

# DIGITAL MAPPING TECHNIQUES 2026

The following was presented at DMT '26  
May 10 - 13, 2026

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<http://ngmdb.usgs.gov/info/dmt/>

## **Pinpoint Drilling using ArcPro**

### Pros and Cons of using 136-year-old data with current imagery

**Slide 1:** Opening Slide

**Slide 2:** Hello, I'm Anthony Roth with the Montana Bureau of Mines and Geology located in beautiful Butte, America. Today, I'm going to present on one of the issues that occurred in our GIS department this year.

**Slide 3:** In today's presentation, I'll provide a brief history of the mine we were working with, explain why the project was necessary, discuss the challenges we encountered, and describe how the project was ultimately completed.

**Slide 4:** But, before I begin my presentation, I thought it would be wise to bring you up to speed on some terminology used in hard rock ..... Oops, I'm terribly sorry, wrong slide.

**Slide 5:** What I was referring to was Hard Rock mining, as I believe that most of you have never been in an underground mine before. A haulageway, or sill as it is commonly known, is an underground passage in a mine used primarily for transporting ore, materials, or personnel. The haulageway is typically equipped with railway tracks which are essential for moving extracted materials from the working face in the mine to the mine shaft.

**Slide 6:** Next, we have a level, which is a "floor" above the sill. In the Stope Books, each level is represented by a number which averages a height of 6.64 feet in elevation. For example, if the sill elevation was 5,145.3 feet, the elevation of the 1000-5 level would be 5,178.5 feet above sea level because it is 33.2 feet in total height above the sill.

**Slide 7:** Then, there are stopes. A stope is an underground excavation. It is often step-like and leads up from a sill which is created to extract ore from steeply inclined or vertical veins.

**Slide 8:** Chutes are vertical or slightly inclined passageways used to transfer ore to the ore bin during underground mining. These passageways were often lined with steel and were created for efficiency. Gravity is used to move the ore through them to the desired location so it can be stored and dumped into an ore cart on the Sill for transporting to the shaft.

**Slide 9:** And last, is the manway. A manway is a dedicated, often vertical or steeply inclined, passage equipped with ladders, allowing personnel to travel safely between mining levels, raises, or stopes. In the Butte Stope Books, I have oftentimes seen these passages lead three-hundred to four-hundred feet up into a stope. Most of these manways were built prior to OSHA and MSHA regulations so there was usually no landing or deck to stand on. Current MSHA regulations require a ladder landing interval of no greater than thirty feet.

**Slide 10:** With terminology out of the way, the location of the Lexington Mine is located in the vast mining metropolis of beautiful Butte, America just above the Historic Landmark District and on top of the Continental Divide.

**Slide 11:** "The Lex", as she is also known as, was one of the hundreds of mines that sit atop the Richest Hill on Earth. The mine was in use from 1876 until 1957 and was subsequently the deepest

mine in Montana in the late 1880's producing silver ore until the rich ores were depleted and silver prices plummeted in 1893. In 1904, Copper King Augustus Heinze leased the mine with intention to exploit the mine for zinc.

**Slide 12:** The Anaconda Company acquired the mine in 1916 and, although a minor producer, contributed to the supply of copper and zinc that aided the United States and its allies in winning World War I. The Anaconda Company did not operate the Lex again until 1938, as a second world war loomed on the horizon. Mining continued until 1943 when operations ceased while the company rebuilt the surface plant.

**Slide 13:** After reopening in 1946, the Lex became one of the top producers of zinc and copper in Butte. In the early 1950's, the company drilled a nearly mile-long tunnel from a site north of the Anselmo Mine to the Lexington's 400-foot-level and started using it as a haulage tunnel for production from the Lexington and other Walkerville mines. Mining and production continued strong until 1957 when ACM closed the Lexington for good.

**Slide 14:** Underground mining on the Butte hill ended in the early 1980's and shortly after the site was listed as a Superfund site. Beginning in 1988, the Montana Bureau of Mines and Geology used the Lexington shaft as a monitoring site to monitor Static water levels, water temperature, and water quality. By 1990, the Lexington had become a full-time monitoring well.

**Slide 15:** The MBMG continued to utilize the monitoring well until 2024, when the shaft was unfortunately lost due to a structural failure of the mine timbers in the shaft between the surface and the 300-foot-level which destroyed the monitoring equipment and made the shaft unsafe for continued use as a monitoring site.

**Slide 16:** Following the shaft collapse, Ted Duaine and his crew developed a plan to identify a suitable location for a new monitoring well. The selected area needed to be relatively level and located on either Butte-Silver Bow or Atlantic Richfield (ARCO) property. During this time, as I transitioned from Data Preservation into the GIS Department and worked through the detailed process of transferring stope book subsidence data into ArcPro, Gary Icopini asked if I could project the Lexington workings to the 1,000-foot level. I readily accepted the task, as I have a well-known interest in working with the Butte Stope Books.

**Slide 17:** A replacement well needed to intersect underground workings and reach the flooded zone. Working with MBMG staff, potential drill locations were identified using historic stope records. Two candidate locations were selected. Both Target Areas 1 and 2 measured approximately thirty-one feet wide by fifty-four feet long.

**Slide 18:** Target Area 1 was grand spot! Beautiful views, fairly level, free of excess debris and the location was very easy to get to. But, there was one issue! This site had overhead power lines directly above the proposed drill pad, forcing its elimination.

**Slide 19:** Target Area 2 also offered a great view, something us Montanans are keen to. But, it also offered a relatively flat drilling area, no overhead powerlines, and easy access for drilling equipment. It also contained one notable landmark... a large shrub that would later play an unexpected role in the project.

**Slide 20:** For over one-hundred years, underground projections had been aligned using the Anaconda Grid, a coordinate system historically used by the Anaconda Mining Company. I also use this coordinate system as there are multiple surface reference points still in existence that I can use

to align the grid to current imagery, specifically mine shaft locations throughout the city. Initial alignments were performed in Google Earth.

**Slide 21:** I packed up my handy dandy Garmin Rino 110 and I headed out into the great unknown collecting coordinates of shafts in a WGS84 Dataset for seven of the nine control points I had picked out and had access to. There are many more mine shafts in this area, but I was looking for accessible shafts that had been capped by remediation methods that were completed years earlier.

**Slide 22:** Using those control points, the imagery was laid out in Google Earth. Now, remember the shrub I had spoken about earlier? This is where everything that I had diligently worked on takes a twist.

**Slide 23:** Do you notice anything different about the shrub? Of course not, because you are not “SHRUB” experts!

**Slide 24:** After importing the data into ArcGIS Pro, something strange happened. The shrub moved. Of course, the shrub itself had not moved — the data had. This revealed a significant projection mismatch between datasets.

**Slide 25:** And that’s when the lightbulb went on! We had inadvertently found out in a prior email that the current mining company Montana Resources was still using the Anaconda Grid System in their mining operations. We contacted Montana Resources and they agreed to send a survey team out to our site with their equipment which could convert the Anaconda Company coordinates directly to WGS84. So, a survey was conducted at the drill site. Great, we were making progress!

**Slide 26:** When the new survey data was loaded into ArcGIS Pro, the projection shifted again. The difference between datasets was nearly thirty feet. That margin of error was unacceptable when trying to hit a target between nine-hundred to one-thousand feet below ground. During the time all of this time was being sorted out, a construction crew had been sent out to build a drill pad and retaining pond. Now, we have a dilemma. We can’t just keep widening the drill pad as the retention pond was already in place.

**Slide 27:** So, I did what every good ‘ol Montana elk hunter does when he needs information. I turned on my cellphone and opened up my onX Hunt app.

**Slide 28:** I went back to the site to confirm the correct location and mapped the drill pad using my cell phone. I also revisited and checked the original Survey Points. Mind you, not an easy task when it is so cold that cell phones do not like to work correctly and the touch screen cannot be operated with gloves on.

**Slide 29:** Once the onX data was loaded into ArcGIS Pro we had a correct projection in the ArcPro imagery. The survey points in red matched. More progress had been achieved! But what about the original points brought in from Google Earth?

**Slide 30:** The points shifted yet again! Eventually, it was discovered that Montana Resources uses a different imagery base than Arc Pro. Which now meant that my original points brought in from Google Earth were in fact correct!

**Slide 31:** With all the information we had compiled, we opted to use the original imagery set in WGS84 coordinates to the new survey points Montana Resources provided along with the onX Hunt

data and VOILA.....an area that looked promising to drill! Again, the blue outline represents the excavated drill pad site.

**Slide 32:** Now remember, we are monitoring water levels and water temperatures on the Butte hill, so we had to drill into the mine workings and make it past the static water level. The static level, when last measured, was approximately 840 feet lower than the collar of the Lexington mine. But again, there were a few more items to consider.

**Slide 33:** Our largest target was an area that was comprised of several things. The distance from the 800 sill, the widest possible area to hit, and where the static water level was in comparison to surface. We would definitely have to miss the 800 Sill as it would almost certainly contain steel railroad tracks due to its primary use as a haulage way for ore. Another issue was not hitting any other workings between surface and our drill target as it would cost a lot more money if a void space was hit above water. If that would have happened, the drilling company would have to drive steel casing to maintain circulation as opposed to drilling an open hole.

**Slide 34:** Also, there were other possible underground obstacles that reduced the safe drilling window. A manway (indicated by an "M") that was used to connect mine levels and an Ore chute (indicated by a "C") which could potentially be steel-lined which could possibly deflect the drill head. Again, we thought we were in the clear to pick a drill point until historical imagery of the area bared its ugly head!

**Slide 35:** As it turned out, there was a historic water reservoir in our immediate area that had been filled in with dirt. We definitely had to make sure we steered clear of this as we did not want to damage any historically significant structures. Once the reservoir was geo-located and we knew the location of the edge of the reservoir, the project was again moving forward.

**Slide 36:** Gary Icopini was finally able to select the drill location. The chosen window needed to intersect the top of the stope at its widest horizontal extent (the 1000-16 level) while also reaching the flooded workings near the 1000-15 level. This left a vertical target window of only about forty-seven feet.

**Slide 37:** For additional context, the drill target window was extremely tight. The lateral position was 9.72 feet east of the existing 800 Sill that had to be avoided, and 11.46 feet west of a potential steel lined chute shown on the stope map. As a reminder, any error in our projection could have potentially caused the drill to strike a railroad track or be deflected by the ore chute. Either outcome would have ruined the hole, forcing us to abandon a four-hundred-thousand-dollar project and find a new drill site.

