Fugitive Mercury Emissions from Two Gold Mines in Nevada

On November 20, 2009, Dr. Chris Eckley, a post doctoral researcher working with Dr. Mae Gustin presented a preview of his work and that by a graduate student, Matthieu Miller, on fugitive mercury emissions from two gold mines in Nevada (see the attached slides). The research focused on measuring mercury emissions from a variety of surfaces disturbed by mining activities at Newmont's Twin Creeks Mine northeast of Winnemucca, Nev., and Cortez Pipeline, a Barrick property located south of Battle Mountain, Nev, and used this information to develop an estimate of emissions for the mine surface area. Fugitive emissions from waste rock, heap leaches, tailings impoundments, active pit surfaces, stockpiles and reclaimed sites were estimated and compared to mercury releases from sites undisturbed by mining.

The results showed that mercury emissions from mining disturbances are approximately 20 percent of the total mercury emitted at these two gold mines. The study showed heap leaching and tailings impoundments produced the greatest emissions and that current reclamation practices can reduce the current emissions to near natural levels.

Importantly, the work showed that the amount of mercury emitted from these types of disturbances can vary significantly among mines, depending primarily on the mercury concentration at the disturbed site, the moisture content of the tailings and whether or not the heaps are actively being leached with cyanide. Because there are a variety of factors (such as mercury concentration, age of the materials, climatic conditions, weather, ore type, ore processing techniques, etc.) that can affect the emission of fugitive mercury from different mining surfaces and the uncertainty associated with each of those factors, this data, developed for these two mines, cannot be extrapolated to come up with emissions estimates for other mines. Additionally since a mine is a dynamic entity with surfaces changing over time, and the emission estimates developed in the UNR study represent the surfaces present at the two mines s in 2008, the amount of Hg released in future years may differ depending on the types and extent of mining related surfaces at each facility.

The data contained in the attached power point presentation have not been peer reviewed.

Fugitive Mercury Emissions From Nevada, USA Gold Mines

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Acknowledgements

Nevada Division of Environmental Protection (NDEP)

Nevada's mining companies

Fugitive Mercury Emissions Project Oversight committee

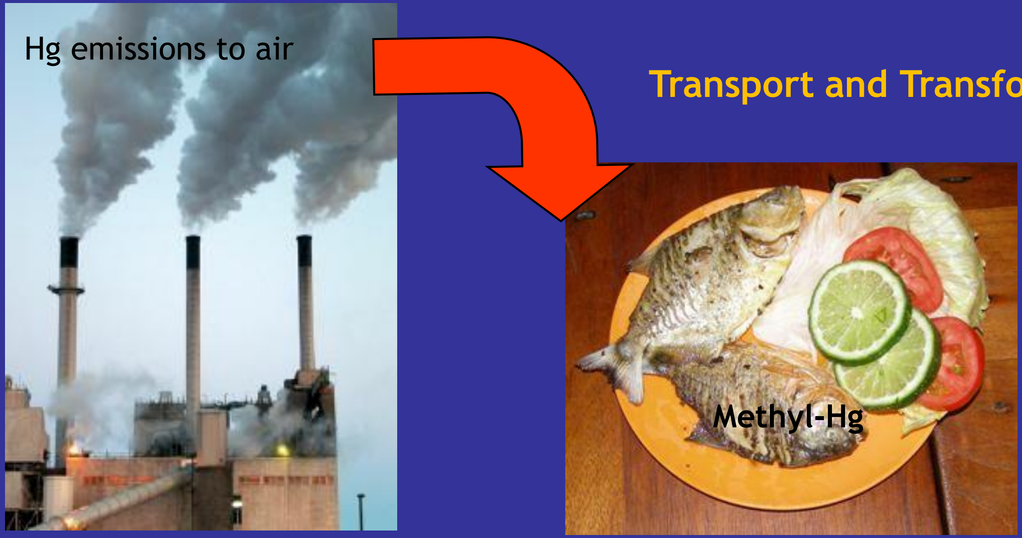
Project Participation

Barrick

Newmont North America

Note: Information presented has not be subjected to final scientific peer review

Mercury (Hg) is a pollutant of global concern



Transport and Transformation

Mercury exposure through fish

Numerous studies have identified Hg enriched soils are a source Hg to the air

Project Context

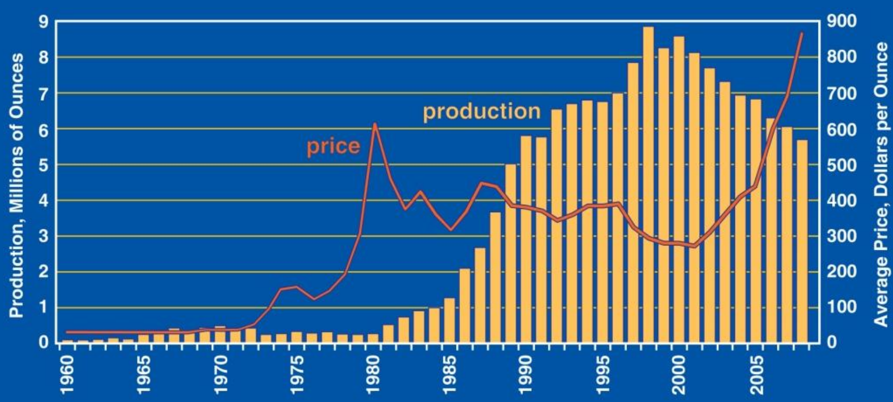
The modern gold rush

Mineral trends with high gold content are often enriched in Mercury (Hg)

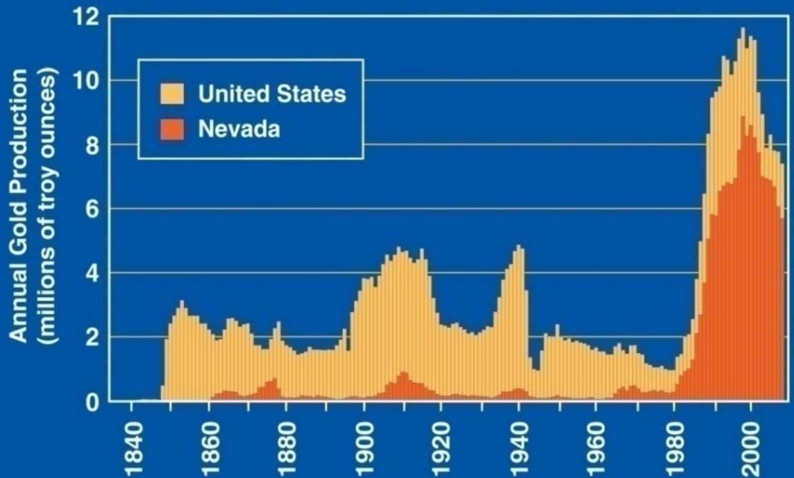
NV Cinnabar (HgS)

~$1,000 oz

Nevada Gold



Gold Production, 1835—2008



Graphs from Nevada Bureau of Mines and Geology

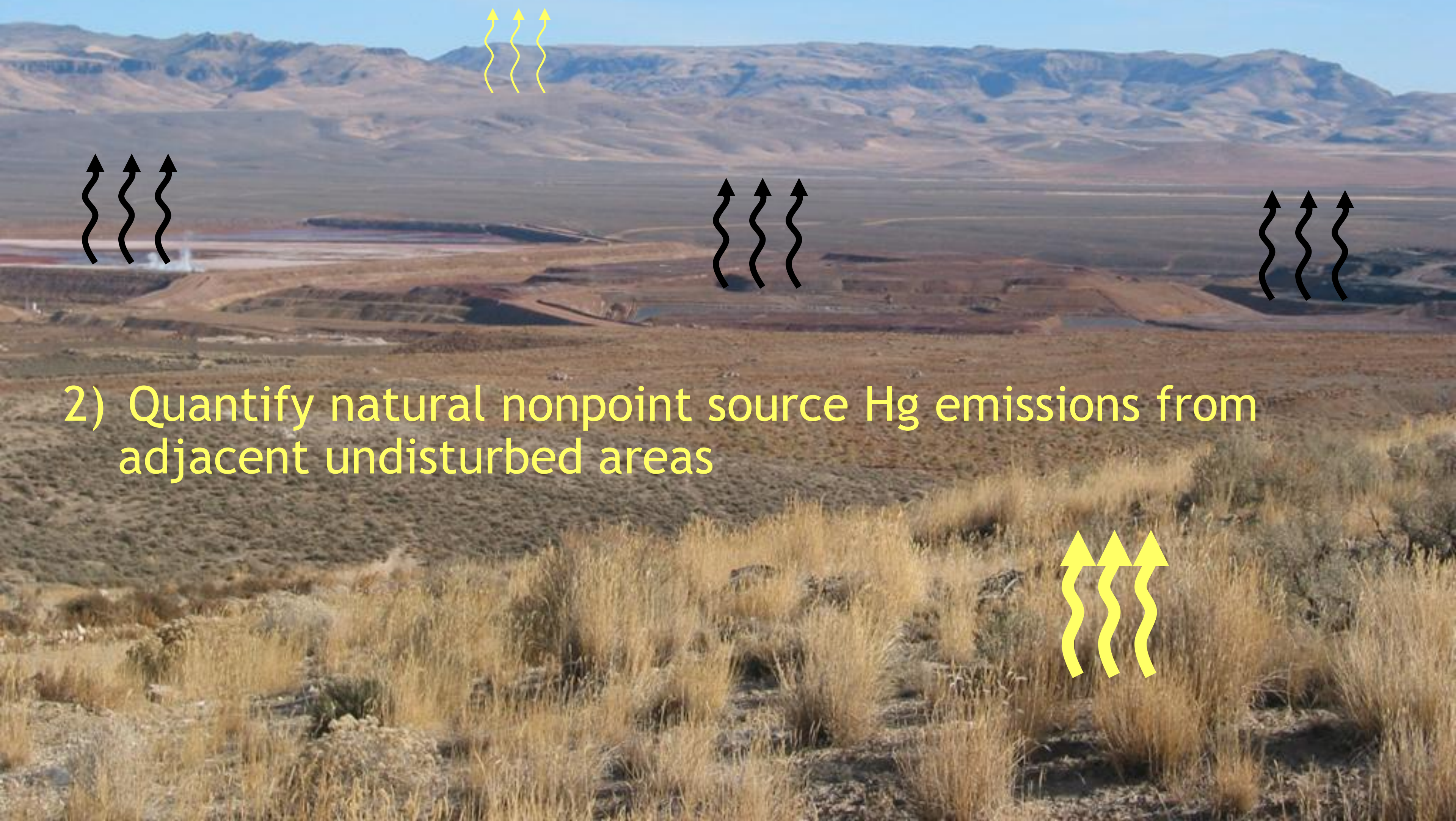
Nevada Gold mines contain point sources of Hg emissions:

2,000 kg/yr (NDEP 2006/2007)

Nonpoint source Hg emissions from Nevada Gold mines: ???? kg/yr

Project Objectives:

1) Quantify nonpoint source Hg emissions from active gold mines



2) Quantify natural nonpoint source Hg emissions from adjacent undisturbed areas

Introduction to Mine Processes

Holes drilled and ore examined for grade and metallurgical properties

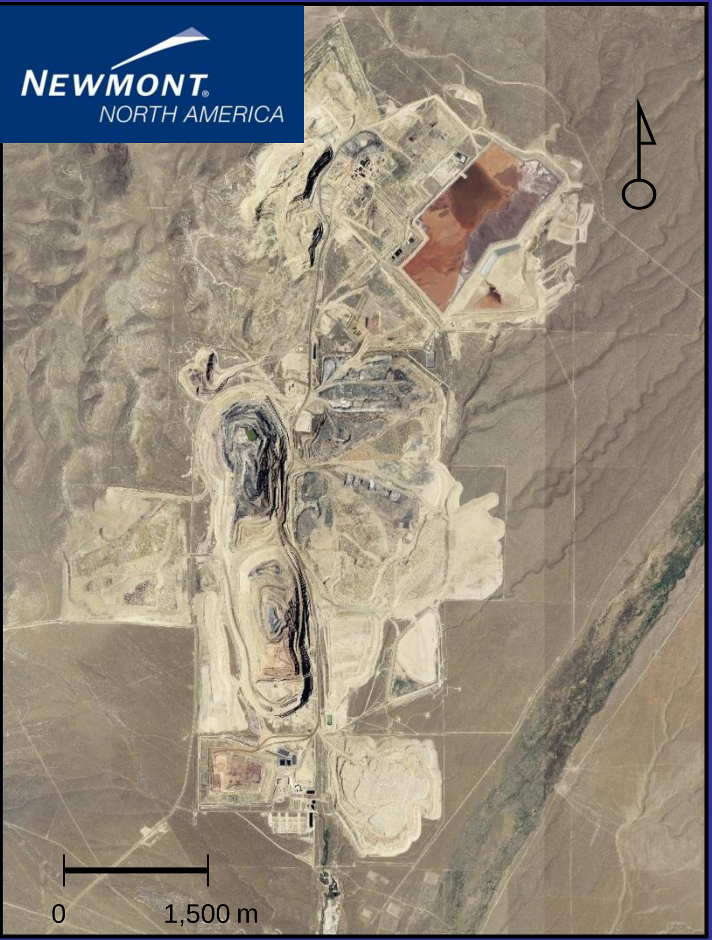
Blast rock

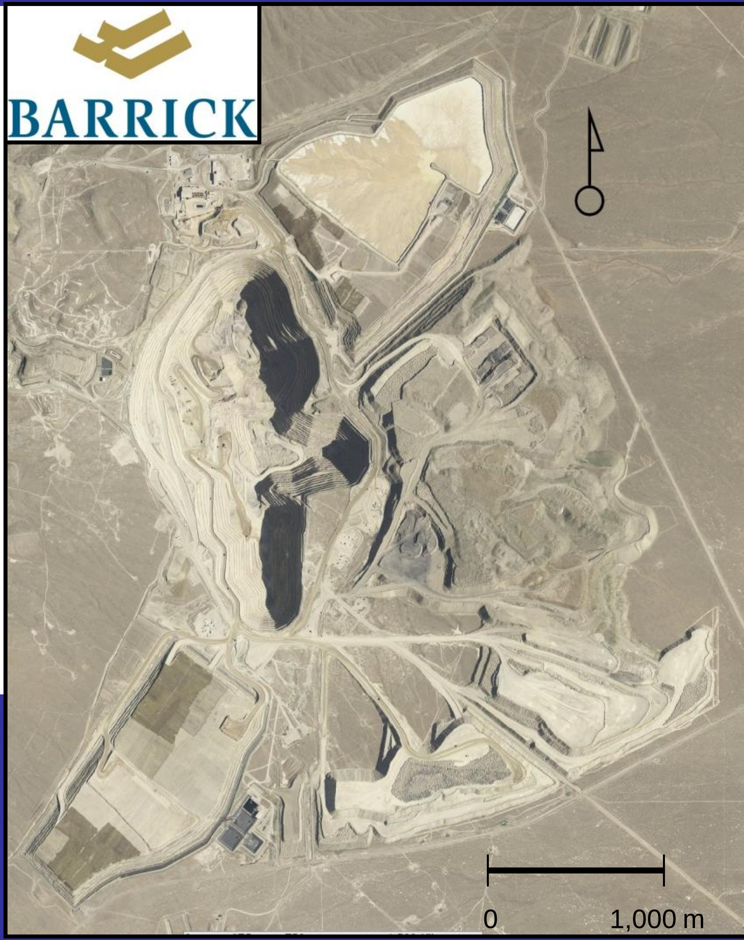
Based on gold content trucks deliver the ore to different processing locations

Schematic pictures from Nevada Mining Association Brochure

Schematic pictures from Nevada Mining Association Brochure
Waste Rock/Overburden
High grade ore
Grinding Mill
Low grade ore
Carbonaceous
Oxide
Sulfide
Heap Leach Pad
Tailings pond
Gold Collected on Activated Carbon

Two mines chosen for study



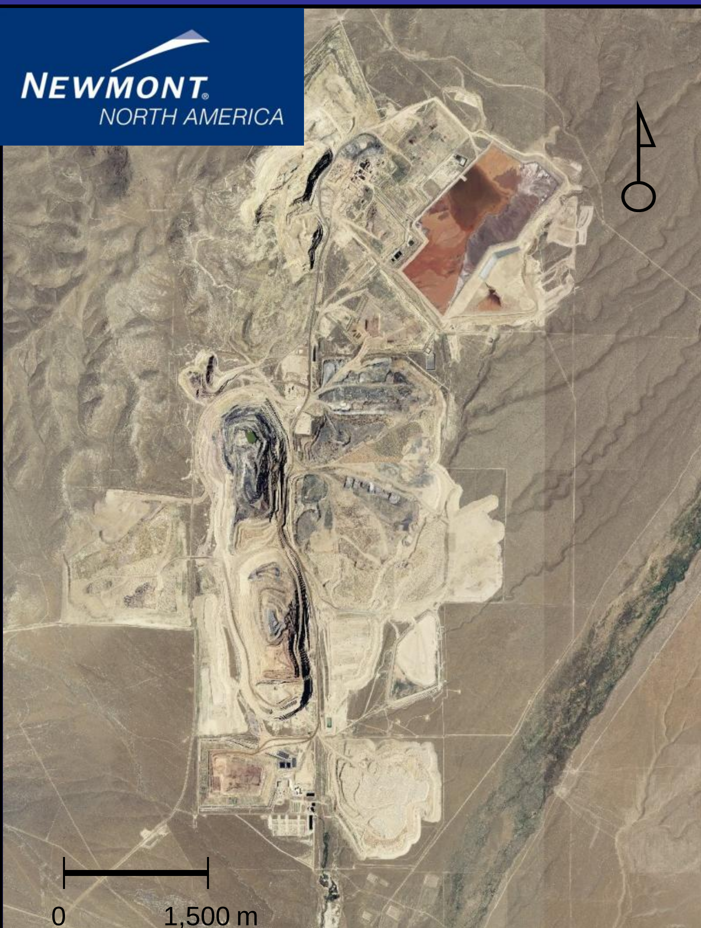


Twin Creeks Gold Mine

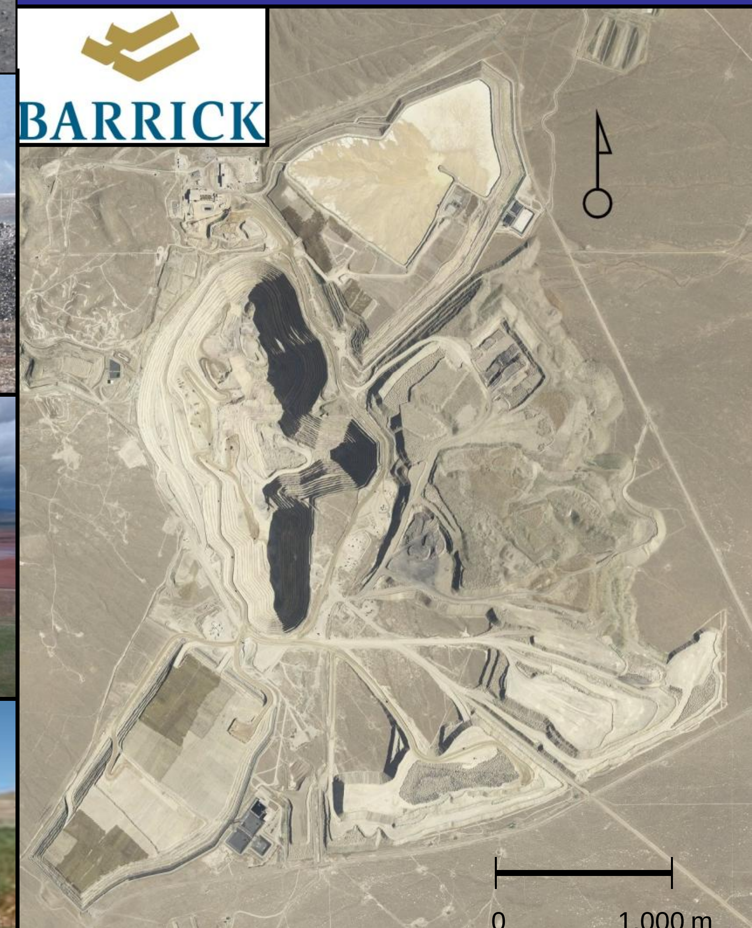
Cortez Gold Mine

Two mines chosen for study

Different materials have different surface areas that change over the life of a mine



