Agricultural Impacts of Longwall Mine Subsidence: The Experience in Illinois, USA and Queensland, Australia

Robert G. Darmody, Robert Bauer, and Dan Barkley

Univ. of Illinois, Illinois Prairie Research Inst., and Illinois Natural Resources Dept., USA

and

Stuart Clarke and David Hamilton

Bandanna Energy Limited and Agricultural Coexistence Research Committee, Australia

Longwall Mining Advantages

- High extraction ratio
- Safety
- Lower cost
- Works well in Illinois, Queensland
- Planned subsidence

Longwall Mining Disadvantages

- Subsidence
- About 70% subsidence or 1.2 to 1.5 m of surface subsidence, typically in Illinois
- First done in 1856, by hand, by late 1970's advanced dedicated machinery was being adopted.
- Concerns about subsidence lead to citizen opposition.

A Community Divided

Illinois Times

Free
March 23-29.06

THE RETURN OF KING COAL

FARMERS IN CENTRAL ILLINOIS FIGHT A NEW THREAT – A METHOD OF MINING THAT WILL CHANGE THEIR LAND FOREVER

By BRUCE RUSHTON p10

Schultz

Similar Concerns In Australia

Morning Bulletin, Rockhampton QLD. 13 Sep 2013:

Locals List Their Concerns For Land

EMERALD: Flooded houses, subsidence, and concerns over accountability were issues raised by landholders affected by Bandanna Energy's Springsure Creek project at a meeting. Members of the community met with the Agricultural Co-Existence Research Committee (ACRC) to discuss their concerns:

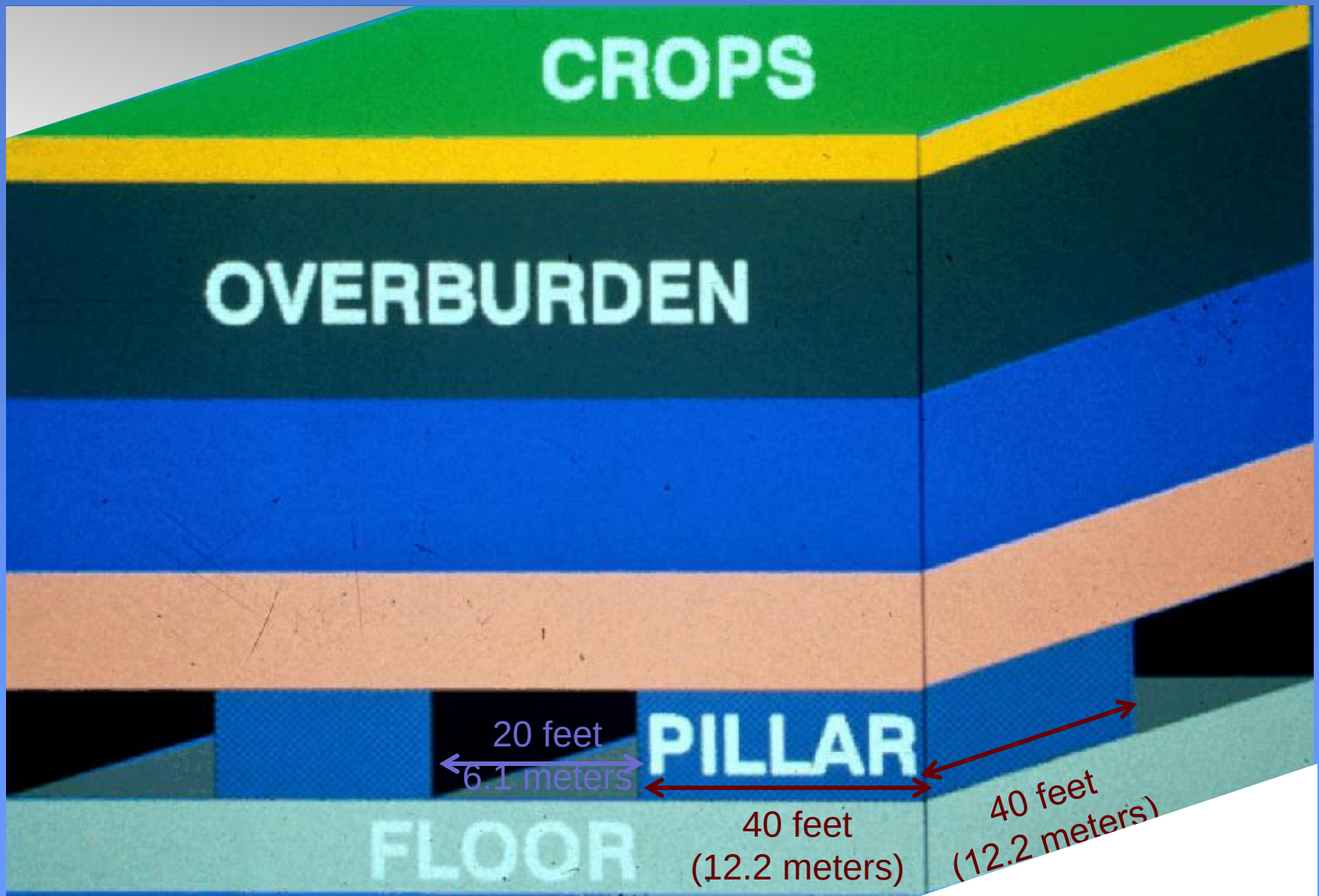
"We will have the most significant area of subsidence, as much as 2.7m. So to say the mine company is going to put contours in and manage that water flow, well that sounds right, but there hasn't been a soil survey across the block, so how much soil will I have left to grow my crop on?"

David Hamilton, from the committee, said research would be undertaken concerning that issue.

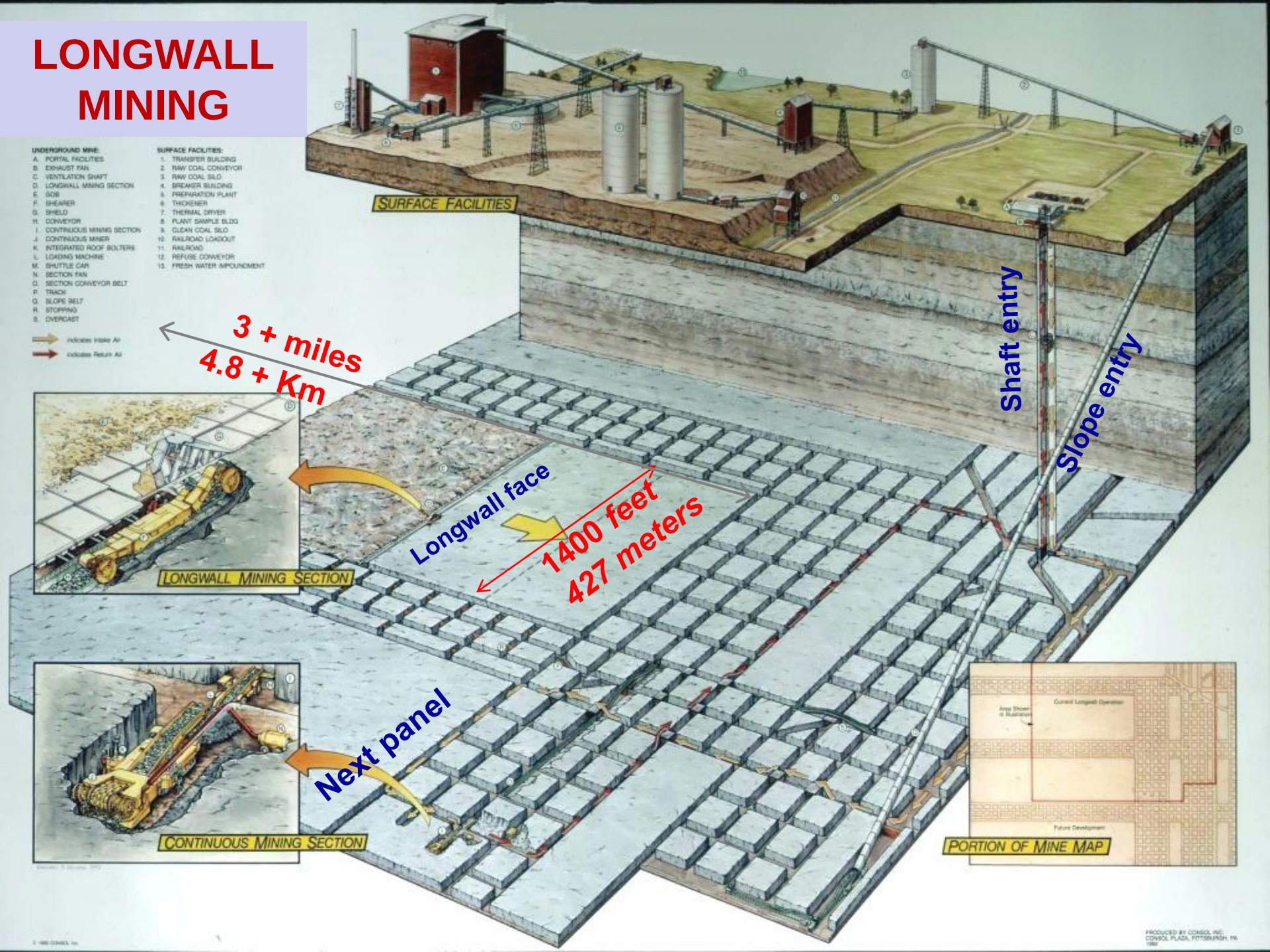
Potential Agricultural Impacts of Longwall Mine Subsidence

