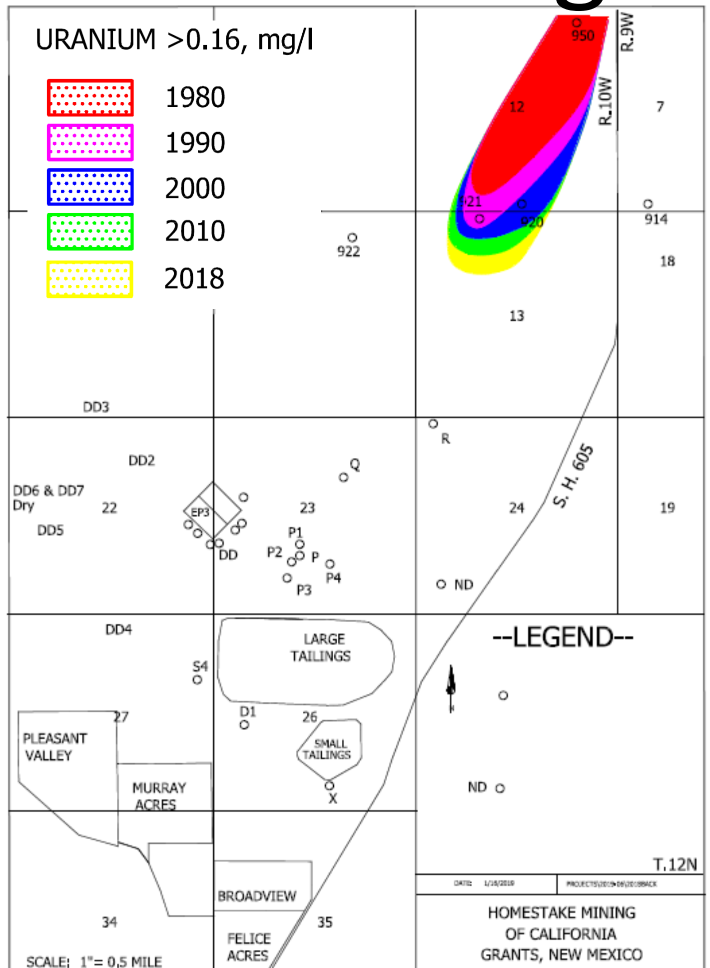


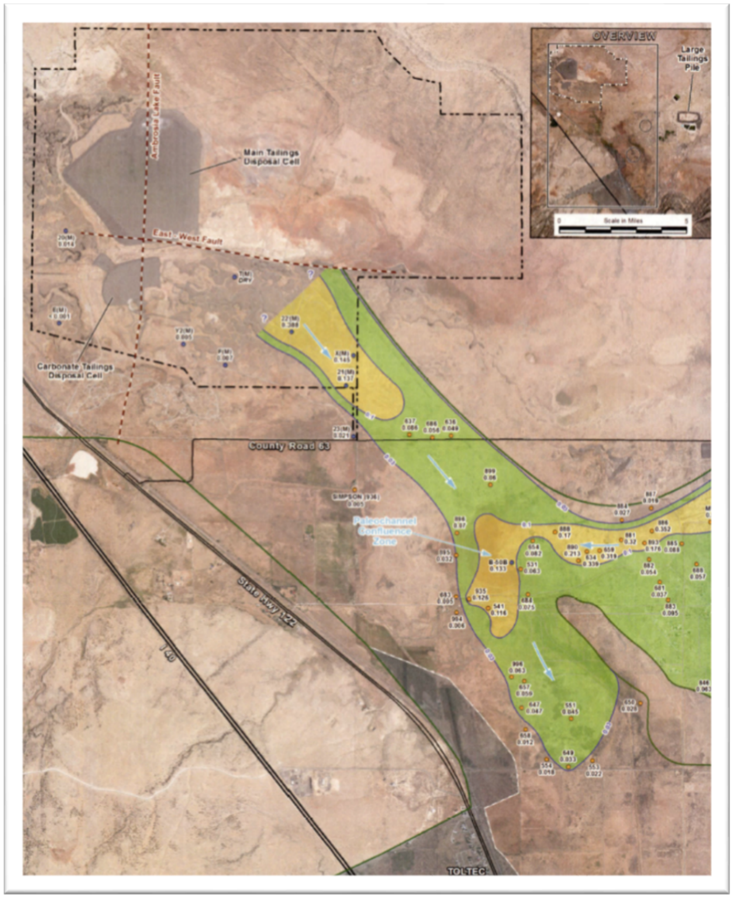
FIGURE 4.3-1B. EXTENT OF ALLUVIAL URANIUM CONCENTRATIONS ABOVE BACKGROUND, BY YEAR

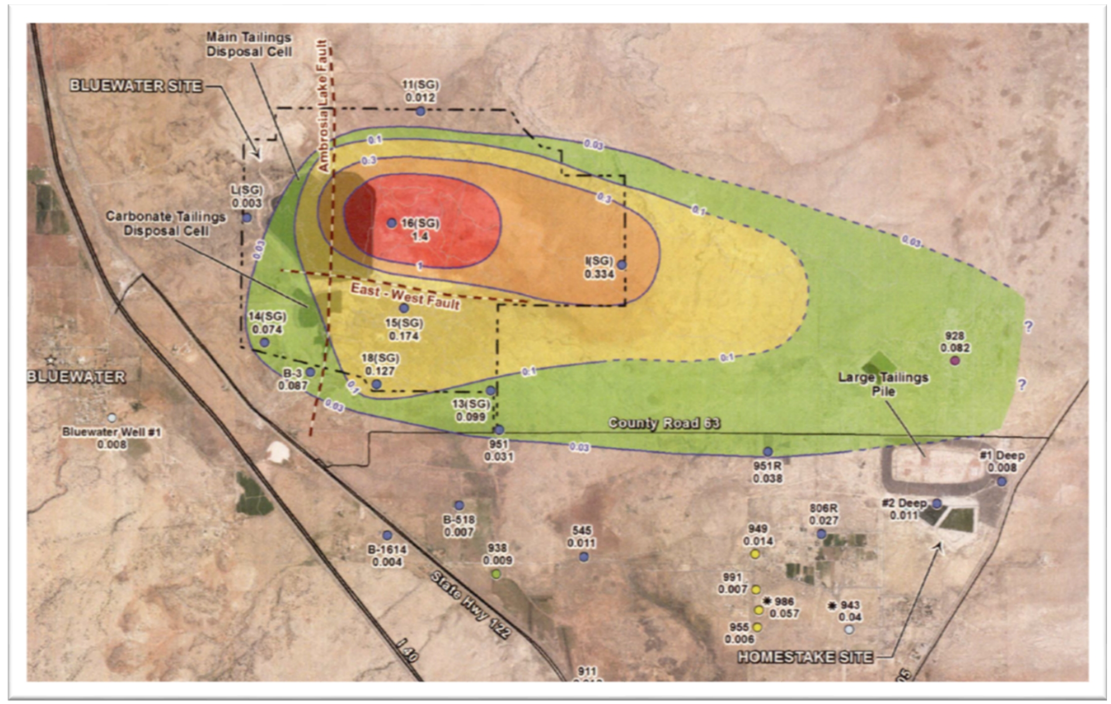
- Differentiating between natural vs anthropogenic sources
- Monitoring wells
  - Location
  - Quantity
  - Completion records
  - Integrity

