Dewatering Effects of Underground Mining

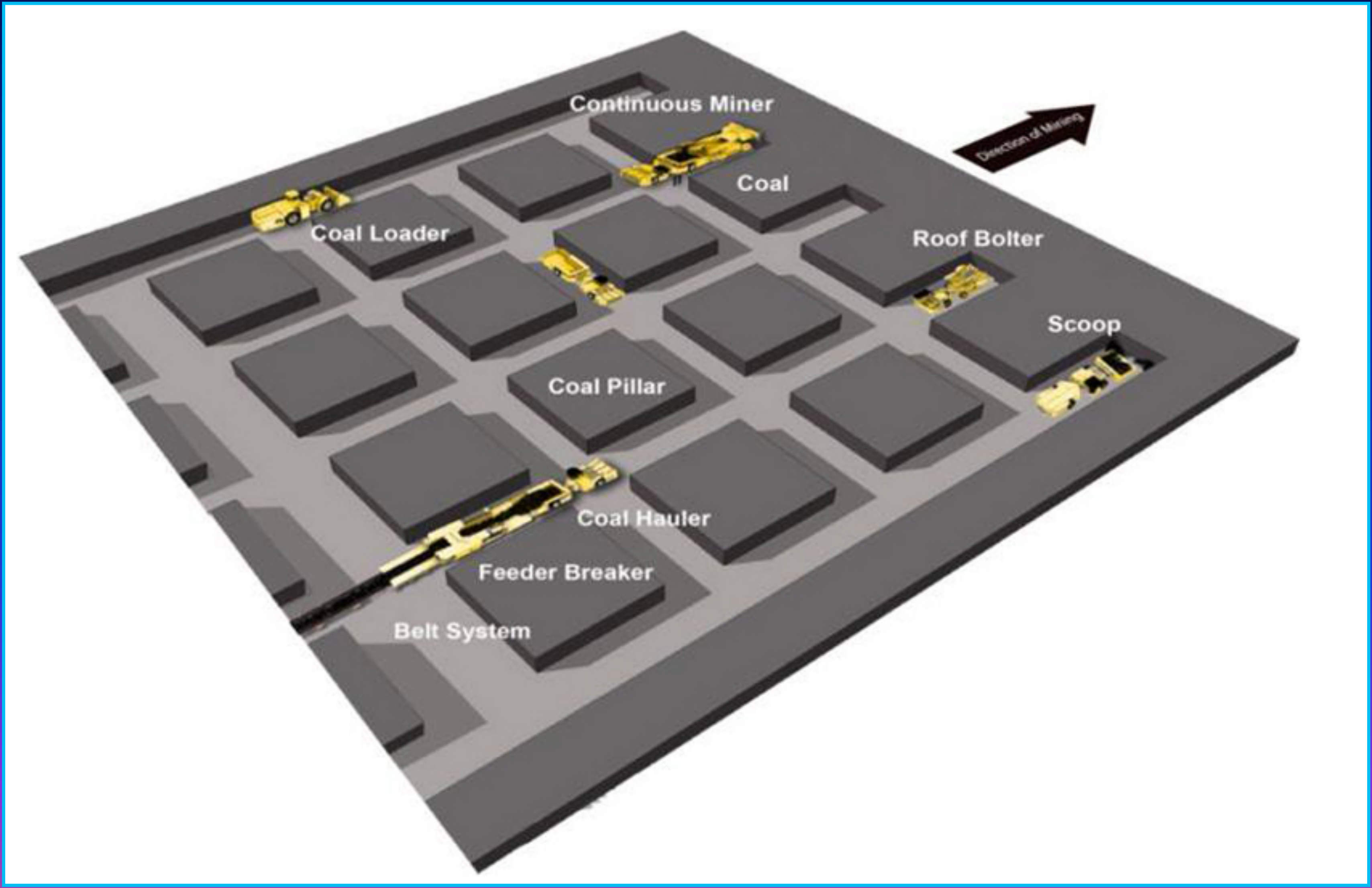
Important Factors to be Considered

- Type of mining:
  - First mining (room and pillar)
  - High extraction (e.g., 2nd, retreat, and longwalling)
- Overburden thickness
  - Shallow (< 300 feet)
  - Deep (> 300 feet)
- Overburden lithology
  - Sandstone-rich strata
  - Clay-rich strata
- Fractures and Faults – main avenue of groundwater flow

Room and Pillar Mining

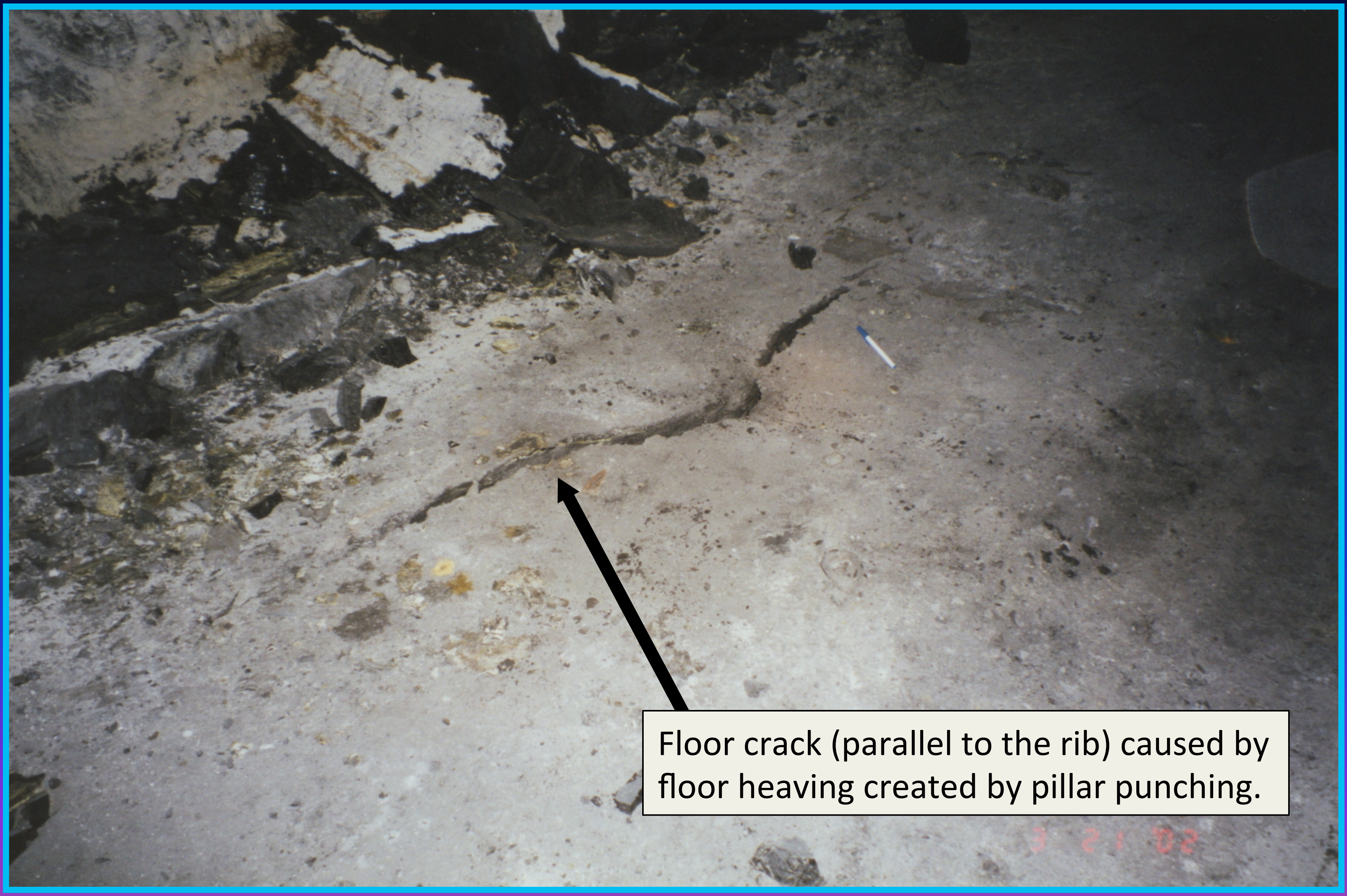
- Rule-of-thumb is if 50% or less of the coal is removed, subsidence will not occur in the foreseeable future (Peng, 2006).
- If subsidence does not occur, the impacts to overlying aquifers and/or streams is generally anticipated to negligible.
- There are known exceptions to this “rule”
  - Overburden is very thin (<150 to 200 feet).
  - Highly fractured and faulted sandstones.
  - In-mine conditions: pillar failure, roof falls, etc.

