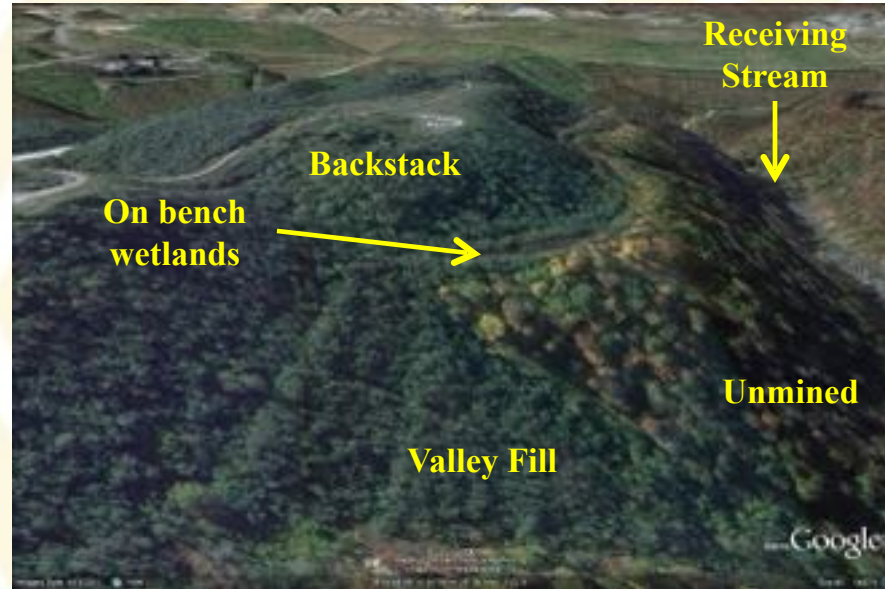# Long-term trends in selenium attenuation at a Central Appalachian surface mine

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# Allegheny Plateau-pre mining



Old, contour/auger mining

# Hobet: a typical mountaintop mine: Oldest mining (1985) in foreground

# Field studies:  Identifying the time-[Se] relationship at the stream level. Muddy Ck.

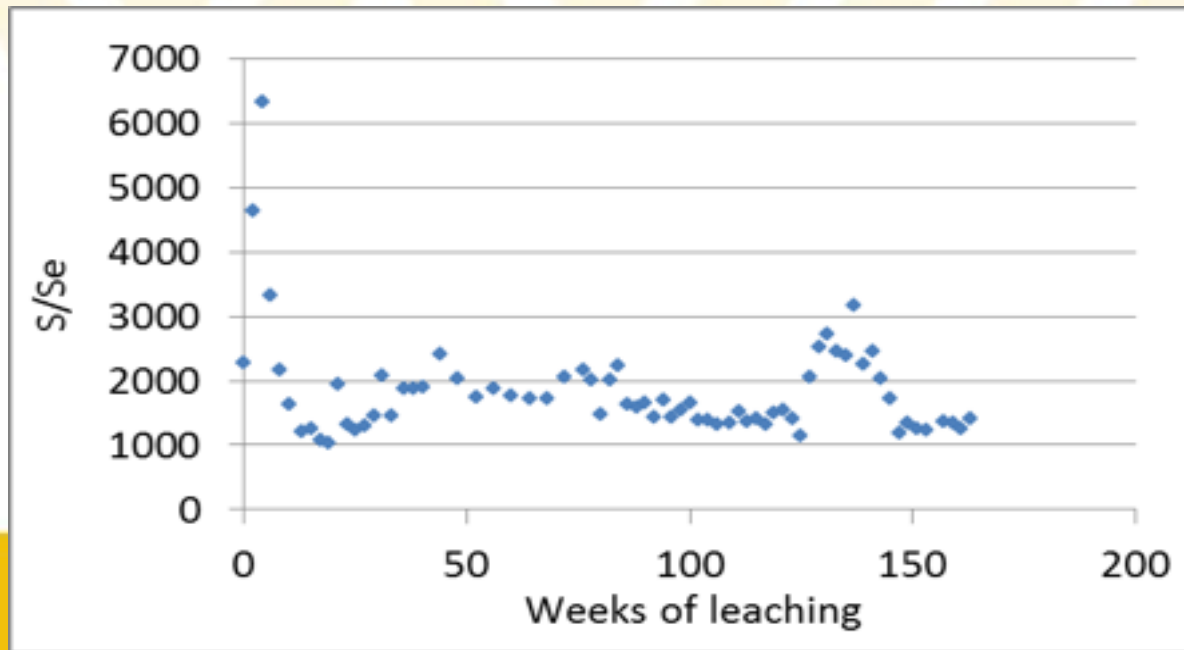# 2012 STUDY

1. Humidity Cells
2. Outlet Study
3. Stream Study

# The ratio of sulfur to selenium release is nearly constant suggesting a mineralogical link

Iron selenide, replaces pyrite?