**Slide 38:** At one point, Silver Bow Mining Company offered their assistance and entered Gary's drill coordinates into their 3D modeling software. What we ended up with was a really cool visual of the stopes and drill projection to say the least. My projection imagery, Gary's Spud point location and Silver Bow Mining's 3D projection looked great. In the model and in my overlays, we had missed the 800 sill, caught the top of the stope at the 1000-16 level and were projected to hit the static water level about midway through the 1000-15 level.

**Slide 39:** As a reminder, our window (the area in yellow) was approximately forty-seven feet tall before the workings shifted to the South meaning that we would be drilling into solid granite again. Everything was finally a go! You could say we were "Threading a Needle" with very little margin for error. In this kind of setup, the key risk factors are: Survey Accuracy, Projection and Modeling

Assumptions and Drill Deviation Behavior, even though the drill company guaranteed that the drill would not deviate at all. All of the stakes justified a severe level of caution—losing the hole to steel or deflection wouldn't just damage equipment, it would invalidate the whole setup!

**Slide 40:** Work commenced shortly afterward, and after three weeks of drilling, the well was completed successfully.

**Slide 41:** The total depth of the well is 1,038 feet with a ten-inch casing dropped to a depth of 945 feet. The six-inch inner casing is set at a depth of 996 feet and during the final well test, it was found that the monitoring station was producing a thirty-seven gallon per minute flow rate. The well successfully intersected the flooded mine workings and restored groundwater monitoring capability for Butte Hill.

**Slide 42:** Together with the efforts of Silver-Bow Mining Company, Montana Resources, and the MBMG Hydrology Department and GIS Department, we were able to demonstrate the successful integration of historic mining records and modern GIS technology along with survey control, 3D underground modeling and precision drilling. All of this to successfully hit a very small target almost one-thousand feet below the surface.

**Slide 43:** To conclude, through collaboration of all involved, the Lexington Monitoring System was fully restored. Another successful project by the Montana Bureau of Mines and Geology! I would also like to say thank you for allowing me to present to you today.

**Slide 44:** Questions?

# Digital Mapping Techniques - 2026



# Pinpoint Drilling using ArcPro

Pros and Cons of using  
136-year-old data with current imagery



**Lexington Mine History**

**Project Details**

**Issues during the project**

**Finished product**





# Mining Terminology 101



**Haulageway or Sill**

# Mining Terminology 101

1000-5  
(+6.64')

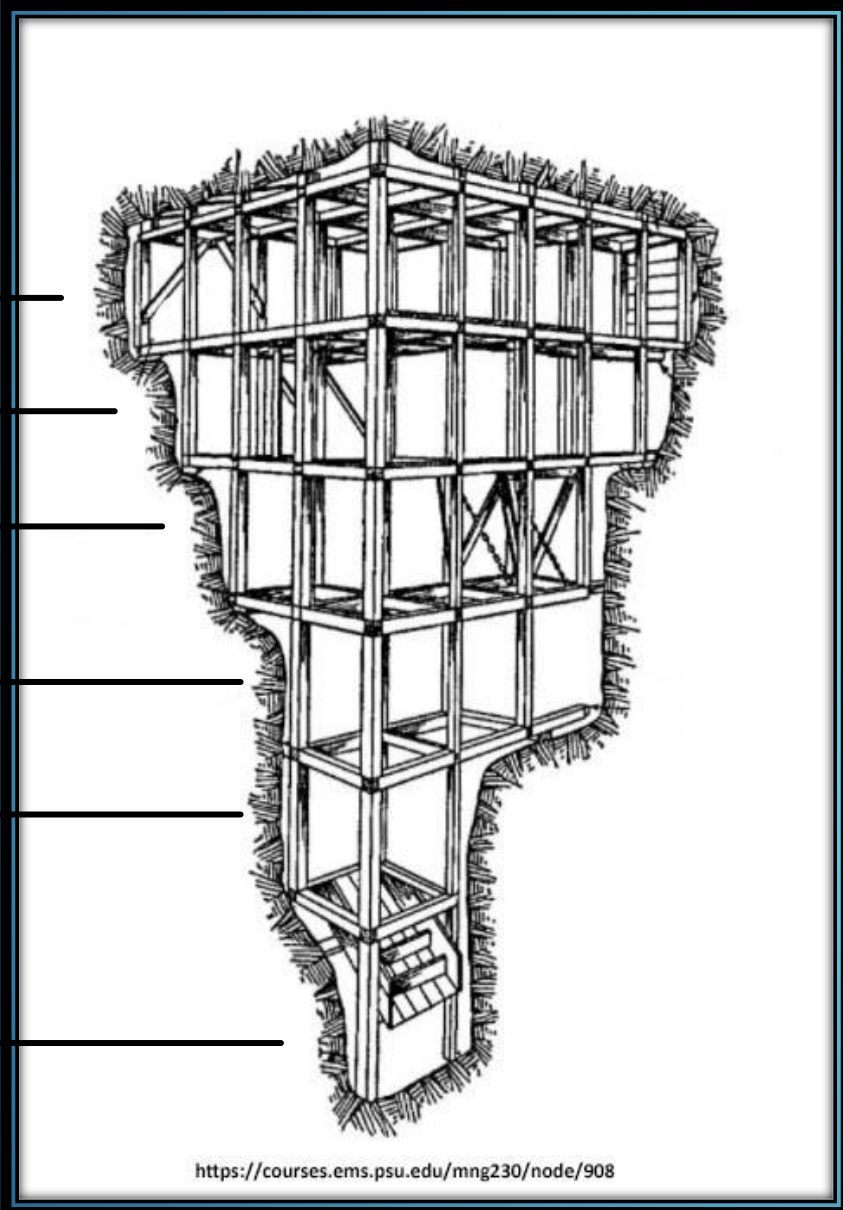
1000-4  
(+6.64')

1000-3  
(+6.64')

1000-2  
(+6.64')

1000-1  
(+6.64')

1000 Sill  
El. 5,145.3'



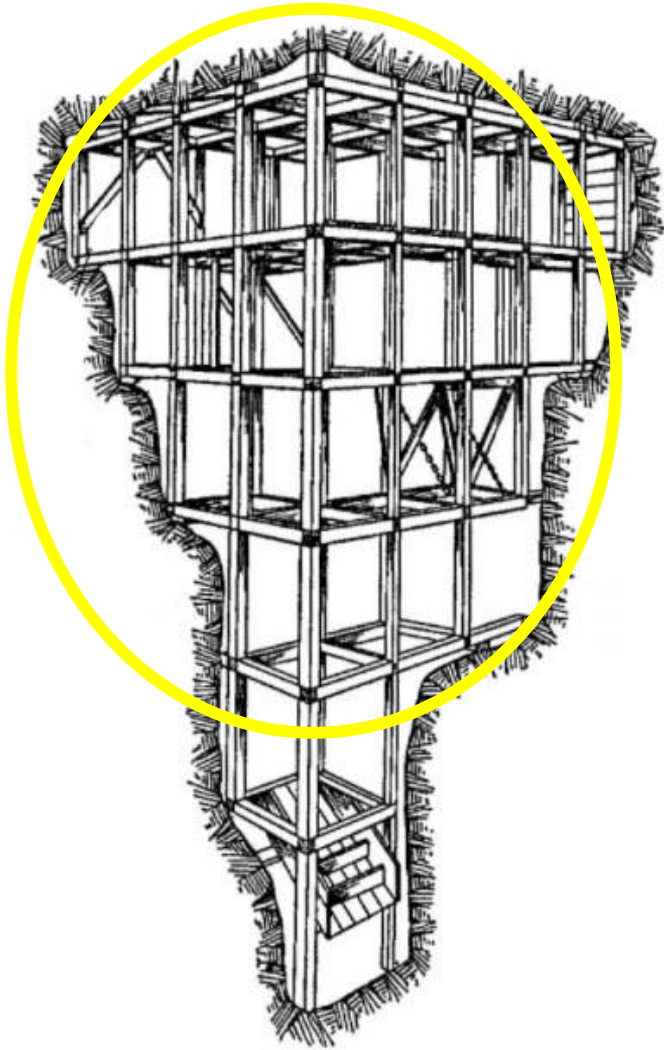
<https://courses.ems.psu.edu/mng230/node/908>

