TSMV Undermining Information Session

The Webinar will begin shortly

13 January 2021

THREE SISTERS MOUNTAIN VILLAGE

Undermining Information Session

Chris Ollenberger, P. Eng.
Director of Strategy and Development
Three Sisters Mountain Village

James (Jim) Tod, M.Sc. (Eng), P.Eng.
Associate Rock Mechanics Engineer
Wood E&IS

Adam Coulson, P.h.D., P.Eng.
Principal Rock Mechanics Engineer
Wood E&IS

Outline

PART 1: Overview of Undermining Process and Regulation

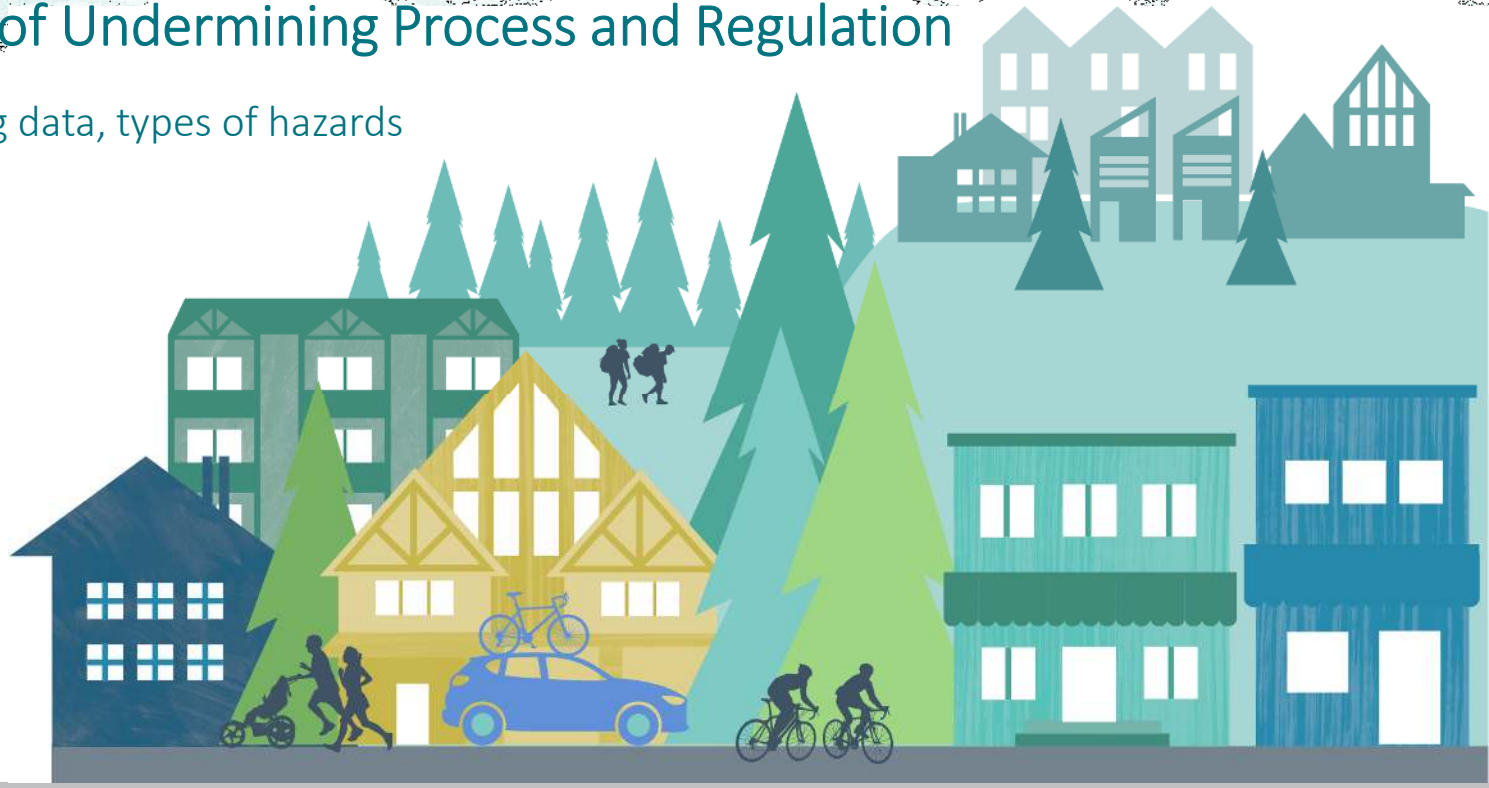
- Background, history, existing data, types of hazards
- How hazards are identified
- How risks are mitigated

PART 2: Undermining Considerations for the Three Sisters Village

- Site specific findings and background
- Preliminary hazard mapping
- Next steps

Part 1: Overview of Undermining Process and Regulation

- Background, history, existing data, types of hazards
- How hazards are identified
- How risks are mitigated



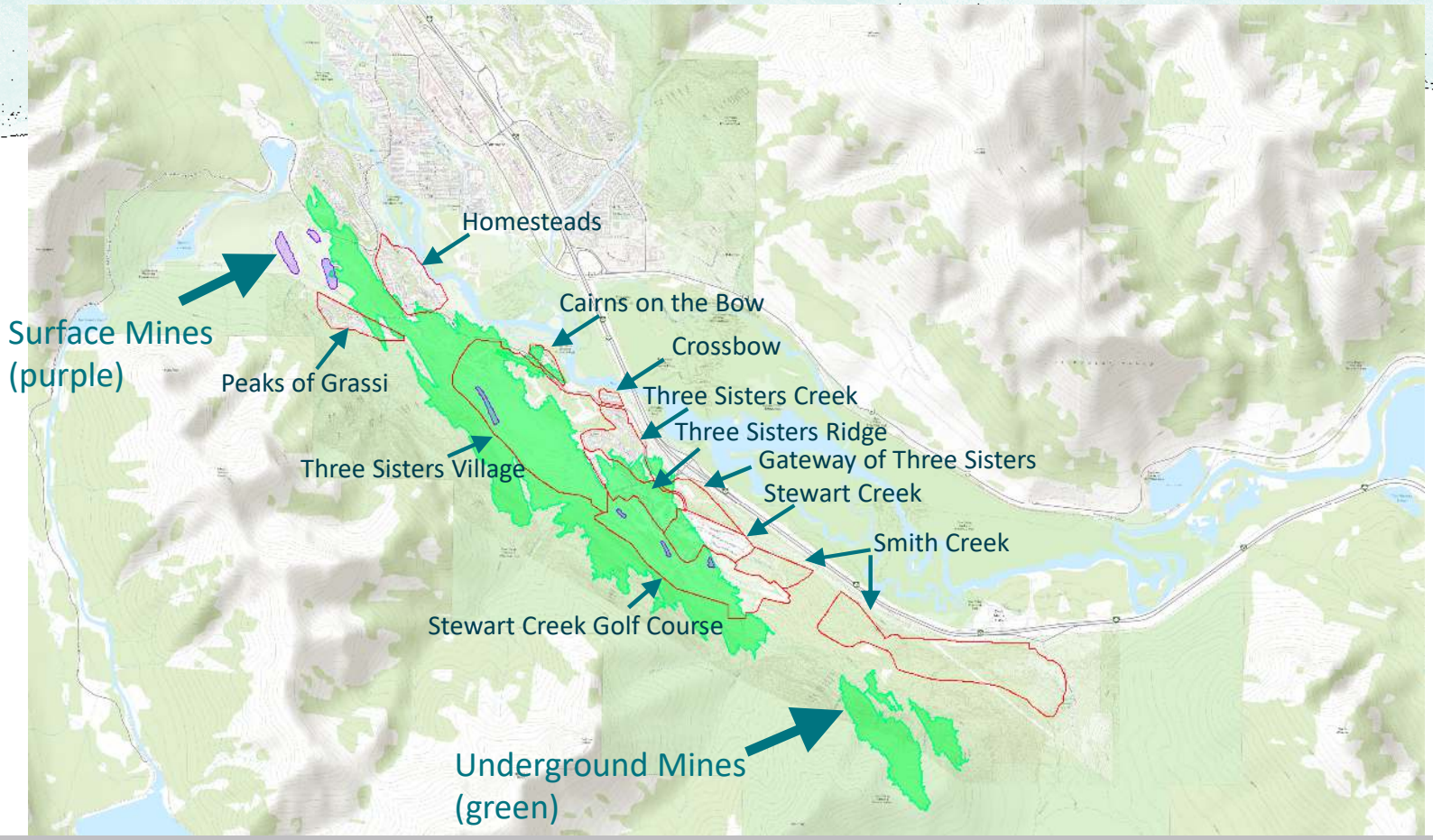
Historical Photos of Canmore Area

The No. 2 Mine looking north towards the tipple, 1956.CMAGS 2008.013.010.001

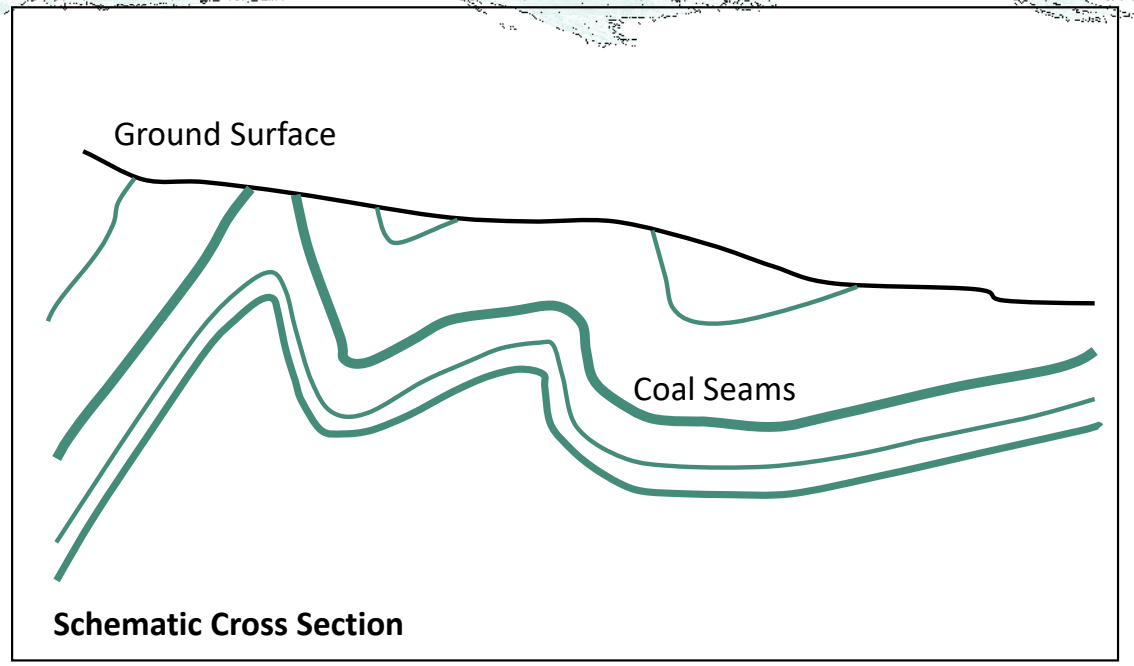
Canmore Mines Ltd. narrow gauge electric locomotive hauling coal from the No. 3 Mine to the tipple at the No. 2 Mine. CMAGS 1983.001.127.001

An unidentified Canmore coal miner loads a dump truck with coal, ca. 1970s.CMAGS 2008.030.004.001

