Jamestown Mine
Harvard Pit
Water Balance Model

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Characterizing, Predicting and Modeling Water at Mine Sites

SWRCB Training Academy Short Course

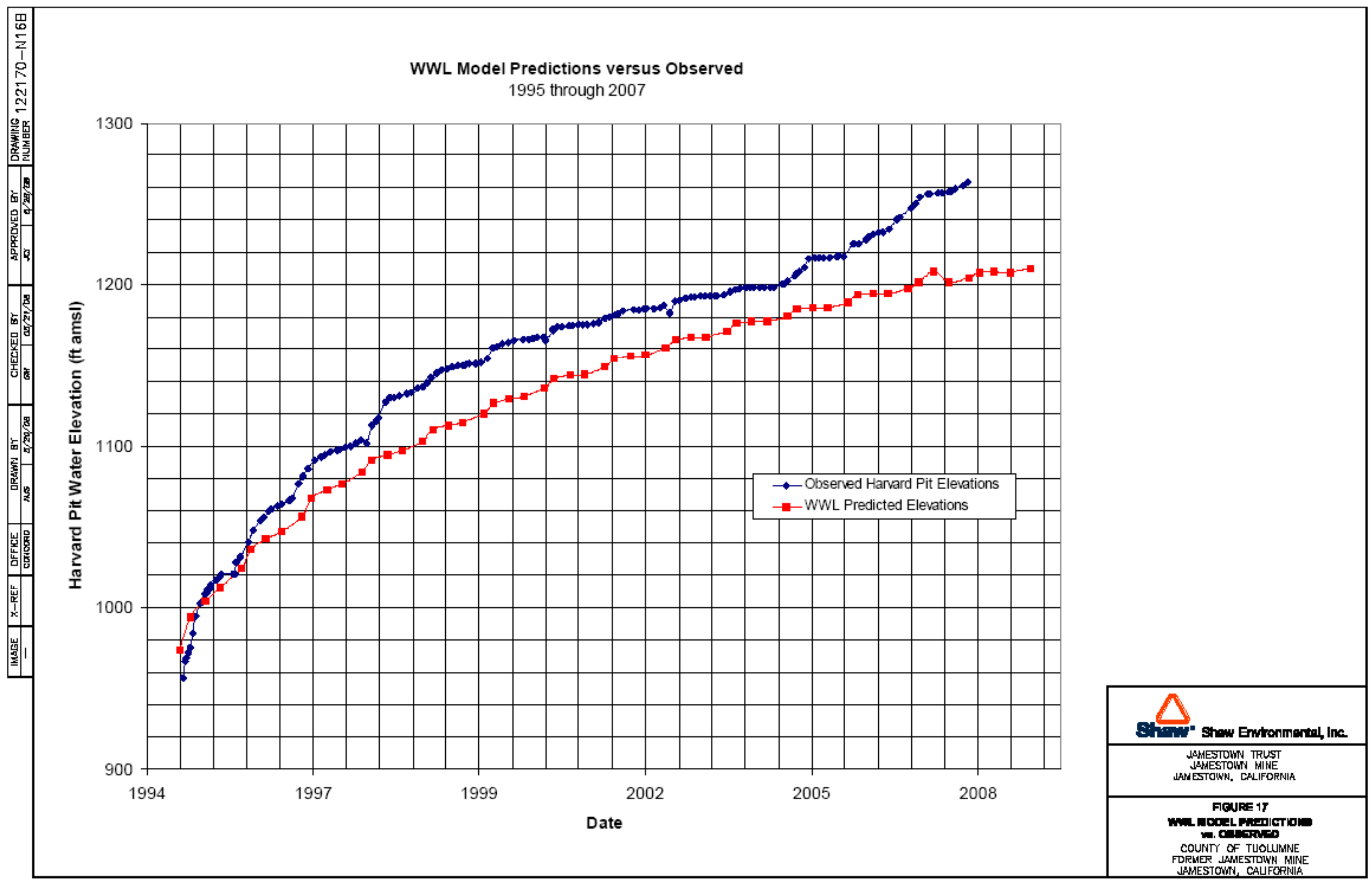
Jamestown, CA

Shaw™
Shaw E & I, Inc.