Twin Creeks Gold Mine



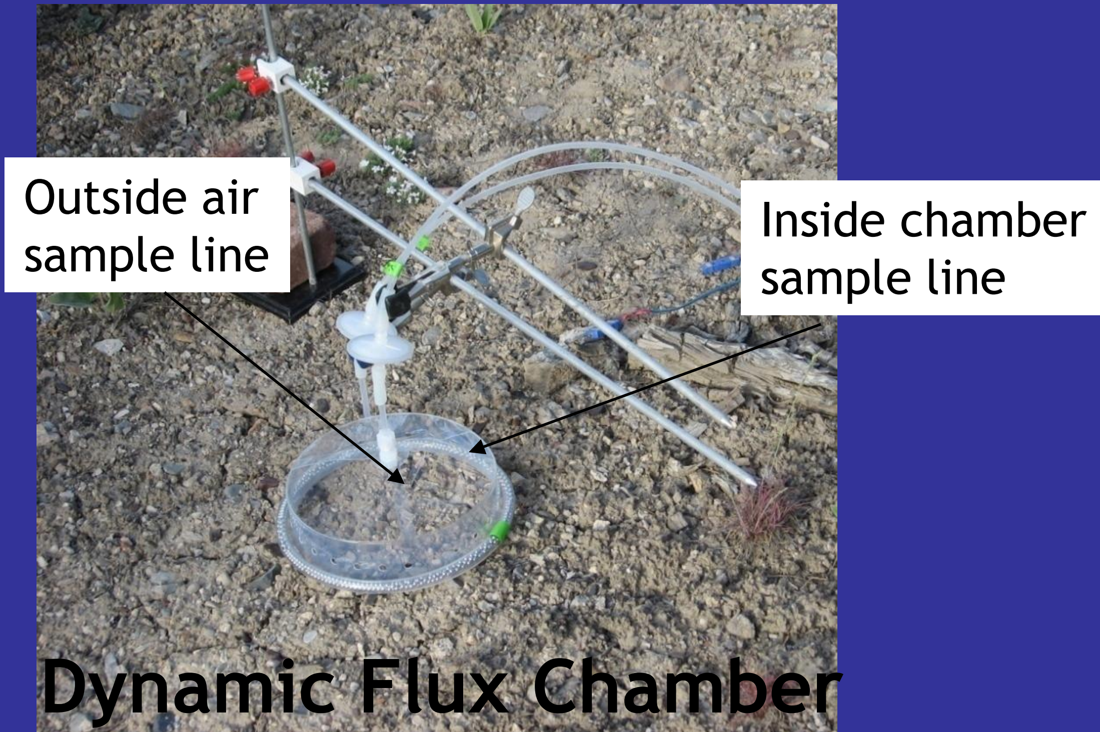
Cortez Gold Mine

Undisturbed Areas: Similar rock types excavated at mines

<u>Twin Creeks Area</u>

<u>Cortez Area</u>

Method to measure emission:



Tekran Total Gaseous
Mercury Analyzer

Flux = $(C_{inside}-C_{outside} *(Q/A)$

Flux is emission or deposition per unit area per time

Units

ng (10^{-9}g) per m^2 per hour or
ng per m^2 per day

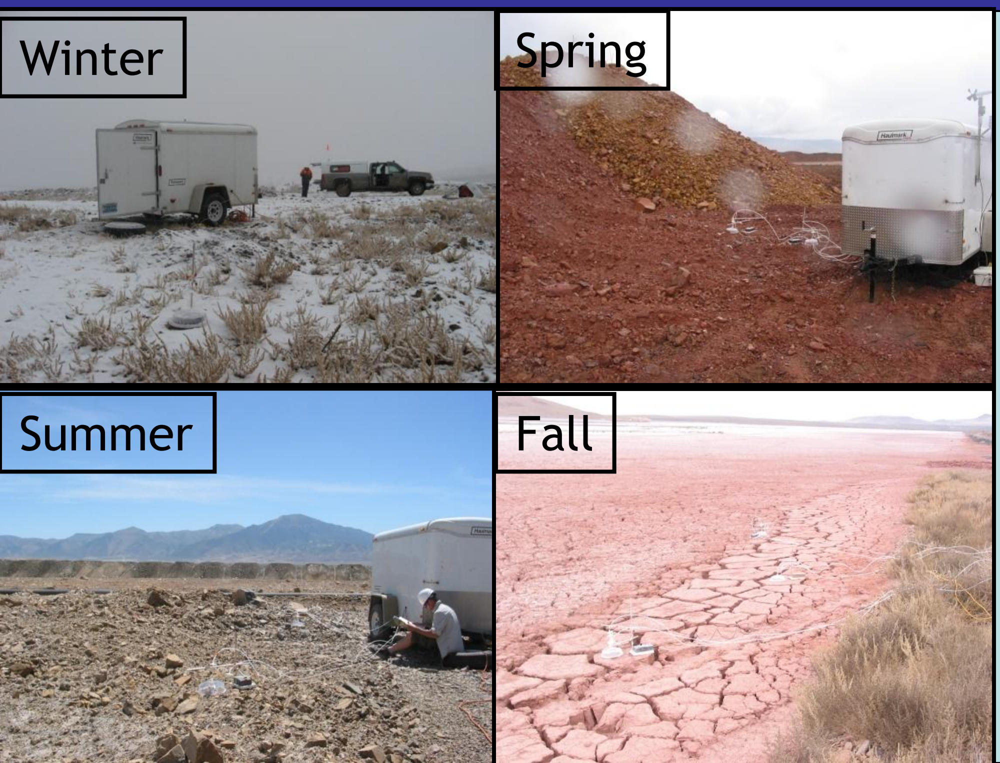
Methods: General Research Approach

1) Identify important factors controlling flux using laboratory experiments

- 48 tubs—3 from each surface type
- Each tub: 24 hr fluxes twice per season
- >400 diel flux measurements
- Meteorological data collected on site
- Develop algorithms

Methods: General Research Approach

1) Identify important factors controlling flux using laboratory experiments
2) Measure fluxes at the mines
   compare with laboratory derived data
   develop data for surfaces not represented in lab study

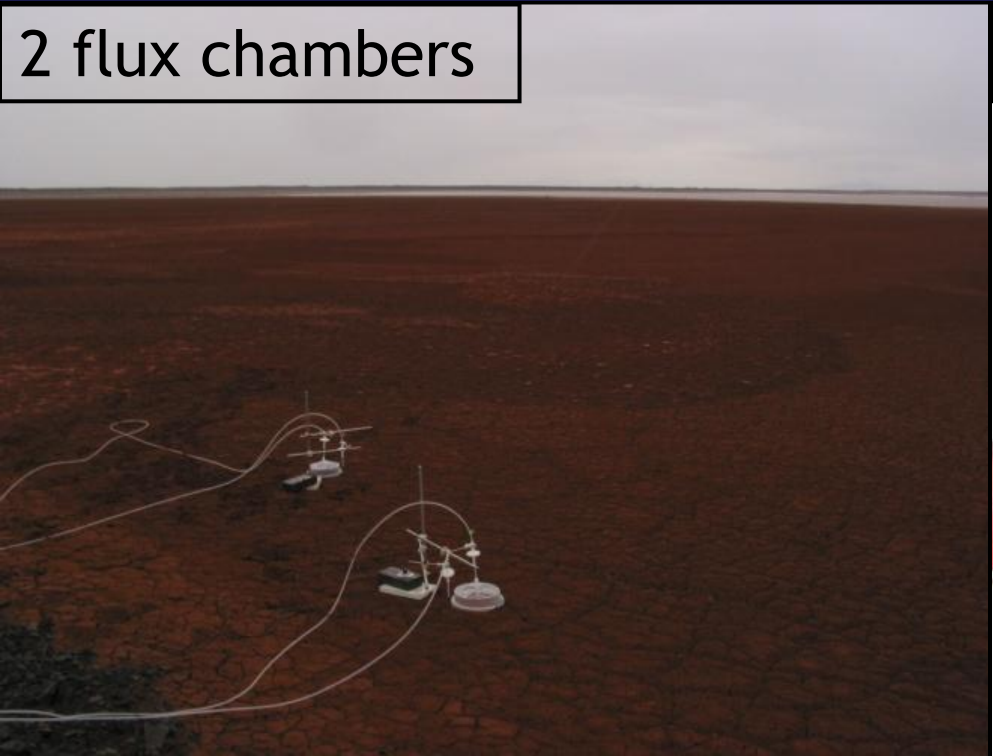


~ 1 week at each mine each season

24 hours sampled from each surface

Methods: General Research Approach

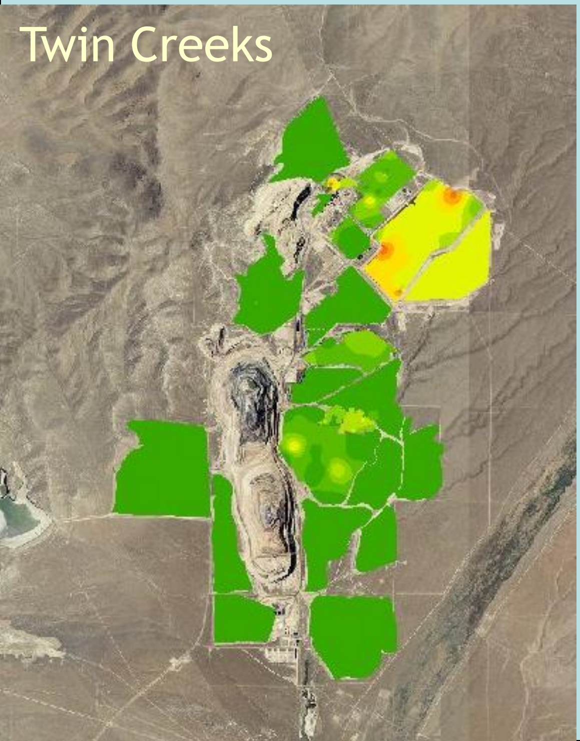
1) Identify important factors controlling flux using laboratory experiments
2) Measure fluxes at the mines
   compare with laboratory derived data
   develop data for surfaces not represented in lab study



Methods: General Research Approach

1) Identify important factors controlling flux using laboratory experiments
2) Measure fluxes at the mines

3) Estimate emissions for each mine based on current surface areas and environmental conditions over the year of study