Room and Pillar Mining



Relatively thin overburden of predominantly fractured sandstone can dewater overlying units as well as effect stream dewatering, even with 1st mining only and less than a 50% extraction rate.

Pillar Failure



Floor crack (parallel to the rib) caused by floor heaving created by pillar punching.

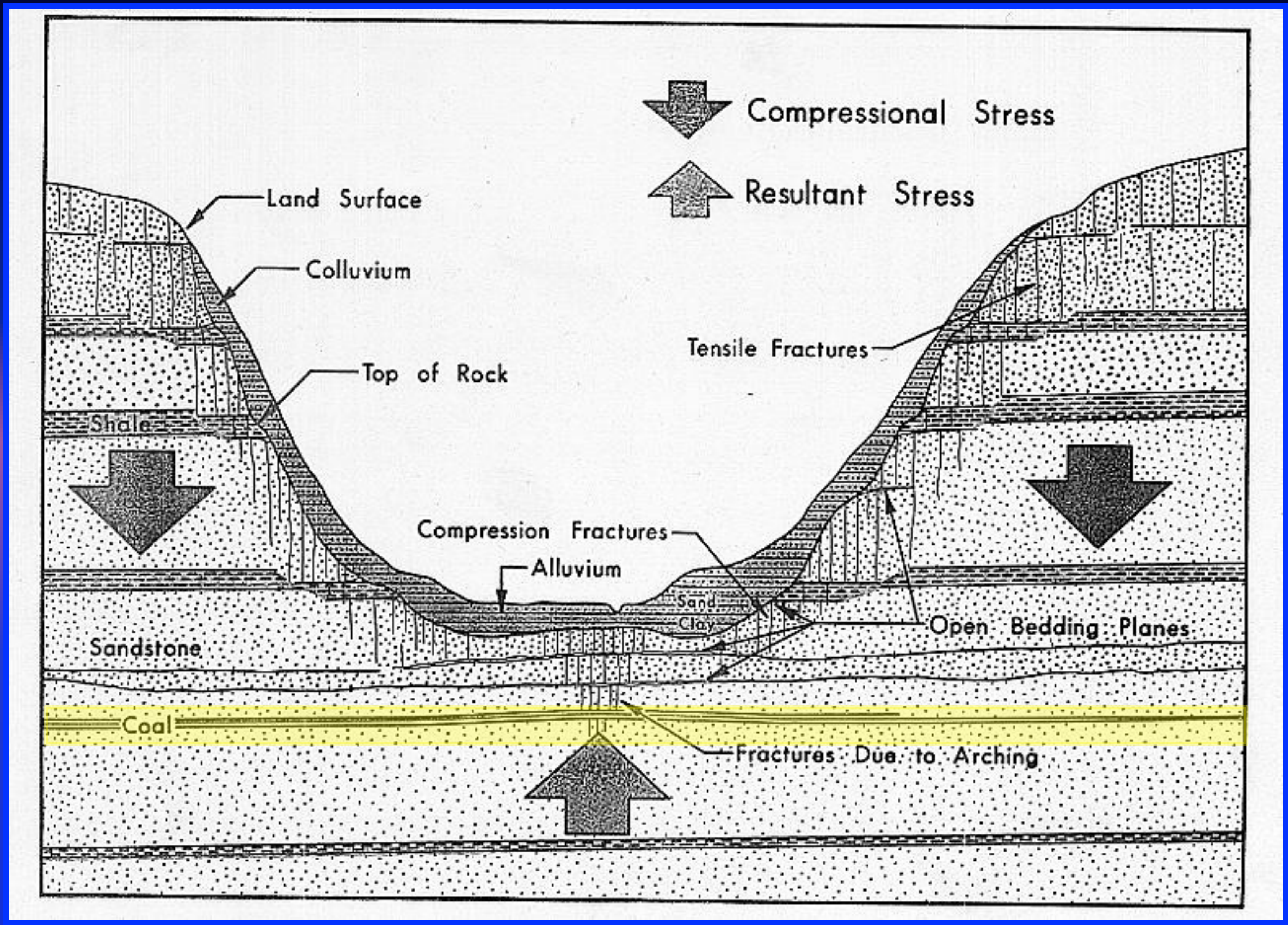
Roof falls beneath streams are not unexpected.

Thin Overburden

- With less than 150 to 200 feet of overburden, the stress-relief fracture system strongly comes into play (Ferguson, 1967; 1974).
- There can be a direct hydrologic connection of the mine to the shallow aquifers and ultimately overlying surface water systems.
- A large amount of sandstone vs. shale and other clay-rich strata will facilitate this hydrologic interaction.
- Other in-mine reactions can also come into play.
- And other fracture types that can extend to greater depths (Phillipson and Tyrna, 2002).

Example of Stream Loss Over A Shallow Cover Underground Mine

Fracture Flow of Groundwater



After Ferguson (1974)

Stress-Relief Fractures

- Fractures are more frequent in the near surface and decrease with increasing depth.
- Fracture apertures tend to be more open at shallow depths and tighter the deeper you go.
- Shales tend to have higher frequency of fracturing than sandstones.
- But, the fractures in shales tend to be tighter than those found in sandstones.
- Literature: Wyrick and Borchers, Wright, Harlow and LeCain, etc.

General Example Lithologic Impacts

Mines in southern West Virginia tend to have mostly sandstone overburden and even at considerable depths (>300') they see substantial inflow from shallow aquifers and overlying streams. Avg. > 0.5 gpm/ac.

