Important Improvements in Groundwater Quality and Quantity Resulting from Hydraulic Adit Plug Closure Method Glengarry Adit New World District, Montana.

Mine Design, Operations and Closure Conference
May 2, 2012

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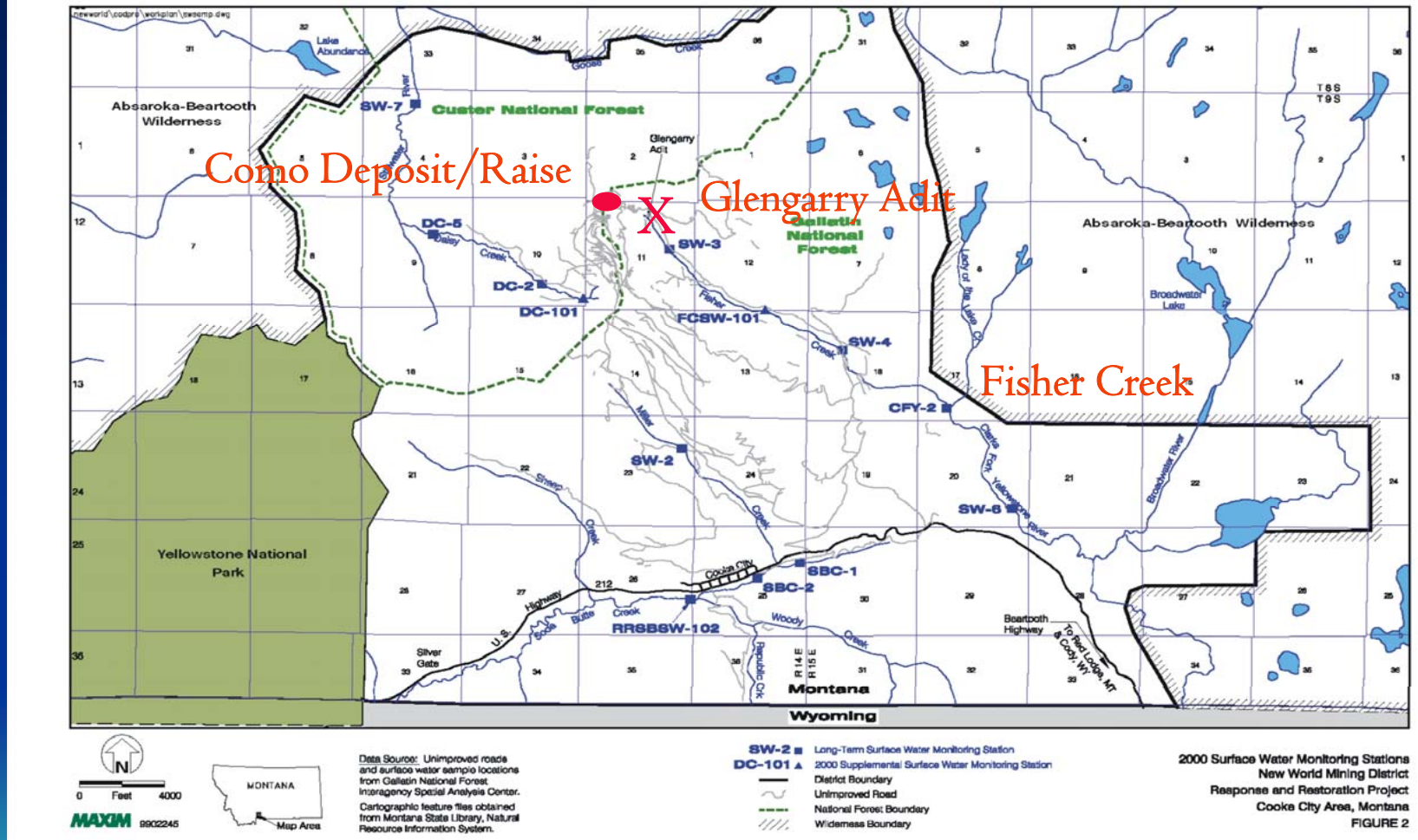
Mary Beth Marks, USFS, Bozeman, MT

The New World District



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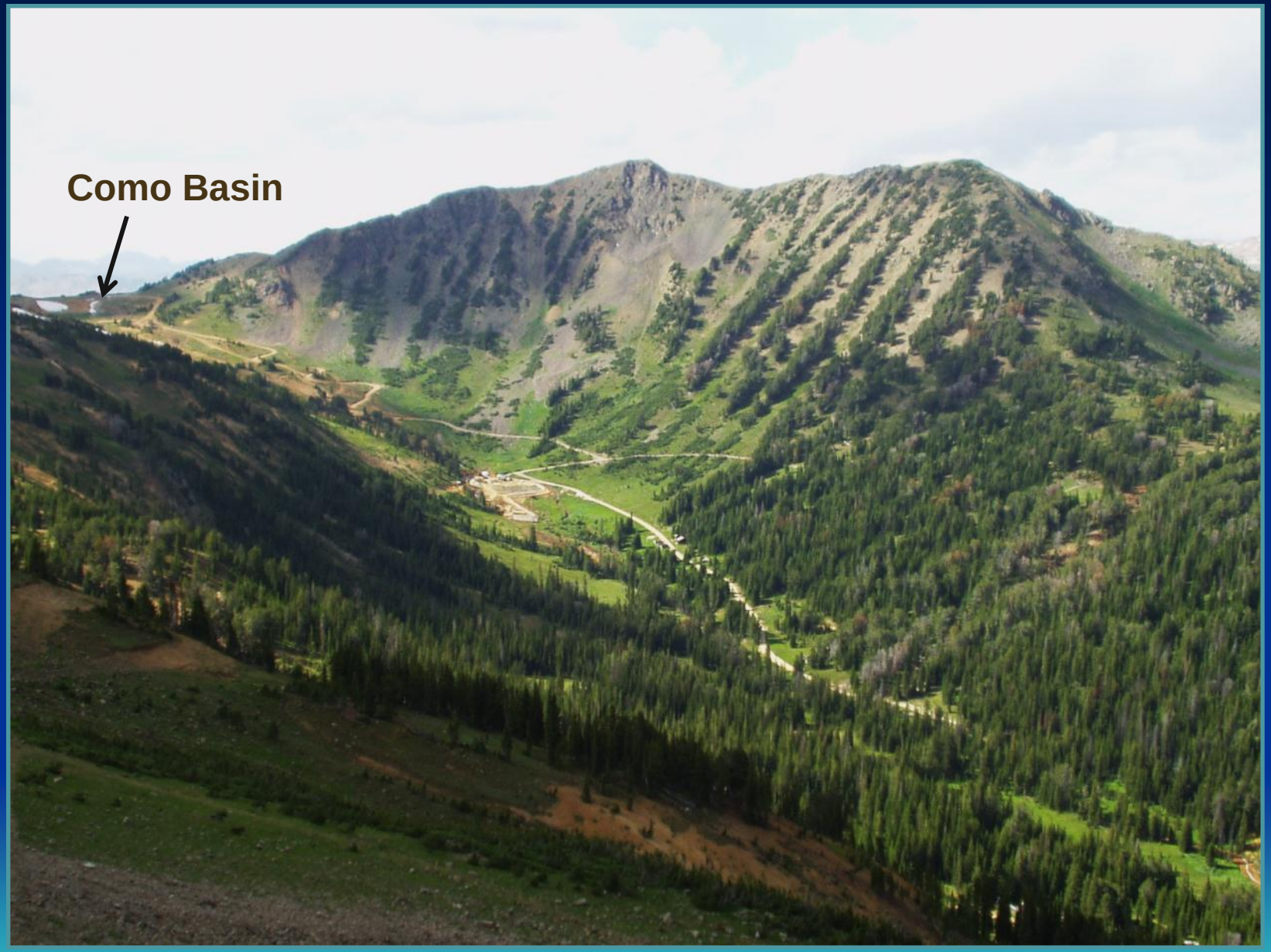
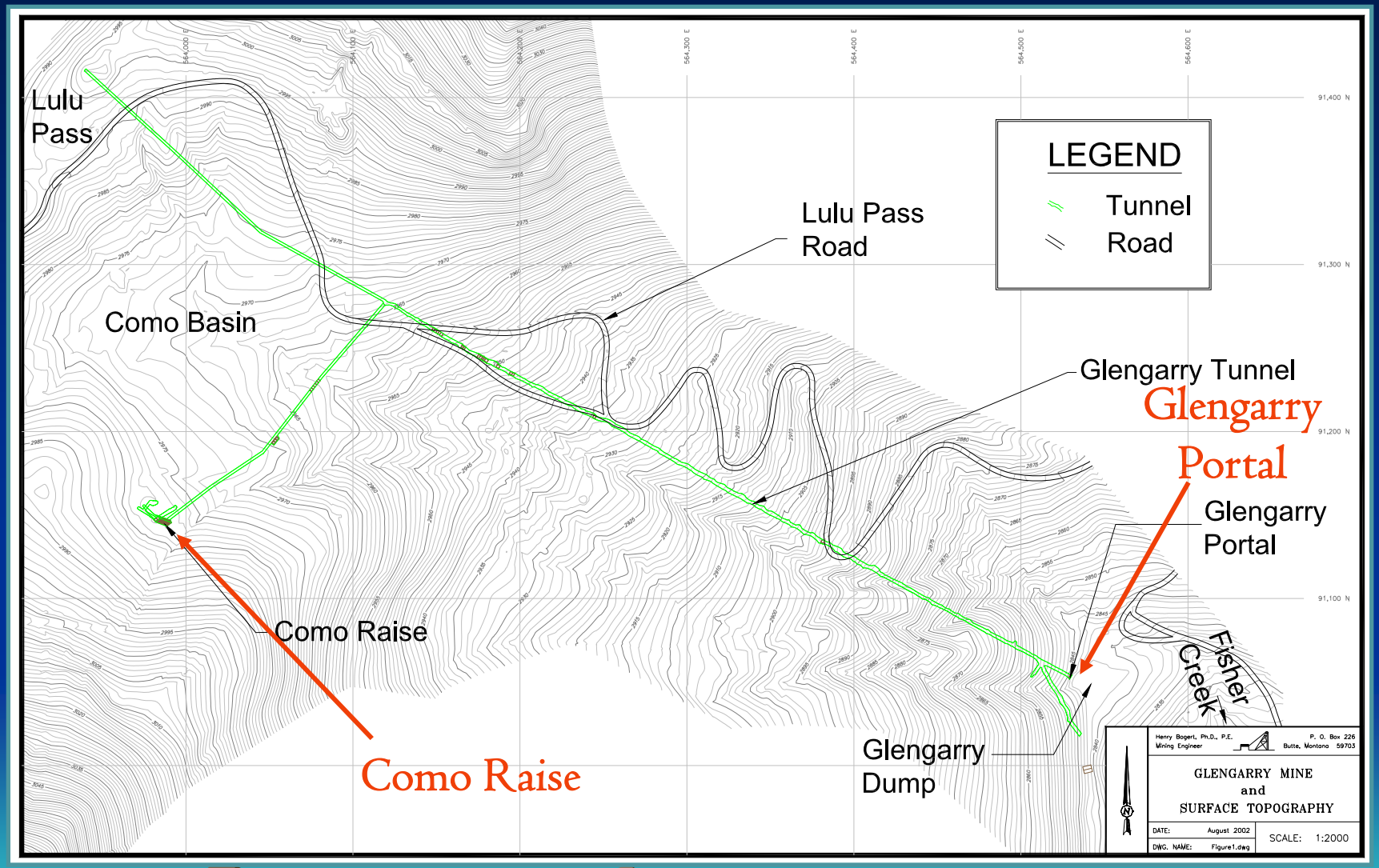
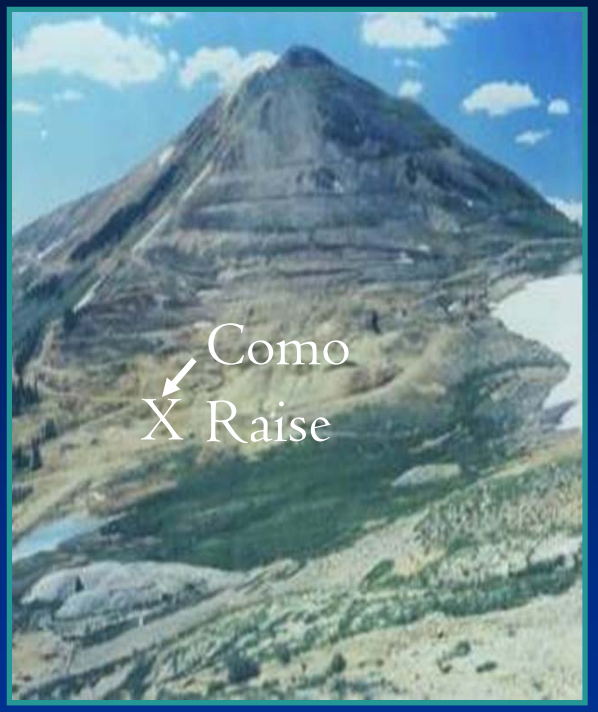

Como Basin

Plan Map Glengarry Mine



Como/Glengarry



Glengarry Mine

- 3,200 feet of underground workings, with raise to surface in the Como Basin

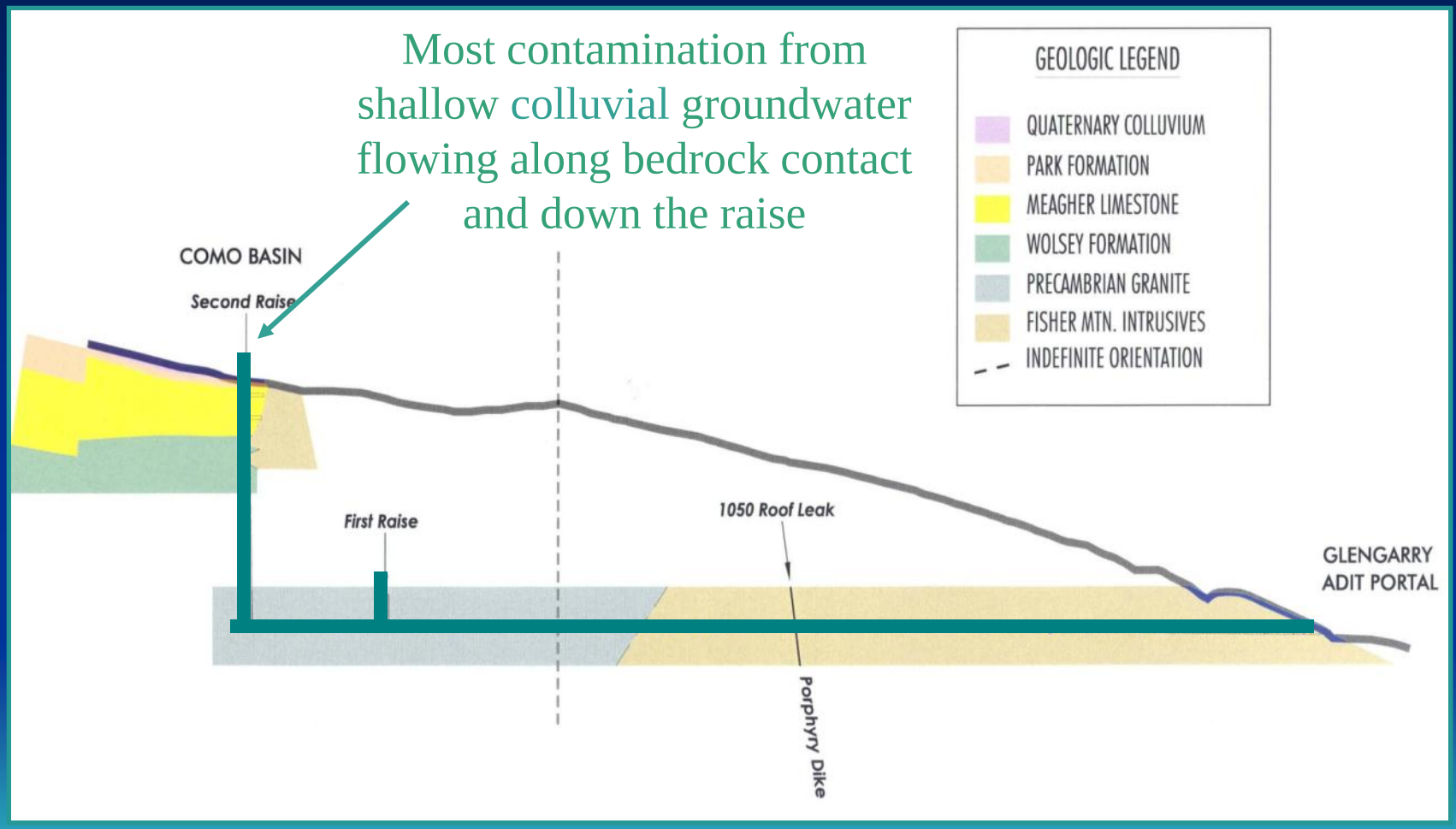
Como Basin

- 950,000 tons massive sulfide (30-80% pyrite) in ore and soils at the surface, covering 5.5 acres