## Level

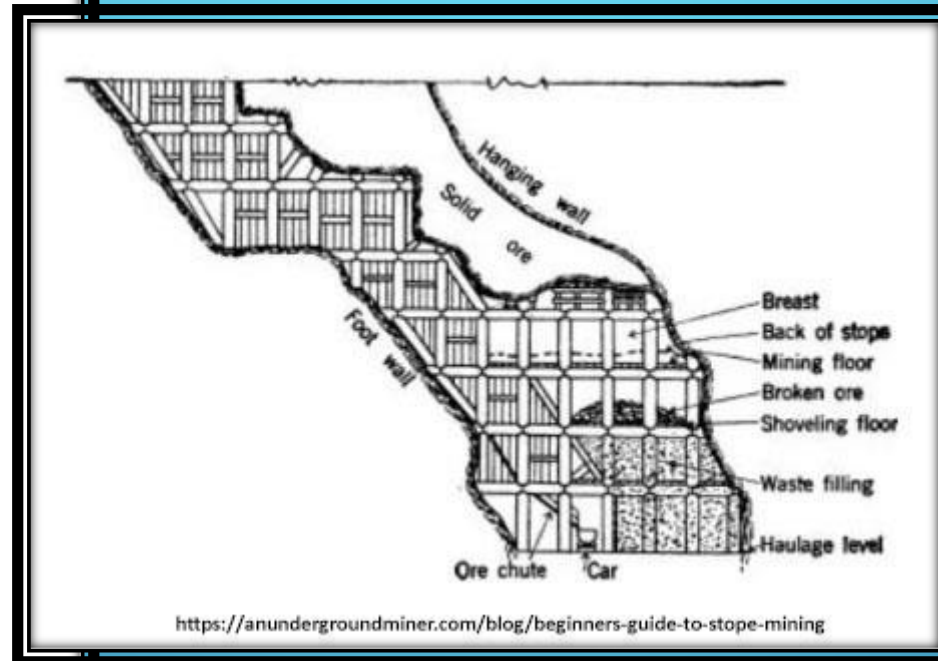


# Mining Terminology 101

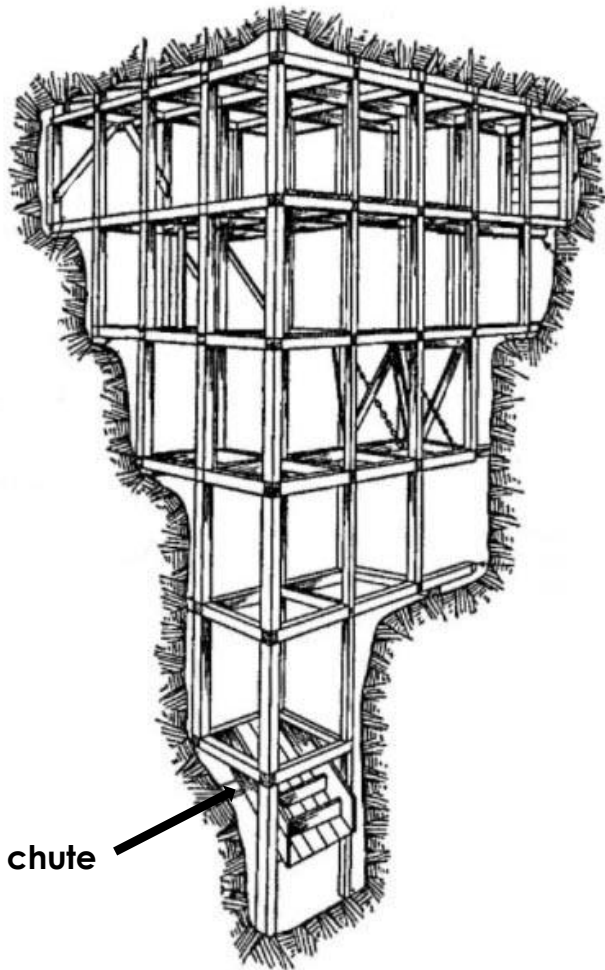
## Stope



<https://courses.ems.psu.edu/mng230/node/908>



# Mining Terminology 101



chute

<https://courses.ems.psu.edu/mng230/node/908>



Top Of Chute

## Chute

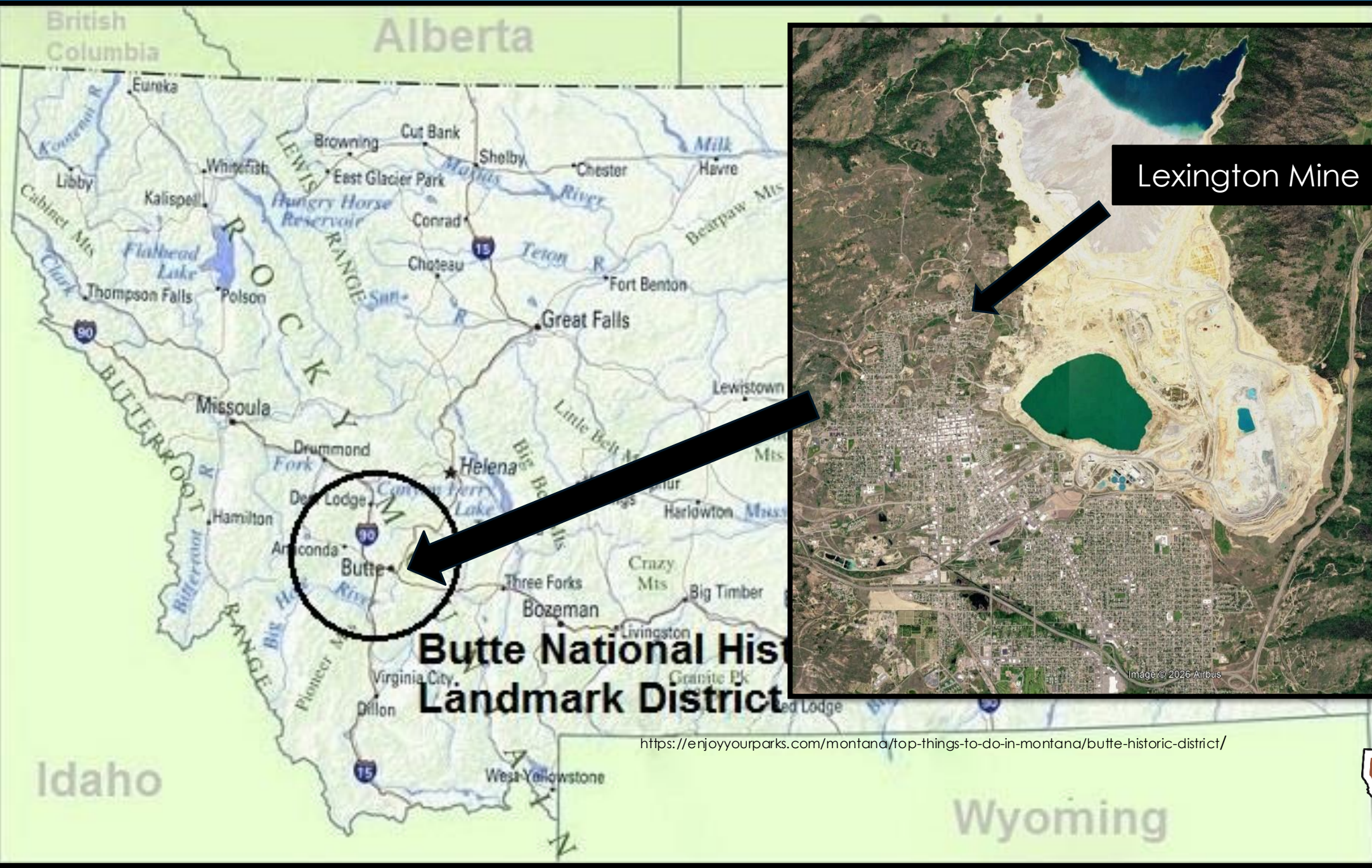


<https://youtu.be/cPVtG9gvgNg?si=1Ec72qs8TmRz5w-6>

# Mining Terminology 101



**Manway**



Lexington Mine

<https://enjoyyourparks.com/montana/top-things-to-do-in-montana/butte-historic-district/>





*Smithers  
Bohr*

LEXINGTON MINE - Butte

**Image courtesy of the Butte-  
Silver Bow  
Public Archives**

**Creator:  
C. Owen Smithers**



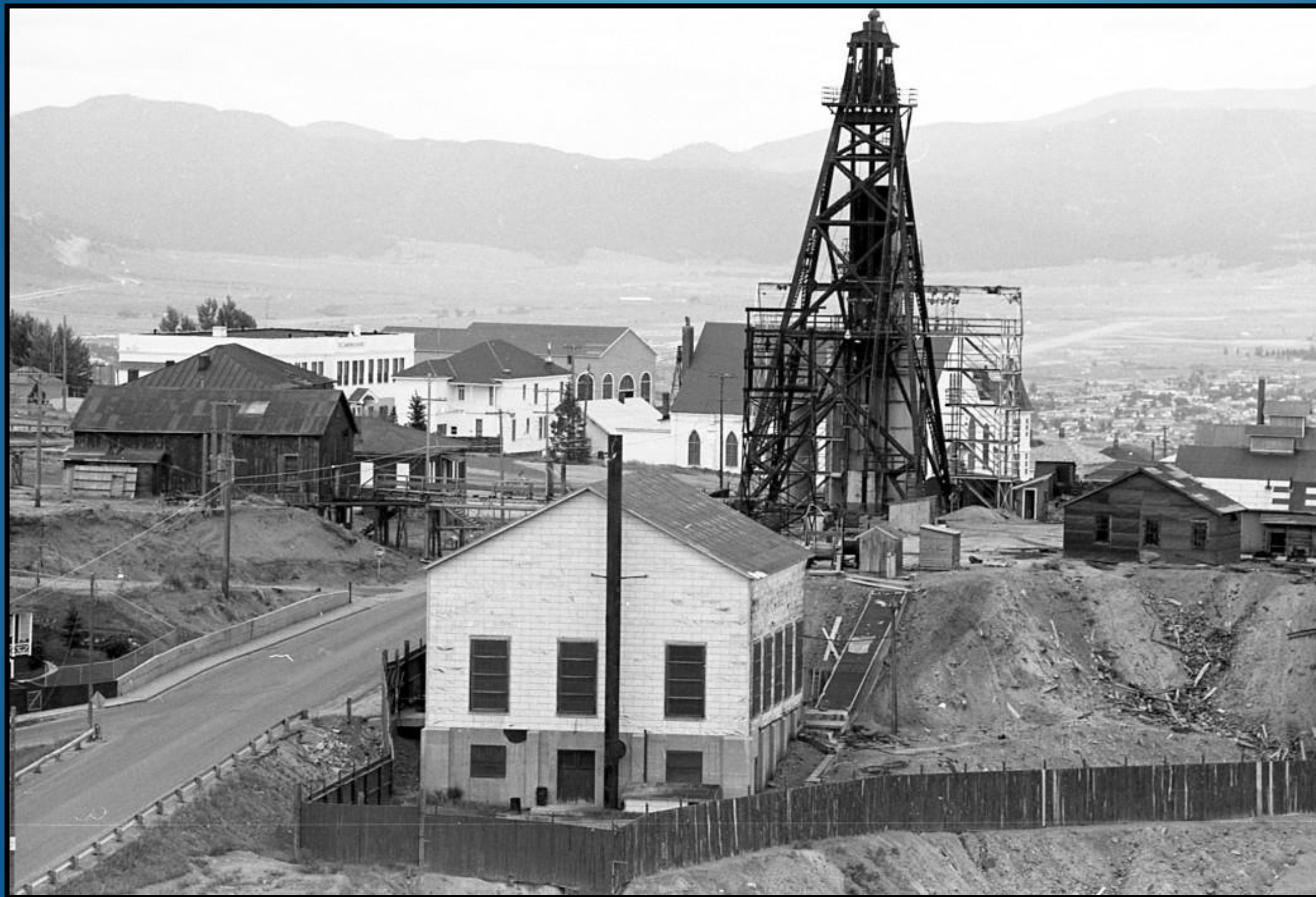


Image courtesy  
of the World  
Museum of  
Mining.