Whereas, mines in southwestern Pennsylvania tend to have substantial amounts of clay-rich rocks (shales, siltstones, and claystones) and at considerable depths (>300') they make substantially less water and any stream dewatering is a near-surface issue. Avg. inflow < 0.1 gpm/ac., one section receives < 0.01 gpm/ac.

Large Land ("Mountain") Crack

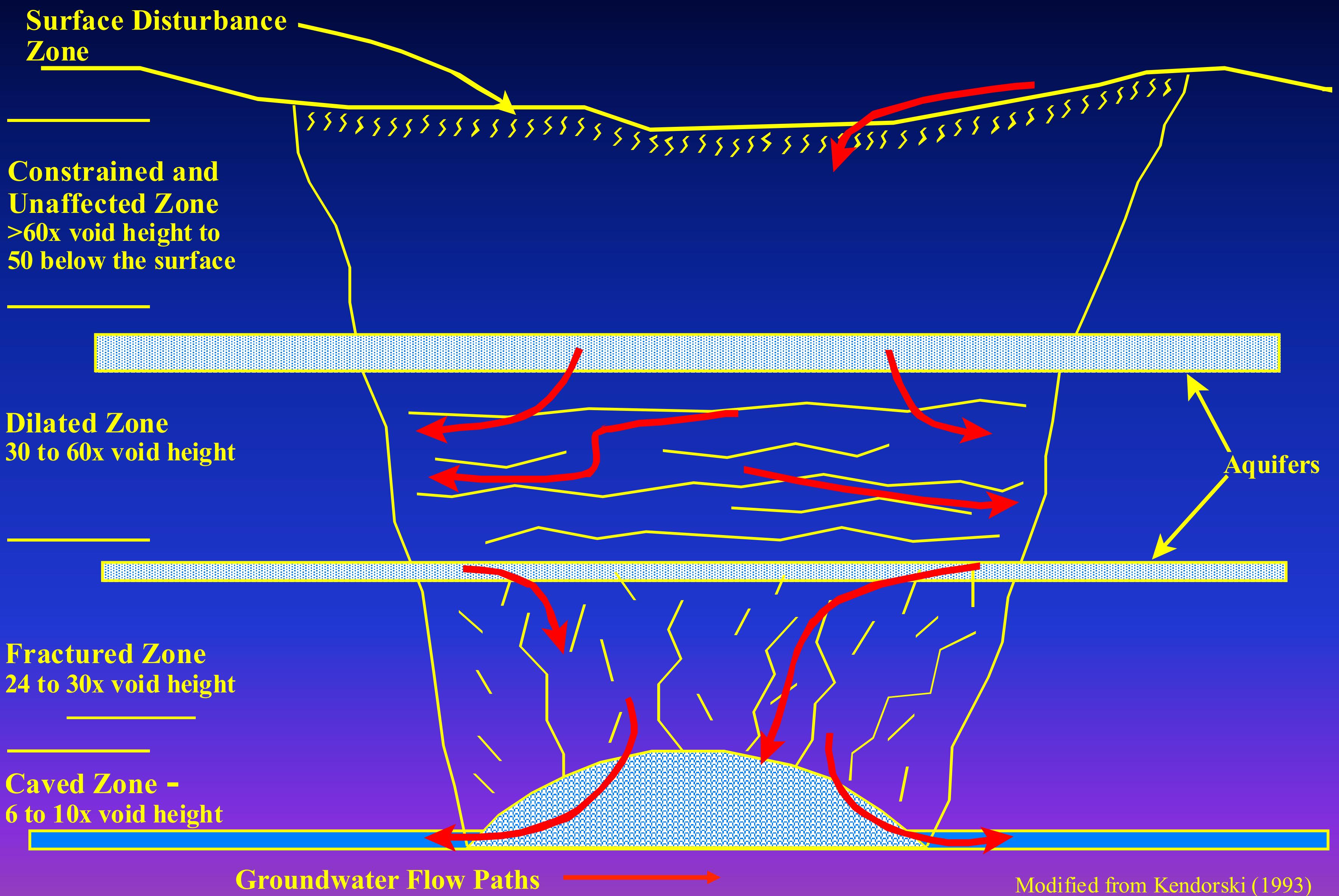
High-Extraction Mining

- Hydrologic impacts can occur at much greater depths.
- Mining-induced fracturing from subsidence extends upward toward the surface can intersect the stress-relief fractures.
- Overburden lithology still influences the degree and scope of impacts.
- The impacts of the subsidence may be visible at the surface.

Subsurface and Surface Hydrologic Impacts

- Impacts to deeper and regional aquifers.
- Dewatering of shallow aquifers and/or lowering of the water level in these units.
- Interaction of shallow aquifers and surface water bodies.
- Stream dewatering – visually obvious or not.
- Impacts to stream morphology – creation of pools and troughs.

Impacts from Longwall Mining



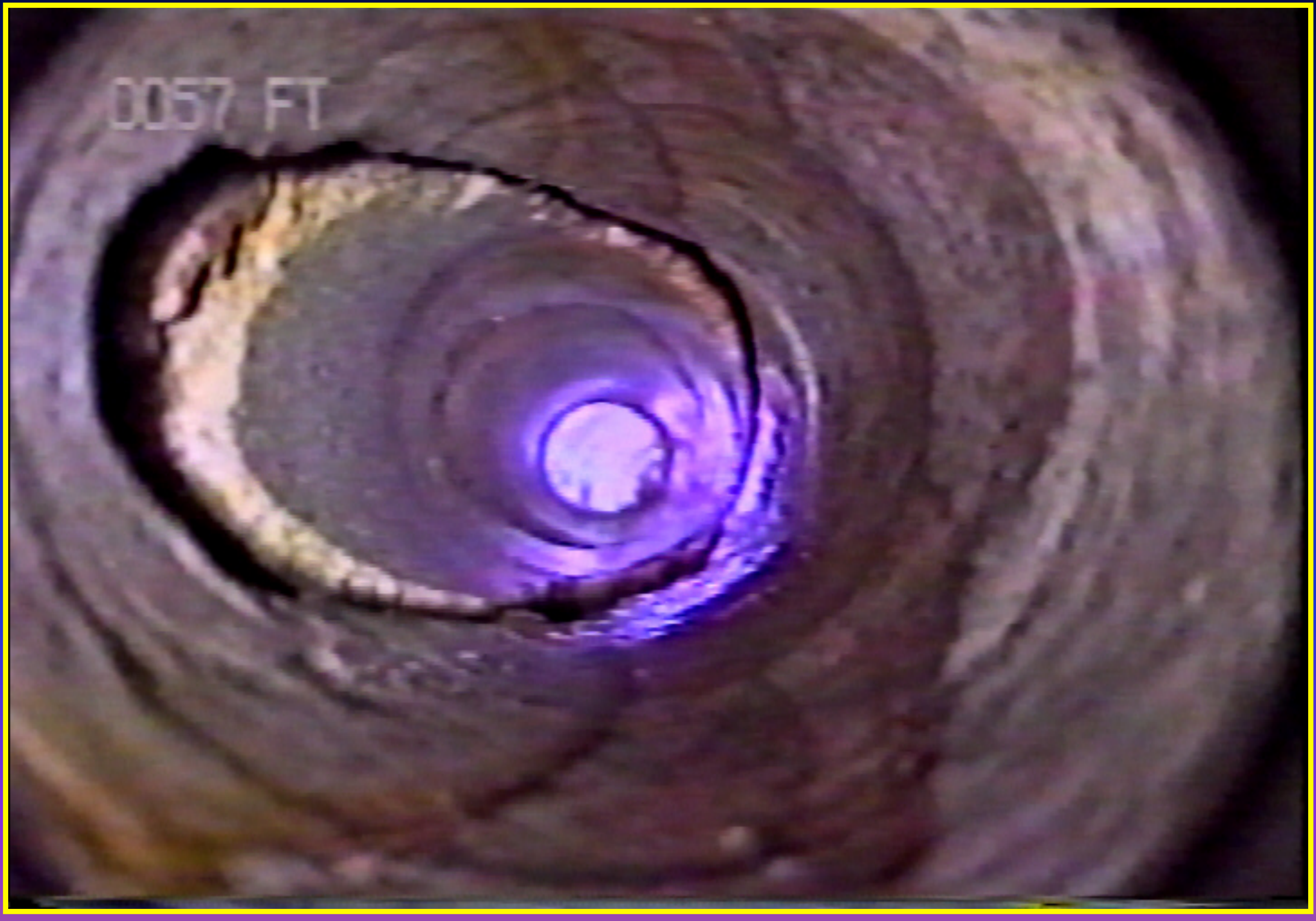
Modified from Kendorski (1993)