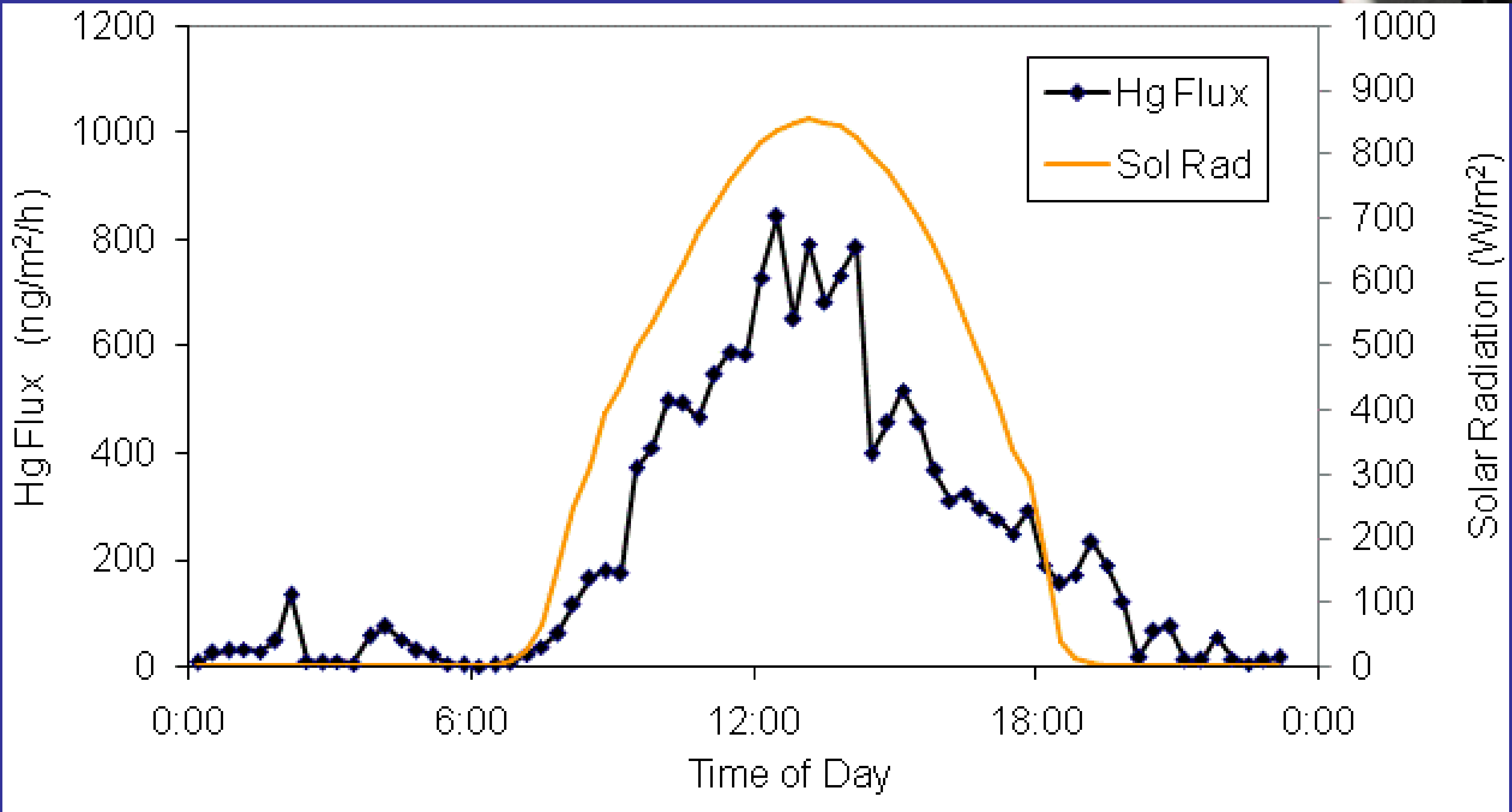


Geographic Information System (GIS)

Results: Laboratory

Fluxes vary:

Daily

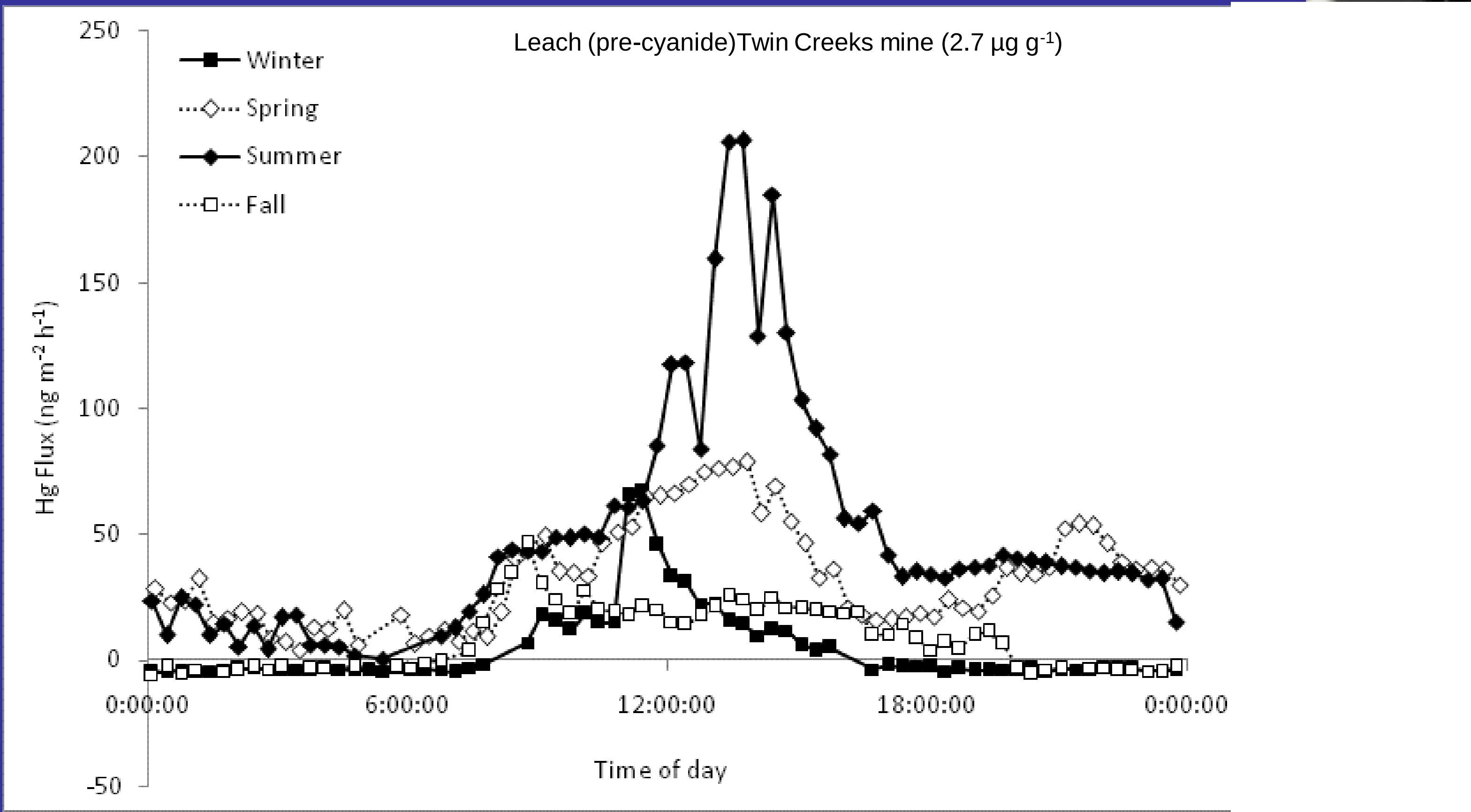


Results: Laboratory

Fluxes vary:

Daily

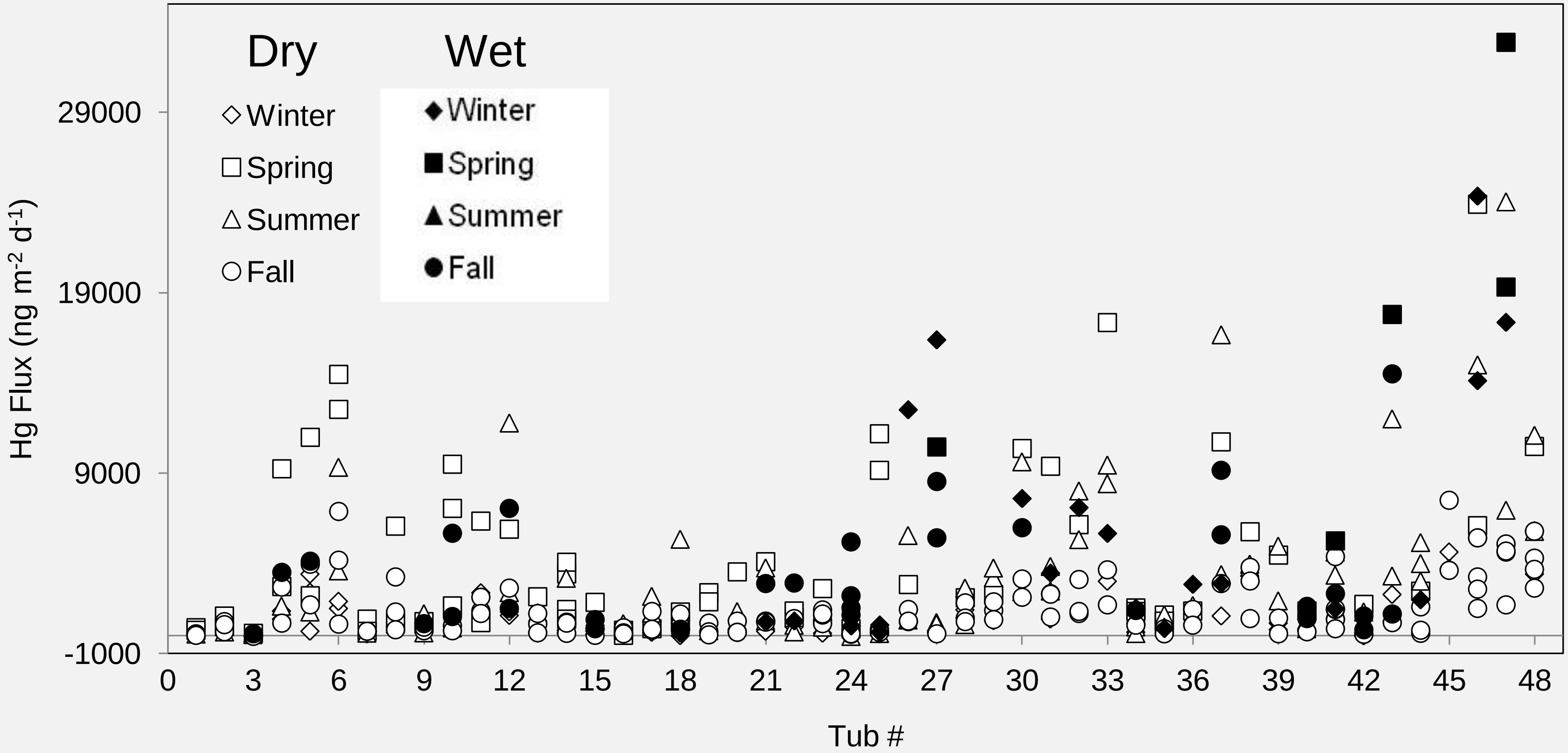
Seasonally



Results: Laboratory

Fluxes influenced by:

surface type, material Hg content

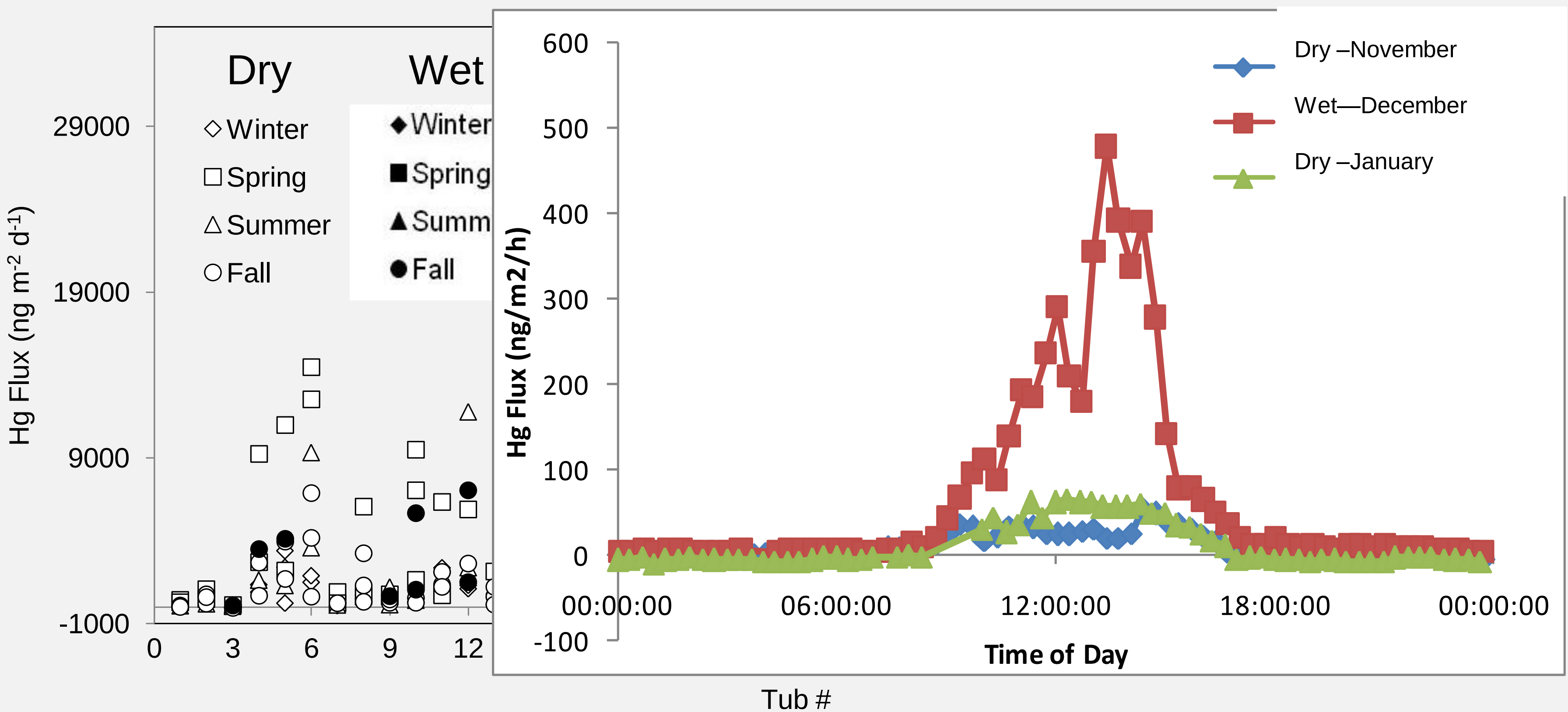


Results: Laboratory

Fluxes influenced by:

surface type, material Hg content

precipitation events—4-fold emission increase



Results: Laboratory

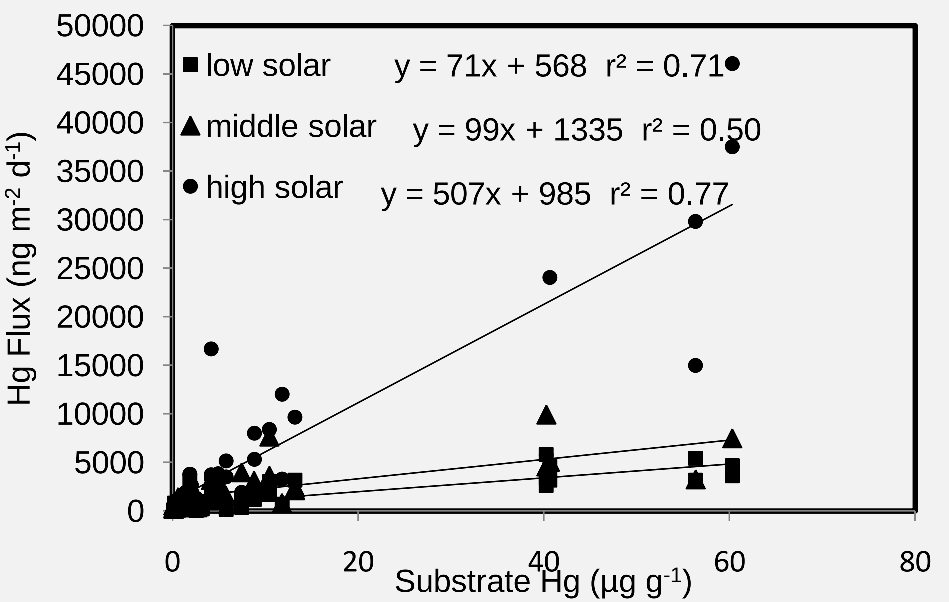
Use statistical analyses to determine most important variables and develop model equations

Daily Hg Flux (between materials)			Hourly Hg Flux (individual materials)	
Parameter	**T-statistic**	**p-value**	**Median T-statistic**	**Median p-value**
Substrate Hg	15.2	<0.001	-----	-----
Substrate moisture	3.4	0.001	-----	-----
Solar radiation	2.2	0.023	8.3	<0.001
Air temperature	3.3	0.001	2.8	<0.001
Relative Humidity	2.5	0.014	-0.3	<0.001
Wind speed	3.3	0.001	-0.2	<0.001

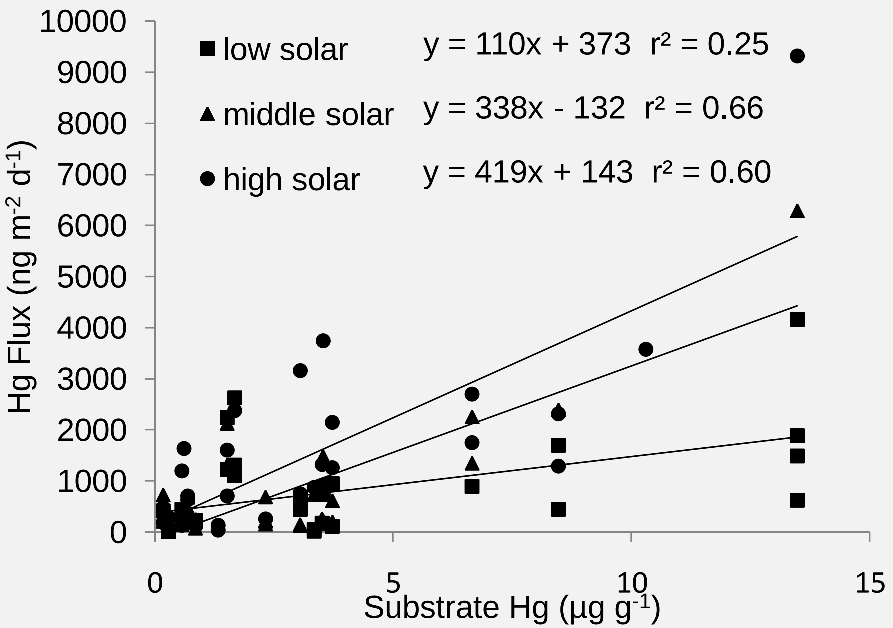
Results: Laboratory

Develop equations that allows us to predict flux as a function of material Hg concentration and solar radiation