- Damage to structures and buildings
- Surface cracks
- Erosion and slope instability
- Disruption of surface and groundwater (salt)
- Increased soil wetness and ponding
- Access to fields, farming patterns disrupted
- Depressed crop yields

Room and Pillar Mining



LONGWALL MINING



Surface crack development

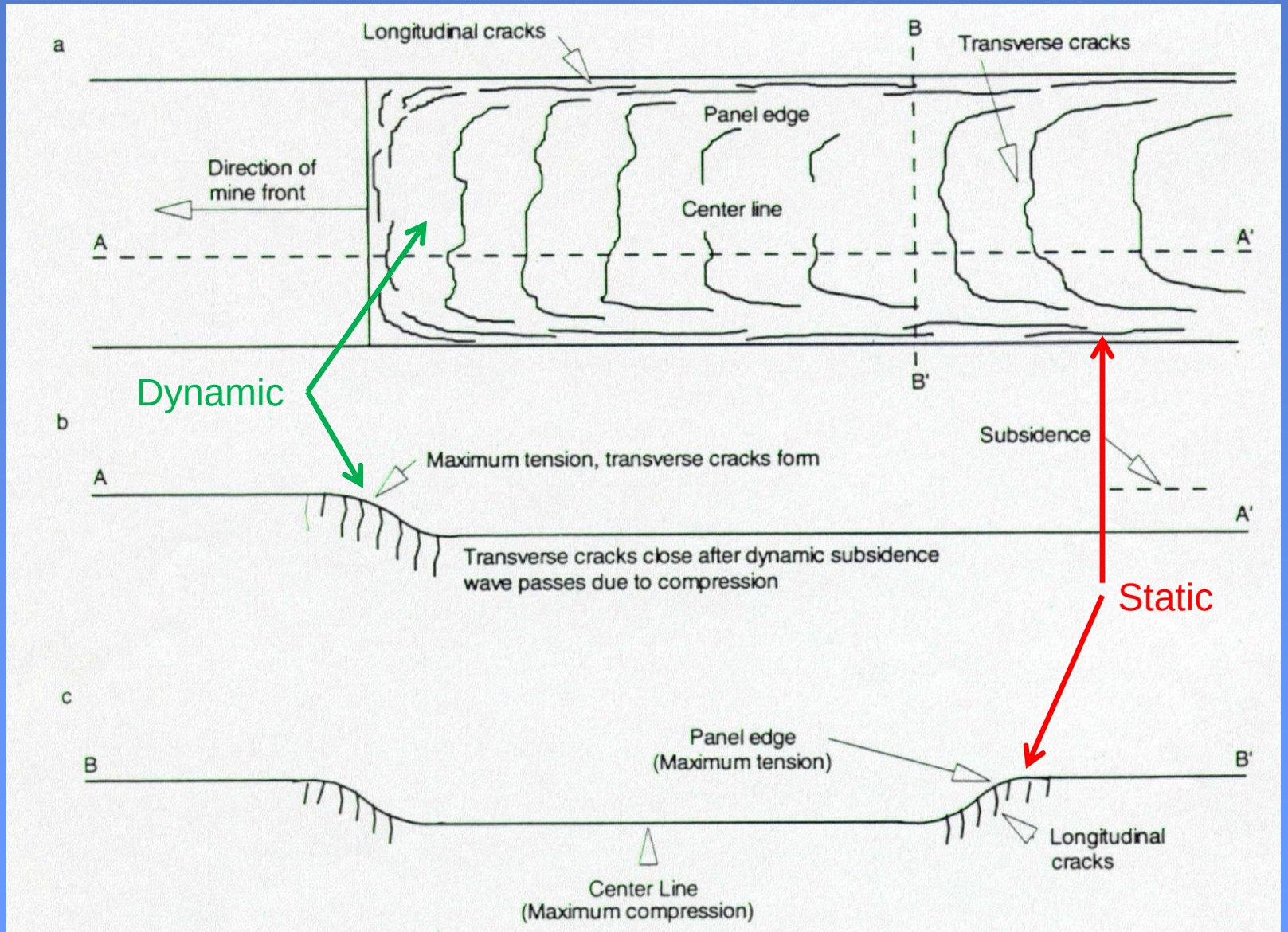


Figure 3 Formation of subsidence cracks above a longwall mine panel.


Extreme case, Not typical magnitude
TENSION


Extreme case, Not typical magnitude
COMPRESSION

Queensland, Australia and Illinois, USA

- Substantial coal reserves
- Longwall mining is a preferred coal extraction method
- High quality agricultural land
- Local opposition to mining
- In Queensland, coal is owned by the government
- In Illinois, coal is privately owned

1977 US Federal Surface Mine Control and Reclamation Act (SMCRA)

- Created the federal Office of Surface Mining (OSM)- Department of Interior
- Created a federal coal severance tax for an abandoned mine reclamation fund
  - Surface Mining = 31½ cents/ton
  - Underground Mining = 15½ cents/ton
- State Primacy: Illinois' Office of Mines and Minerals became the lead regulatory authority in 1983.

Permitting vs. Performance Standards Illinois

- Regulatory Permit Standards detail what is needed to receive approval to begin mining operations.

- Regulatory Performance Standards measure the ability of a company to maintain an operation during the life of the facility.