Courtesy of Tom Galya

Accentuated Stress-Relief Fracturing

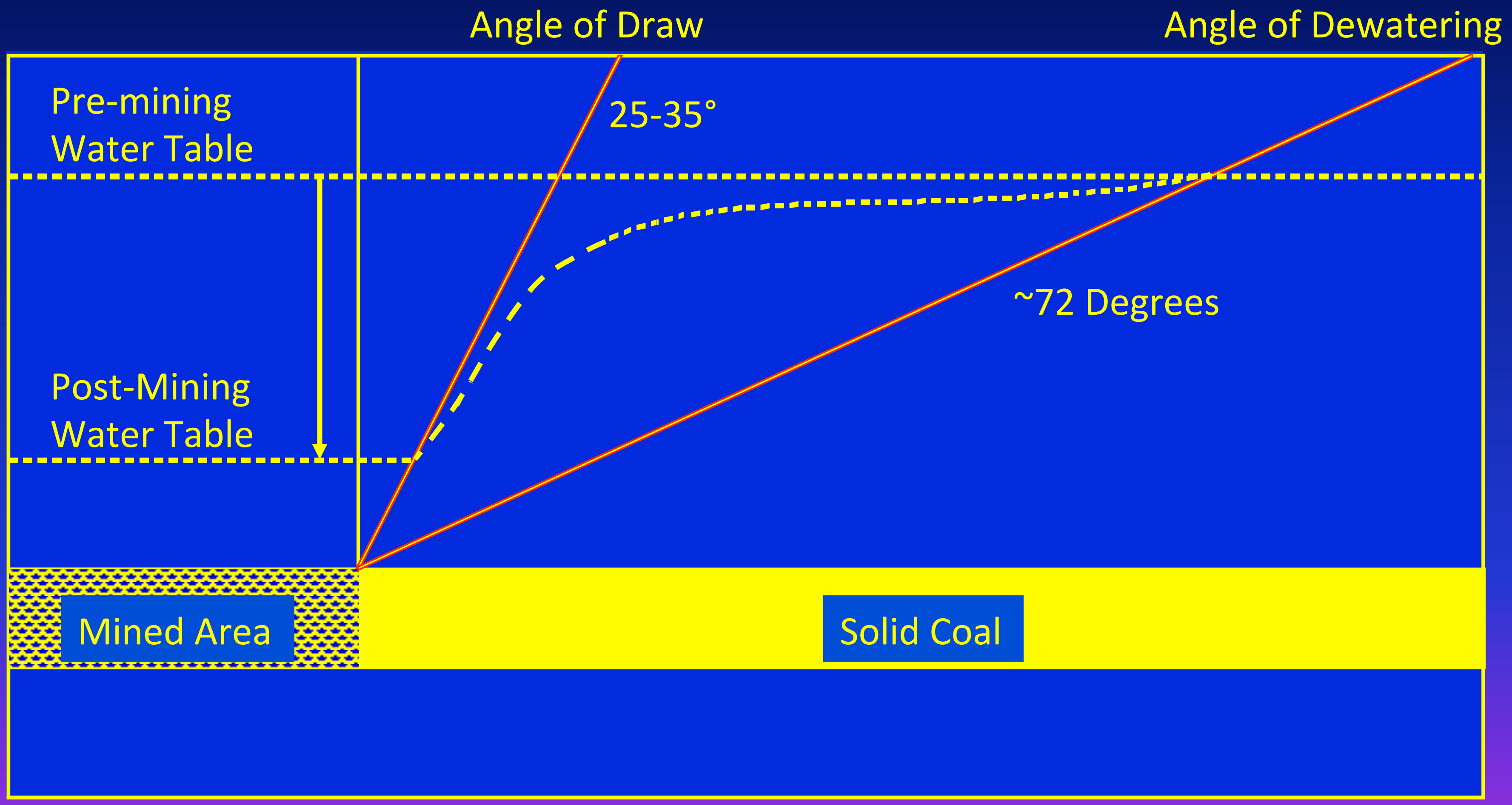
Fractures Formed from Subsidence

Fracturing Related to Mine Subsidence



Fracturing and Buckling from Compressional Stresses

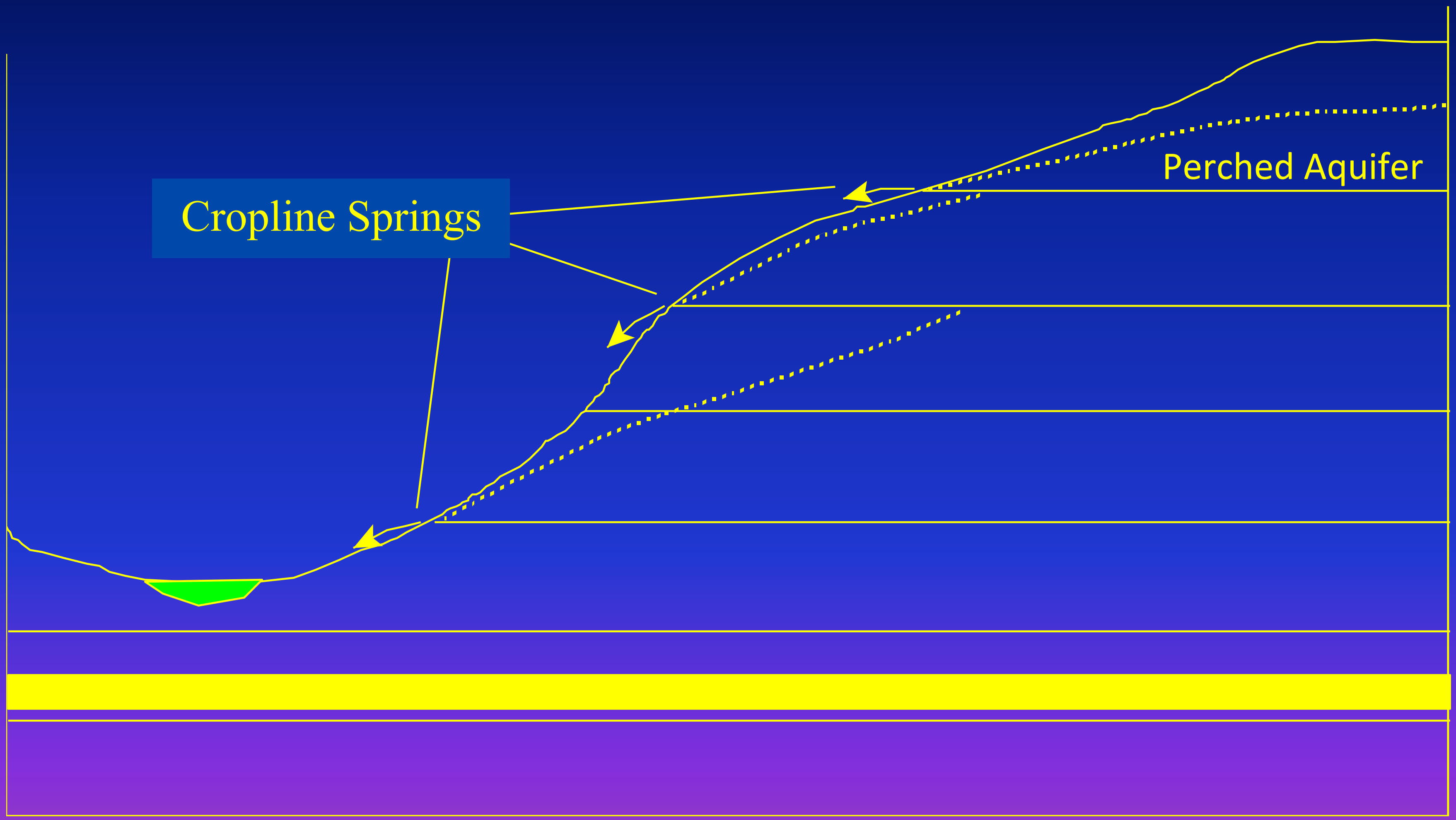
Angle of Dewatering



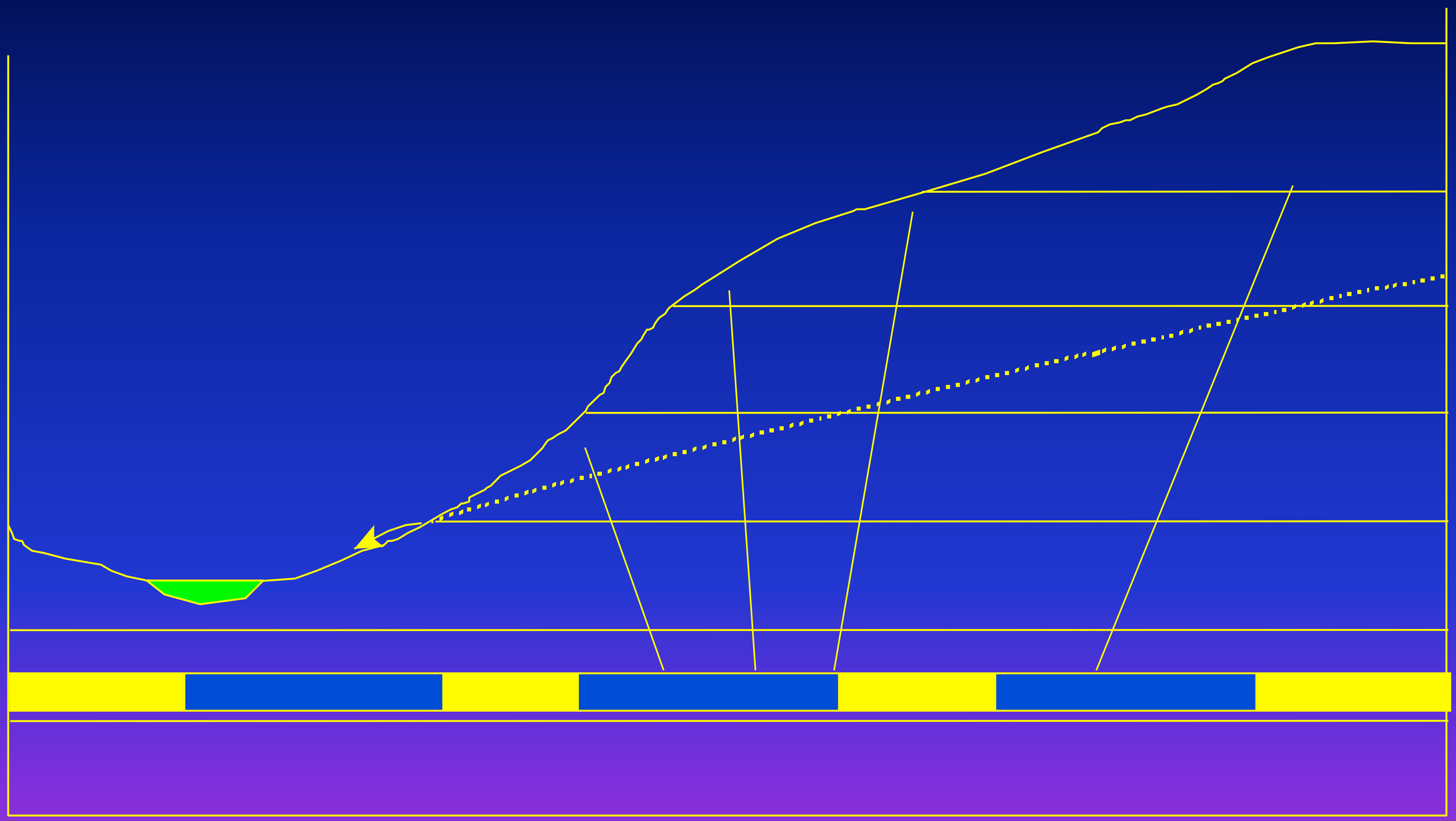
Impacts to Shallow Aquifers

- Confining units that support perched aquifers are often compromised by fracturing.
- Thus perched aquifers frequently will be lost.
- The groundwater tends to accumulate at lower units closer to local base level.
- So you may lose hilltop aquifers and cropline (contact) springs, but the water may emanate nearer to the stream.
- In the larger CHIA picture may not be a problem surface water wise, if within the same CIA or watershed.

Prior to Mining



Post-Mining



Dewatered Developed Spring

Impacts to Shallow Aquifers

- As fractures are opened up, groundwater can flow through them much faster.
- It is a cube root function, so doubling the fracture aperture, will increase the potential flow rate much more than twice as much.
- A K value of 2 cm/s may increase to 8 cm/s.
- So if groundwater can flow through the rocks faster, the water level will be lowered - Darcy's Law.
- Shallow aquifers are often not dewatered to the mine itself the water flows laterally faster and the groundwater level drops.