$Fe_xS(Se)$

average S/Se =1,833

# Most of the selenium is probably in organic shale: where the pyrites are

# Selenium kinetics were studied at three scales

- **Laboratory:** 145 weeks of weathering/leaching in humidity cells
- **Field**
  - **Outlet study:** 67 outlets sampled over an eight- year period representing 25 years post initial mining-5,388 samples
  - **Watershed study:** Stream samples over two years representing 25 years post initial mining
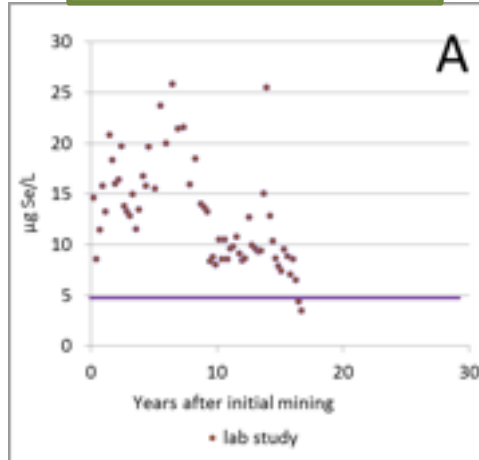
# Organizing the 5,388 data points

- Individual outlets were sampled over a period of 1-8 years

- X axis represents years between permit date and outlet sampling date

- Y axis is the average total selenium concentration sorted per:

  - One year age classes (25)
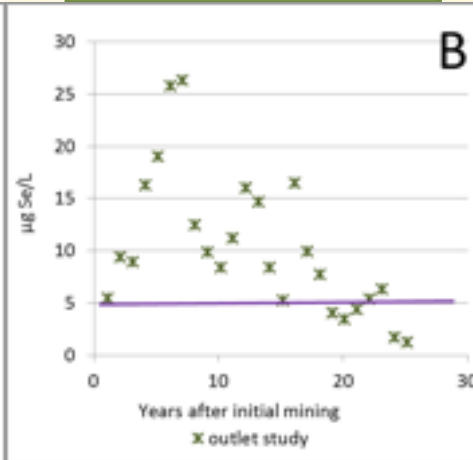
  - Average age of each mine permit