Permitting Process

Queensland

- Mineral rights are owned by the State Government
- Commonwealth plus State Gov. approval required
  - Commonwealth – Matters of National Environmental Significance (e.g. rare or endangered species, water)
  - State – Mineral rights environment and social

Springsure Creek Project – regulatory approval process

- At the State level
  - New and changing legislation relevant to the political party and public perceptions/populist politics in government (3 year election cycle)
  - Multi agency
  - Different statutory timeframe requirements (some legislation has timeframes and others don't)
  - Company driven coordination between government departments and between different legislation

Springsure Creek Project – regulatory approval process

- Mining Lease =
  - Environmental approval (including public consultation)
  - Strategic Cropping Land approval
  - Landholder approval for access and surface disturbance (negotiated agreements)
  - Cultural Heritage approval (negotiated agreements)
  - Native Title approval (negotiated agreements)
  - Overlapping tenure holder approval (negotiated agreements)
  - Local Government approval for access and services (negotiated agreements)

SUBSIDENCE CONTROL PLAN
Illinois

- Existing and projected contours required
- Projected Contours define potential drainage problems
- Drainage interruptions must be corrected
- Addition of drainage tile may be needed to supplement surface drainage
- Temporary crop damage compensation is required until repair is complete

Legal Rights Necessary

For longwall mining in Illinois, company must have:

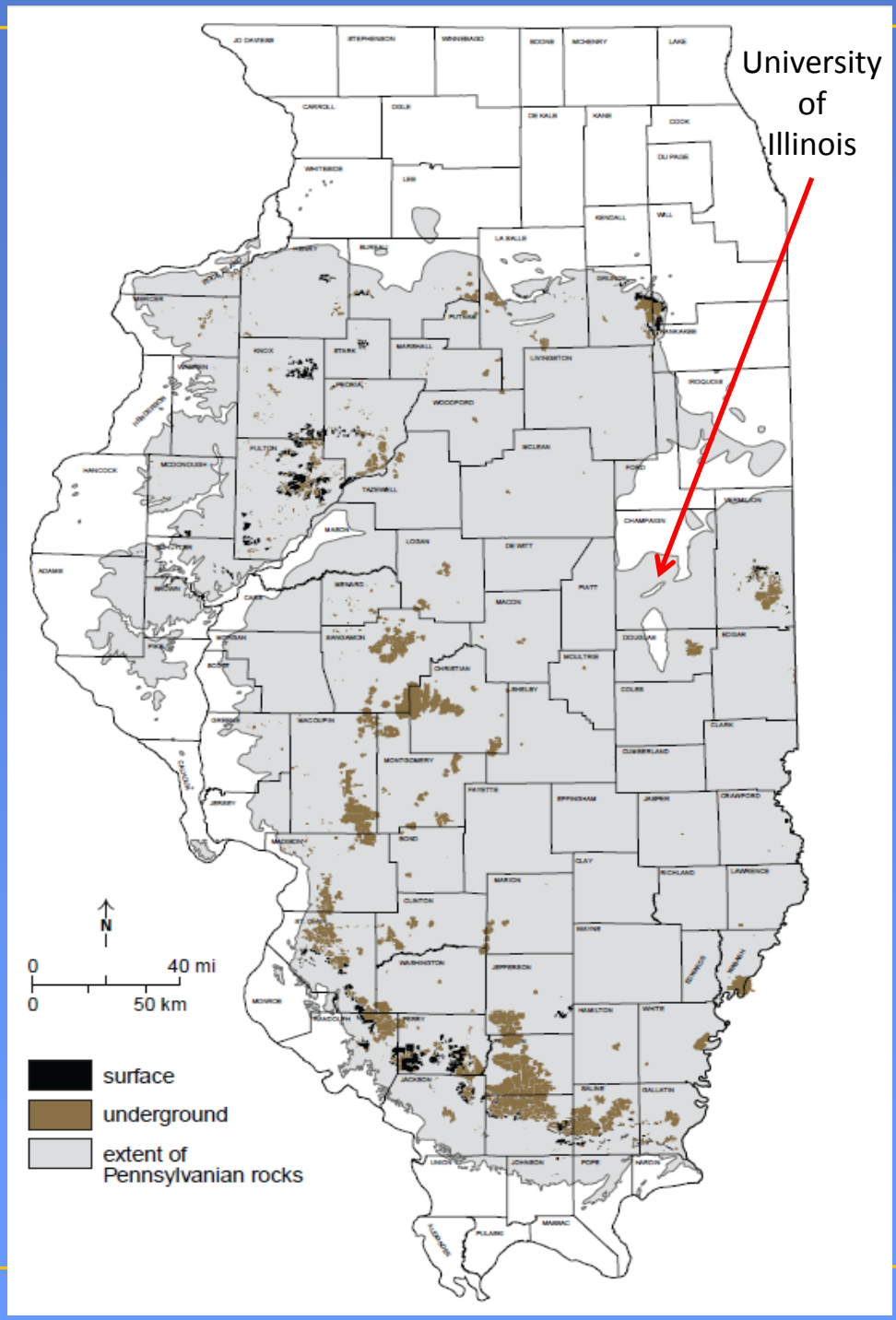
- Right to Mine the Coal
- Right to Subside the Surface
  - Part of the coal severance deed
  - Obtained as a separate agreement with surface owner
- Rights must be in place prior to subsidence

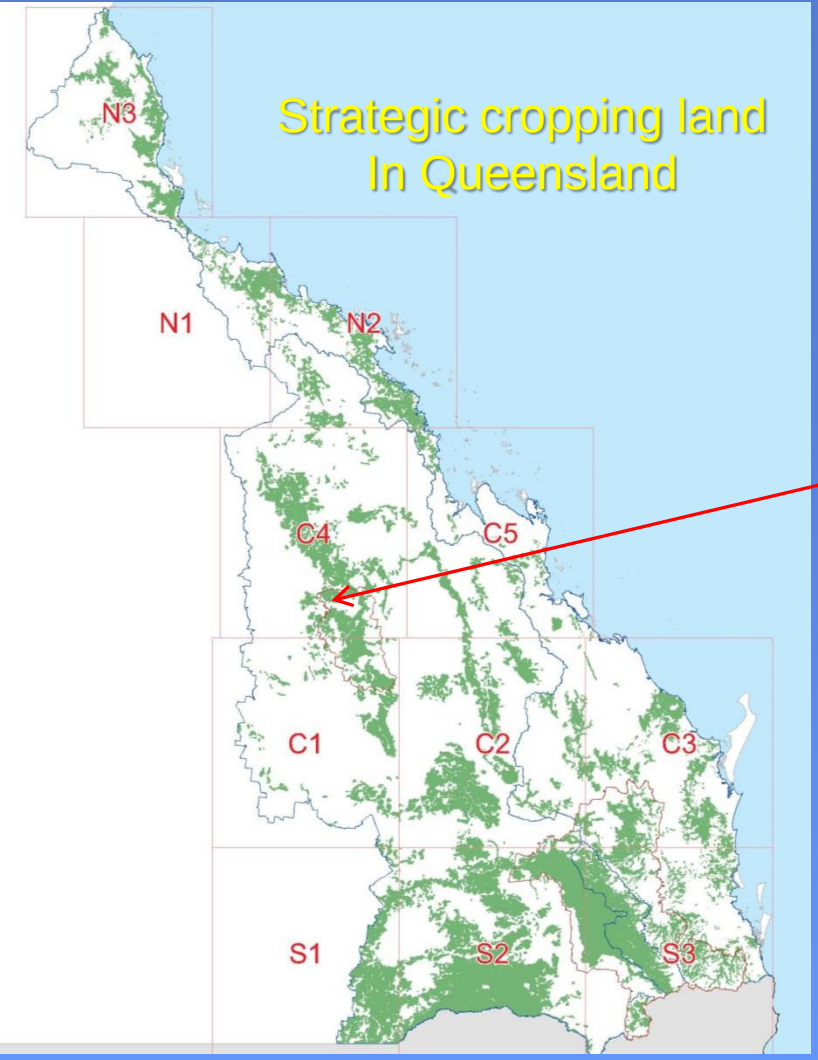
Performance Standards for Subsidence Impacts, Illinois