Adapted from 2018 Annual Monitoring Report/Performance Review for Homestake's Grants Project (ADAMS Accession No. ML19101A370)

Determination of Background

Bluewater Site





Adapted from 2017 Uranium Plumes in the San Andres-Glorieta and Alluvial Aquifers At the Bluewater, New Mexico, Disposal Site (ADAMS Accession No. ML19081A121)

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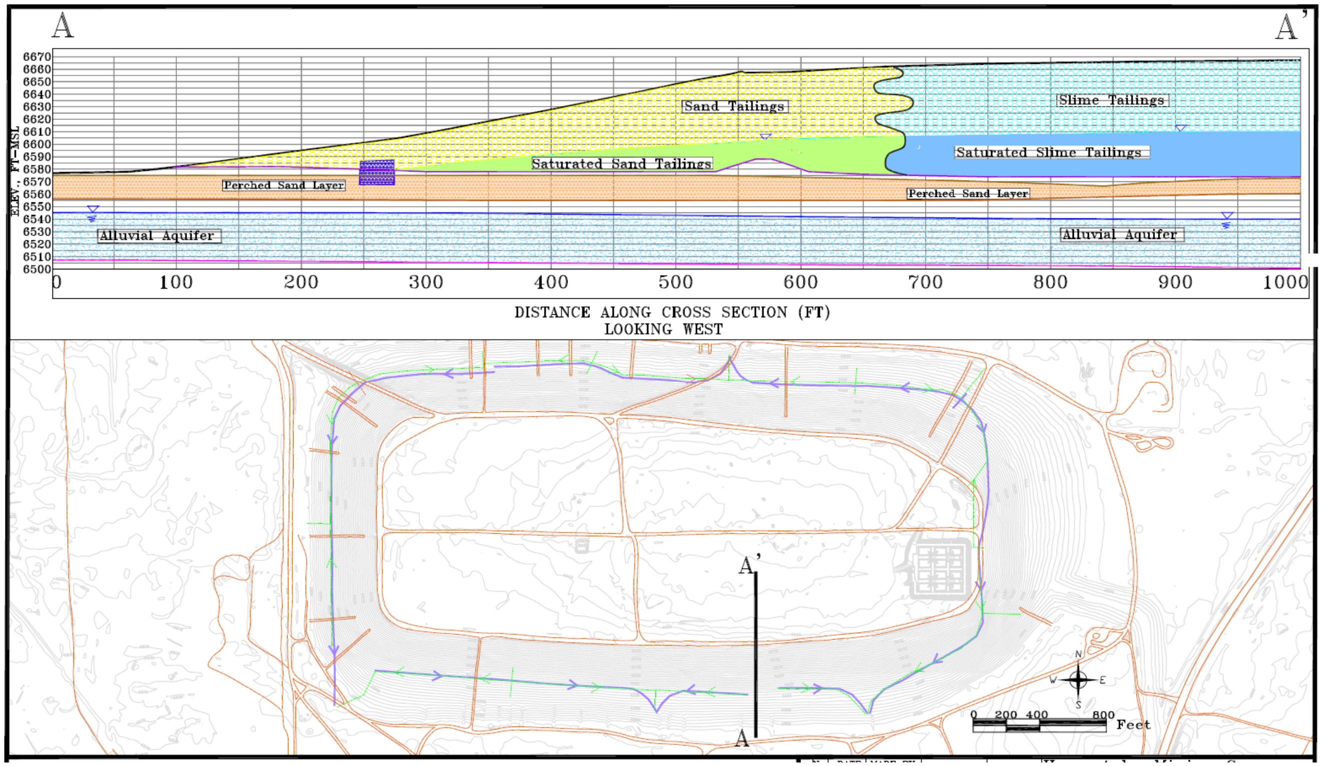
Source Term



- Historical placement can affect site stability and contaminant release
- Composition of tailings can affect contaminant release and transport
- Slimes consolidation and seepage is a long-term process
- Uncertainties
  - Infiltration rate
  - Chemical composition
  - Solubilities
  - Seepage/drainage rate with time

Adapted from 2018 Annual Monitoring Report/Performance Review for Homestake's Grants Project (ADAMS Accession No. ML19101A370)