Image courtesy  
of 95.5 KMBR







**U-25** 26

Volumes 1, 2, Misc. #4

**U-27** 28

Volumes 1, 2, Misc. #4

**U-29** 30

Volume 1

**T-25** 26

Volumes 1, 2, Misc. #4

**T-27** 28

Volumes 1, 2, 3, 4, 5, Misc. #4

**T-29** 30

Volumes 1, 2, (3-4), 5, 6, 7

**S-25** 26

Volume 1

**S-27** 28

Volumes 1, 2, 3, 4, 5, 6, Misc. #3

**S-29** 30

Volumes 1, 2, (3-4), 5, 6, 7

**R-25** 26

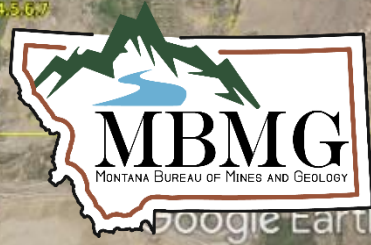
Volumes 1, 2, Misc. #4

**R-27** 28

Volumes 1, 2, 3, 4, 5, 6, 8

**R-29** 30

Volumes 1, 2, 3, 4, 5, 6, 7



Target Area 2



Target Area 1





# Lexington Mine





11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

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113 124 135 146 157 168 179 190 201 212 223 234 245 256 267 278 289 300 311 322 333 344 355 366 377 388 399 410 421 432 443 454 465 476 487

113 124 135 146 157 168 179 190 201 212 223 234 245 256 267 278 289 300 311 322 333 344 355 366 377 388 399 410 421 432 443 454 465 476 487





• Belle of Butte

• Badger State

• Lexington

• Corra No. 1

• Wild Bill No. 1

• Penrose

• W. Gray Rock

• E. Gray Rock

• Mt. Con #2

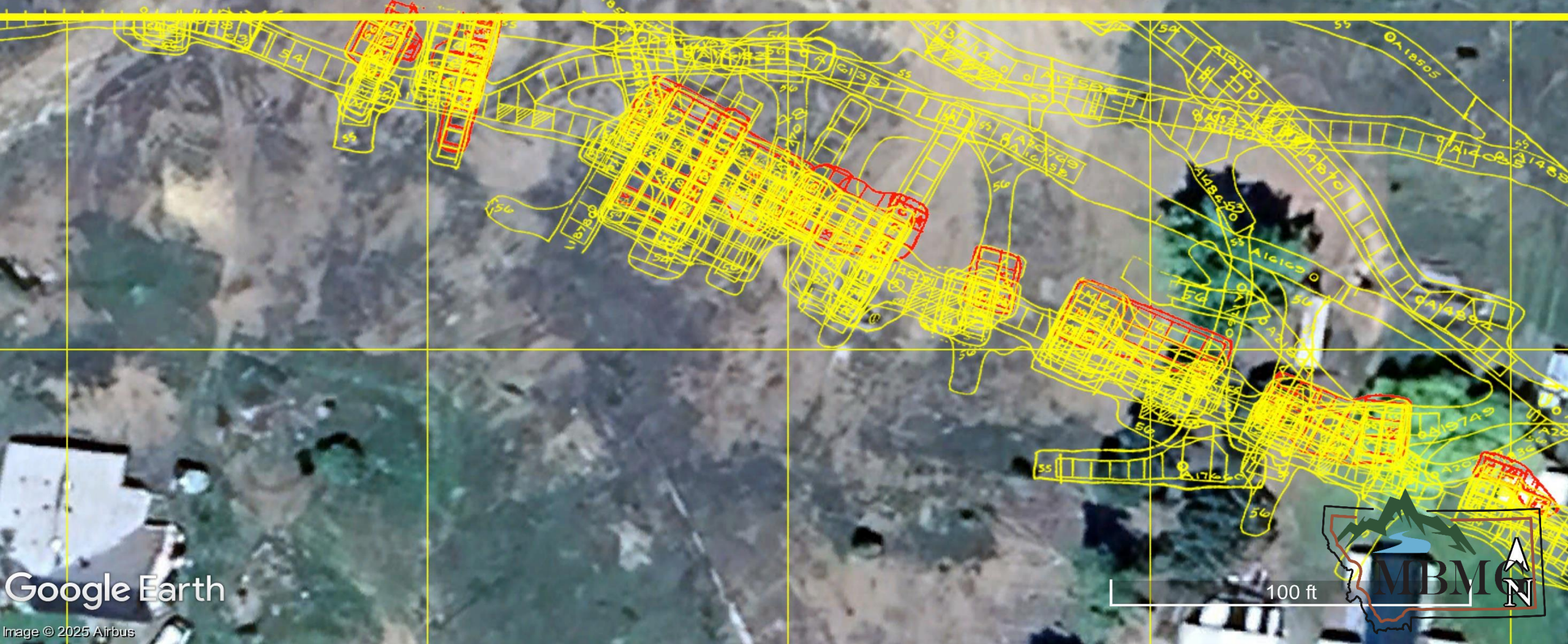
Google Earth

© 2026 Airbus

1000 ft



The "SHRUB OF DOOM"



Google Earth

Image © 2025 Airbus



2002



2013

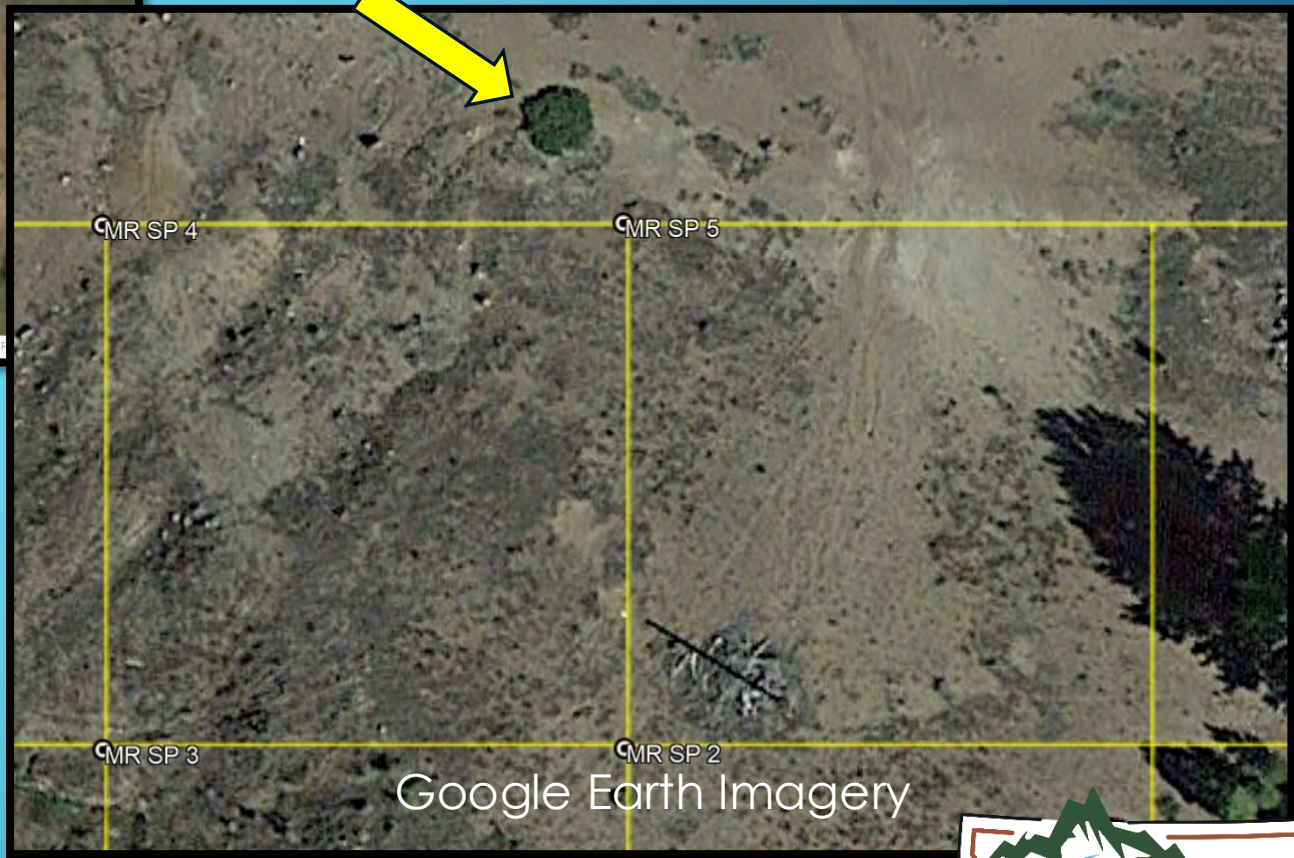
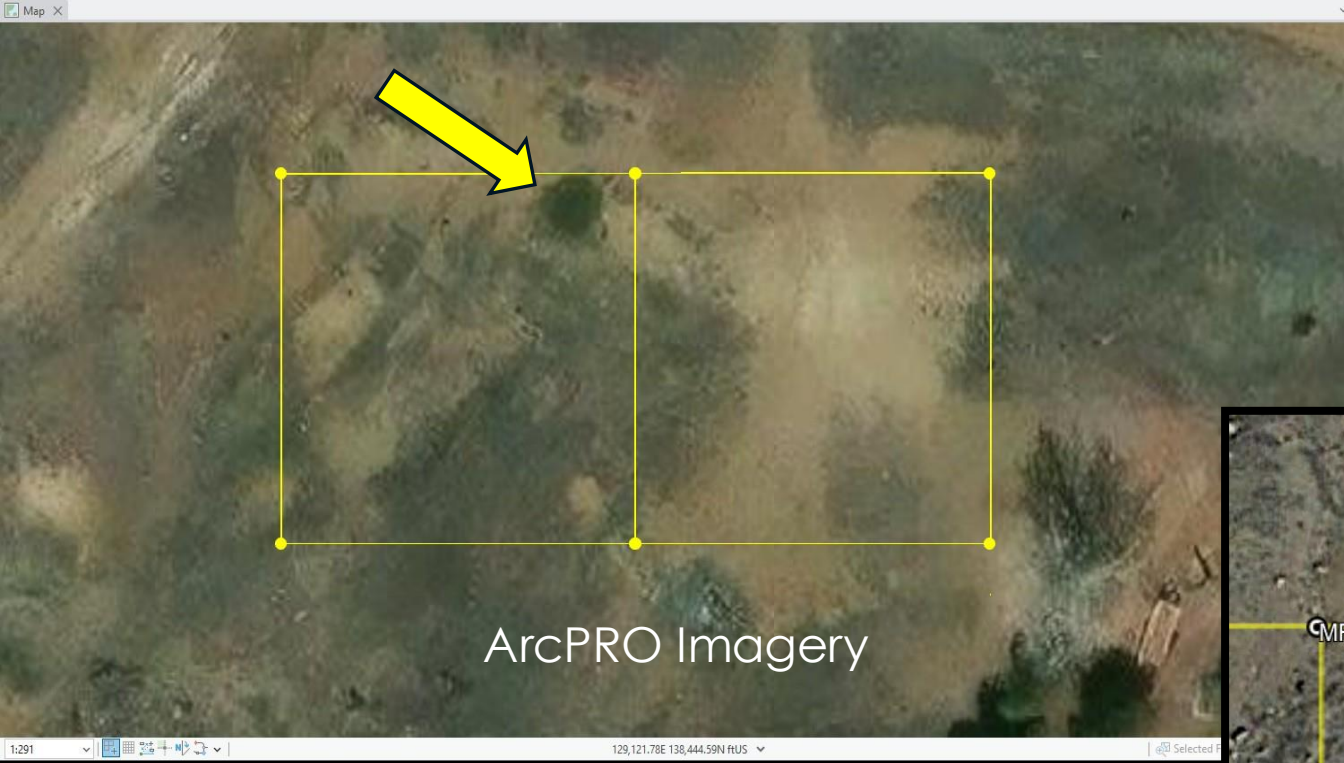


