Subsidence Modeling

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Illinois Basin Coal Mining

- Illinois Basin Coal
  - IL, IN, and west KY
  - Bituminous
  - 10,000 – 12,500 btu/lb
  - Mostly >2% sulfur
- 2010 Statistics
  - 76 Active Mines
    - 34 Underground
    - 42 Surface
  - 105,089,000 Tons Produced
  - 9.69% of U.S. Production
  - 14.4 Billion Tons of Reserve

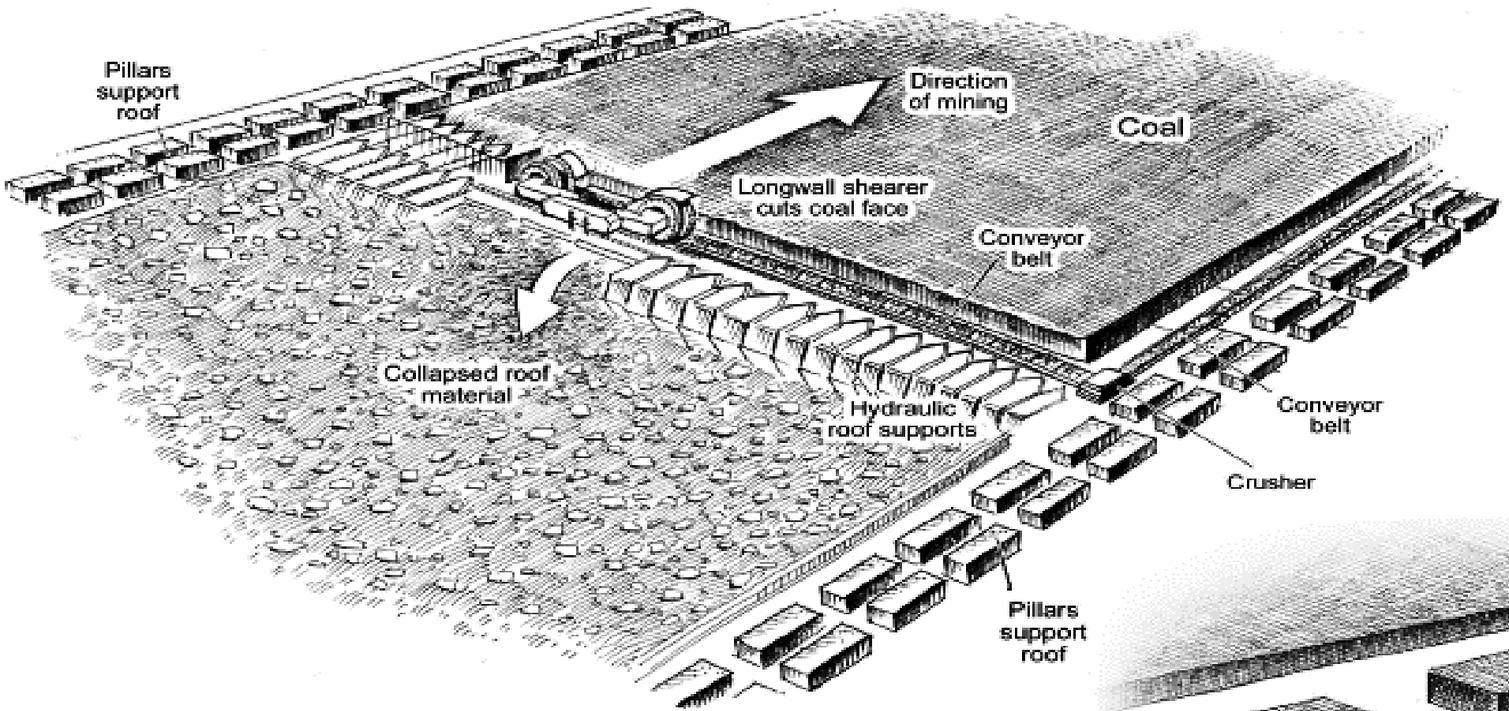
Underground Coal Mining

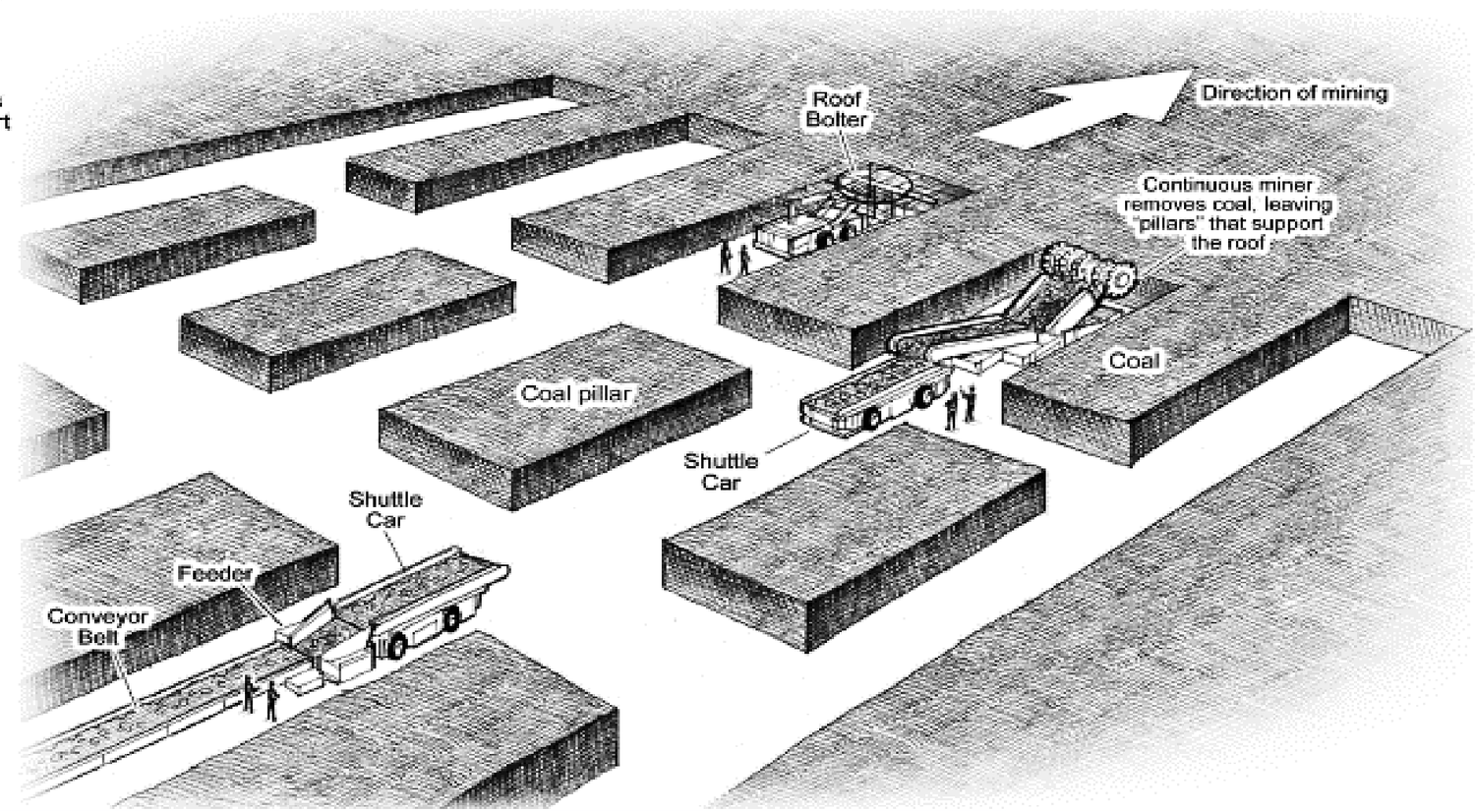
- Used when coal is deep and can't economically or physically be reached by removal of overburden
- Removal of coal underground causes sinking or "subsidence" of the ground surface
- Removed by Longwall mining or Room and Pillar mining methods

Longwall vs. Room and Pillar Mining

- In room-and-pillar mining, “rooms” are excavated, and pillars of coal are left in place between the rooms to support the mine roof.
- Longwall mining involves almost complete extraction of the coal contained in a large rectangular block or “panel” of coal, and the roof in the mined-out area is allowed to collapse. Long “chain pillars” of coal are left between the mined out panels.