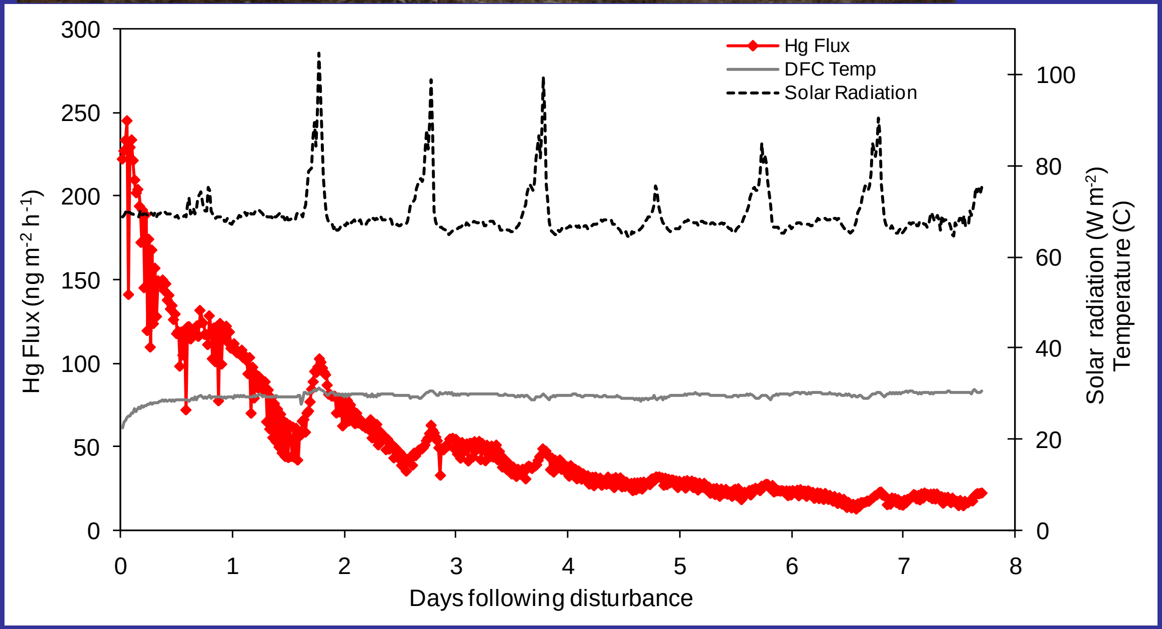
Twin Creeks dry tub data



Cortez-Pipeline dry tub data



Results: Laboratory simulation of surface disturbance



Surface disturbance

Increases flux 7-fold

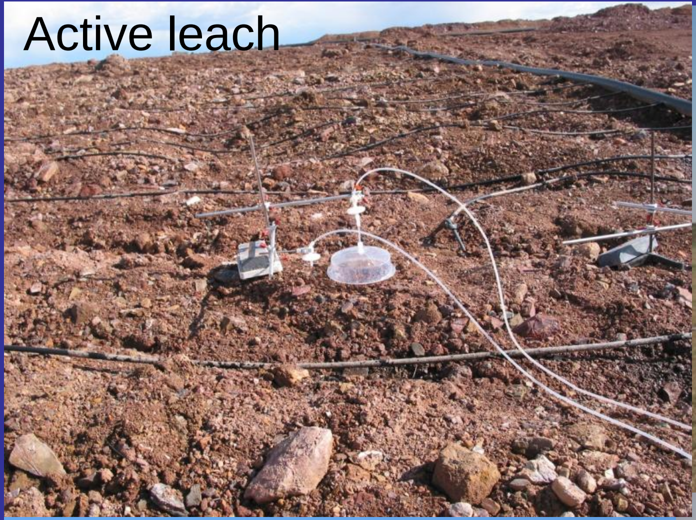
Effect of disturbance decreases over time (~ 7 days)

Field Measurements:

-Characterize Hg concentrations in substrate

-Collect data from field for comparison with laboratory data

-Measure flux from surfaces not represented in laboratory study


Active leach


Reclaimed tailings

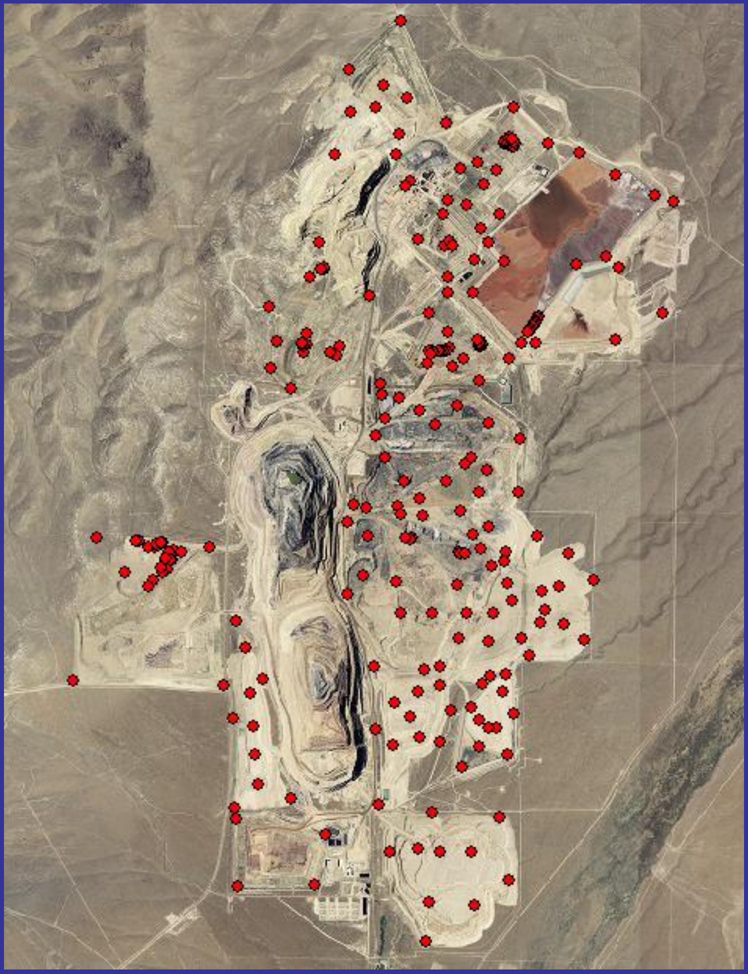

Tailings material


Old leach pad

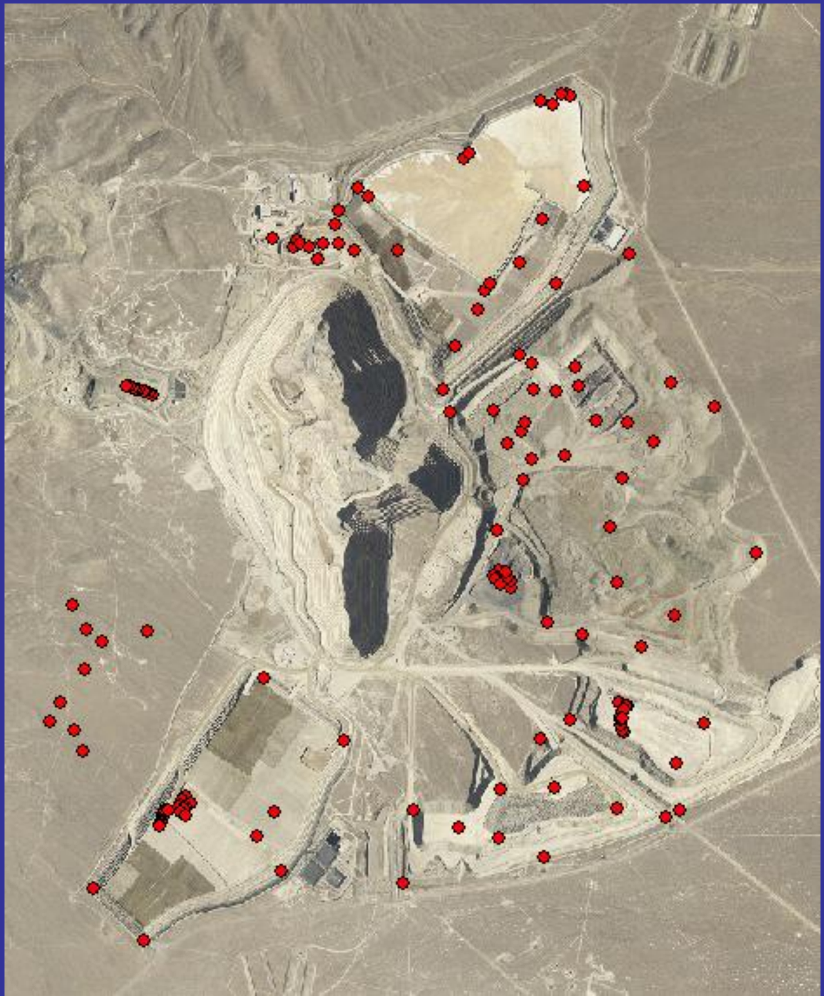
Results: Field data

Characterization of Hg concentrations in substrate

Twin Creeks Gold Mine



Cortez-Pipeline Gold Mine



Results: Surface area/concentration

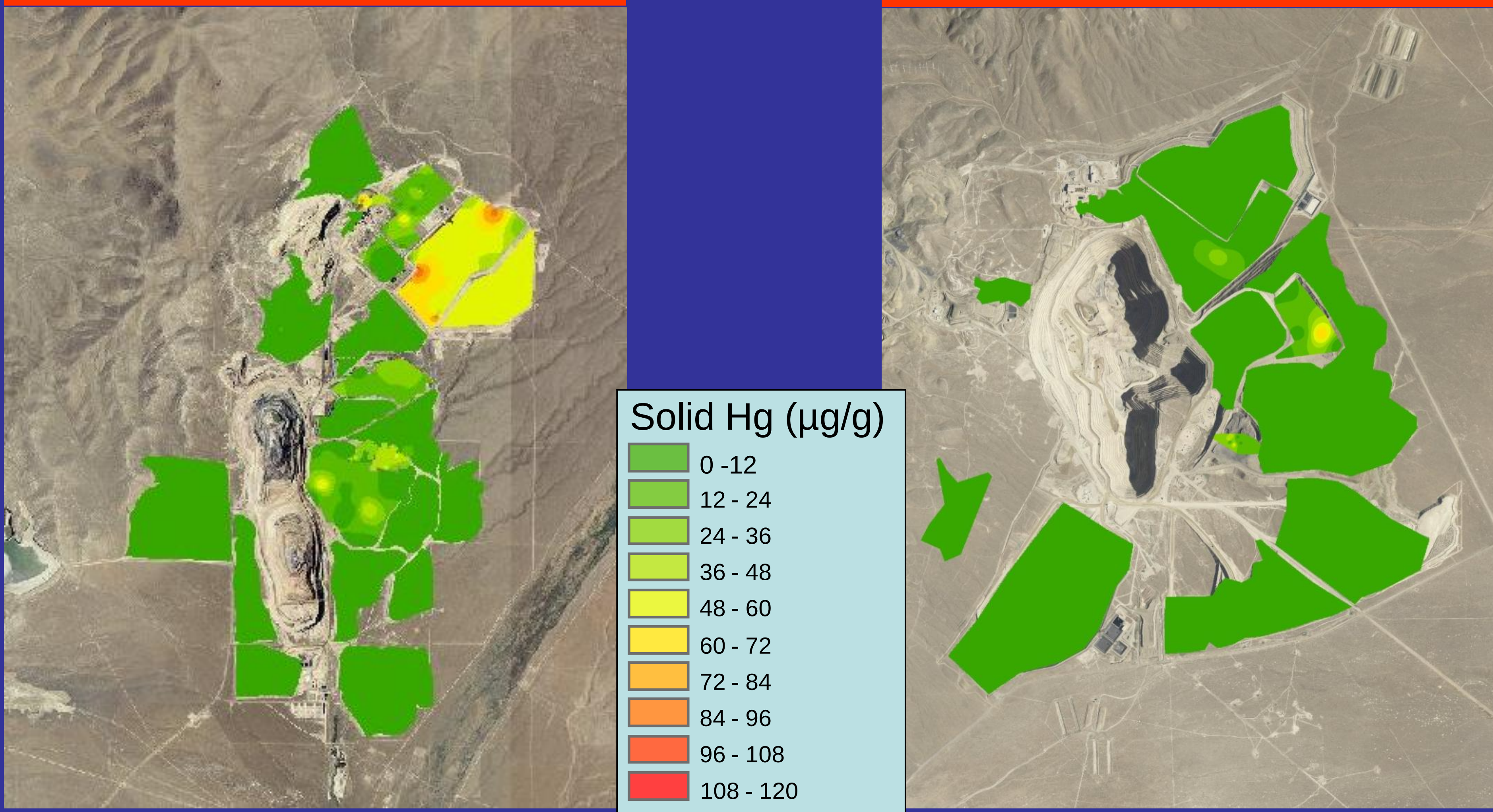
Characterization of Hg concentrations in substrate

