PHASE 2
GROUND WATER STUDY

TRONOX NAUM AMBROSIA LAKE AREA – SAN MATEO CREEK BASIN LEGACY URANIUM SITE

TRONOX Quarterly Meeting
October 25, 2017
Albuquerque, NM

9881681

MULTI-PHASED GROUND WATER INVESTIGATION

Phase 1

Alluvial Aquifer
San Mateo Creek Basin
2012 – 2016

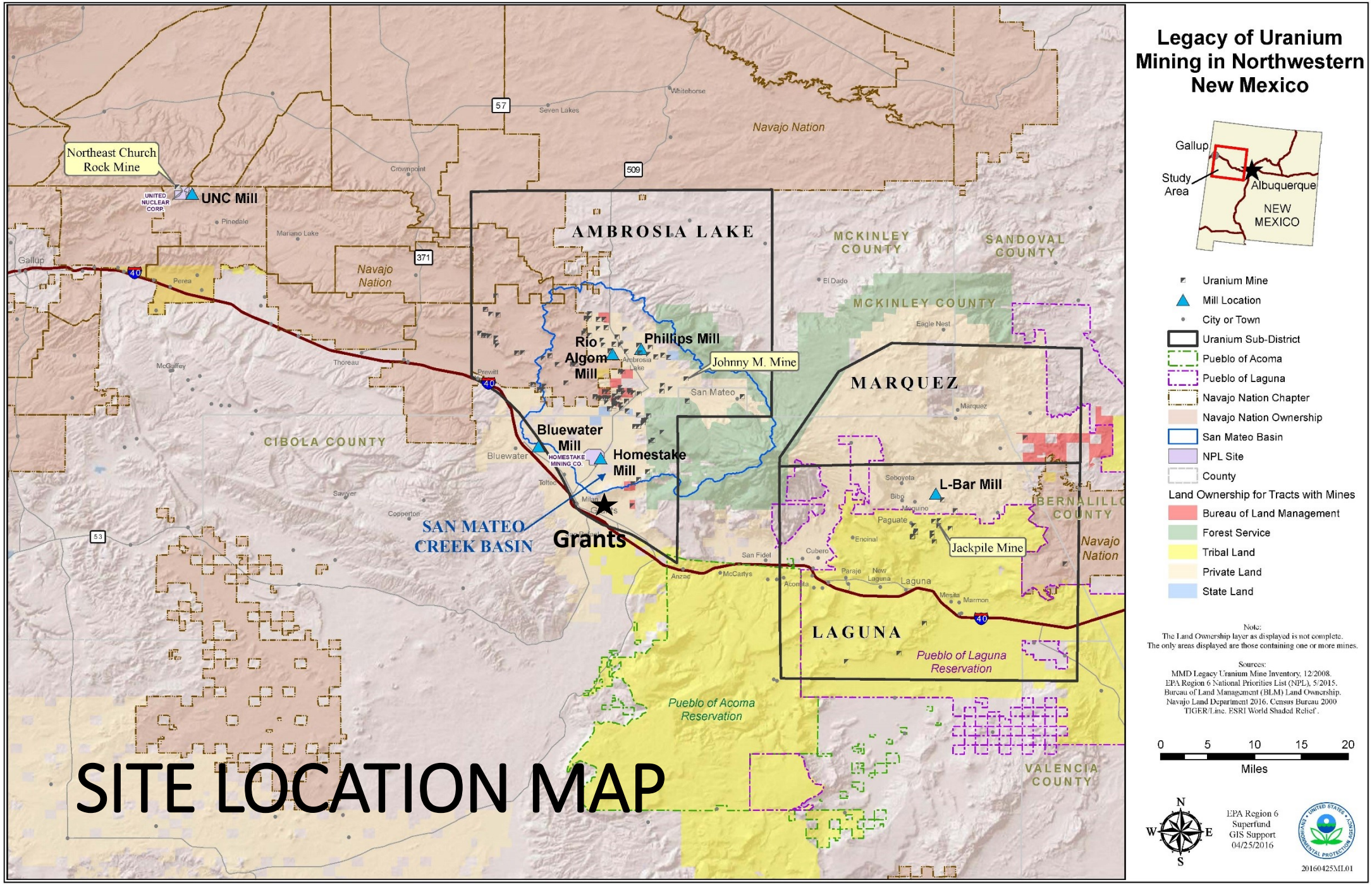
Phase 2

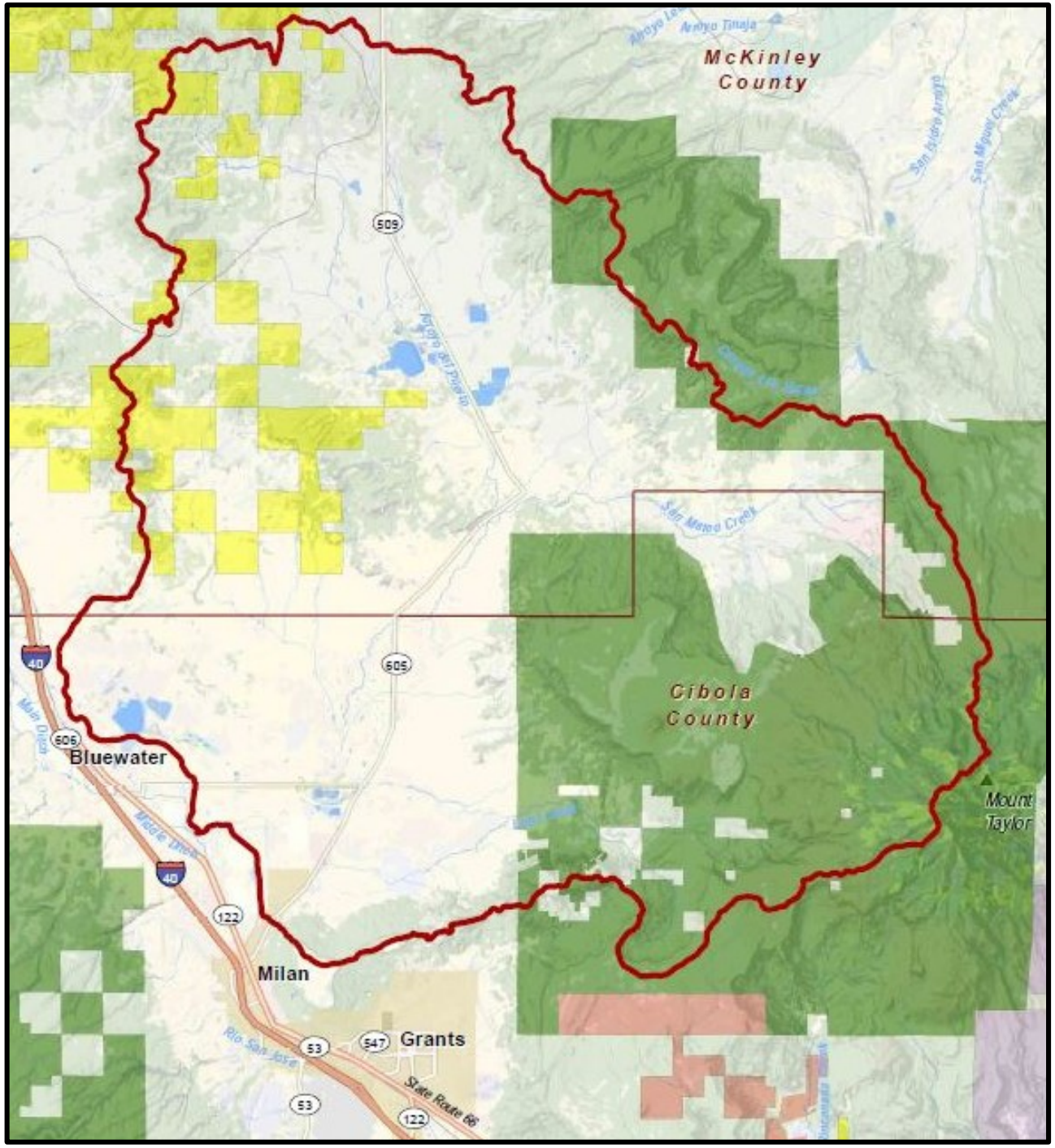
Bedrock & Alluvial Aquifers
San Mateo Creek Basin

Refine Conceptual Site Model
2015 – 2018

PHASE 2 STUDY OBJECTIVES

- ASSESS GROUND WATER IMPACTS FROM TRONOX MINES AND OTHER WET MINES
  - Former Kerr-McGee Mines
  - Primarily located in NAUM Ambrosia Lake Impact Area
  - Within San Mateo Creek Basin
- EXPAND ON 2015 PHASE 1 INVESTIGATION OF ALLUVIUM
- ASSESS BEDROCK AQUIFERS
- REFINE CONCEPTUAL SITE MODEL


Legacy of Uranium Mining in Northwestern New Mexico
Gallup
Study Area
Albuquerque
NEW MEXICO
Uranium Mine
Mill Location
City or Town
Uranium Sub-District
Pueblo of Acoma
Pueblo of Laguna
Navajo Nation Chapter
Navajo Nation Ownership
San Mateo Basin
NPL Site
County
Land Ownership for Tracts with Mines
Bureau of Land Management
Forest Service
Tribal Land
Private Land
State Land
Note:
The Land Ownership layer as displayed is not complete.
The only areas displayed are those containing one or more mines.
Sources:
MMD Legacy Uranium Mine Inventory. 12/2008.
EPA Region 6 National Priorities List (NPL), 5/2015.
Bureau of Land Management (BLM) Land Ownership.
Navajo Land Department 2016. Census Bureau 2000
TIGER/Line. ESRI World Shaded Relief.
0 5 10 15 20
Miles
N
W
E
S
EPA Region 6
Superfund
GIS Support
04/25/2016
20160425ML01
Northeast Church Rock Mine
UNITED NUCLEAR CORP.
UNC Mill
AMBROSIA LAKE
Rio Algom Mill
Phillips Mill
Johnny M. Mine
Bluewater Mill
HOMESTAKE MINING CO.
Homestake Mill
SAN MATEO CREEK BASIN
Grants
MARQUEZ
L-Bar Mill
Jackpile Mine
LAGUNA
Pueblo of Laguna Reservation
Pueblo of Acoma Reservation
Navajo Nation
MCKINLEY COUNTY
SANDOVAL COUNTY
CIBOLA COUNTY
BERNALILLO COUNTY
VALENCIA COUNTY
Gallup
Perea
Pinedale
Mariano Lake
Crownpoint
Whitehorse
Seven Lakes
Thoreau
McGaffey
Prewitt
Bluewater
Toltec
Milan
Savoyer
Copperton
San Mateo
Marquez
El Dado
Eagle Nest
Seboyeta
Bibo
Paguate
Encinal
Cubero
San Fidel
Anzac
McCartys
Acomita
Paraje
New Laguna
Laguna
Mesita
Marmon
57
509
371
40
53
SITE LOCATION MAP



SITE MAP

LEGEND

- Navajo Land
- Forest Service Land
- Acoma Pueblo Land
- Laguna Pueblo Land

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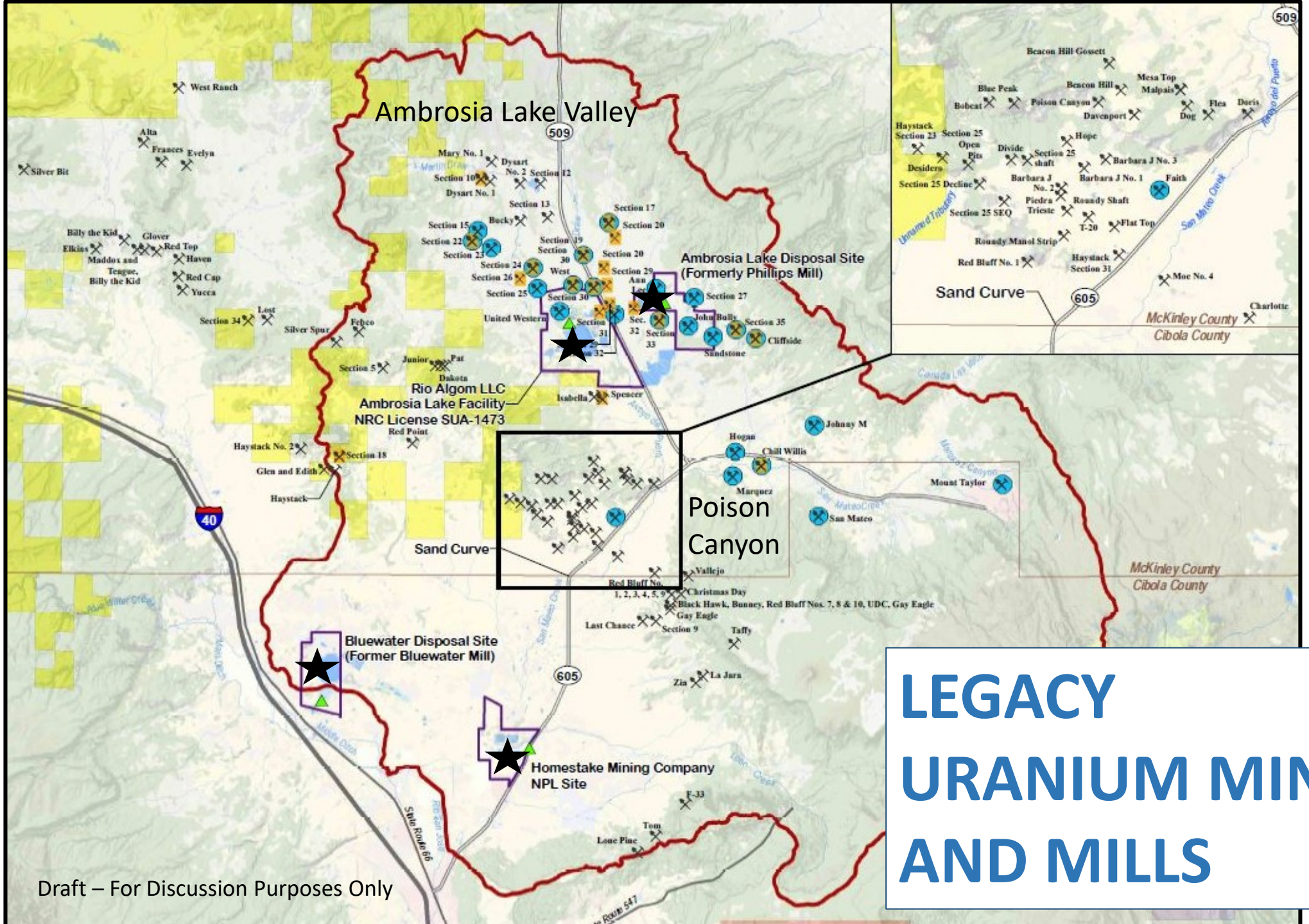

LEGACY URANIUM MINES AND MILLS

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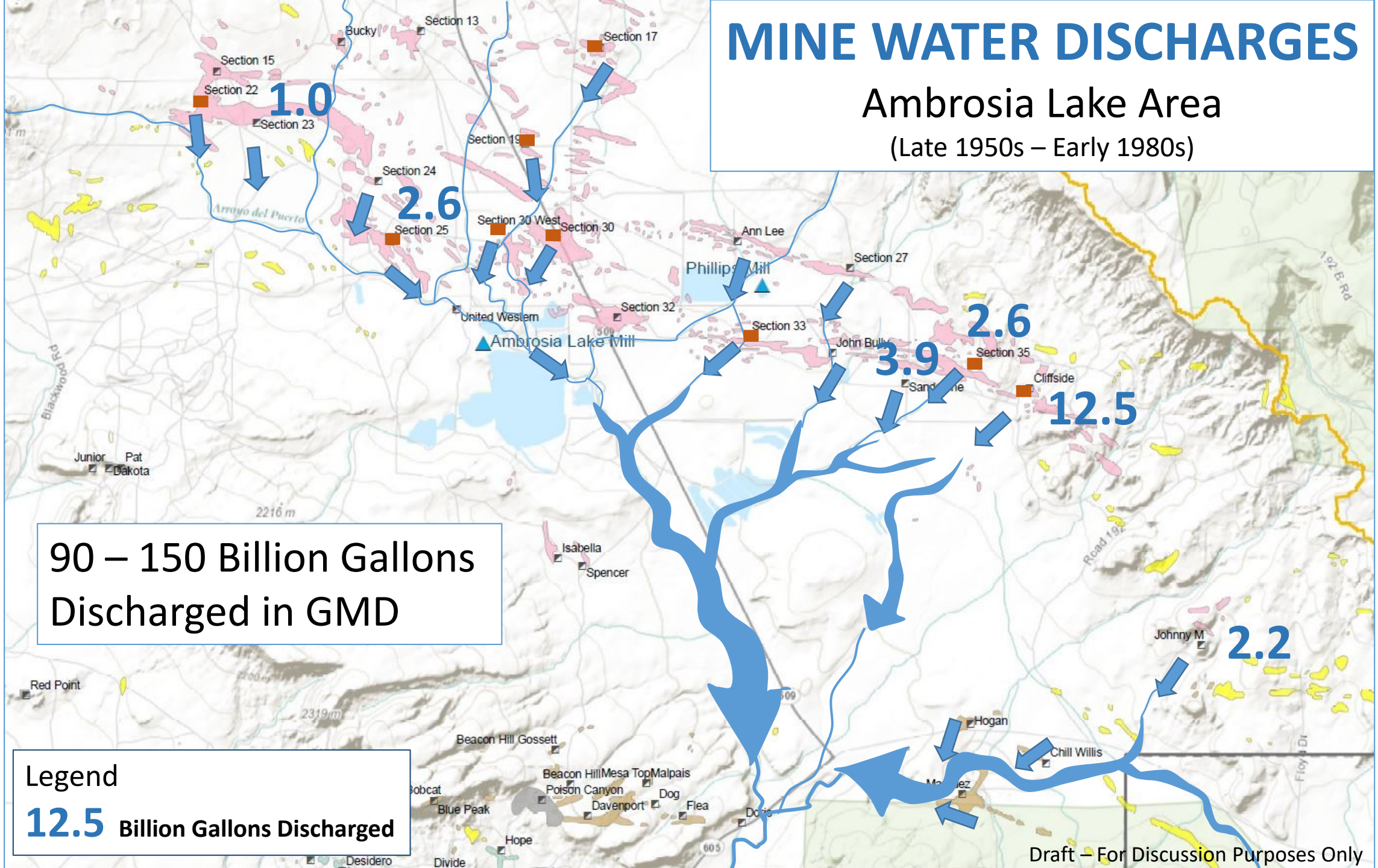
MINE WATER DISCHARGES

Ambrosia Lake Area

(Late 1950s – Early 1980s)



90 – 150 Billion Gallons Discharged in GMD

Legend

12.5 **Billion Gallons Discharged**

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MAJOR PHASE 2 COMPONENTS

EPA CONTRACTOR
WESTON SOLUTIONS

FIELD INVESTIGATION
DRILLING, WELL CONSTRUCTION, AND SAMPLING

ASSESSMENT OF GROUND WATER SAMPLE RESULTS

GEOCHEMISTRY
ENVIRONMENTAL FORENSICS

HYDROGEOLOGY & MINE WATER DISCHARGE IMPACT ANALYSIS

SUB CONTRACTOR
EARLE DIXON
McGinnis and Associates

EPA
MARK PURCELL
ASHLEY CHANG

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PHASE 2 REPORT DRAFT OUTLINE

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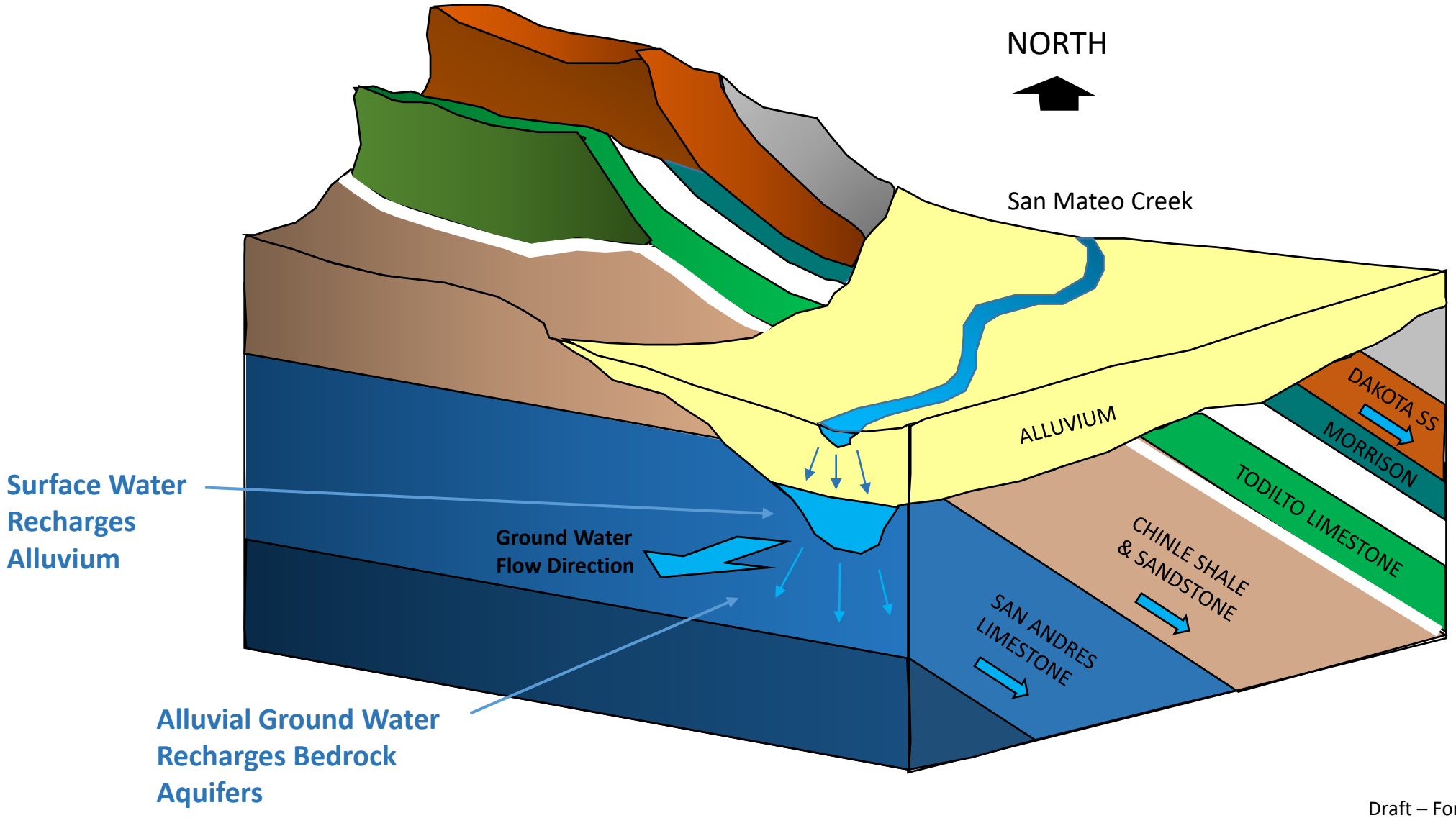
FIELD INVESTIGATION
RESULTS
GEOCHEMISTRY
LEGACY MINE DISCHARGE WATER IMPACT ANALYSIS ★
DISCUSSION
CONCLUSIONS

CONCEPTUAL SITE GROUND WATER MODEL



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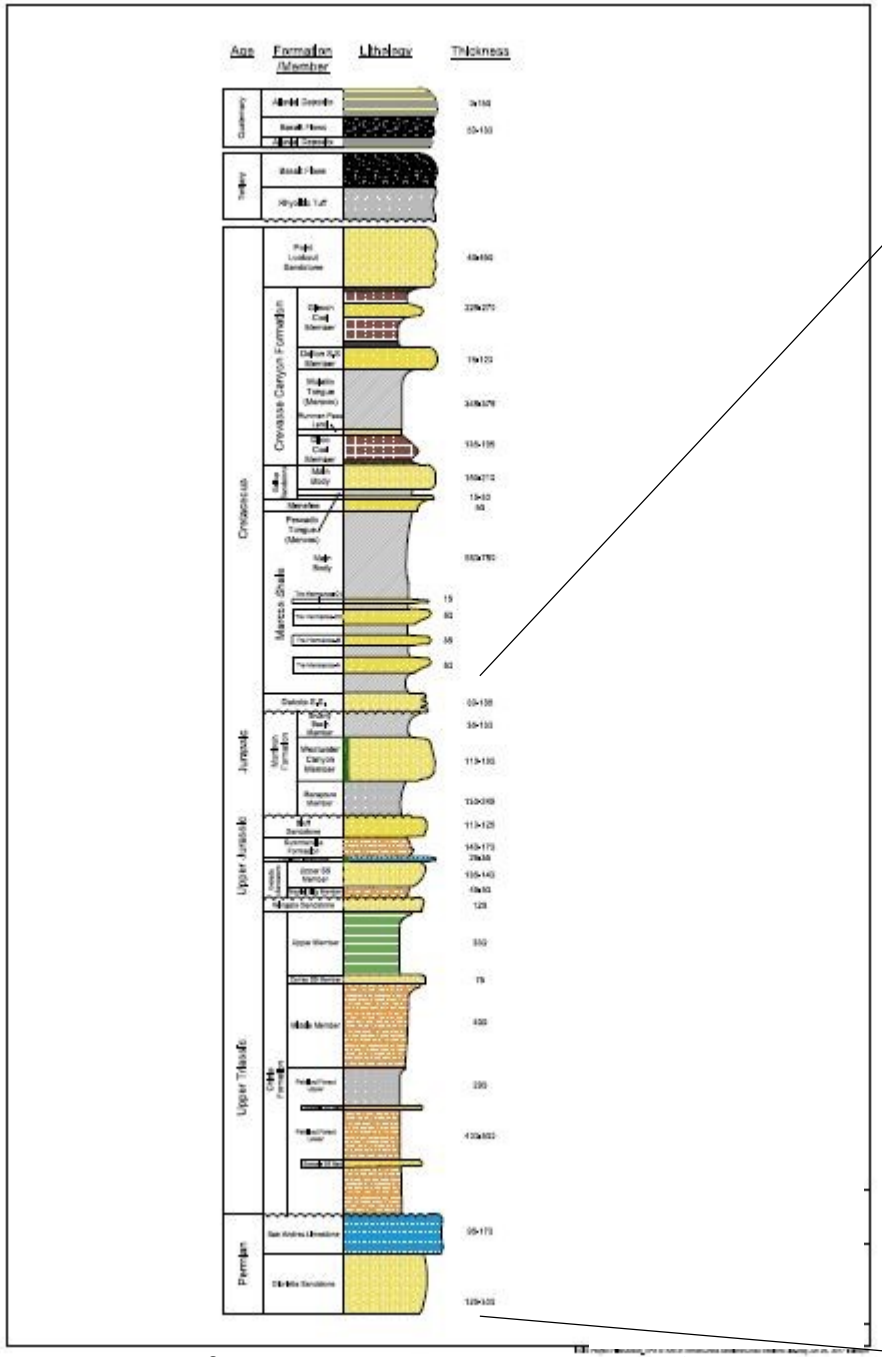
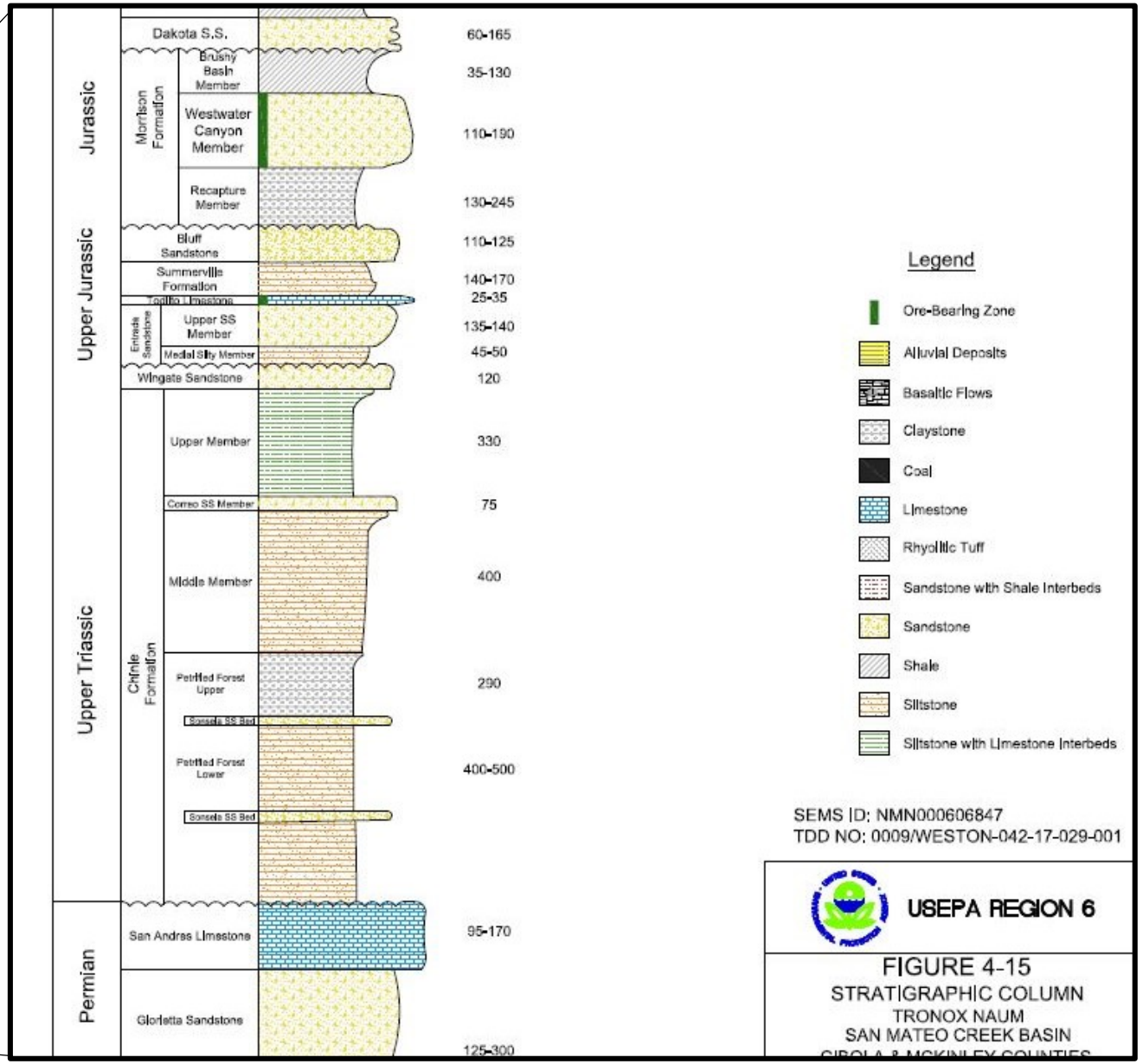
STRATIGRAPHIC COLUMN