Longwall vs. Room and Pillar Mining





- Artist rendering indicating the two methods of mining

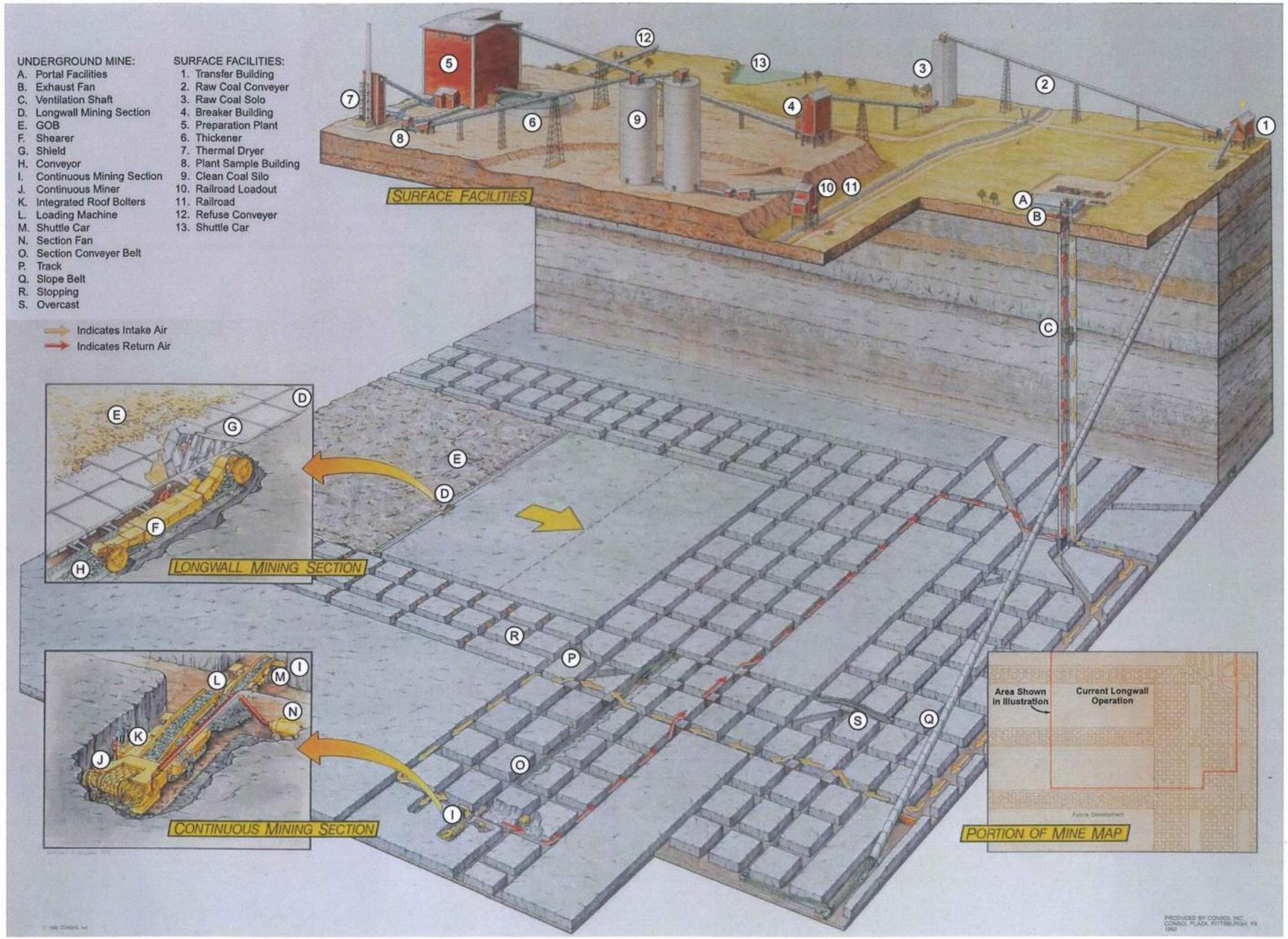


Figure 2 The conceptual diagram illustrates the parts of a modern coal mine. (Diagram used by permission of Consol, Inc.)

Longwall Mining

- Began in 17th Century England
- Technology advances in 1950s led to use in US
- In past few decades it has increased due to changes in longwall panel dimensions and improvements in longwall equipment.
- Longwall panels in Illinois are typically
  - 330 – 970 ft below surface
  - 900 – 1,800 ft wide
  - Up to 4 miles long

Benefits of Longwall Mining

- Longwall results in extraction of 90% of the coal resource vs. 50% extracted by room and pillar mining.
- Coal left by room and pillar is “lost” and can never be mined in the future
- Improved safety
- Mines are easier to manage
- Involves no blasting
- Recovers more coal from deeper beds
- The coal haulage system is simpler
- Ventilation is better controlled
- Subsidence of the surface is more predictable.

Subsidence

- Subsidence
  - Immediate and predictable
  - Somewhat uniform
  - Surface max subsidence ~70-80% of seam thickness
  - Typical Illinois subsidence is up to 6 feet in the center of panels
  - 98% + subsidence completed within a year