Groundwater Flow Response to Fracture Accentuation

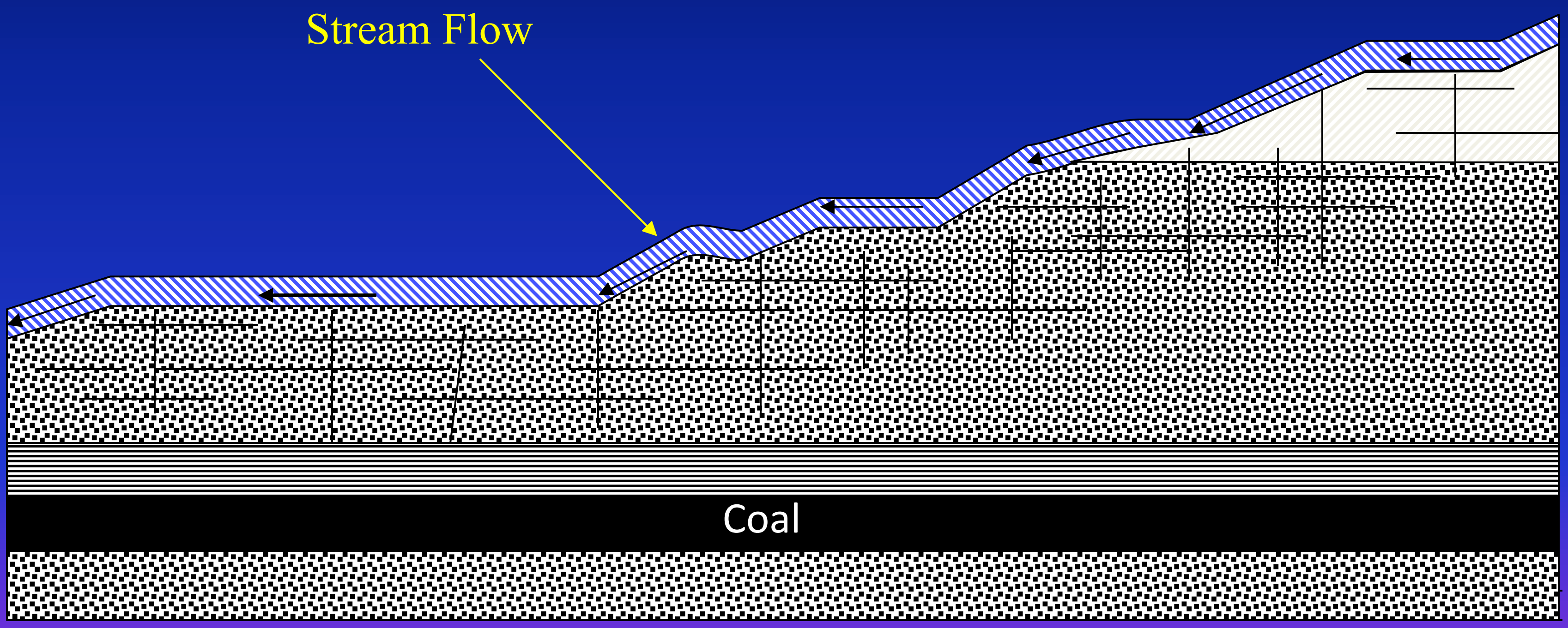
Darcy's Law shows that if K increases and all other parameters remain unchanged, the water level will be lowered.

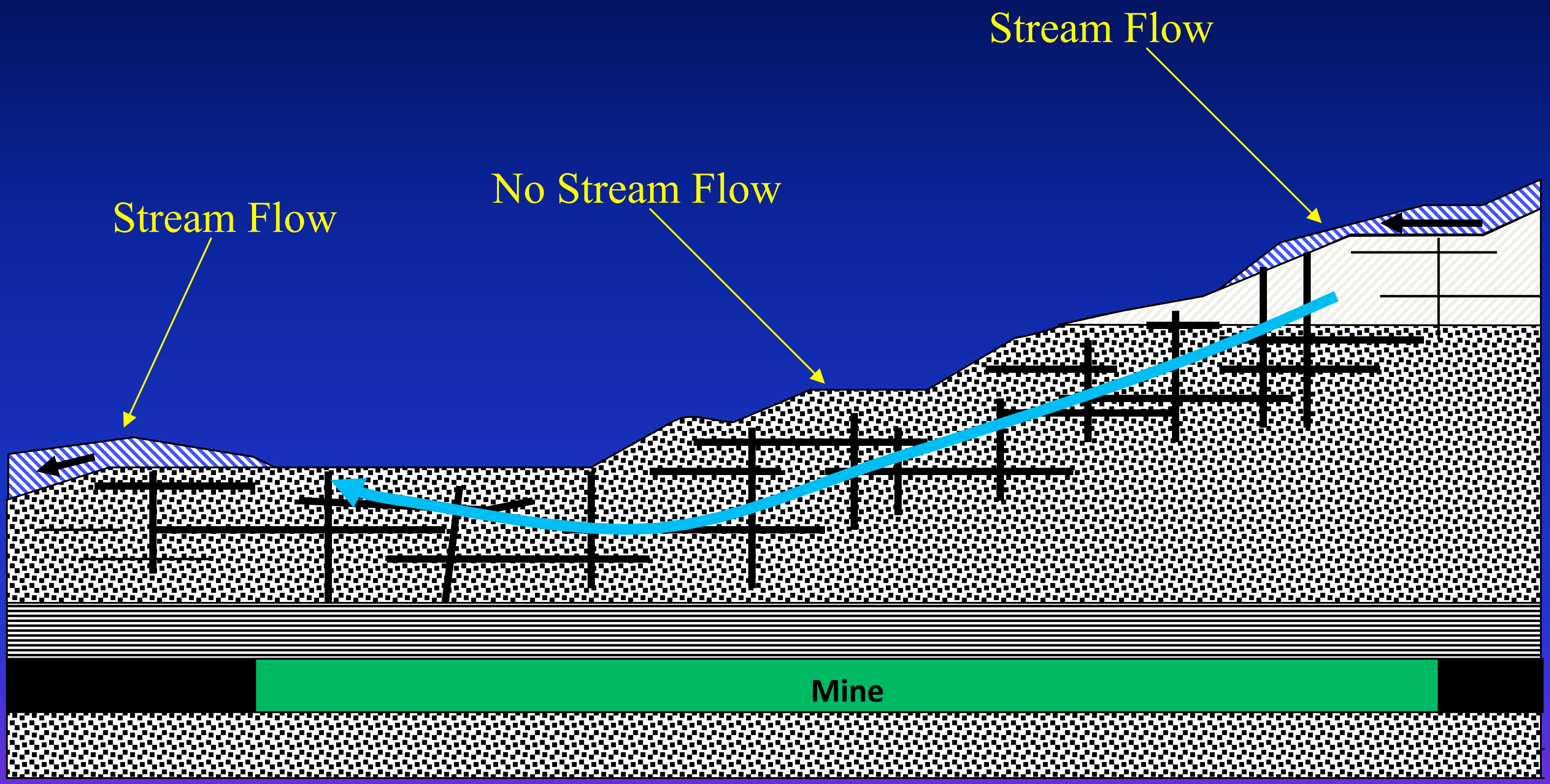
$$Q = K\uparrow * A * (\downarrow h_A - h_B / L)$$

For streams and creeks, we commonly see the water disappear into the subsurface above the mine, but then reappear downgradient beyond the impacts of the mine.