Water Waste & Land
Time-Step Water Balance Model

- $V_t = V_{t-1}$ + 2(GW+runoff+precip) - evap
- Assumed groundwater inflow would equal dewatering rates.
- Does not account for the increase in pit area as mine depth increased.
- Linear Regression calculation based solely on dry season inflow.
- Wet season dewatering rates ignored.
- Resulted in underestimation of groundwater contribution to refill of HP.
- Model predicted 1,270 elevation reached in 2025

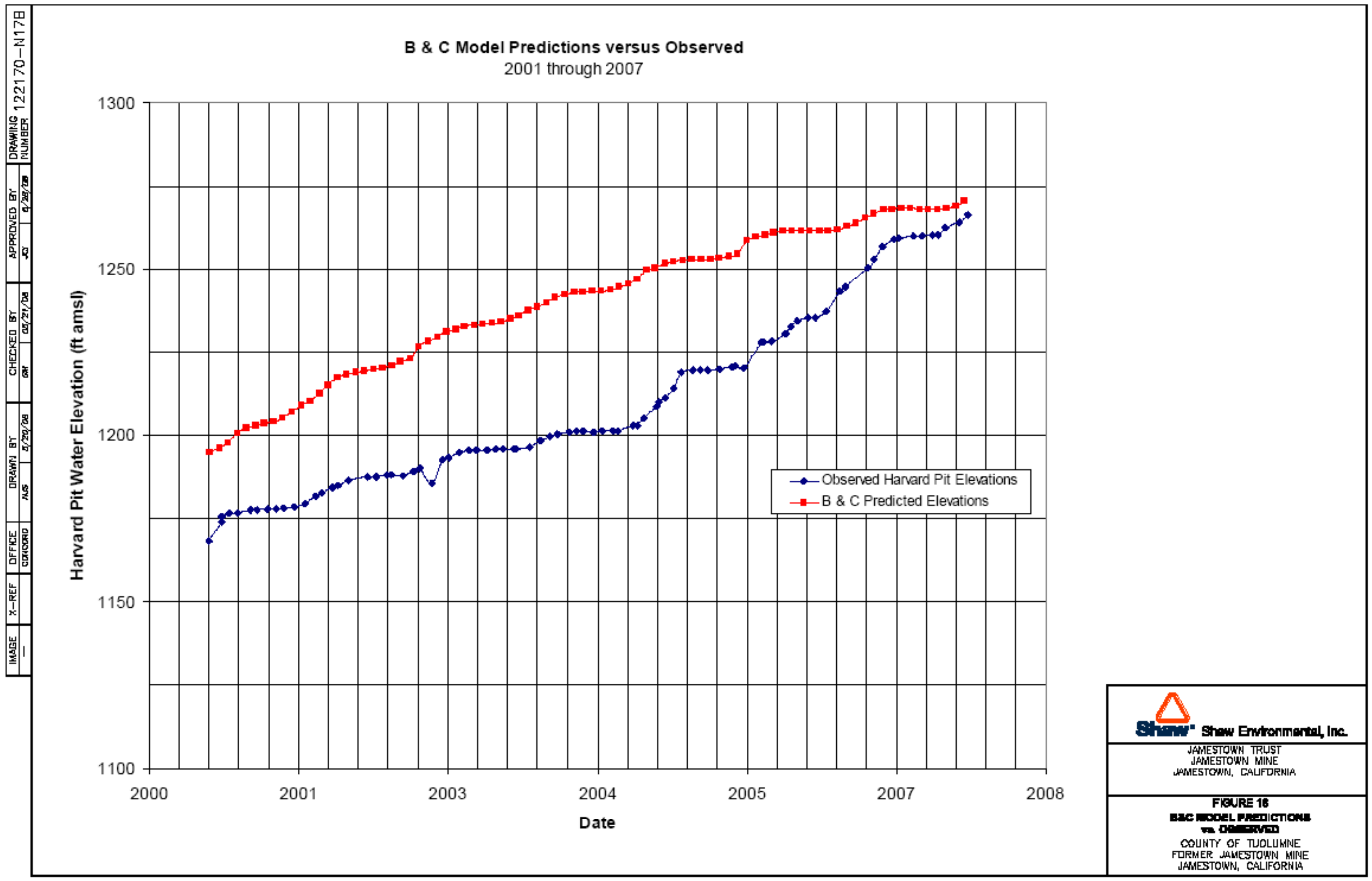
Water Waste & Land vs Observed



Brown & Caldwell
Similar to WWL Model

- Precipitation used Monte Carlo simulation
- GW inflow used Jacob-Lohman constant drawdown equation to model HP as large diameter well
- Produced higher, flatter curve.
- B&C used 1,340 as pre-mining water level
- Model did not account for pre-mining hydraulic gradient

Brown & Caldwell vs Observed



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Harvard Pit Refilling Model

- **Conceptualization**

- Visual MODFLOW (VMF) V. 4.2
- HP - surface water body, simulated by creation of 2 highly conductive zones (10cm/s)
- Bedrock - 4 hydrologic zones

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- **Model Construction**

- Model domain - 2x length by 3x width of HP