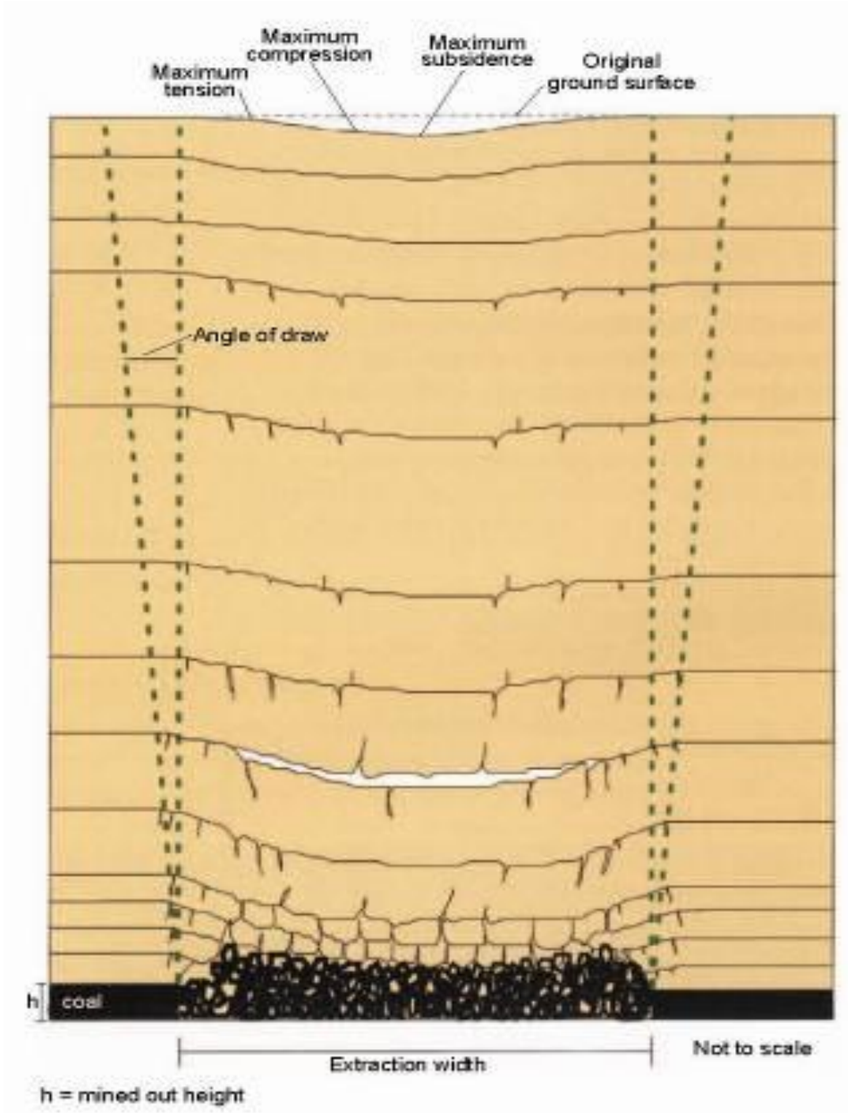
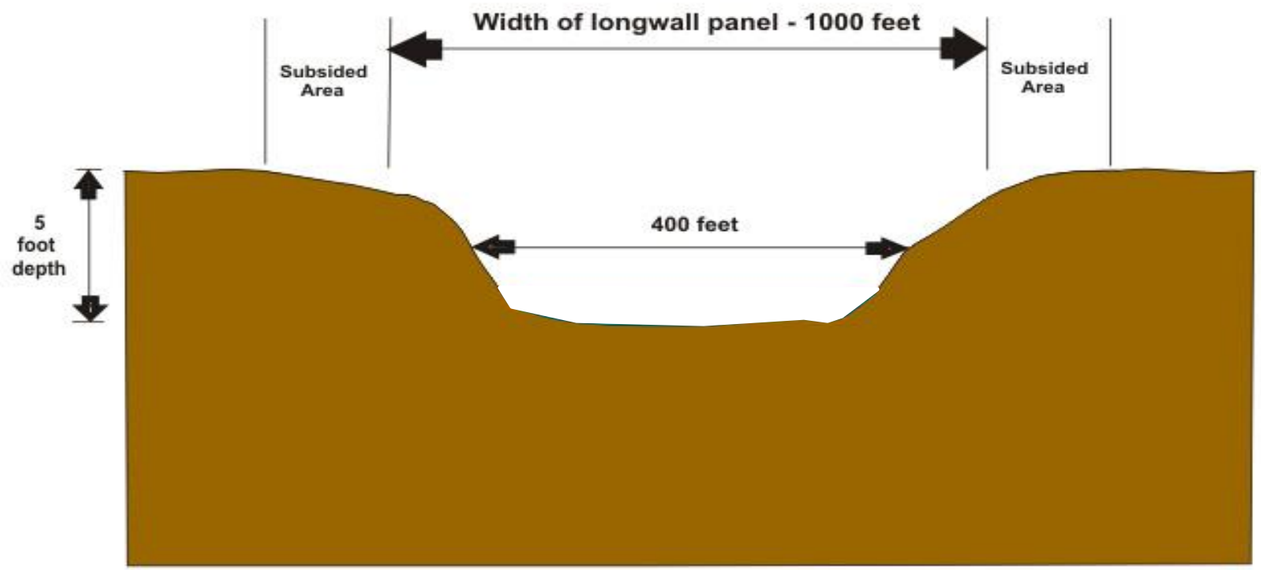


Figure 6 This schematic diagram shows the general behavior of overburden above longwall panels and the location of surface subsidence features (Peng and Chiang 1984, New South Wales Coal Association 1989).