Major Problems

- Portal discharge to headwaters of Fisher Creek
- Poor surface and groundwater quality

Como Raise-Glengarry Mine



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Glengarry Adit Portal

Water Quality

pH = 2.2

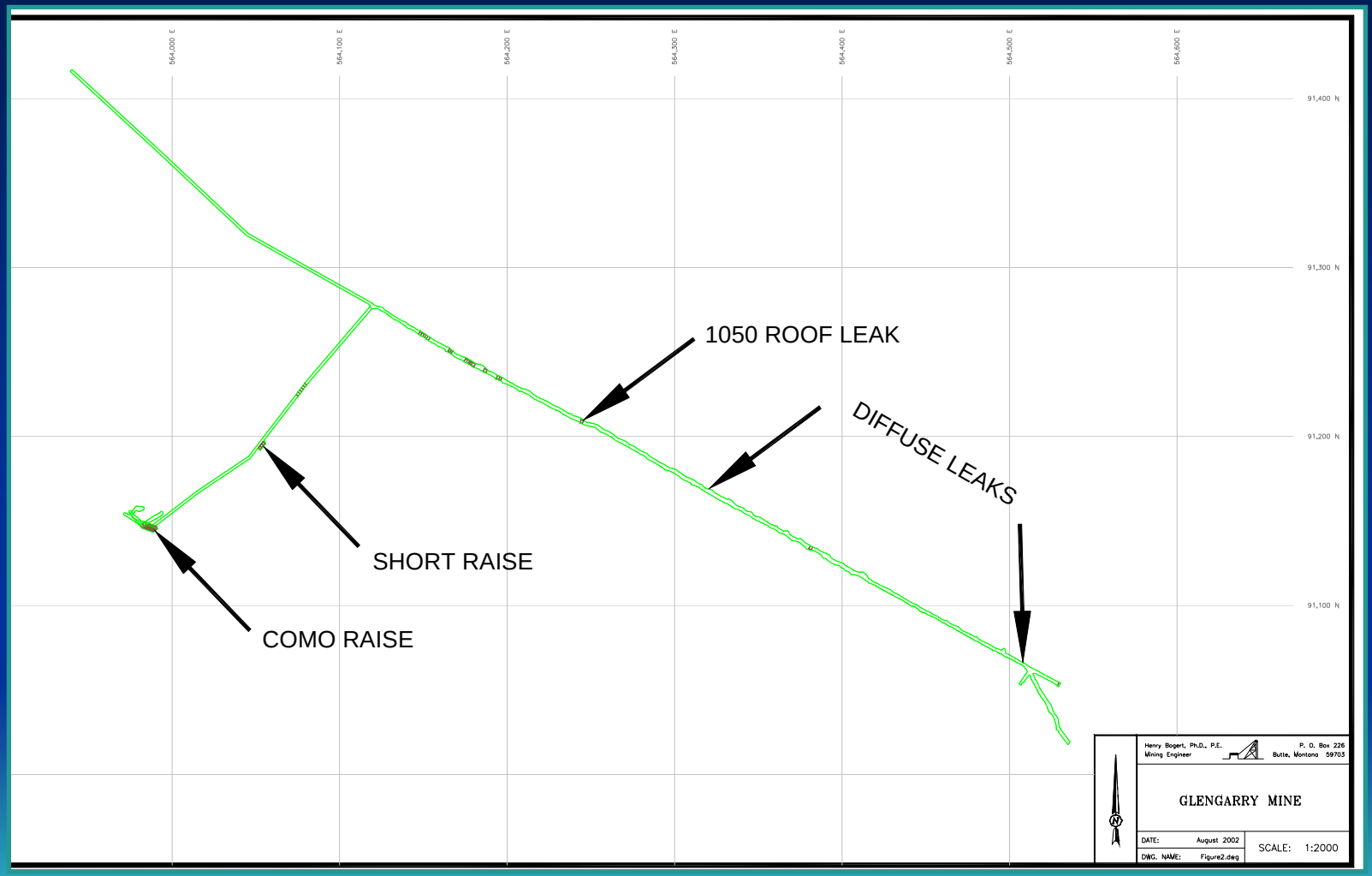
Cu = 6.9 ppm

Std. = 0.009 ppm

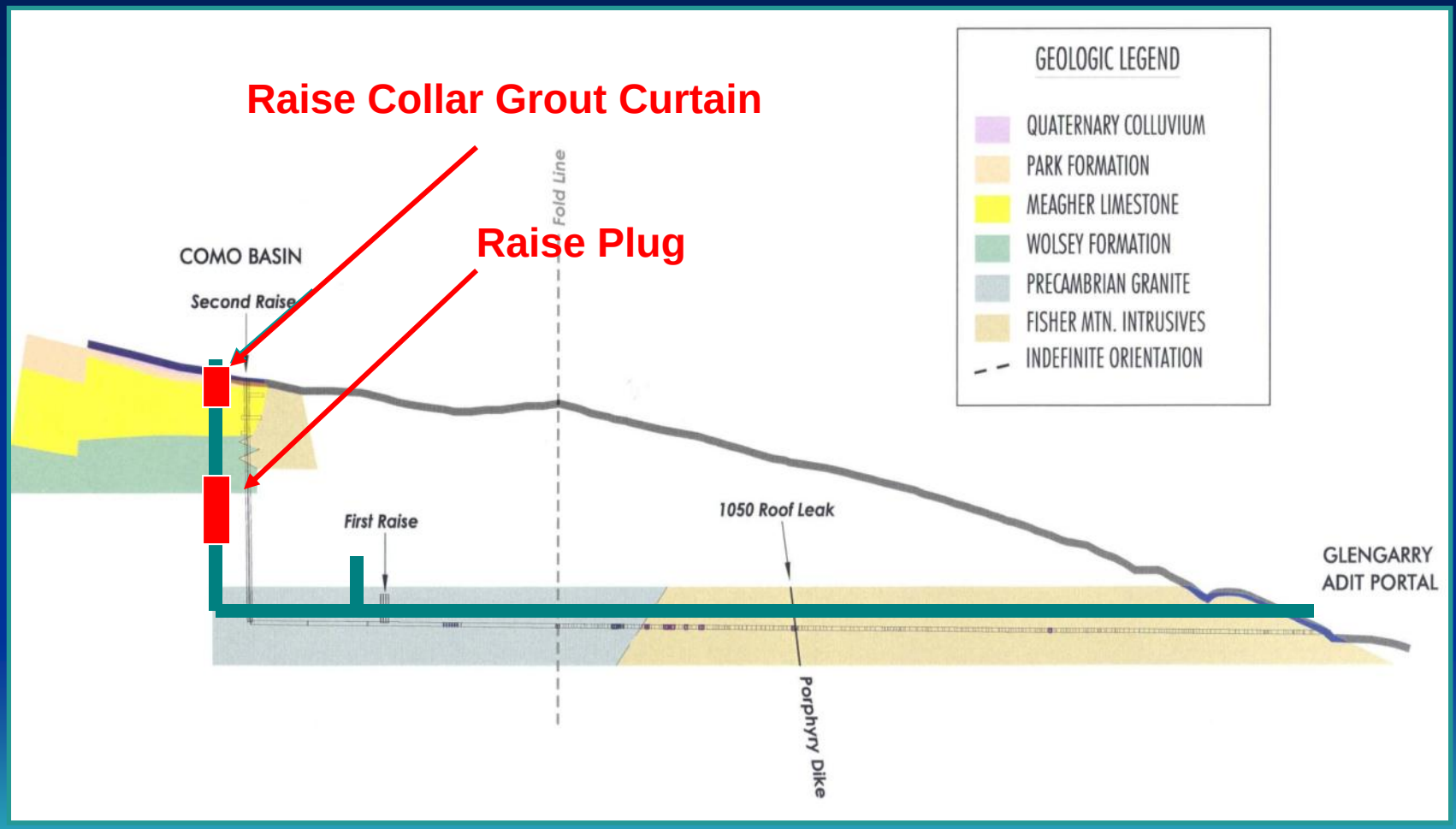
Fe = 77.6 ppm

Std. = 0.3 ppm

Four Major Water Sources Glengarry Mine



Como Raise Closure



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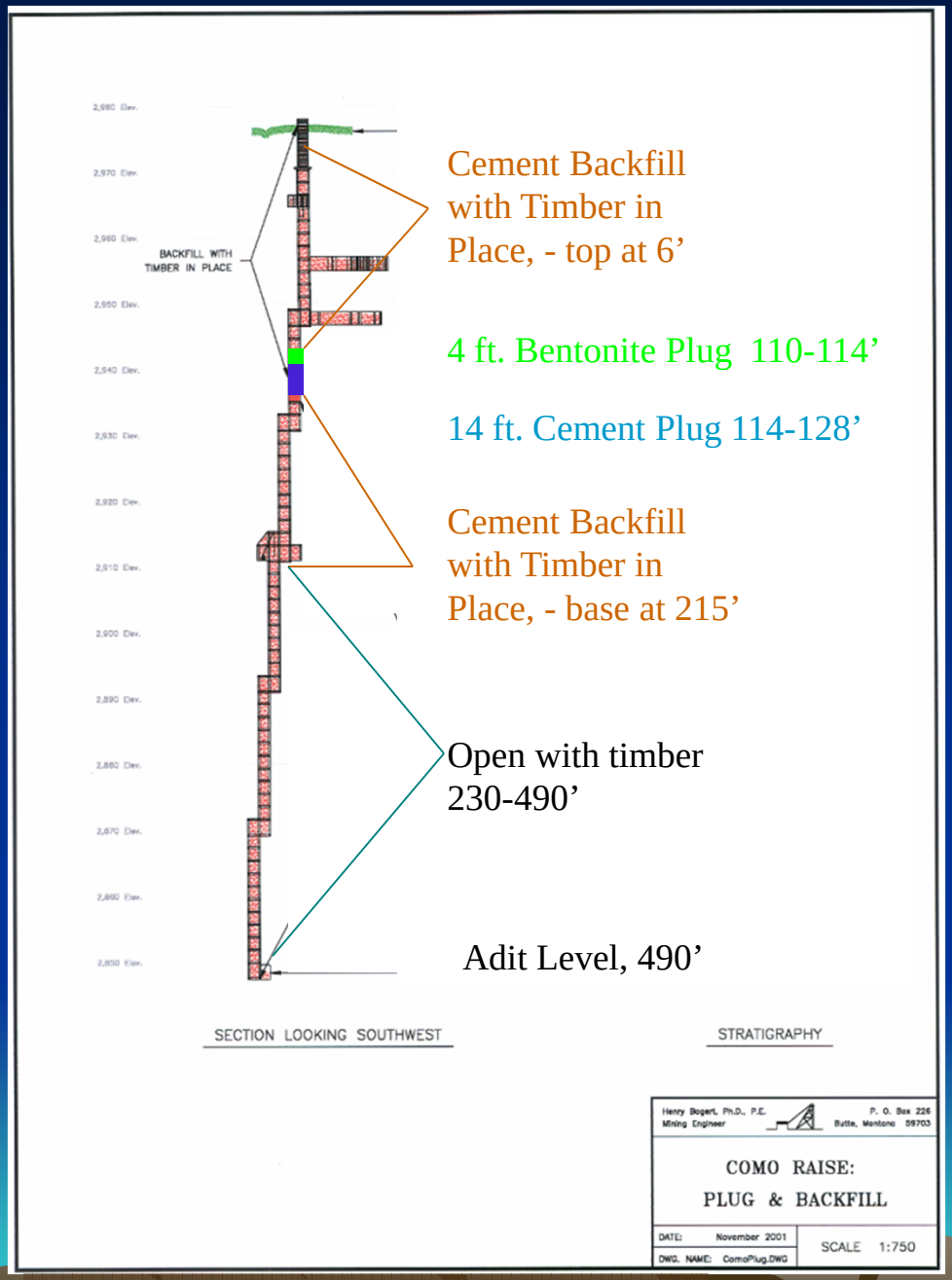


"As Built"