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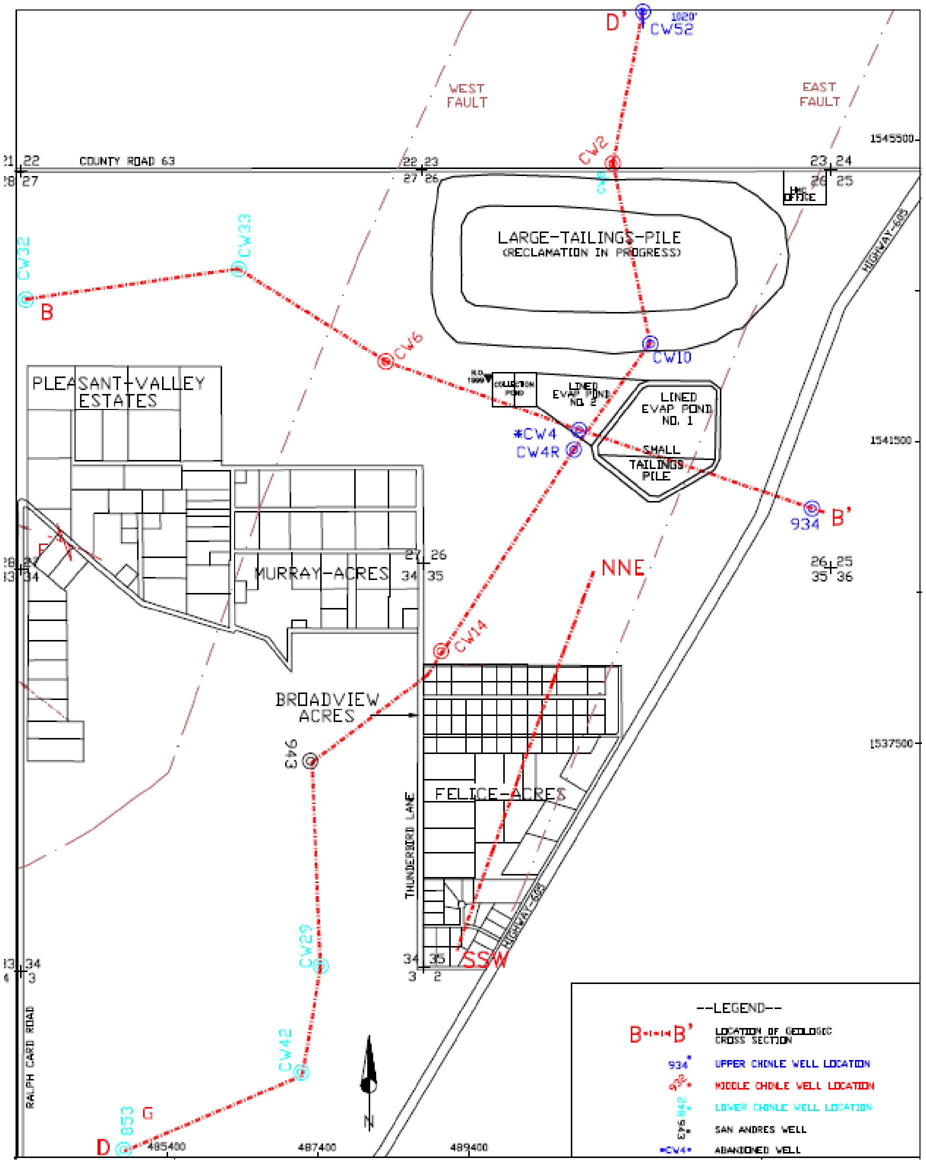

Site Characterization

Complex subsurface

- Series of underlying aquifers
- Paleochannels
- Differing flow directions
- Subcropping of aquifers
- Mixing of aquifers
- Faulting

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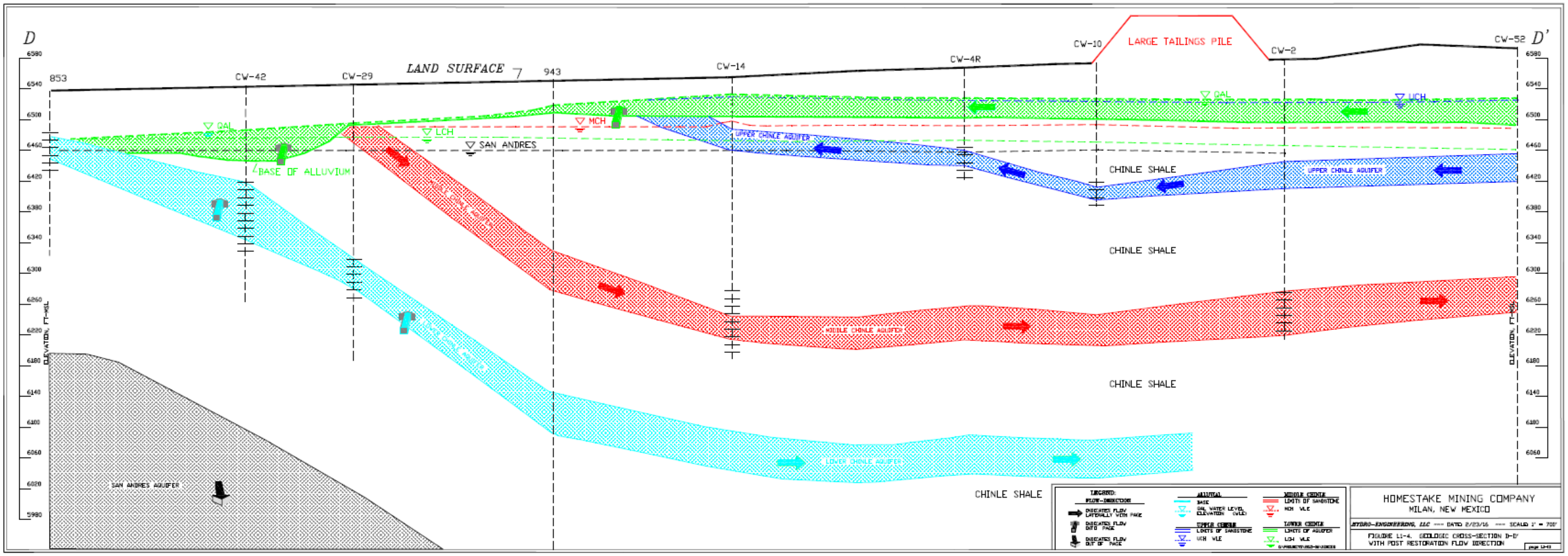
Site Characterization