(source: Illinois State Geological Survey, Circular 573)

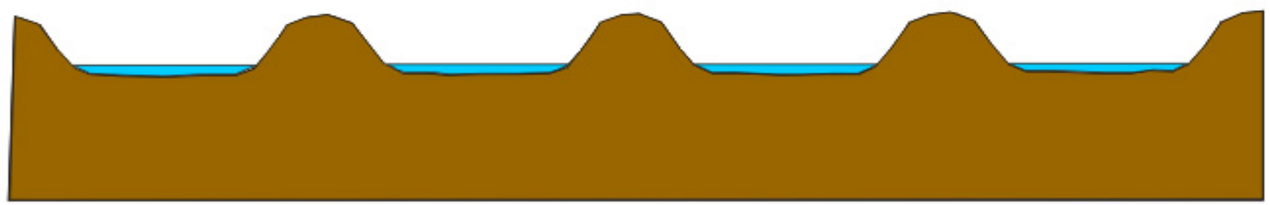
Figure 1 - Profile of a completed longwall panel - mined 700 feet deep



(Illustration above is not to scale)

Source of data: Several Geological Engineering Publications

Figure 2 - Cross sectional view of landscape change due to four longwall panels



Uplands are room and pillar access areas that only partially subside.

Why Predict Subsidence

- Subsidence can cause:
  - Ponding
  - Decrease in crop productivity (from flooding)
  - Damage to houses, barns, communication towers
  - Damage to or flooding of roads and railroads
  - Damage to utility lines (above and underground)
- Mining companies routinely correct the effects of subsidence to prevent the above from happening.
- Owners of surface properties above longwall mines are assured the surface will be restored to pre-mining capability by regulation.

Impacts to Structures

The coal company took measures to protect this home in advance of subsidence. Structures were raised from the foundations and kept level during subsidence. Foundations were restored and structures lowered onto them after damaging ground movements ceased. Foundations are often replaced during year or two after mining.

(source: Illinois State Geological Survey, Circular 573)

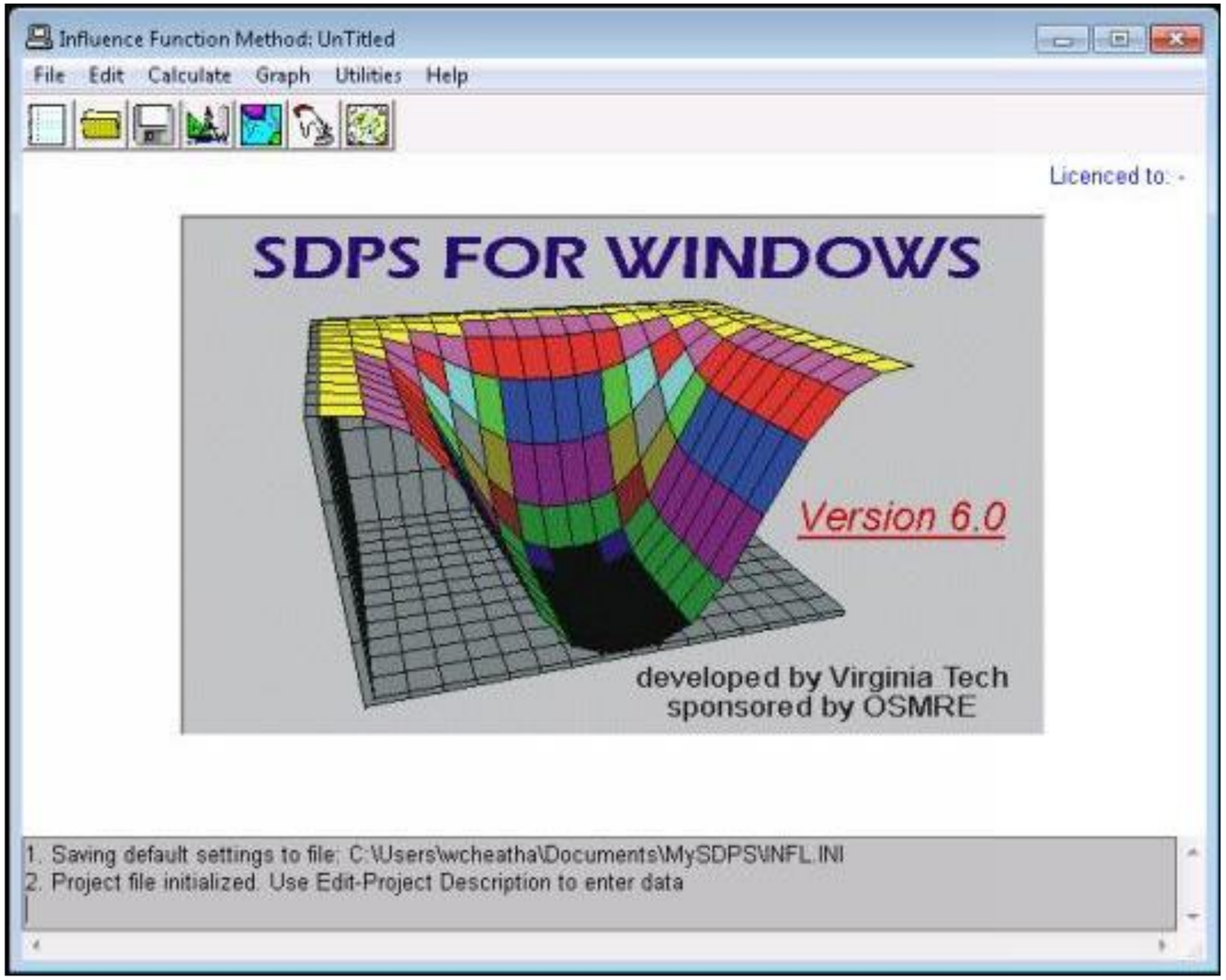
Impacts to Roads

(source: Illinois State Geological Survey, Circular 573)