2014



2025









- = Google Earth Data
- = M.R. Survey Points





Image courtesy of Montana Fish Wildlife & Parks



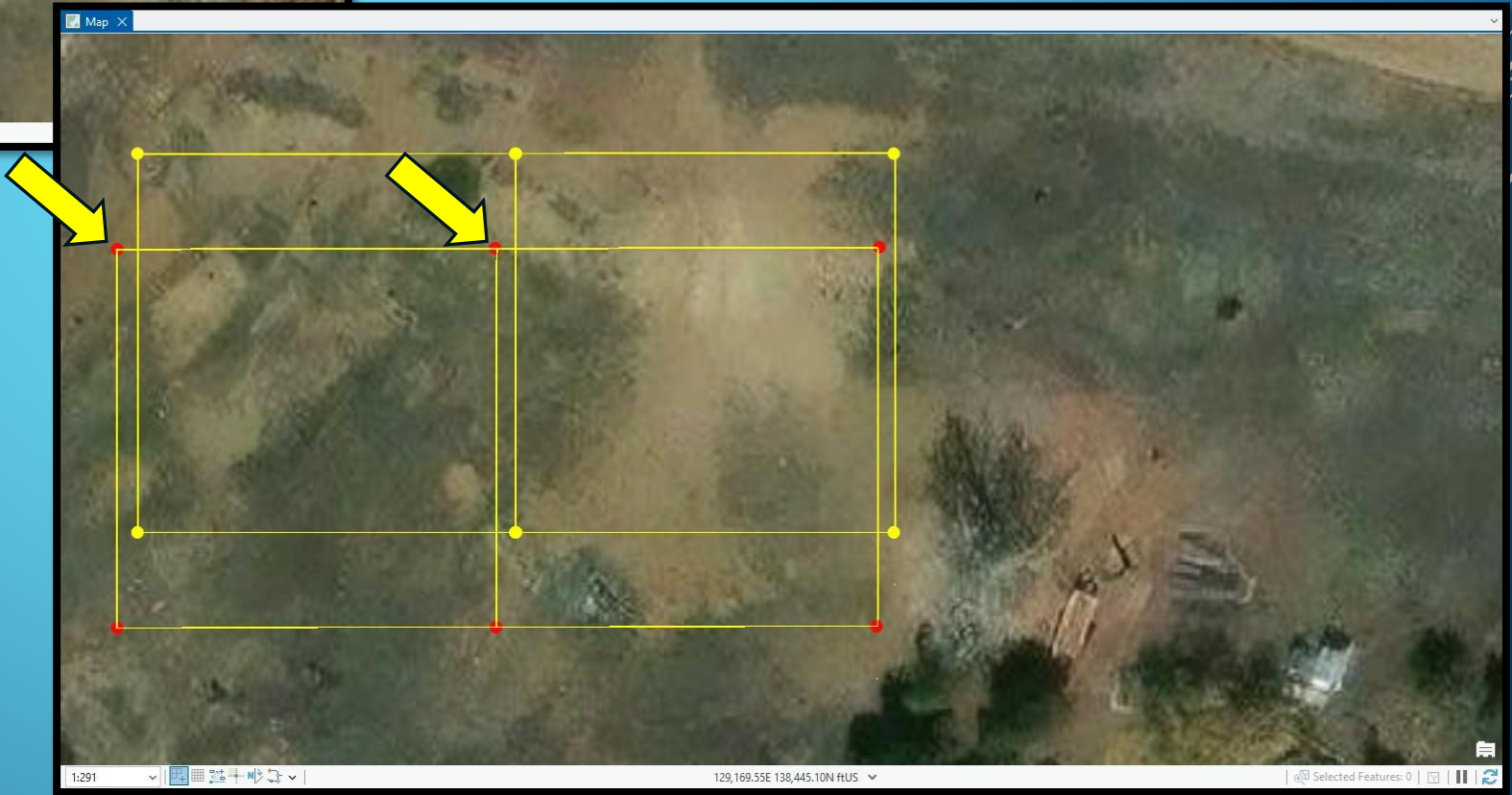


**Blue Dotted Line: Well Pad**

**Yellow Points : resurvey of Montana Resources survey points using onX Hunt**

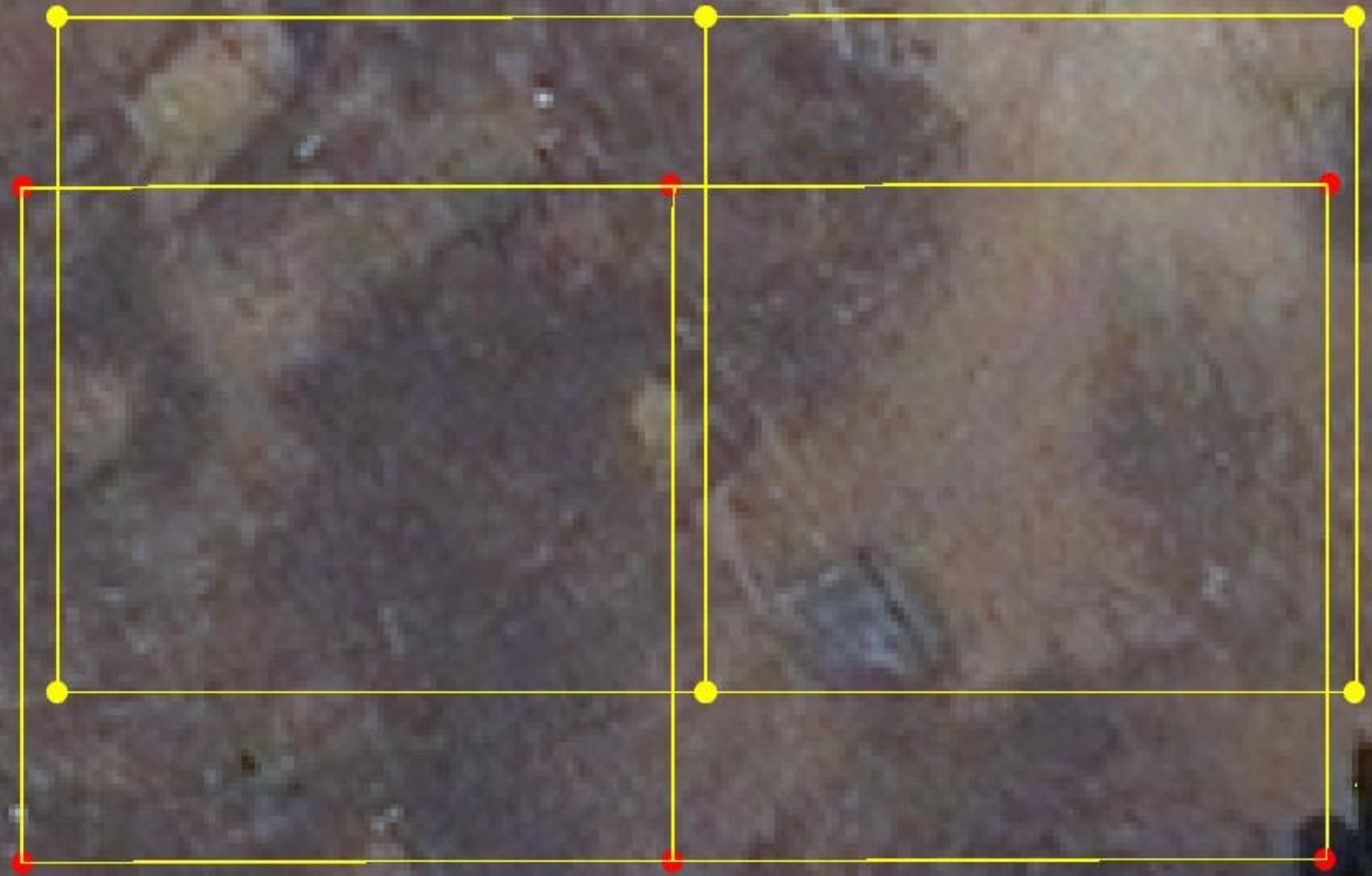
**Green Point: Northernmost point of “The Shrub”**