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SUMMARY OF IMPACTS FROM FORMER MILLS

- REGULATED BY U.S. NUCLEAR REGULATORY COMMISSION
  - Reclamation
  - Decommissioning and Closure
  - Ground Water Restoration
- DOE LEGACY MANAGEMENT PROGRAM
  - Long-Term Custody and Care
- URANIUM MILL TAILING RADIATION CONTROL ACT (UMTRCA) OF 1978
- FOUR MILLING AND TAILING DISPOSAL FACILITIES
  - RIO ALGOM AMBROSIA LAKE FACILITY
  - DOE AMBROSIA LAKE DISPOSAL FACILITY (FORMER PHILLIPS MILL) – Title I Site
  - DOE BLUEWATER DISPOSAL SITE
  - HOMESTAKE MINING COMPANY NPL SITE

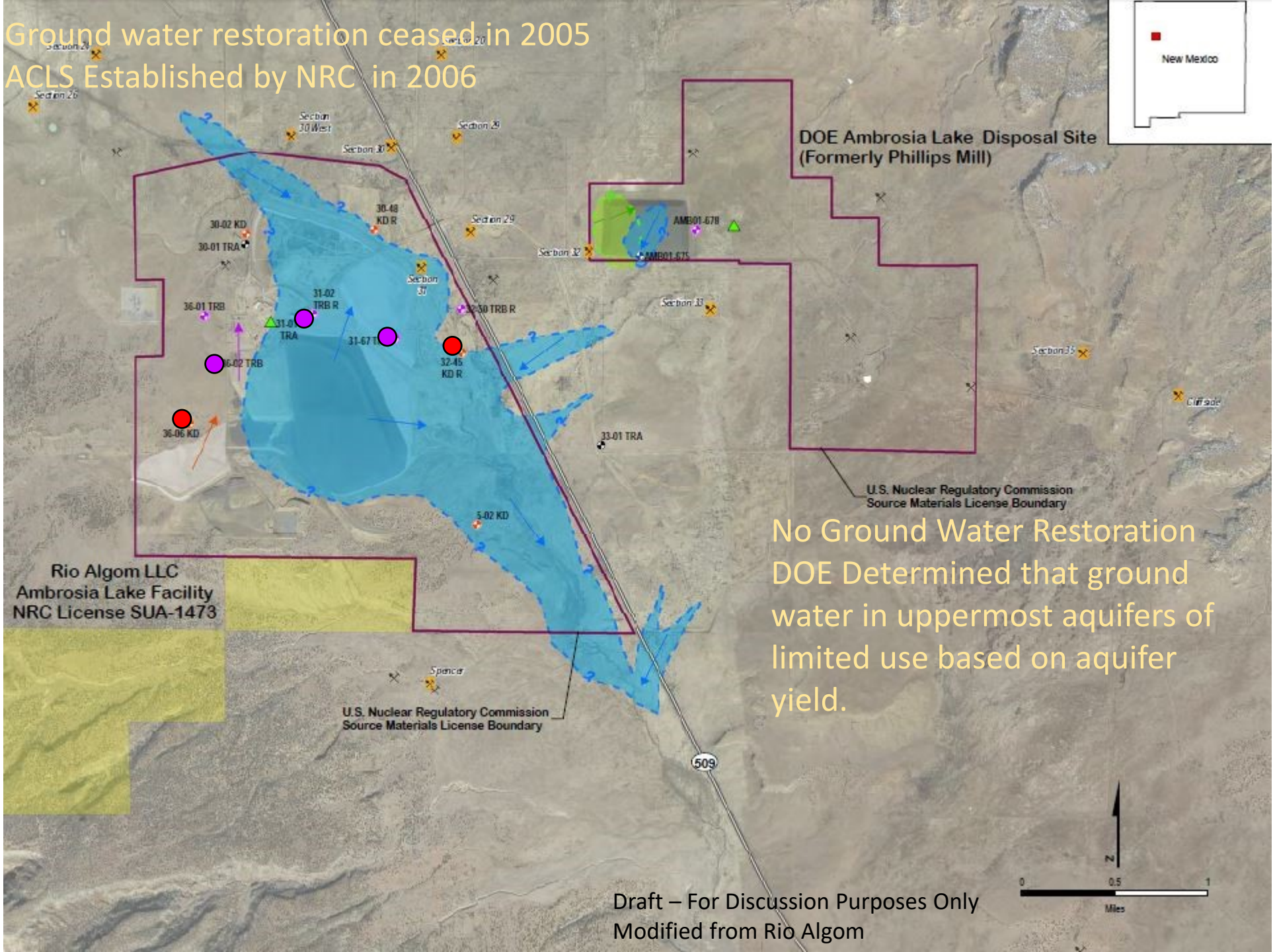
ALTERNATE CONCENTRATION LIMITS (ACLs)

- UNDER UMTRCA, NRC HAS AUTHORITY TO CONTROLS HAZARDS AT TITLE II SITES
  - Implementation of Standards for Protection of Human Health/Environment
  - Ground Water Protection Standards Established by EPA at 40 CFR Part 192
- CONCENTRATION LIMITS (STANDARDS) ESTABLISHED IN SITE LICENSE
- NRC MAY ESTABLISH AN ACL THAT IS LESS RESTRICTIVE THAN STANDARD
  - When GWPS or Background are not practically achievable
  - ACL Must Be As Low As Reasonably Achievable (ALARA)
  - ACL Must Be Protective of Human Health and Environment

MILL IMPACTS TO GROUND WATER

LEGEND

- Alluvium Impacted by Mill and Mine Discharge Water
- Impacted Tre Hermanos B Well
- Impacted Dakota Well



No Ground Water Restoration
DOE Determined that ground water in uppermost aquifers of limited use based on aquifer yield.

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Modified from Rio Algom

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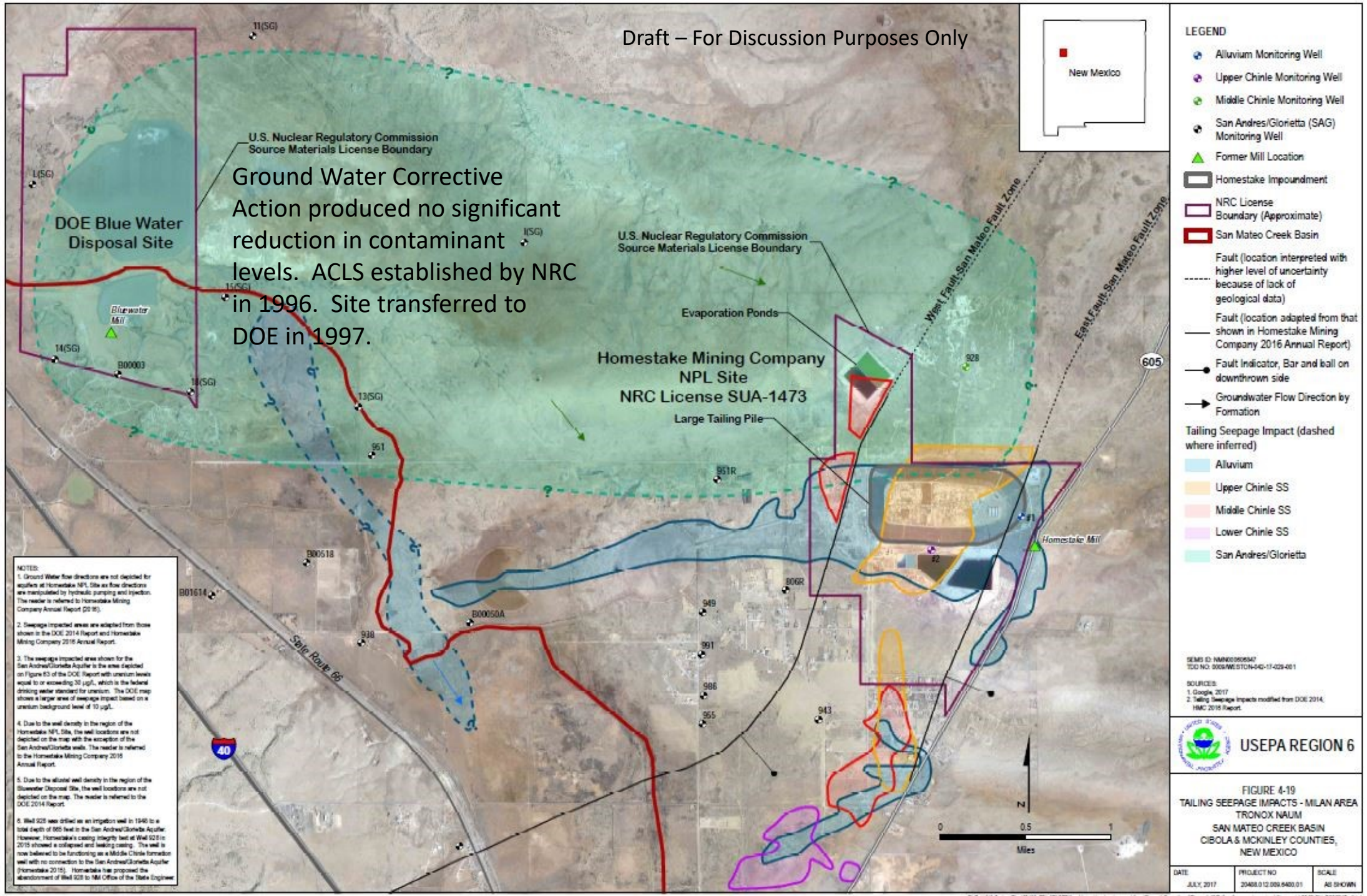
Ground Water Corrective Action produced no significant reduction in contaminant levels. ACLS established by NRC in 1996. Site transferred to DOE in 1997.

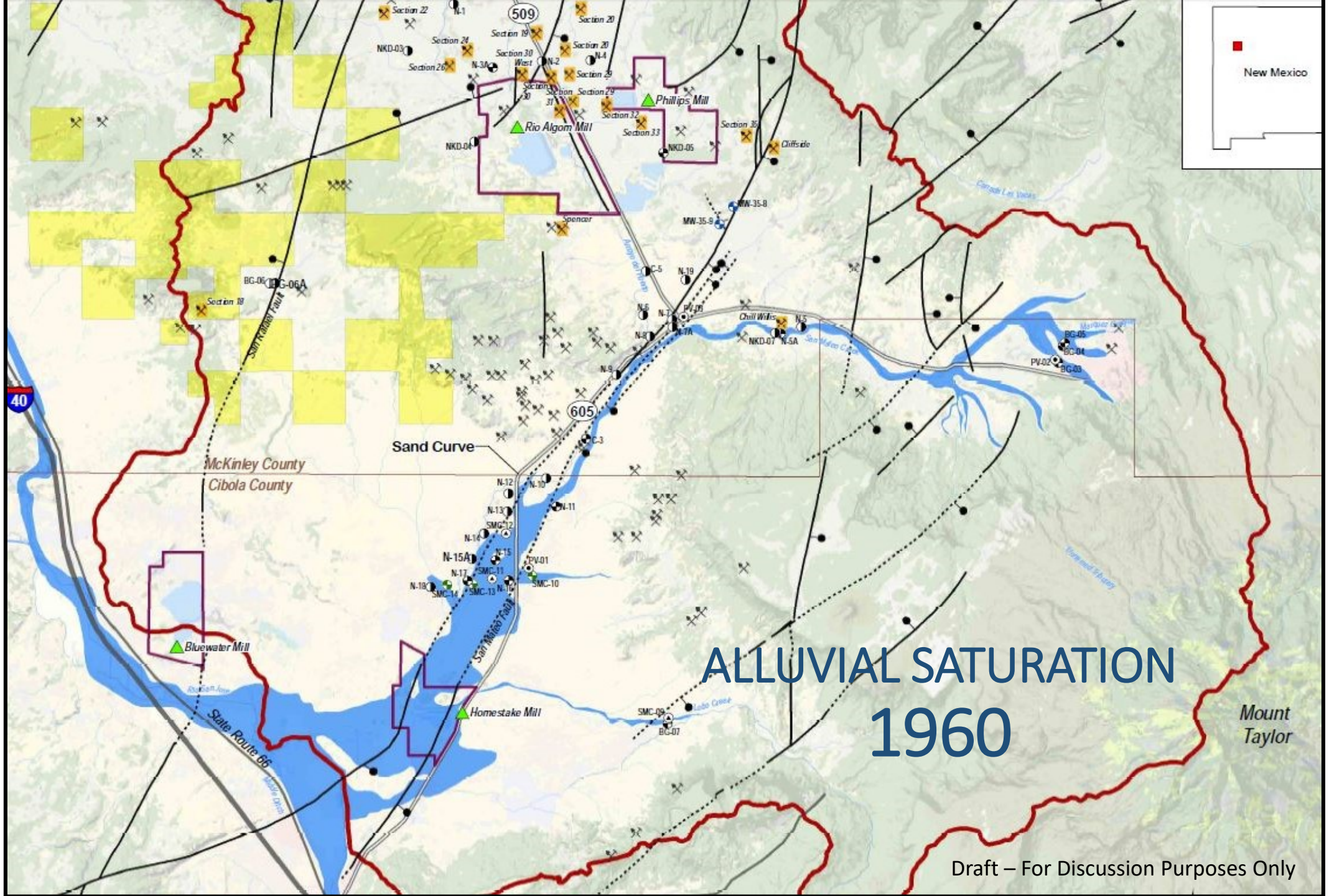


MAJOR HYDROSTRATIGRAPHIC UNITS

- ALLUVIUM
- ALLUVIUM – BEDROCK MIX
- BEDROCK
  - Dakota Sandstone
  - Morrison Formation (Westwater Canyon Member – Ore Bearing Zone)
  - Chinle Formation
  - San Andres Limestone – Glorietta Sandstone (SAG) Formations

ALLUVIUM

- BASIN-WIDE SATURATION
- BASIN-WIDE GROUND WATER FLOW DIRECTION
- AMBROSIA LAKE AREA FLOW DIRECTION
- WATER QUALITY


New Mexico
Phillips Mill
Rio Algom Mill
Cliffside
Spencer
Chill Willis
Sand Curve
McKinley County
Cibola County
San Mateo Fault
Bluewater Mill
Homestake Mill
State Route 66
Mount Taylor
509
605
40
ALLUVIAL SATURATION
1960
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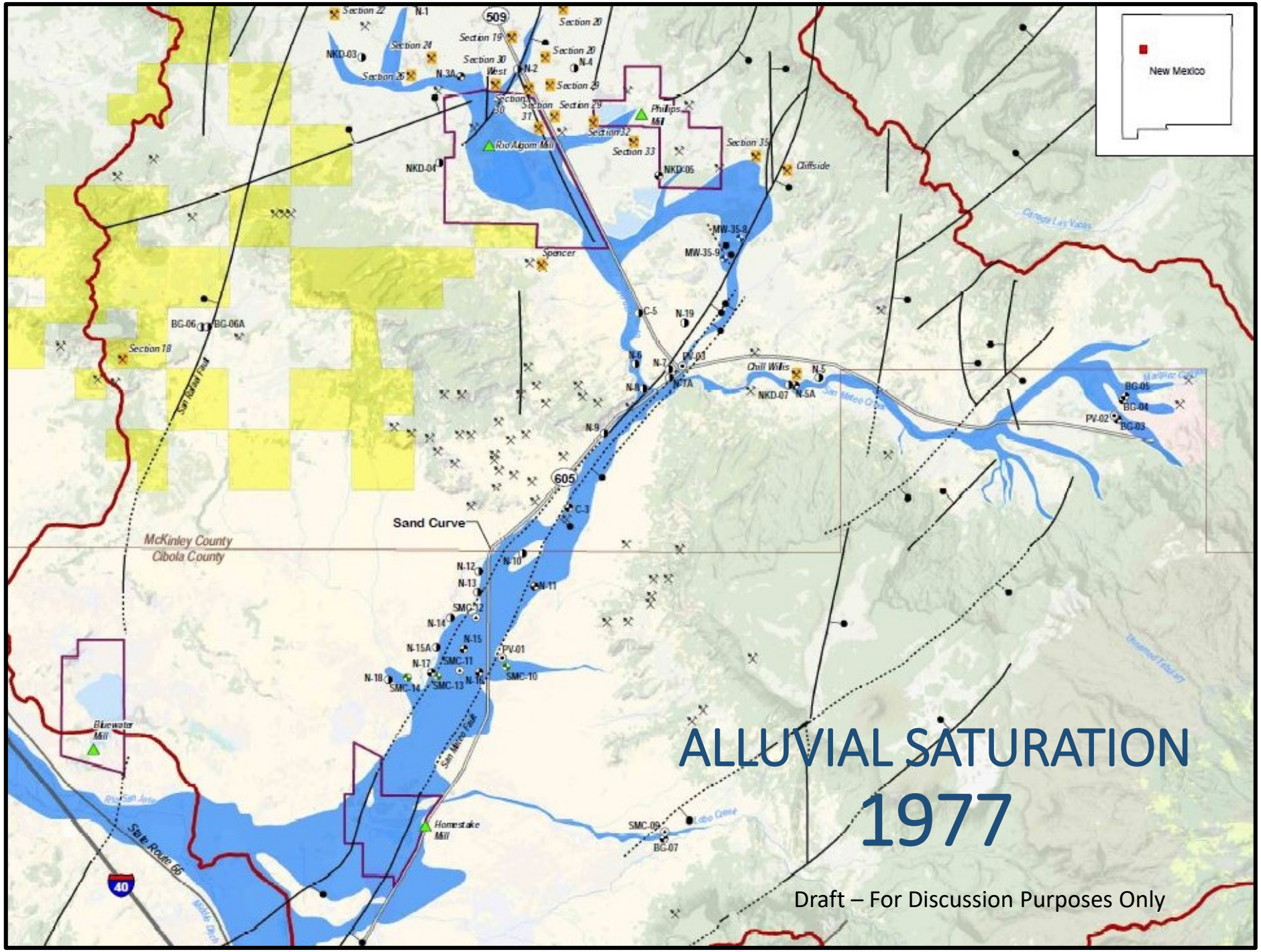

ALLUVIAL SATURATION

1977

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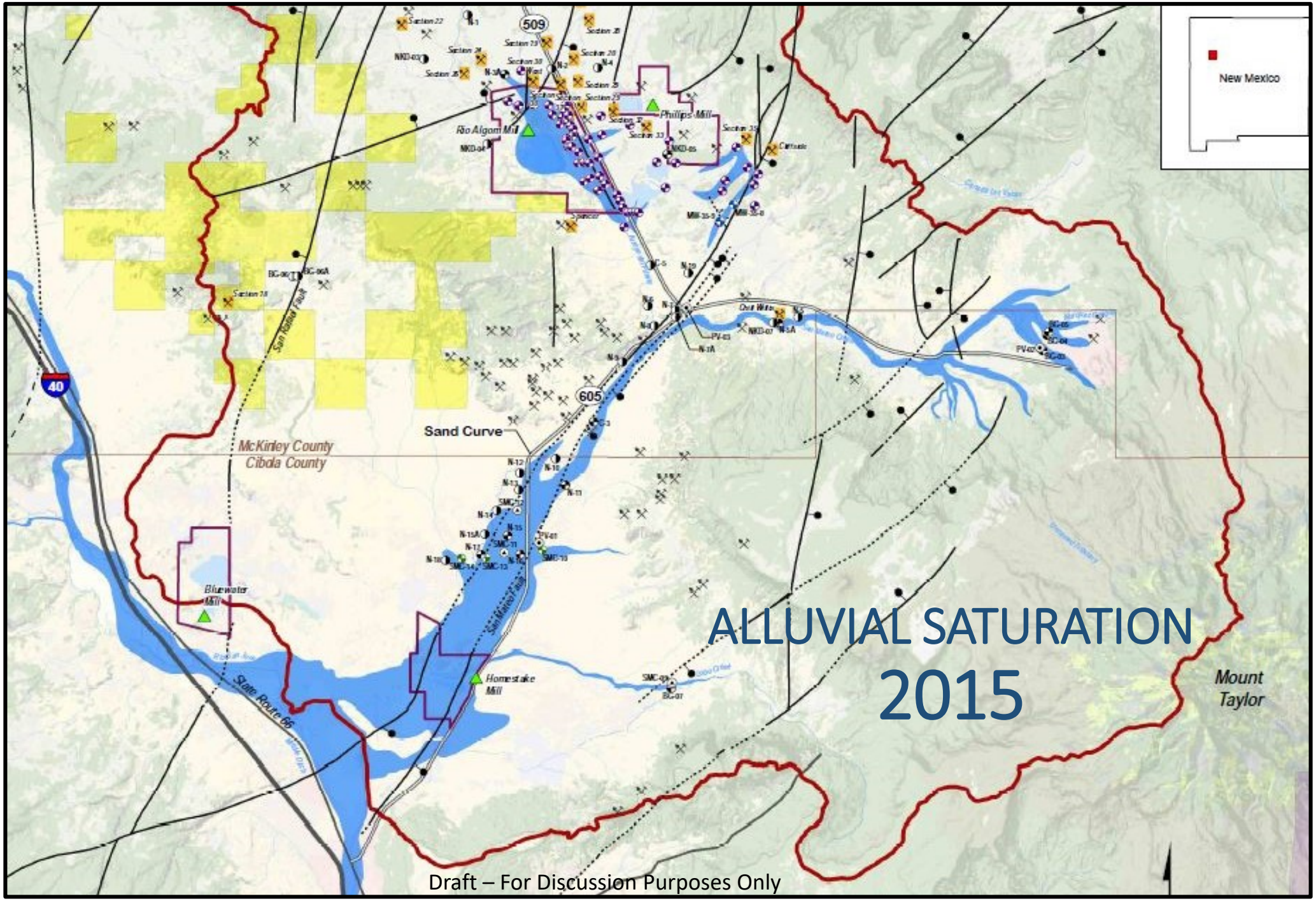

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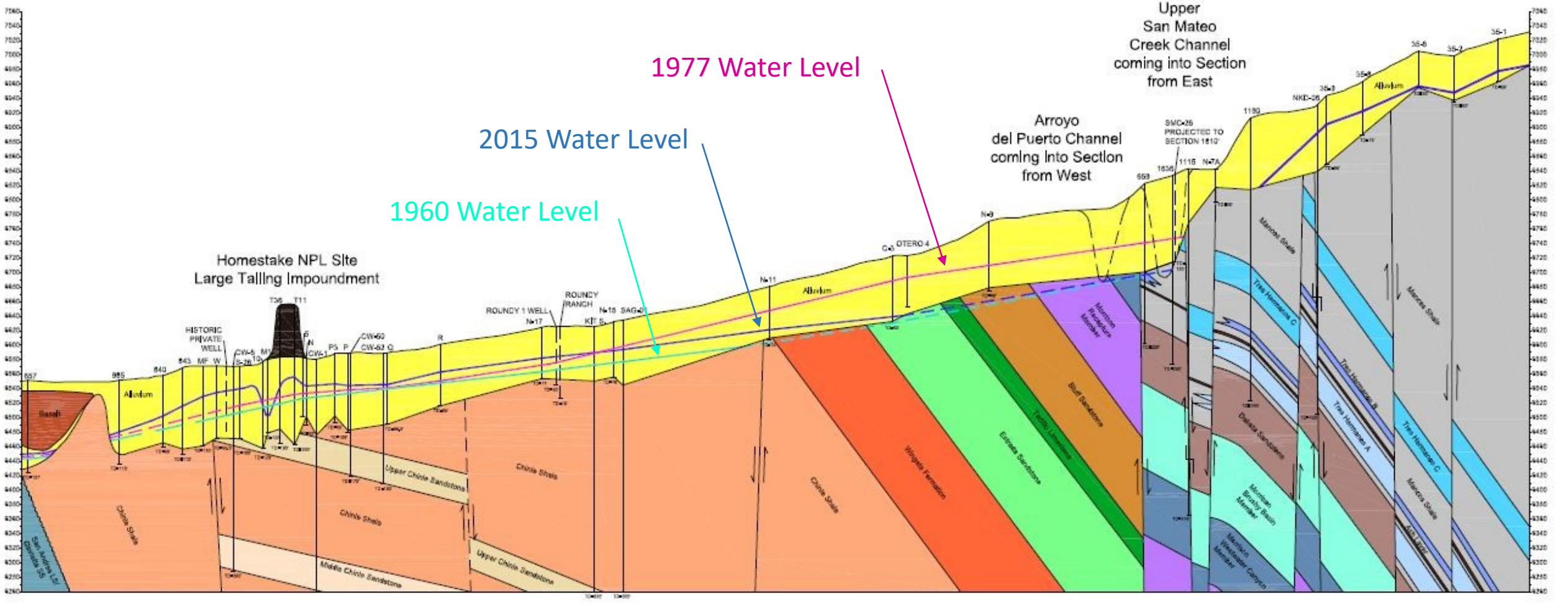
HYDROGEOLOGIC CROSS-SECTION