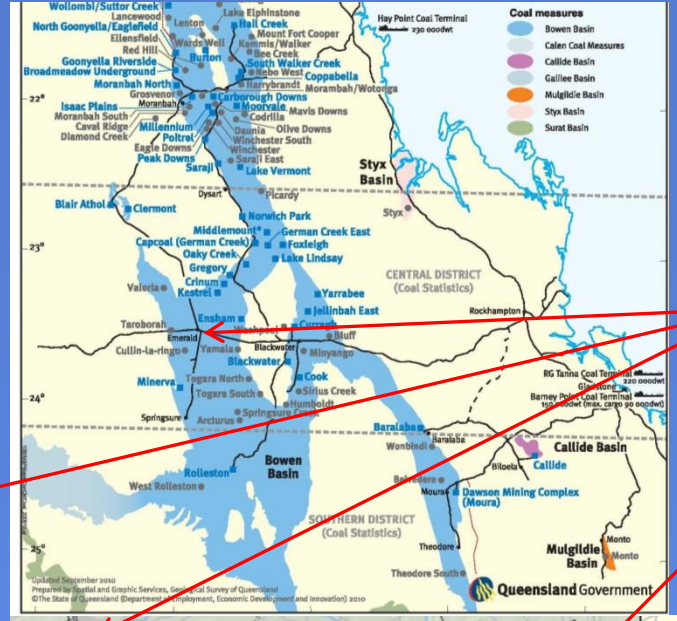
1. All land must be restored to its pre-mining capability
2. All structures must be repaired, replaced or compensated for
3. All drinking and domestic water supplies (wells and springs) must be restored or replaced

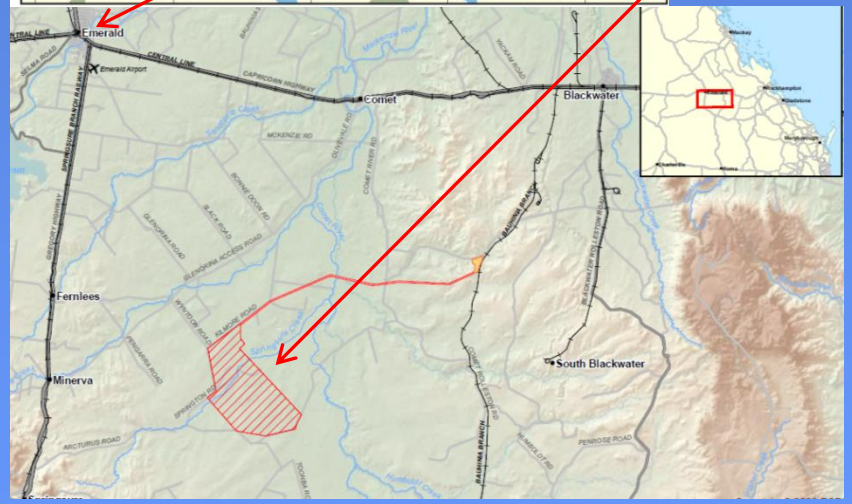
Map of Illinois showing extent of coal reserves and mined out areas from both underground and surface mines.

This is also a very productive agricultural area of fertile, nearly level soils i.e. “Prime”.





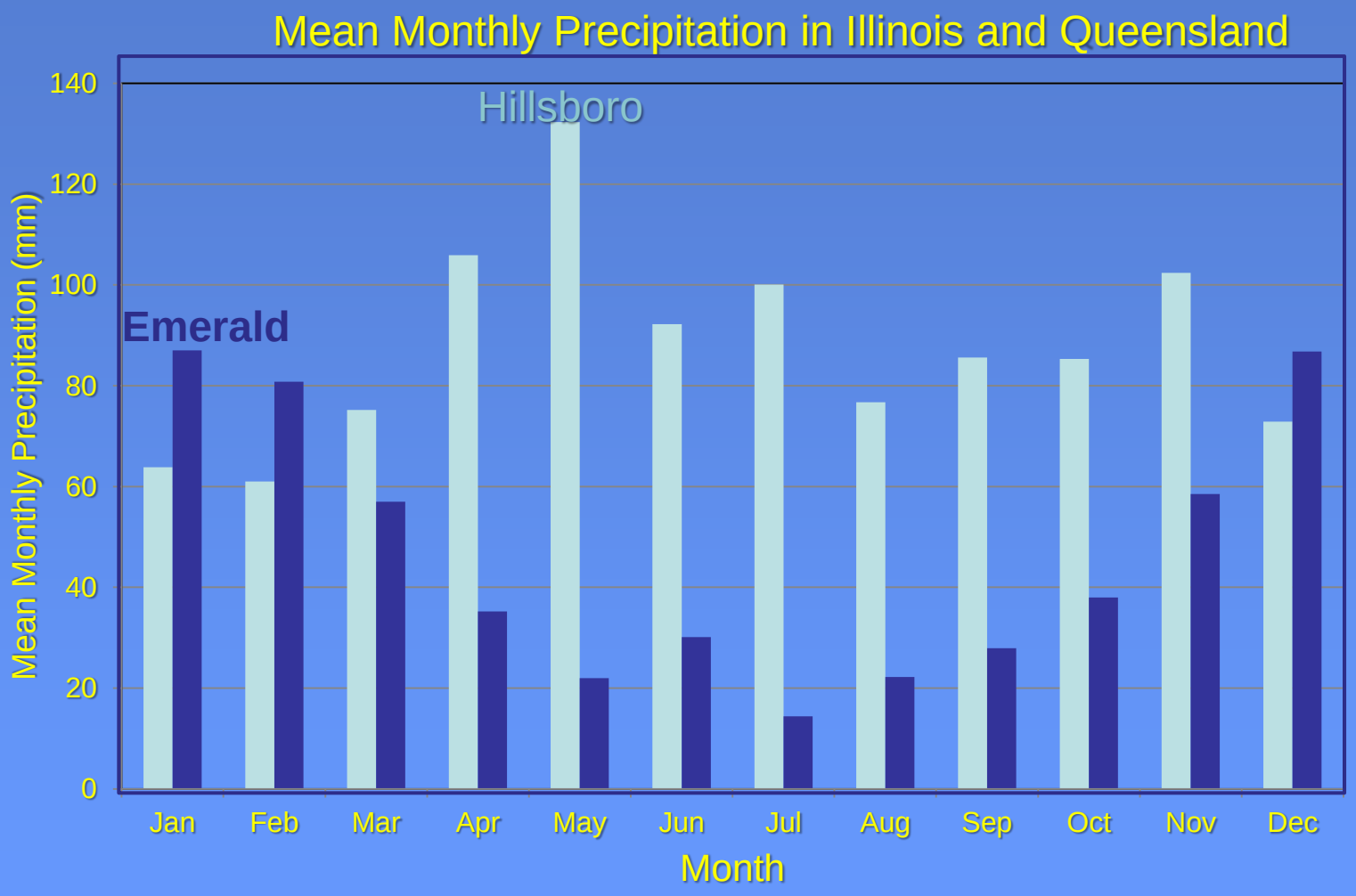




"The Queensland Government is committed to protecting the State's best cropping land, called strategic cropping land, from development that will have an adverse impact on the productive capacity of the land."