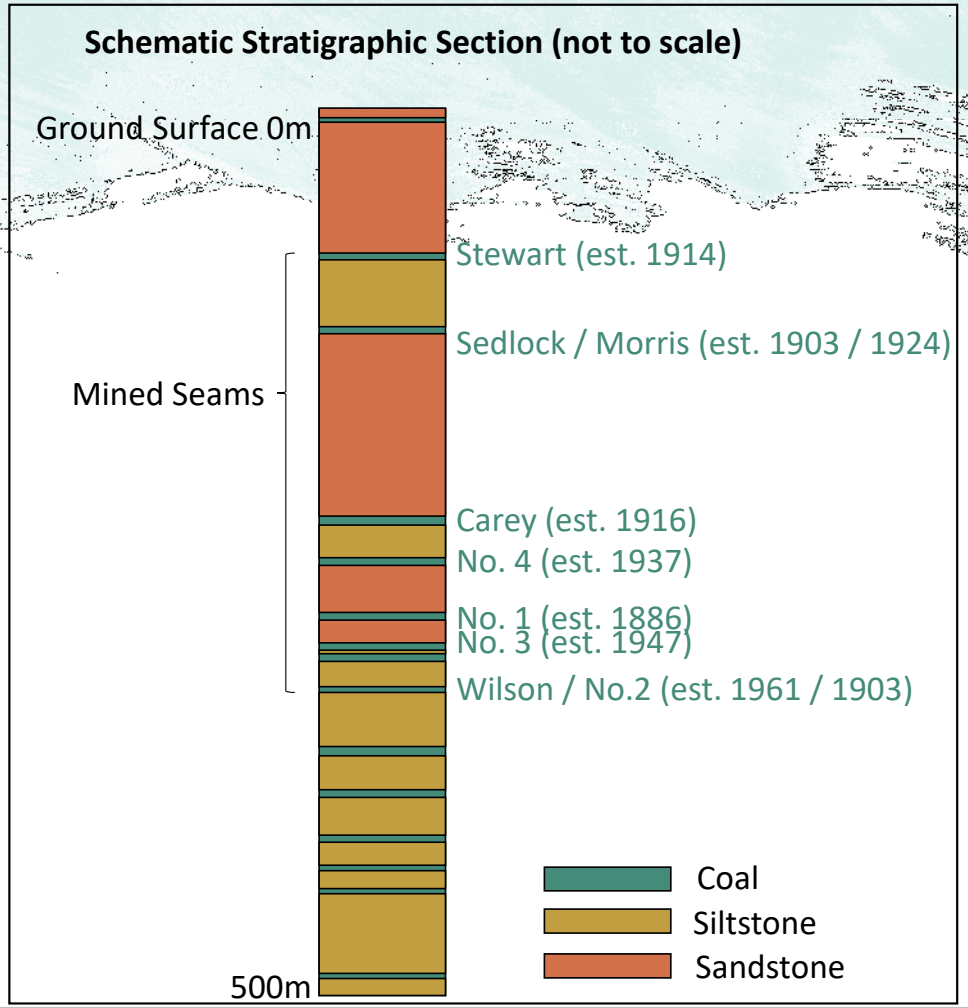
Extents of Coal Mining in Canmore



Mines Within Extents

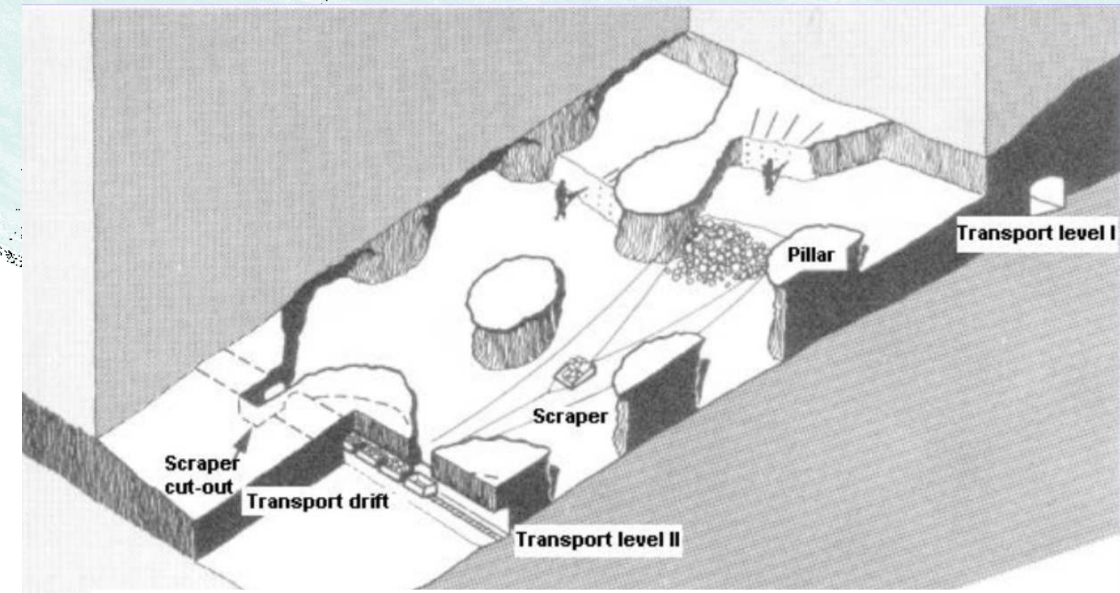


Schematic Cross Section

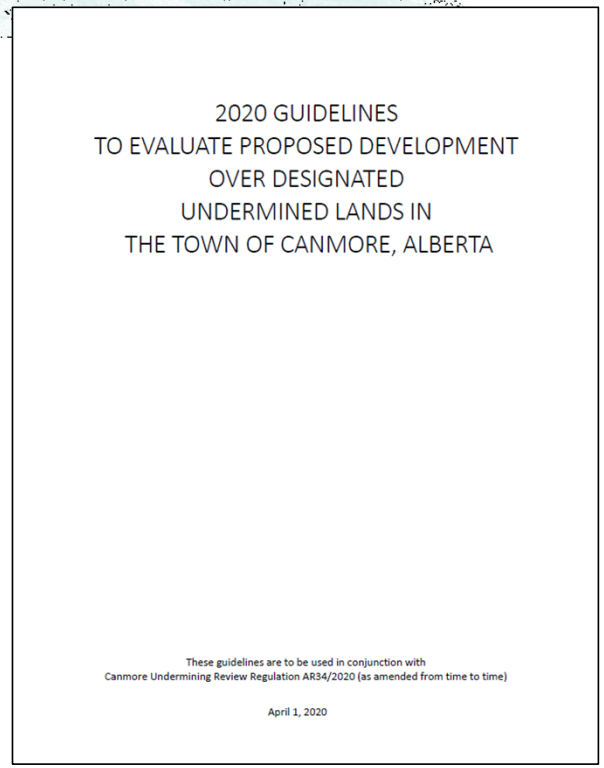


Mining Techniques

- Generally room and pillar, with pillar extraction following
- Drill and blast
- Initially air locomotives and rope haulages for 1.5 to 2 tonne cars
- Later continuous miners and cable reel shuttle cars, then slusher hoists
- Surface mines used for subvertical near-surface deposits



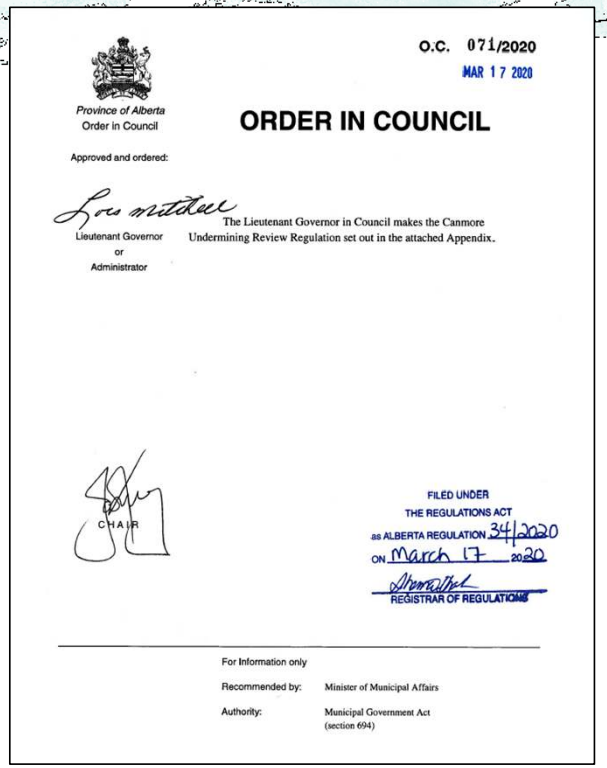
2020 Regulations



2020 GUIDELINES
TO EVALUATE PROPOSED DEVELOPMENT
OVER DESIGNATED
UNDERMINED LANDS IN
THE TOWN OF CANMORE, ALBERTA

These guidelines are to be used in conjunction with
Canmore Undermining Review Regulation AR34/2020 (as amended from time to time)

April 1, 2020



Province of Alberta
Order in Council

O.C. 071/2020
MAR 17 2020

ORDER IN COUNCIL

Approved and ordered:

Lieutenant Governor or Administrator

The Lieutenant Governor in Council makes the Canmore Undermining Review Regulation set out in the attached Appendix.

CHAIR

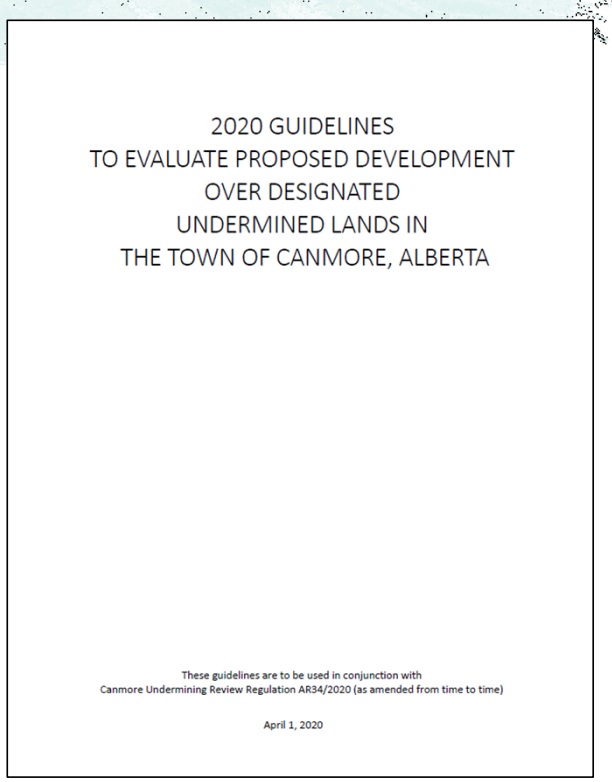
FILED UNDER
THE REGULATIONS ACT
as ALBERTA REGULATION 34/2020
ON March 17 2020
REGISTRAR OF REGULATIONS

For Information only

Recommended by: Minister of Municipal Affairs

Authority: Municipal Government Act (section 694)

2020 Regulations



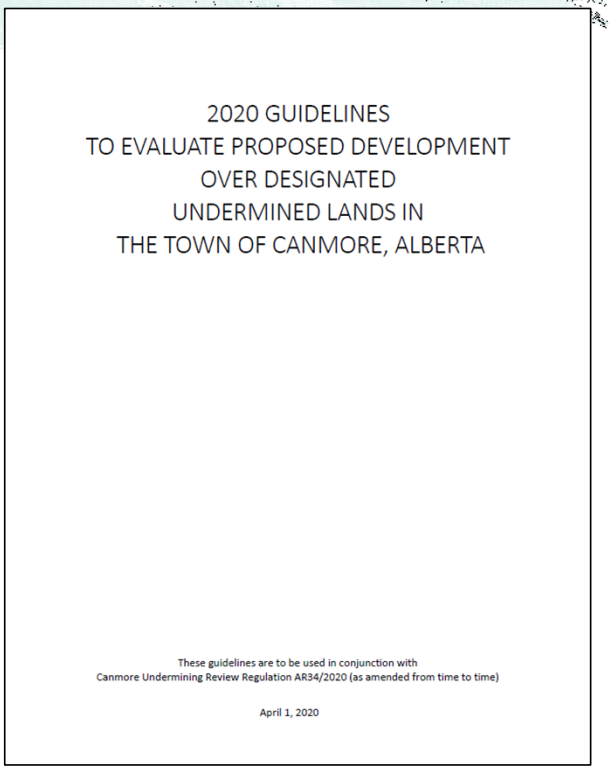
2020 GUIDELINES
TO EVALUATE PROPOSED DEVELOPMENT
OVER DESIGNATED
UNDERMINED LANDS IN
THE TOWN OF CANMORE, ALBERTA

These guidelines are to be used in conjunction with
Canmore Undermining Review Regulation AR34/2020 (as amended from time to time)

April 1, 2020

"The goal of these guidelines is to provide a clear and reasonable procedure to guide assessments for developing undermined lands. Natural and man-made subsurface risks exist on virtually all land under development, and this is the case in Canmore. The outcome of assessments performed according to these guidelines should be a clear understanding of subsurface risks and the intent for safely mitigating them for their intended uses as known on the date of the assessment. As with other geotechnical hazard assessments such as steep creeks, earthquakes and landslides, risk is not eliminated, but quantified and managed to reasonable levels." – PURPOSE SECTION, 2020 GUIDELINES APPROVED BY MINISTER

2020 Regulations



2020 GUIDELINES
TO EVALUATE PROPOSED DEVELOPMENT
OVER DESIGNATED
UNDERMINED LANDS IN
THE TOWN OF CANMORE, ALBERTA

These guidelines are to be used in conjunction with
Canmore Undermining Review Regulation AR34/2020 (as amended from time to time)

April 1, 2020

"The purpose of these guidelines is to establish a staged process which provides for progressively increasing levels of confidence and confirmation as to whether a surface development may be undertaken without jeopardy to public safety and without incurring an unacceptable risk of damage appropriate to the anticipated use of a property as a result of development potentially impacted by previous mining activity within the designated lands identified by the Canmore Undermining Review Regulation (as amended from time to time).