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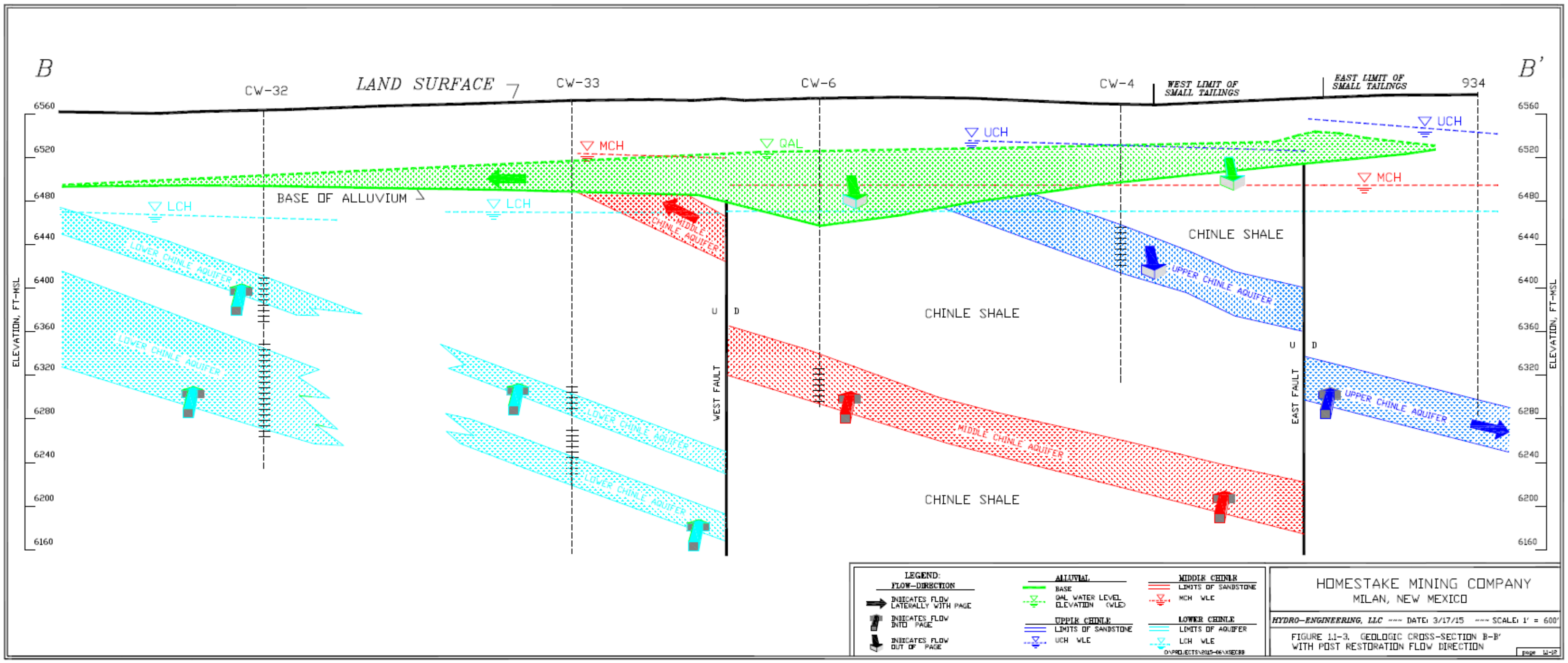

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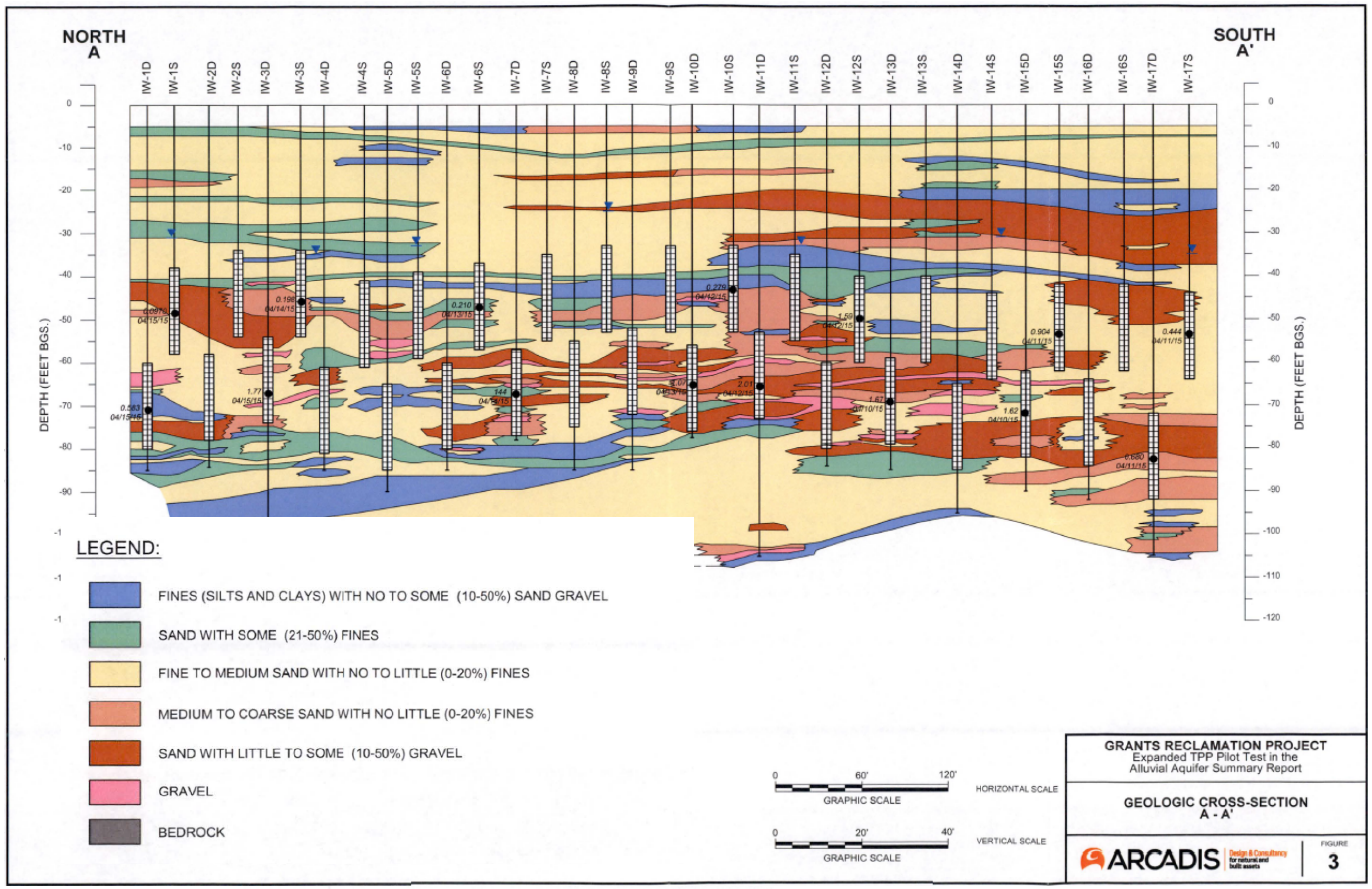