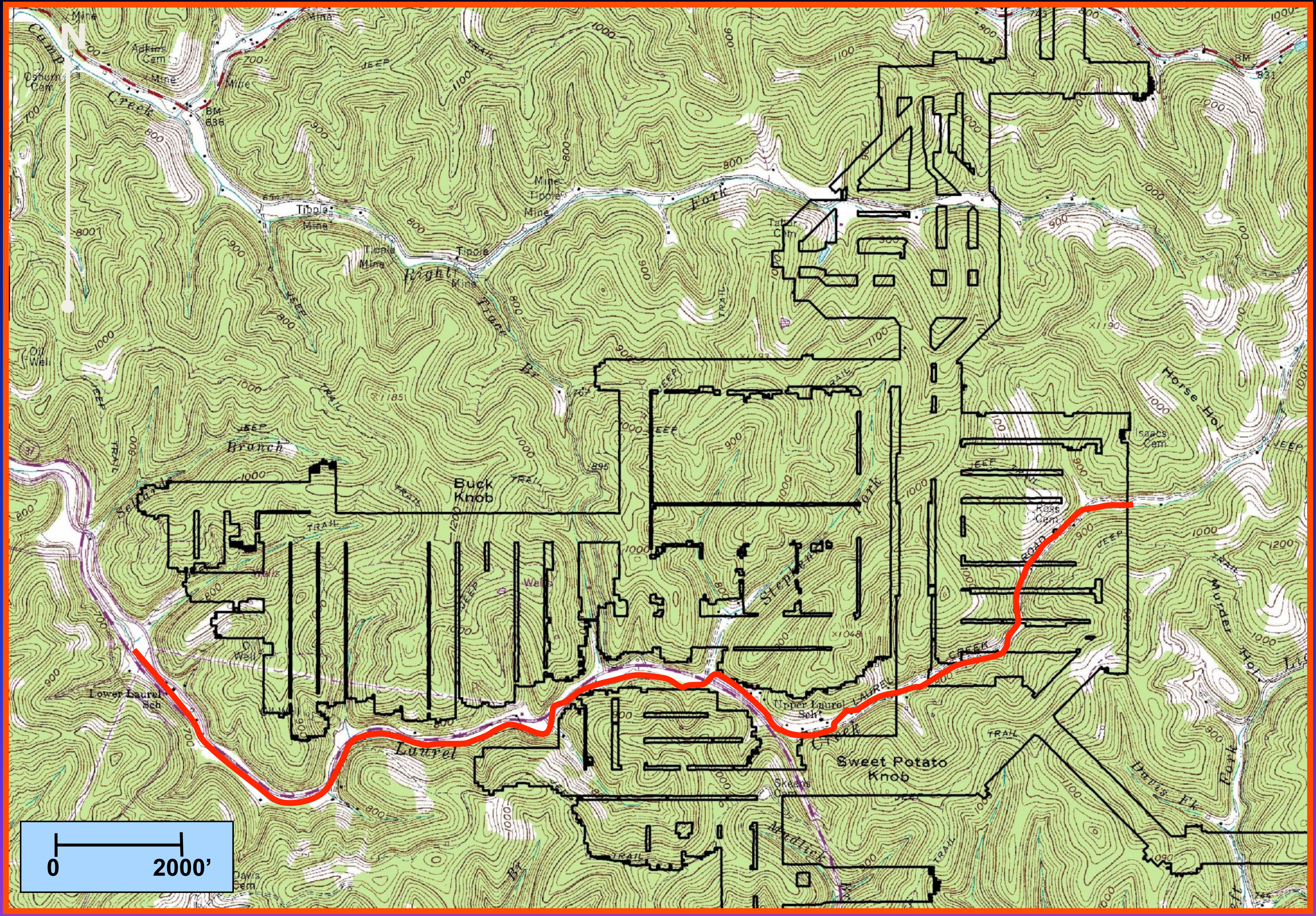
Especially true for streams directly underlain by a thicker sandstone units.

The accentuated fractures are able to accept the water and allow it to flow in the subsurface until non-dilated fractures are encountered then the water is forced back to the surface.