- Domain separated into 6 hydrologic zones
  - (4)Gabbro, serpentine, phyllite & schist
  - (2) Open HP & northern backfilled HP
- Model consists of 8 individual layers
- HP modeled by high conductivity zones

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- **Model Construction**

- GW flow - anisotropic
- Boundaries:
  - Top & bottom - constant head recharge boundaries
  - Sides – no flow

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- **Model Construction**

- TMF transfer
- Modeled as injection well
- Turned on, October 2006

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- **Model Construction**

- Precipitation- Sonora ranger stn, avg monthly rain fall
- Runoff – 30%
- Evaporation – New Melones dam, pan coefficient 0.72
- Recharge to GW – 14.77% of precipitation.

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Calibration – primarily trial & error

- Initial run, 3,652 days, 1/1/1998 to 12/31/2007 to calibrate
- Model Runs (2) -
- 23 years 1/1/1998 to 12/31/2020 an
- 53 years 1/1/1998 to 12/31/2050
- Observation wells – 10 + Harvard Pit; head observations plus initial head.

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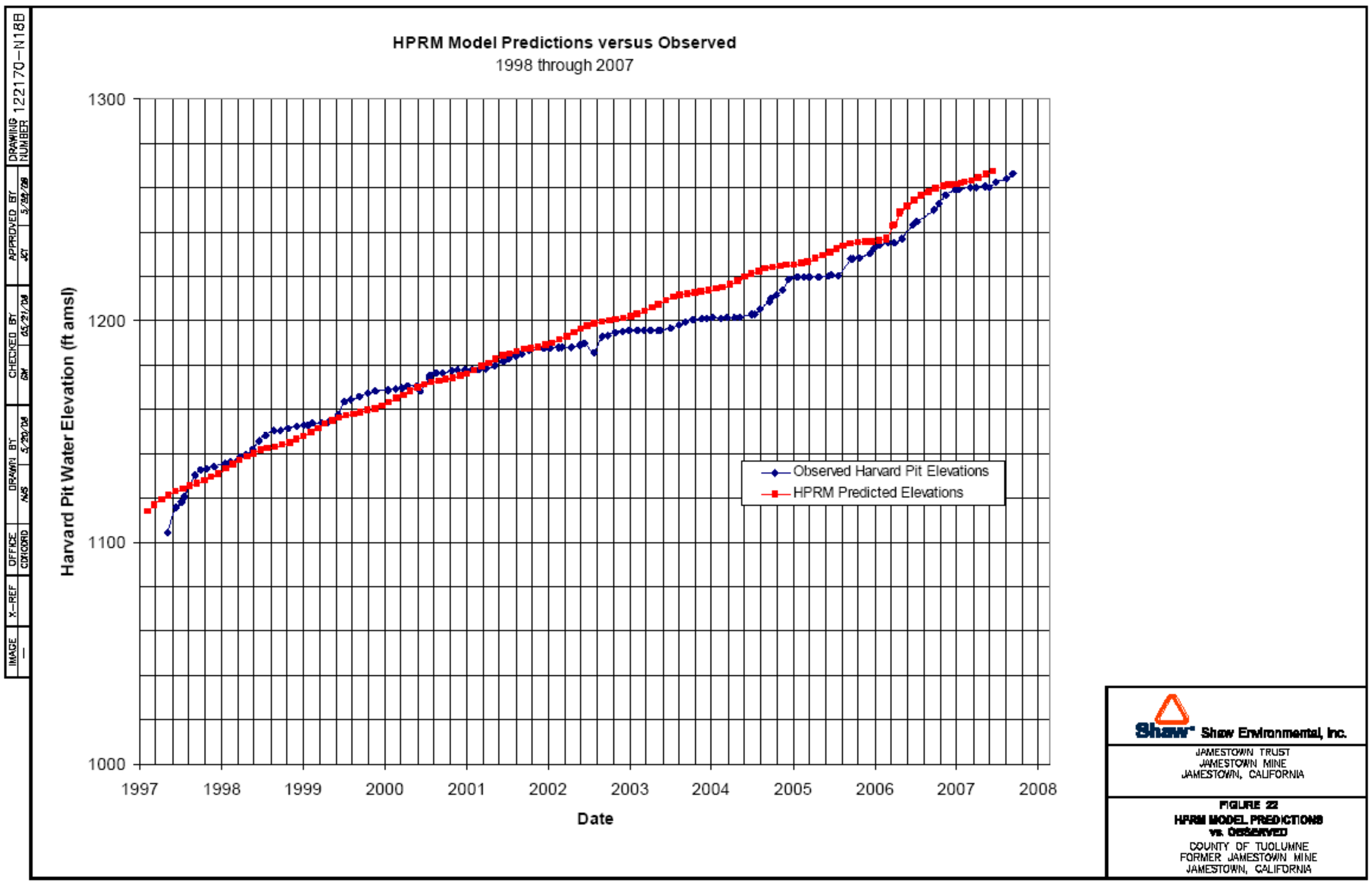
- **Sensitivity Analysis**