● = Google Earth Data

● = M.R. Survey Points



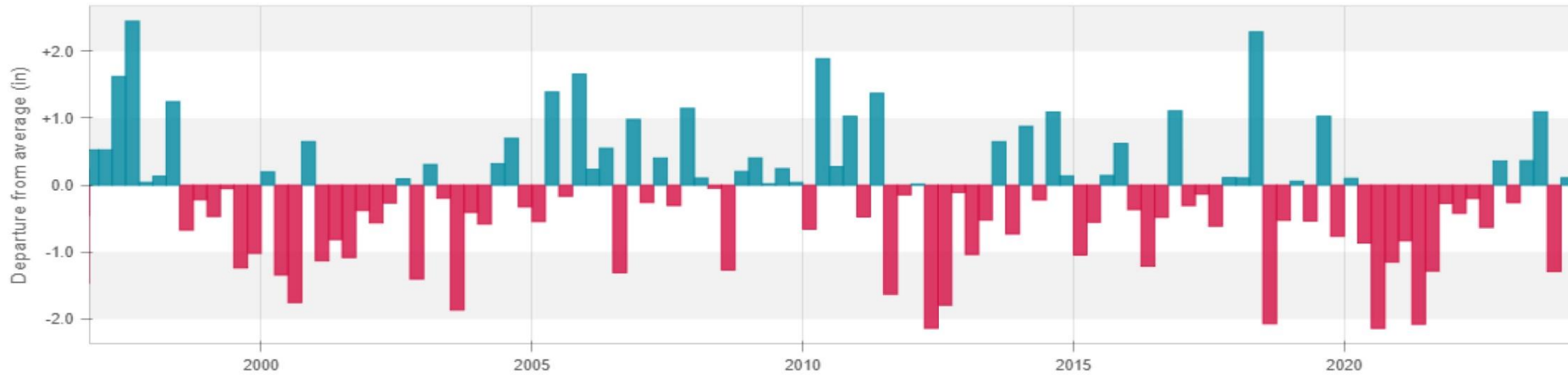




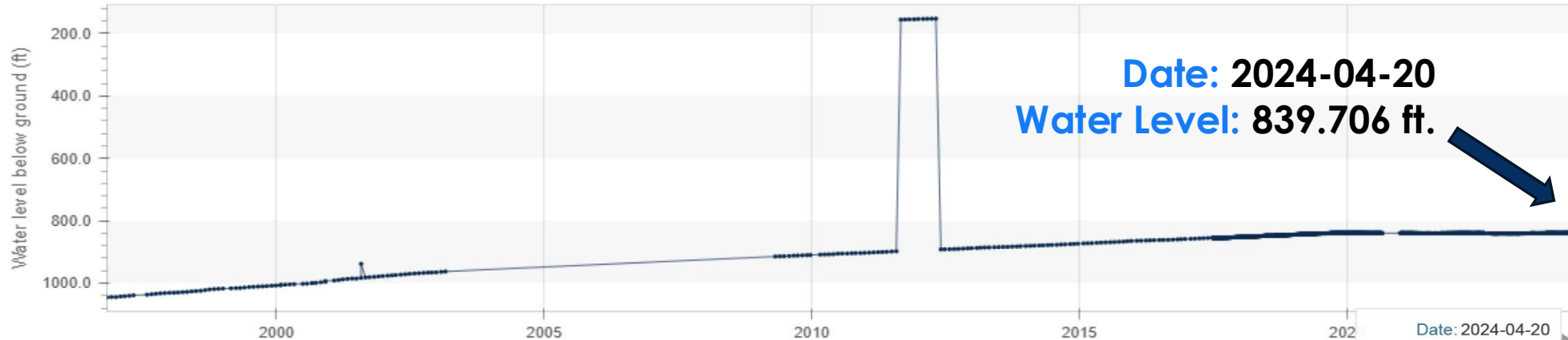
Sign Out | 3/9/2026

# Ground Water Information Center Hydrograph and Precipitation Display

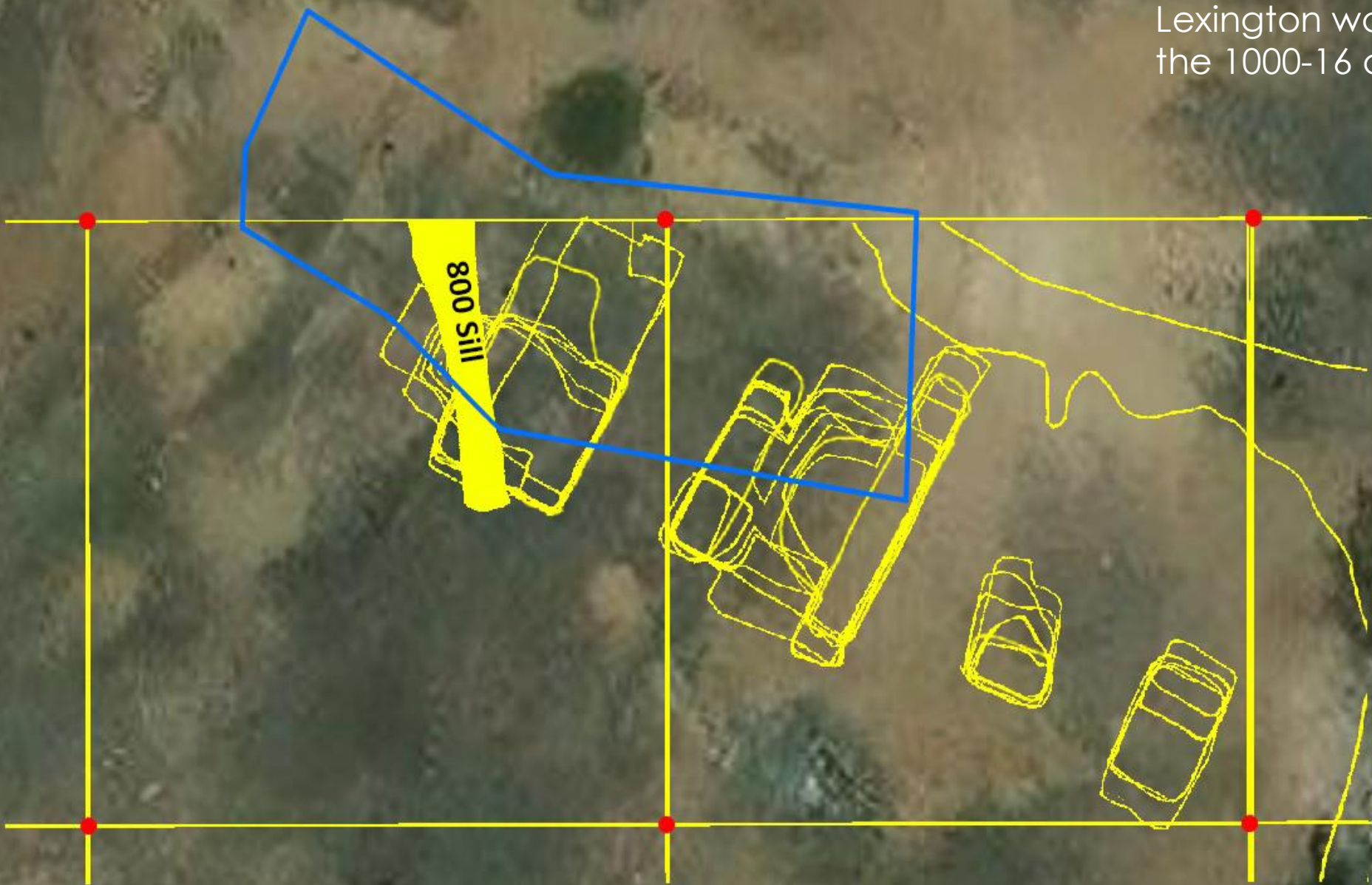
Quarterly Precipitation Departure for Southwest Climate Division

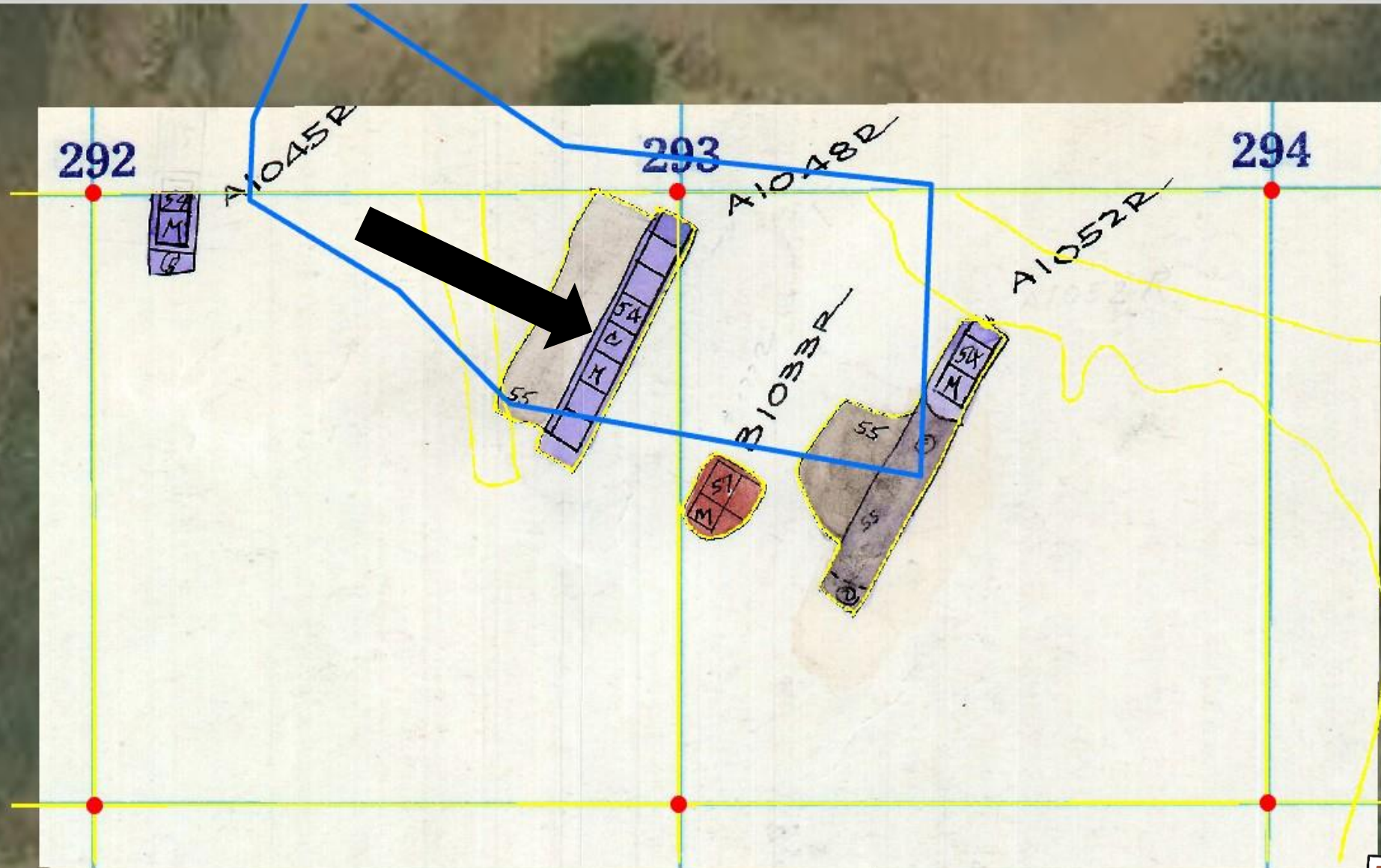


Daily Average Water Level (GWIC ID 4737)