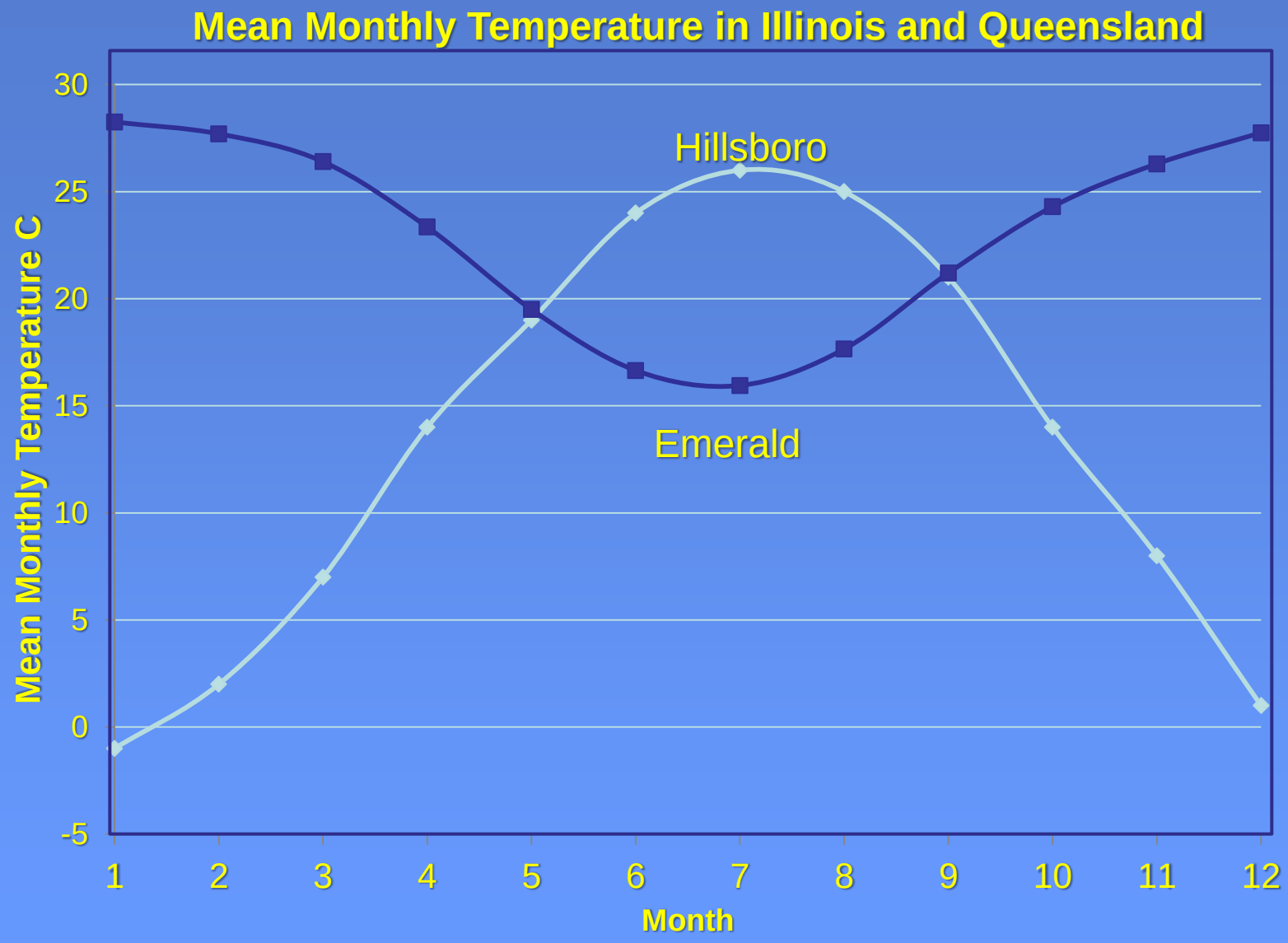
http://www.nrm.qld.gov.au/land/planning/strategic-cropping

Climate: Queensland vs Illinois



Mean annual precipitation (mm); Hillsboro 1053, Emerald 563.

Climate: Queensland vs Illinois



Mean annual temperature (°C); Emerald 23, Hillsboro 13.

Illinois farmland in spring, soils tend to be somewhat poorly drained, note ponded areas