- Hydraulic conductivity, Y direction largest effect on model results

Harvard Pit Refilling Model vs Observed



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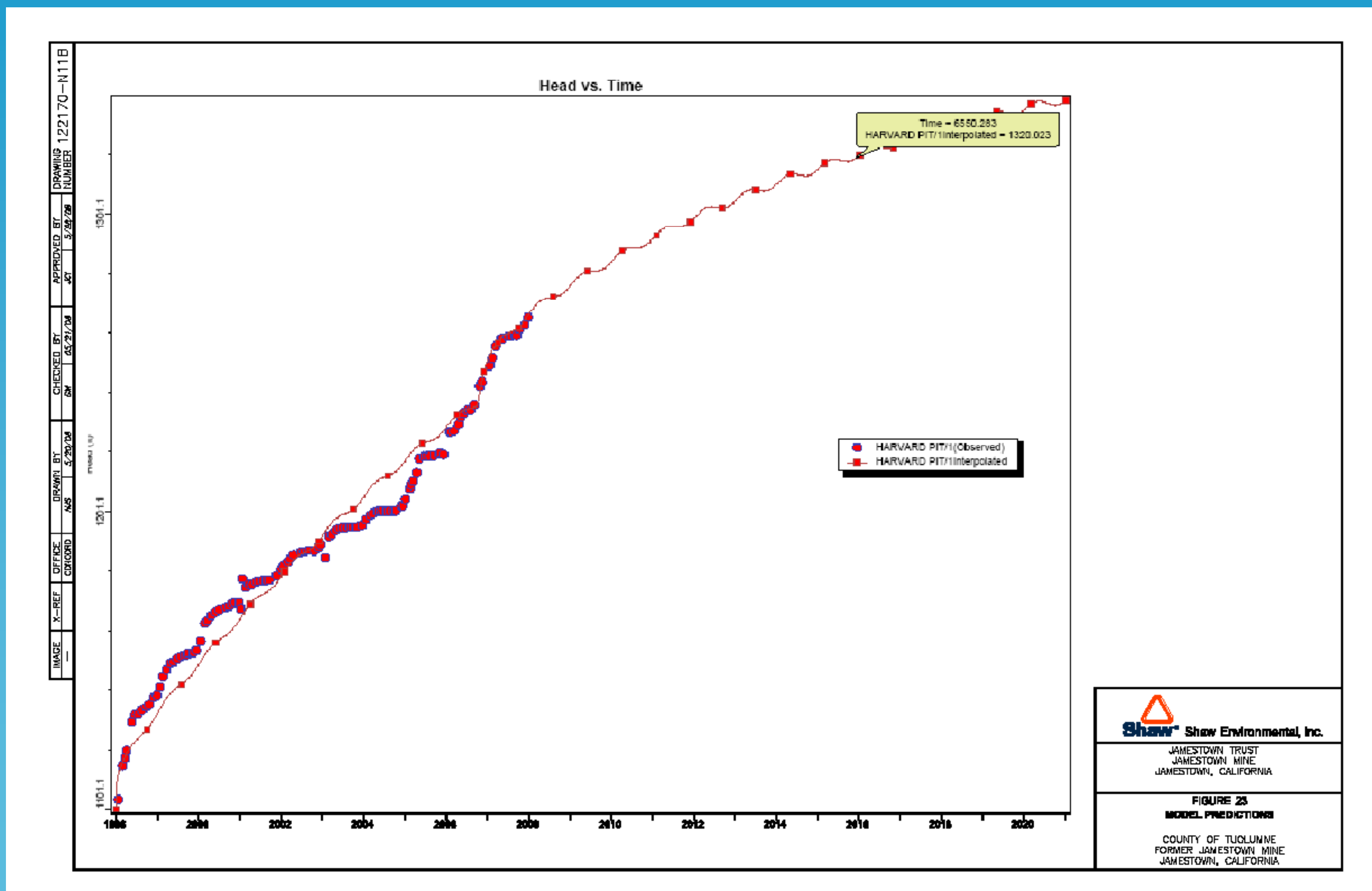
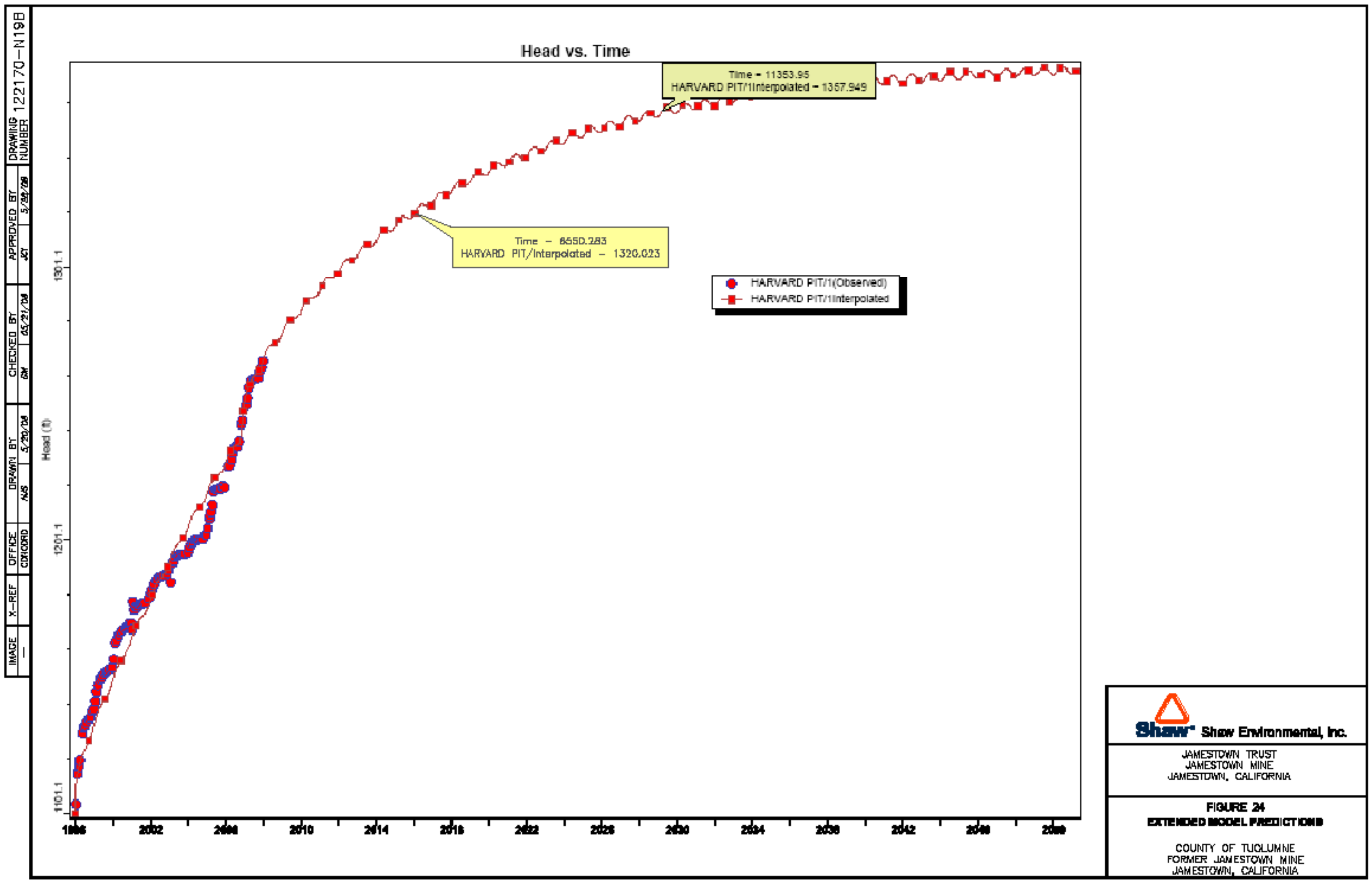
Results