- Heterogeneity of the alluvium
- Characterization – How much?
- Abstraction/ Simplification – To what extent?
- Representation of key features
- Effective continuum vs Dual porosity/ permeability

Adapted from 2016 Expanded TPP Pilot Test in the Alluvial Aquifer: Summary Report for Grant's Reclamation Project (ADAMS Accession No. ML16351A351)

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Groundwater Restoration

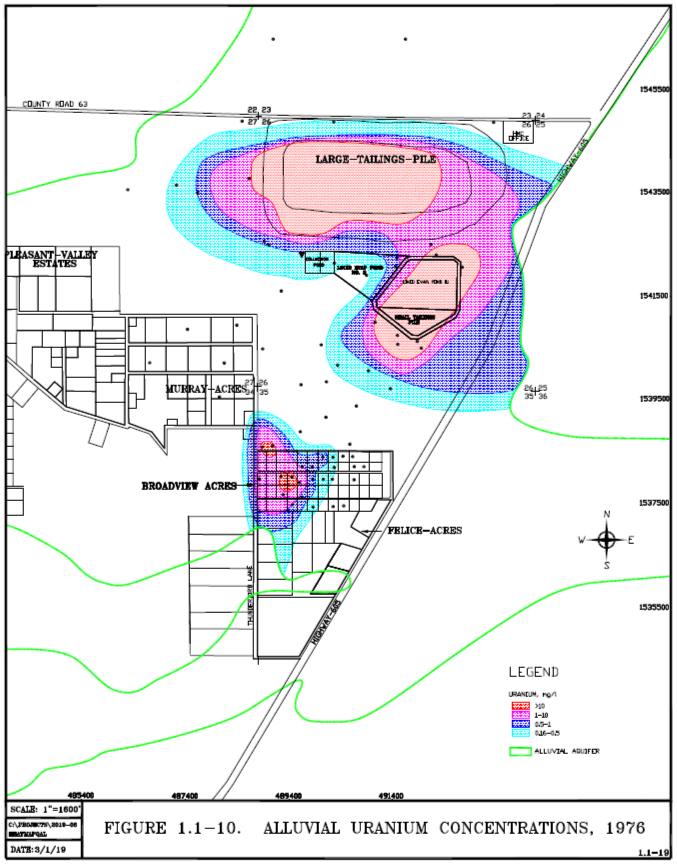


FIGURE 1.1-10. ALLUVIAL URANIUM CONCENTRATIONS, 1976

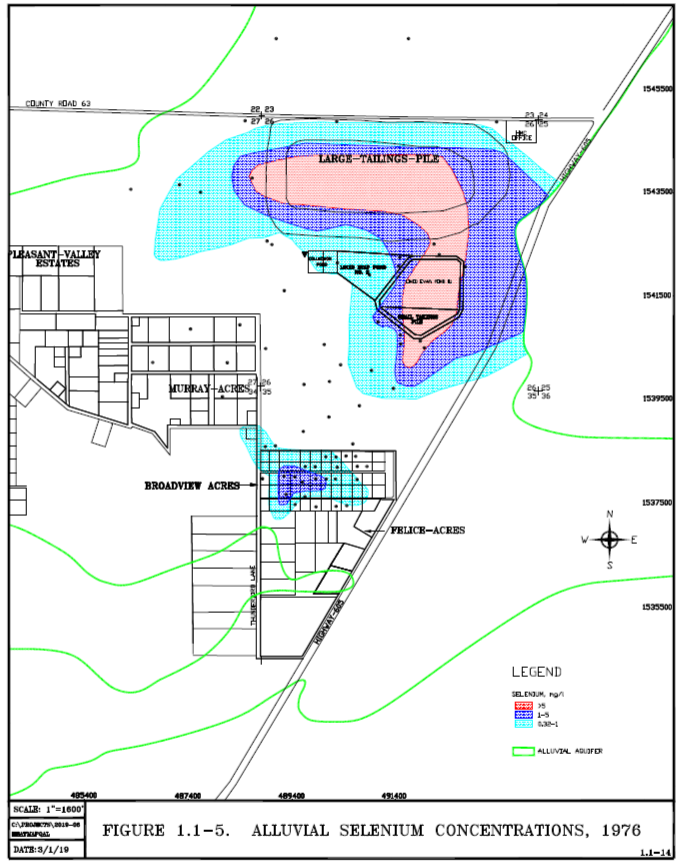
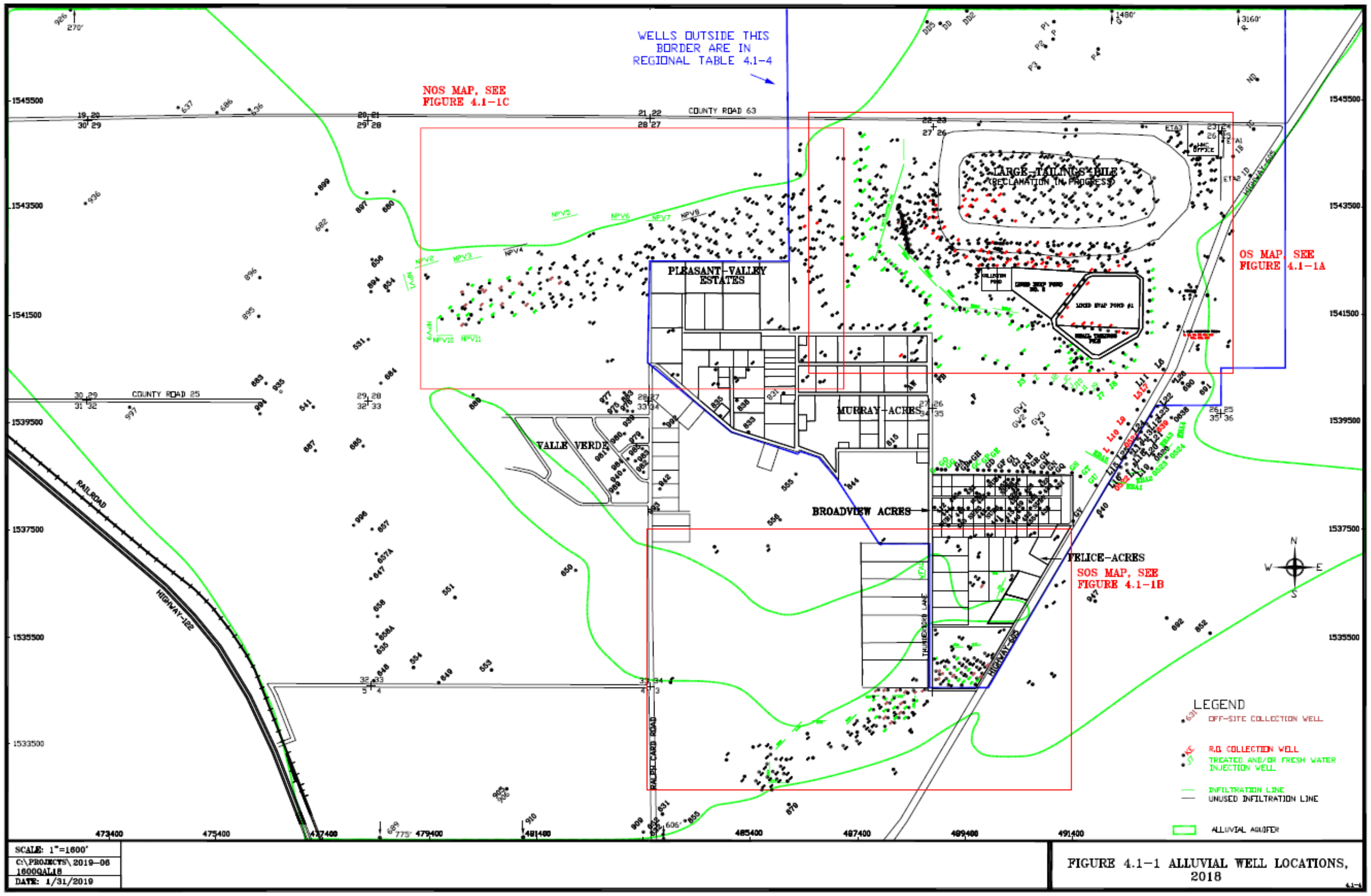