Predicting Subsidence

Surface Deformation Prediction System

- Originally developed in 1987 at Virginia Tech. by Dr. Michael Karmis and Dr. Zach Agioutantis.
- Program has been refined to the Version 6.0 used today.
- SDPS uses two alternative methods for calculating subsidence:
  - Profile Function Method
  - Influence Function Method



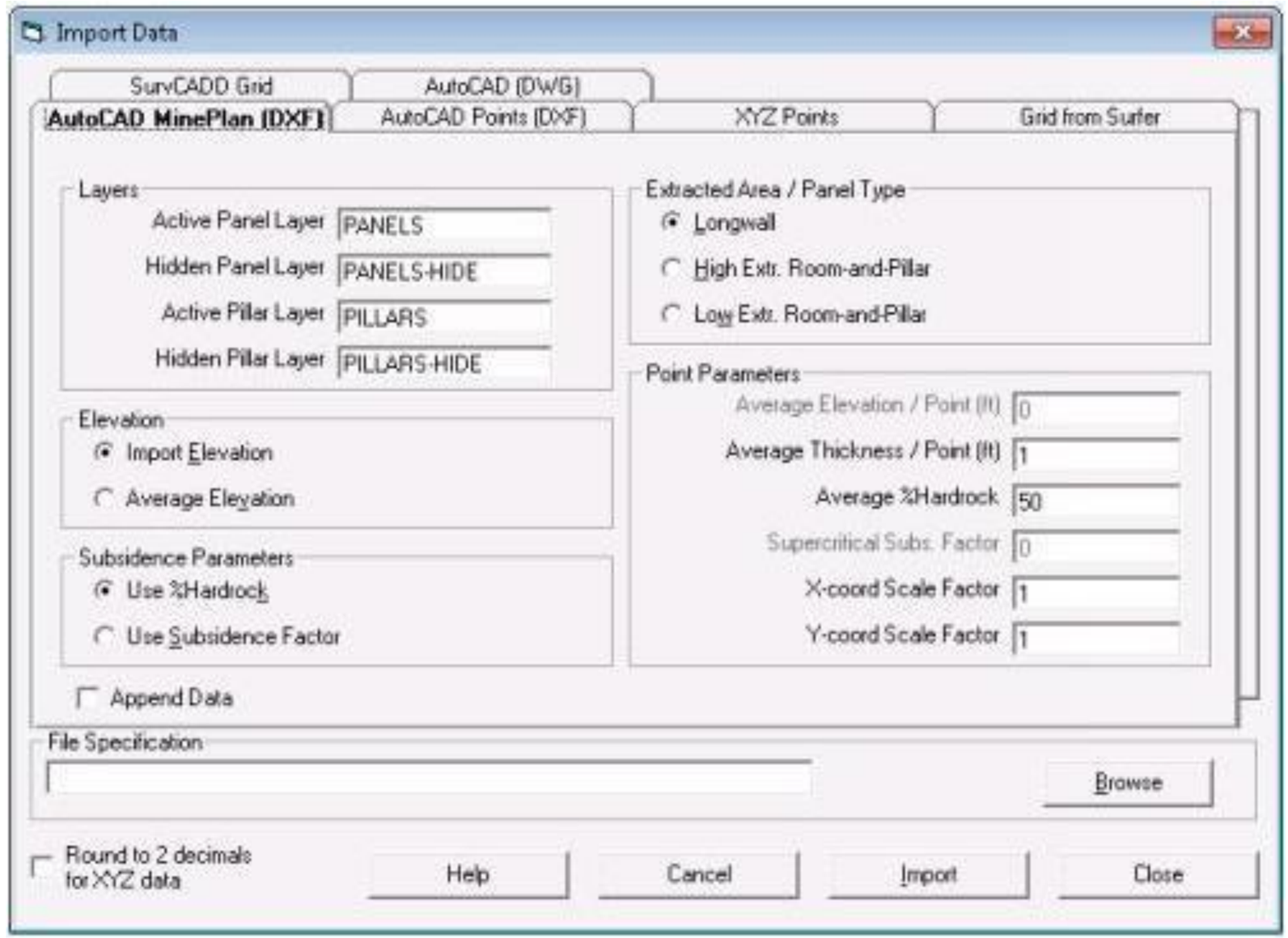
Background on the Influence Function Method