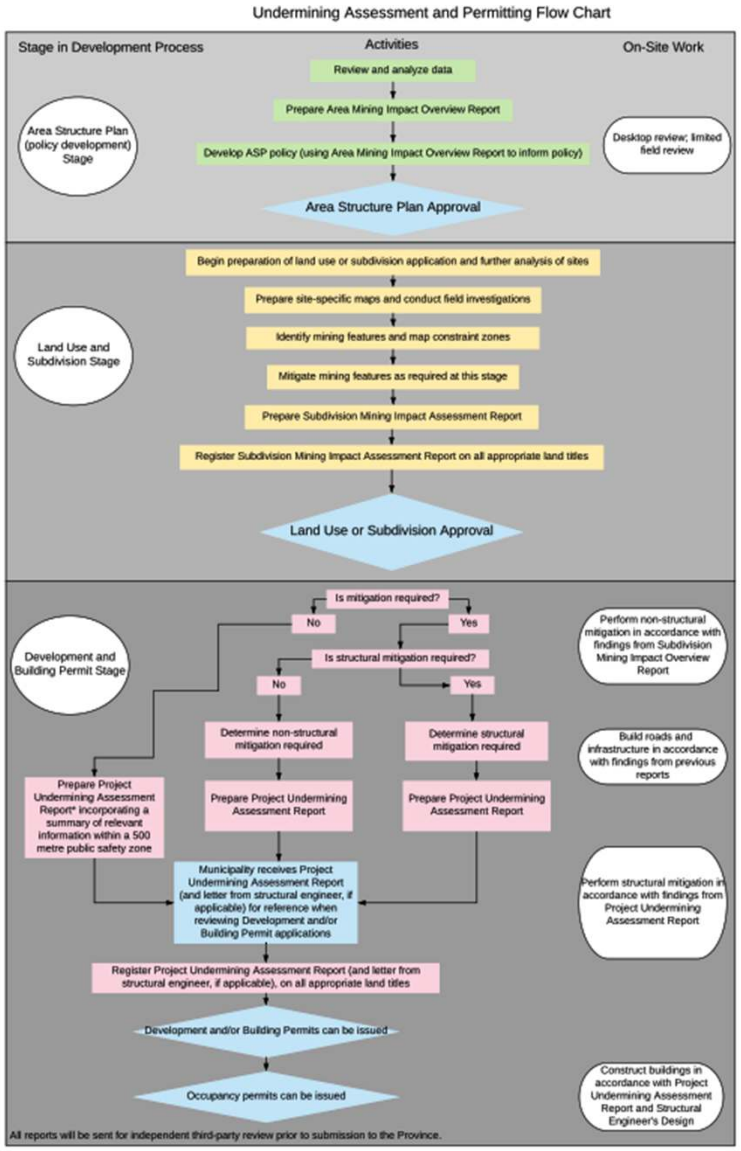
The flow chart in Appendix II outlines how such a staged process aligns with typical planning processes." – PURPOSE SECTION, 2020 GUIDELINES APPROVED BY MINISTER

2020 Regulations

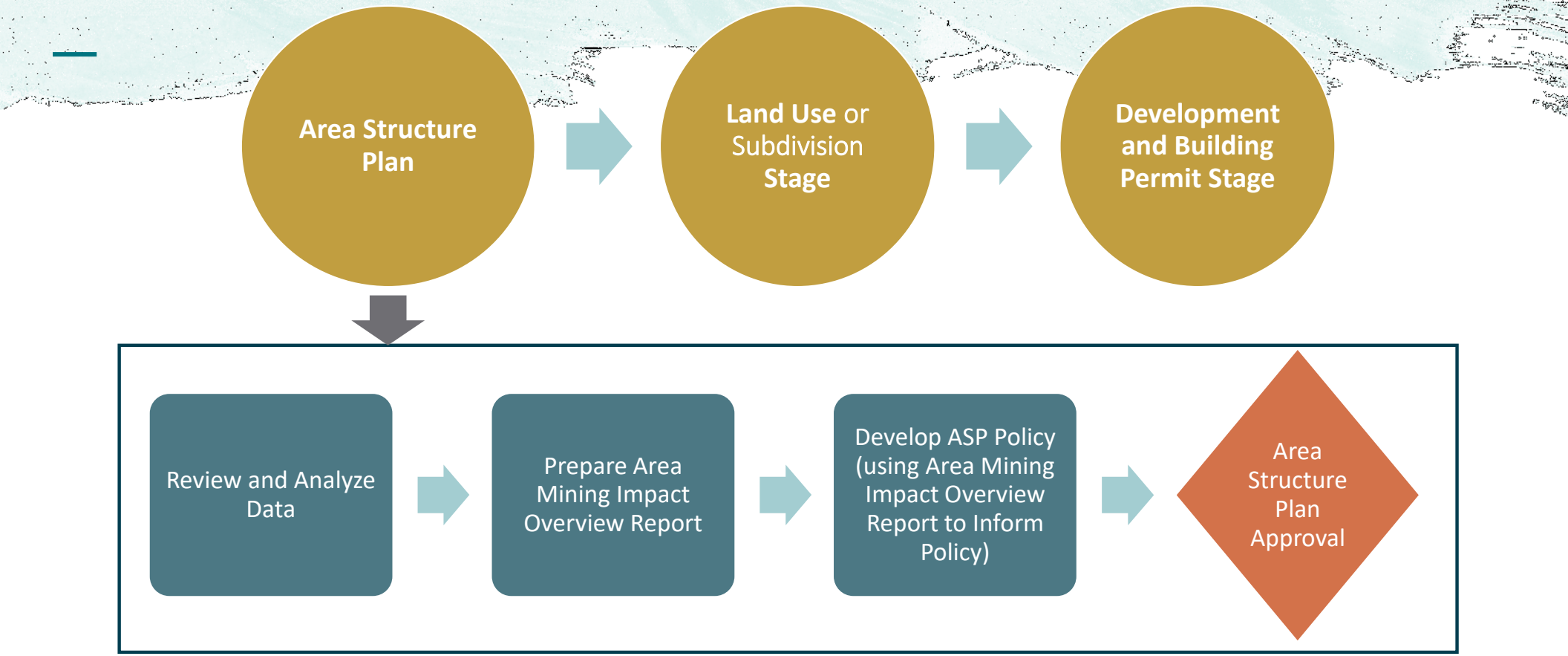
2020 GUIDELINES
TO EVALUATE PROPOSED DEVELOPMENT
OVER DESIGNATED
UNDERMINED LANDS IN
THE TOWN OF CANMORE, ALBERTA

These guidelines are to be used in conjunction with
Canmore Undermining Review Regulation AR34/2020 (as amended from time to time)