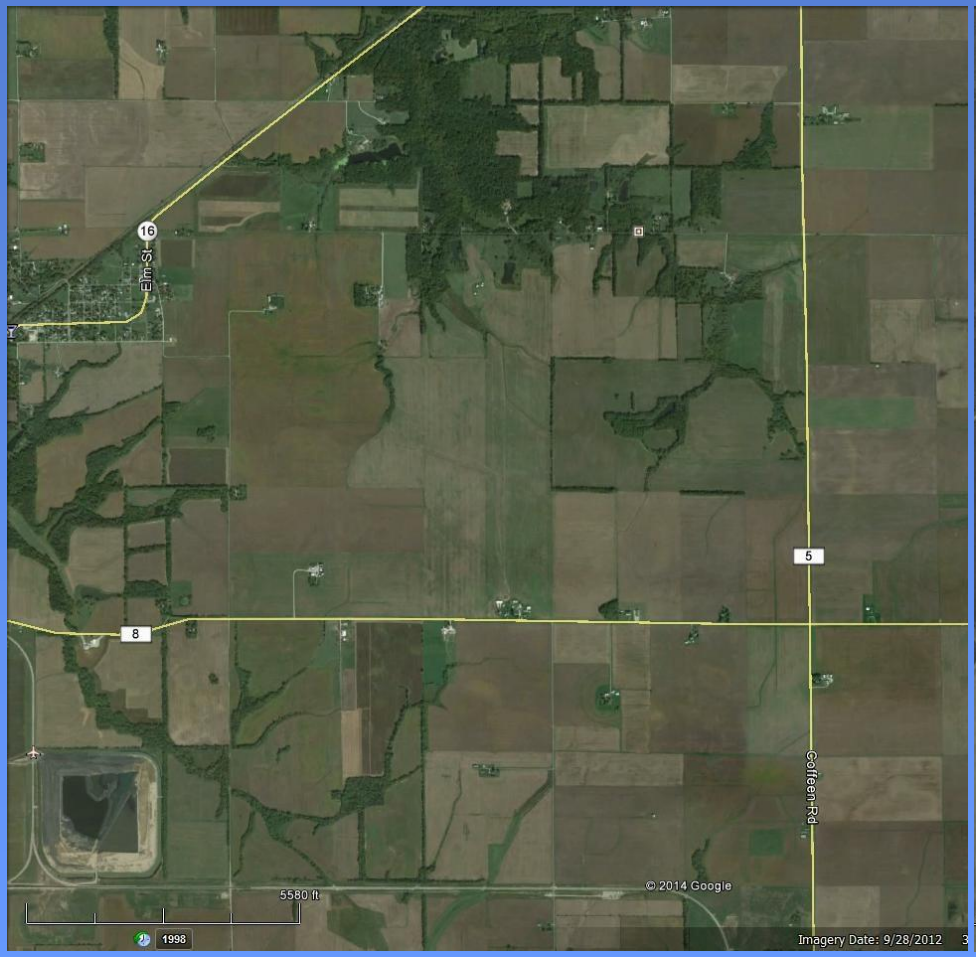
Soils: Queensland vs Illinois

Queensland Vertisol

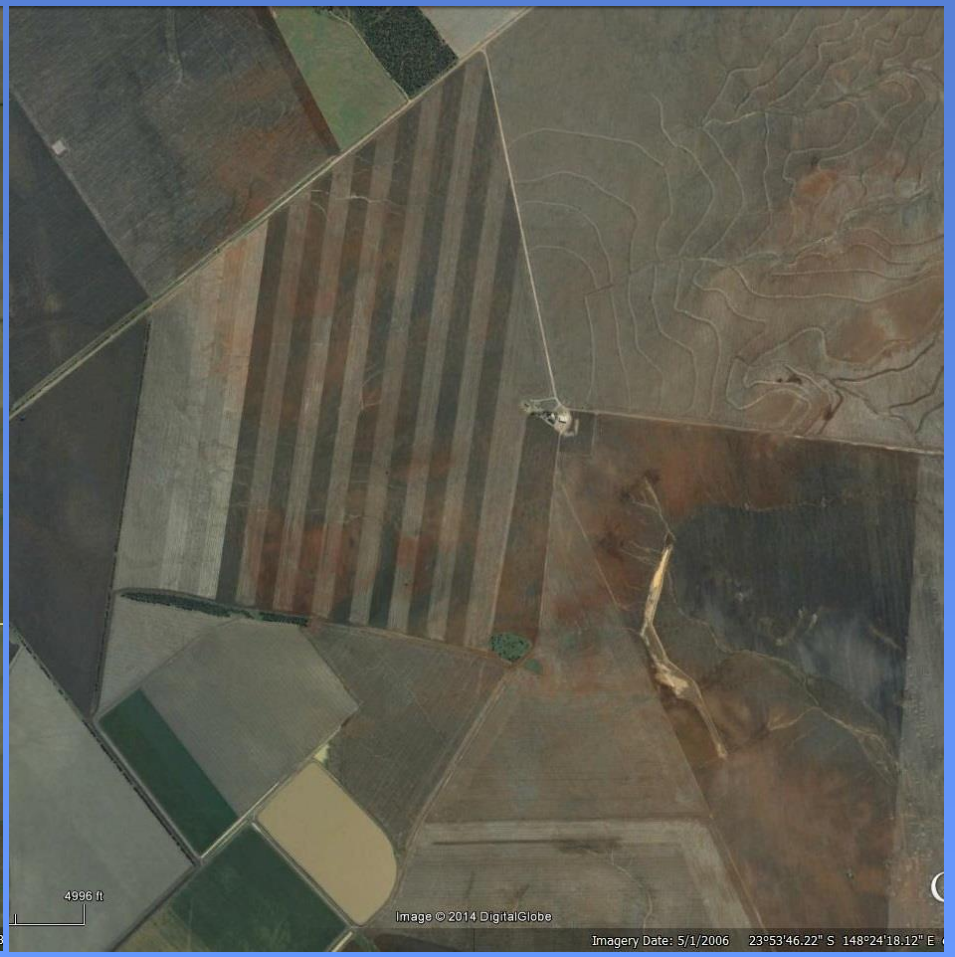
Illinois Alfisol

Soil mapping is extensive in Illinois (1:15,840), not as developed in Queensland.

Land Use: Queensland vs Illinois



Near Hillsboro, Illinois



Near Emerald, Queensland

Google Earth Images

Land Use: Queensland vs Illinois

Flat topography + Longwall mining + Poorly drained soils = Bad combination

Unmitigated subsidence, Illinois

Photo courtesy of Dan Barkley

Subsided area in Illinois farmland in late spring

Subsided area in Illinois farmland in early summer

Longwall Mining Subsidence and Mitigation Agricultural Concerns

- Unknown effectiveness in restoring agricultural productivity
- Citizen suspicion of techniques and approaches of mining mitigation
- Citizen concerns about possible effects of mining on water resources, farmland productivity, structures, and environment.

Illinois Mine Subsidence Research Program (IMSRP)

- Sponsored by Illinois Farm Bureau, IL Coal Association, US Bureau of Mines, and IL Coal Development Board, started in 1985.
- University of Illinois and State Geological Survey Cooperated.
- University was responsible for investigating agricultural impacts.
- Included assessment of subsidence mitigation effectiveness on agriculture.

Specific Objectives of ISMRP

- Determine impact of mine subsidence on agricultural soils.
- Determine overall impact of coal mine subsidence on crop yields.
- Determine effectiveness of subsidence mitigation on crop yields.

Coal Mine Subsidence In Illinois ISMRP

- We conducted 9 years of research under the Illinois Mine Subsidence Research Program (IMSRP).
- In addition to the research findings, mining companies and regulatory agencies in Illinois now have 30 years of experience with over 285 modern mechanized longwall panels.

Illinois Mine Subsidence Research Program

- Agricultural impact assessment method:
  - Measured aerial extent of mine subsidence on infrared aerial photos.
  - Included three levels of impact; low, medium, high.
  - Took crop yields from subsided areas.
  - Related yield reduction in subsided areas to nearby undisturbed fields with similar soils.

Aerial photos were used to locate subsided areas for study of the effects of unmitigated subsidence on corn yields

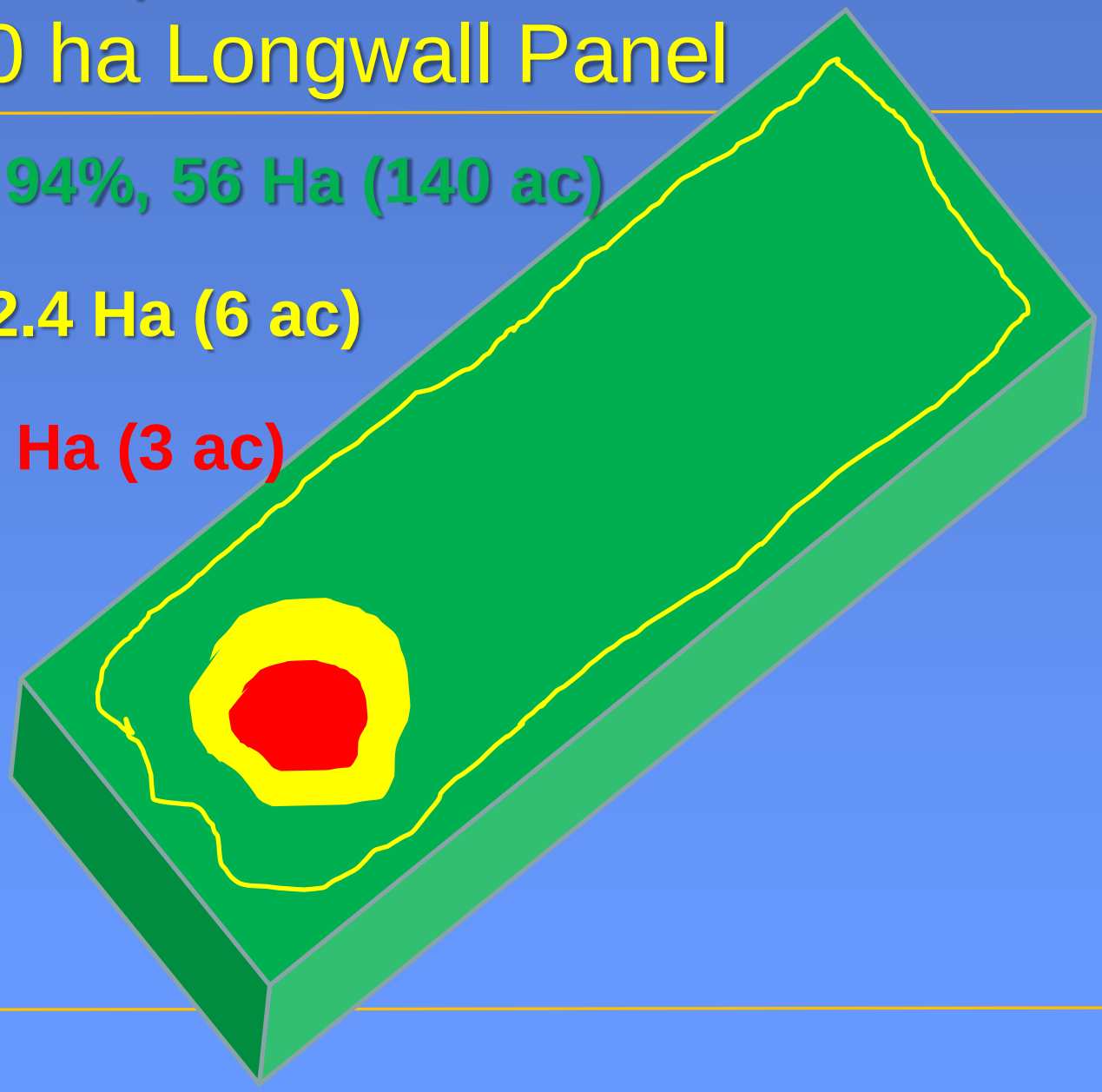
Subsidence Impacted Areas on a Typical 60 ha Longwall Panel

None to Slight 94%, 56 Ha (140 ac)

Moderate 4%, 2.4 Ha (6 ac)

Severe 2%, 1.2 Ha (3 ac)

+ Cracks



Crop yields on subsided and nearby references areas were determined by hand harvesting.