Vertical Exaggeration 50x

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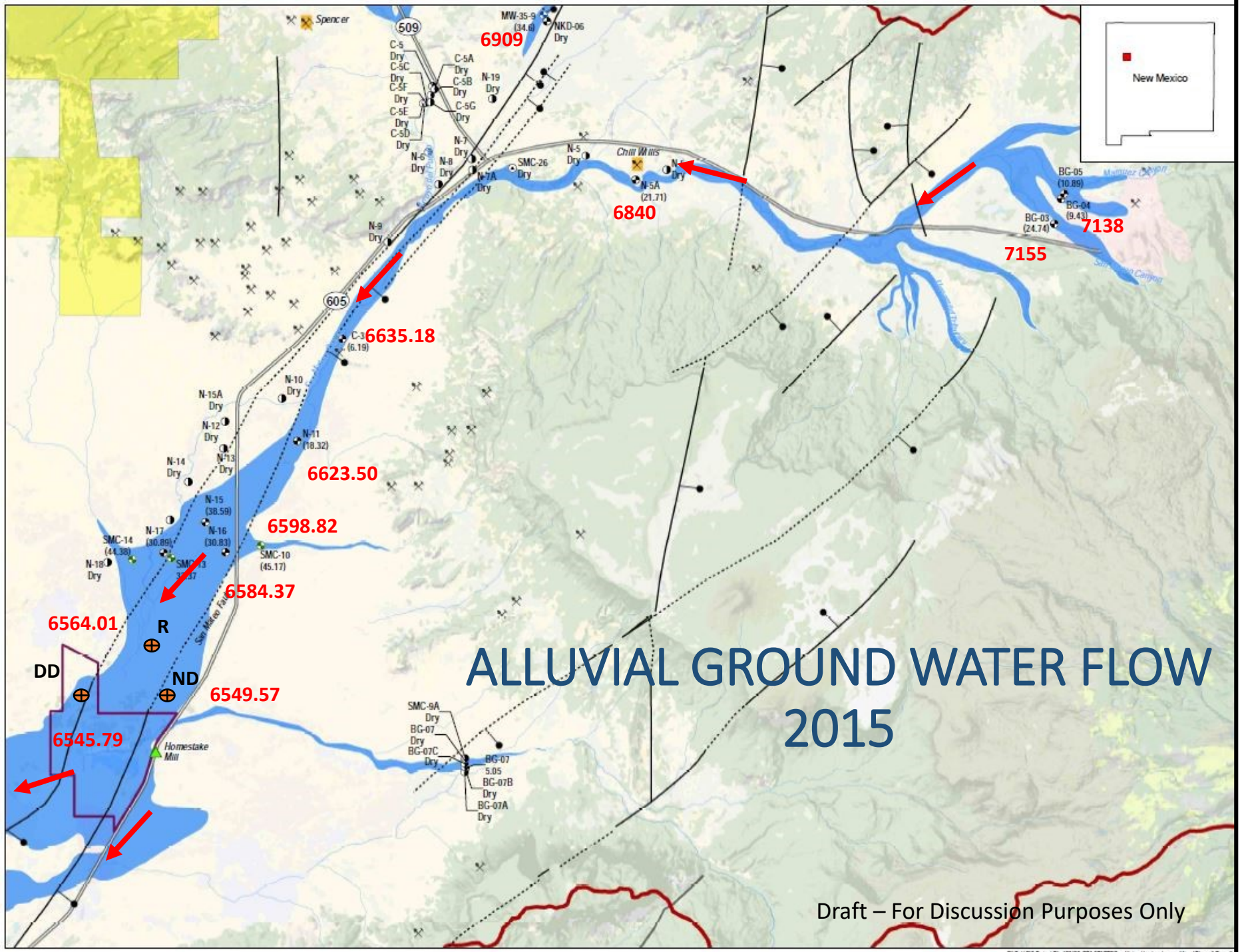
ALLUVIAL GROUND WATER FLOW
2015
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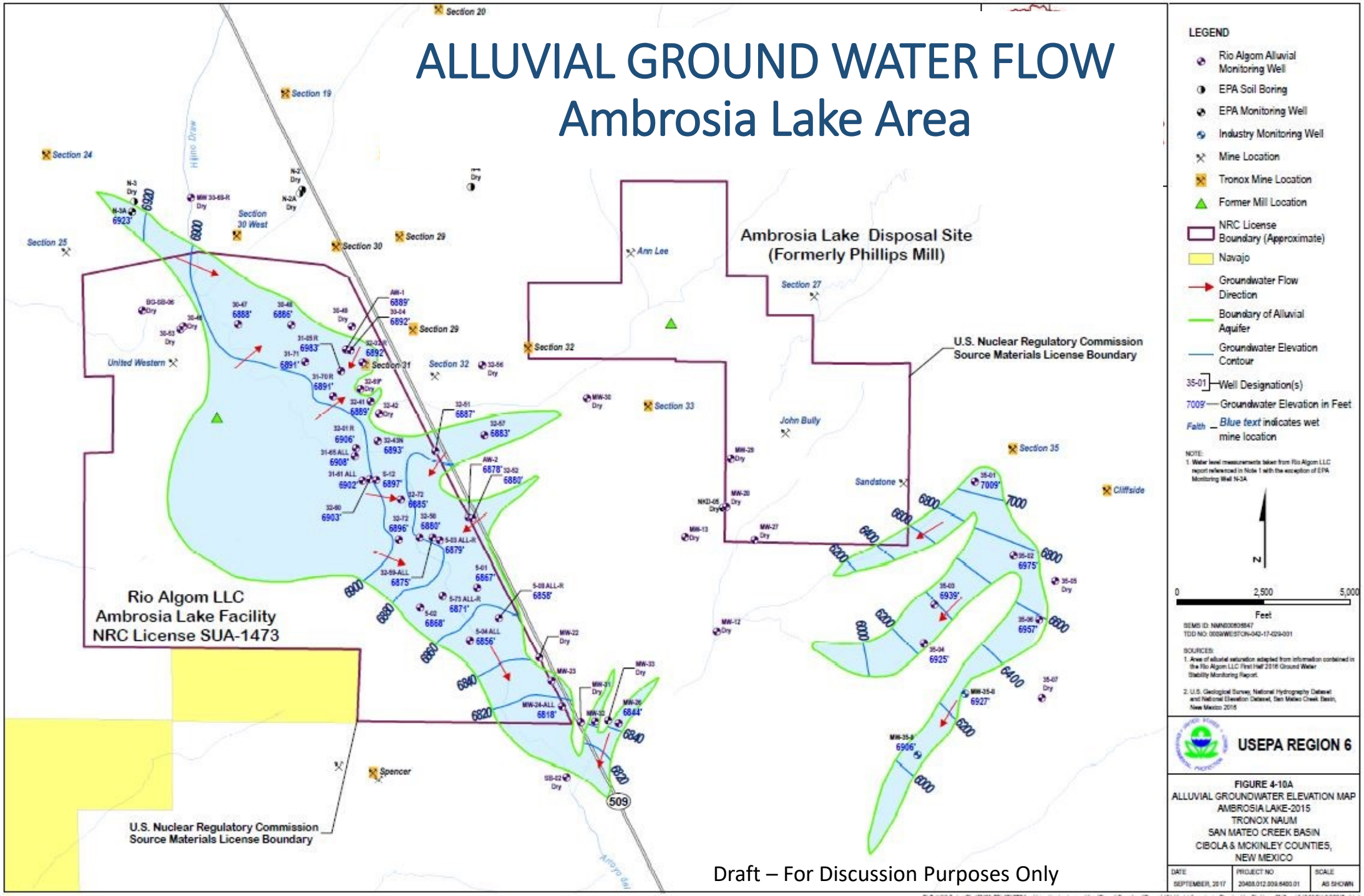
New Mexico
Spencer
Chill Mills
Homestake Mill
509
605
6909
6840
7138
7155
6635.18
6623.50
6598.82
6584.37
6564.01
6549.57
6545.79
R
DD
ND
MW-35-9 (34.6)
NKD-06 Dry
C-5 Dry
C-5C Dry
C-5F Dry
C-5E Dry
C-5D Dry
C-5A Dry
C-5B Dry
C-5G Dry
N-19 Dry
N-7 Dry
N-6 Dry
N-8 Dry
N-7A Dry
SMC-26 Dry
N-5 Dry
N-5A (21.71)
N-9 Dry
C-3 (6.19)
N-10 Dry
N-11 (18.32)
N-15A Dry
N-12 Dry
N-13 Dry
N-14 Dry
N-15 (38.59)
N-16 (30.83)
N-17 (30.89)
SMC-14 (44.38)
N-18 Dry
SMC-10 (45.17)
BG-05 (10.89)
BG-04 (9.43)
BG-03 (24.74)
SMC-9A Dry
BG-07 Dry
BG-07C Dry
BG-07 5.05
BG-07B Dry
BG-07A Dry

ALLUVIAL GROUND WATER FLOW
Ambrosia Lake Area



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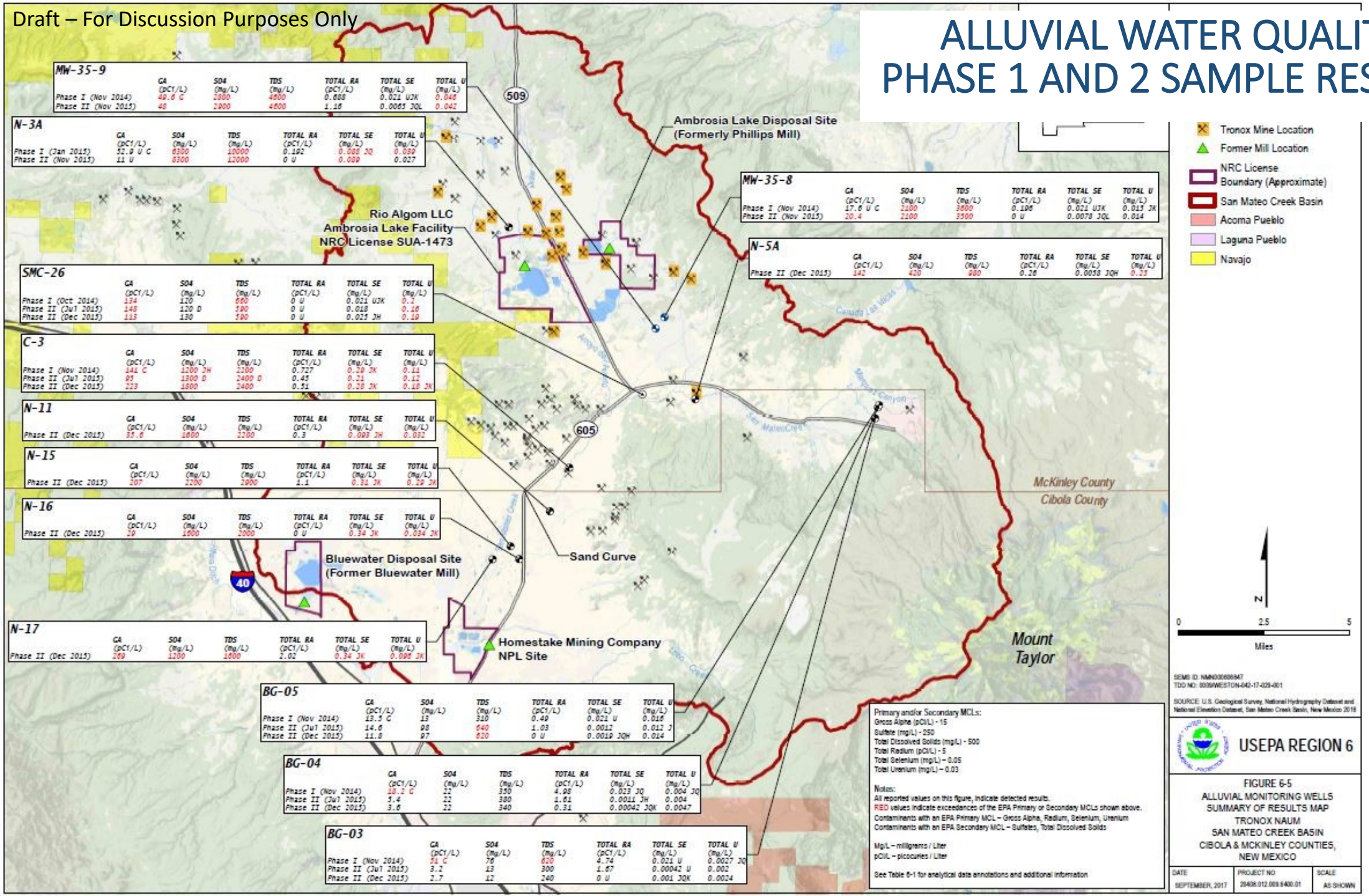
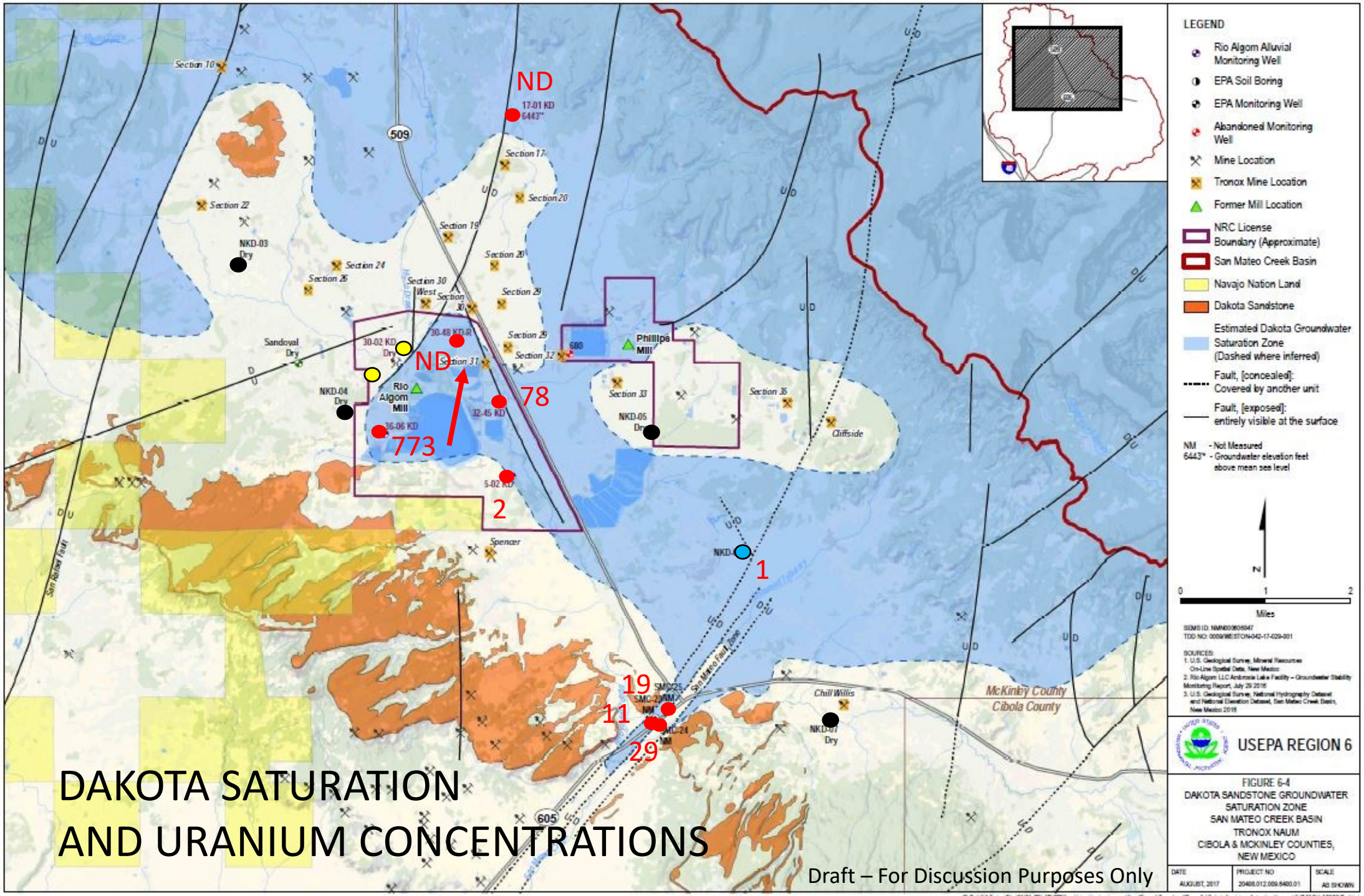
ALLUVIAL WATER QUALITY PHASE 1 AND 2 SAMPLE RESULTS



DAKOTA SANDSTONE AQUIFER

- SATURATION
- GROUND WATER FLOW DIRECTION
- WATER QUALITY
- DETAILED CROSS-ROADS AREA



DAKOTA SATURATION AND URANIUM CONCENTRATIONS

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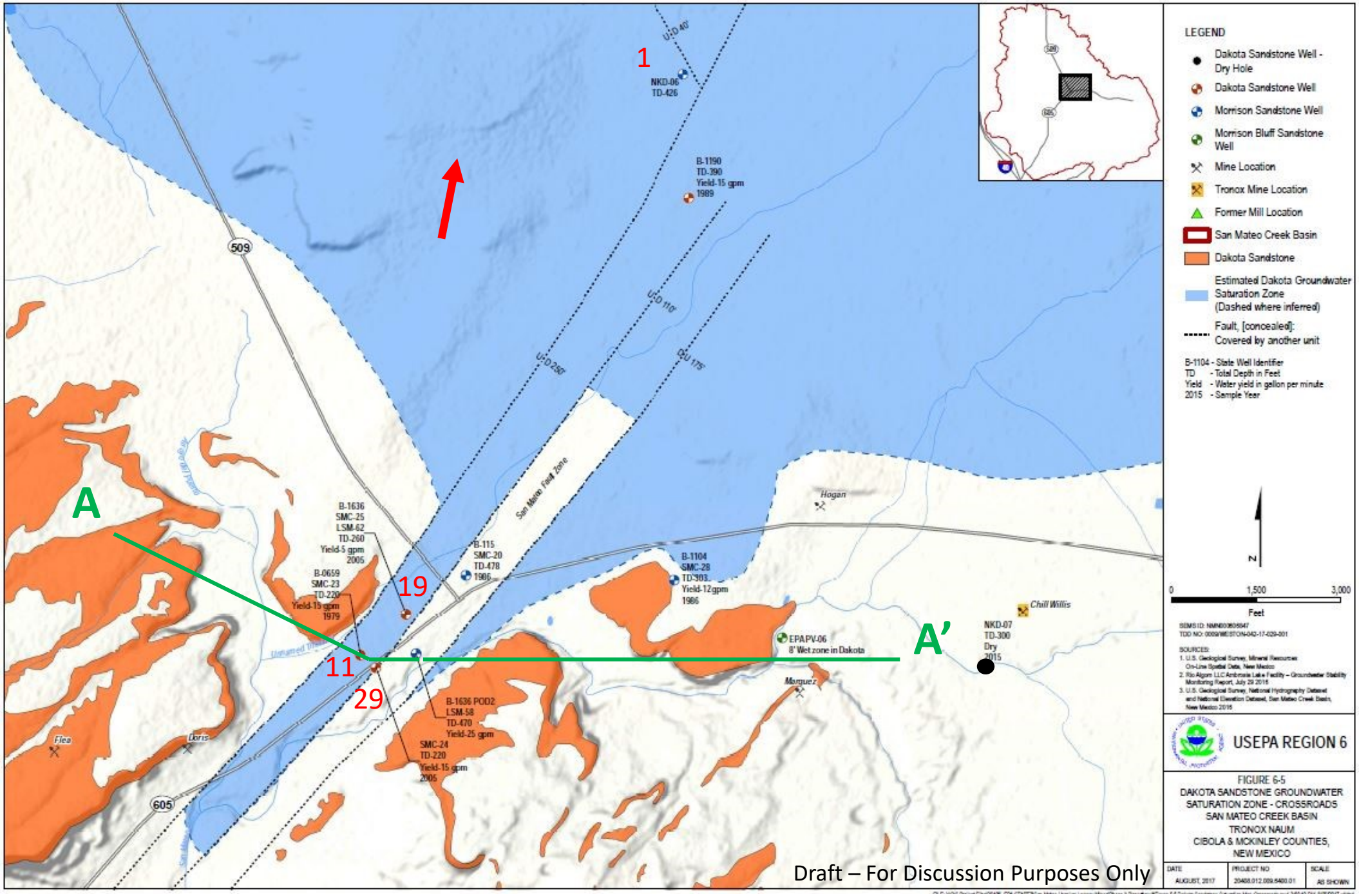
LEGEND
Dakota Sandstone Well - Dry Hole
Dakota Sandstone Well
Morrison Sandstone Well
Morrison Bluff Sandstone Well
Mine Location
Tronox Mine Location
Former Mill Location
San Mateo Creek Basin
Dakota Sandstone
Estimated Dakota Groundwater Saturation Zone (Dashed where inferred)
Fault, [concealed]: Covered by another unit
B-1104 - State Well Identifier
TD - Total Depth in Feet
Yield - Water yield in gallon per minute
2015 - Sample Year
0 1,500 3,000
Feet
USEPA REGION 6
FIGURE 6-5
DAKOTA SANDSTONE GROUNDWATER SATURATION ZONE - CROSSROADS
SAN MATEO CREEK BASIN
TRONOX NAUM
CIBOLA & MCKINLEY COUNTIES, NEW MEXICO
DATE AUGUST, 2017
PROJECT NO 20408.012.009.5400.01
SCALE AS SHOWN
A
A'
1
19
11
29
NKD-06 TD-426
B-1190 TD-390 Yield-15 gpm 1989
B-1636 SMC-25 LSM-62 TD-260 Yield-5 gpm 2005
B-0659 SMC-23 TD-220 Yield-15 gpm 1979
B-115 SMC-20 TD-478 1986
B-1104 SMC-28 TD-303 Yield-12gpm 1986
EPAPV-06 8' Wet zone in Dakota
NKD-07 TD-300 Dry 2015
B-1636 POD2 LSM-58 TD-470 Yield-25 gpm
SMC-24 TD-220 Yield-15 gpm 2005
San Mateo Fault Zone
Hogan
Chili Willis
Marquez
Flea
Doris
509
605
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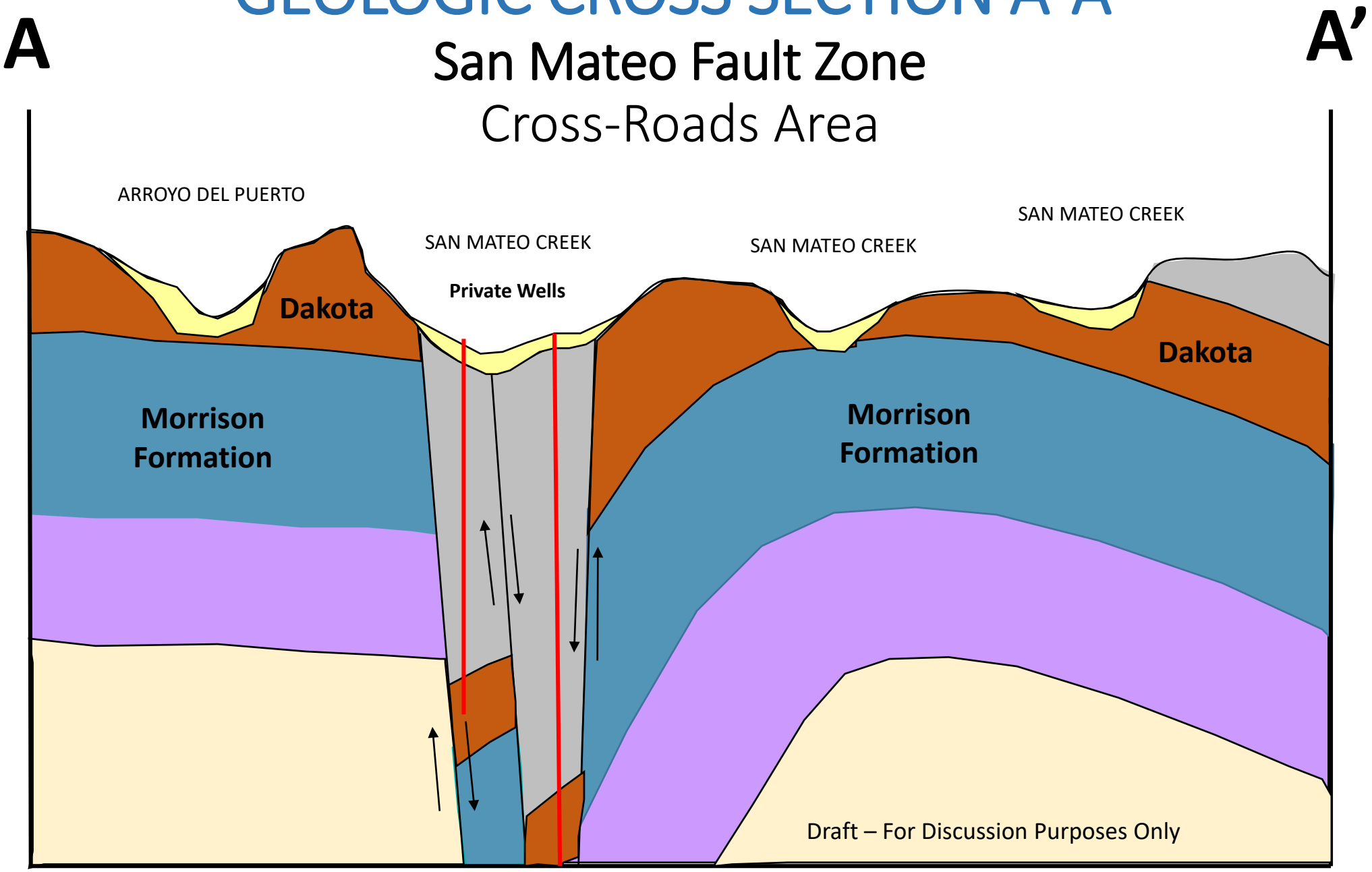
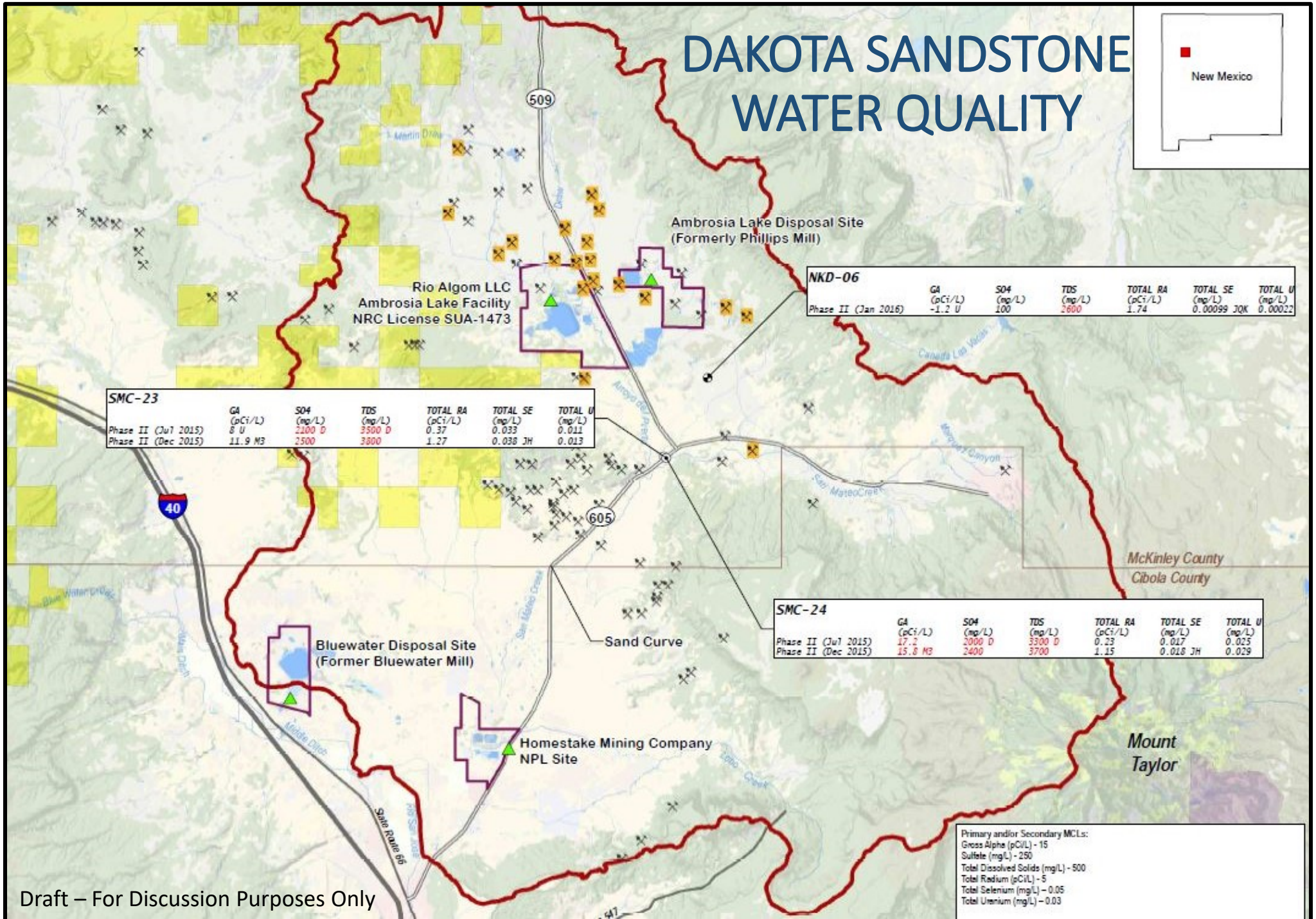
GEOLOGIC CROSS SECTION A-A’