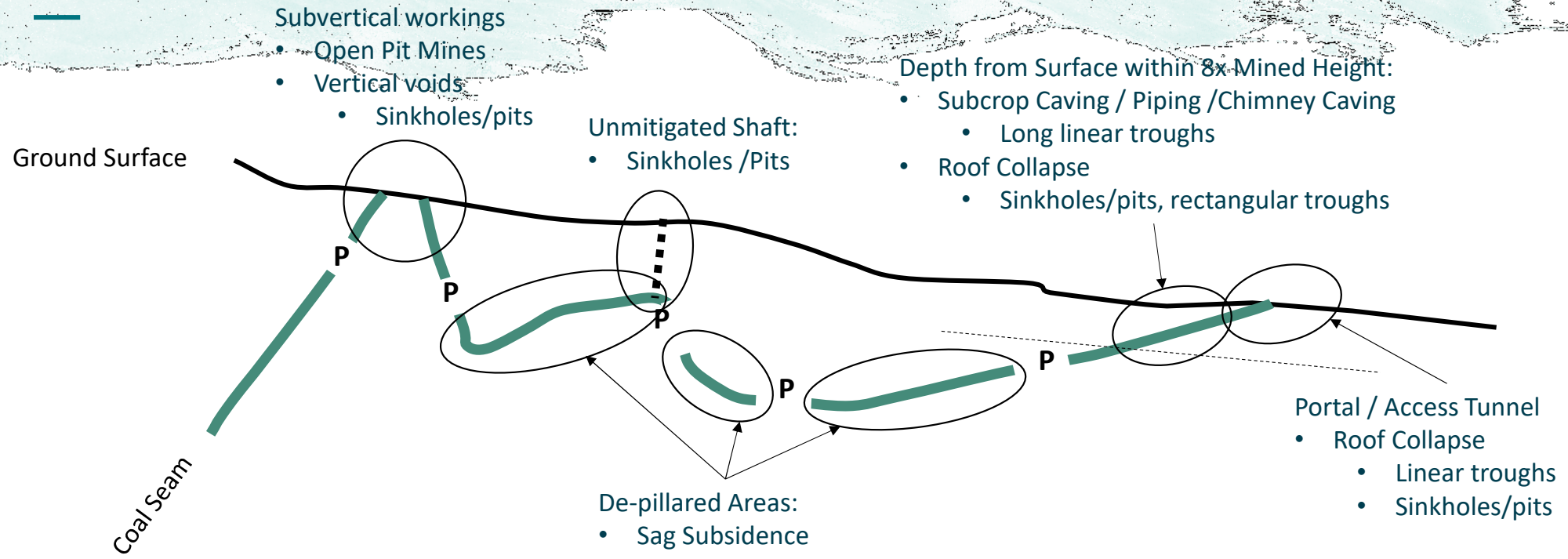
April 1, 2020



2020 Regulations



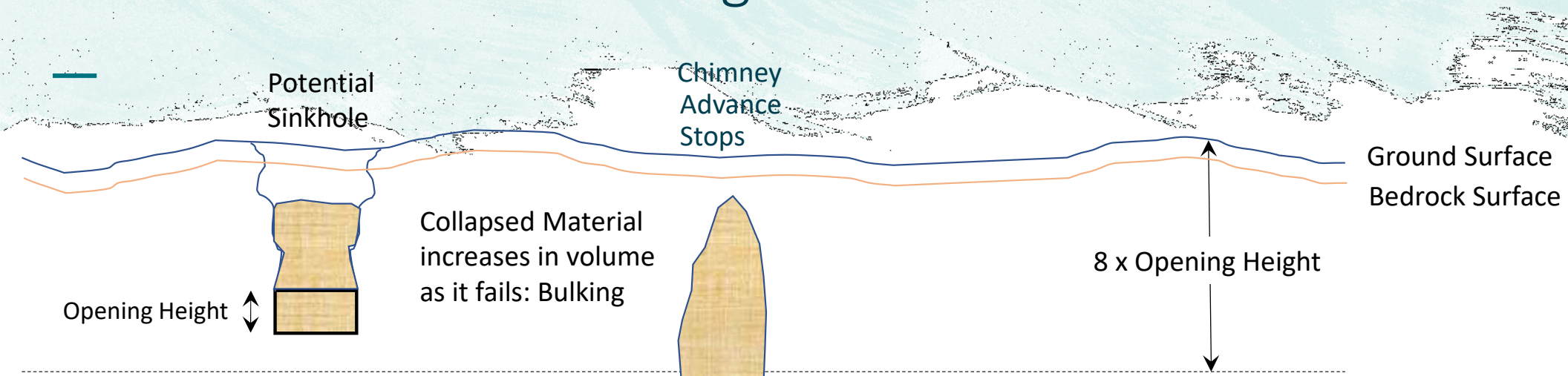
Types of Undermining Hazards



Schematic Cross Section – Illustrative Only - NTS

P - pillars

Formation of Undermining Hazards

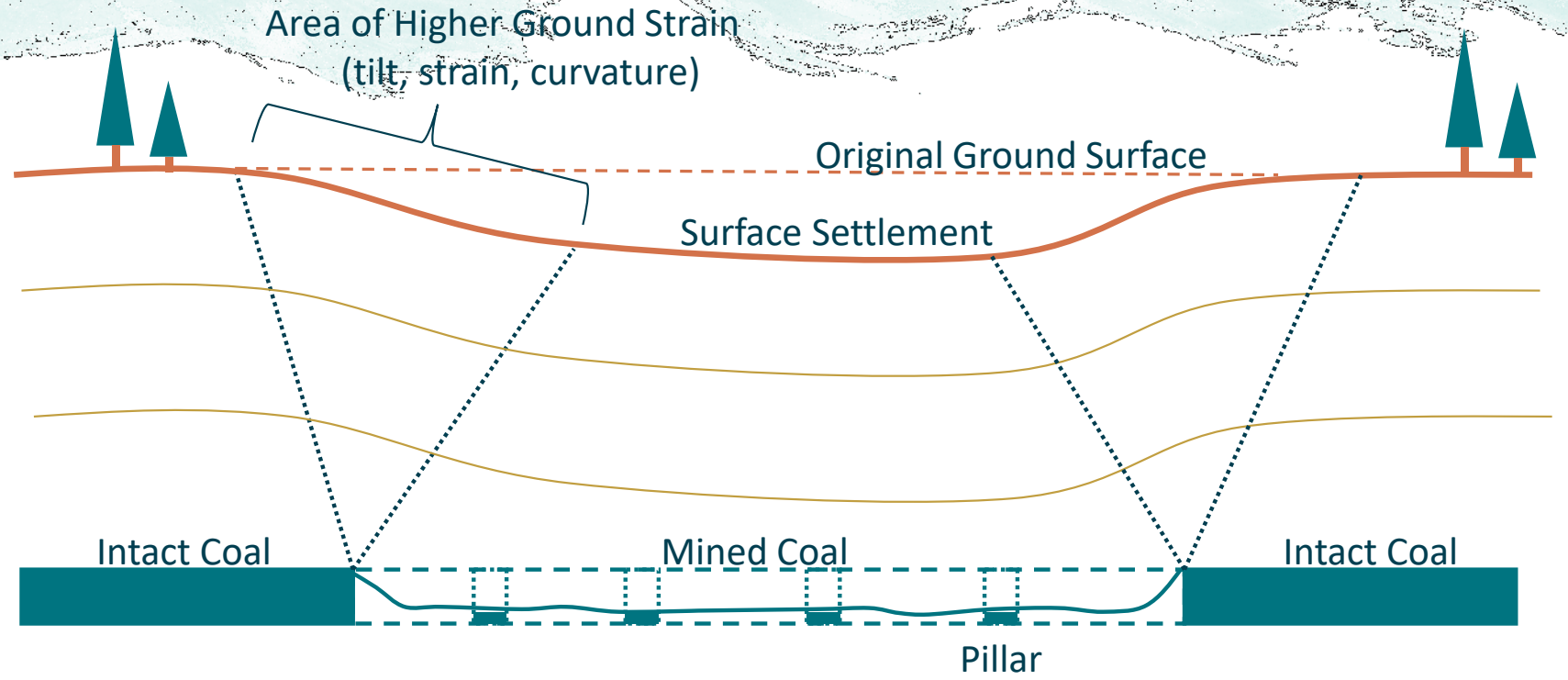


Within 8x the opening height below ground surface there is not sufficient material, and the chimney can progress to surface and form a sinkhole

Generally in TSMV conditions, beyond 8x the opening height, there is sufficient material to bulk and fill the void, stopping the chimney advance before it gets to surface

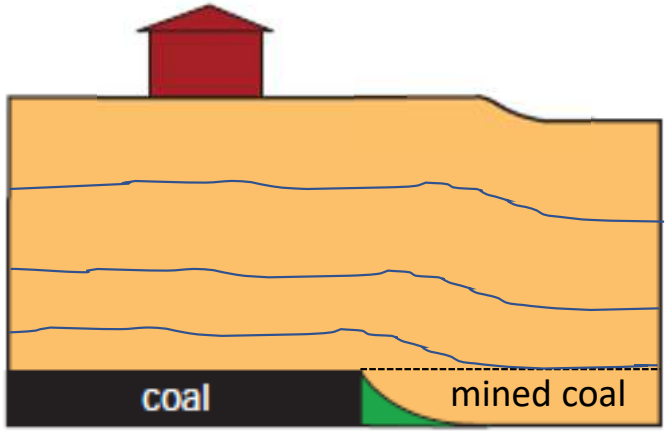
Schematic Cross Section – Illustrative Only - NTS

Formation of Undermining Hazards

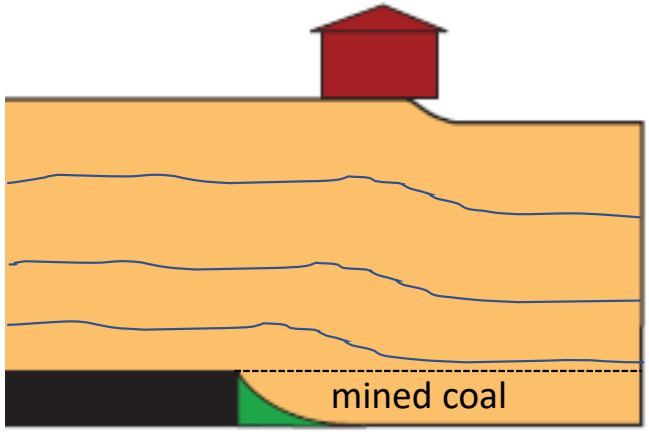


Schematic Cross Section – Illustrative Only - NTS

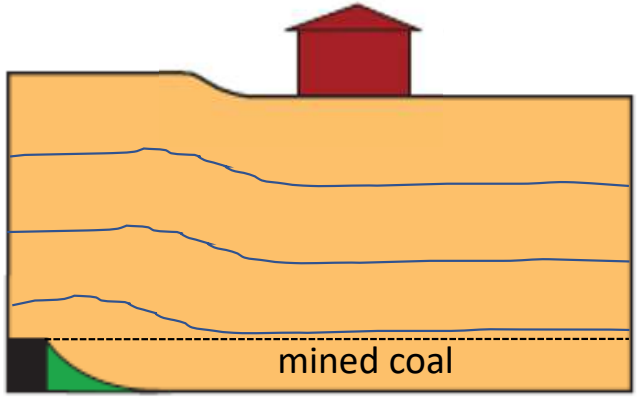
Formation of Undermining Hazards



Building outside of trough



Building within critical zone of trough



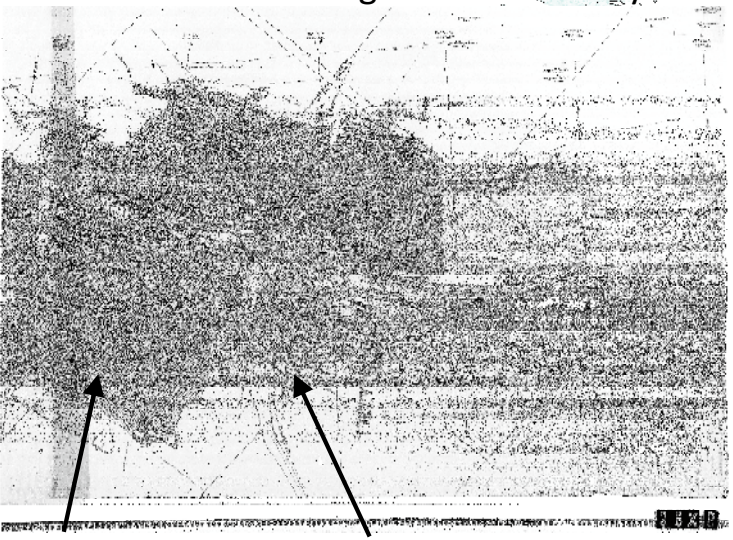
Building within trough but outside critical zone

Schematic Cross Section – Illustrative Only - NTS

Images from: Planned Coal Mine Subsidence in Illinois: A Public Information Booklet, Circular 573 2008, Bauer, Robert A.

Creating 3D Models

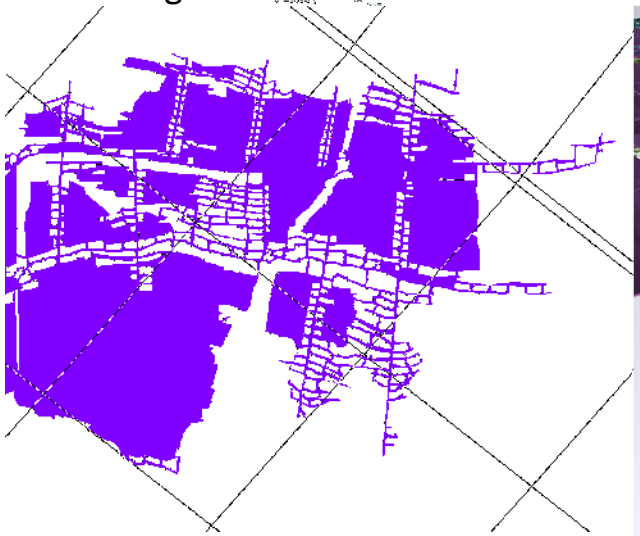
Scan of Original Mine Survey



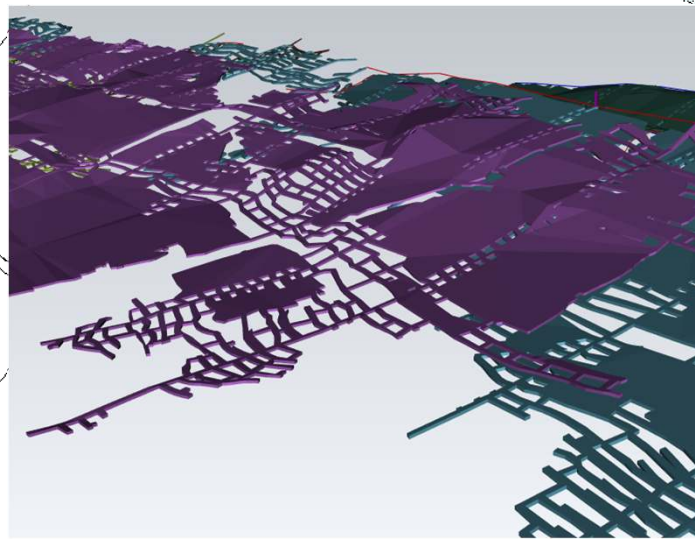
Depillared

Pillars intact

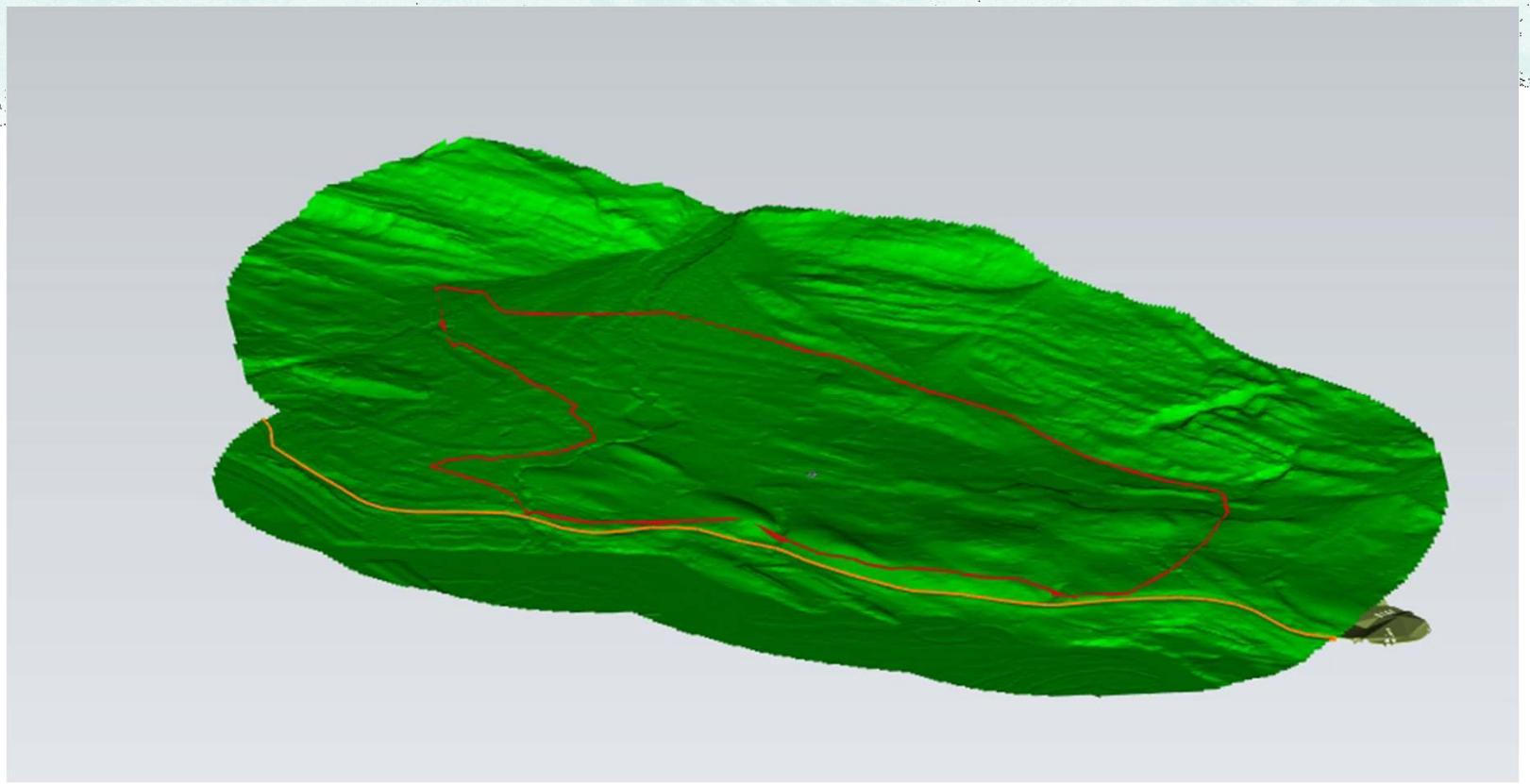
Digitized and Geolocated



3D Model

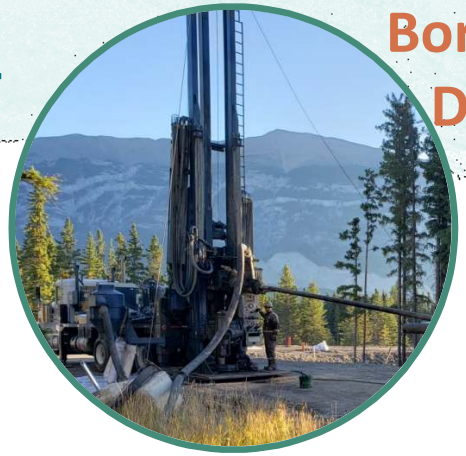


Creating 3D Models (Village ASP area shown)