Twin Creeks Gold Mine

Spatial Ave Substrate Hg: 5.9 µg/g

Cortez-Pipeline Gold Mine

Spatial Ave Substrate Hg: 1.3 µg/g



Results: Surface area/flux

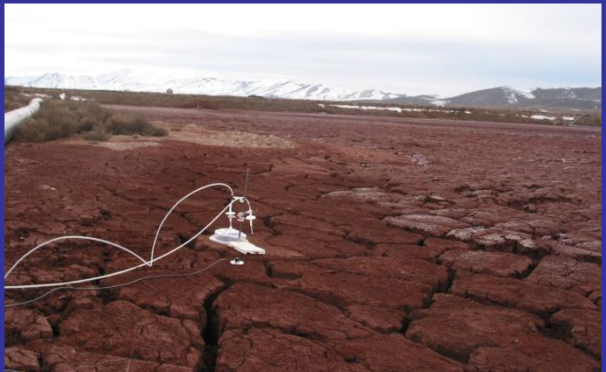
Spatial Variability of Hg fluxes

Lowest Emissions:

- Waste rock materials
  (~10's to 100's ng m^{-2} d^{-1})

Highest Emissions:

- Active leach pads & tailings
  (~1,000's to 100,000's ng m^{-2} d^{-1})

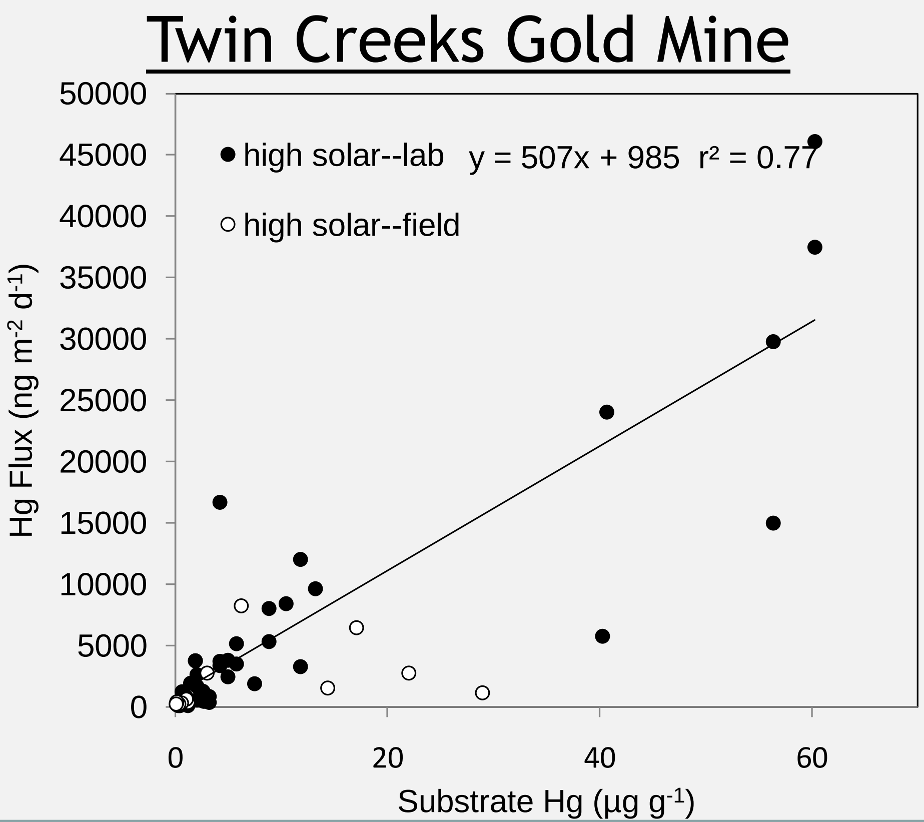


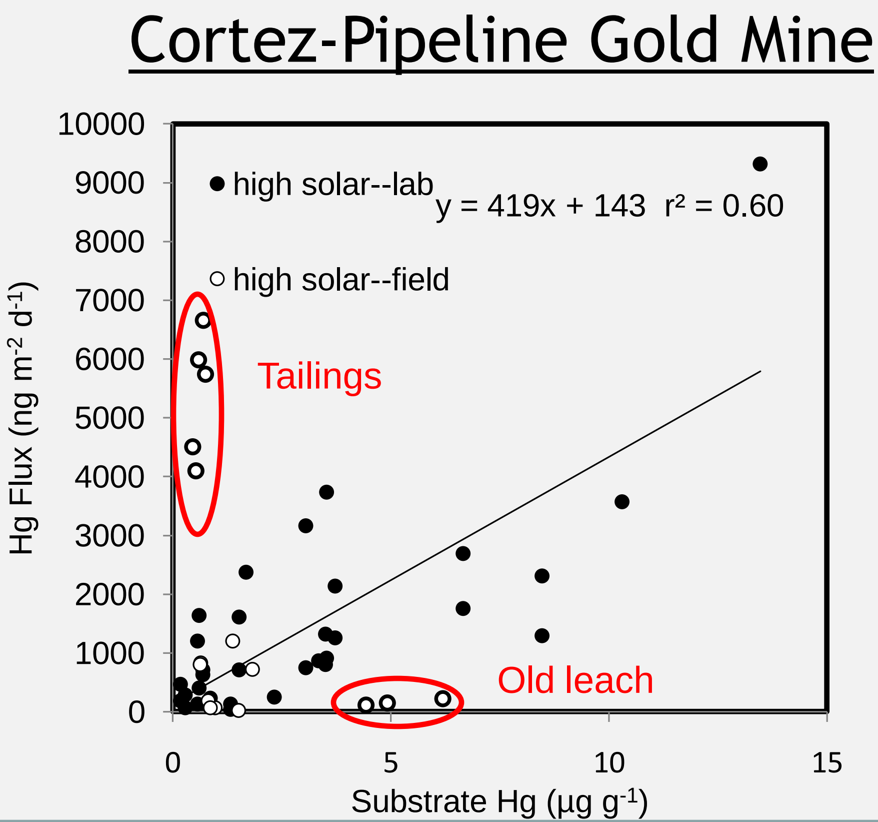
Surface Area

Surface	Cortez Area–ha (%)	Twin Cks Area–ha (%)
Reclaimed	228 (15%)	172 (7%)
Waste rock dump	361 (24%)	1,182 (45%)
Leach pads (Actively leached)	222 (15%) 63 (4%)	122 (5%) 42 (2%)
Inactive leach pads	20 (1)	106 (4%)
High-grade stockpiles	46 (3%)	112 (4%)
Tailings	70 (5%)	294 (11%)
Pit	472 (32%)	621 (23%)
TOTAL	**1482 ha**	**2651 ha**

Comparison of field data with laboratory derived model

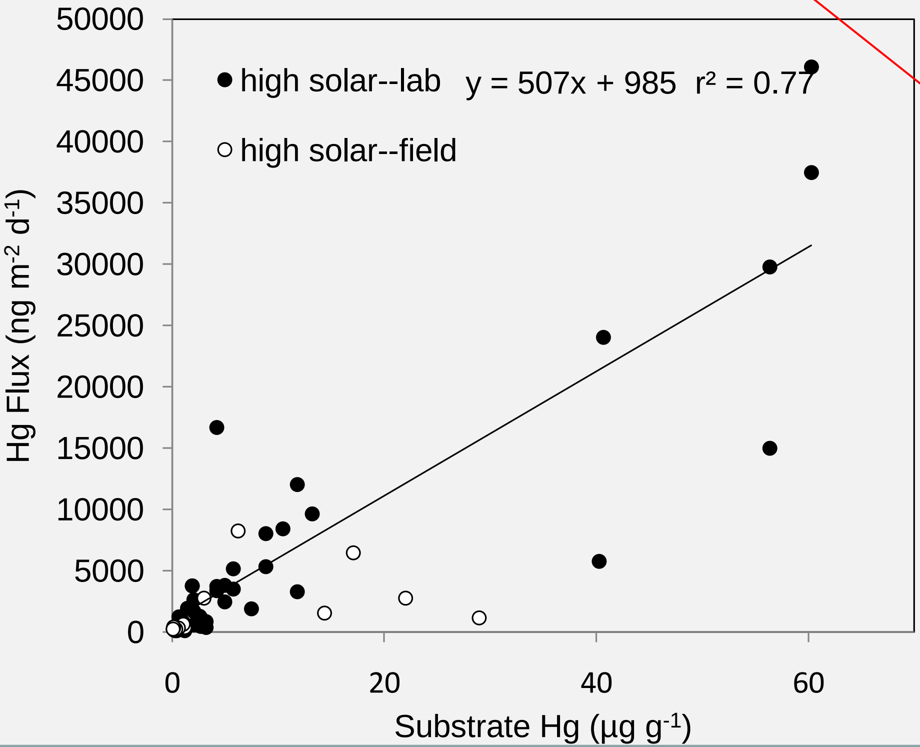
>80% of field measurements were within the 95% prediction intervals of the laboratory data