DAKOTA SANDSTONE WATER QUALITY



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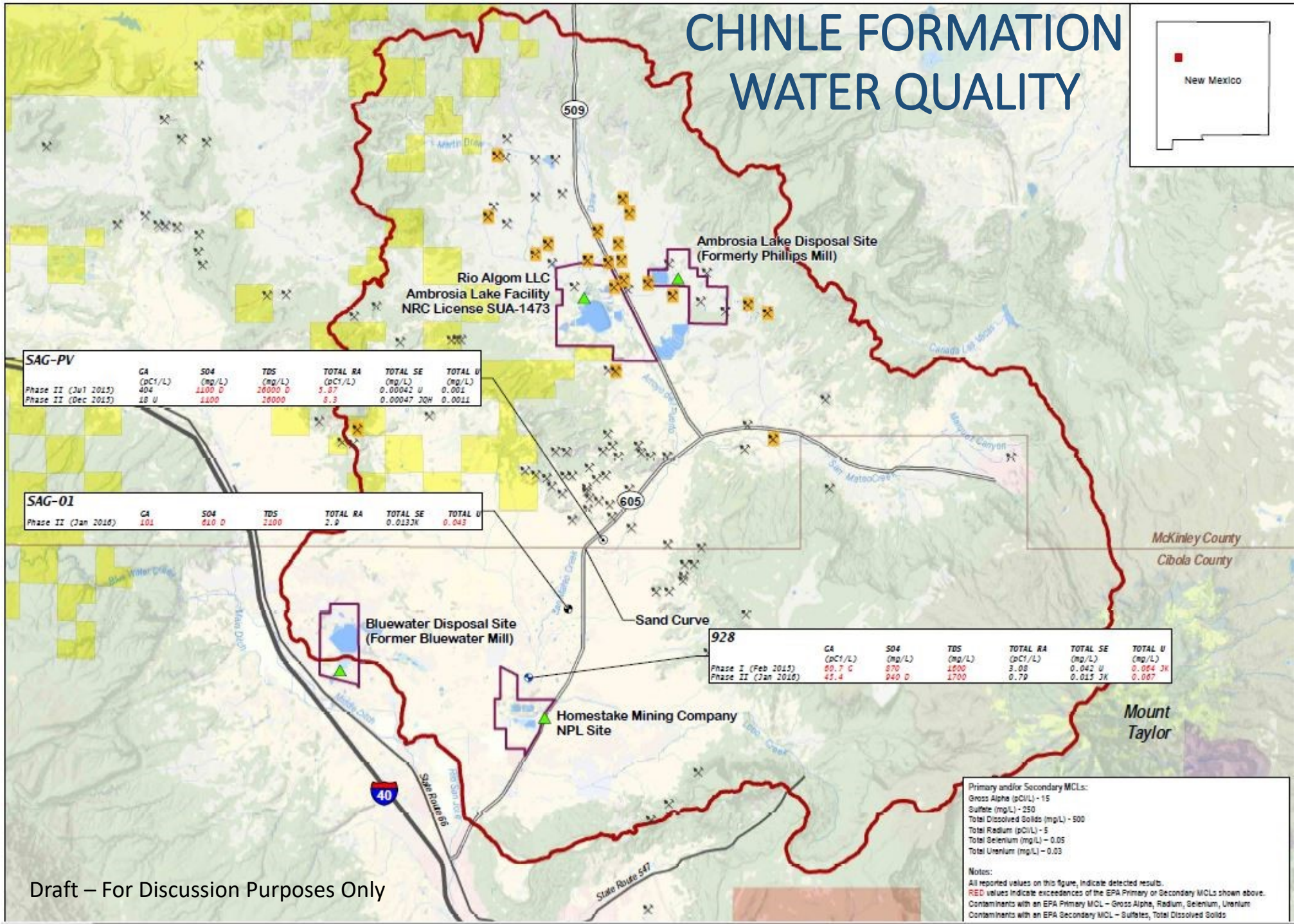
CHINLE FORMATION WATER QUALITY



SAG-PV

	GA (pCi/L)	SO4 (mg/L)	TDS (mg/L)	TOTAL RA (pCi/L)	TOTAL SE (mg/L)	TOTAL U (mg/L)
Phase II (Jul 2015)	404	1100 D	26000 D	5.87	0.00042 U	0.001
Phase II (Dec 2015)	18 U	1100	26000	8.3	0.00047 JQH	0.0011

SAG-01

	GA	SO4	TDS	TOTAL RA	TOTAL SE	TOTAL U
Phase II (Jan 2016)	101	610 D	2100	2.9	0.0133K	0.043

928

	GA (pCi/L)	SO4 (mg/L)	TDS (mg/L)	TOTAL RA (pCi/L)	TOTAL SE (mg/L)	TOTAL U (mg/L)
Phase I (Feb 2015)	60.7 G	870	1600	3.08	0.042 U	0.064 JK
Phase II (Jan 2016)	43.4	940 D	1700	0.79	0.015 JK	0.067

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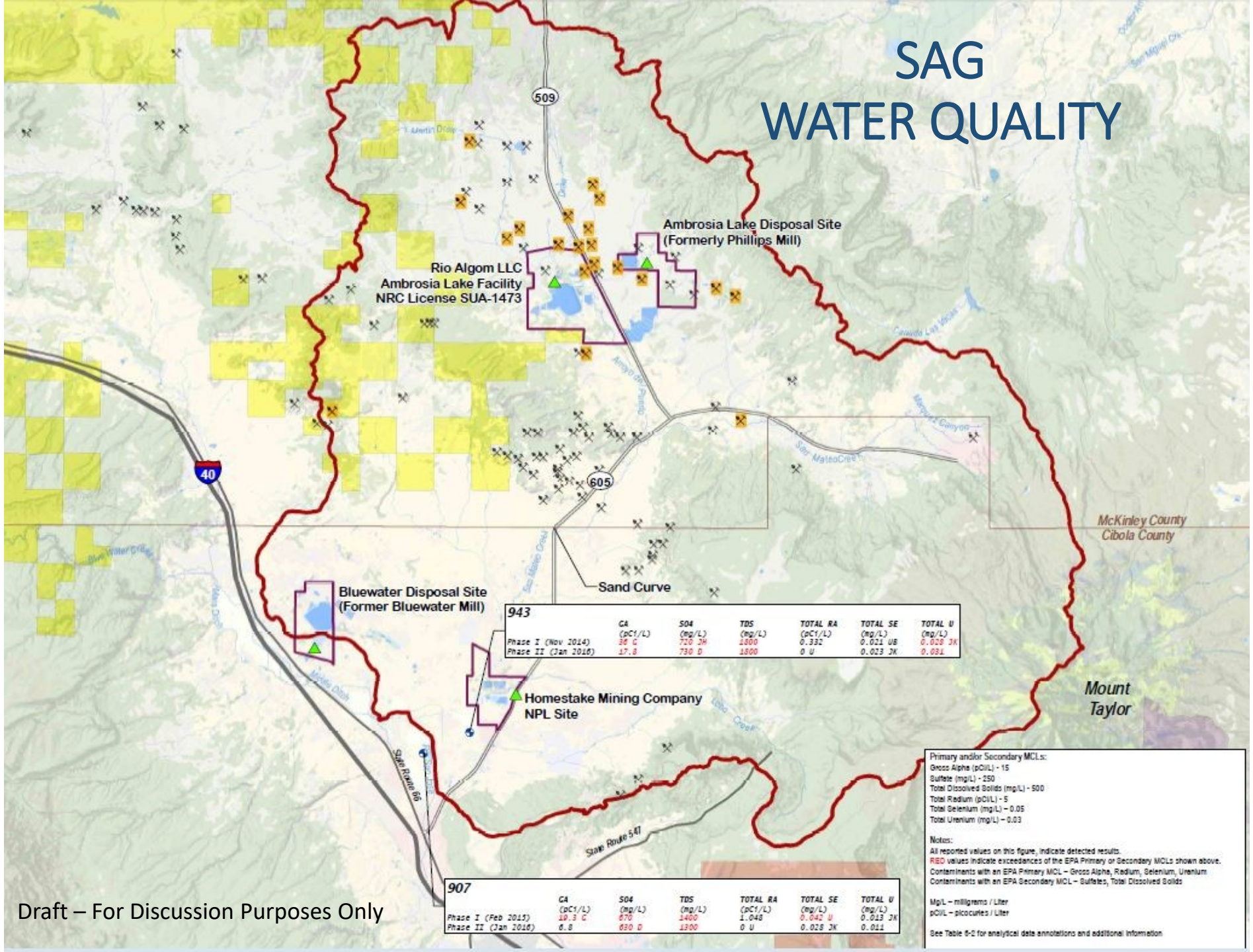
SAG
WATER QUALITY



943

	GA (pCi/L)	SO4 (mg/L)	TDS (mg/L)	TOTAL RA (pCi/L)	TOTAL SE (mg/L)	TOTAL U (mg/L)
Phase I (Nov 2014)	36 C	720 JH	1800	0.332	0.021 UB	0.028 JK
Phase II (Jan 2016)	17.8	730 D	1800	0 U	0.023 JK	0.031

907

	GA (pCi/L)	SO4 (mg/L)	TDS (mg/L)	TOTAL RA (pCi/L)	TOTAL SE (mg/L)	TOTAL U (mg/L)
Phase I (Feb 2015)	19.3 C	670	1400	1.048	0.042 U	0.013 JK
Phase II (Jan 2016)	6.8	630 D	1300	0 U	0.028 JK	0.011

Primary and/or Secondary MCLs:
Gross Alpha (pCi/L) - 15
Sulfate (mg/L) - 250
Total Dissolved Solids (mg/L) - 500
Total Radium (pCi/L) - 5
Total Selenium (mg/L) – 0.05
Total Uranium (mg/L) – 0.03

Notes:
All reported values on this figure, indicate detected results.
RED values indicate exceedances of the EPA Primary or Secondary MCLs shown above.
Contaminants with an EPA Primary MCL – Gross Alpha, Radium, Selenium, Uranium
Contaminants with an EPA Secondary MCL – Sulfates, Total Dissolved Solids

Mg/L – milligrams / Liter
pCi/L – picocuries / Liter

See Table 6-2 for analytical data annotations and additional information

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GEOCHEMISTRY – ENVIRONMENTAL FORENSICS

- SYSTEMATIC INVESTIGATION OF WATER TYPES
  - Major Ions (Cations and Anions)
  - Trilinear Diagrams
    - Classify Water Ion Composition
  - Stiff Diagrams
    - Presents Ion Concentration Data as Graphic Shapes
  - Ion to Ion Relationships
  - Uranium Activity Ratios
  - Stable Isotopes – Oxygen, Hydrogen, Sulfur, Carbon
    - Use as Tracer or Fingerprint to Source
- MULTIPLE LINES OF EVIDENCE

Mine Discharge Water *is primarily from Morrison Fm (Ore Zone) and Overlying Dakota Sandstone Formation (Drained into Morrison Fm)*

GEOCHEMISTRY

- ASSESS WATER TYPES OF THREE MAJOR HYDROSTRATIGRAPHIC UNITS
  - Alluvium
  - Alluvium – Bedrock Mix
  - Bedrock
- IDENTIFIED BASED ON GEOCHEMISTRY

USGS TRILINEAR (PIPER) DIAGRAM

Upper San Mateo Creek Basin Study

Assessment of Ion Composition

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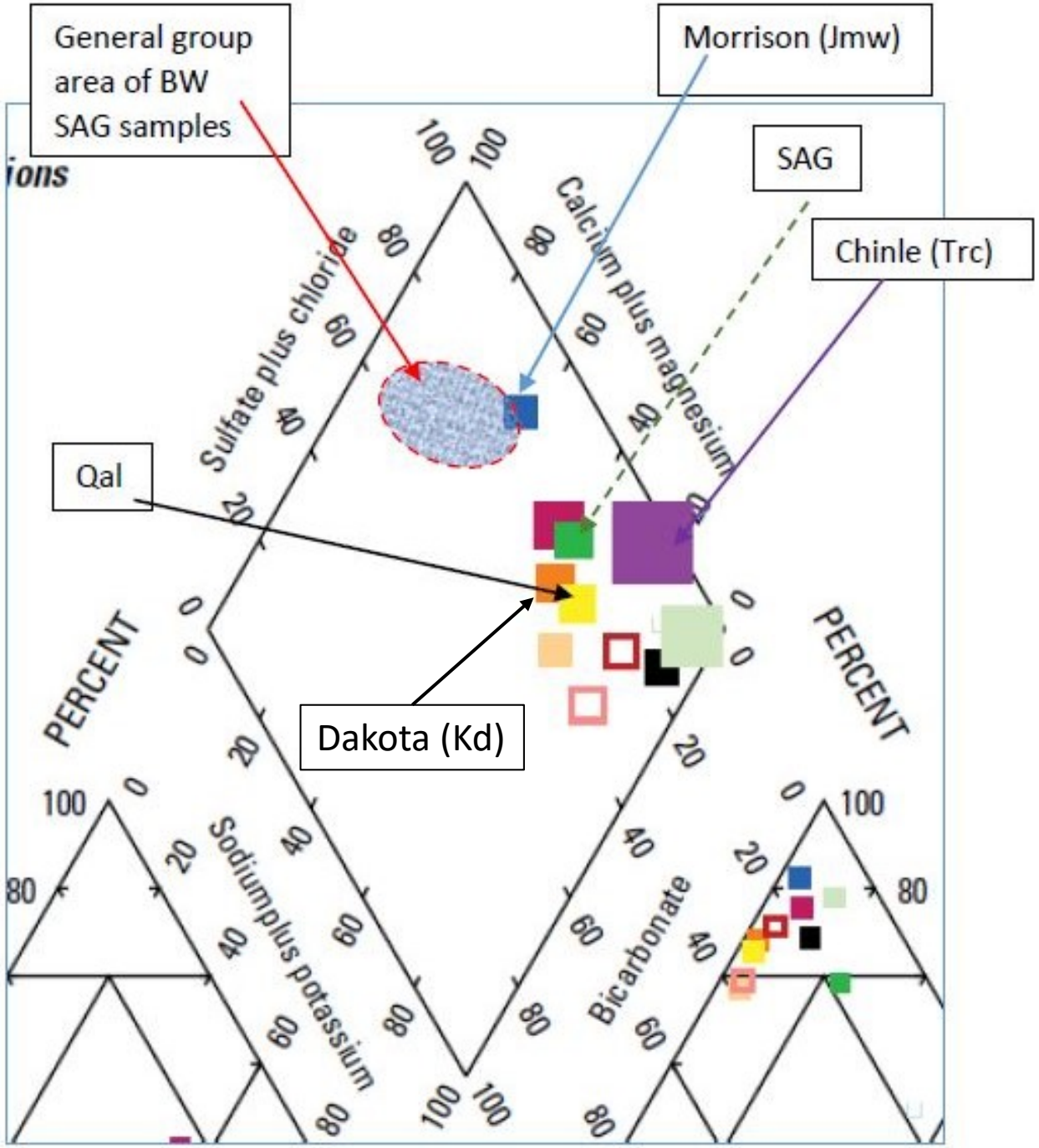
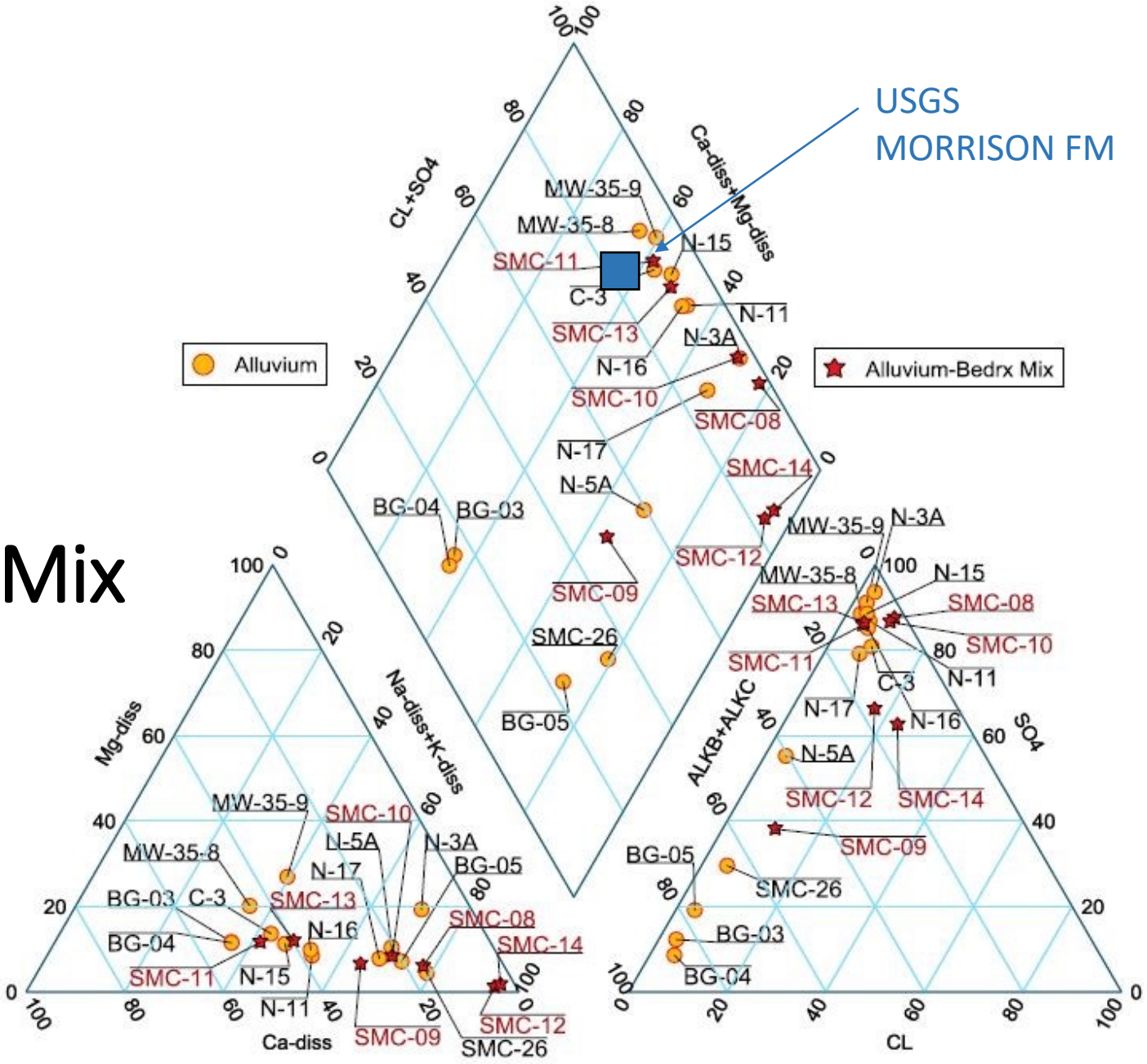
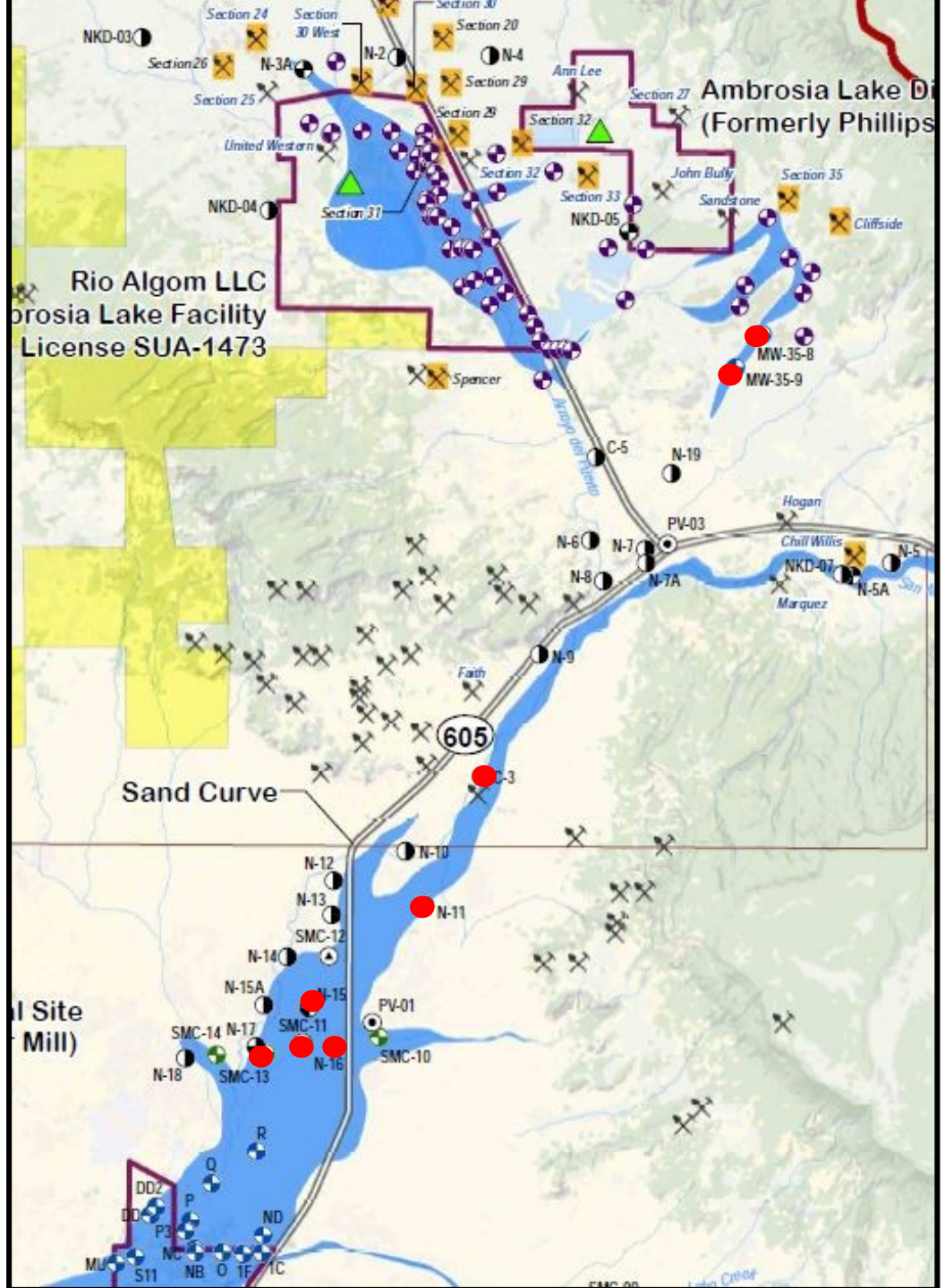