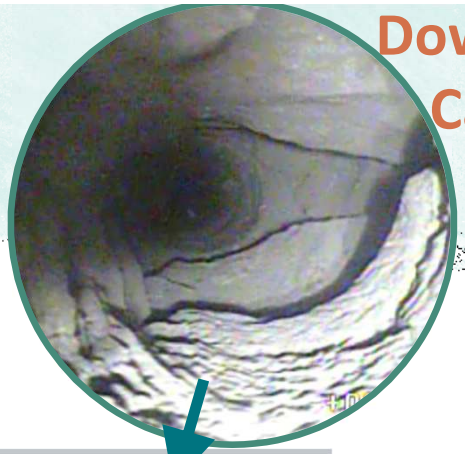


Confirming 3D Models

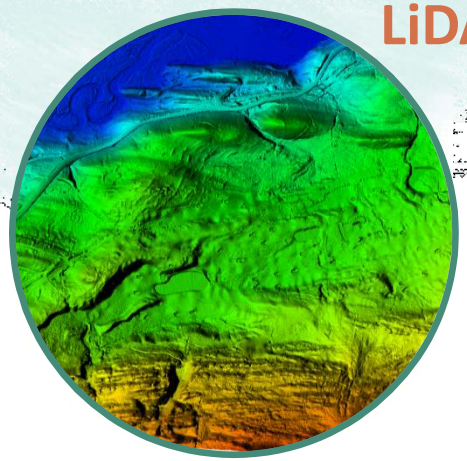
Borehole Drilling

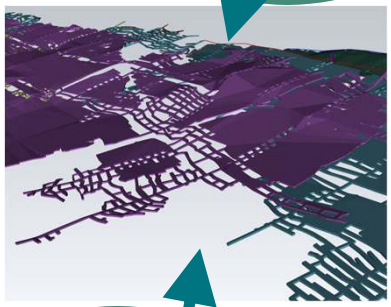


Downhole Camera

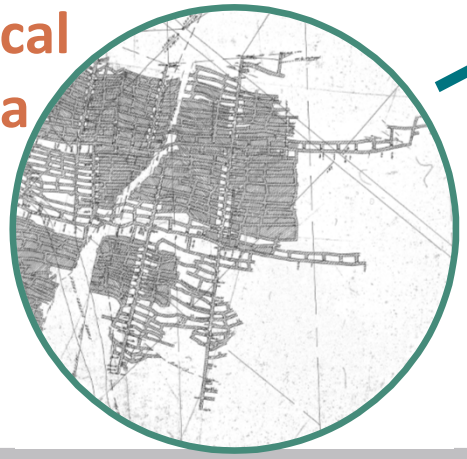


LiDAR





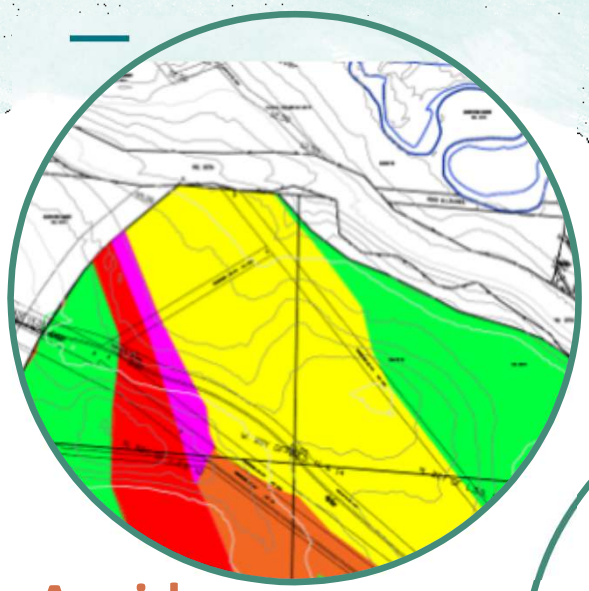
Historical Data



Site Reconnaissance

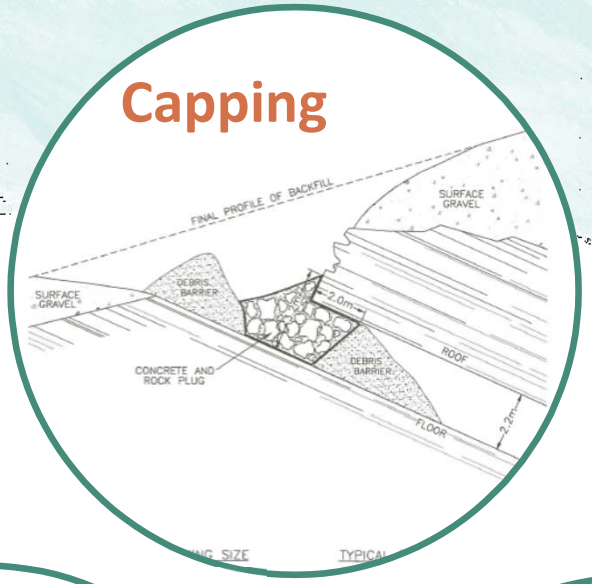
Orthophotos

Mitigation of Hazards

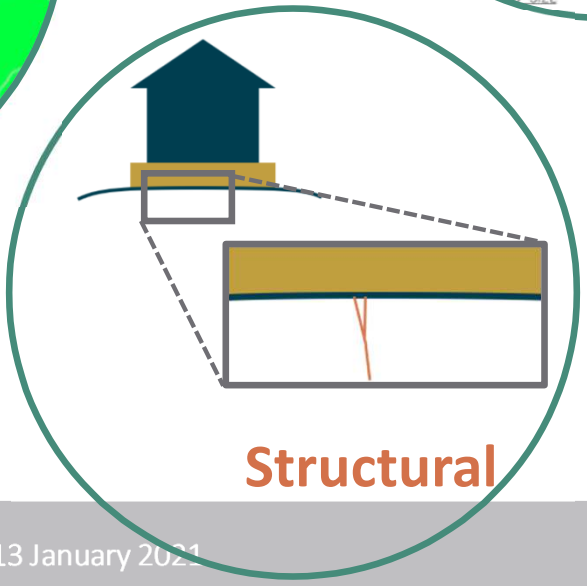


Avoidance

Capping



Paste Backfill



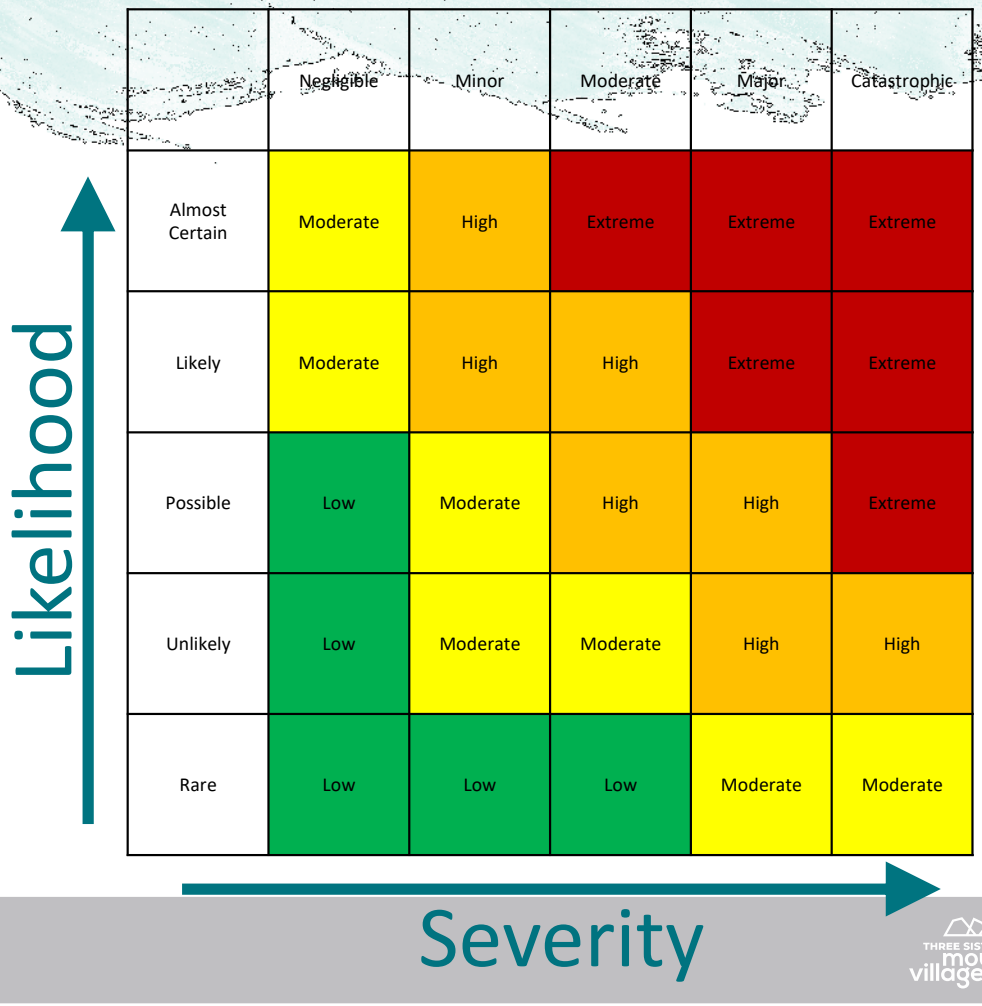
Structural

Disclosure

Mitigation Through Paste Operations

Understanding and Mitigating Risk

- Risk helps determines what gets developed
- Risk tolerance is different for different structures
- Mitigation can lower the risk

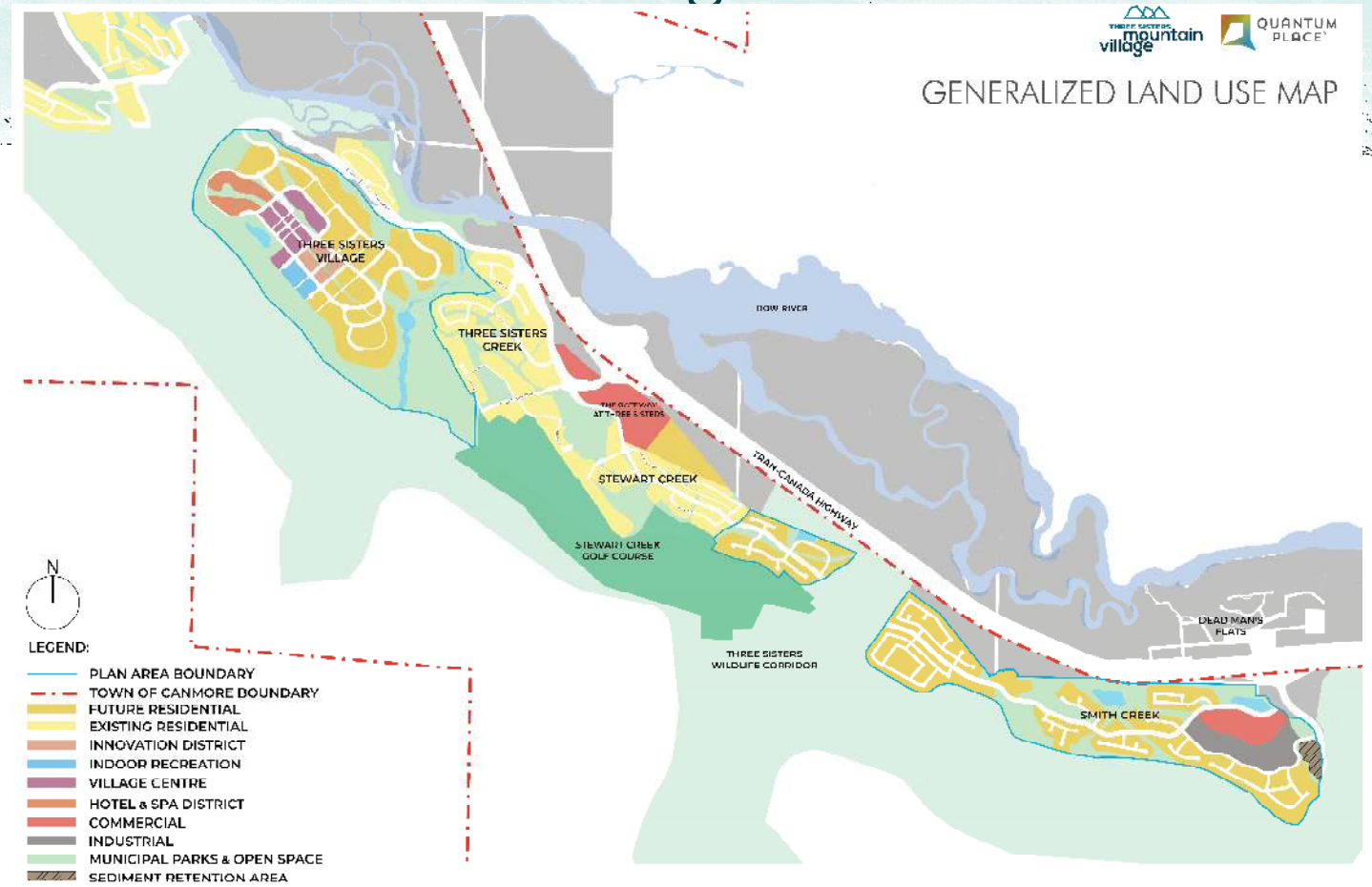


	Negligible	Minor	Moderate	Major	Catastrophic
Almost Certain	Moderate	High	Extreme	Extreme	Extreme
Likely	Moderate	High	High	Extreme	Extreme
Possible	Low	Moderate	High	High	Extreme
Unlikely	Low	Moderate	Moderate	High	High
Rare	Low	Low	Low	Moderate	Moderate