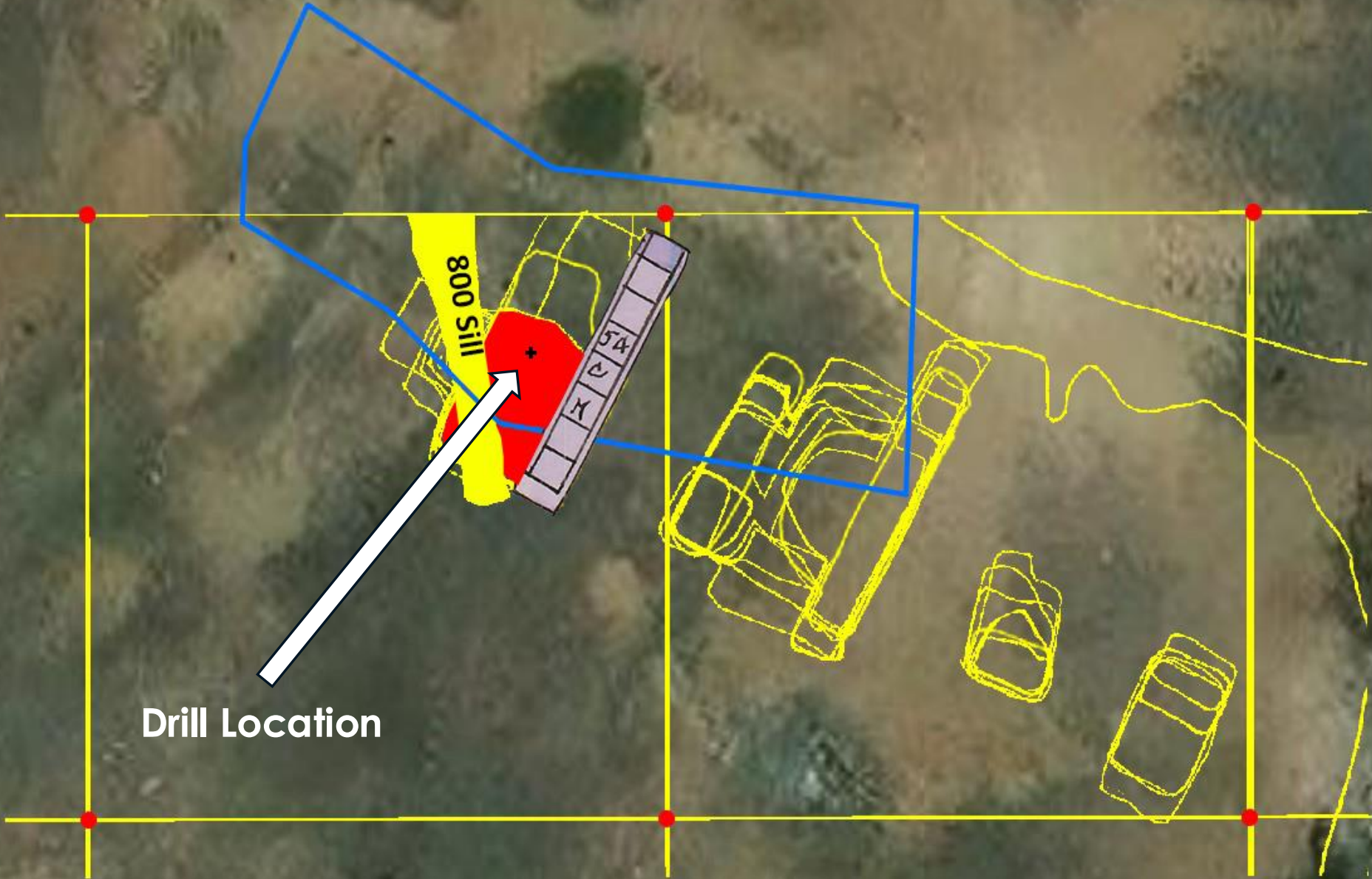


Lexington workings between the 1000-16 and 1000-9 levels





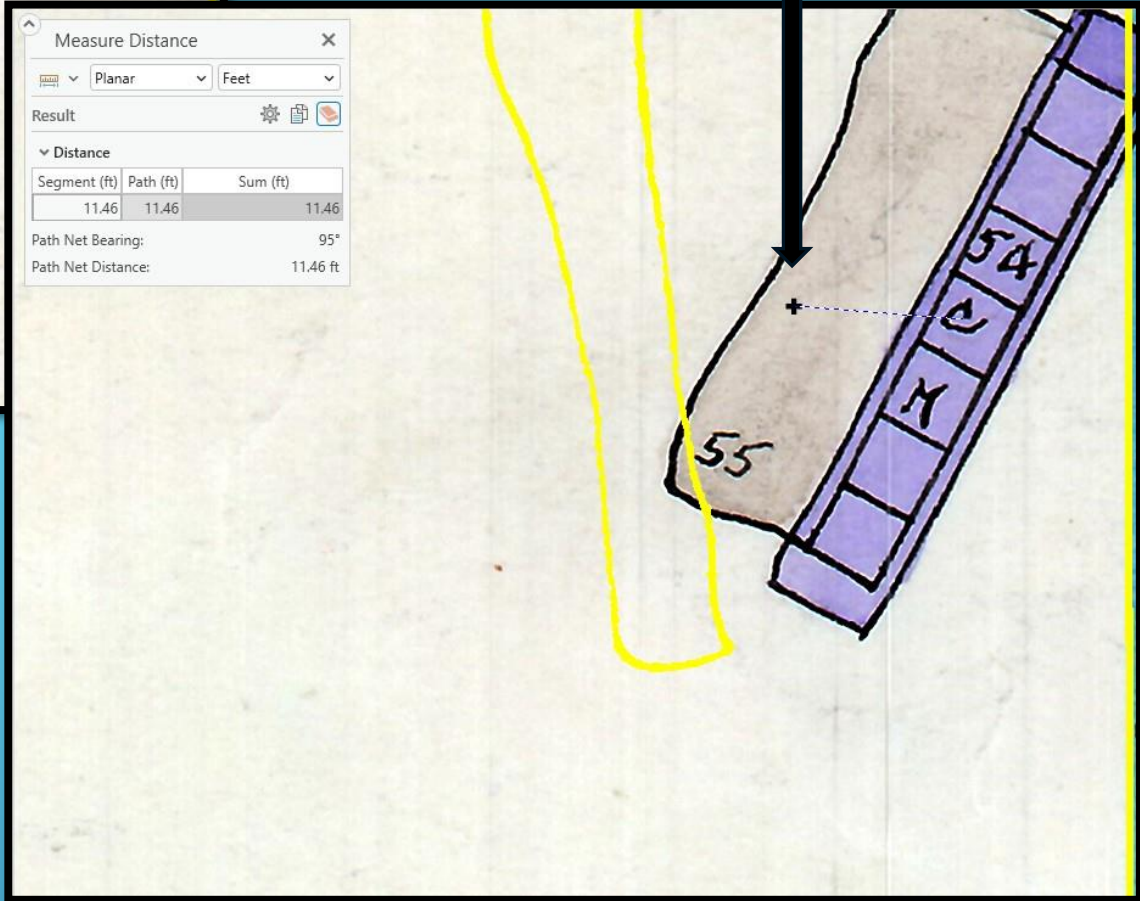
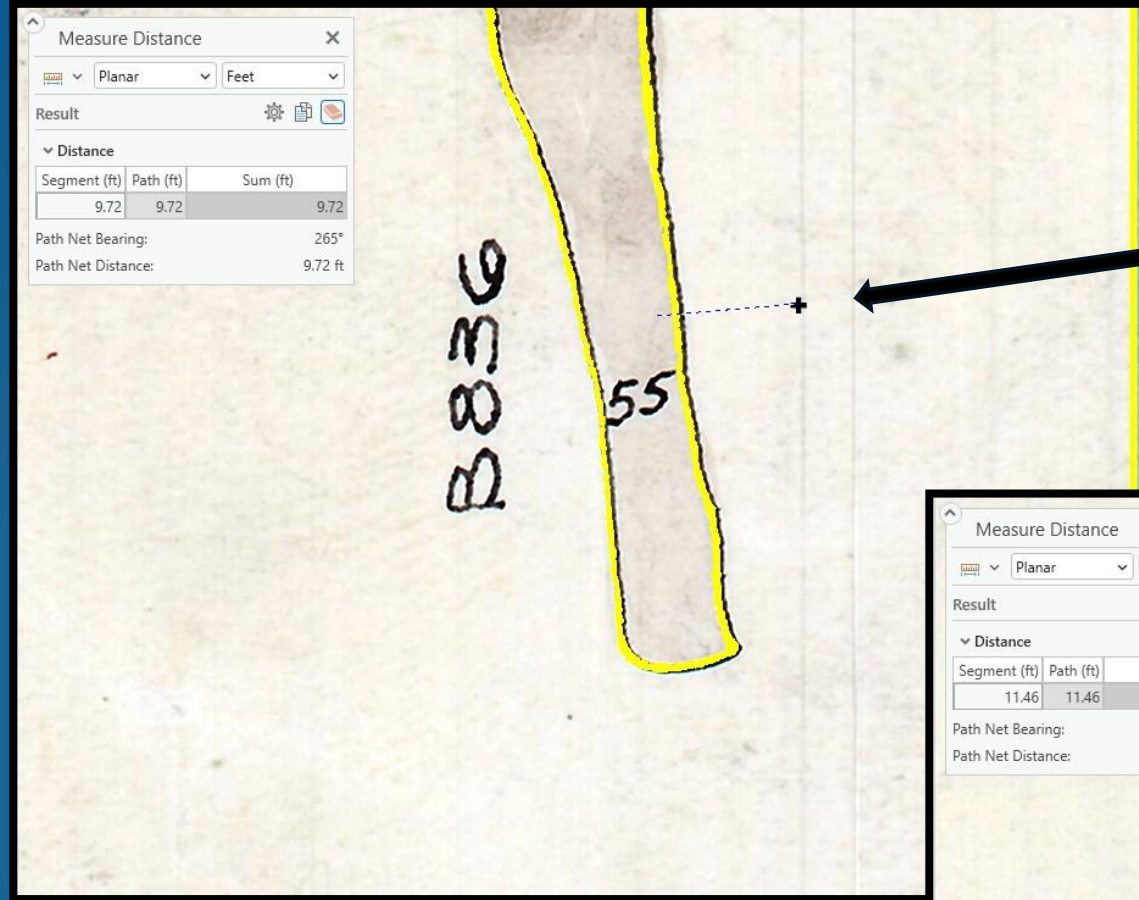