Como Raise

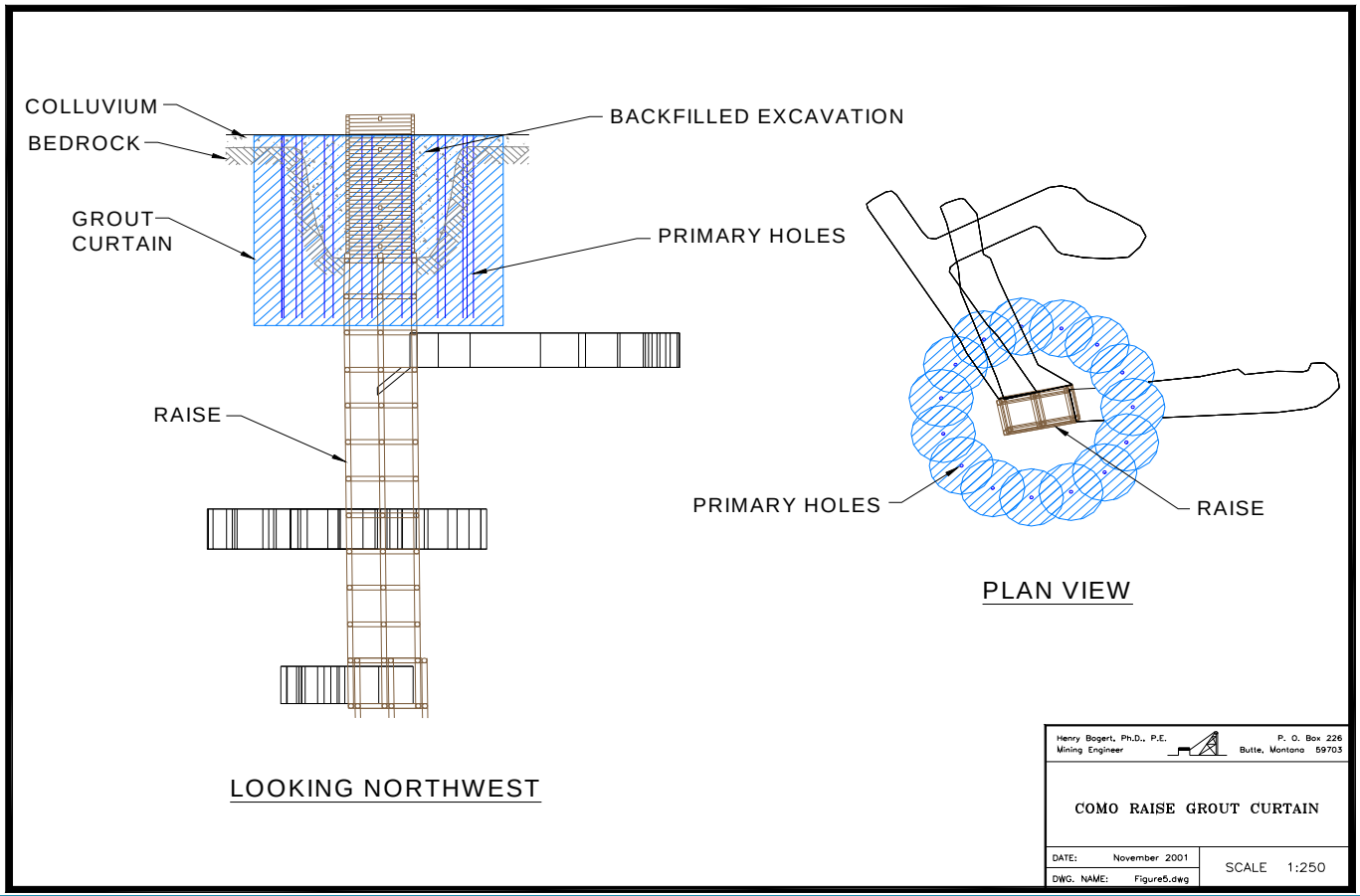
Watertight Plug

And

Backfill

No Time for –
Portal Pad Construction

No Time for – Como Raise Grout Curtain



Primary and Secondary Holes for Shallow and Deep Bedrock Grouting

Cement Batch Plant

Como Raise Watertight Plug Interval

Rock Bolt Pinned / I-beam Braced Timber Sets

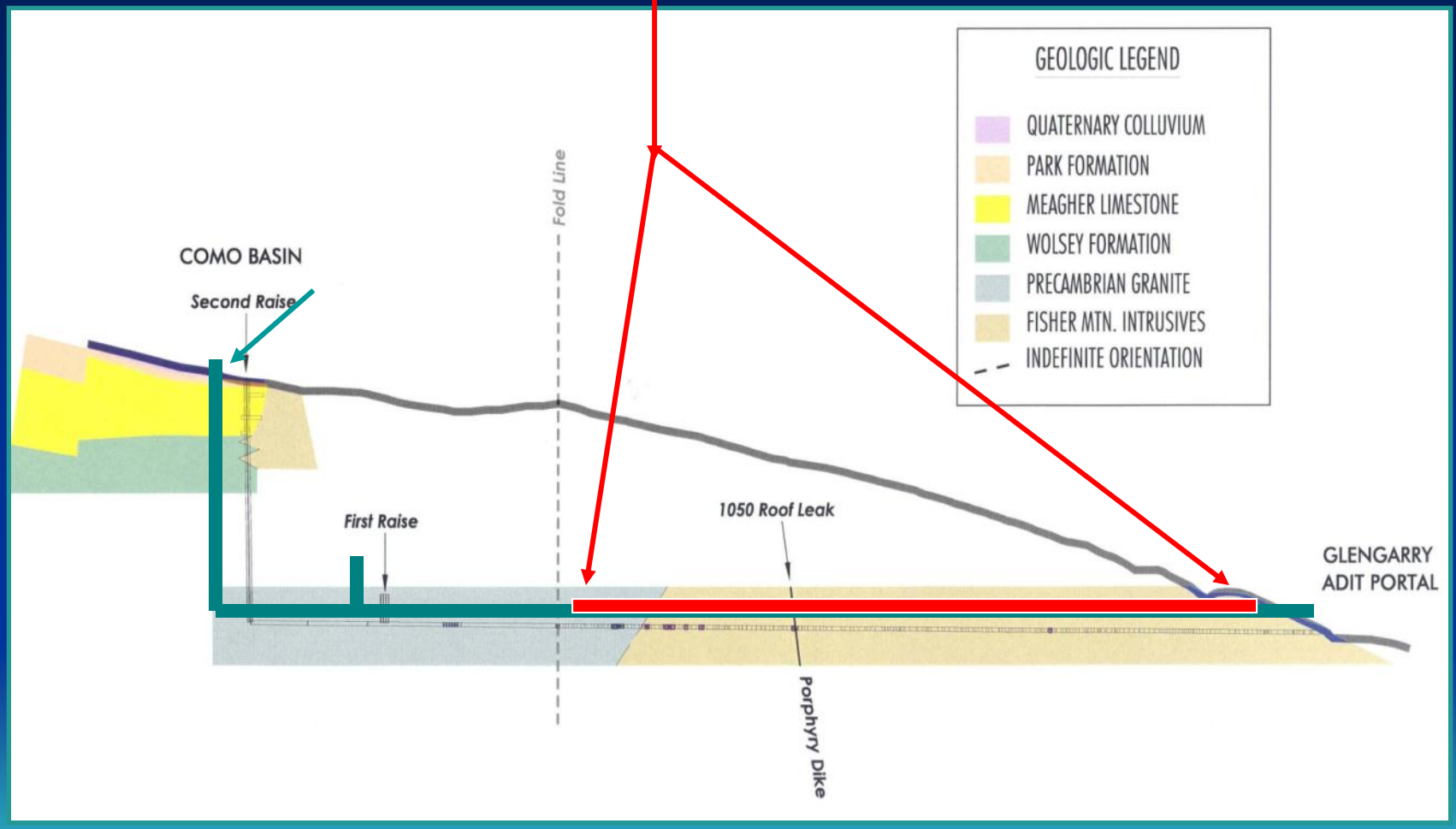
Interval stripped of timber for watertight plug (18')

1066- Conqueror Fault

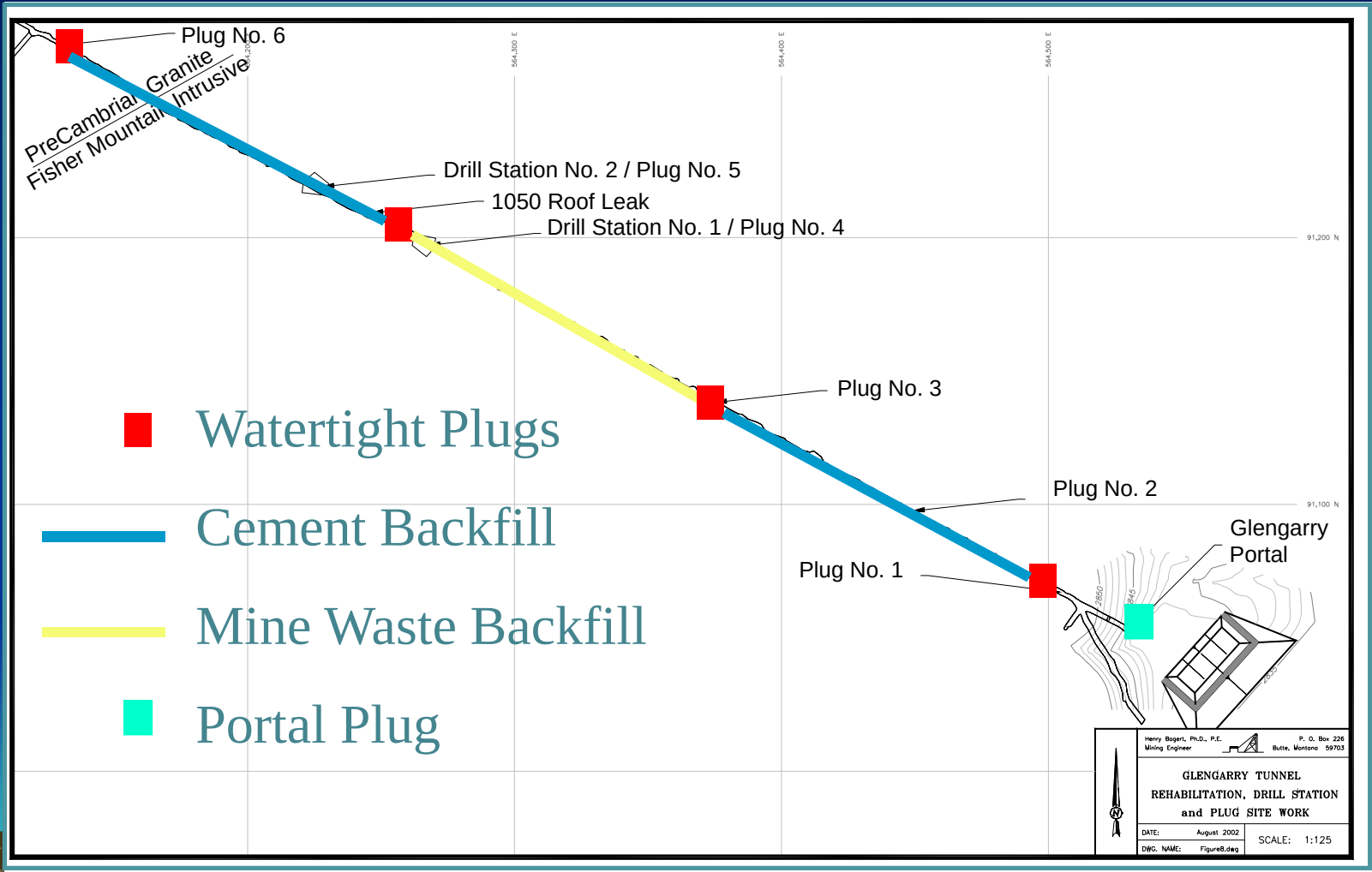
Underground Grouting

Certainly No Time for Explaining The Shear Thrill of Grouting

Adit Plugs and Backfill



Glengarry Adit
Watertight Plugs and Backfill



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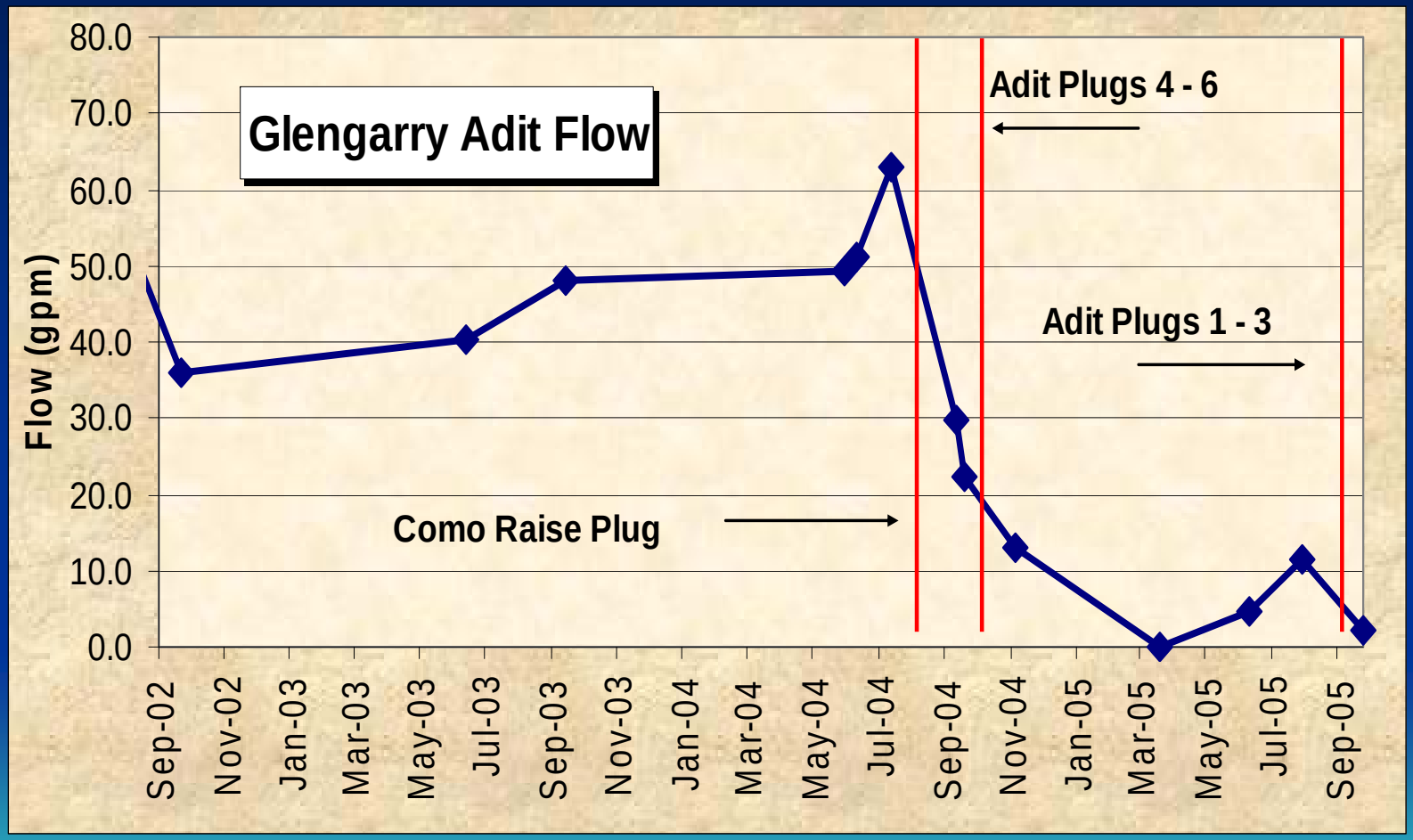
Water Tight Hydraulic Plug #1