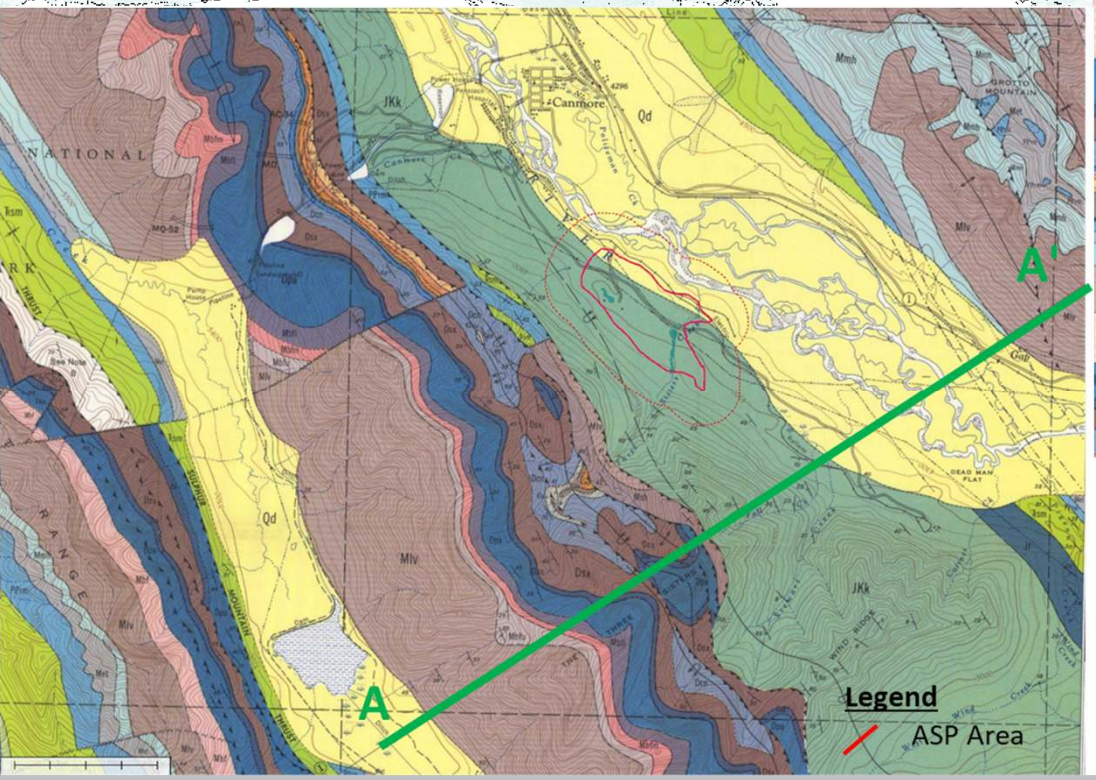
Part 2: Undermining Considerations for Three Sisters Village

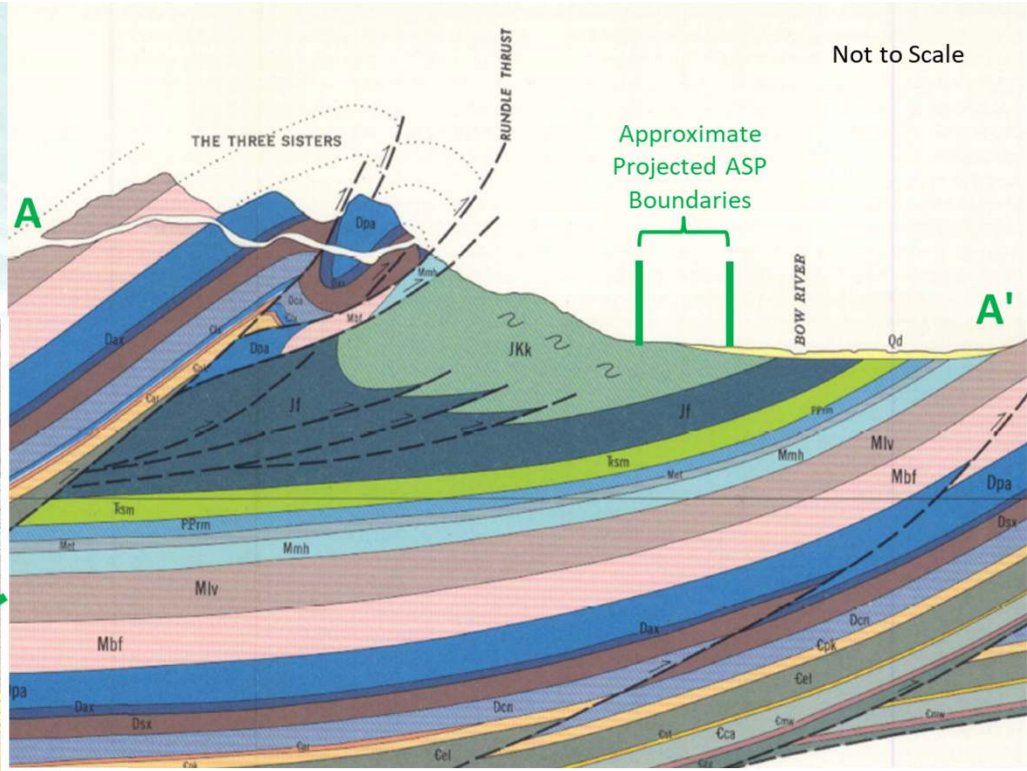
- Site specific findings and background
- Preliminary hazard mapping
- Next steps

Three Sisters Mountain Village Communities



Bedrock Geology

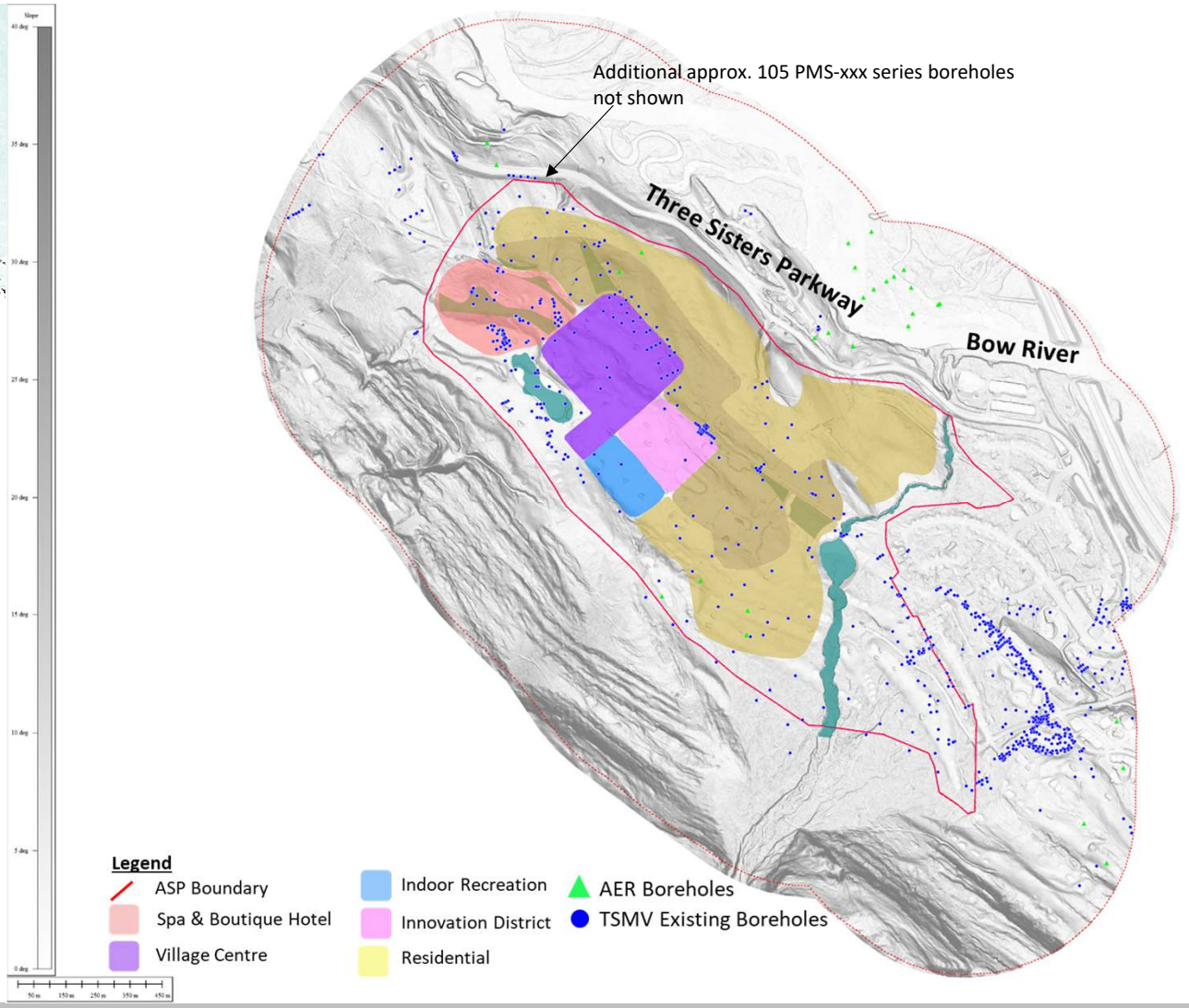




Map and Section Modified from:
Geological Survey of Canada, Map 1266A, Canmore, Scale 1:50,000, Published 1970