- Calculates magnitude of predicted subsidence based on the complex equation to the right.
- Factors influencing subsidence behavior include, but are not limited to;
  - Overburden depth
  - Makeup of overlying geologic strata
  - Coal seam thickness
  - Longwall panel geometry (width, length, etc.)

$$S(x,s) = \frac{S_{max}}{r} \int_{x_1}^{x_2} S_0(x) exp\left[-\pi \frac{(x-s)^2}{r^2}\right] dx$$

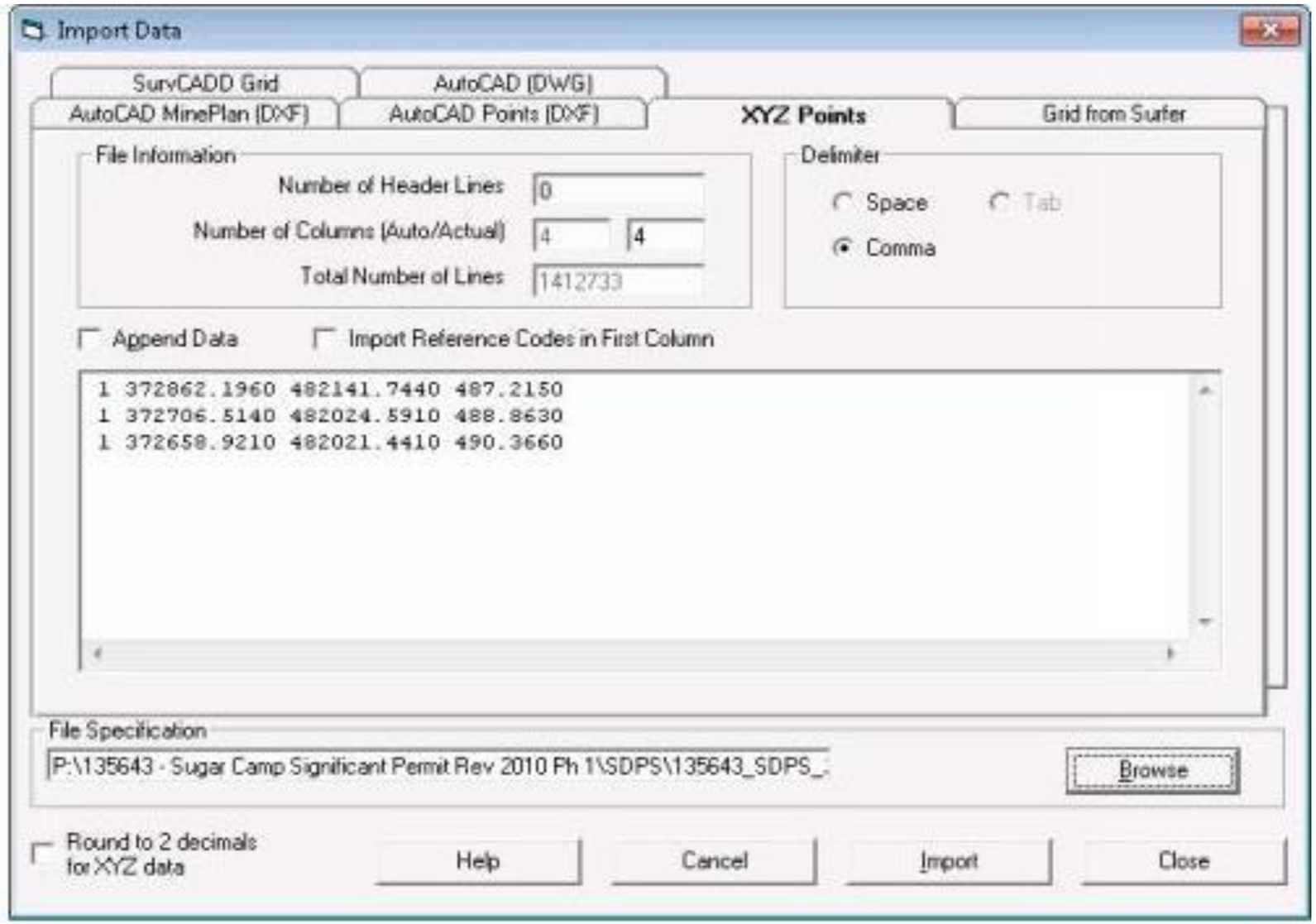
SDPS Imports a Mine Plan with AutoCAD

- The geologic boring data is used in conjunction with AutoCad to develop a surface model for the top of coal seam.
- The average % hardrock and coal seam thickness is also determined and entered into this section to aid in the subsidence modeling.