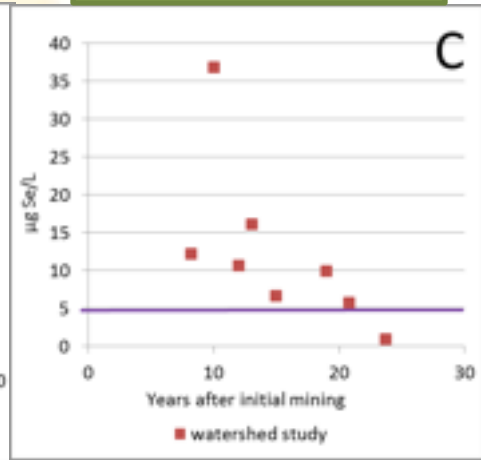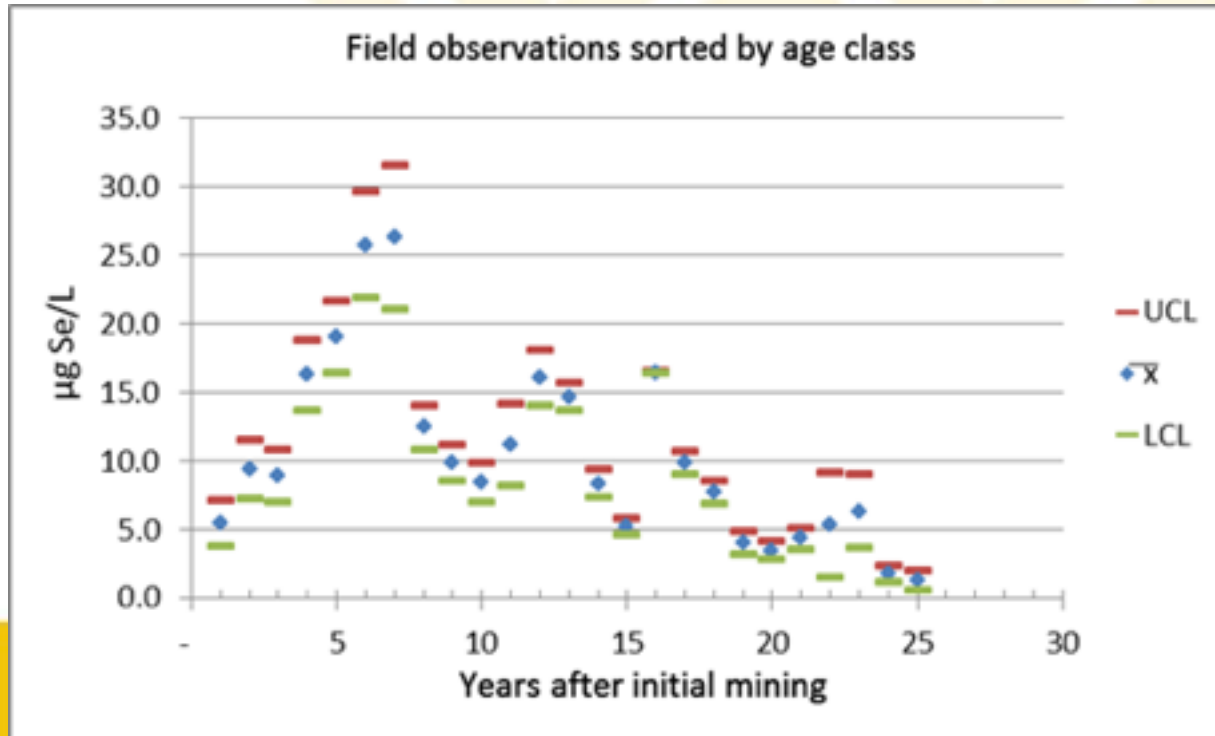# Laboratory and field studies yield similar attenuation curves

# 5,388 data points sorted by age class-95% confidence intervals
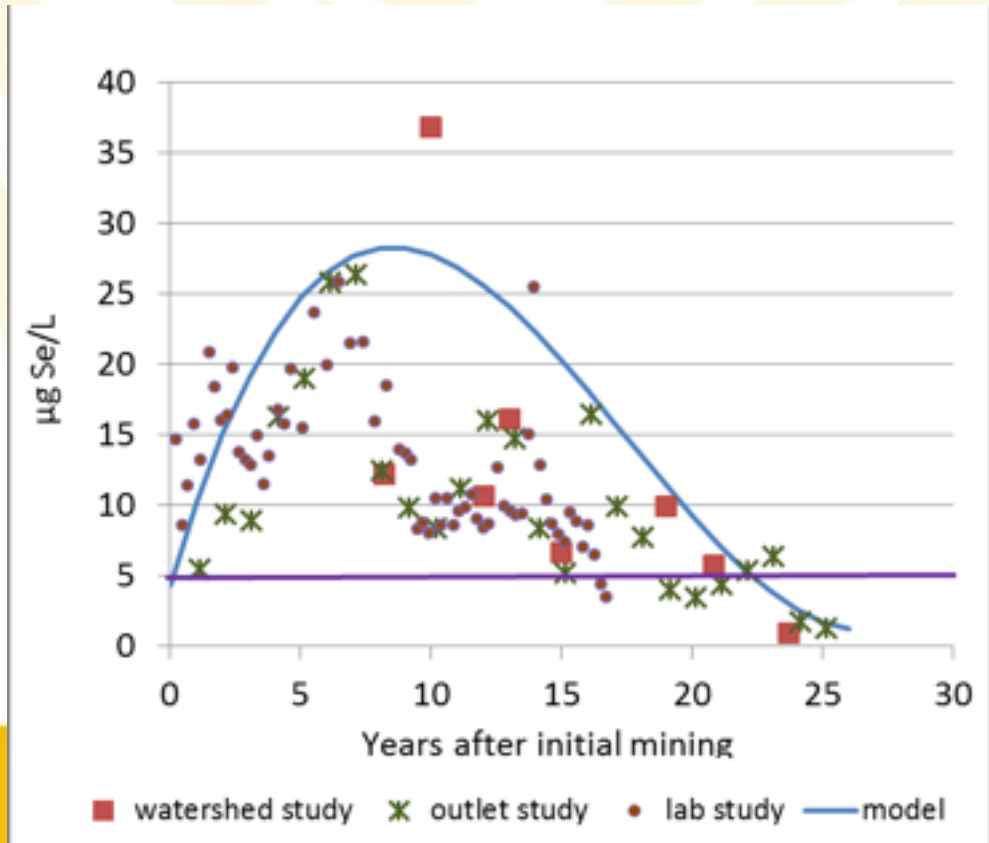
# Descriptive Model