Note Grout in Fractures Outboard of Plug

Resulting Reduction in Flow and Metal Concentration from the Adit

Reduction in Flow from the Adit

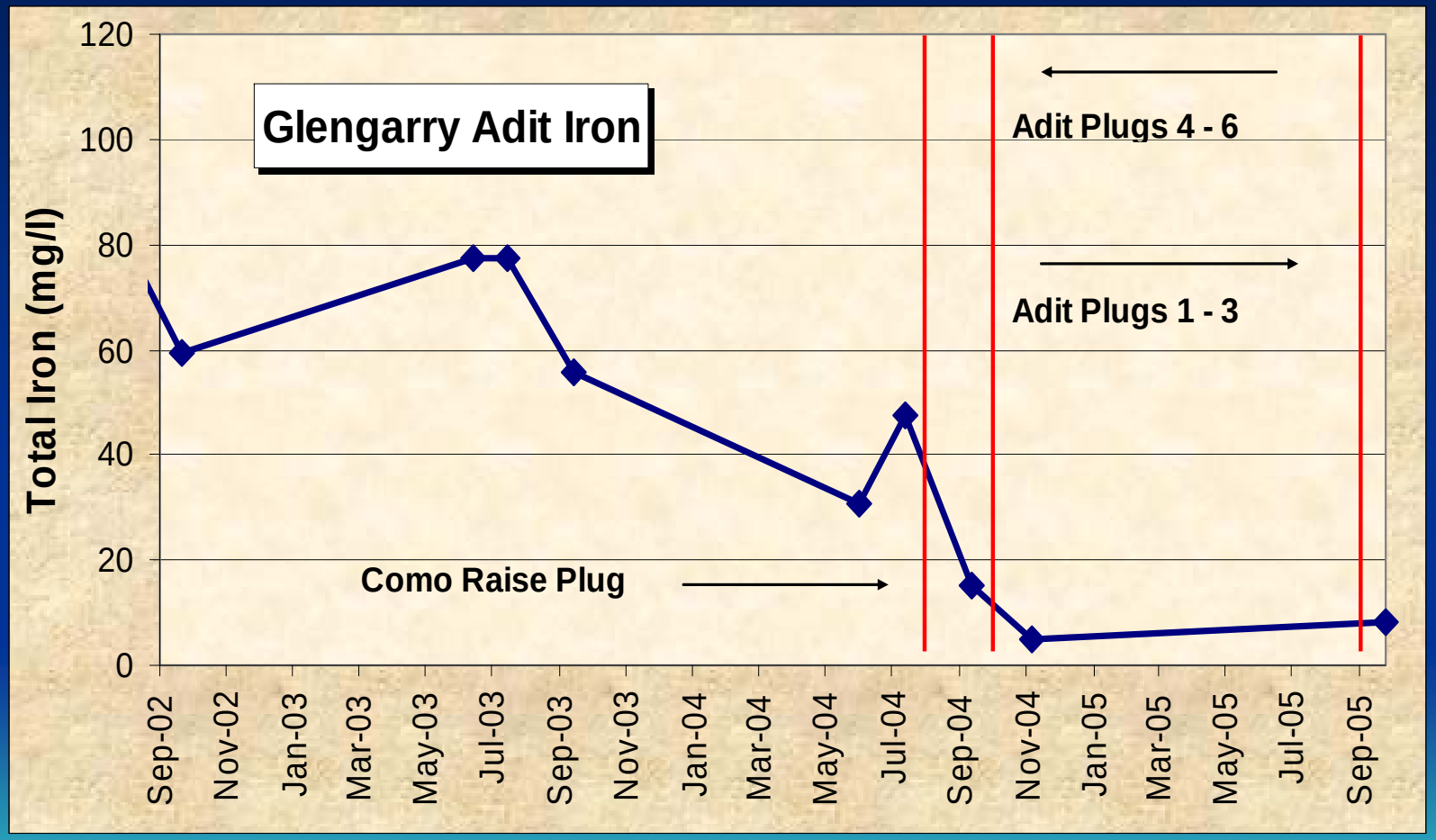
From 38 to 0.5 gpm



Historical flows
5 to 245 gpm

Reduction in Iron Concentration

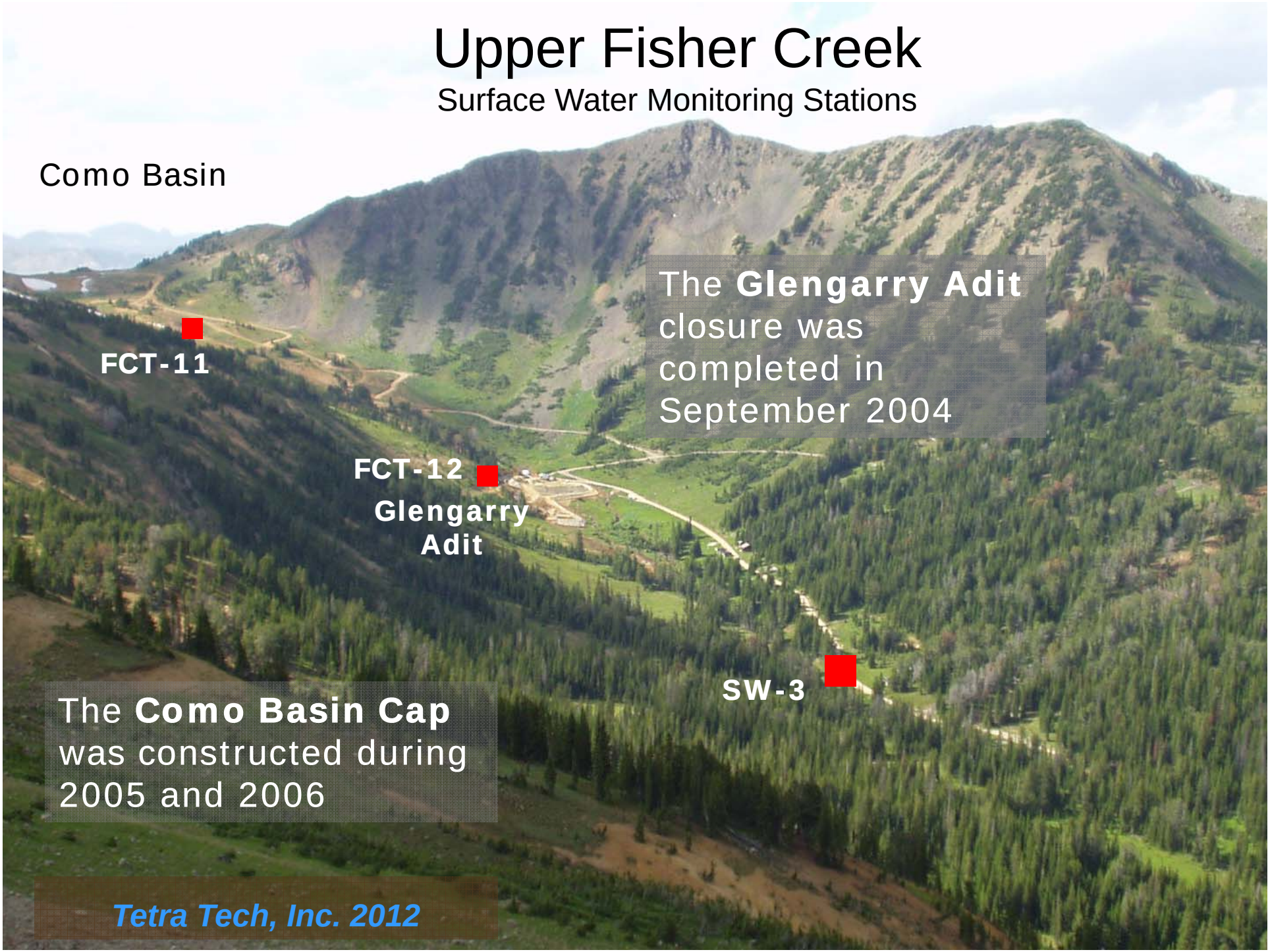
From 77.6 to 5.1 ppm



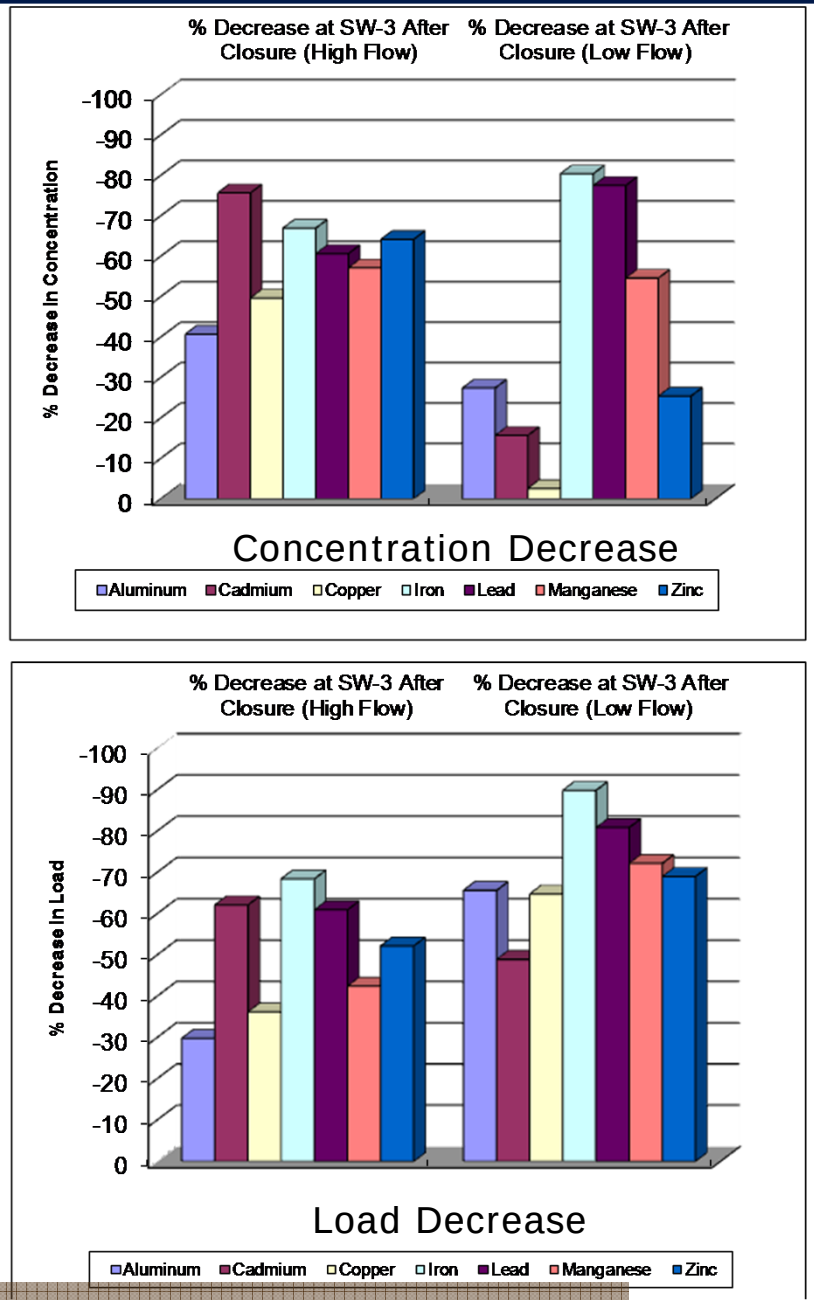
Impacts to Down-gradient Surface Water

Upper Fisher Creek

Surface Water Monitoring Stations



Surface Water Station SW-3



Post Glengarry Adit Closure (2005 – 2011)

Average decrease in metal concentrations:

High Flow – 59%
Low Flow – 41%

Average decrease in metal loads:

High Flow – 50%
Low Flow – 70%

Impacts to Groundwater Quantity

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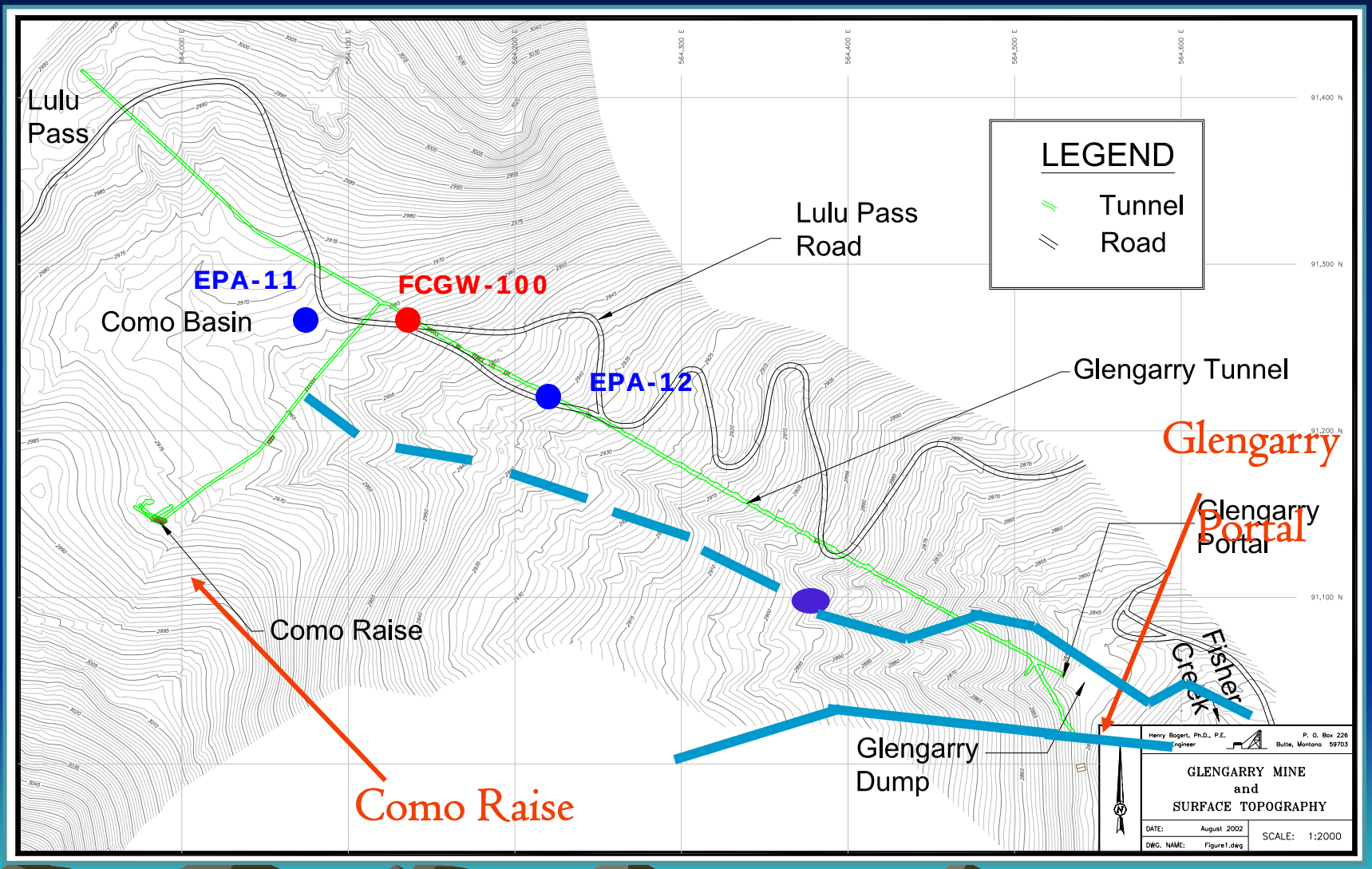
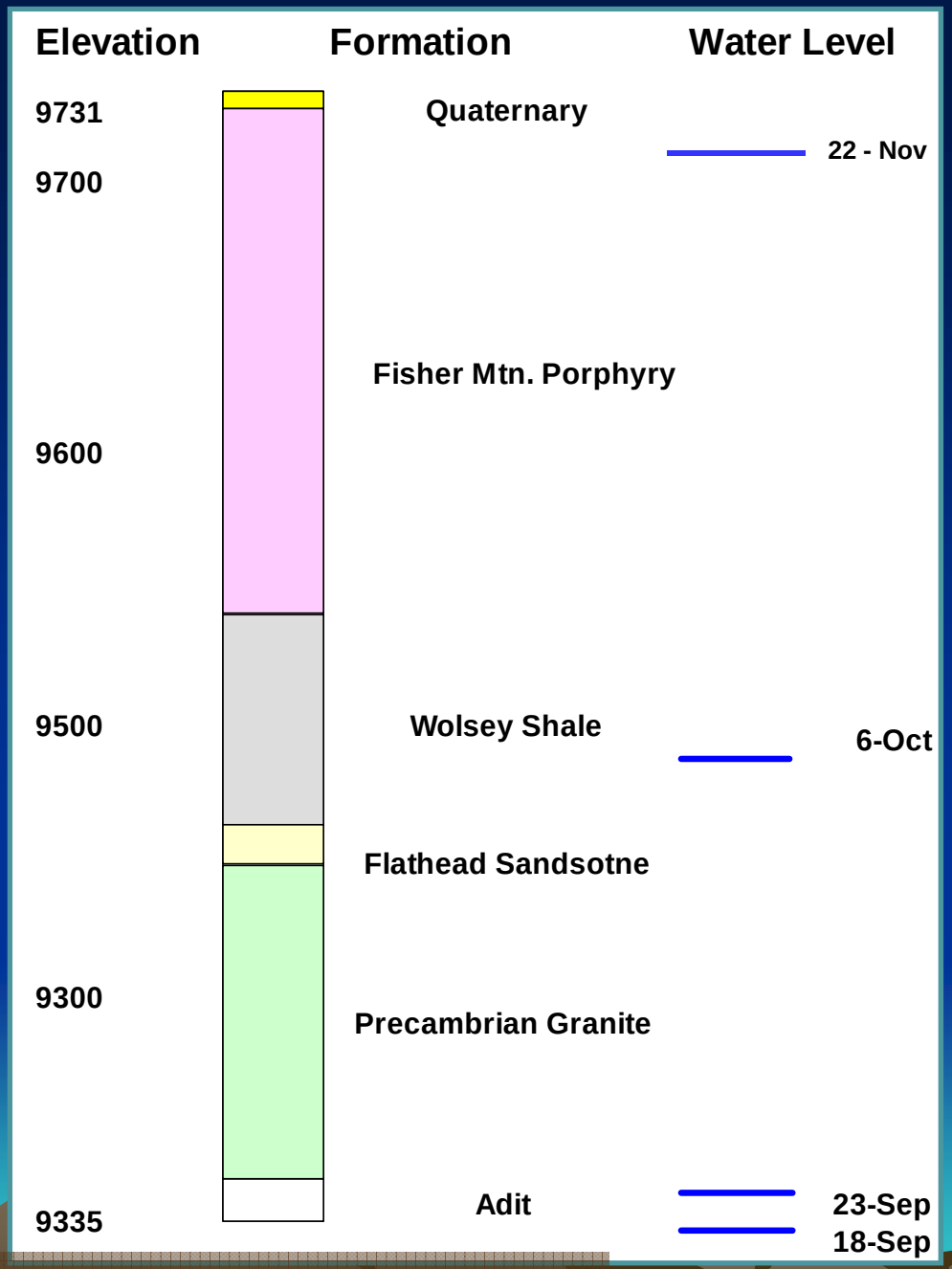
Location of Glengarry Monitor Well (FCGW-100)



Glengarry Adit

Monitor Well FCGW-100 Completed in Underground workings

20’ Stainless Steel Screen



Elevated Groundwater

FCGW-100

Monitor Well Completed in Underground Workings

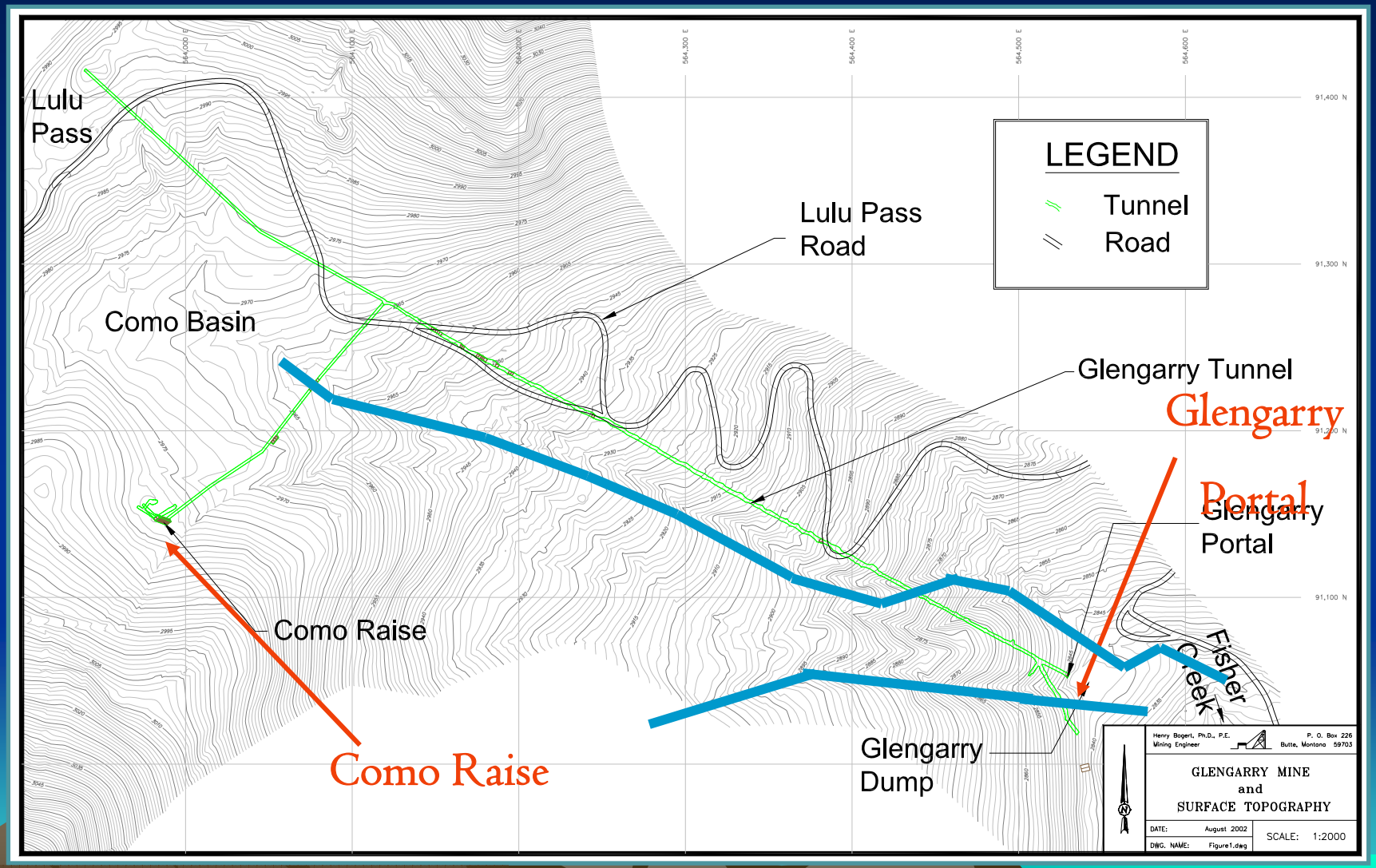
Head raised 400 feet in 60 days

Glengarry Adit Flow

- Average flow 38 gpm
  - 2,600 foot long, 7 feet diameter hole through mountain
    - Only capable of generating average flow of 38 gpm
  - No true porous aquifers
    - Fracture controlled porosity and permeability
  - Raise the head of groundwater 400 feet in 60 days
    - Fracture system low storage capacity, and/or
    - Interconnectivity of fracture systems are low

Rising Groundwater

FCT-11 and 12 Ephemeral to Perennial Flow?