- 1,320 elevation by December 2015
- 1,330 by February 2018
- GW flow 0 to 12 gpm
- 1,358 by February 2029 spill over
- Surface flow 0 to 200+ gpm to Woods Creek
- TMF – 1,320 reached 2 yrs earlier

Harvard Pit Refilling Model
1,320 elevation by December 2015



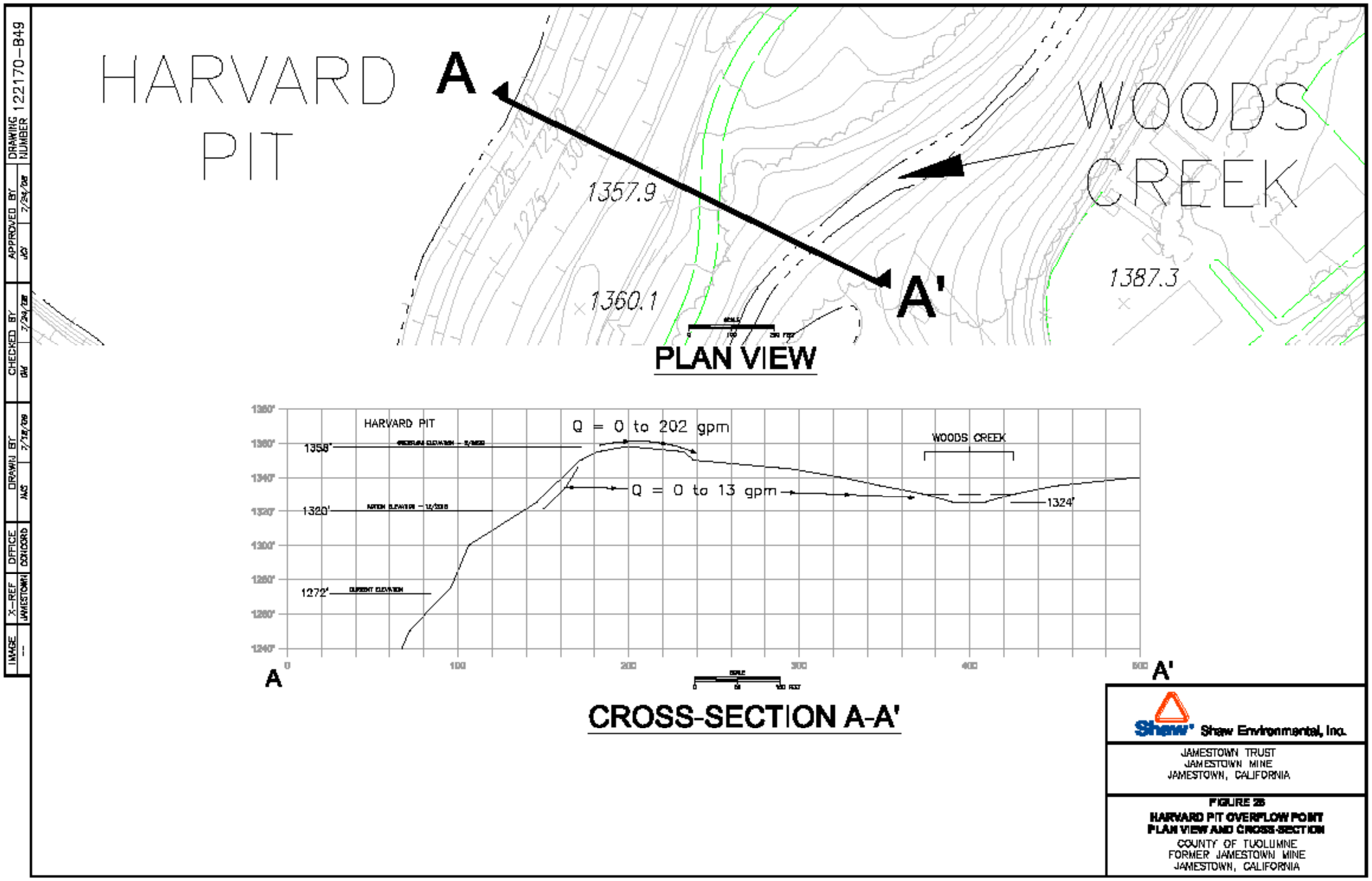
Harvard Pit Refilling Model
1,358 by February 2029 spill over