$$y = 0.0093x^3 + 0.49x^2 + 6.30x + 4.31$$

**Postulated Ferrihydrite Sequestration**

- Occurs at year seven in all three studies.
- Coincides with maximum acidity generation (Meek, 1994)
- Saturation/exhaustion of ferrihydrite by year thirteen.
- Selenium then resumes according to the model
- The missing selenium appears to be permanently sequestered

# Conclusions (2012 study):

- Selenium increase rapidly over the first seven years after mining followed by a decline over the next fifteen years to below 5 µg/L

- The same trends pertained at three scales:
  - Laboratory
  - Outlet
  - Watershed

# Conclusions (2012 study)

- Between 25 and 35% of selenium in southern West Virginia coal mine spoil is potentially mobile

- Pyrite sulfur is between 2,000 and 10,000 more prevalent in unweathered spoil than selenium

- Selenium weathers and leaches out of spoil about 10x faster than sulfur
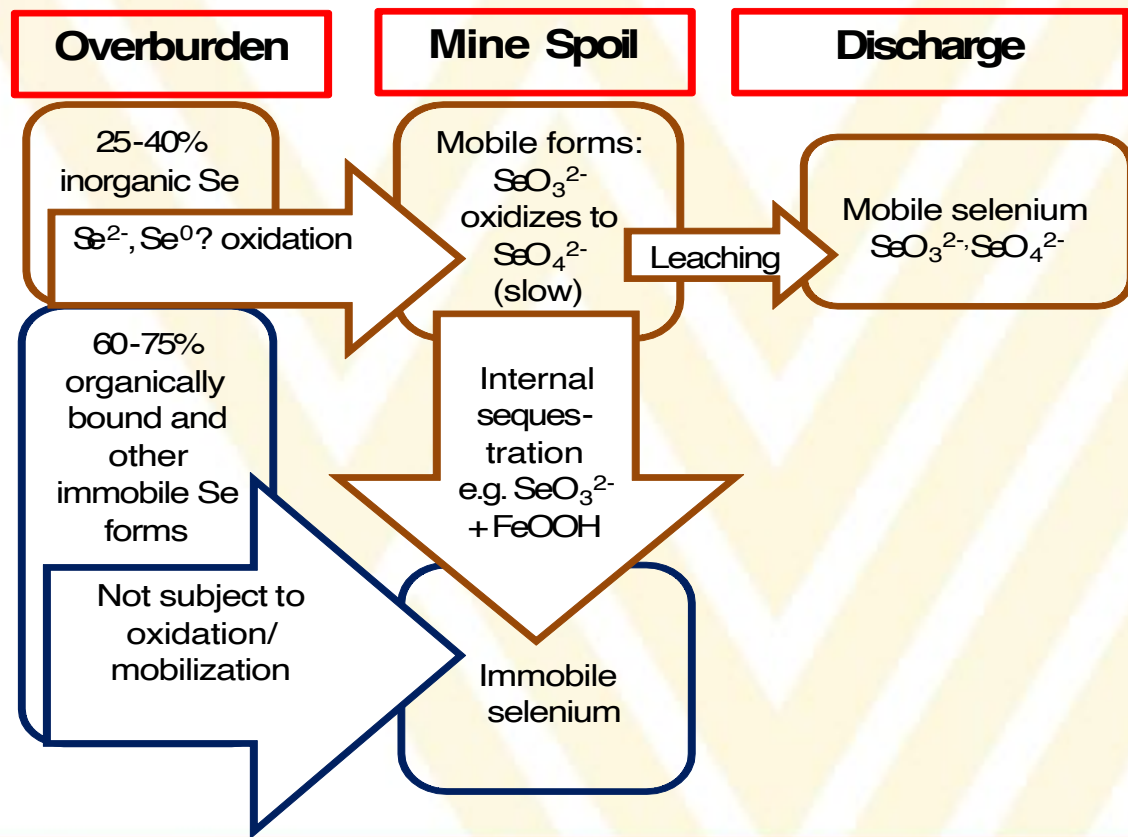
# Conclusions (2012 study)