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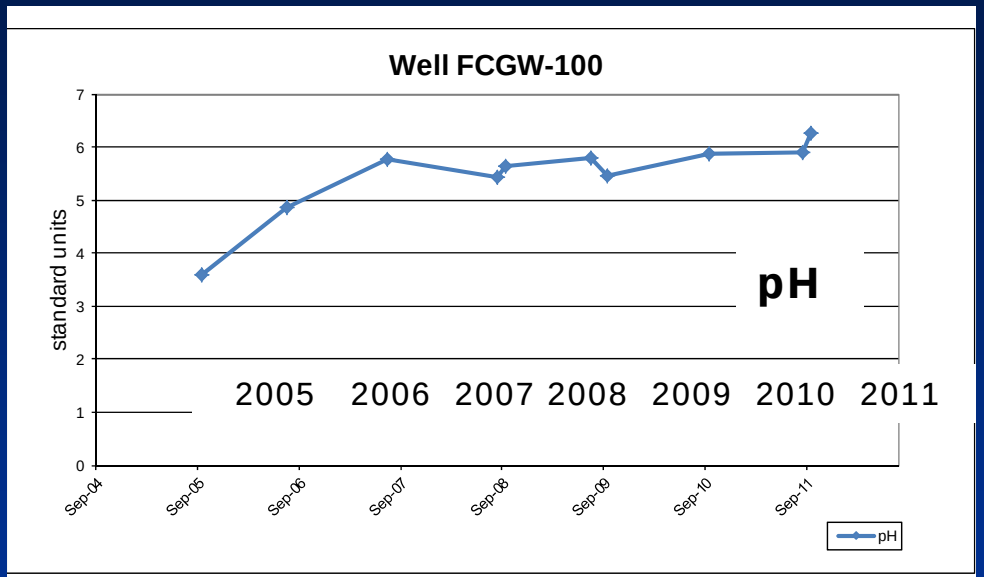
Upper Fisher Creek – Como Basin

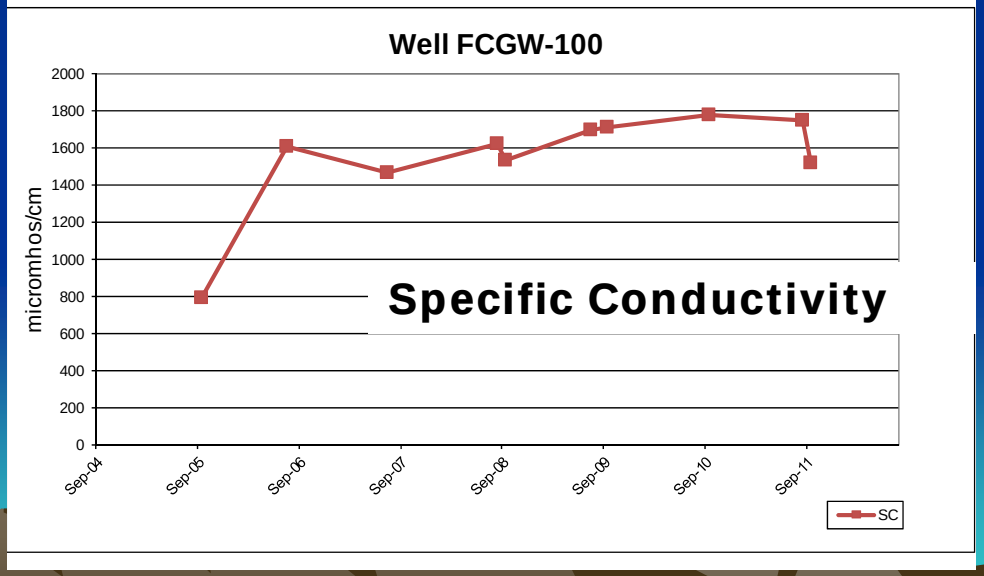
Anticipated Groundwater Changes with rise in water level

- O_2 recharge by diffusion would be very low
- Oxidation of sulfides would consume available oxygen
- Reduced groundwater conditions would be established
- Sulfide oxidation would cease, eliminating production of acid
- pH would rise by dilution with adjacent GW
- Increase in pH would decrease solubility and mobility of base metals
- Increased solubility of Fe

Observed Water Quality Changes from Ground Water Wells

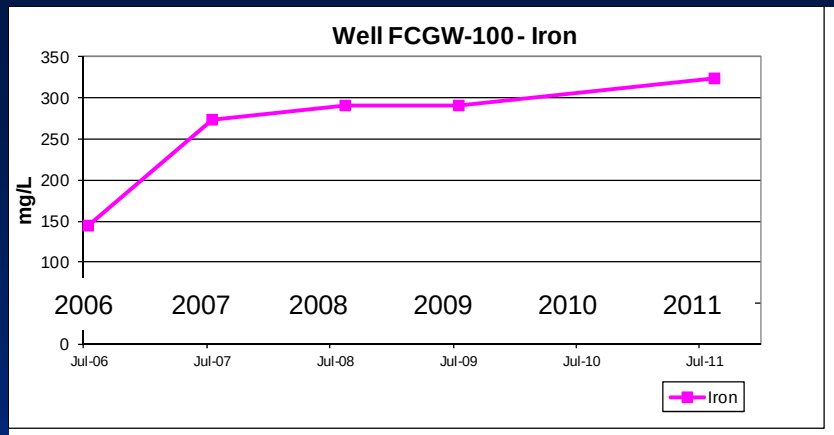
Fisher Creek – Well FCGW-100

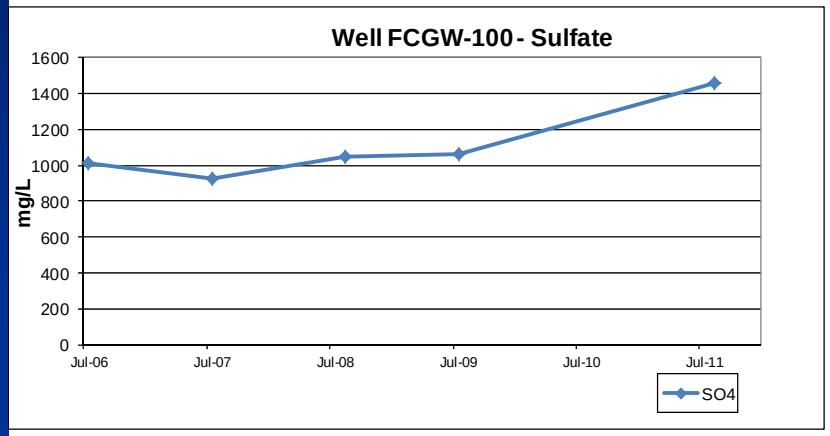


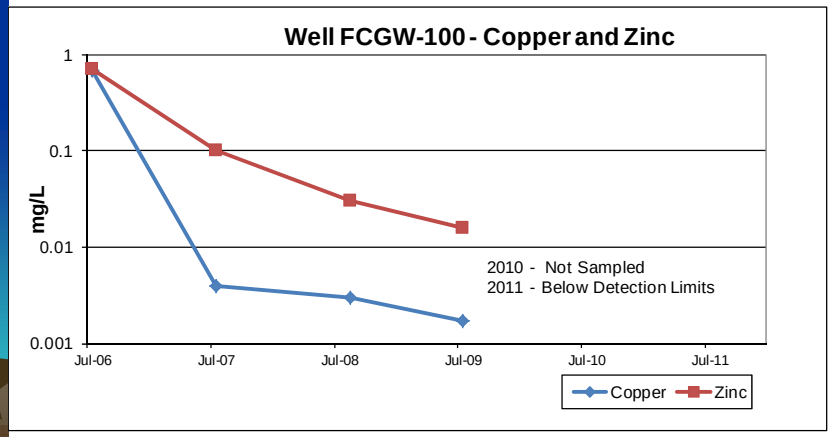


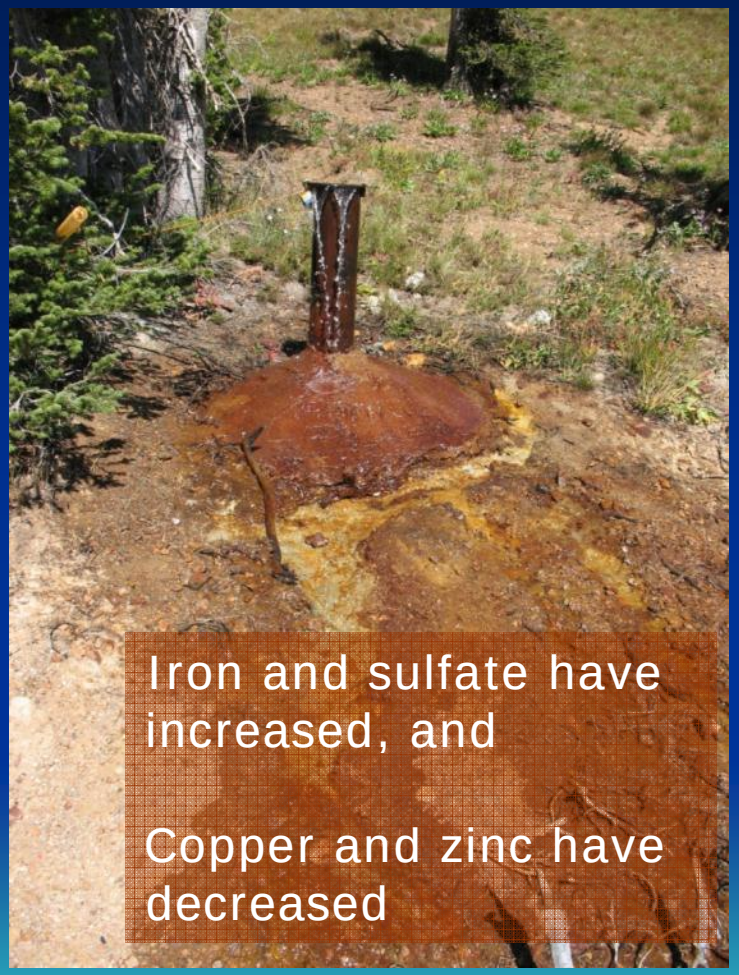
Since monitoring was initiated in 2005, pH and specific conductivity has increased