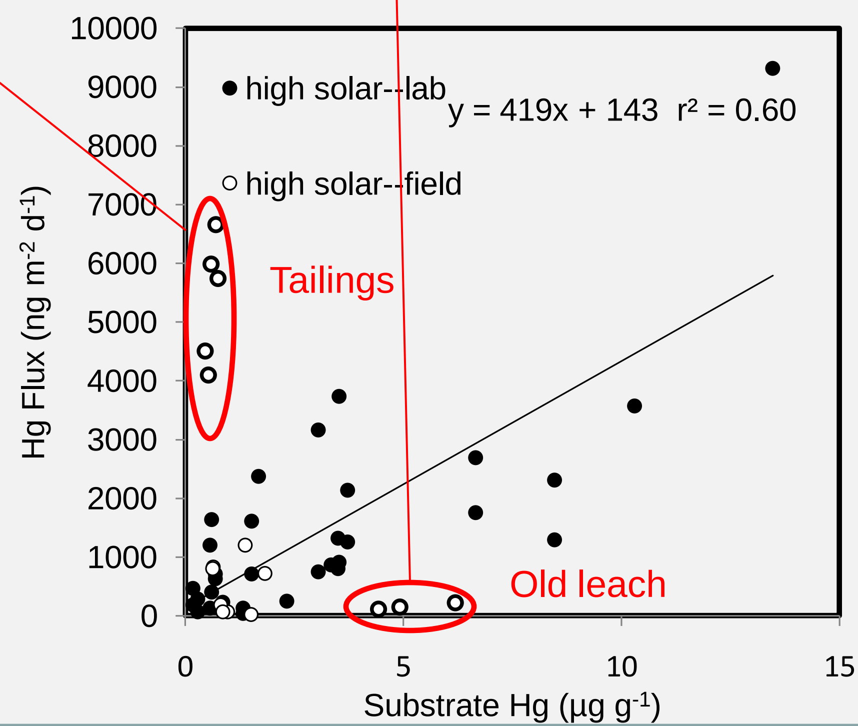


Comparison of field data with laboratory derived model

Twin Creeks Gold Mine



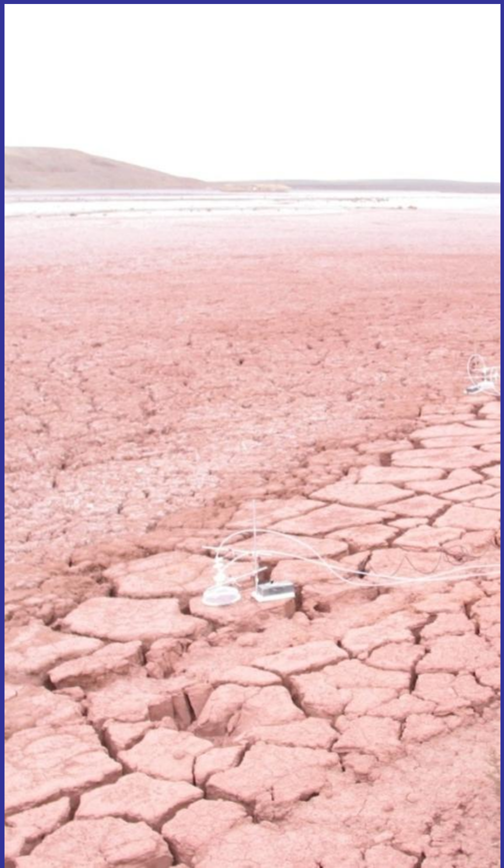
Cortez-Pipeline Gold Mine



Hg fluxes from tailings

Heterogeneous
Hg content (19 to 177 µg g^{-1}),
Moisture (0.1% to liquid solution)
Flux (889 to 684,000 ng m^{-2} d^{-1}).

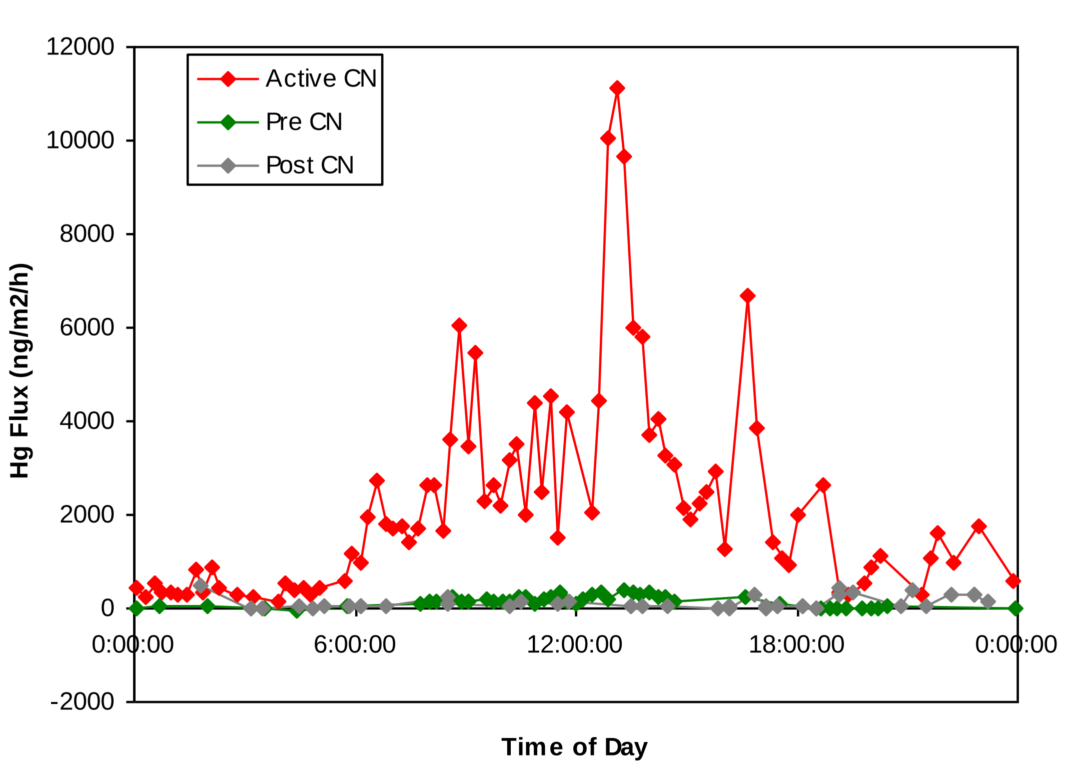
Magnitude of emissions best correlated with % moisture $r^2 = 0.55$ p=0.001



Results: Cyanide Heap Leaching

Hg fluxes from substrate actively under leach only obtained at Twin Creeks

Results: Cyanide Heap Leaching

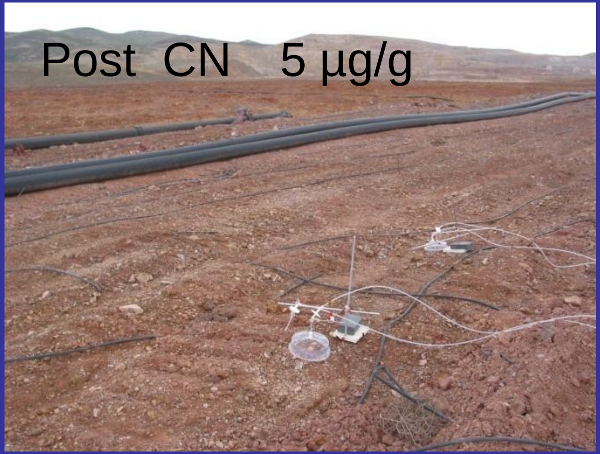


Twin Creeks Spring Data

Pre leach: 2,280 ± 1,470 ng/m^2/d

Active leach: 101,300 ± 53,400 ng/m^2/d

Post leach: 1,750 ± 572 ng/m^2/d



Results: Cyanide Heap Leaching

Daily Emissions increase ~4-fold from the effect of wetting alone

Daily Emissions ~35-fold higher during leaching than from pre and post leaching

Mean Hg Content of leach solution:
17 µg/L (Cortez)
470 µg/L (Twin Creeks)

Nevada rainwater: 0.002-0.4 µg/ L
(Mercury Deposition Network Data Station: NV02, 2007 data)

A component of Hg emitted during active leaching is from the cyanide solution

Results: Material age/reclamation

Emissions from capped tailings Twin Creeks (spring, 2008 data)

Ave flux from tailings: 27,600 ng/m^2/d

Ave flux from capped tailings: 1,160 ng/m^2/d

Fluxes may be greatly reduced post-reclamation

Data from 5 year old/inactive leach suggest fluxes decline as materials age

Annual Emission Estimates

- 1) Calculate fluxes
  - Use substrate Hg concentrations versus solar radiation relationship for dry and wet surfaces

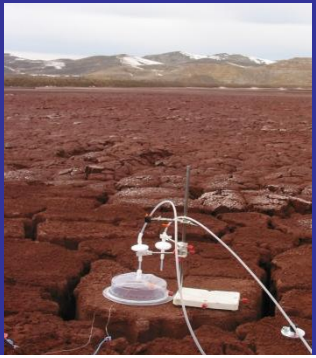
  Make adjustments based on field data
  - Tailings
  - Leach pads during cyanide addition
  - Account for surface disturbance
  - Account for surface age

- 3) Scale emissions: Flux ($ng/m^2/d$) X surface area (m^2) X days

- 4) Sum fluxes from each surface for all days of the year = total emissions

- 5) Sensitivity and Uncertainty analysis performed on the models

Annual Emission Estimates



Total nonpoint source (NPS) emissions kg/yr:

Twin Creeks: 105 (range 60 to 121)

Cortez-Pipeline: 19 (range 16 to 43)

tailings and active heap leach < 15% area at both mines released >75% of Hg

waste rock/reclaimed/inactive leach >85% area at both mines released <25% Hg

Total point source emissions kg/yr :

Twin Creeks: 449

Cortez-Pipeline: 94

(Nevada Division of Environmental Protection data)

Total emissions point and NPS kg/yr:

Twin Creeks: 554 (509 to 570); Cortez-Pipeline: 113 (110-137)

% of *total* mine emissions that are NPS:

Twin Creeks: 19% (12 to 21%); Cortez-Pipeline: 17% (15 to 31%)

% increase in total mine emissions from NPS: Twin Creeks: 23% (13 to 27%)
Cortez-Pipeline: 20% (17 to 46%)

Annual Emission Estimates

Total nonpoint source emissions kg/yr:
Twin Creeks: 105
Cortez-Pipeline: 19

Emissions prior to mining kg/yr:
Twin Creeks: 1.5
Cortez: 0.25

Projected emissions post mine reclamation

Twin Creeks: <8 kg/yr
Cortez-Pipeline: <3 kg/yr

Concluding remarks:

- Large differences in emissions between mines

- Emission estimate reflects one stage in the life of a mine
  - Emissions will vary depending on activity, age, and reclamation

- Factors important to consider:

  mercury concentration/host rock characteristics

  surface area of mining disturbed materials

  characteristics of tailings impoundments

  climatic conditions

  ore-processing techniques (i.e heap leaching)

  age of materials and reclamation


Questions?