FIGURE 1.1-5. ALLUVIAL SELENIUM CONCENTRATIONS, 1976

- Transport pathways
- Restoration began in 1977
- NRC approved Groundwater Corrective Action Plan in 1989
- Communities
  - Involvement
  - Public water supply
  - Well prohibition
- Upcoming revision to the Groundwater Correction Action Plan

Adapted from 2018 Annual Monitoring Report/Performance Review for Homestake's Grants Project (ADAMS Accession No. ML19101A370)

Groundwater Restoration – Source & Plume Control
Alluvial Groundwater Collection and Injection Wells



- Five Components
  - Source control
  - Plume control
  - Reverse Osmosis
  - Evaporation
  - Land Application
- Evolution of activities
  - Injection wells
  - Extraction wells
  - Monitoring wells
  - Zeolite systems
  - Evaporative Capacity
- Performance Monitoring
  - Groundwater plume
  - Radon
  - Evaporation Pond leakage
  - Erosion

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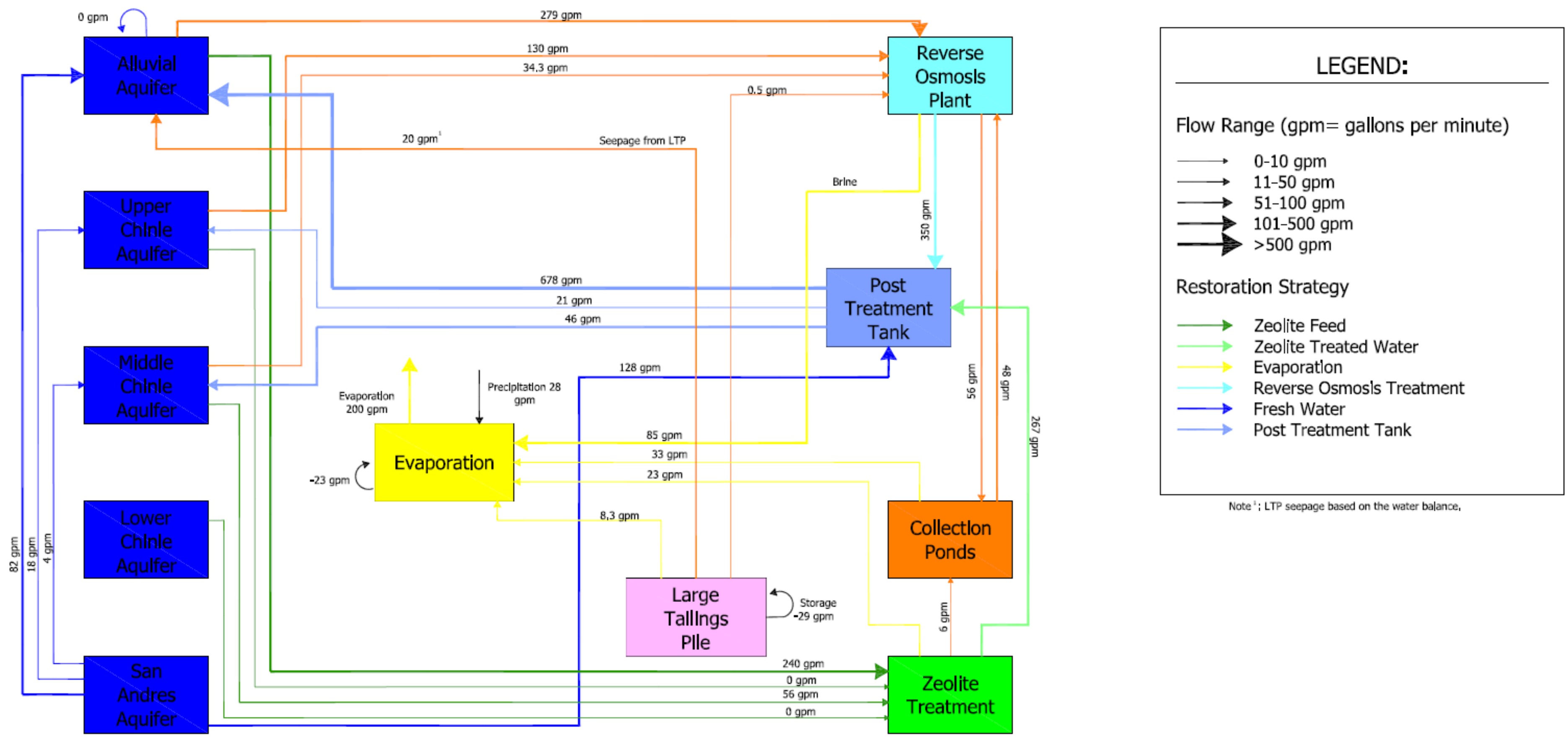
Operational Flows