Fisher Creek Well FCGW-100

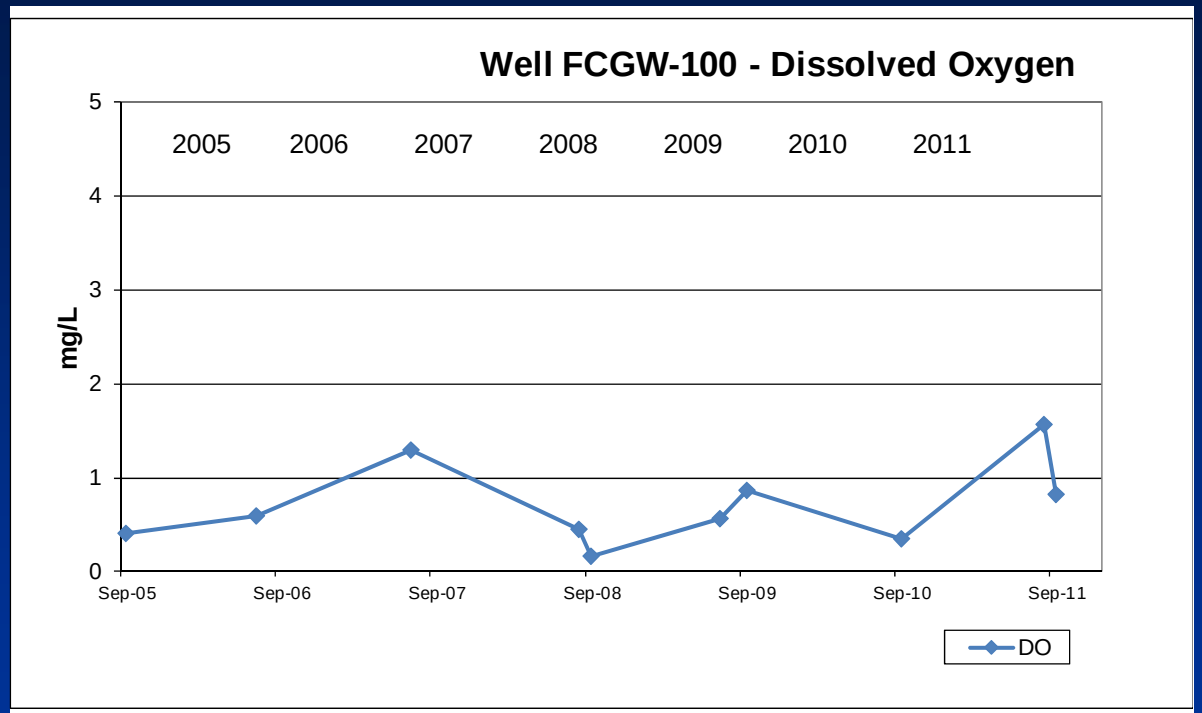


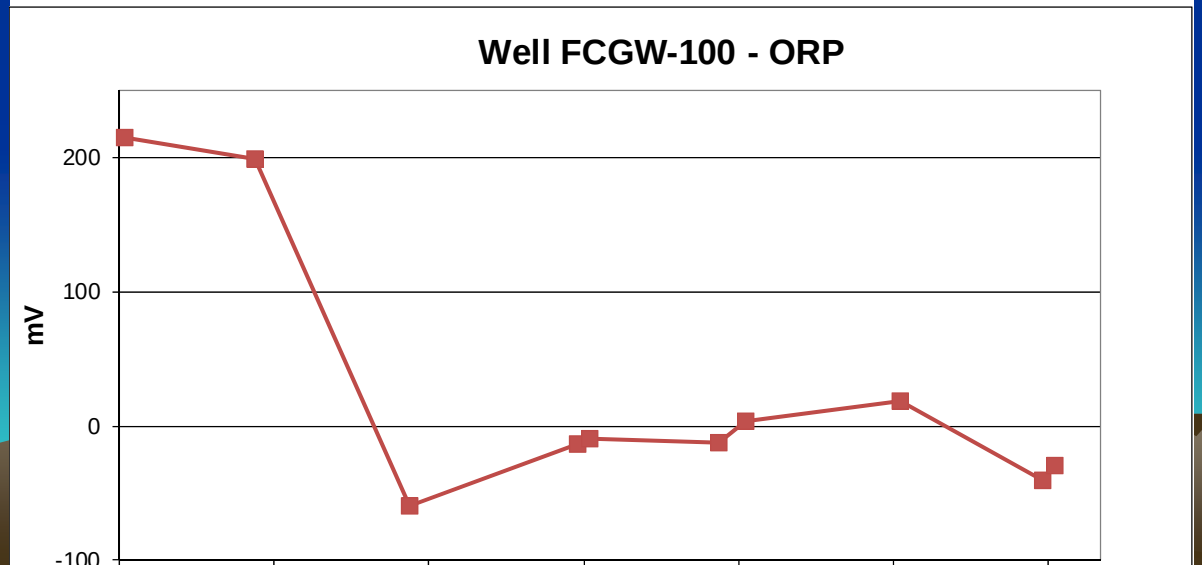




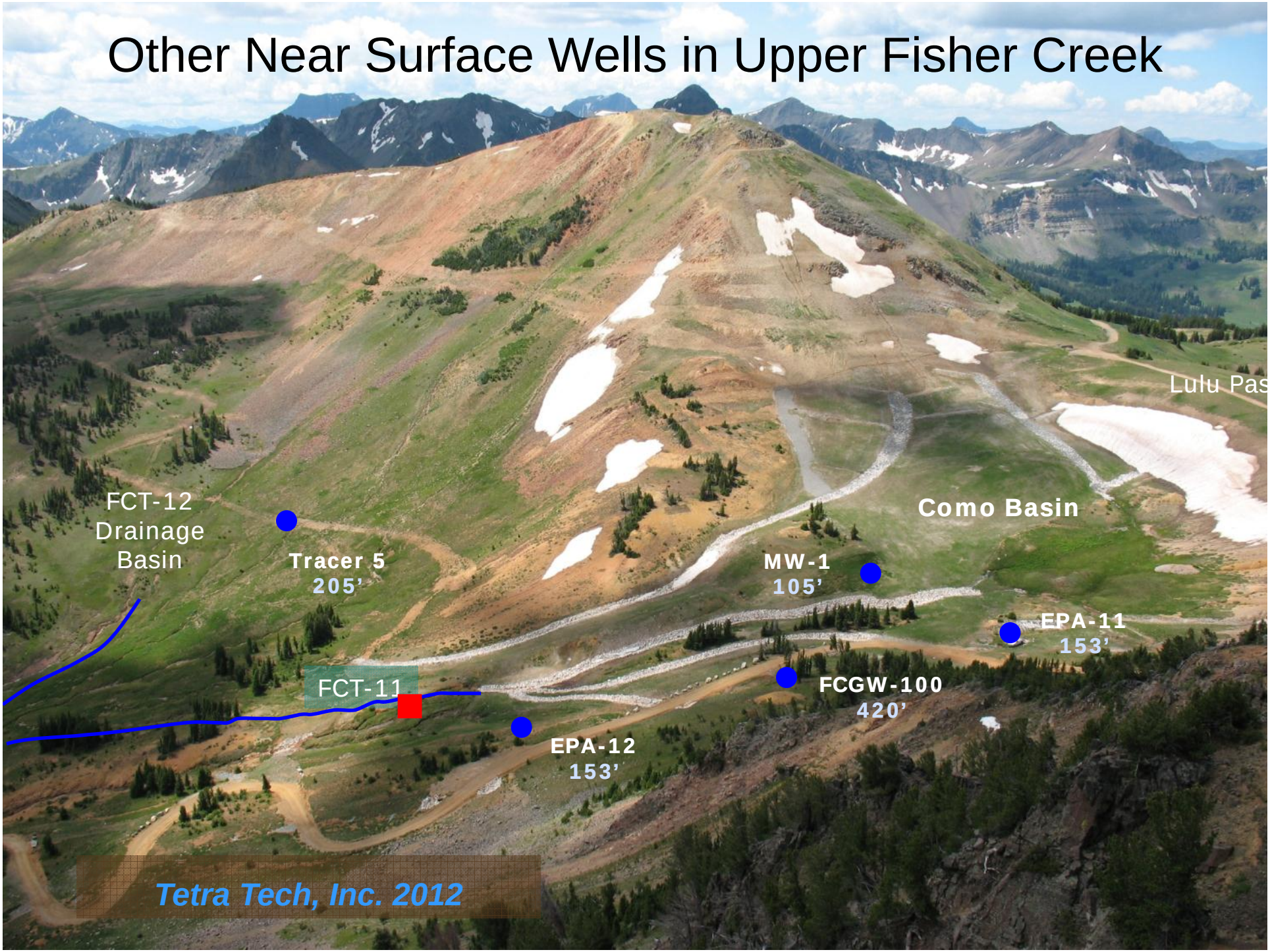


Fisher Creek – Well FCGW-100 DO and ORP

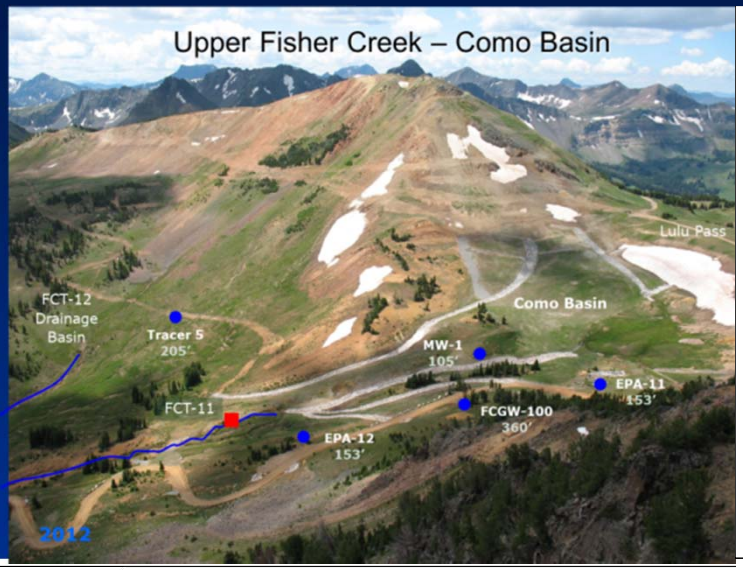


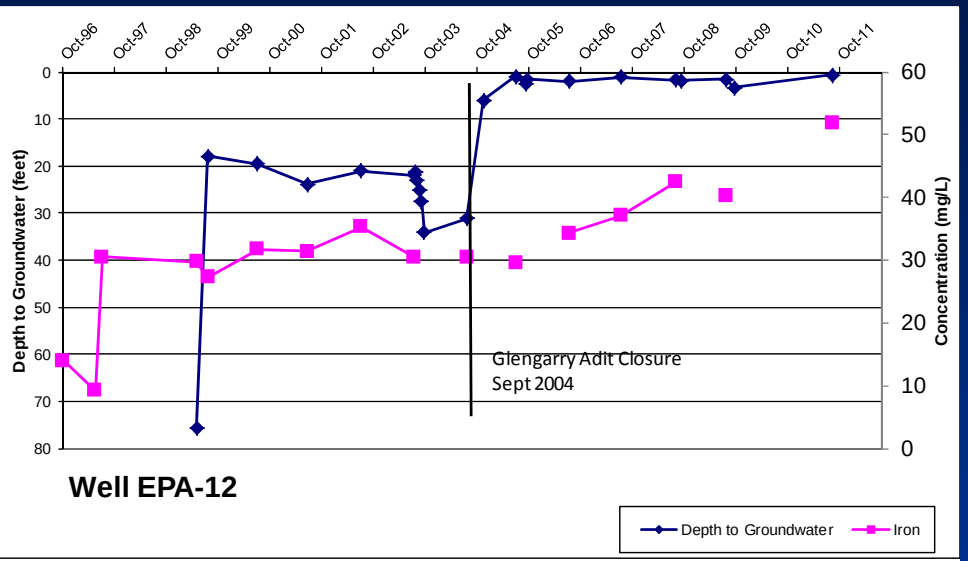


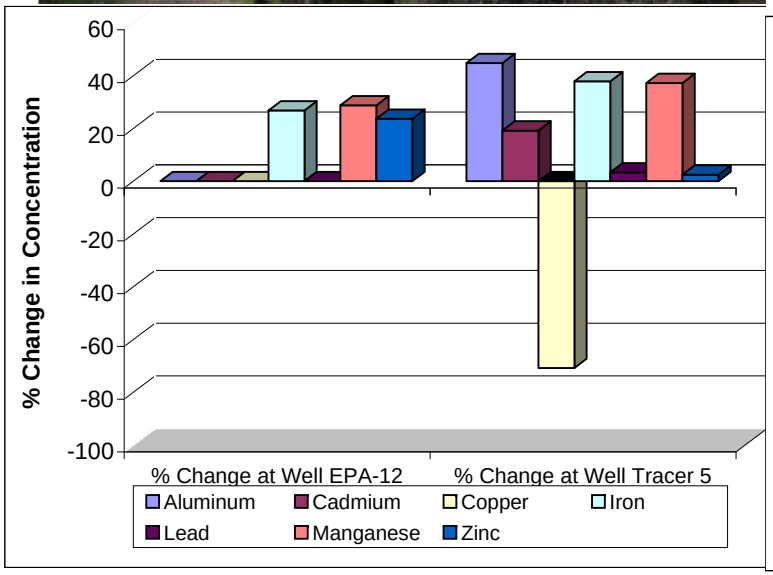
Other Near Surface Wells in Upper Fisher Creek