- Laboratory results can be scaled to predict field results

- A substantial portion of the original selenium is 'lost' probably due to ferrihydrite sequestration

- Any spoil disturbance resets the clock

# SELENIUM WEATHERING MODEL

**Overburden**

**Mine Spoil**

**Discharge**

25-40% inorganic Se

$Se^{2-}$, $Se^0$ ? oxidation

Mobile forms: $SeO_3^{2-}$ oxidizes to $SeO_4^{2-}$ (slow)

Leaching

Mobile selenium $SeO_3^{2-}$, $SeO_4^{2-}$

60-75% organically bound and other immobile Se forms

Internal sequestration e.g. $SeO_3^{2-}$ + FeOOH

Not subject to oxidation/ mobilization

Immobile selenium

# Current study at Hobet:



HOBET OUTLETS: 2025

active 40%

inactive 60%

-198 total outlets
-80 active outlets:  currently monitored
-118 inactive outlets:  compliant, dried up, reconfigured
-Sampled over 20 years
-Metric:  Average Se per outlet since outlet initiation
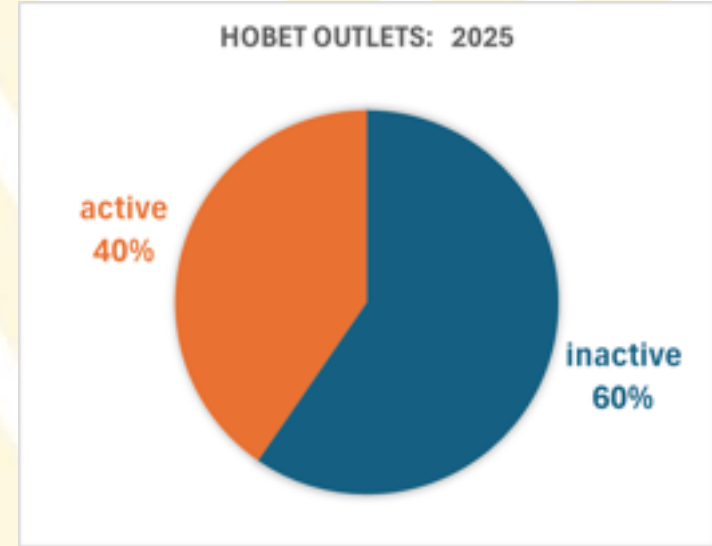
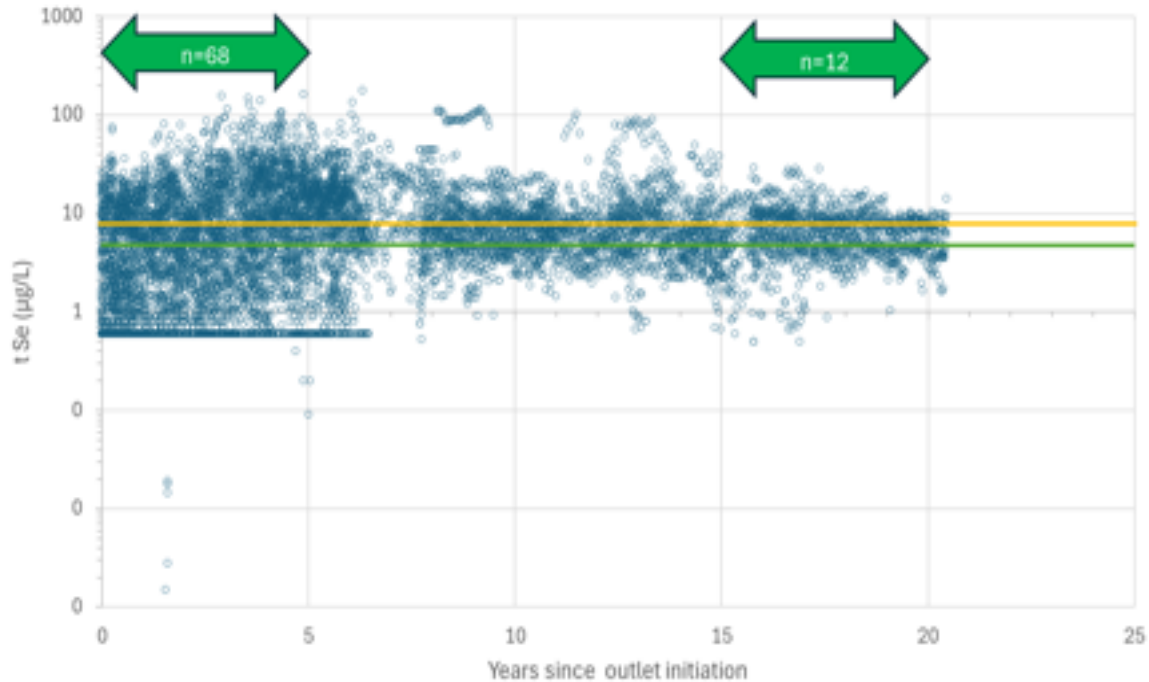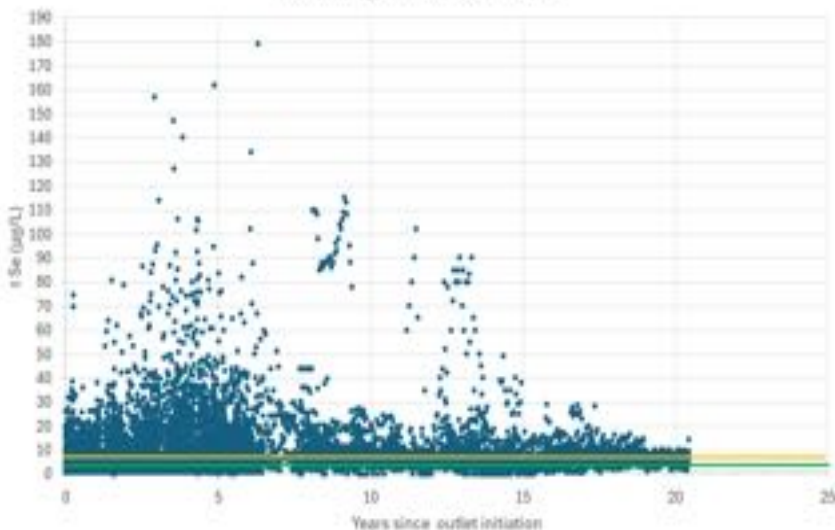# 82.4% of outlets are compliant after 20 years
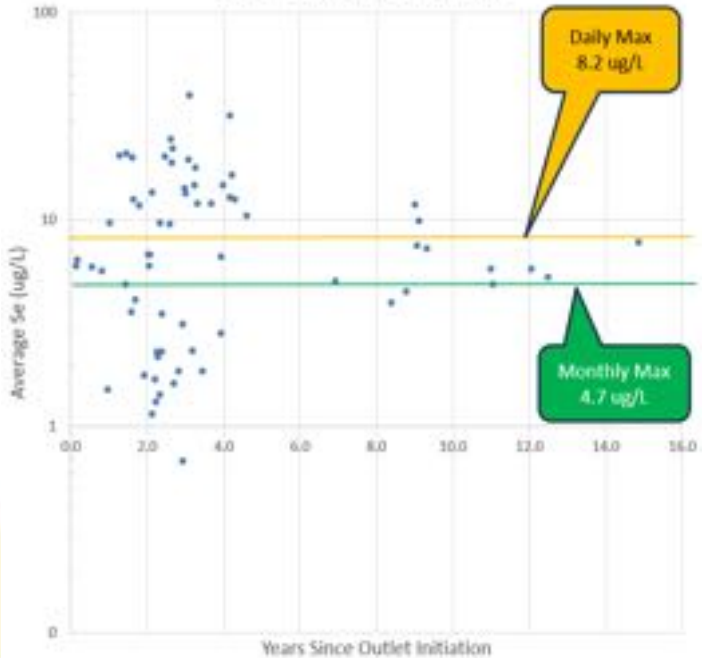
# Se vs. years post outlet initiation
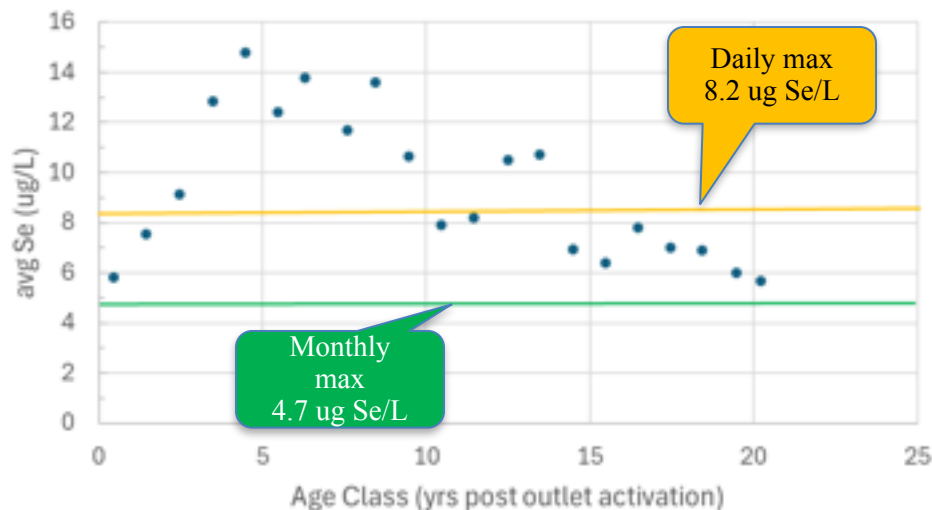
# All Hobet outlets