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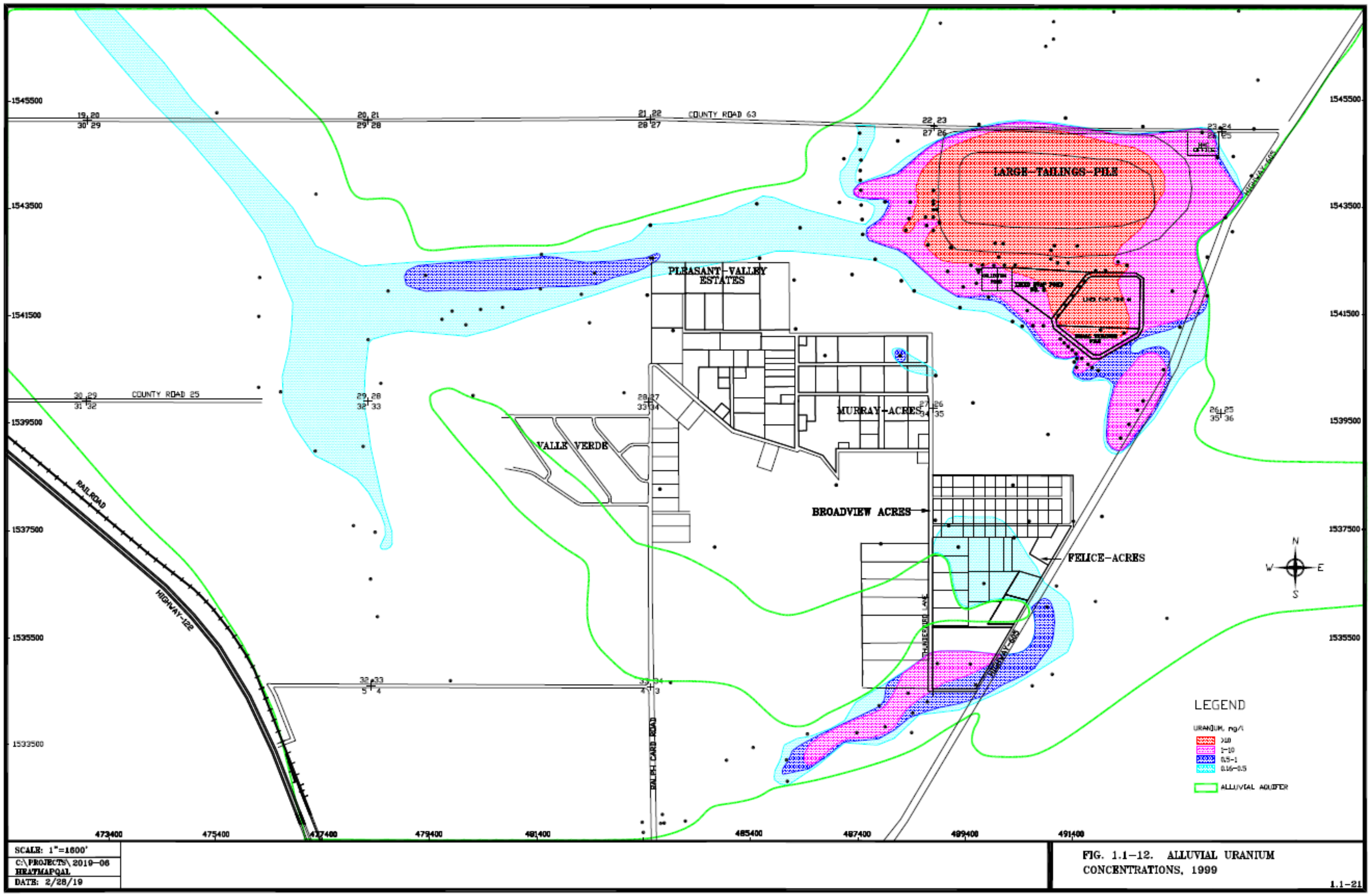
Alluvial Groundwater Uranium Concentration 1999



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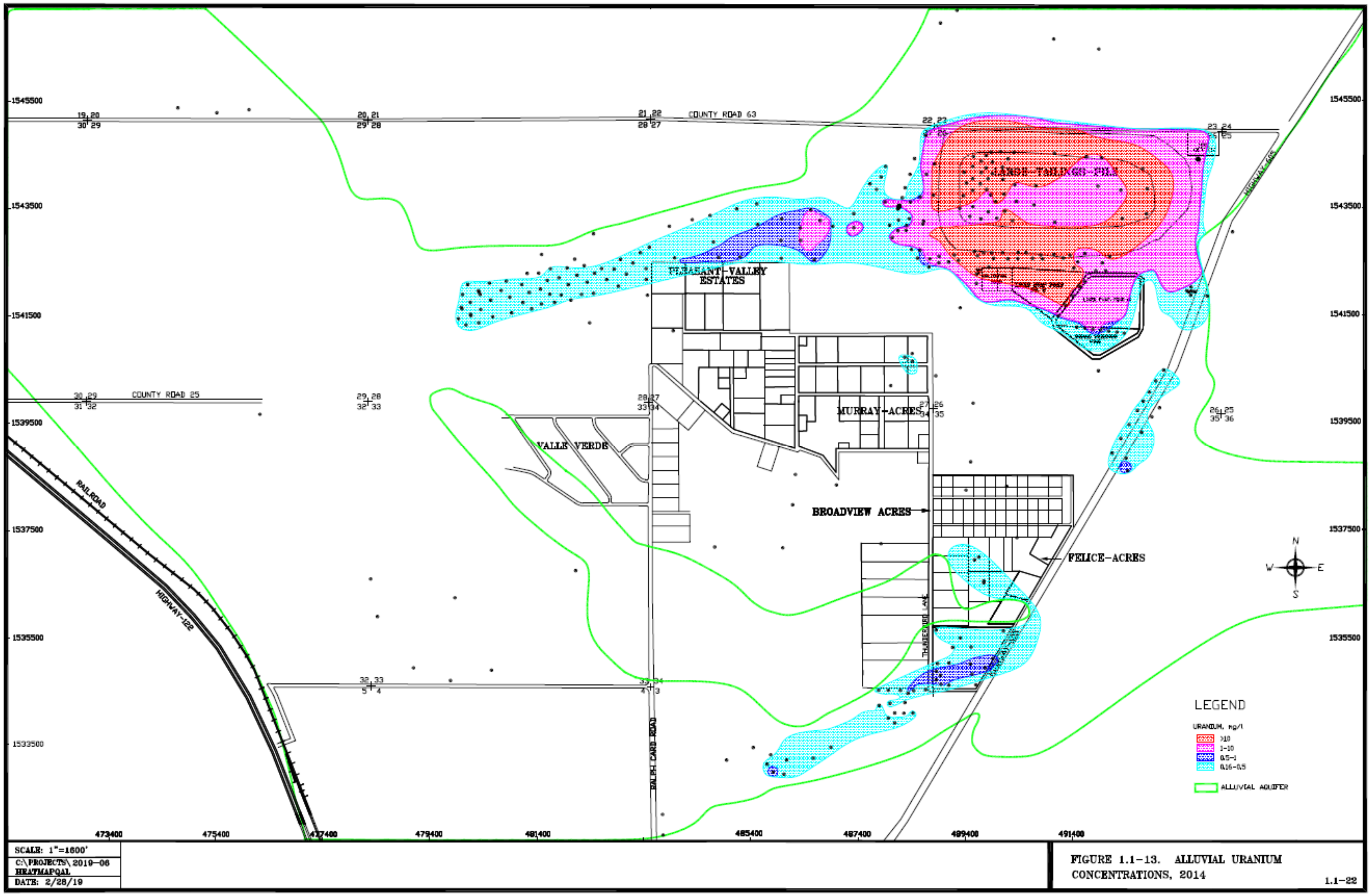
Alluvial Groundwater Uranium Concentration 2014