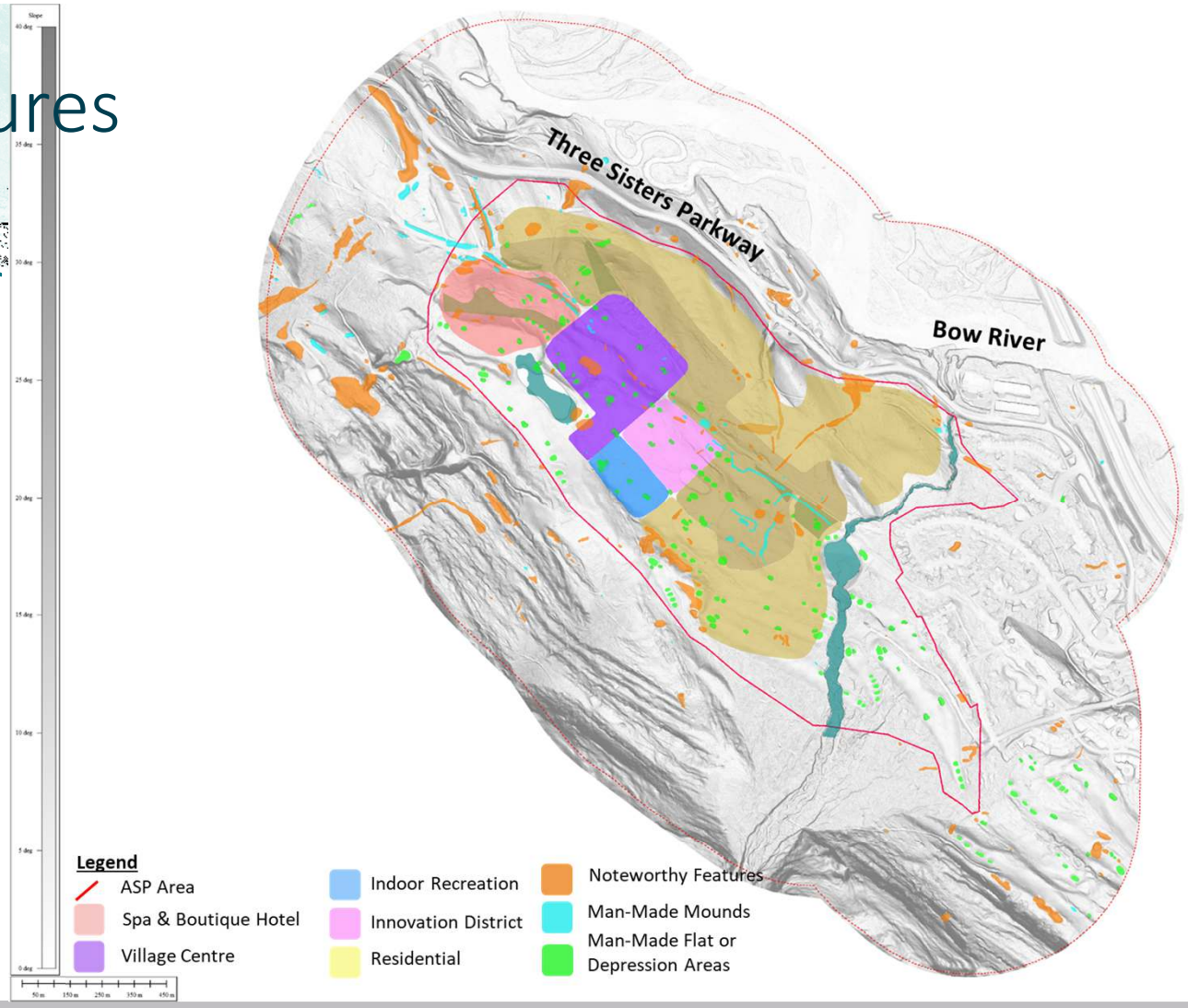
Existing Boreholes

- AER boreholes (total 38) drilled between 1967-1979 by private companies, often for exploration purposes and later handed over to the AER (Alberta Energy Regulator) for storage
- TSMV boreholes (total 441+) drilled between 1997 and 2008. Depths range from 6.0 to 230.0 m below surface. In some of these casing pipe was installed for later camera work and/or mitigation.

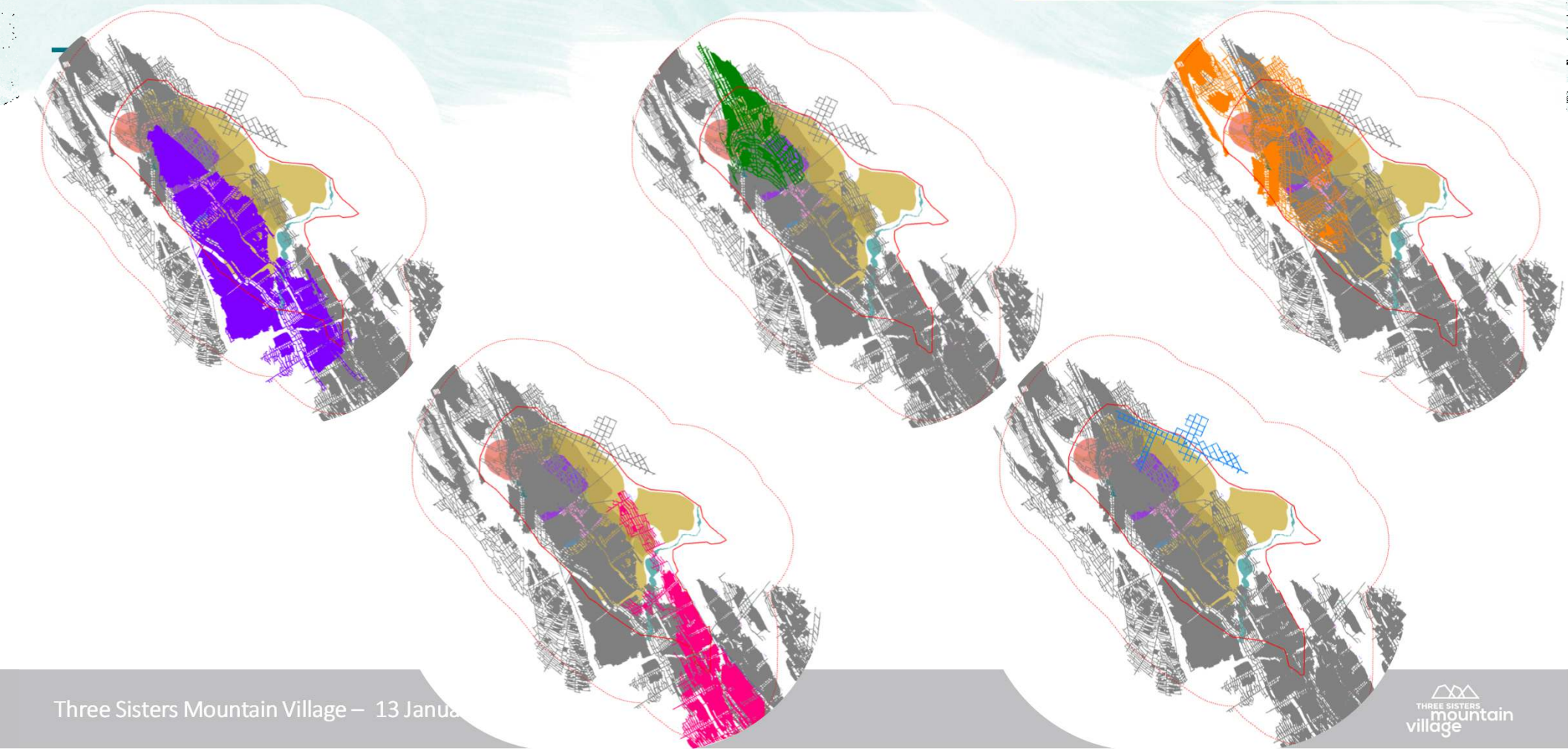


LiDAR Mapped Features

Previously mapped features, over the last 20+ years was reviewed, along with new LiDAR technology collected by helicopter. The LiDAR data allows for an accurate topographic surface to be generated, which was studied for evidence of mining and subsidence features



Mines Within ASP



Mines within ASP

Mine Name	Mining Dates	Average Mined Height (m)	Depth Below ASP (m)	Stratigraphic Sequence (top down)
Stewart	1914-1952	2.1	17 - 172	1
Sedlock	1903-1915	1.8	19 - 88	2*
Morris No. 1	1924-1941	1.5	23 - 99	2*
Carey	1916-1934	2.75	55 - 211	3
Riverside	1976-1979	1.8	100 – 300	4