Stream Flow
Coal



Stream Flow
No Stream Flow
Stream Flow
Mine

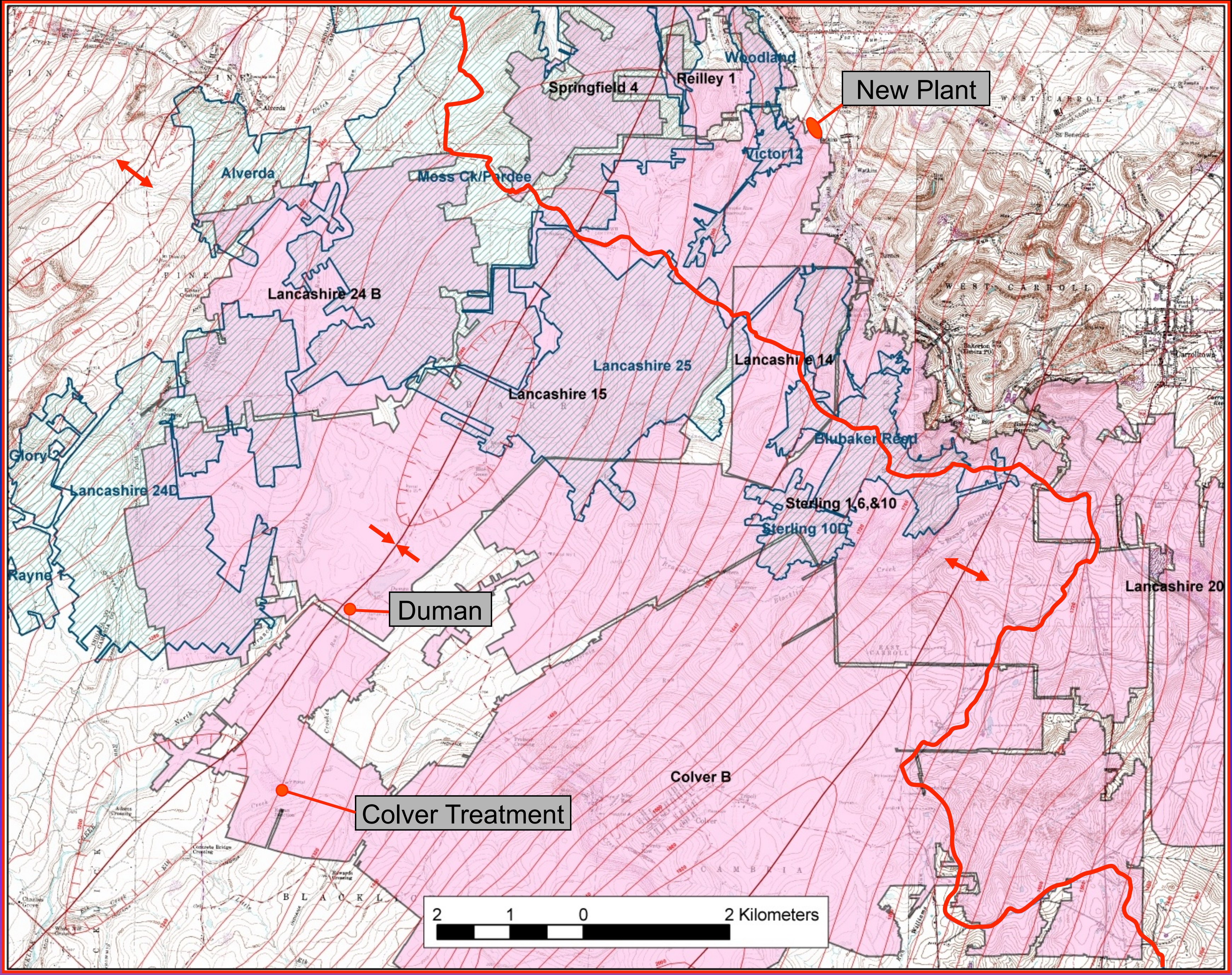


N
0
2000’
Buck Knob
Sweet Potato Knob
Laurel
Lower Laurel Sch
Right Fork
Horse Hol
Tipple
Mine

Impacts to Stream Morphology

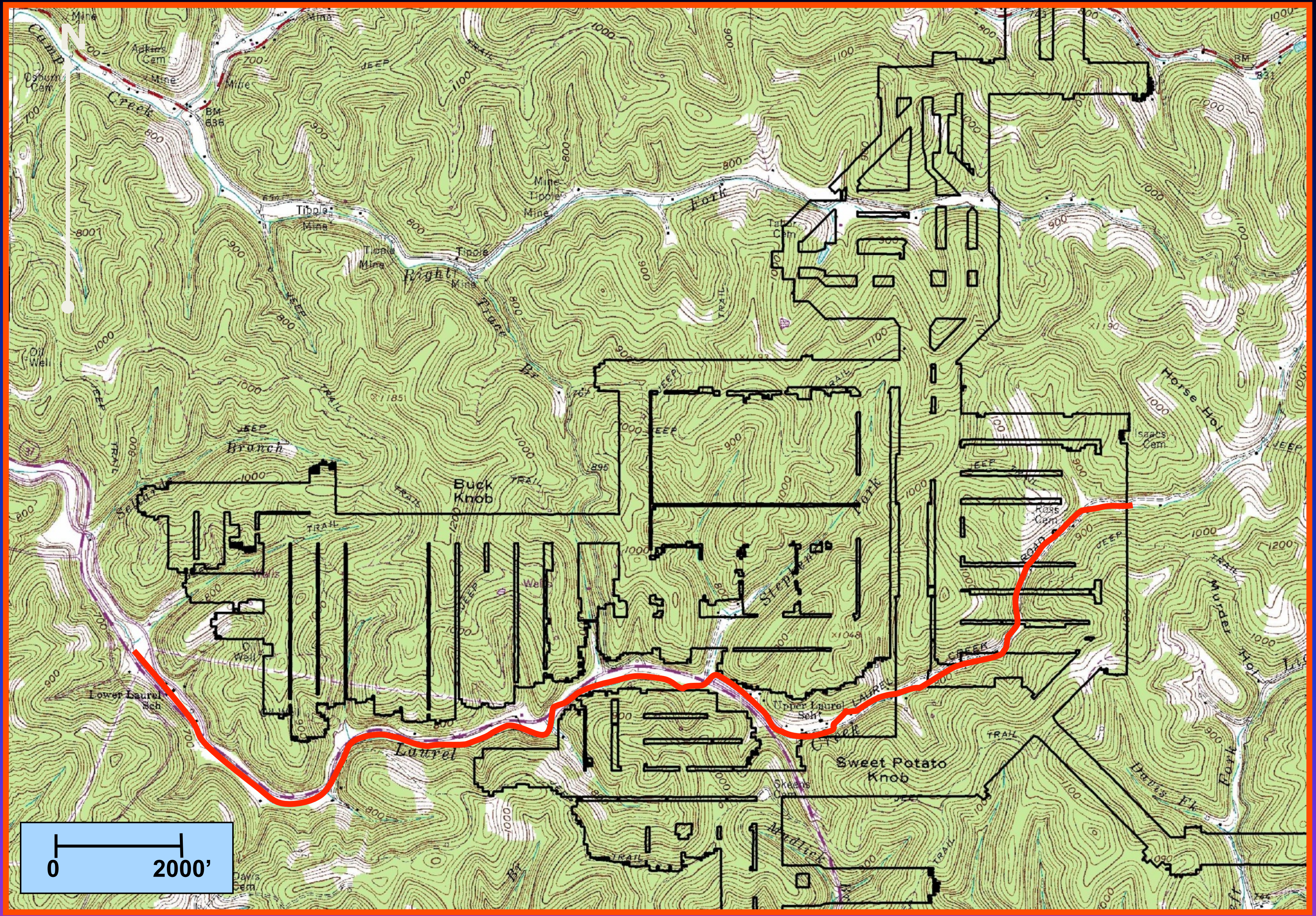
Interbasin Transfer of Water

- Surface and groundwater lost in one watershed will reappear in a separate watershed via an underground mine.
- May not a major problem if the watersheds relatively small and both are within the CIA above the tipping point for the CHIA.
- If not, obviously there will be an impact within the CIA for the watershed losing water and the one gaining.
- Interbasin movement of water needs to be clearly accounted for in the CHIA.


New Plant
Woodland
Reilley 1
Springfield 4
Victor 12
Alverda
Moss Ck/Pardee
Lancashire 24 B
Lancashire 25
Lancashire 14
Lancashire 15
Blubaker Reed
Glory 2
Lancashire 24D
Sterling 1,6,&10
Sterling 10D
Rayne
Lancashire 20
Duman
Colver B
Colver Treatment
2 1 0 2 Kilometers

You May Not Have to Reinvent the Wheel

- What has happened in the past when mining occurred will likely happen again?
- Under similar geologic, hydrologic, topographic, and other conditions, what happened when mining similar to what is proposed was conducted?
- If all of the factors are similar, one can logically expect similar impacts.
- This is not only logical, it is **scientifically defensible**.


N
0
2000’
Buck Knob
Sweet Potato Knob
Laurel
Creek
Camp Creek
Right Fork
Branch
Lower Laurel Sch
Upper Laurel Sch
Skeans
Adkins Cem
Osburn Cem
Ross Cem
Davis Cem
Tipple
Mine
JEEP
TRAIL
Horse Hol
Davis Fk

Defensible CHIAs

- Document, document, document…
- Reference the published literature, preferably peer reviewed papers, but conference proceedings etc. are much better than nothing.
- Be very *<u>specific and detailed</u>* in how you came to the answer as to the anticipated hydrologic impacts of the proposed operation in conjunction with previous, existing and future mining operations.
- Show your data and calculations to bolster your predictions of the hydrologic impacts.

That's All Folks!