PHASE 2 TRILINEAR (PIPER) DIAGRAM

Alluvium and Alluvium – Bedrock Mix



ALLUVIAL WATER WITH MORRISON FM MAJOR ION COMPOSITION



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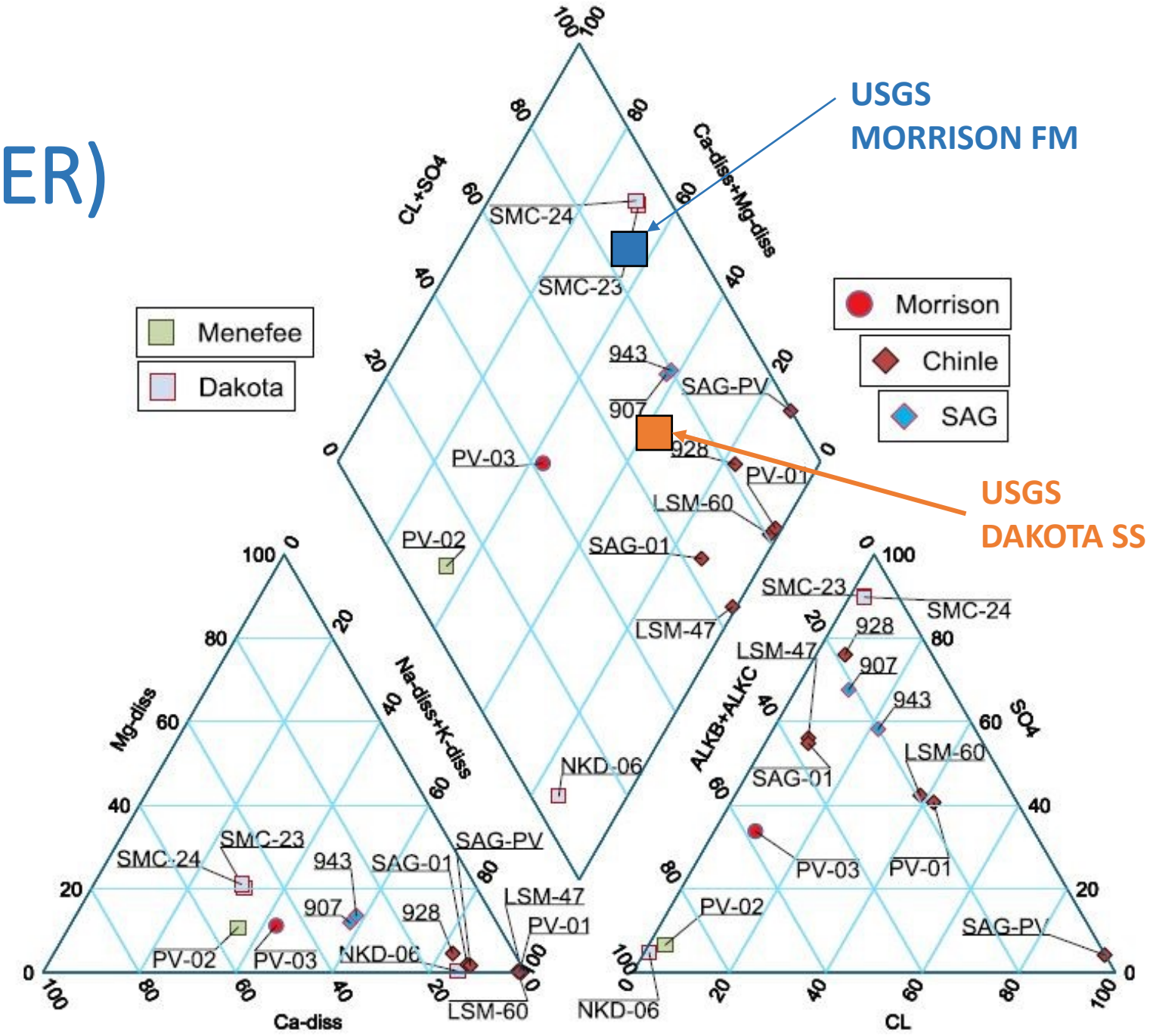
PHASE 2 TRILINEAR (PIPER) DIAGRAM

Bedrock



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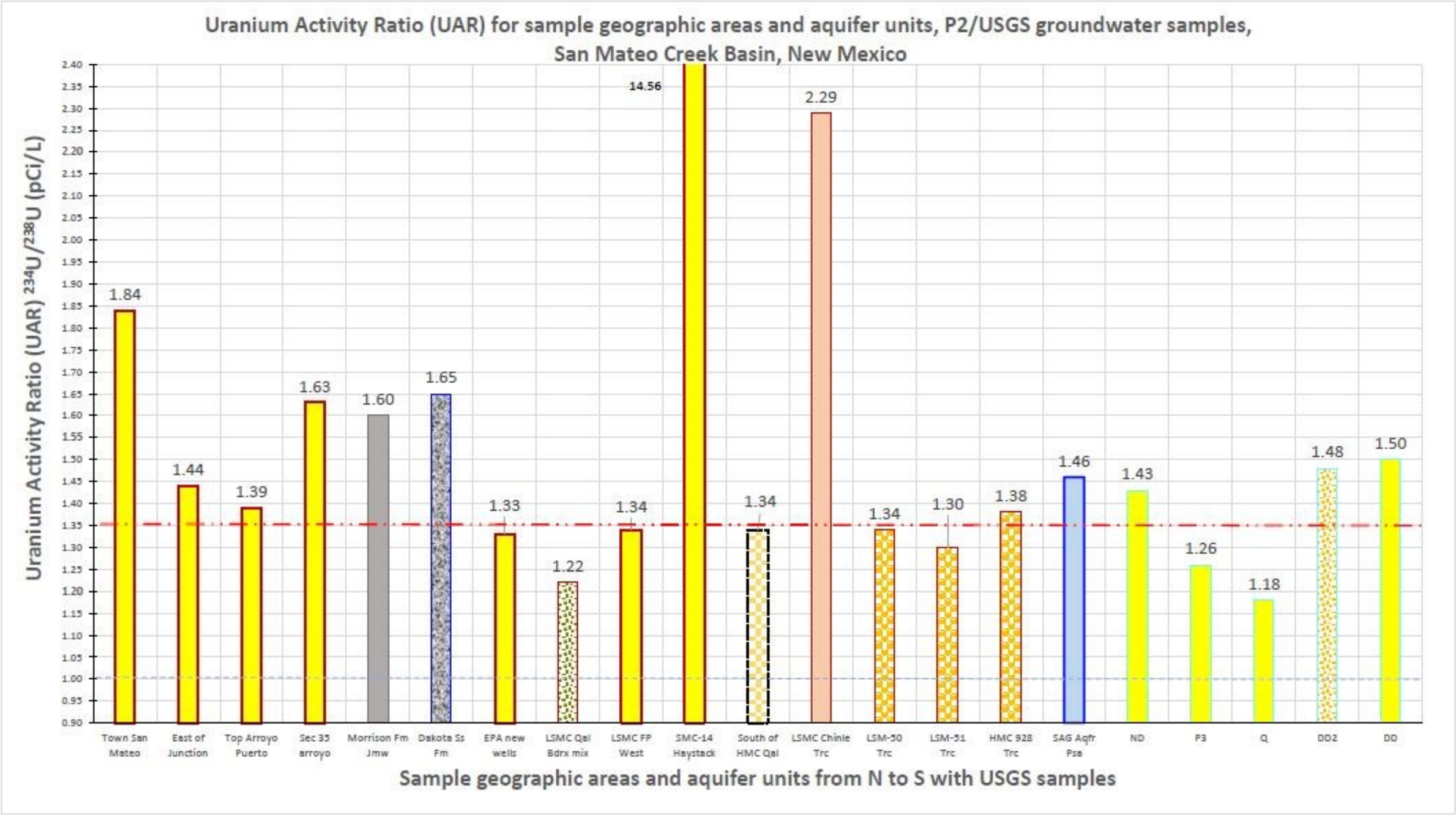
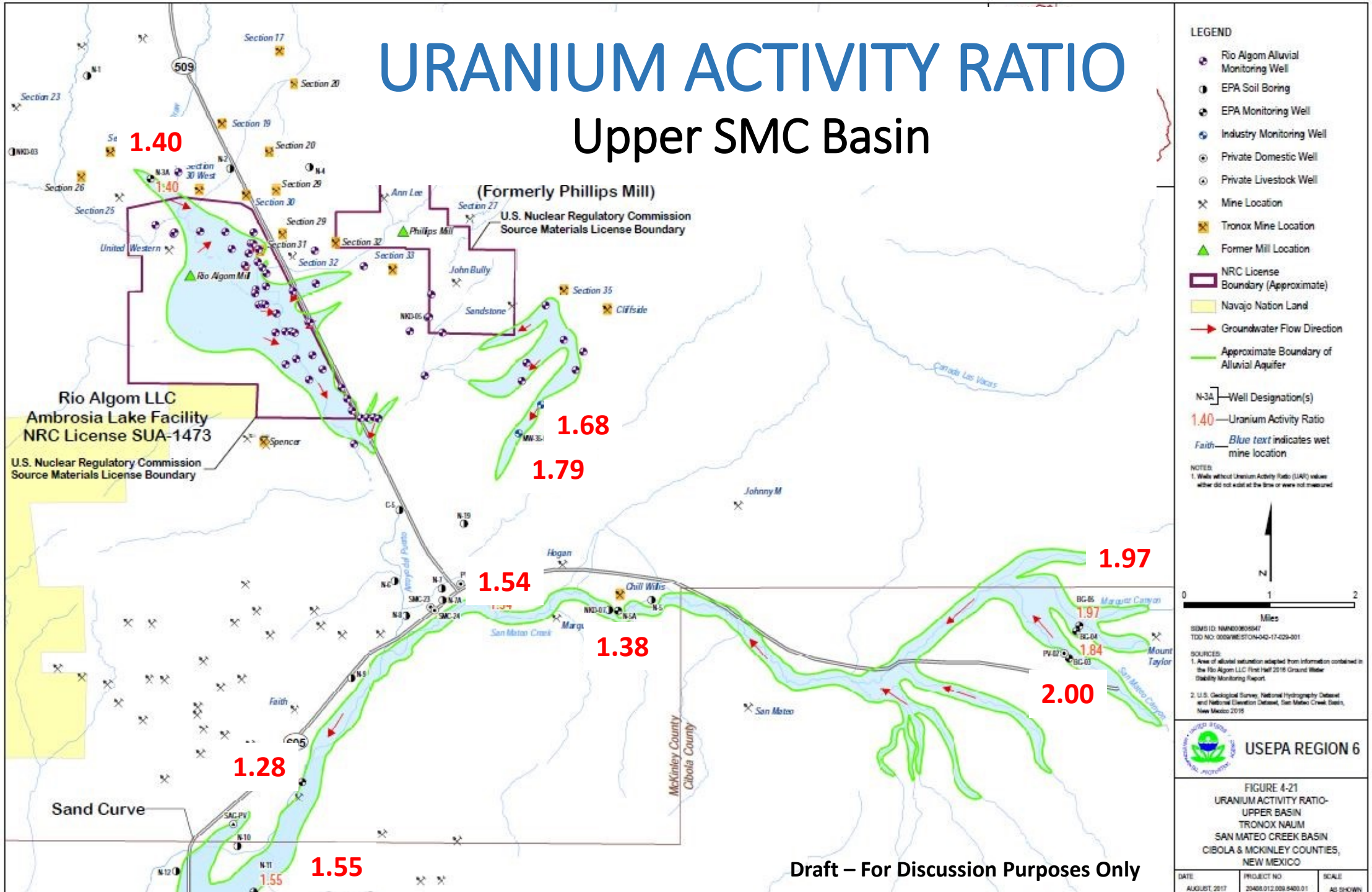
URANIUM ACTIVITY RATIO (UAR)

- U-234/U-238 RATIO
- DISTINGUISH BETWEEN MILL/MINE URANIUM CONTAMINATION AND NATURALLY OCCURRING BACKGROUND
  - U-234 AND U-238 Reach Secular Equilibrium in Closed System (Rock)
    - U-234 Production from U-238 Decay = U-234 Loss through Decay
    - UAR = 1.0
  - U-234 Preferentially Released in Ground Water
    - Caused by Disruption of crystalline structure
    - Elevates UAR Values in most natural ground waters
- UAR VALUES > 1.5 = BACKGROUND
- UAR VALUES < 1.35 = URANIUM MINE OR MILL SOURCE


Uranium Activity Ratio (UAR) for sample geographic areas and aquifer units, P2/USGS groundwater samples, San Mateo Creek Basin, New Mexico
Uranium Activity Ratio (UAR) 234U/238U (pCi/L)
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
1.84
1.44
1.39
1.63
1.60
1.65
1.33
1.22
1.34
14.56
1.34
2.29
1.34
1.30
1.38
1.46
1.43
1.26
1.18
1.48
1.50
Town San Mateo
East of Junction
Top Arroyo Puerto
Sec 35 arroyo
Morrison Fm Jmw
Dakota Ss Fm
EPA new wells
LSMC Qal Bdrx mix
LSMC FP West
SMC-14 Haystack
South of HMC Qal
LSMC Chinle Trc
LSM-50 Trc
LSM-51 Trc
HMC 928 Trc
SAG Aqfr Psa
ND
P3
Q
DD2
DD
Sample geographic areas and aquifer units from N to S with USGS samples

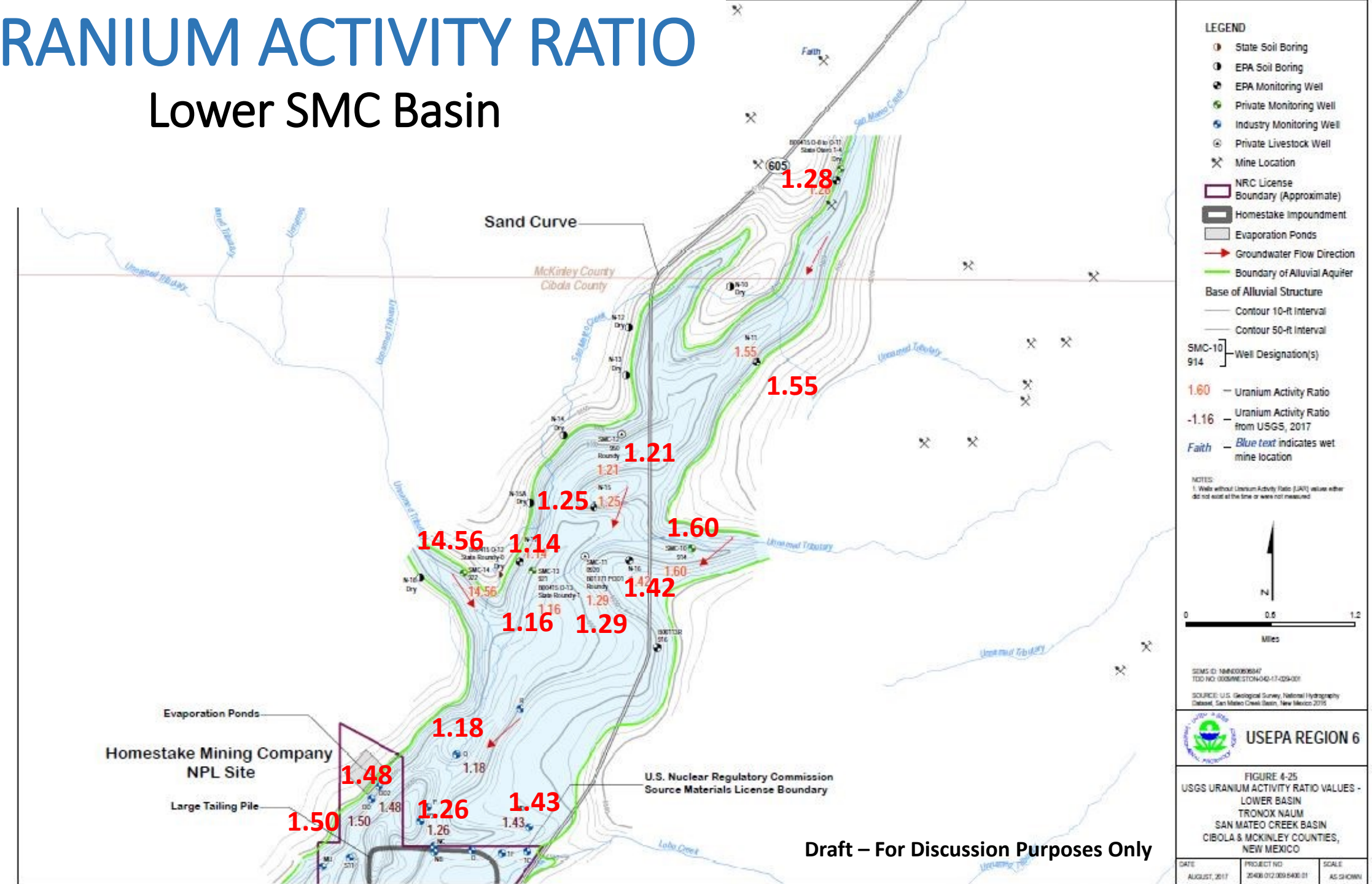
URANIUM ACTIVITY RATIO

Upper SMC Basin



URANIUM ACTIVITY RATIO

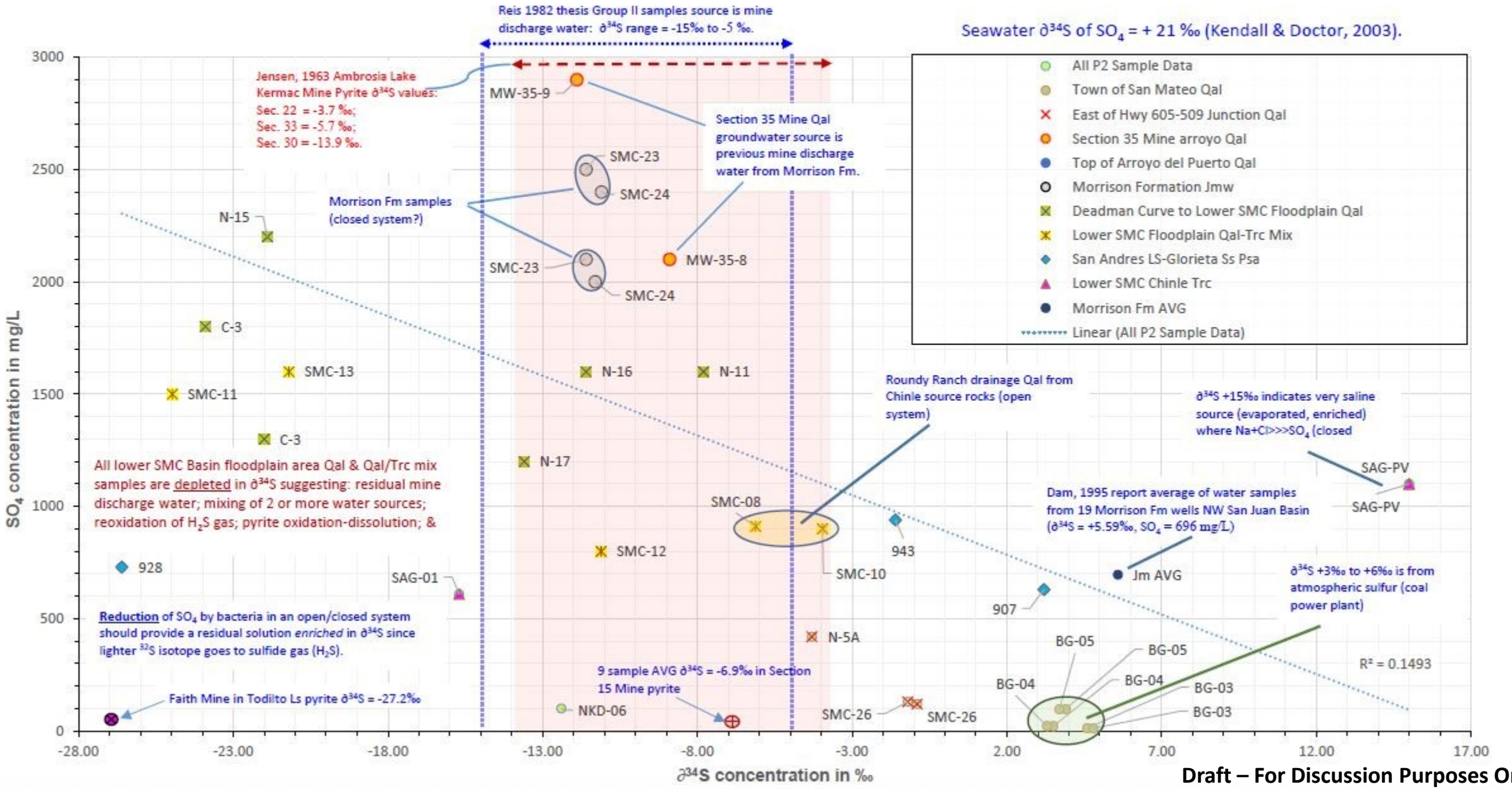
Lower SMC Basin



δ34S ISOTOPE

- ISOTOPIC COMPOSITION OF SULFUR (δ34S) IS KNOWN
  - For Global, Regional and Local Sources
  - Sulfate Minerals (Gypsum, Anhydrite)
  - Sedimentary Sulfides (Pyrite)
    - ✓ Sandstone-Type Uranium Deposits in Colorado and Grants Area
- USED AS TRACER OR FINGERPRINT TO SOURCE OF SULFATE

SULFUR ISOTOPE ASSESSMENT



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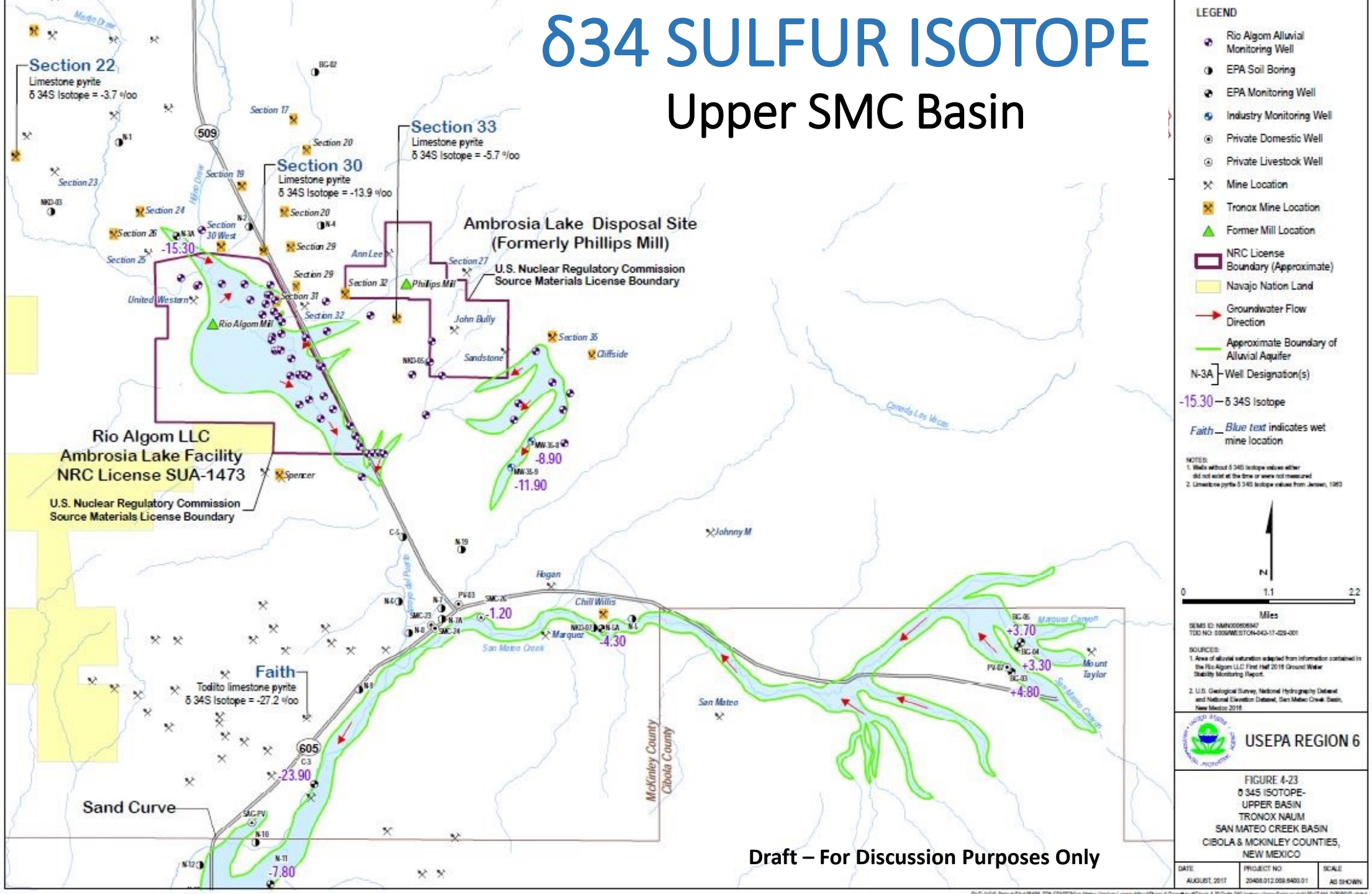
δ34 SULFUR ISOTOPE

Upper SMC Basin



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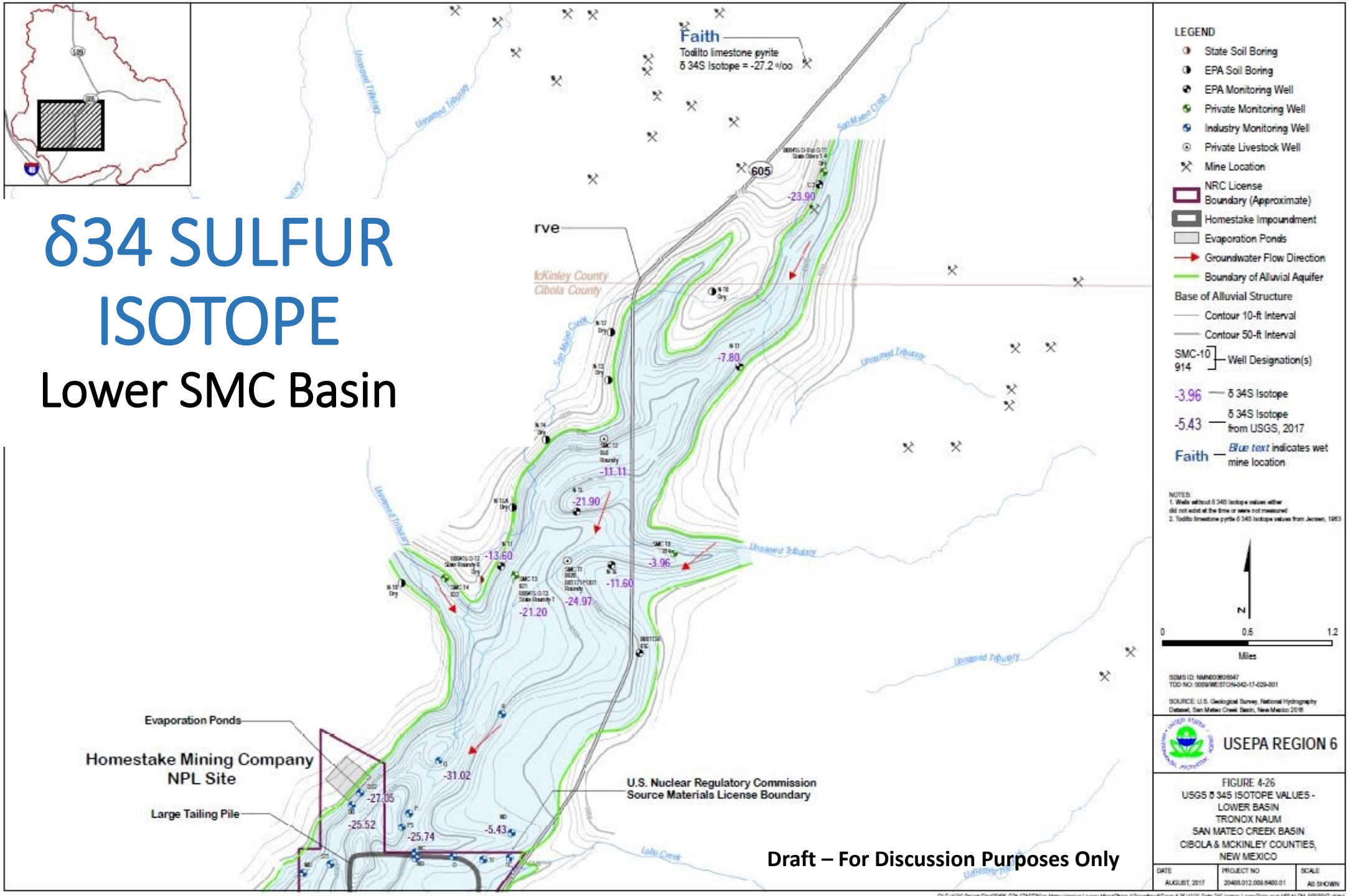
δ34 SULFUR ISOTOPE