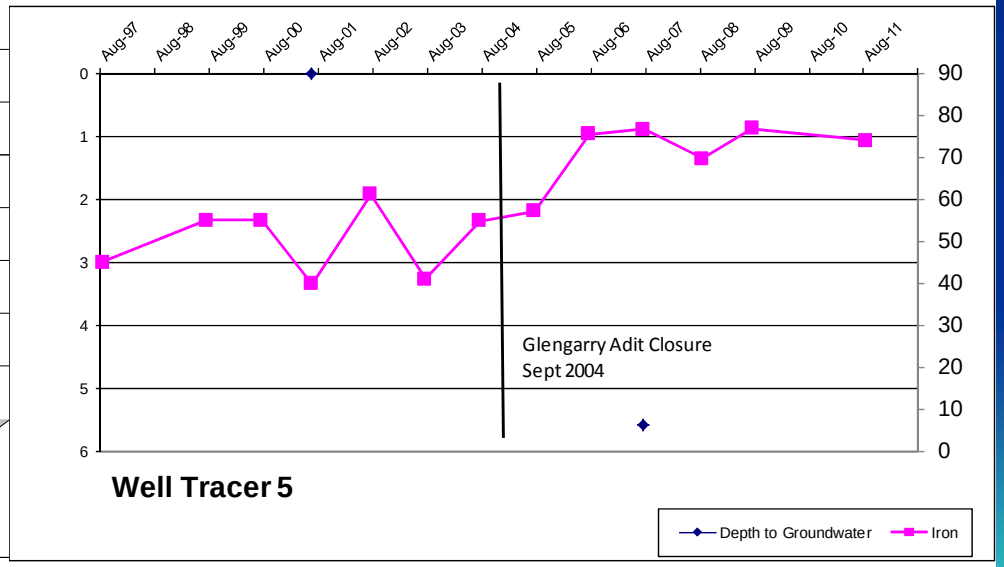


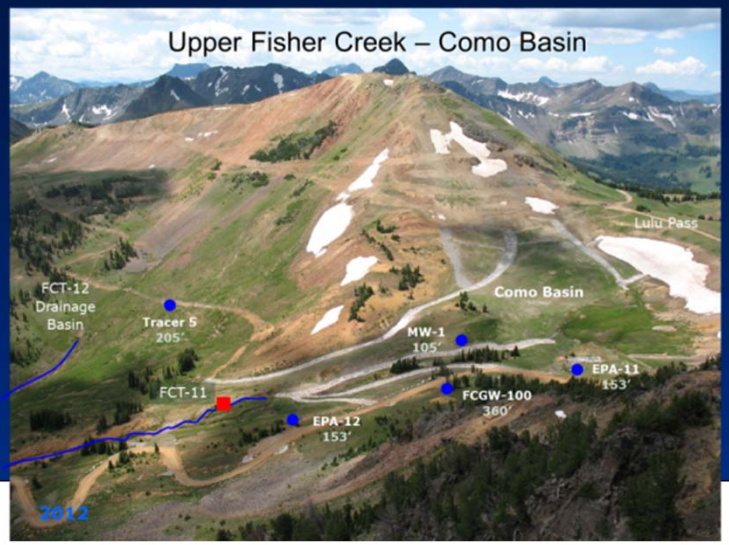
Fisher Creek - Ground Water

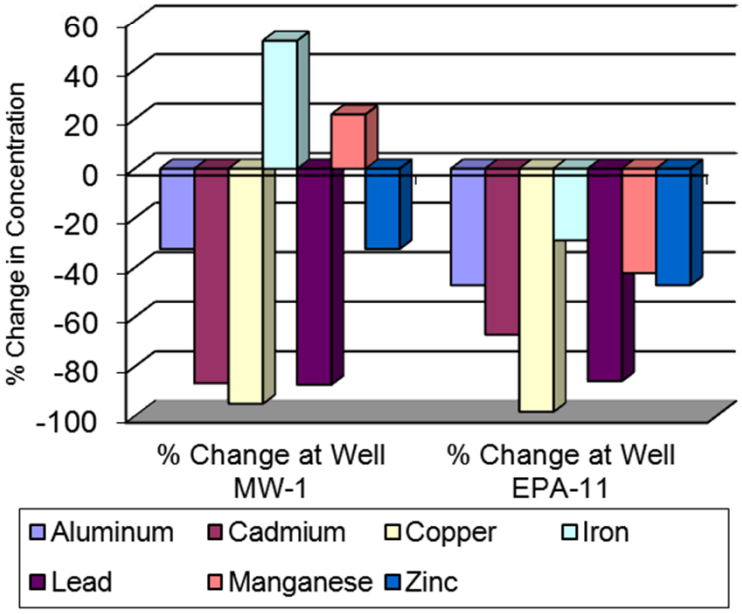


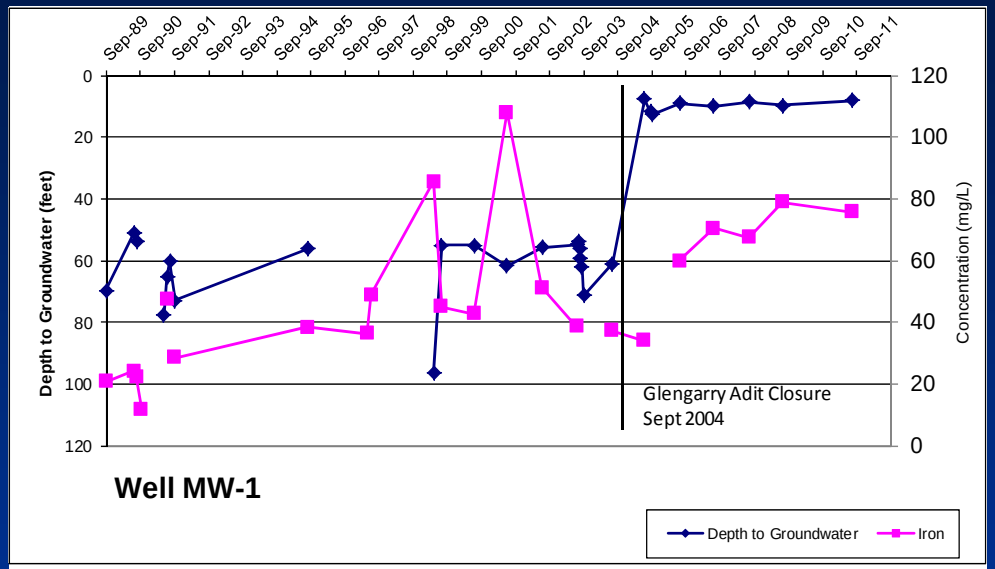


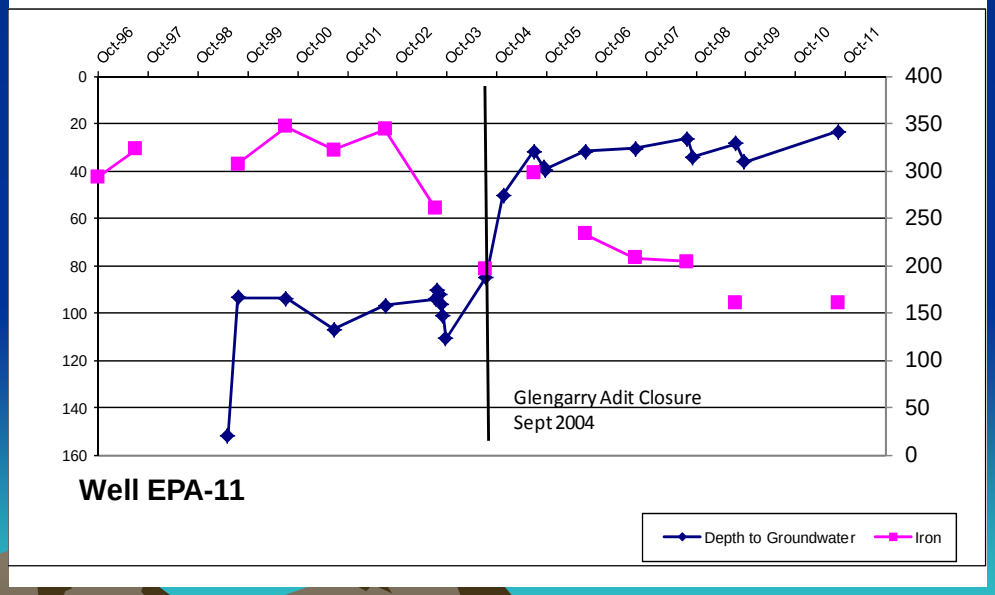












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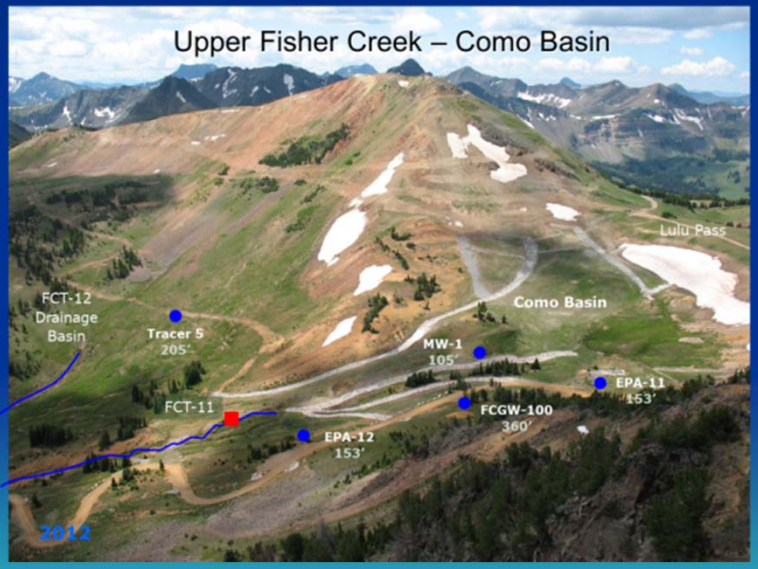
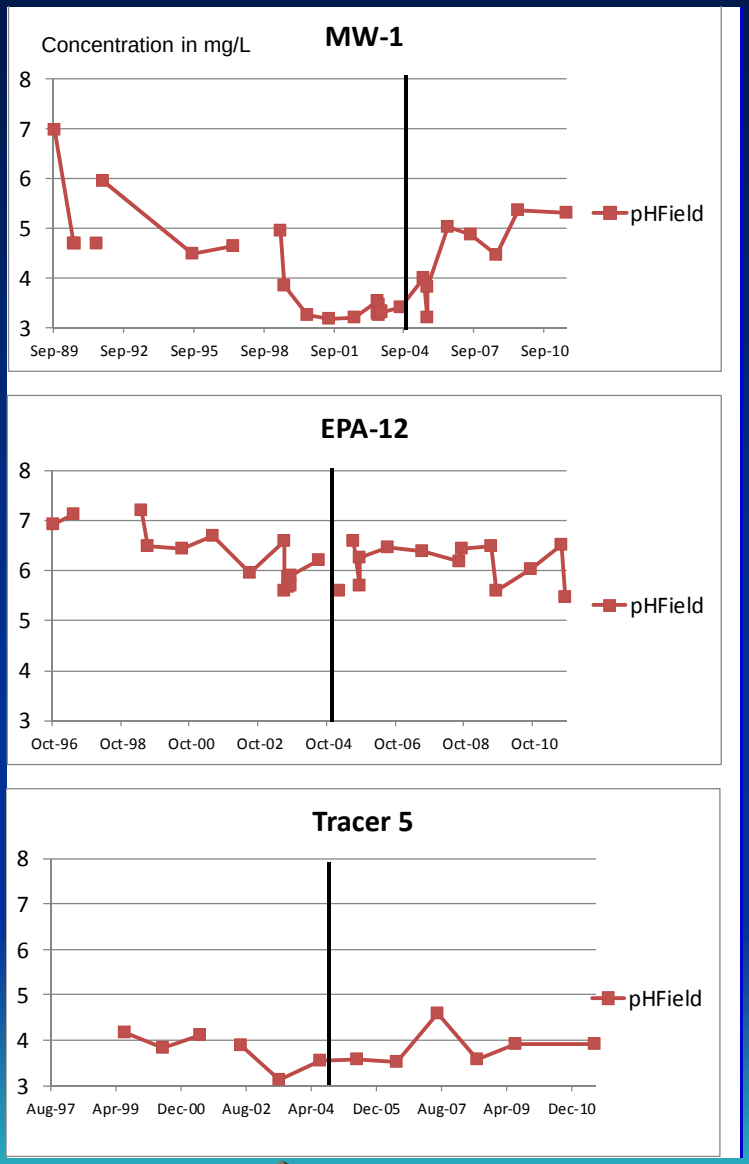
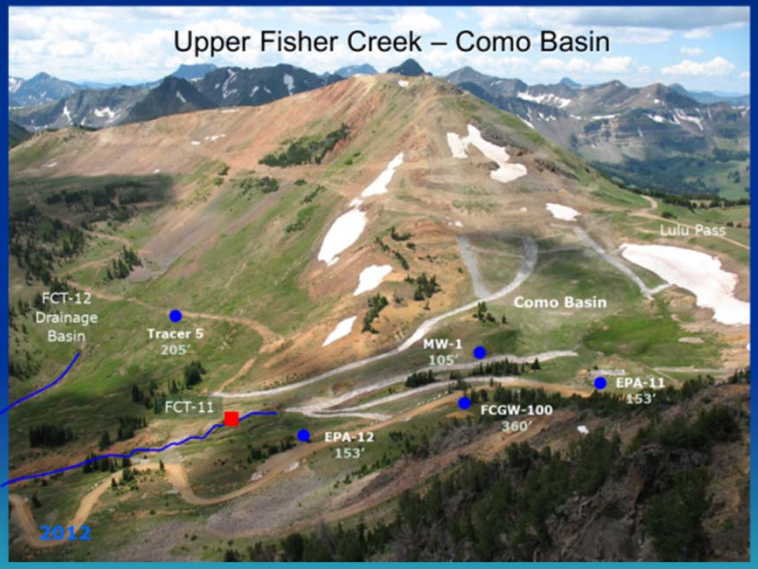
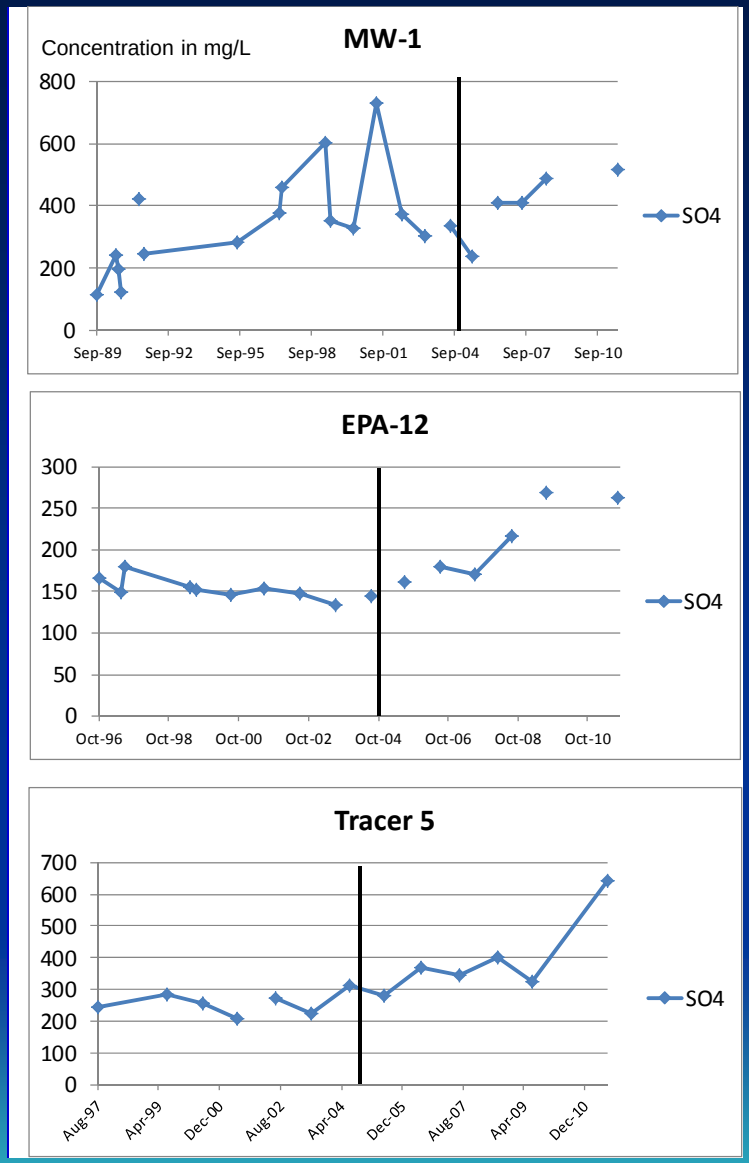
Shallower Fisher Creek Wells - pH



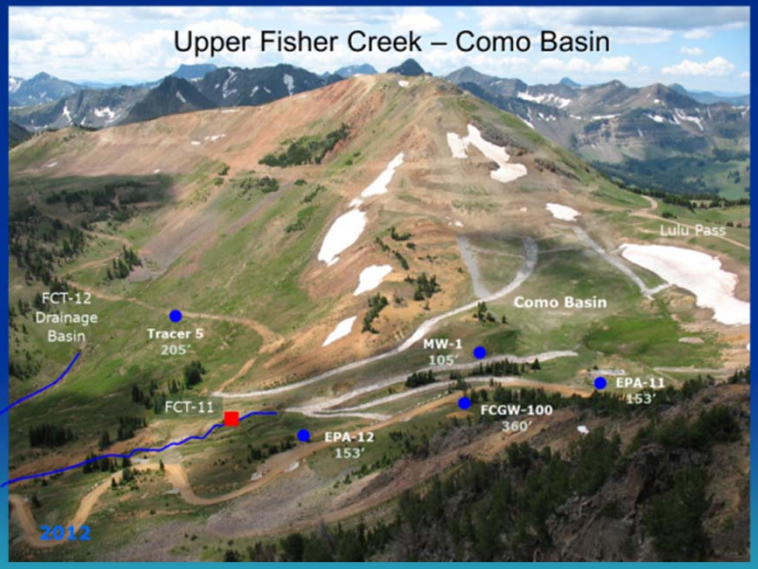


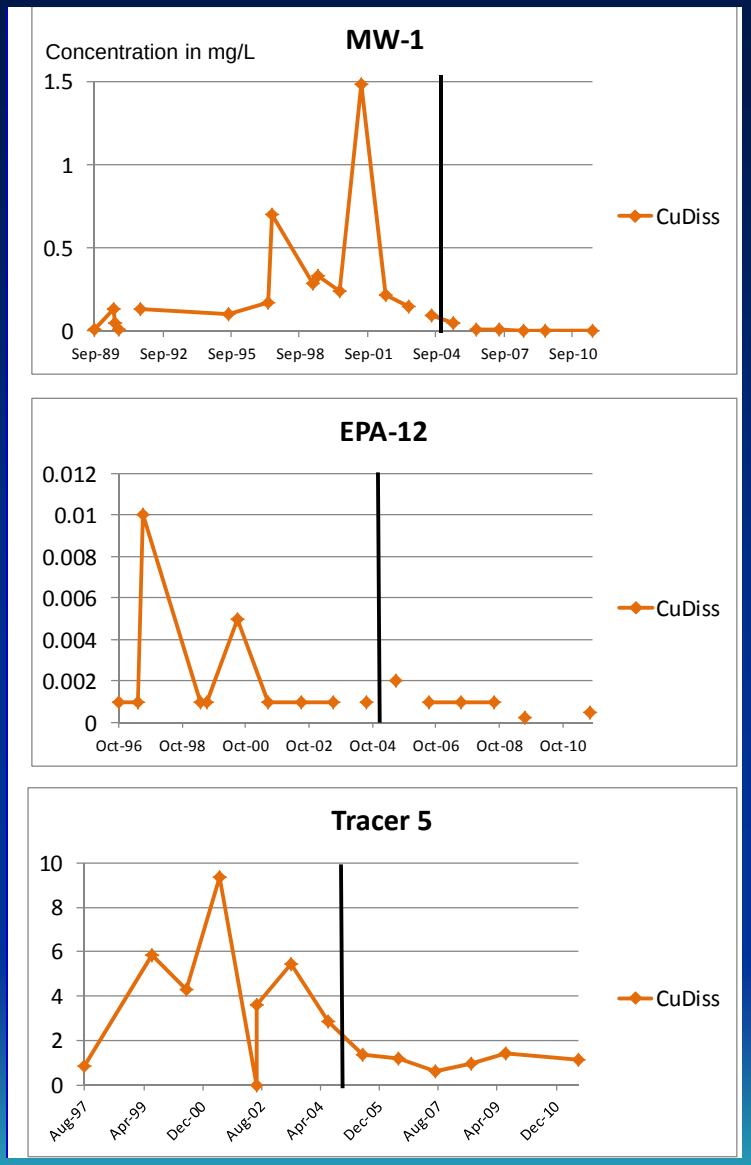
Shallower Fisher Creek Wells – SO_4



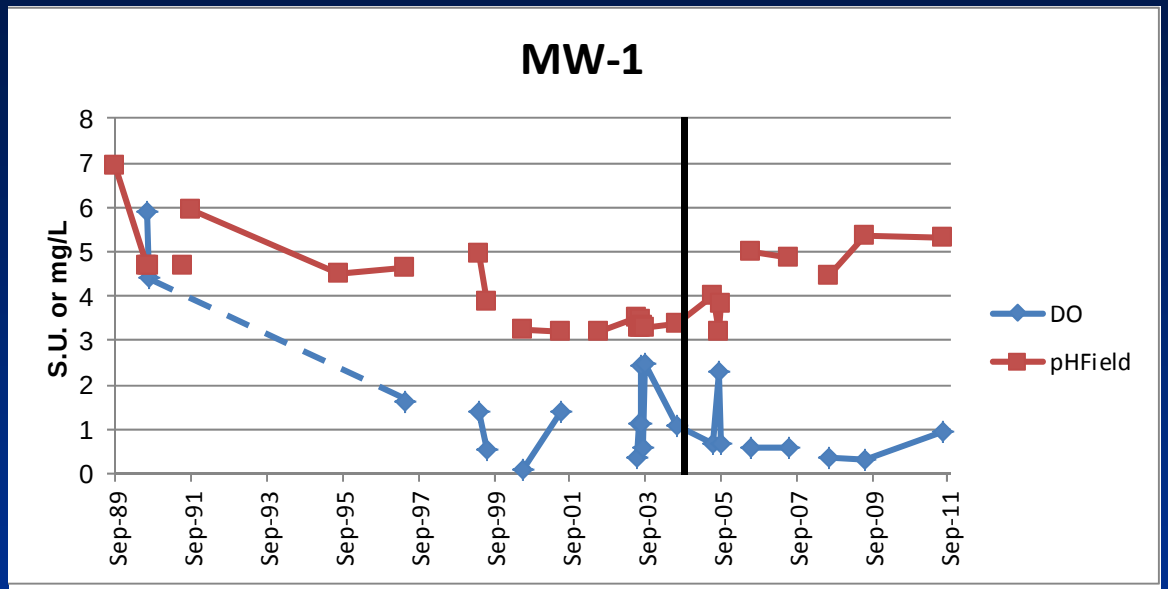


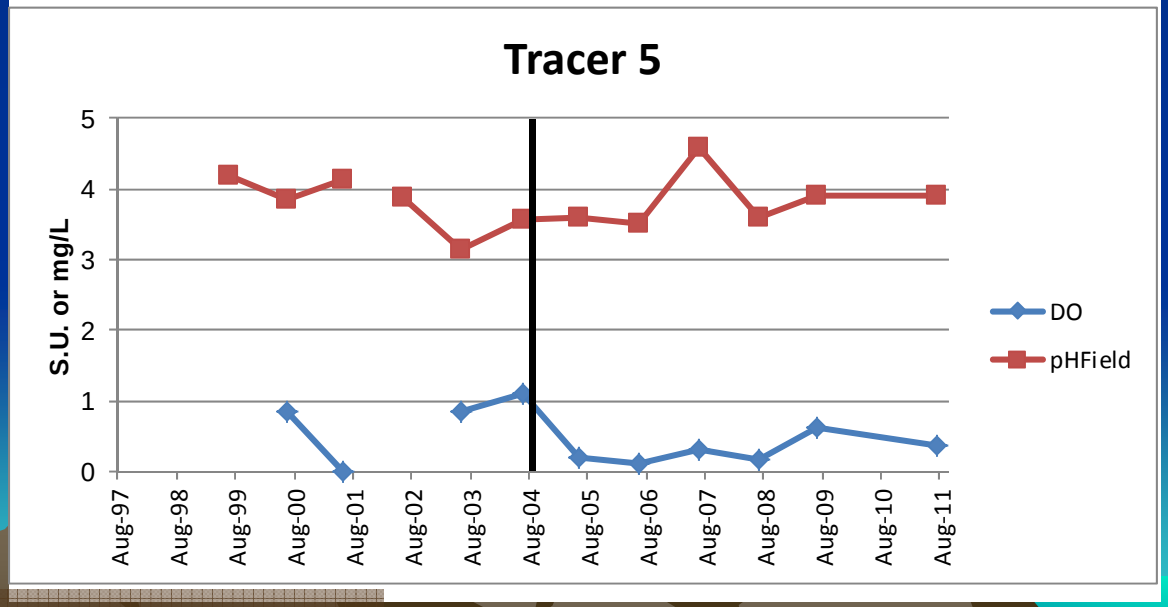
Shallower Fisher Creek Wells – Cu dissolved