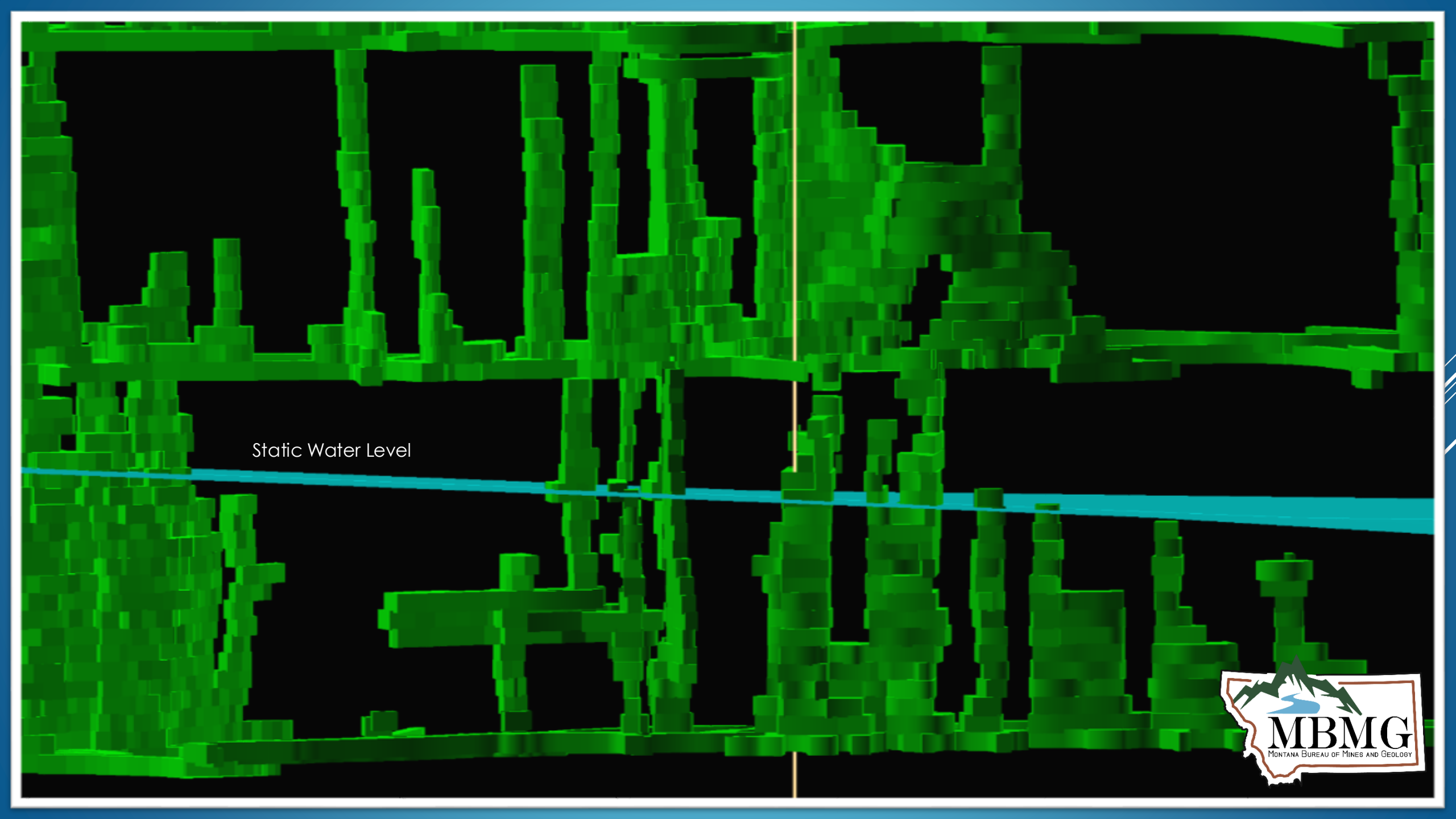


Drill Location



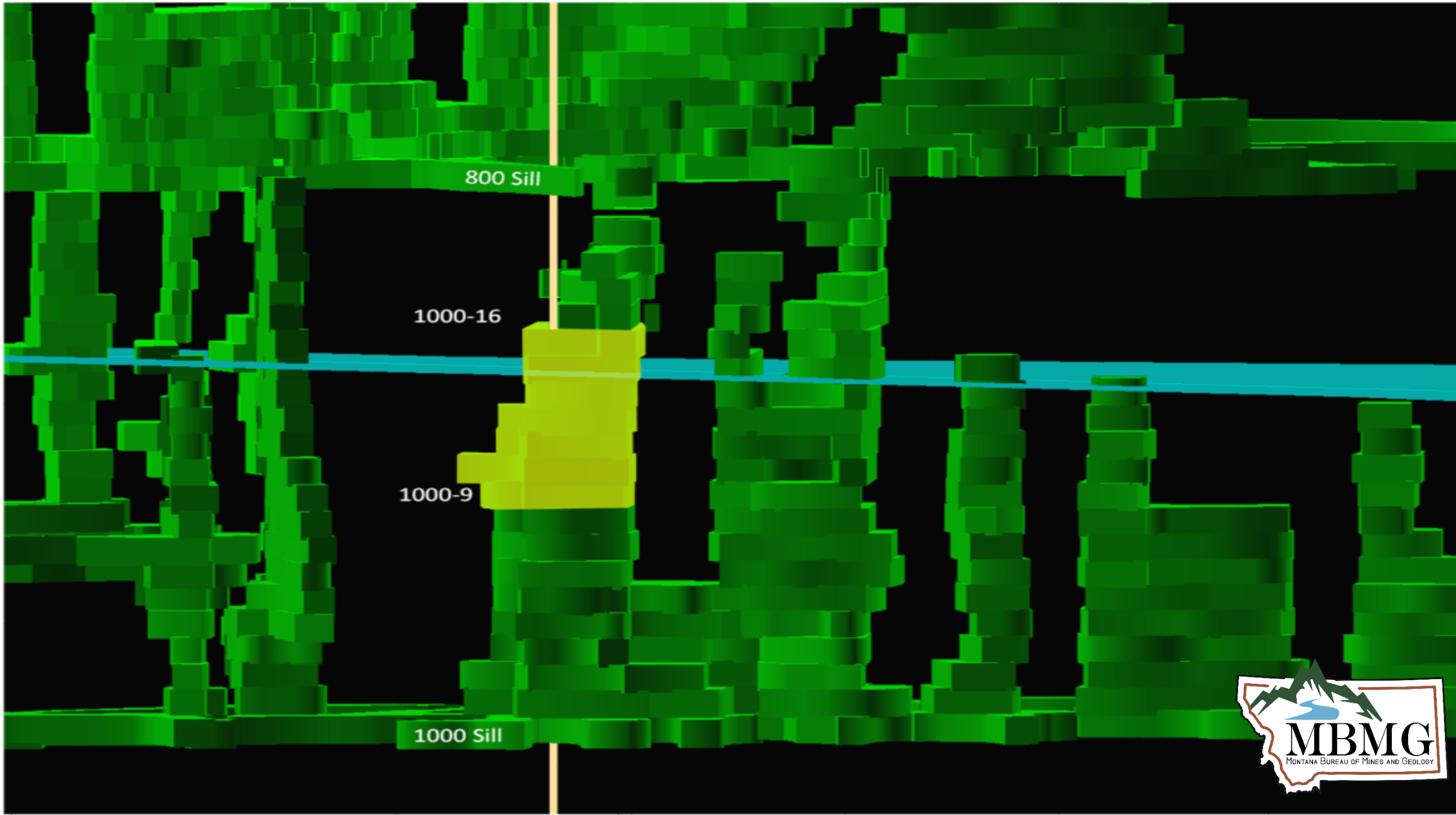
# Drill Location



A 3D perspective view of a mine shaft. The shaft is a vertical cylindrical structure with a blue interior. The shaft walls are composed of brown, textured blocks representing rock layers. A horizontal blue line is drawn across the shaft, representing the static water level. The text "Static Water Level" is placed to the left of this line. The shaft extends from the top to the bottom of the frame. The background is a dark, textured surface representing the mine floor or surrounding rock.

Static Water Level







Images courtesy of:  
Jackson Quarles  
Gary Icopini PHD



## Well Information

**Total Depth: 1038 Feet**

**10" Casing Depth: 945 Feet**

**6" Inner Casing Depth: 996 Feet**

**Flow Rate: 37 GPM @ final test**



# Project Significance:

This project demonstrates the successful integration of:

- Historic mining records
- Modern GIS technology
  - Survey control
- 3D underground modeling
  - Precision drilling

All to hit a very small target nearly 1,000 feet below the surface.



# Conclusion

Through collaboration between MBMG, survey teams, and mining partners, the Lexington monitoring system was successfully restored.

Another successful project for the **Montana Bureau of Mines and Geology**.



# Questions?



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