| permit | # outlets | avg outlet age yrs | # in compliance | % in compliance |
|---|---|---|---|---|
| WV0099392 | 117 | 11.1 | 72 | 62% |
| WV1016776 | 44 | 18.6 | 12 | 27% |
| WV1017225 | 7 | 8.9 | 4 | 57% |
| WV1021028 | 13 | 7.2 | 2 | 15% |
| WV1020889 | 17 | 5.9 | 6 | 35% |
| | 198 | 10.3 | 96 | 48% |

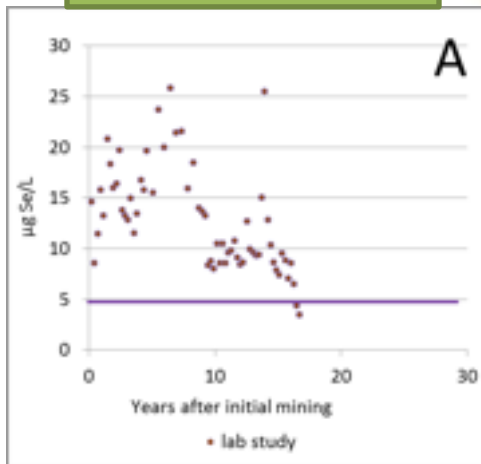# About half of the outlets fall below 5 μg Se/L within 30 years