Harvard Pit Over Flowing

- MODFLOW predicts pit will fill to 1320 ft msl in 2015.
- Flow through bedrock into Woods Creek and affect water quality.
- Flow increases to 12 gpm until level reaches spillover of 1358 ft msl in 2029.
- Flow over southern wall into creek.
- Rate to creek varies by season from 0 gpm to 200 gpm in rainy season.

Over Flow Point



Harvard Pit Treatment

- Trees (phytohydraulics) up-gradient in Crystalline Pit, to reduce GW inflow.
- 650 mature trees equals 20 gpm, initially plant 5,000 small trees.
- Extract 55 million gallons per year.
- Pit contains over 2,500 mg/L TDS, mostly Ca and Mg sulfates.
- As removed by ferrous/ferric iron or GeoBind™ blended MgO.
- TDS by reverse osmosis (RO).

Harvard Pit Treatment Options

- **Ultra filtration/reverse osmosis (UF/RO) system –** UF/RO 55% clean water discharge to creek. Concentrate to pit.
- **Dry season evaporation ponds (with/without treatment) –** 60-acre evap. pond on TMF fill April to Oct., concentrate to pit. Treat to remove As, lowering risk in creek.
- **Enhanced spray evaporation with treatment –** Spray Evap units increase evaporation with smaller ponds. Treat to remove As, operate April to Oct, concentrate to pit.
- **Wet season discharge to Woods Creek –** During high creek flow treat to remove As. Treated water contains high sulfates, discharge fixed to creek flow.

Treatment Costs

- **UF/RO -** Capital cost is $3,390,000; O&M is $543,000/yr; 10-year capital and O&M is **$8,820,000.**
- **Dry season evap. with treatment -** Capitol cost is $9,650,000; O&M is $556,000/yr; 10-year capitol and O&M is **$15,210,000.**
- **Dry season evap. no treatment -** Capital cost is $5,700,000, O&M is $234,000/yr; 10-year capital and O&M is **$8,040,000.**
- **Spray evap. with treatment -** Capital cost is $3,750,000; O&M is $398,000/yr; 10-year capital and O&M is **$7,730,000.** ***
- **Wet season discharge with treatment -** Capital cost is $3,200,000; O&M is $351,000/yr; 10-year capital and O&M is **$6,710,000.**

Note: *** indicates preferred option

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