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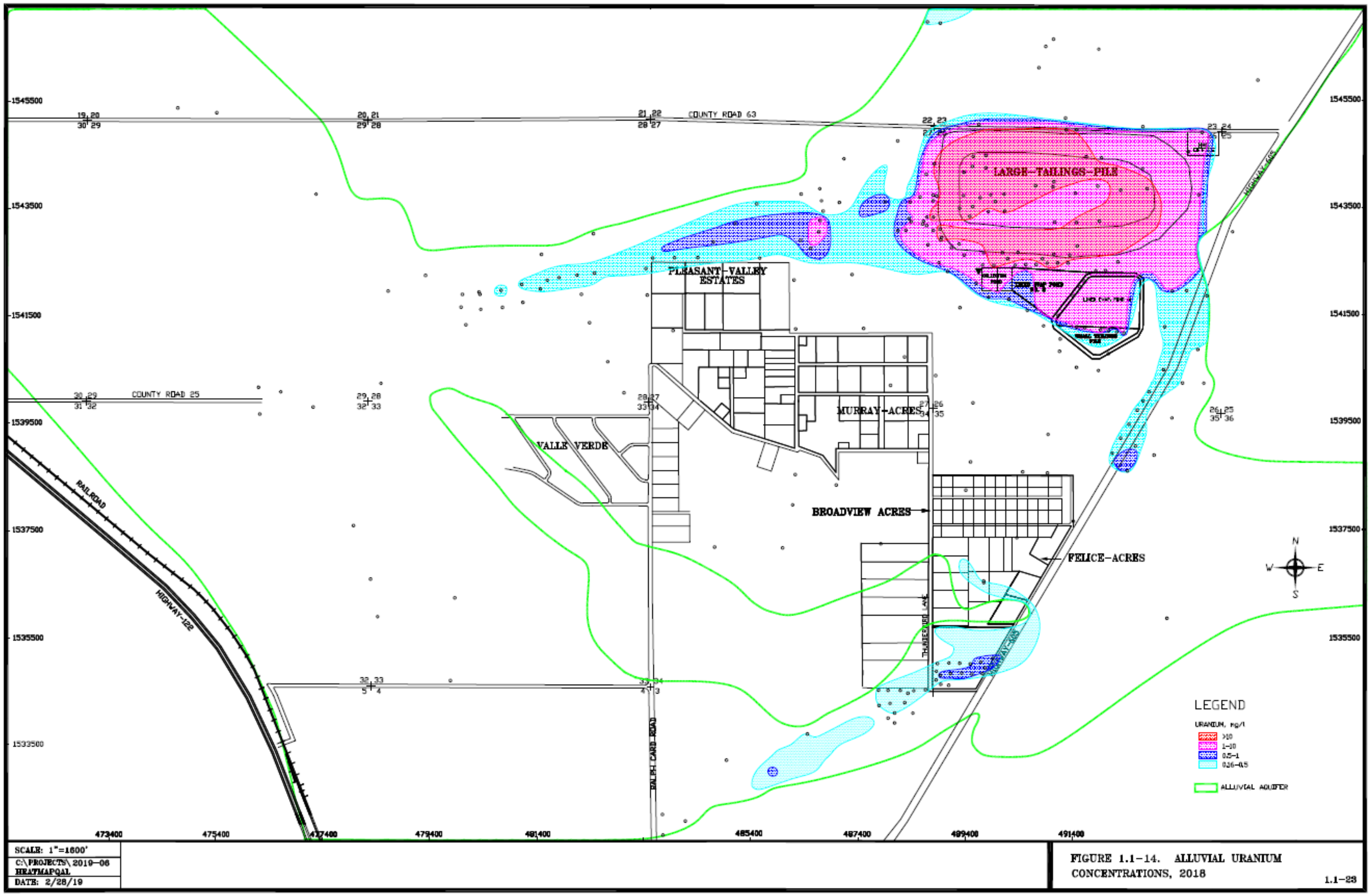
Alluvial Groundwater Uranium Concentration 2018



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Lessons Learned

- The impacts due to conceptual model uncertainty can significantly exceed those due to parameter uncertainty
- Iterative process of collecting data, identifying potential scenarios, developing conceptual and numerical models, and analyzing results
- Obtain key data to support each conceptual site model and update as needed
- Communicate uncertainties with each conceptual site model
- The use of multiple independent modelers and reviewers (i.e., a structured peer review) can help to identify conceptual model uncertainty
- All conceptual site models that are consistent with available information should be evaluated
- Interactions with local communities provide information for the modelers as well as the stakeholders and help to build confidence.