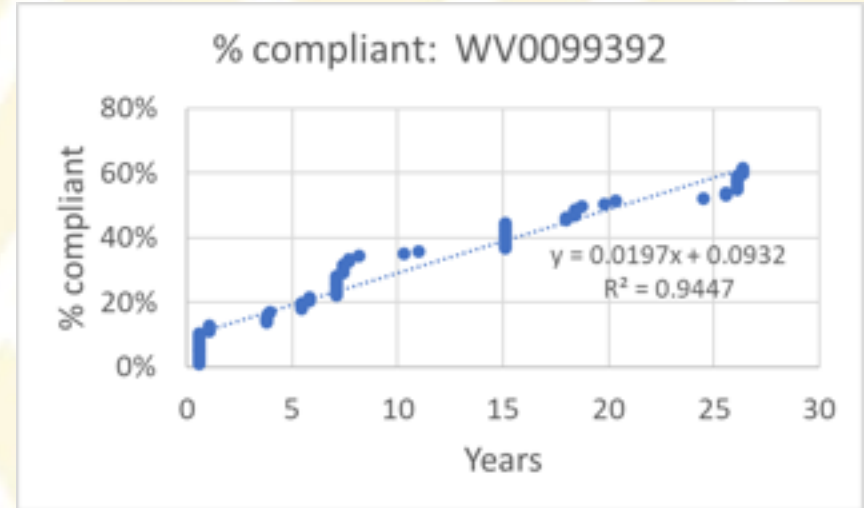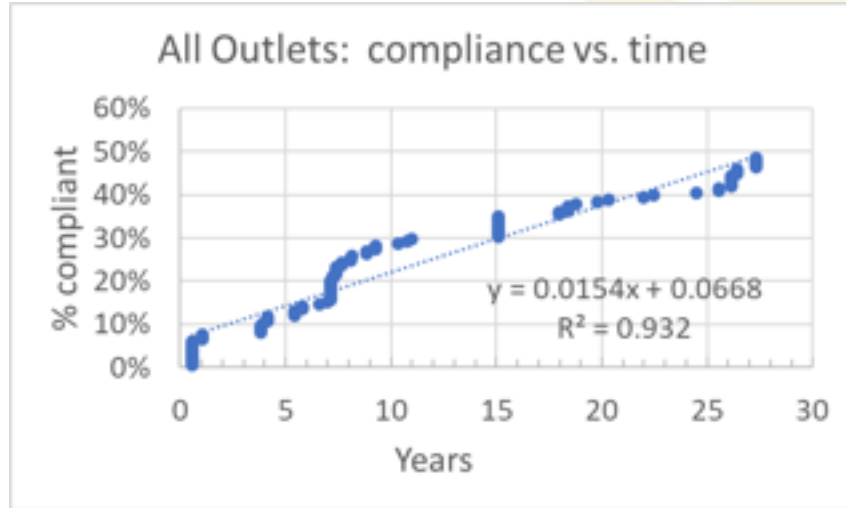
# All outlets should fall below 5 µg Se/L within 45-60 years
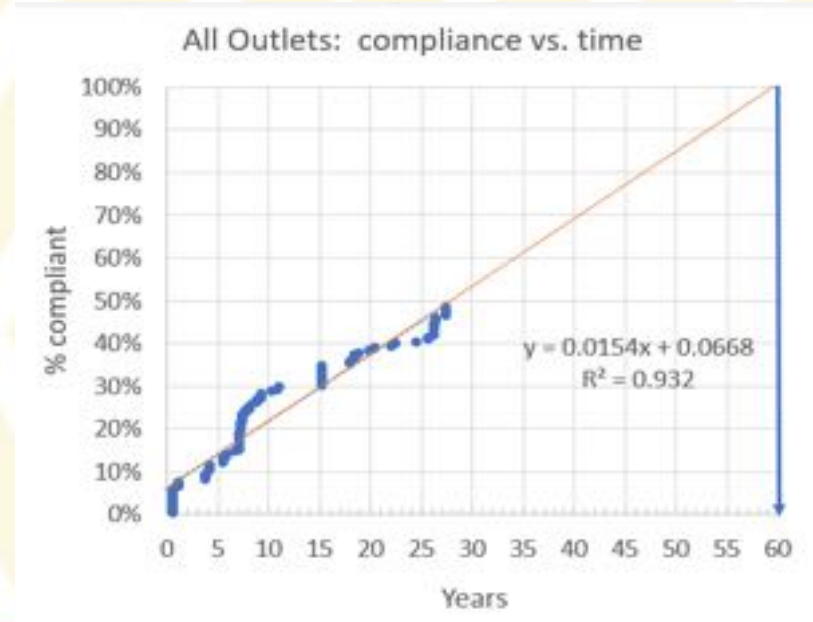
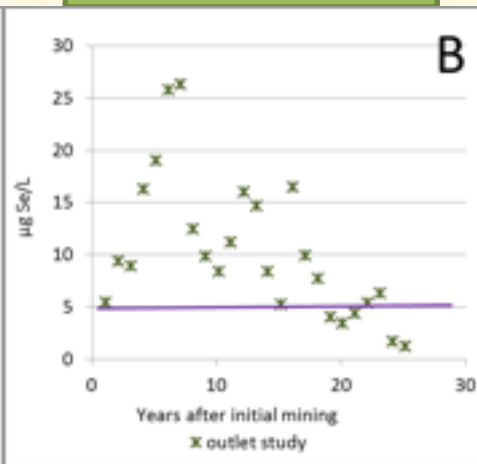# Rapid selenium attenuation explains why the three curves below look similar:
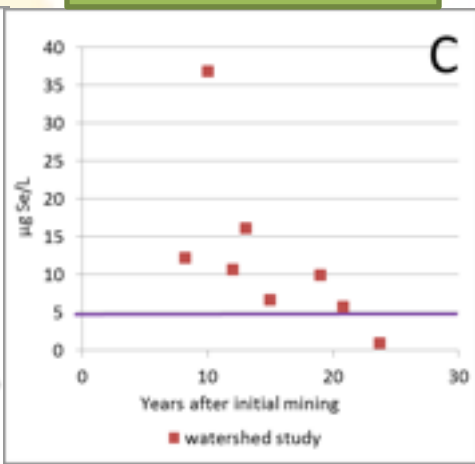## Se is not cumulative in CAPP mining



*Adjusted to estimate field concentrations

# QUESTIONS?

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