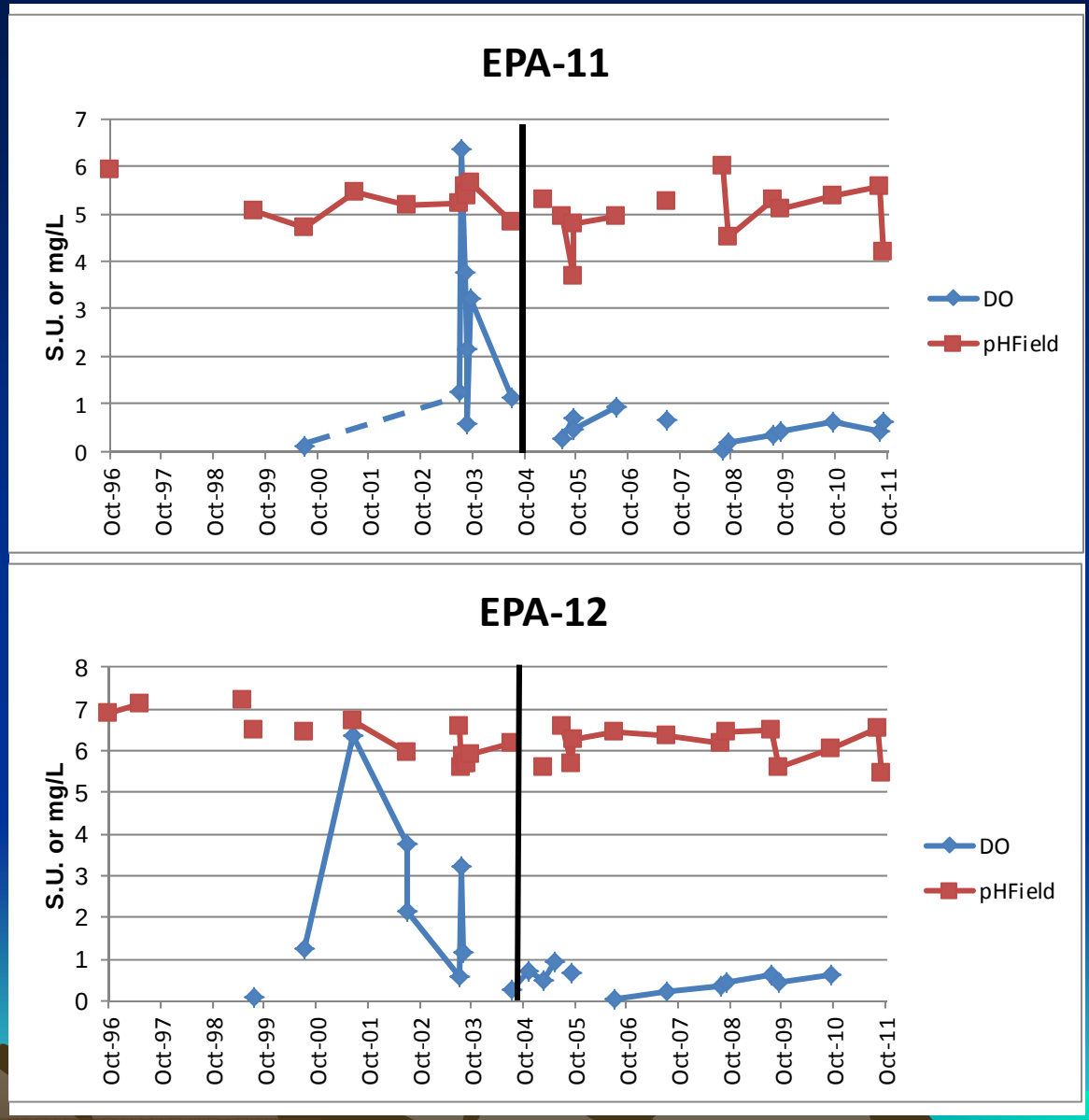


Fisher Creek - Ground Water





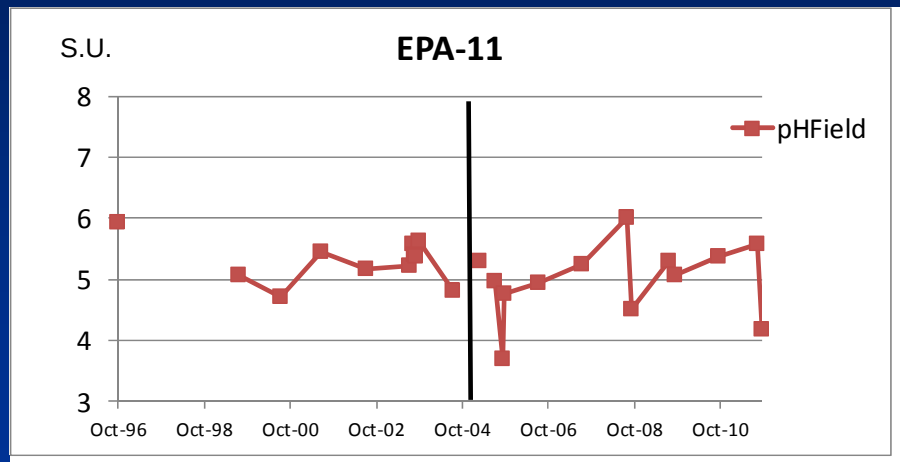
Fisher Creek - Ground Water

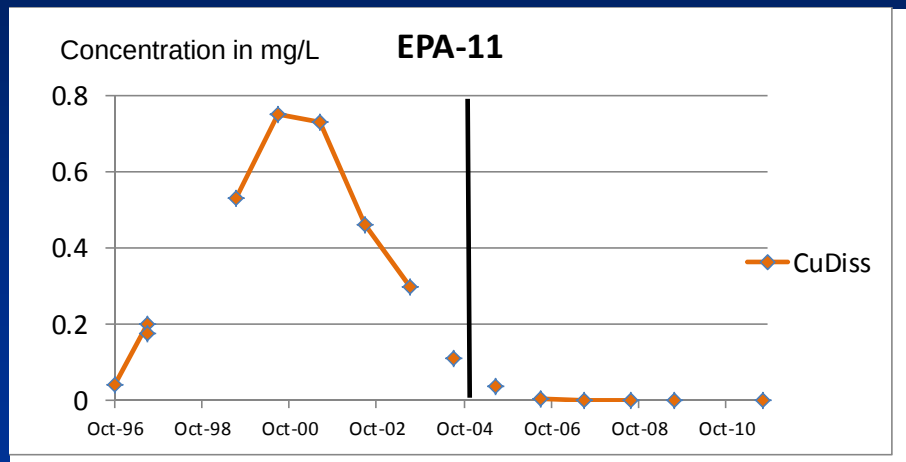


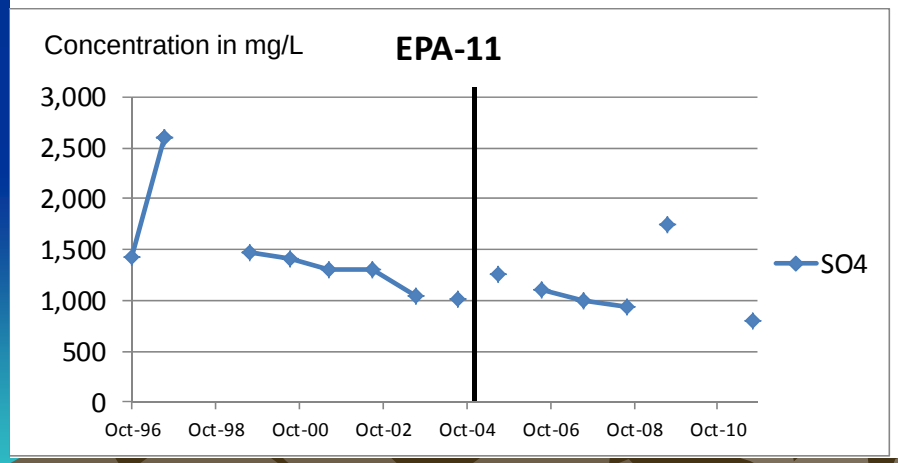
Observations (and inferred causes) as water levels rise

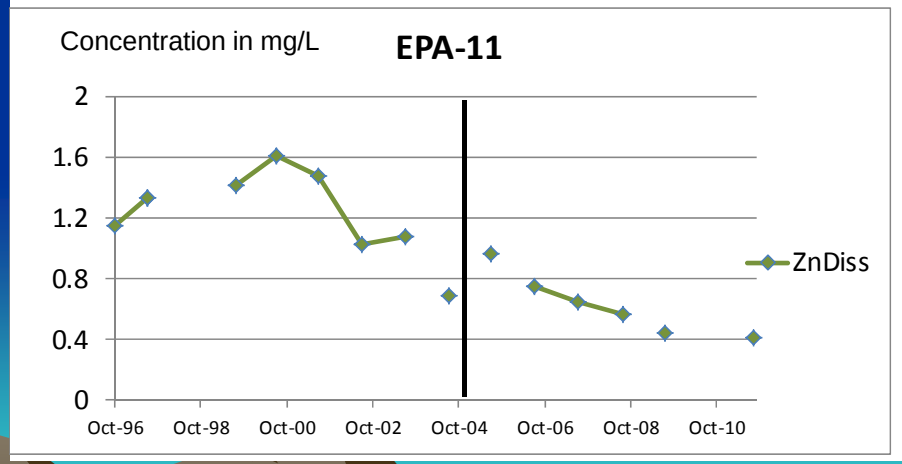
- Oxygen decreases and reduced groundwater conditions are established
  - Rate of oxygen recharge is diminished in saturated zone
  - Oxidation of sulfides consumes much of available oxygen
- pH rises
  - Reduced production of acid by sulfide oxidation
  - Accumulation of CO_2
  - Dilution with inflow of alkaline GW
- Base metal concentrations decrease
  - Solubility reduced at higher pH
- Fe and SO_4 concentration increase
  - decreased but ongoing oxidation of pyrite
  - Sulfate dissolution of acid by-products
  - Iron reduction
- Results
  - Important improvement in local and regional surface / groundwater quality
  - Additional investigations planned

Fisher Creek - Ground Water EPA-11
Decreasing Fe, SO4, Metals
Increasing pH

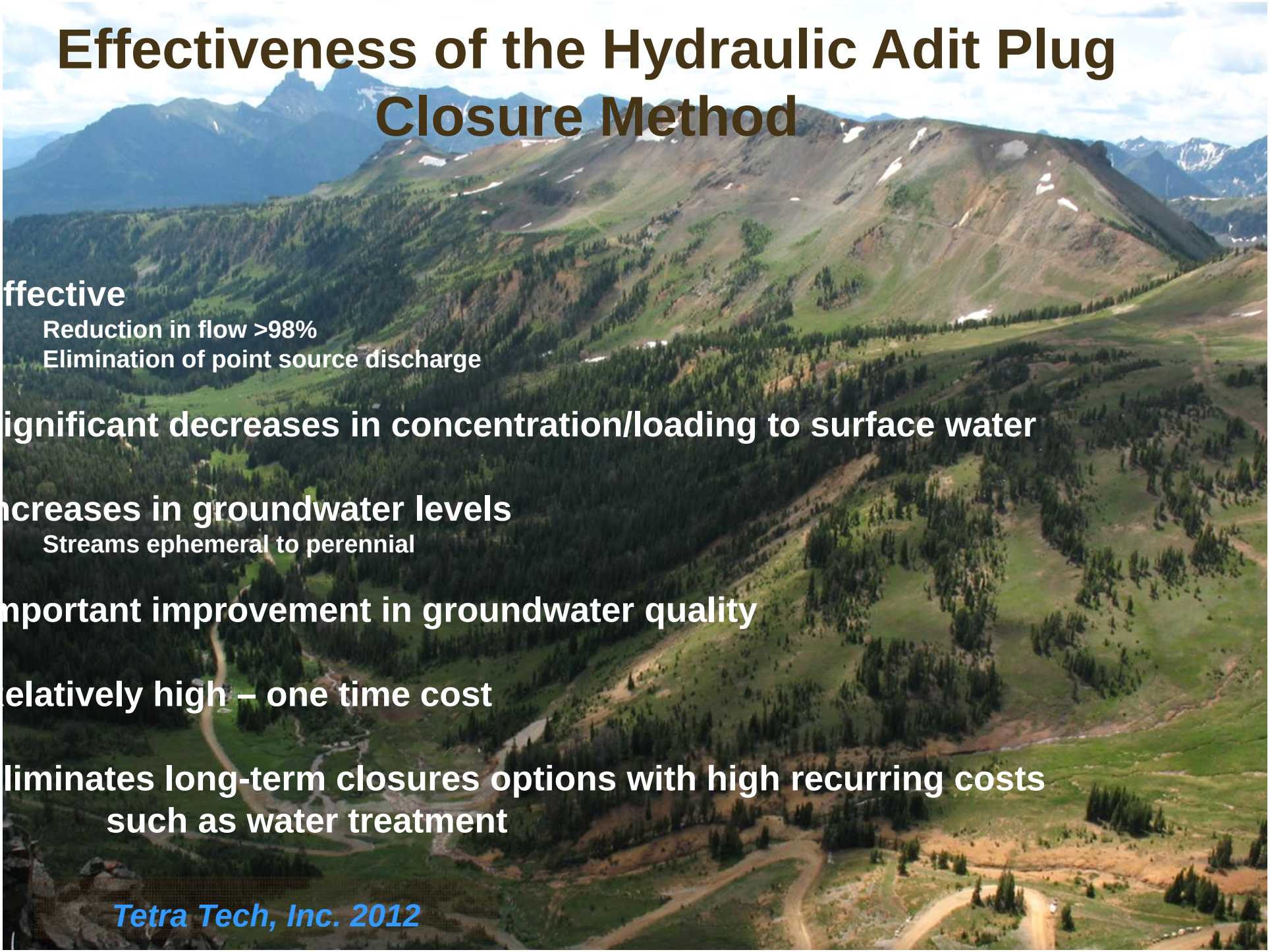








Effectiveness of the Hydraulic Adit Plug Closure Method



ffective

- Reduction in flow >98%
- Elimination of point source discharge

ignificant decreases in concentration/loading to surface water

ncreases in groundwater levels

- Streams ephemeral to perennial

mportant improvement in groundwater quality

elatively high – one time cost

liminates long-term closures options with high recurring costs such as water treatment

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Questions?

So…
Where does the water go?

Flow into Seeps and Springs

Ferricrete Overlying Glacial Till
(8800 year old wood fragments) (from Furniss, 2003)


Any More Questions?


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Near Surface Wells in Upper Fisher Creek

Como Basin Groundwater Elevation Change	Average Depth to Water		Change	% Change
Well	Before Glengarry Closure (before Oct 2004) feet	After Como Basin Response (after October 2006) feet	feet	
MW-1	56	18	38	68
EPA-11	93	30	63	68
EPA-12	23	1	22	96