Field Measured Subsidence-Induced Corn Yield Reduction, IL

Subsidence Effects Class	Corn Yield Reduction %			
	Year 1	Year 2	Year 3	Average
Slight	---------- Not Significant ----------			
Moderate	52	56	22	43
Severe	95	99	91	95

Overall Subsidence –Induced Reduction in Corn Yield

Mining Type	Corn Yield Reduction % †			
	Year 1	Year 2	Year 3	Avg.
Longwall	7.4	4.2	2.4	4.7
High Extraction Retreat	2.4	2.2	0.9	1.8

† Weighted average reduction in yield.
Includes the yield reduction weighted by the impact class area.

Subsidence impact is strongly related to soil slope

Slope Range %				
0 - 1.5	1.5 - 4	4 - 7	7 - 12	>12
---- Frequency of Moderate Plus Severe Subsidence Impacts (%) ----				
53.6	27.6	13.0	5.8	0

Methods of Longwall Mining Impact Mitigation; Illinois

- To remedy Illinois condition of ponding from subsidence:
  - Cut drainage ditch
  - Add fill
  - Re-contouring
  - Any combination of the above methods

Raised road grade and large culvert to remove excess water, IL


Installation of drain tile to remove excess water, Illinois

Broad waterway with subsurface tile inlet in IL

Crop Yields on Mitigated Subsidence Fields

Crop	Year 1	Year 2	Year 3	Year 4	Mean
	Yield Difference on Mitigated Subsidence Fields (% of ref.)				
Corn	101	93	71*	70*	81*
Soybean	96	124*	86*	81*	93

* significant at 5% level, includes a “snap shot” of mitigation success, some sites would be re-mitigated.

IMSRP research sites were those identified as severally impacted and in need of mitigation

Summary of IMSRP Subsidence Research on Crop Yields

- Soil chemistry or physical properties did not control yield variability.
- Weather has a profound impact on subsided soils, wet sites pond rain water.
- Soybean yields were not different, but corn yields were lower in mitigated areas.
- Success of mitigation depends on local conditions and effort applied to correct problems.

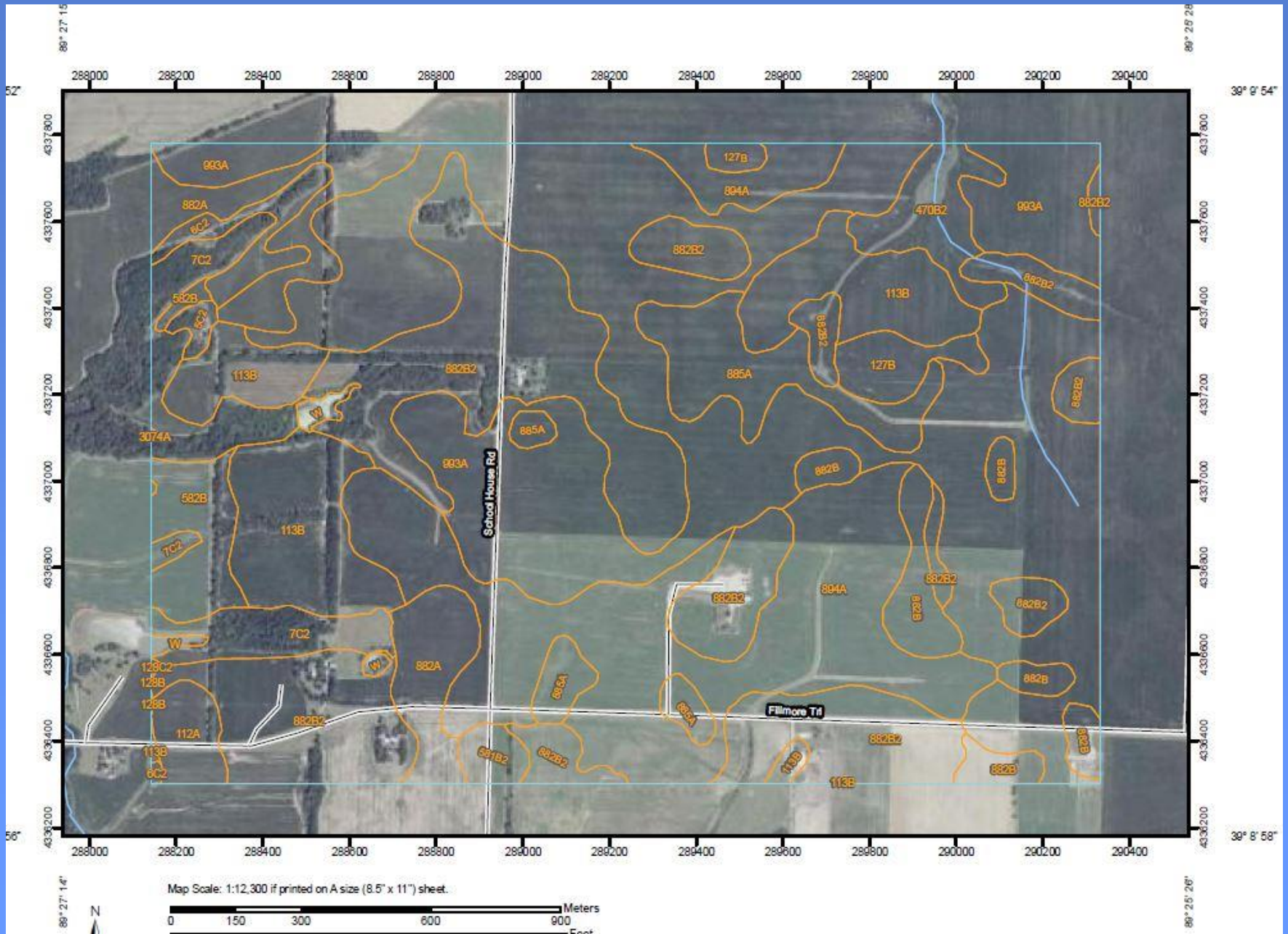
Subsided Illinois Farmland, Before Mitigation