Lower SMC Basin



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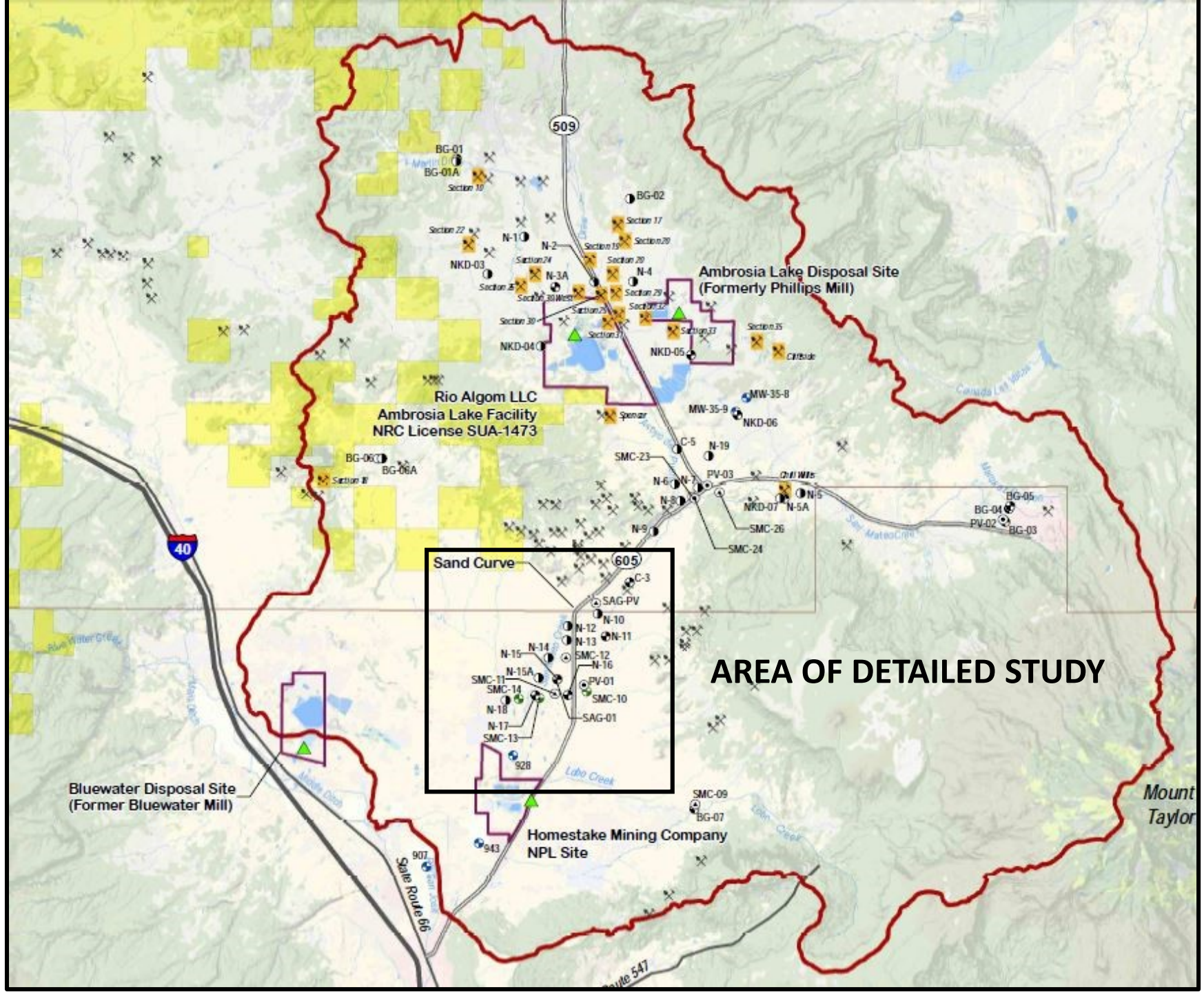
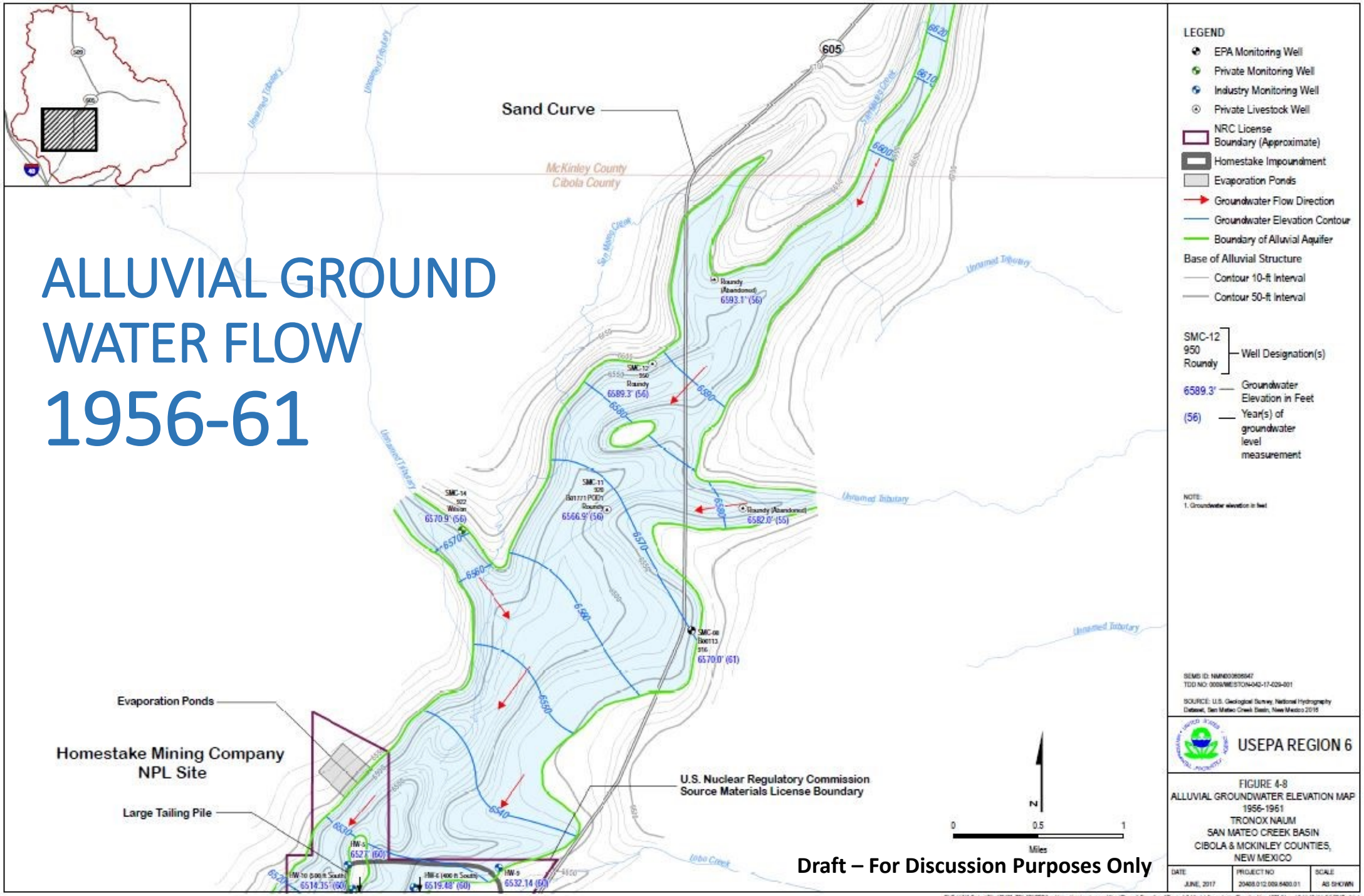
LEGACY MINE DISCHARGE WATER IMPACTS

- MAP CHANGES IN WATER LEVELS OVER TIME
  - Identify Physical Presence of Mine Discharge Water
- MAP CHANGES IN WATER QUALITY OVER TIME
  - Plume Maps for Key Constituents
- TEMPORAL PLOTS OF CONSTITUENT CONCENTRATIONS
  - Look for Upward Trends

TARGET LOWER SAN MATEO CREEK BASIN



ALLUVIAL GROUND WATER FLOW 1956-61



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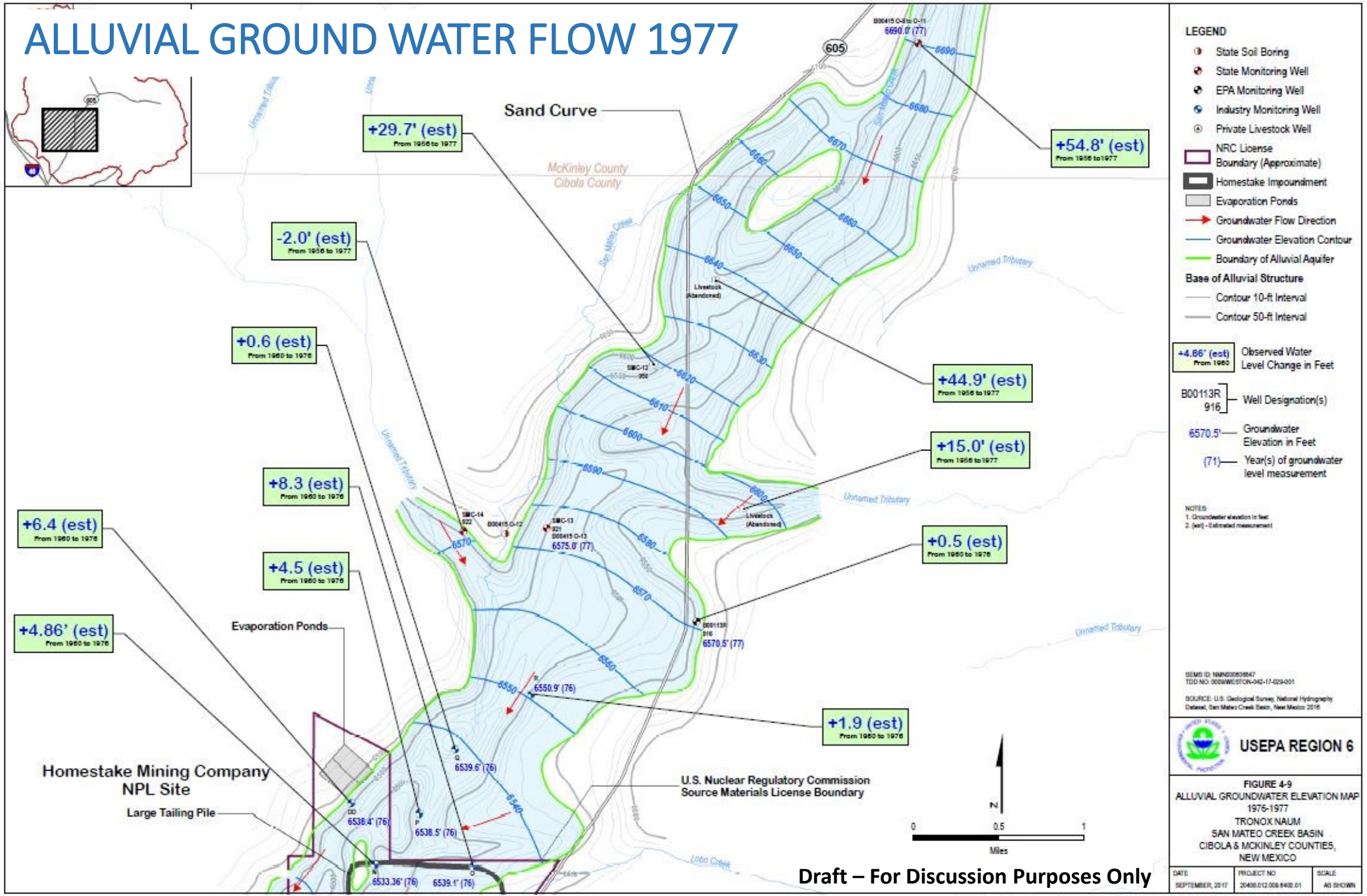
ALLUVIAL GROUND WATER FLOW 1977



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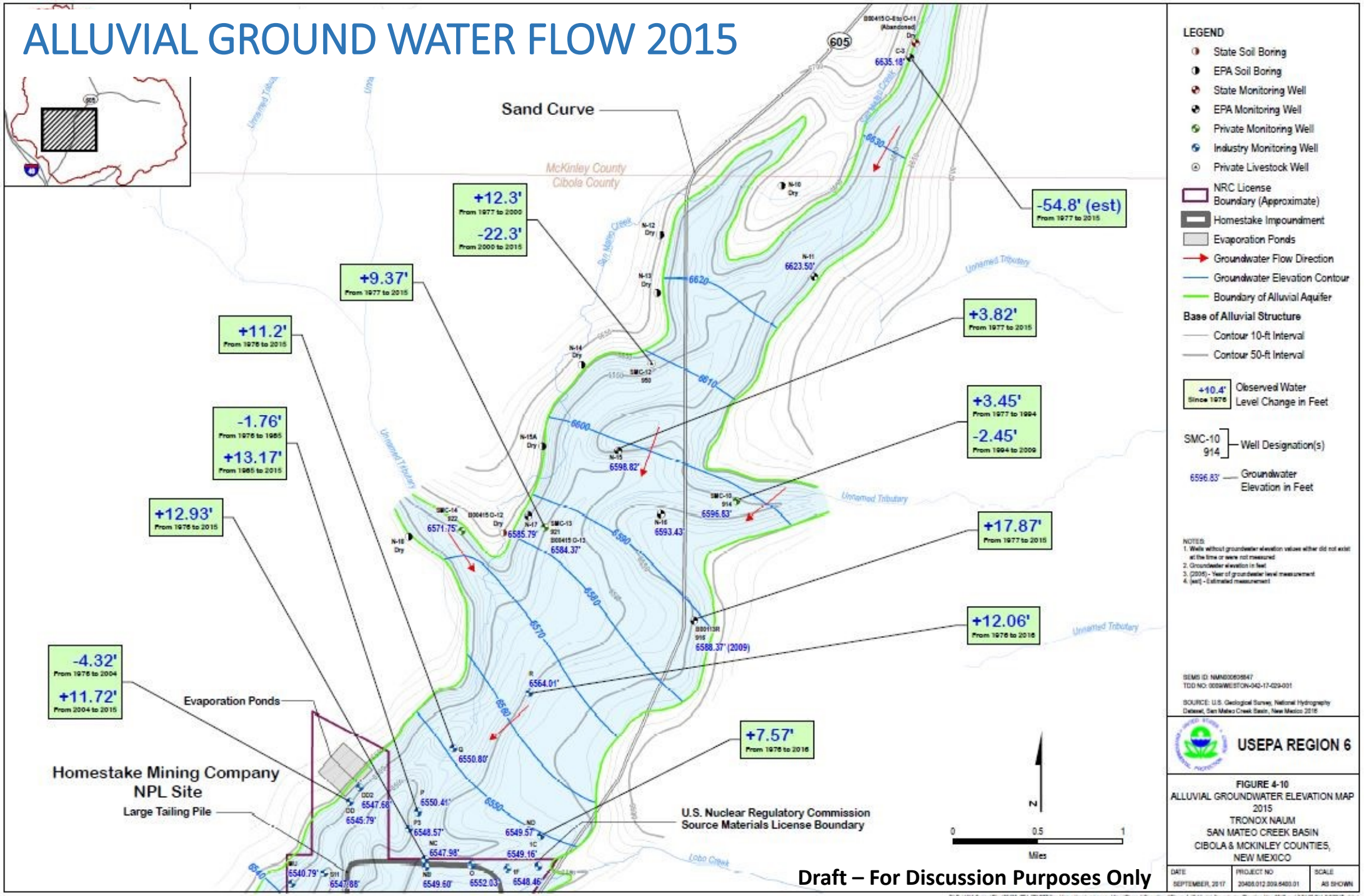
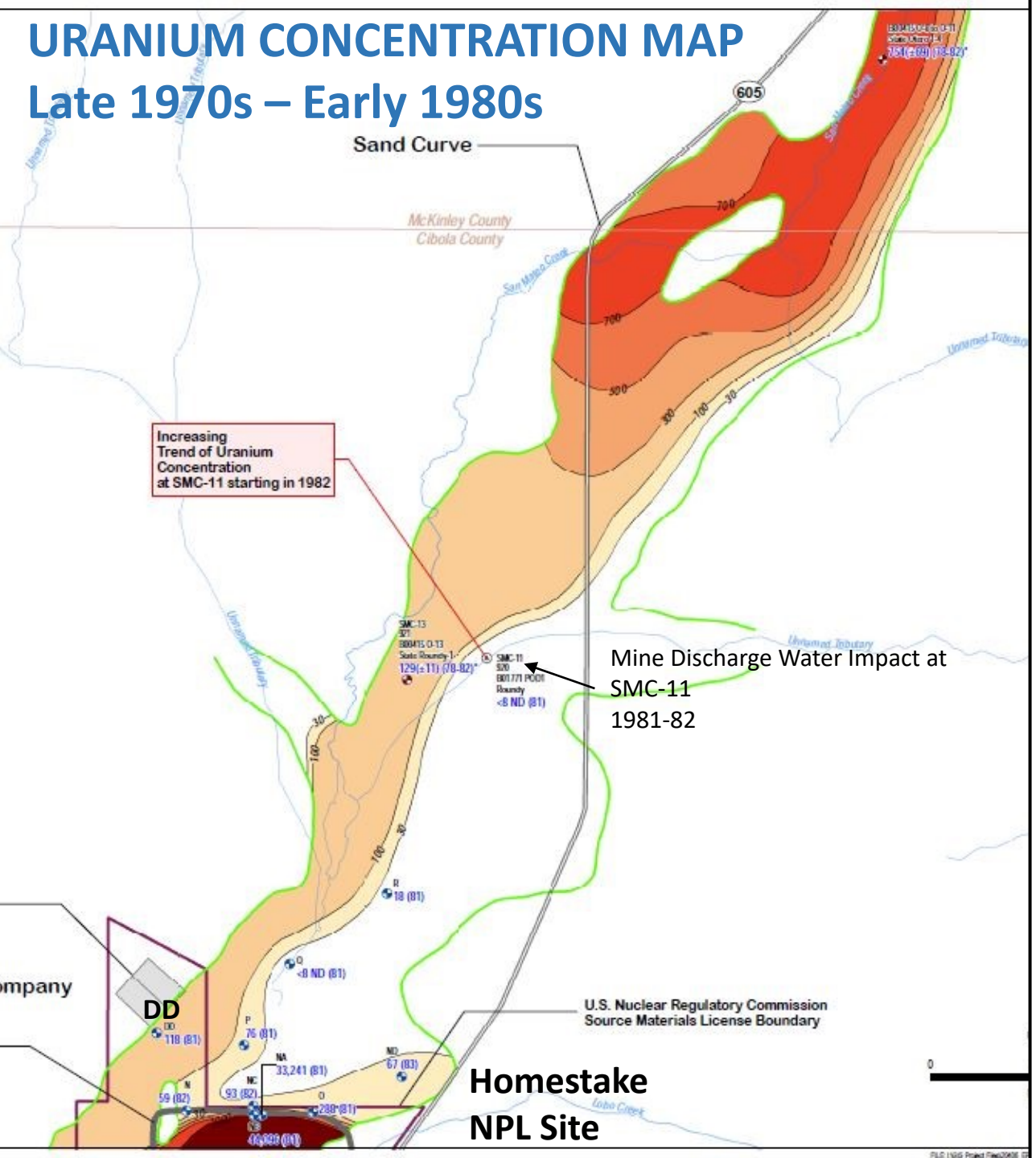
ALLUVIAL GROUND WATER FLOW 2015



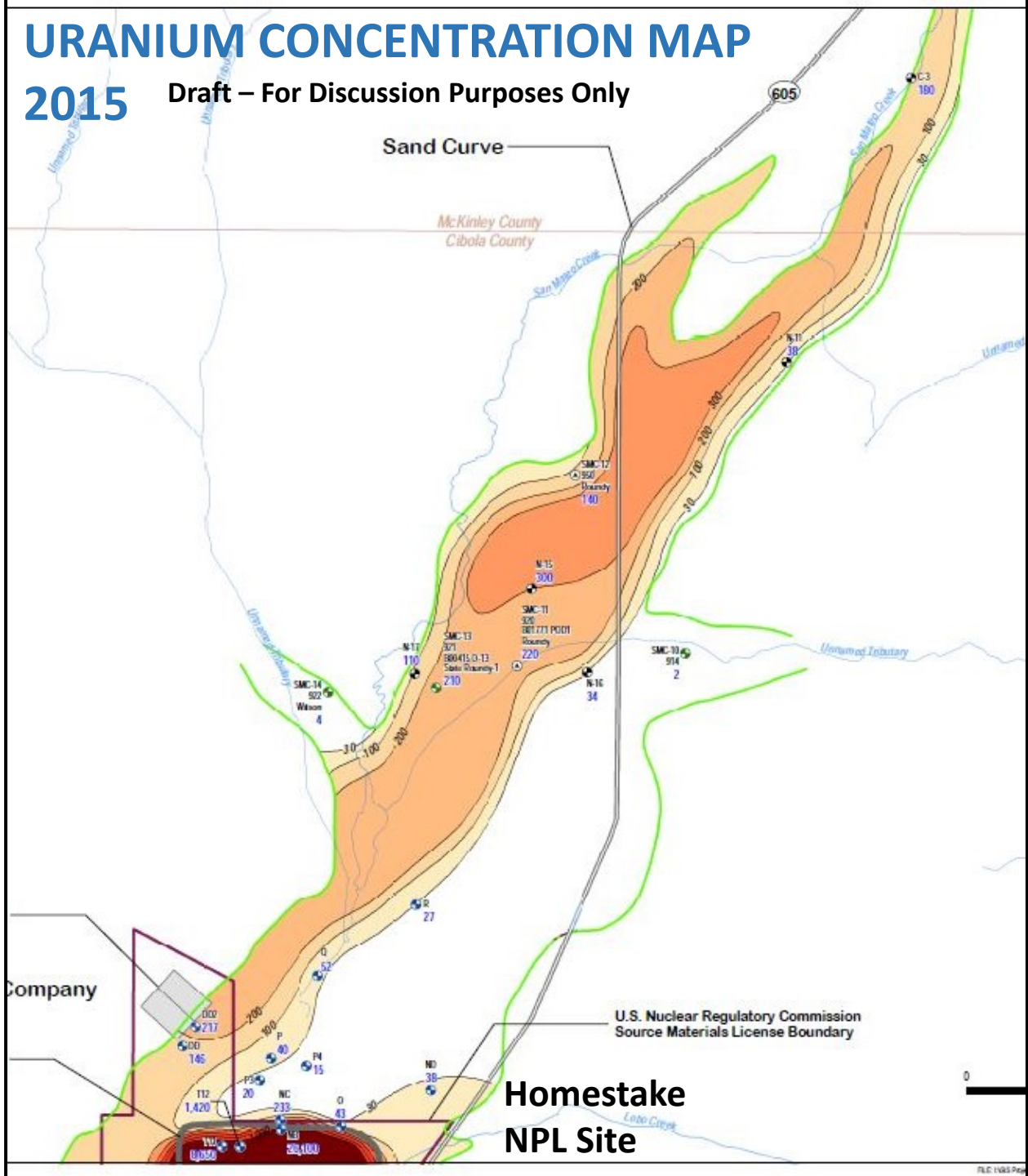
Draft – For Discussion Purposes Only

URANIUM CONCENTRATION MAP
Late 1970s – Early 1980s

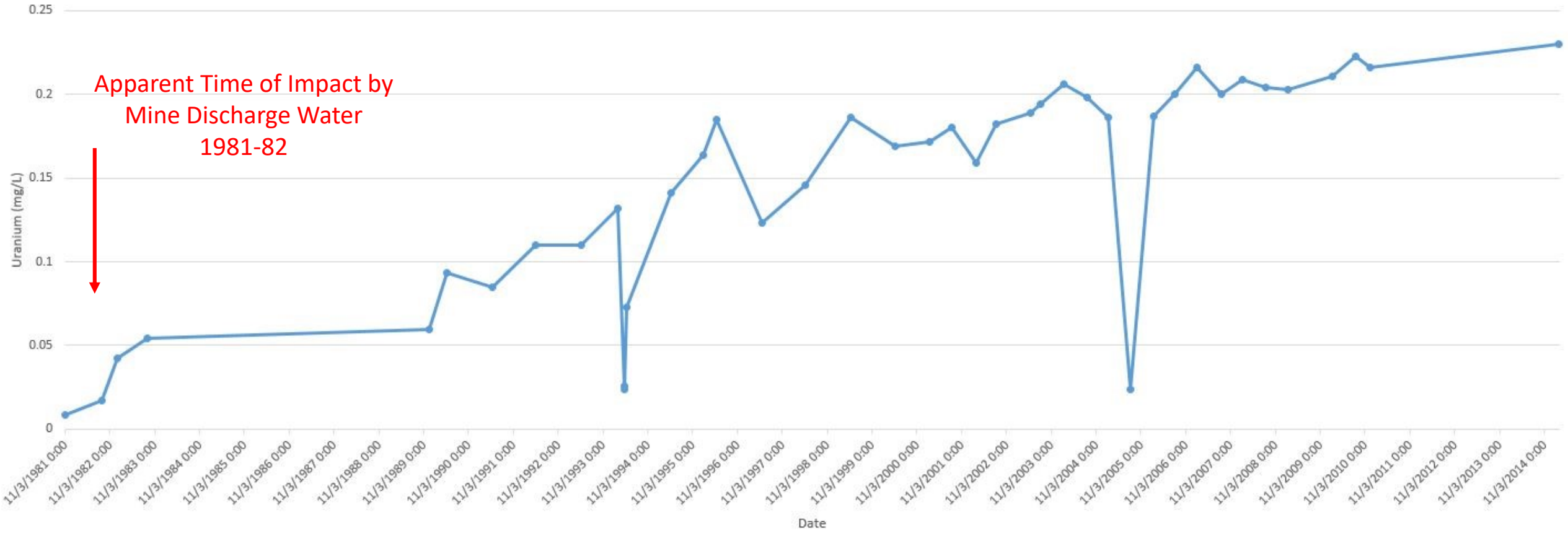


URANIUM CONCENTRATION MAP
2015

Draft – For Discussion Purposes Only



Homestake Well 920 (SMC-11)
Uranium-Time Trend Plot



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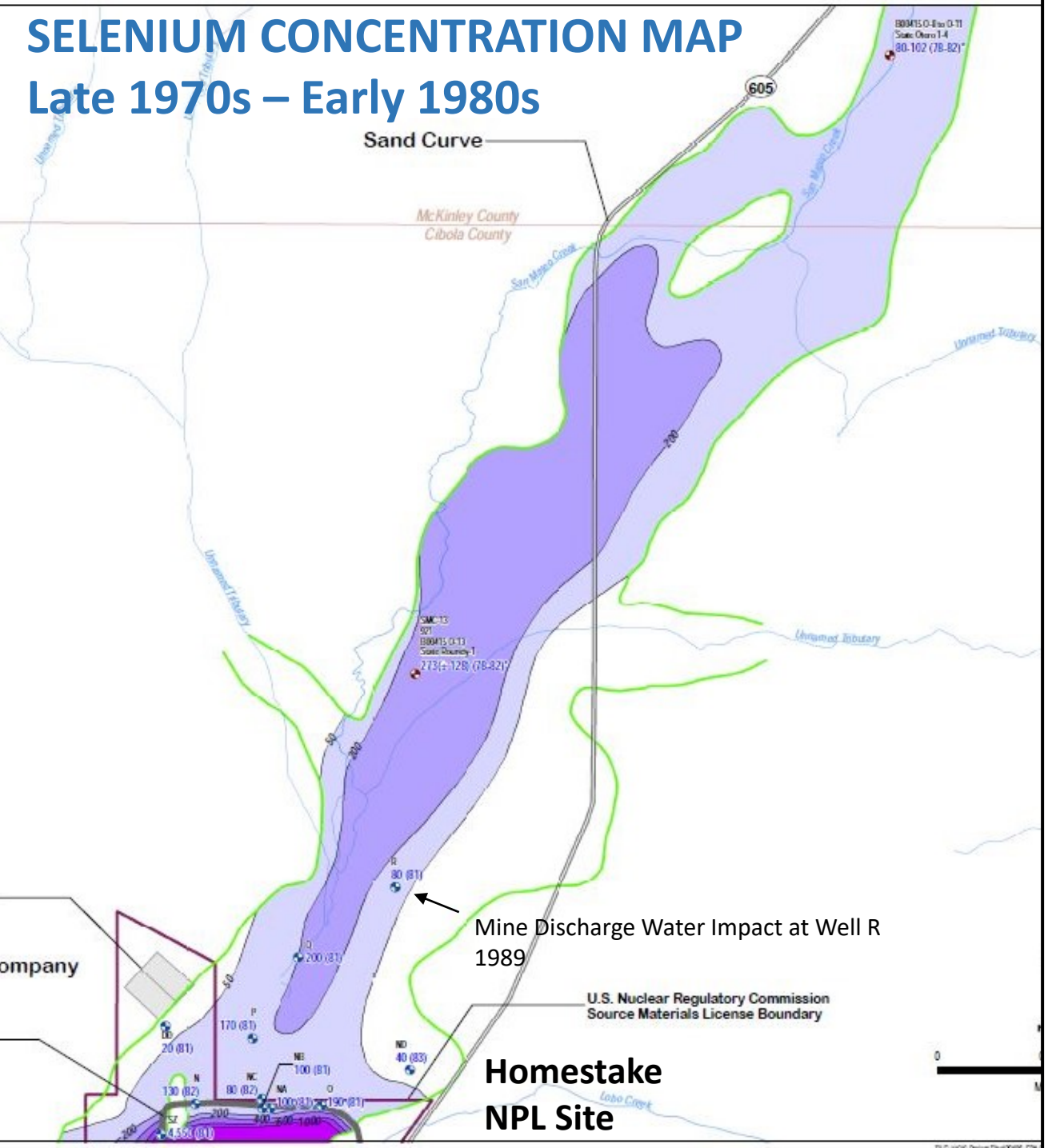
SELENIUM CONCENTRATION MAP
Late 1970s – Early 1980s