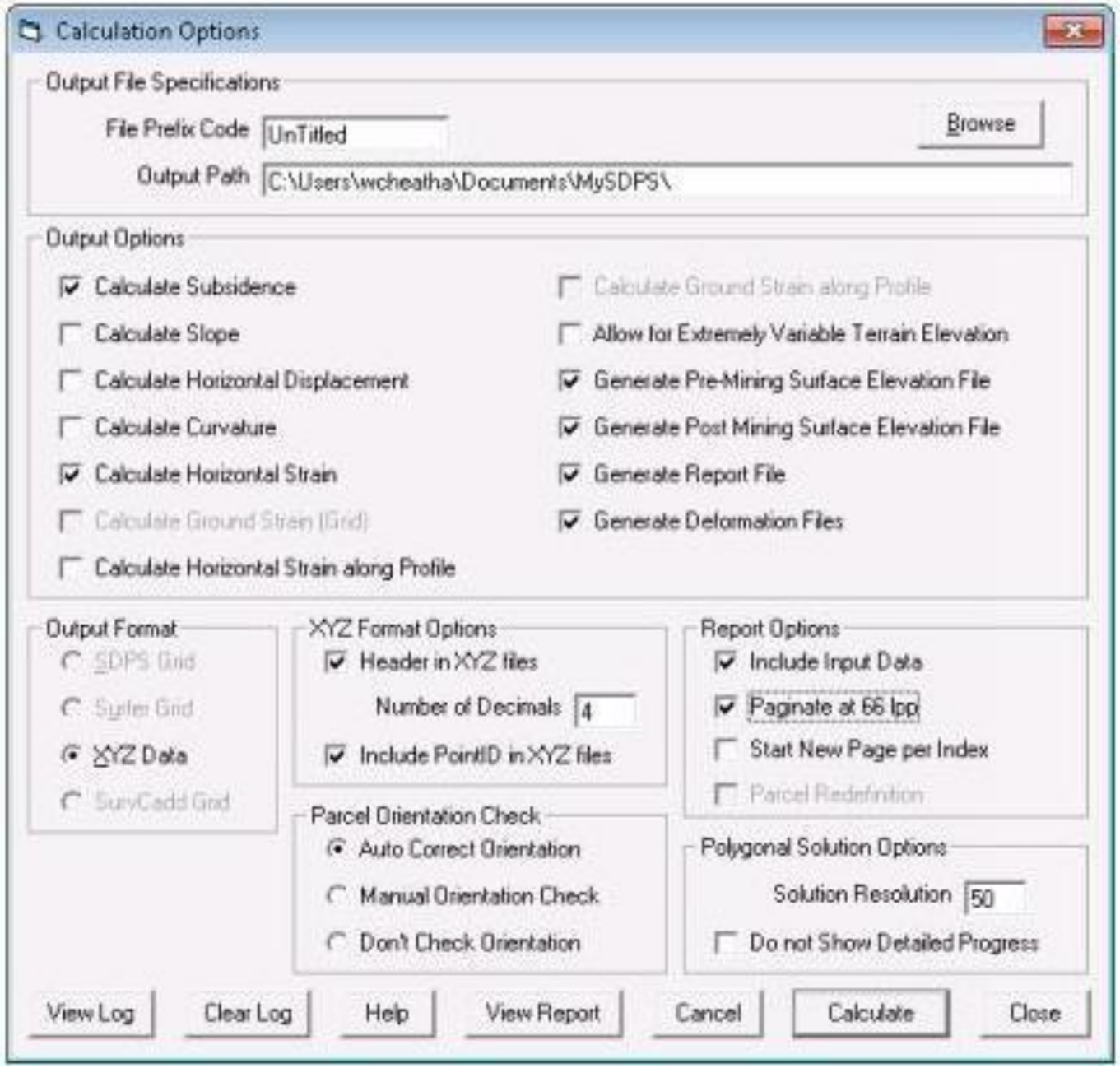
SDPS Imports Ground Surface Topography Points as Text

- To get the best predictions, we take the points and breaklines used to generate the flown topographic contours and turn them all into points using Bentley's Geopak program. This program will assign point codes to enable the lines to be reassembled after the points are subsided with SDPS.



SDPS Calculates Subsidence and Creates Text Files

- SDPS will generate several text files based on the selections made.
- We use these files to generate predicted ground surface contours and ponding in Microstation/Geopak or AutoCAD/Civil 3D.



Typical Post Subsidence Map

- Prepared as a requirement of OMM mine permit application.
- Map Illustrates important features related to the subsidence caused by the mining.
  - Isopachs
  - Limit of predicted subsidence
  - Ponding depressions or other areas that may require corrective measures to drain properly after mining has occurred.
  - Angle of draw

Typical Stream Subsidence Map

- Indicates the effects that the subsidence may have on established waterways and insures that these effects can be mitigated before mining actually takes place.
- This map coupled with the stream profiles offers a conceptual estimate of the work involved to maintain positive drainage.

Typical Stream Profiles

- Compares the existing waterway profile to the post mining waterway profile and indicates areas that need correction as well as the extent of the work involved.
- Stream profiles typically need adjustment at the chain pillars and any other areas where subsidence is minimal or does not occur.

Questions?