*Morris and Sedlock seams are the same stratigraphic unit

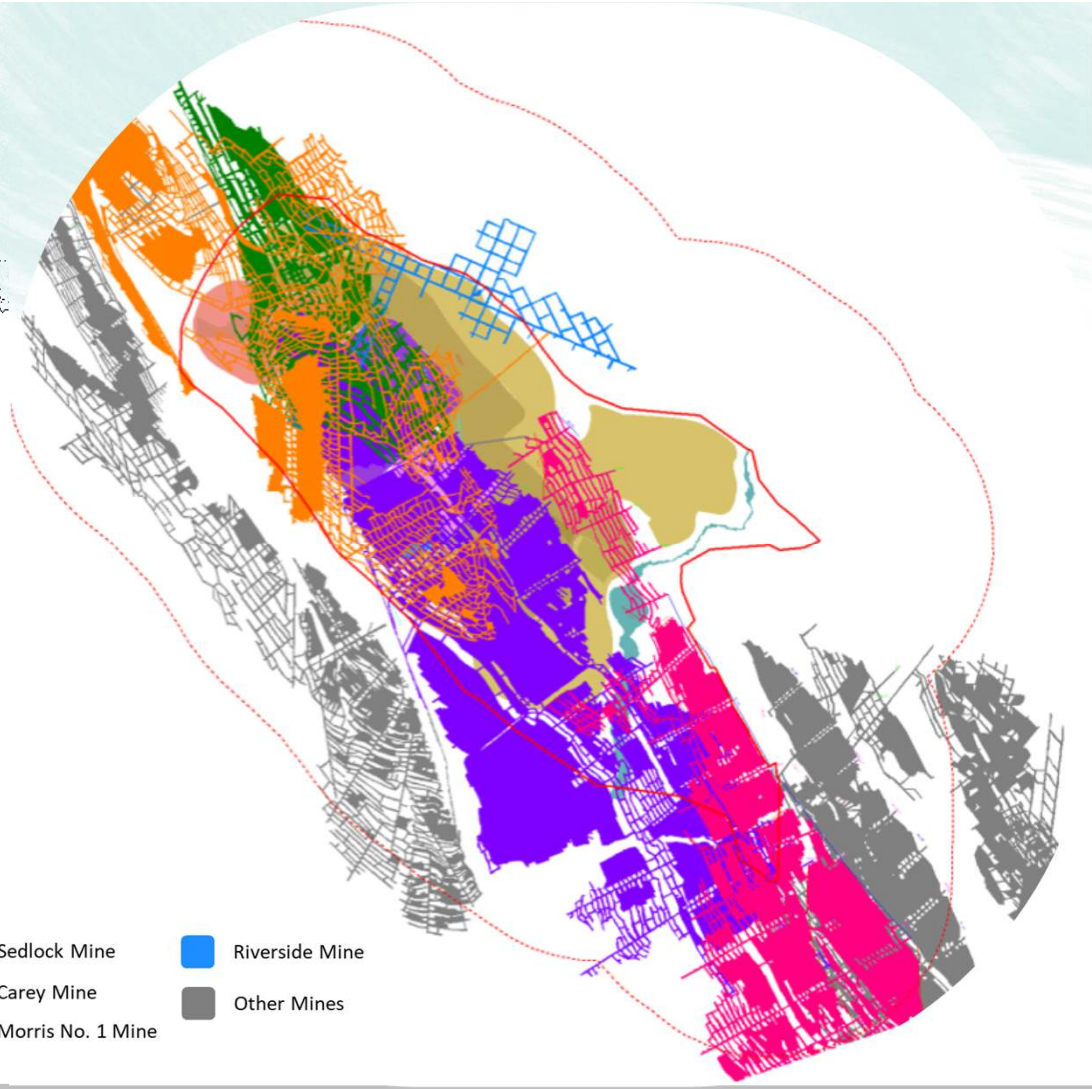


Photo Comparison 2020 vs 2017

Photograph 1: Feature #74, June 2020

Photograph 1A: Feature #74, October 2017

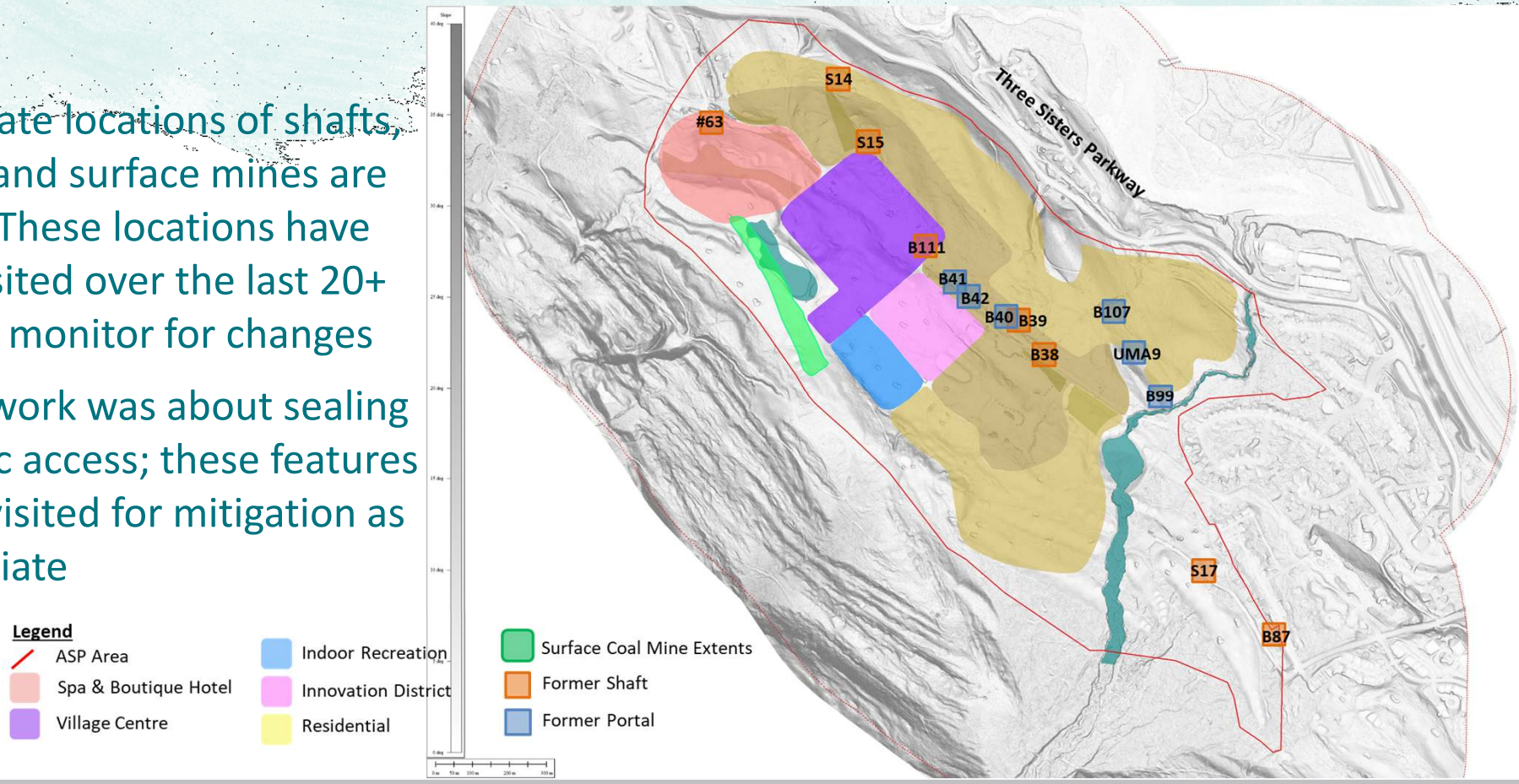
Photo Comparison 2020 vs 2017

Photograph 3: Feature G404, June 2020

Photograph 3A: Feature G404, October 2017

Shafts, Portals and Surface Mines

- Approximate locations of shafts, portals and surface mines are shown. These locations have been visited over the last 20+ years to monitor for changes
- Previous work was about sealing to public access; these features will be visited for mitigation as appropriate



Shaft Location: #63

Photograph 38: Known shaft location with settlement at Waypoint 144, September 2020

Photograph 40: Known shaft location with settlement at Waypoint 144, September 2020

Site Specific Hazard Examples (Carey Mine)

Other Hazards not shown:
Shallow mining
Portals / Shafts

Preliminary Hazard Zone Map

LEGEND:

38%

ZONE 1 (GREEN): NO STRUCTURAL OR GROUND MITIGATION REQUIRED FOR DEVELOPMENT. THESE ARE AREAS THAT HAVEN'T BEEN UNDERMINED, OR ARE LOCATED ABOVE THE MIDPOINT OF BROAD DE-PILLARED AREAS WITH EXPECTED UNIFORM SETTLEMENT.

18%

ZONE 2 (YELLOW): DEVELOPMENT POSSIBLE WITH GROUND MITIGATION. THESE ARE ASSOCIATED WITH NEAR-SURFACE WORKINGS WITH THE POTENTIAL FOR SINKHOLE FORMATION.

12%

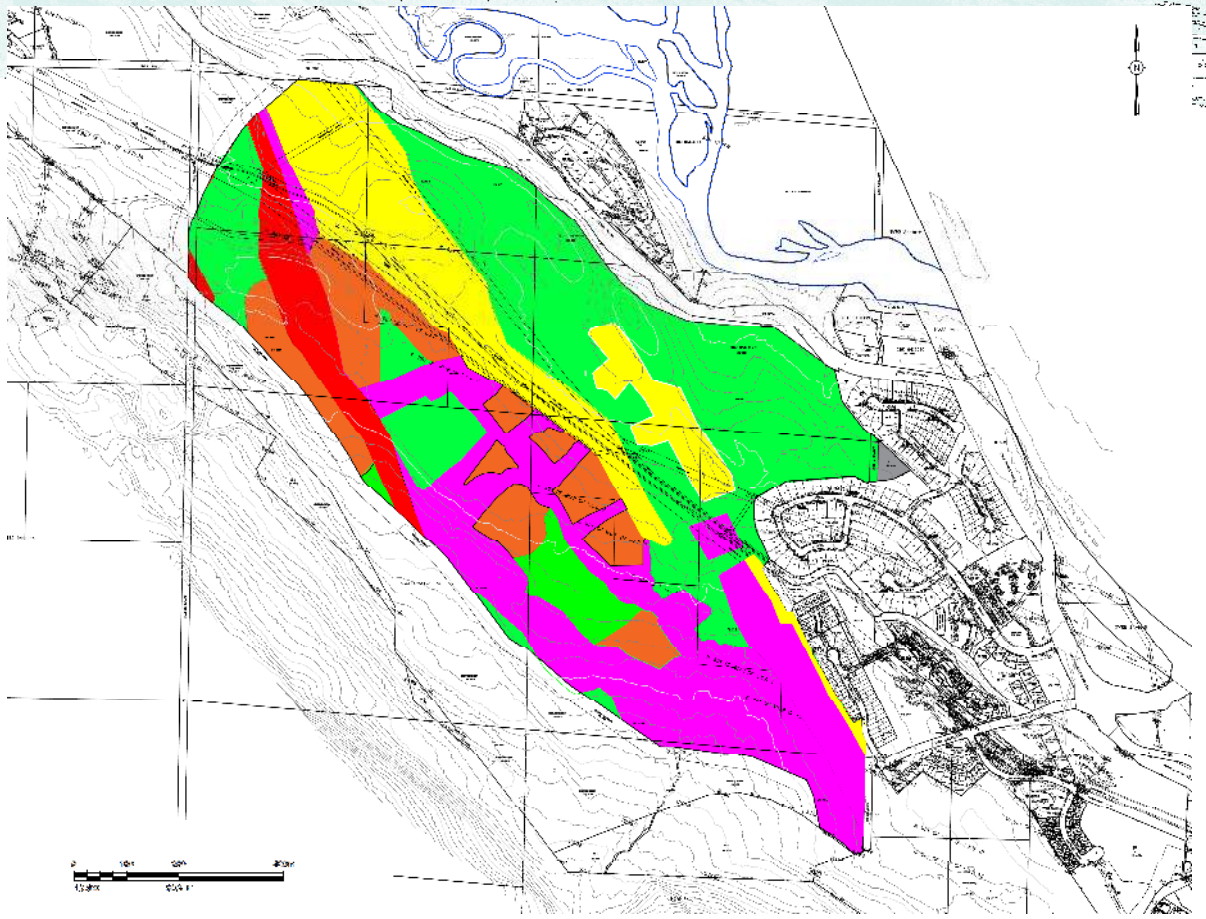
ZONE 3 (ORANGE): DEVELOPMENT POSSIBLE WITH GROUND AND STRUCTURAL MITIGATION, AS NECESSARY. THESE ARE ASSOCIATED WITH AREAS THAT ARE UNDERMINED BY MORE THAN ONE DE-PILLARED SEAM, OR THE POTENTIAL FOR DIFFERENTIAL SETTLEMENT DUE TO UNDERLYING PILLARS AND DE-PILLARED AREAS.

26%

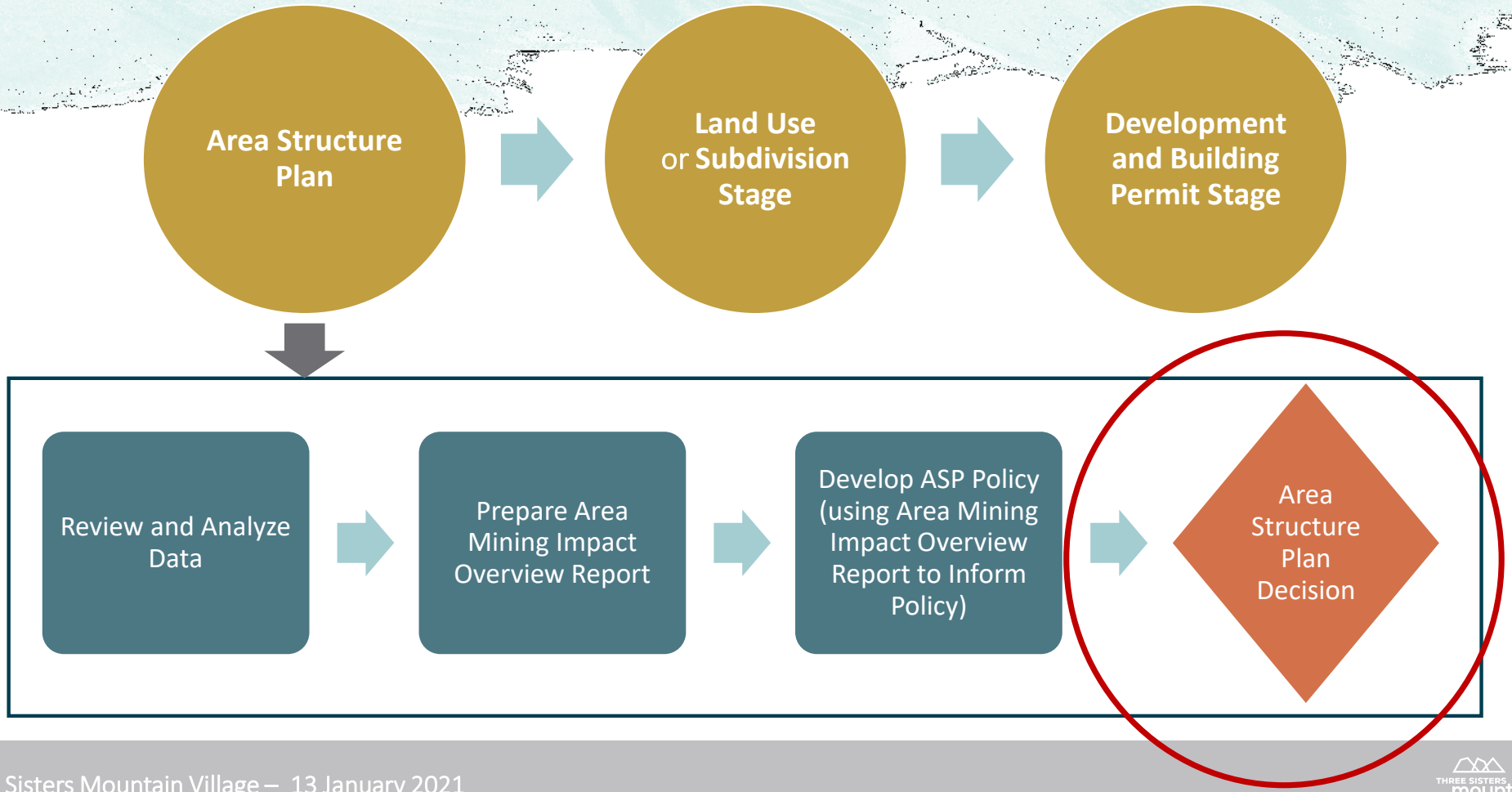
ZONE 4 (MAGENTA): DEVELOPMENT POSSIBLE, BUT HIGHER GROUND STRAINS POSSIBLE. THESE ZONES ARE ASSOCIATED WITH THE MARGINS ABOVE THE EDGES OF DE-PILLARED AREAS WHERE THE STRAINS, TILT AND CURVATURE ARE EXPECTED TO BE LOCALLY HIGHER.

6%

ZONE 5 (RED): STEEPLY DIPPING OR SUBVERTICAL WORKINGS. THESE AREAS HAVE POTENTIAL FOR SINKHOLE OR TROUGH DEVELOPMENT; THE POTENTIAL FOR DEVELOPMENT IS CONSIDERED LOW AS THE POTENTIAL COSTS FOR MITIGATION ARE CONSIDERED HIGH.



Next Steps


Area Structure Plan
Land Use or Subdivision Stage
Development and Building Permit Stage
Review and Analyze Data
Prepare Area Mining Impact Overview Report
Develop ASP Policy (using Area Mining Impact Overview Report to Inform Policy)
Area Structure Plan Decision

THANK YOU!

SHORT BREAK

QUESTIONS

Dyrgas Sinkhole – B14 Airshaft (2010)

Dyrgas Sinkhole – B14 Airshaft (2010)

- B14 airfan shaft abandoned and backfilled by No. 4 mine operators prior to 1949; replaced with fan slope CP-4.
- Norwest attempted to find exact location of shaft in late 90's; not exactly located so broad "beanbag" public safety mitigation installed over general area of shaft.
- Golder undertook further work to find exact shaft location in 2003; found miners previous backfill extents around shaft; installed two layers of geosynthetics for future safe recreation use; set buildings back 15 m from area
- Leaking irrigation line suspected to be linked to settlement in May 2010; shaft was found to not be open but filled with wet, loose materials that settled
- Repaired in 2017 with three layers of geosynthetics similar to 2003 recommendations

Dyrgas Sinkhole – B14 Airshaft (2010)