Subsided Illinois Farmland, after Successful Mitigation

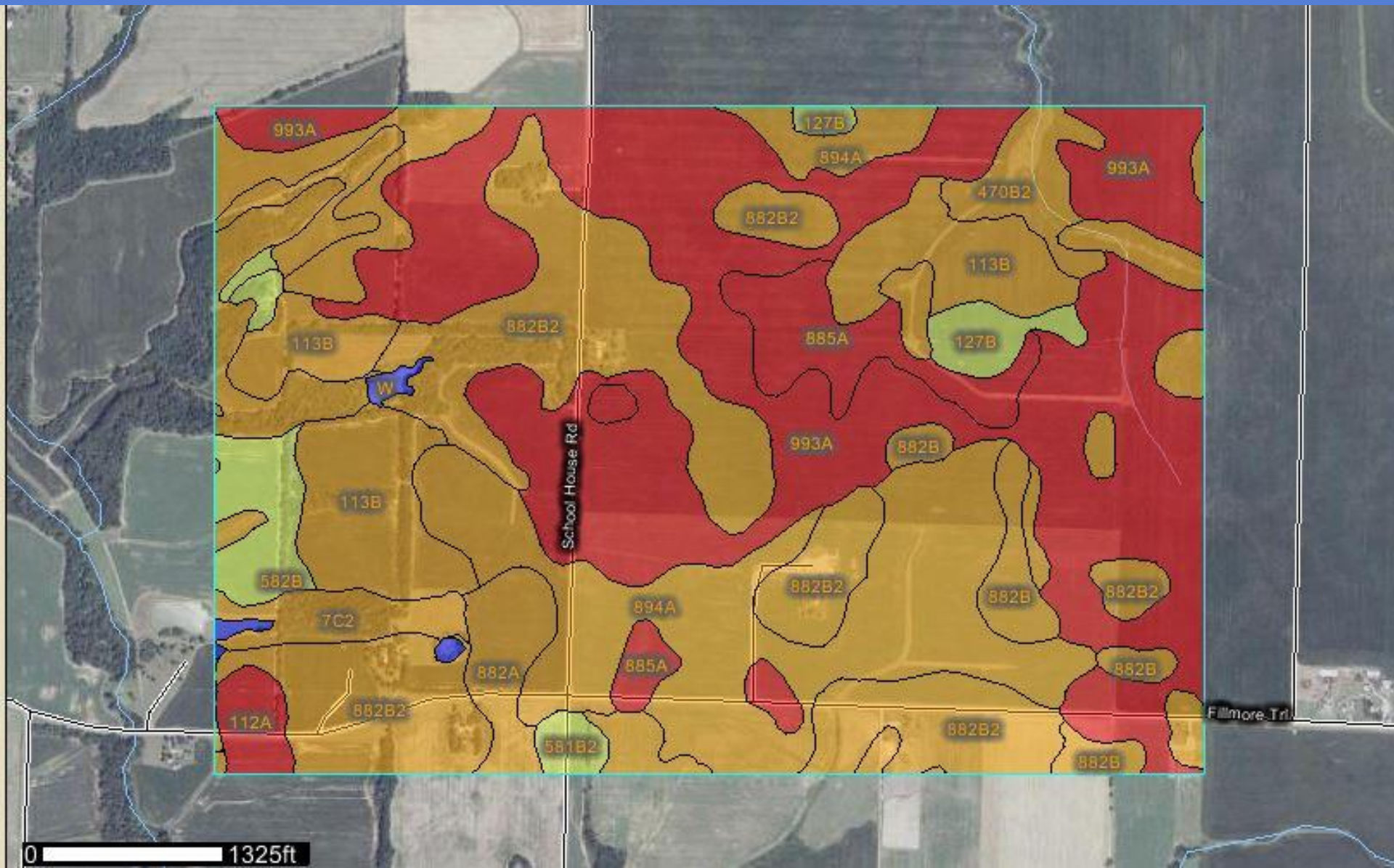
Subsidence and Agriculture Research in Queensland

- The Springsure Creek Agricultural Coexistence Research Committee (ACRC) has been established by Bandanna Energy to guide the Coexistence Research Program for the Springsure Creek Coal Project
- Bandanna Energy has allocated ~$3.5M AUD to support ACRC
- Research project areas proposed and “Expression of Interests” solicited from independent researchers
- Social science projects are included
- http://www.springsurecreekacrc.com.au

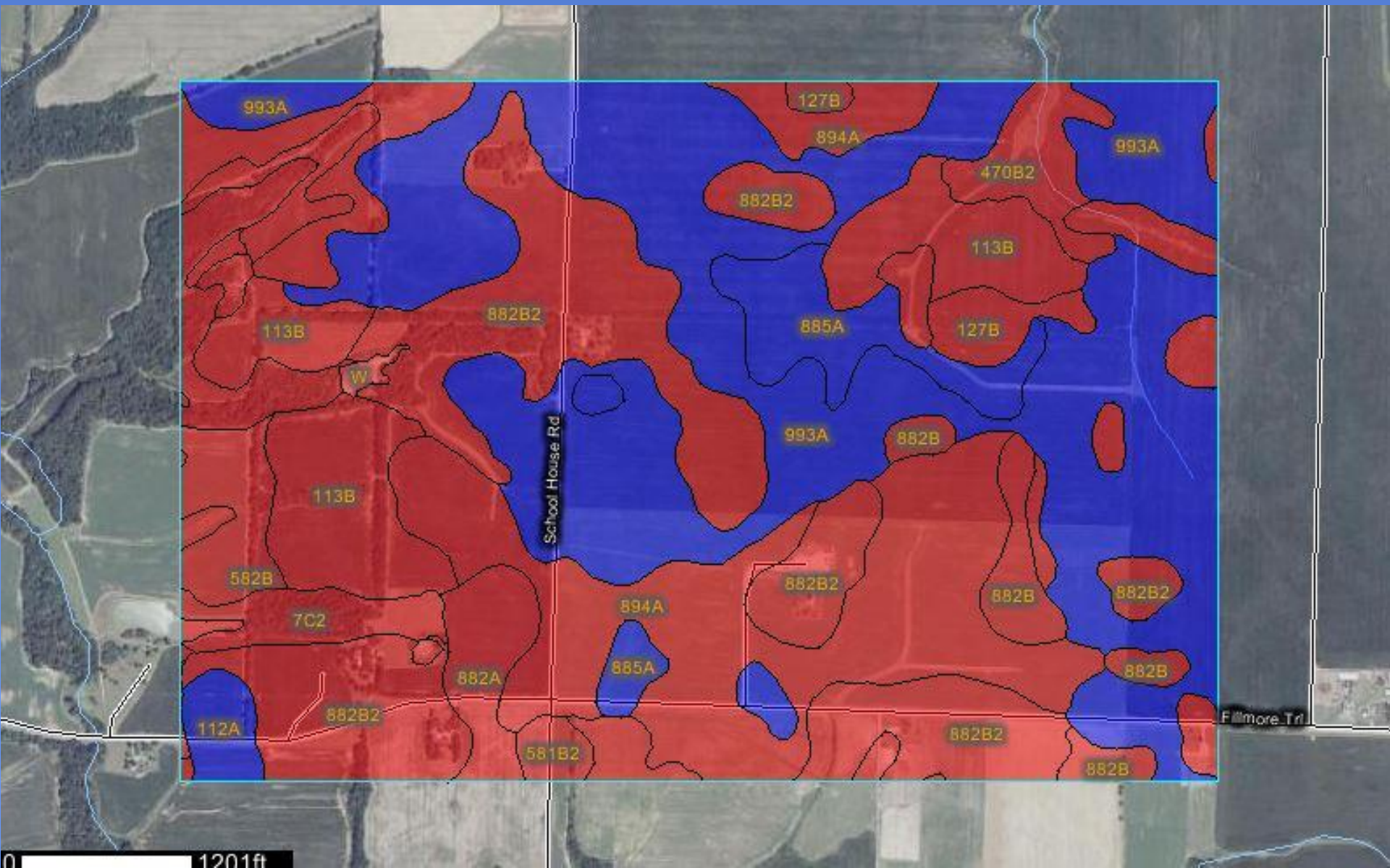
Soil map near Hillsboro IL



Soil drainage map near Hillsboro IL



Soil ponding probability near Hillsboro IL



Conclusions

- Modern GPS enabled yield monitors will make crop yield estimates more accurate
- High climatic variability in Queensland will make it necessary to have a long record before effects can be evaluated statistically
- Erosion, not drainage will be more important in QL than in IL
- Changes in QL groundwater may lead to saline seeps
- Citizen opposition may continue despite research results, aesthetics count.

Before and after Illinois subsidence mitigation

2008 Angle from Aircraft

2010 Vertical from Google Earth

QUESTIONS ?