SELENIUM CONCENTRATION MAP
2015

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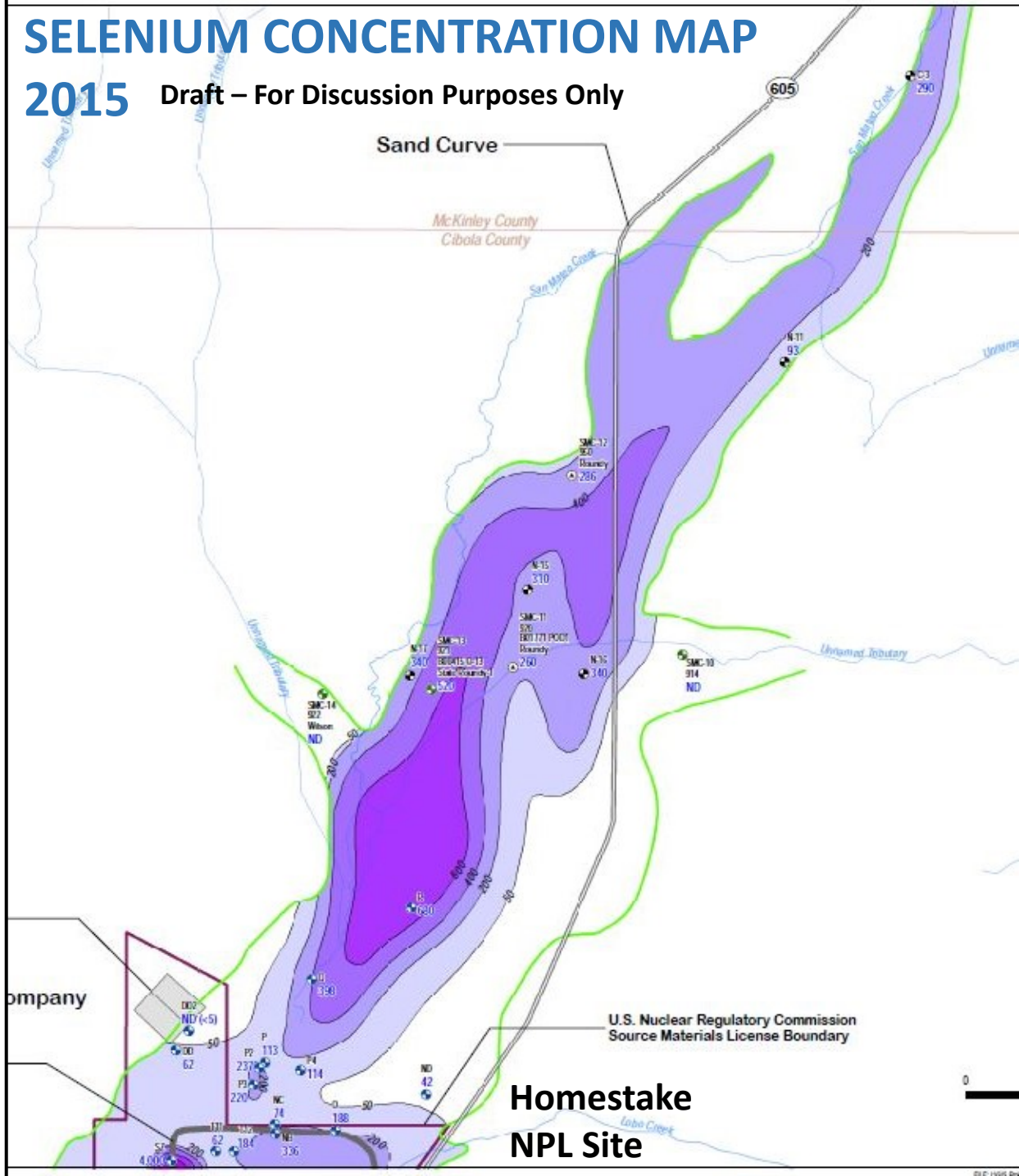
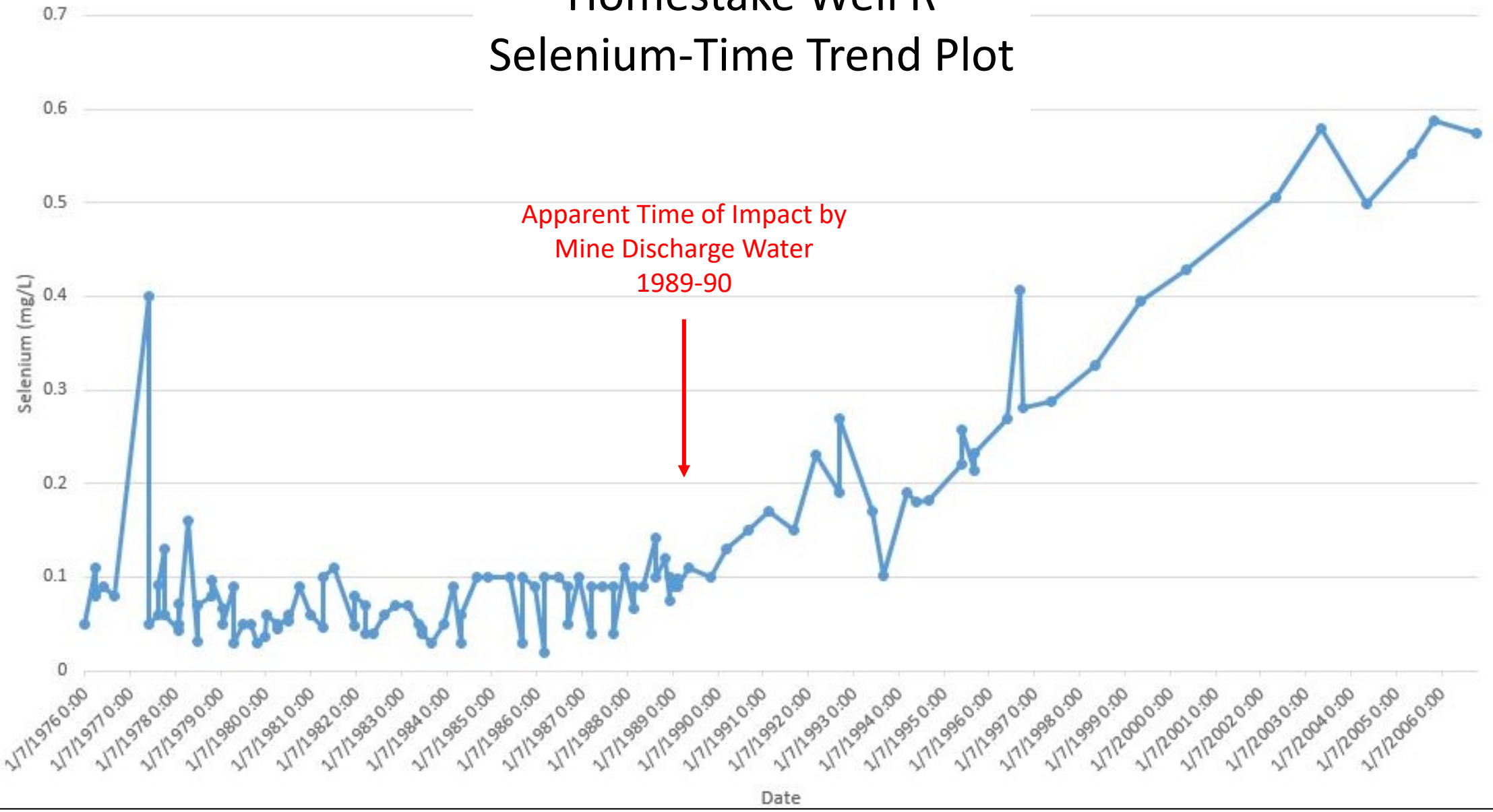


Homestake Well R
Selenium-Time Trend Plot



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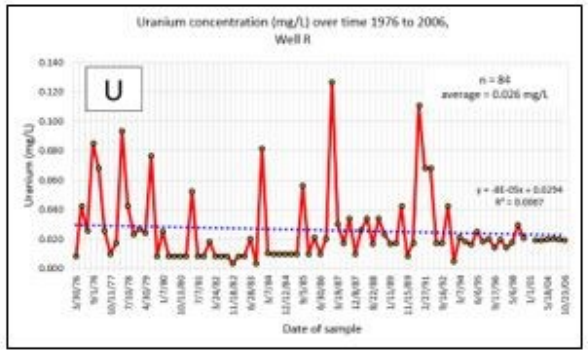
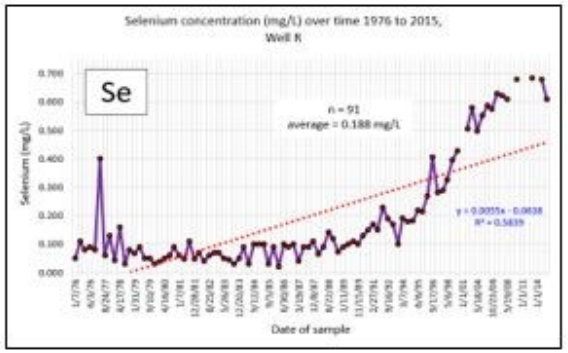
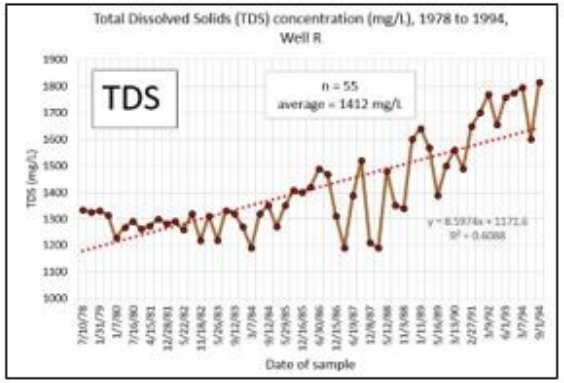
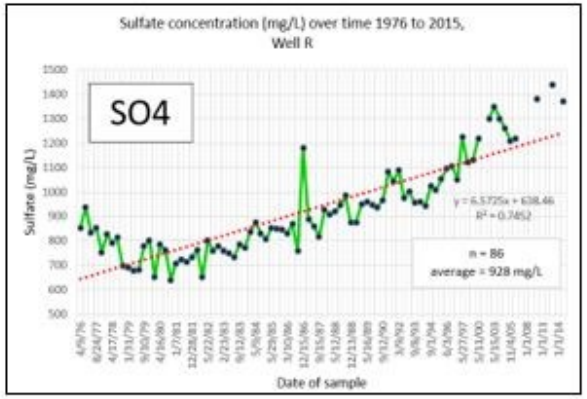
WELL R

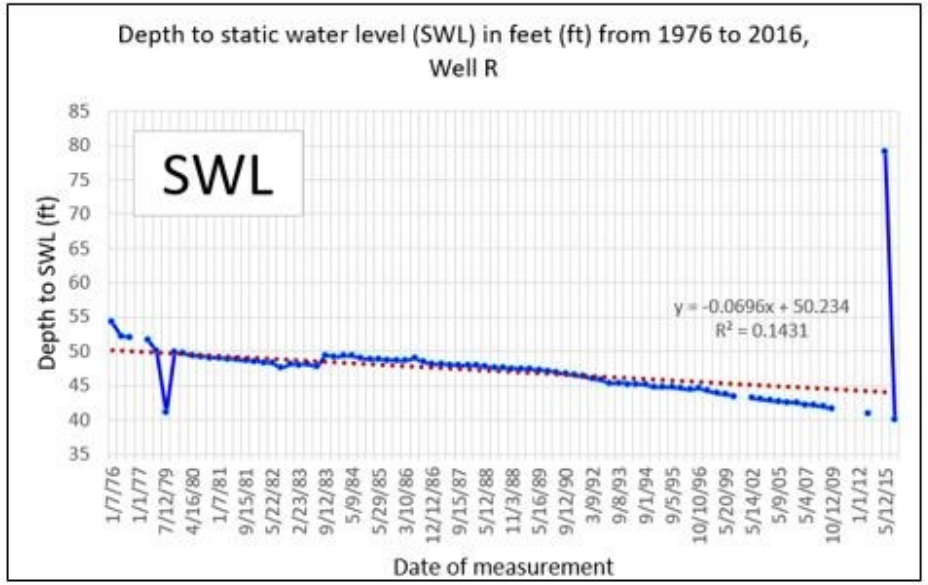
TEMPORAL PLOTS OF CONSTITUENTS CONCENTRATIONS







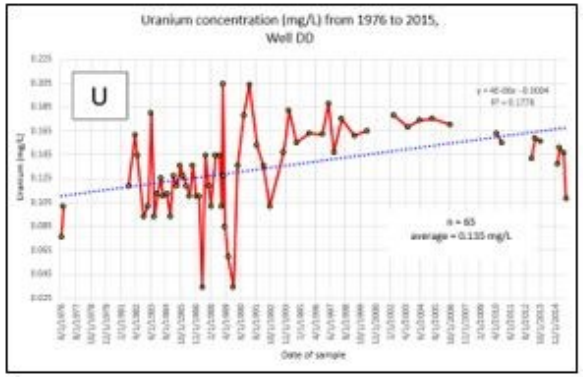


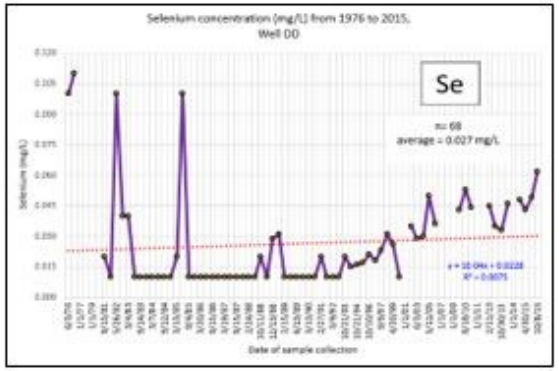


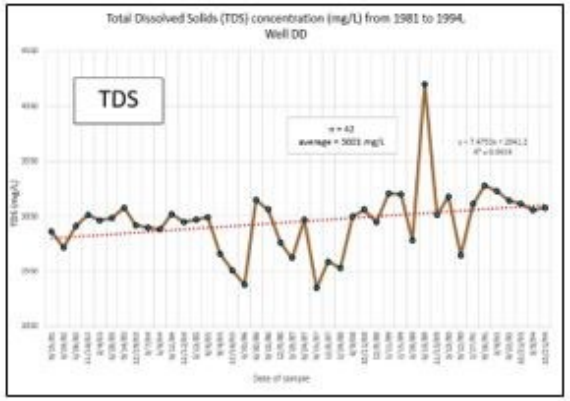
WELL DD

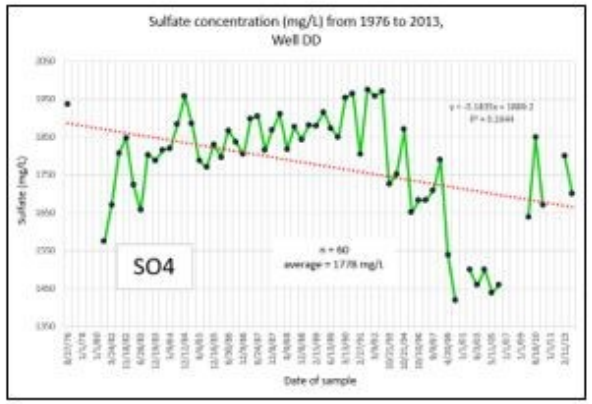
TEMPORAL PLOTS OF CONSTITUENT CONCENTRATIONS

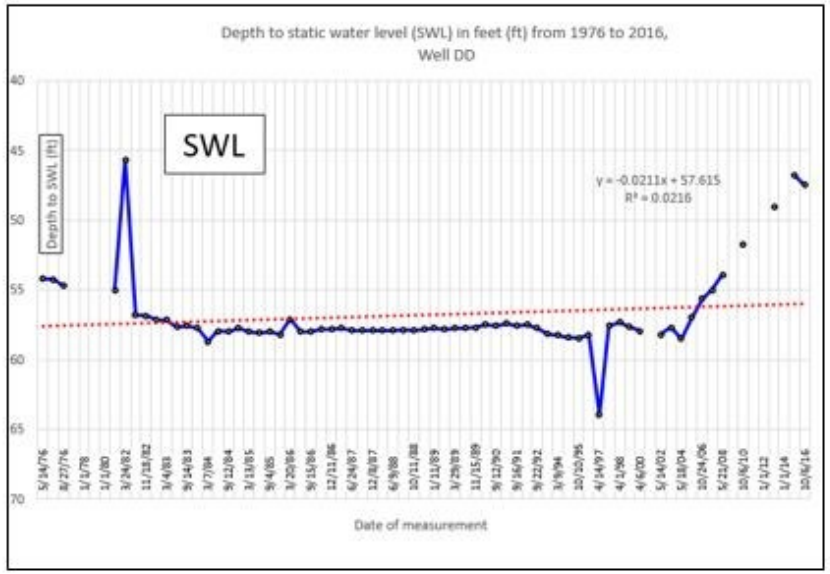
HISTORICALLY HIGH URANIUM
(Since Monitoring Began in 1976)











CONCEPTUALIZED IMPACTS OF MINE DISCHARGE WATER

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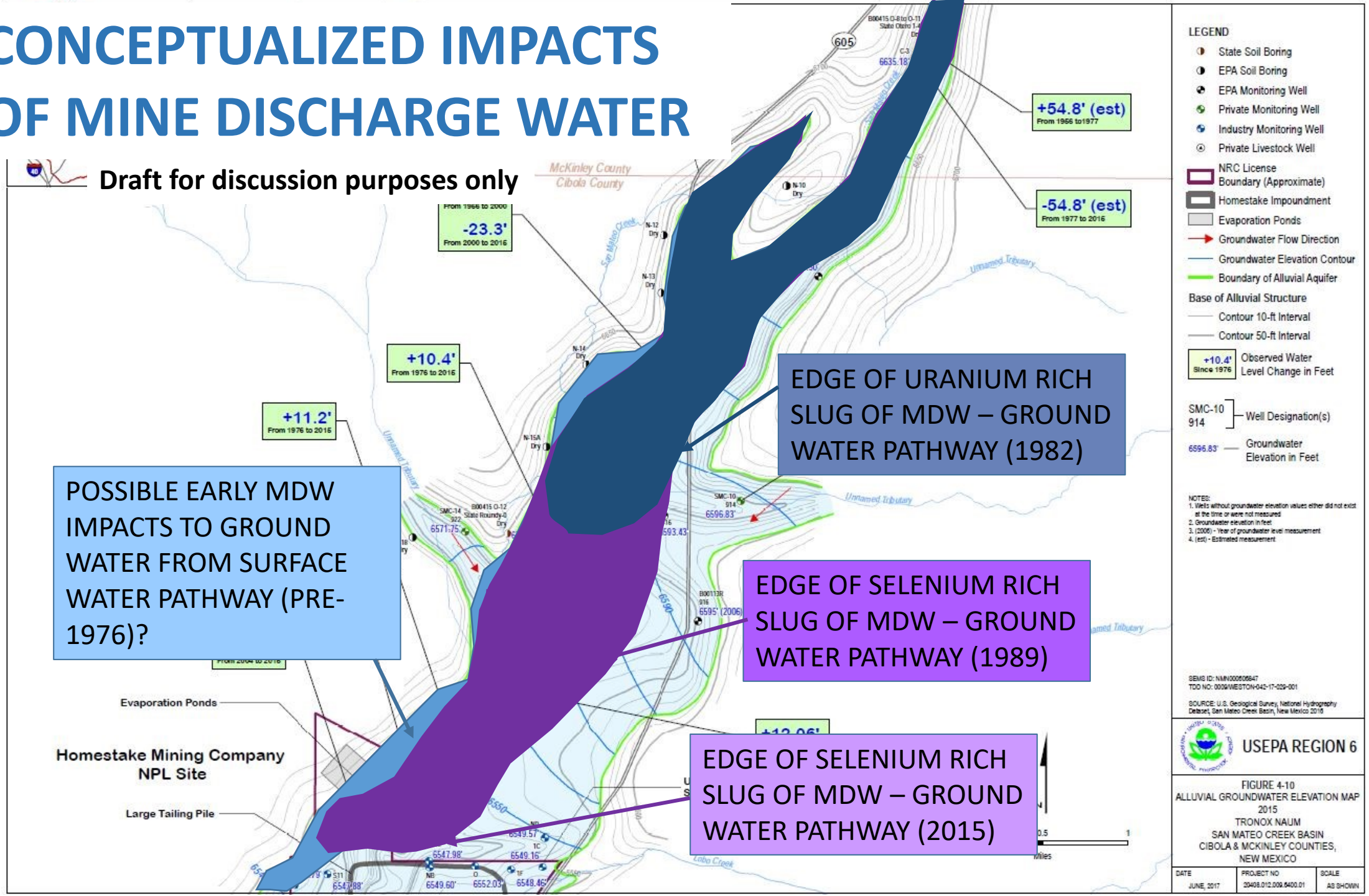
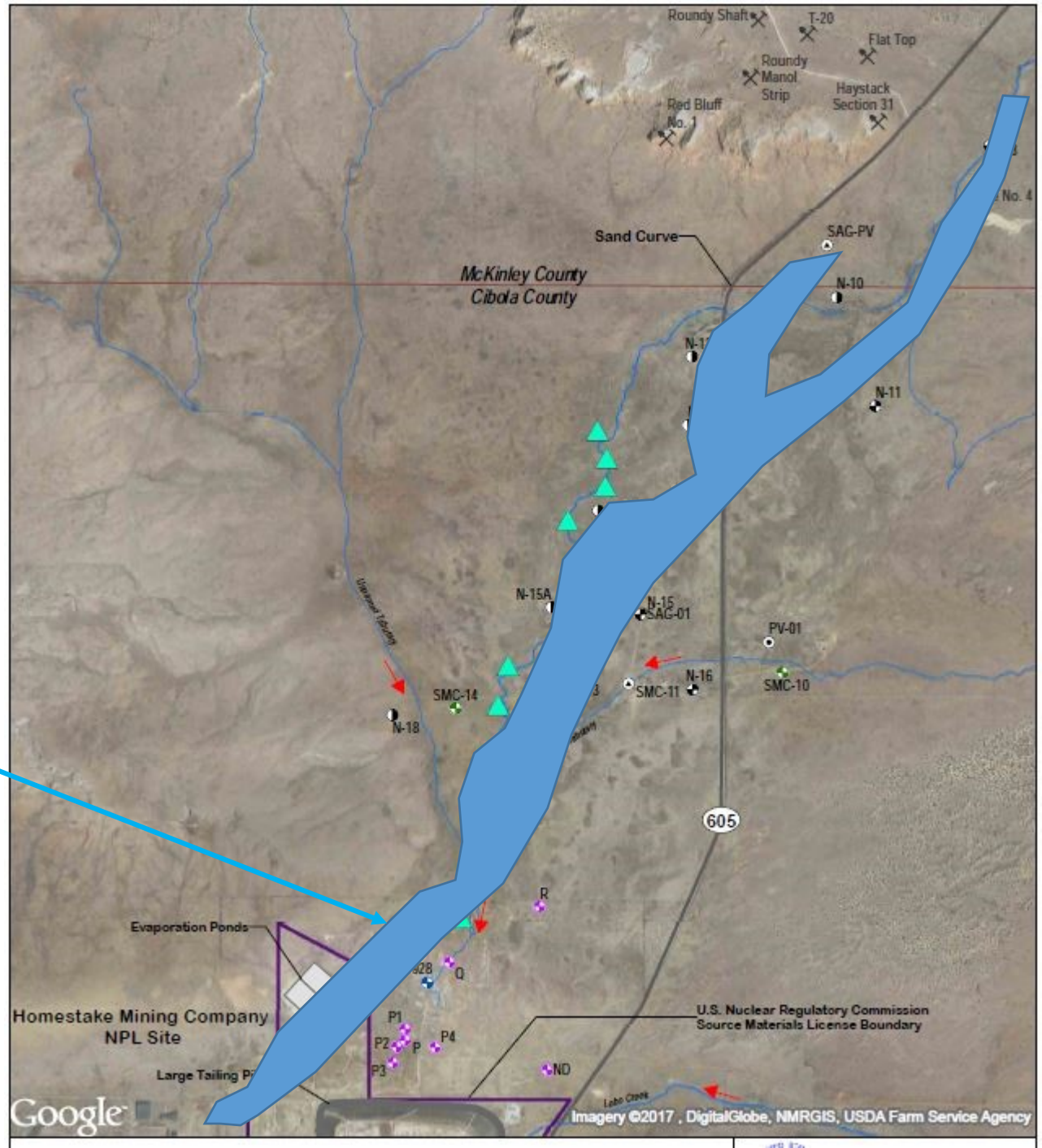


POSSIBLE SURFACE WATER FLOW PATH FOR EARLY URANIUM

▲ SPREADER DAMS FOR CATTLE FORAGE

POSSIBLE EARLY MINE DISCHARGE WATER IMPACTS TO GROUND WATER FROM SURFACE WATER PATHWAY (PRE-1976)?



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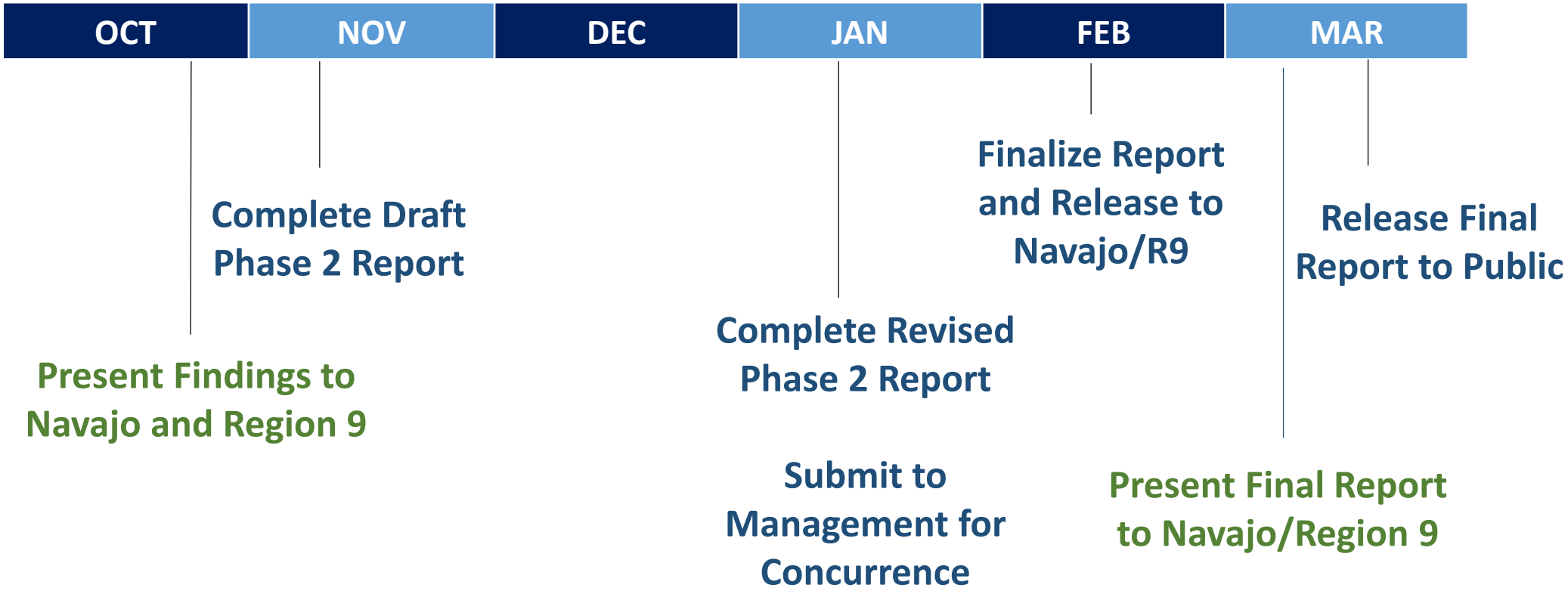
DRAFT PHASE 2 REPORT NEAR COMPLETION

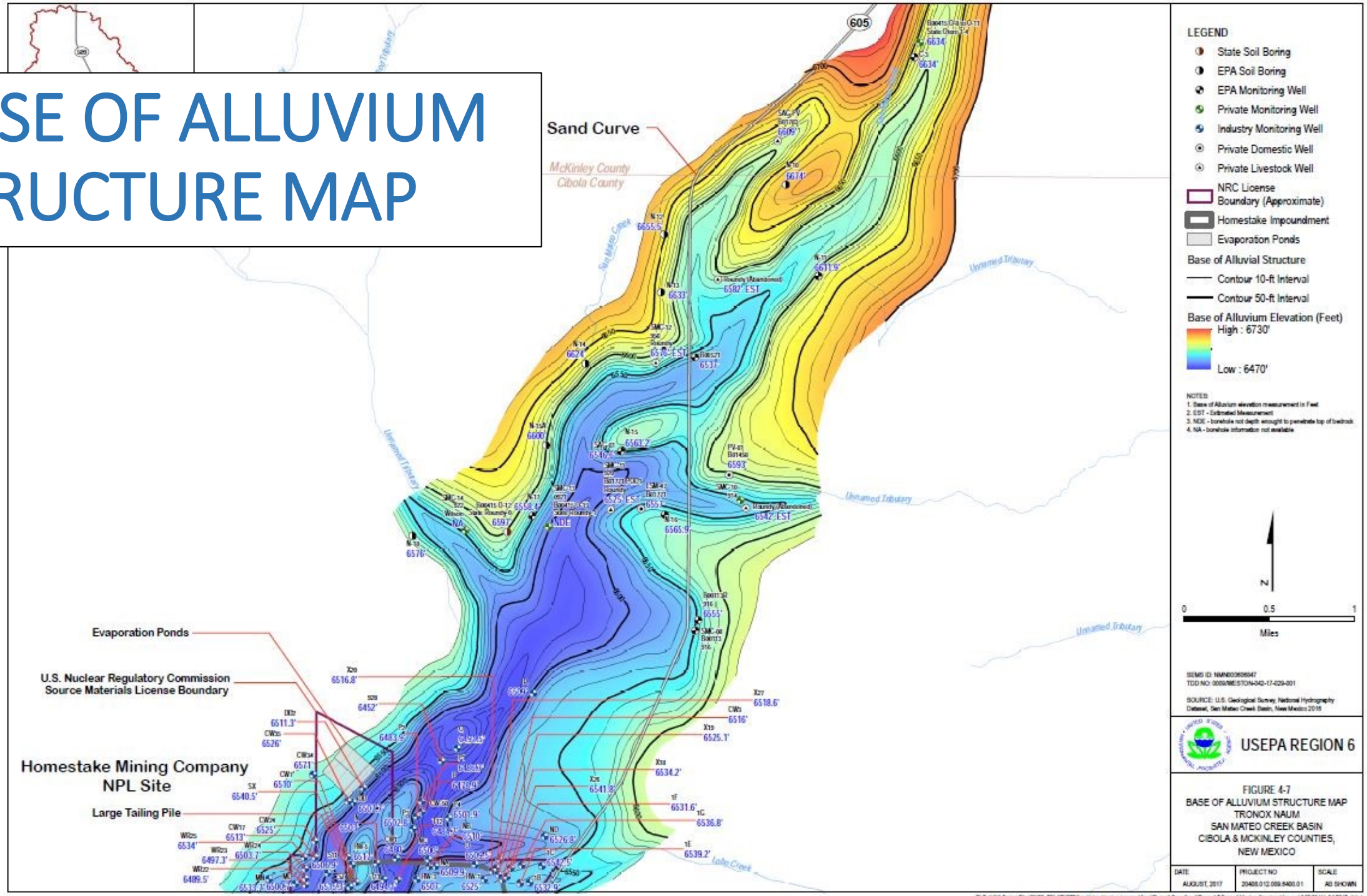
- DISCUSSION AND CONCLUSION SECTIONS YET TO BE WRITTEN
- MUST LOOK AT MULTIPLE LINES OF EVIDENCE TO SUPPORT FINDINGS AND CONCLUSIONS
  - Individual Lines of Evidence May Not be Conclusive

REPORT COMPLETION SCHEDULE – 2017/2018

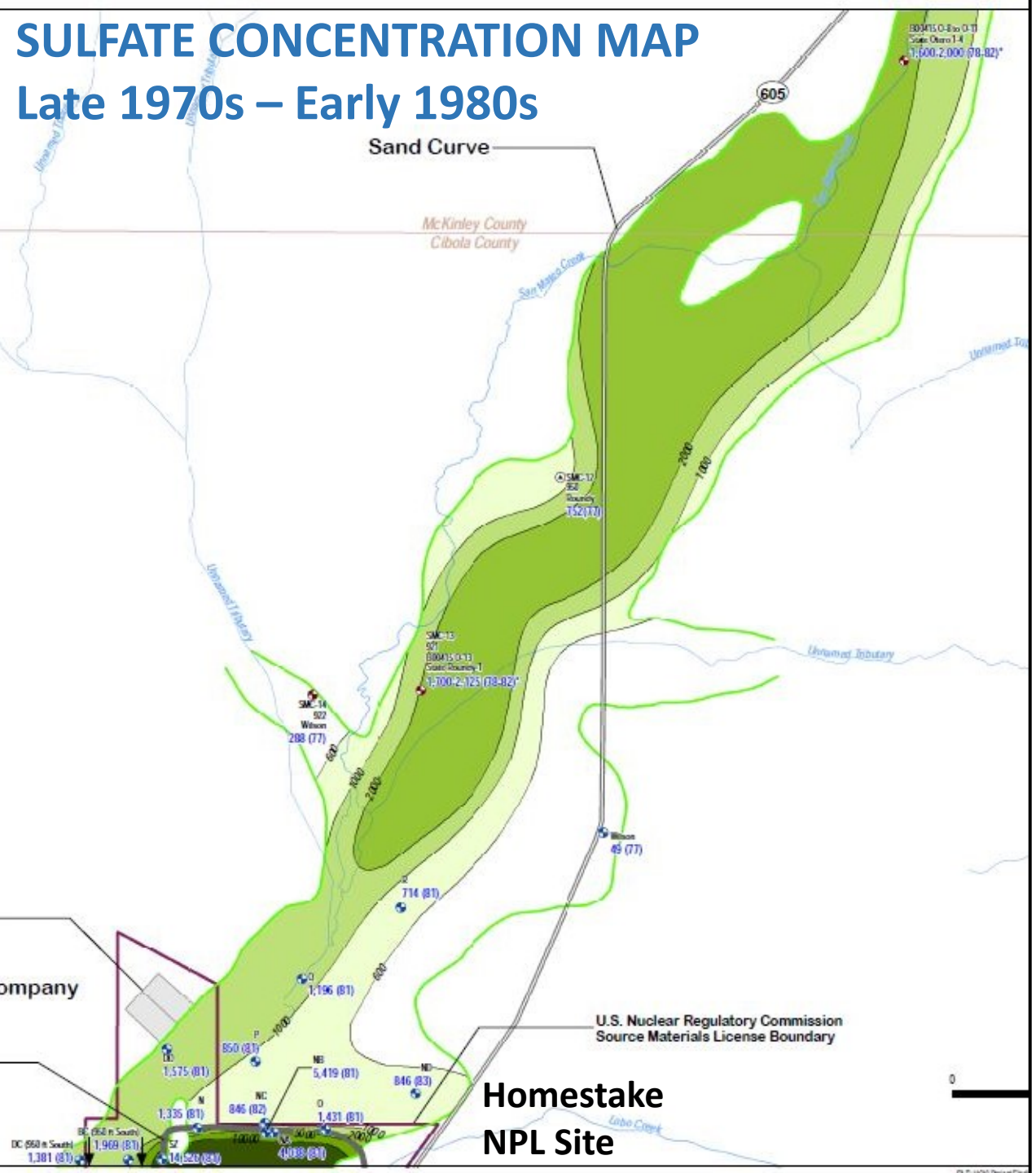


OTHER SLIDES

BASE OF ALLUVIUM STRUCTURE MAP

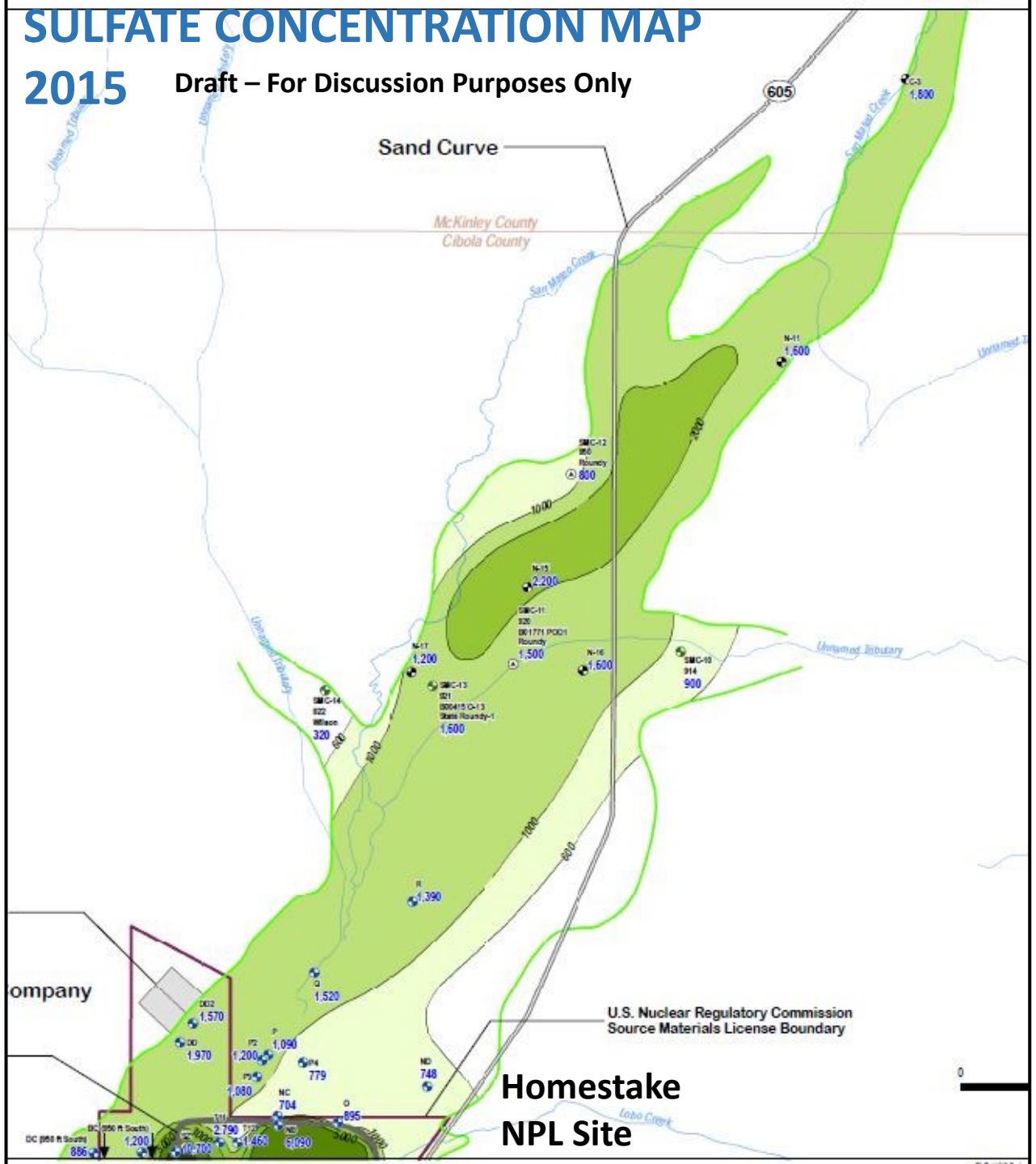


SULFATE CONCENTRATION MAP
Late 1970s – Early 1980s



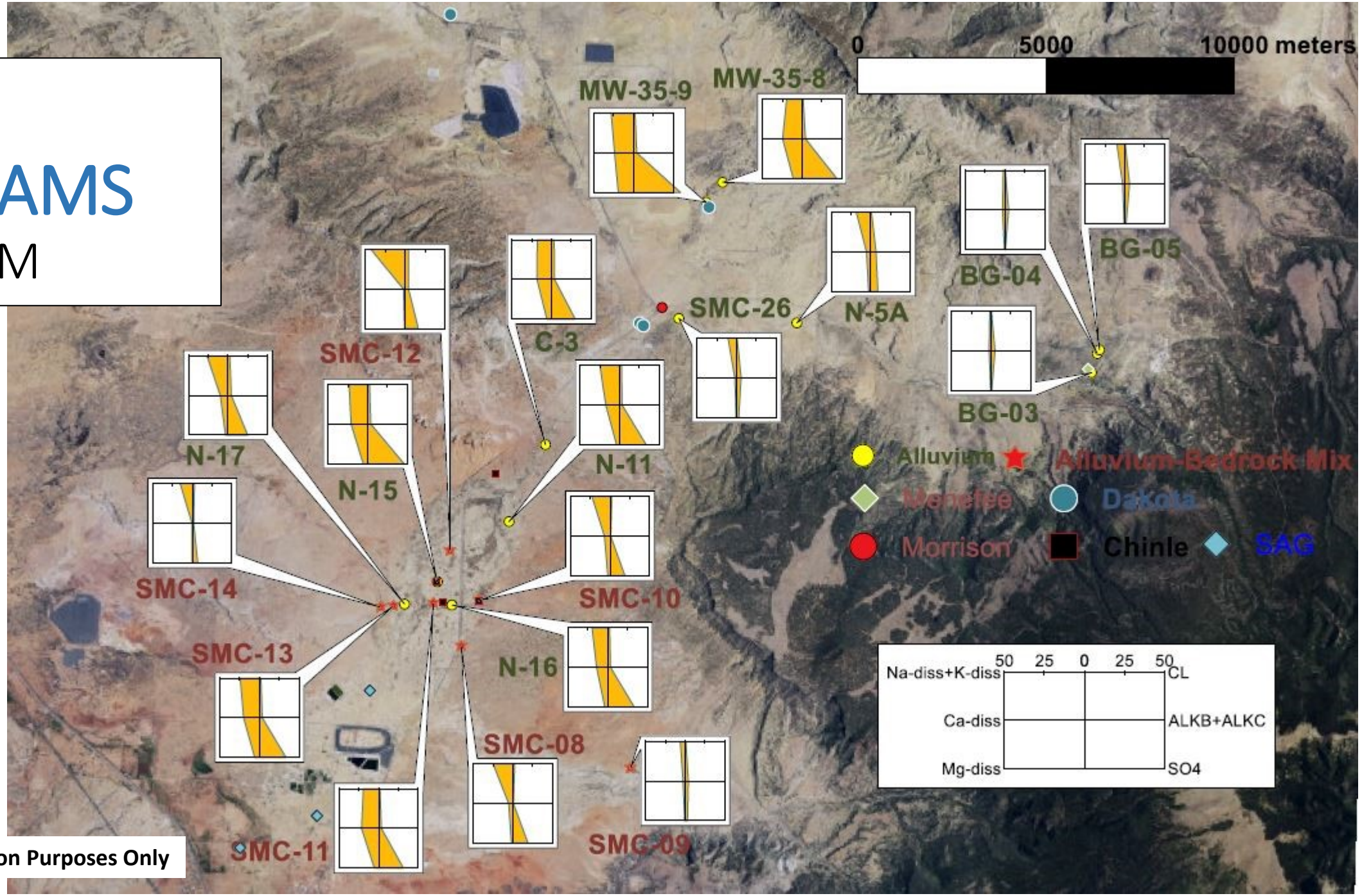
SULFATE CONCENTRATION MAP
2015

Draft – For Discussion Purposes Only



STIFF DIAGRAMS

ALLUVIUM



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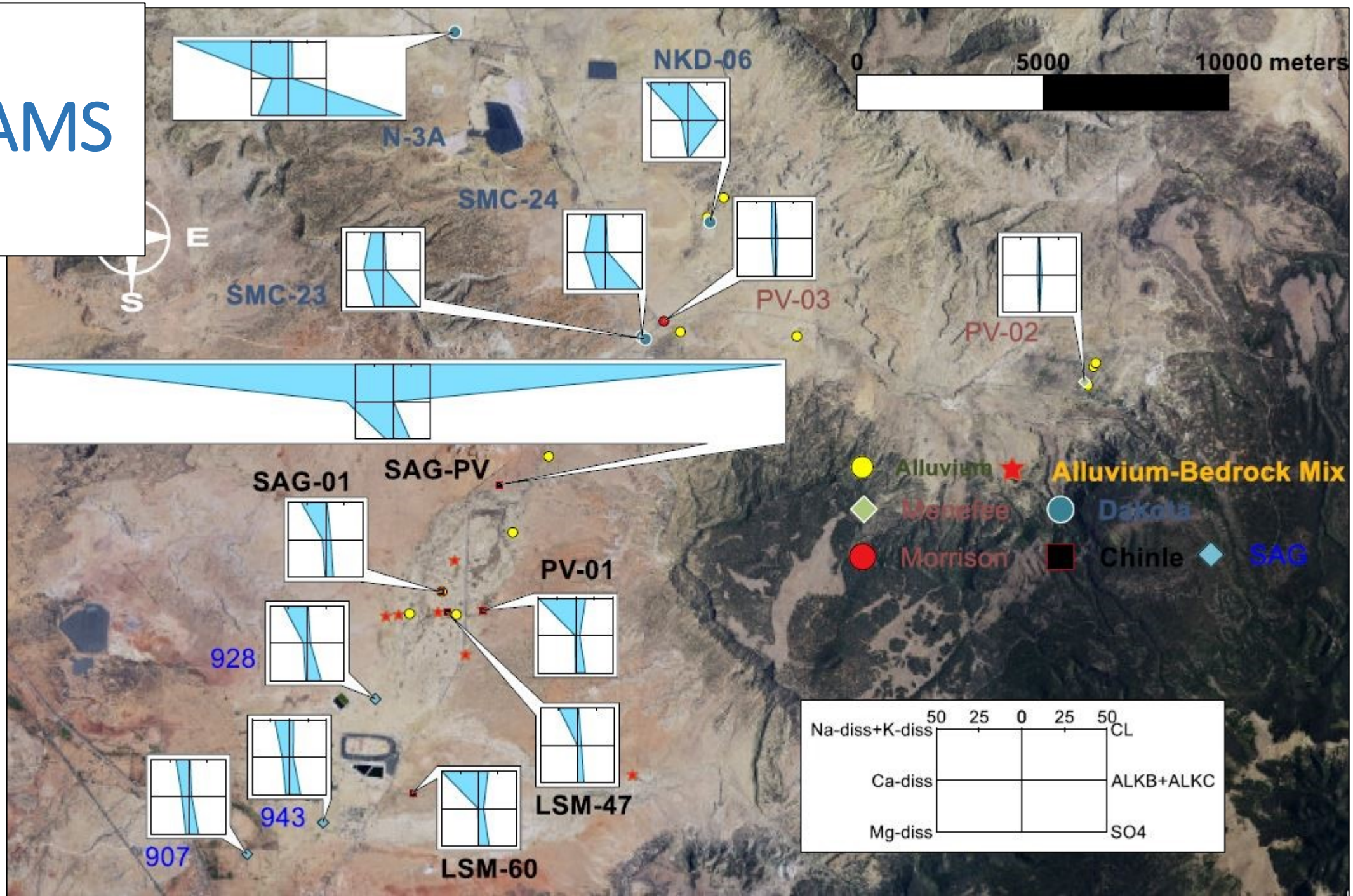
STIFF DIAGRAMS

BEDROCK



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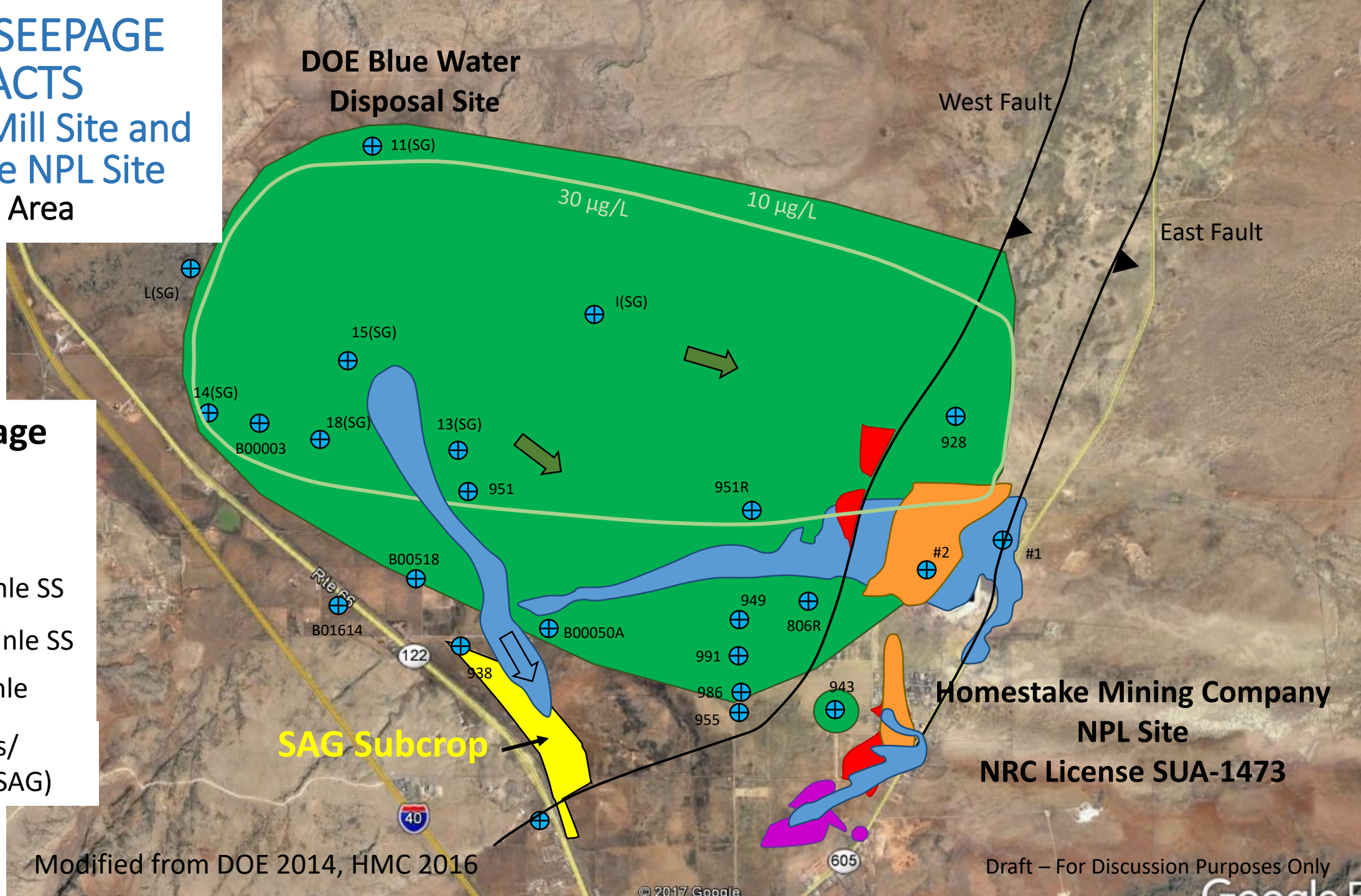
TAILING SEEPAGE IMPACTS

Bluewater Mill Site and Homestake NPL Site

Milan Area



Tailing Seepage Impact

- Alluvium
- Upper Chinle SS
- Middle Chinle SS
- Lower Chinle
- San Andres/ Glorietta (SAG)

Modified from DOE 2014, HMC 2016

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