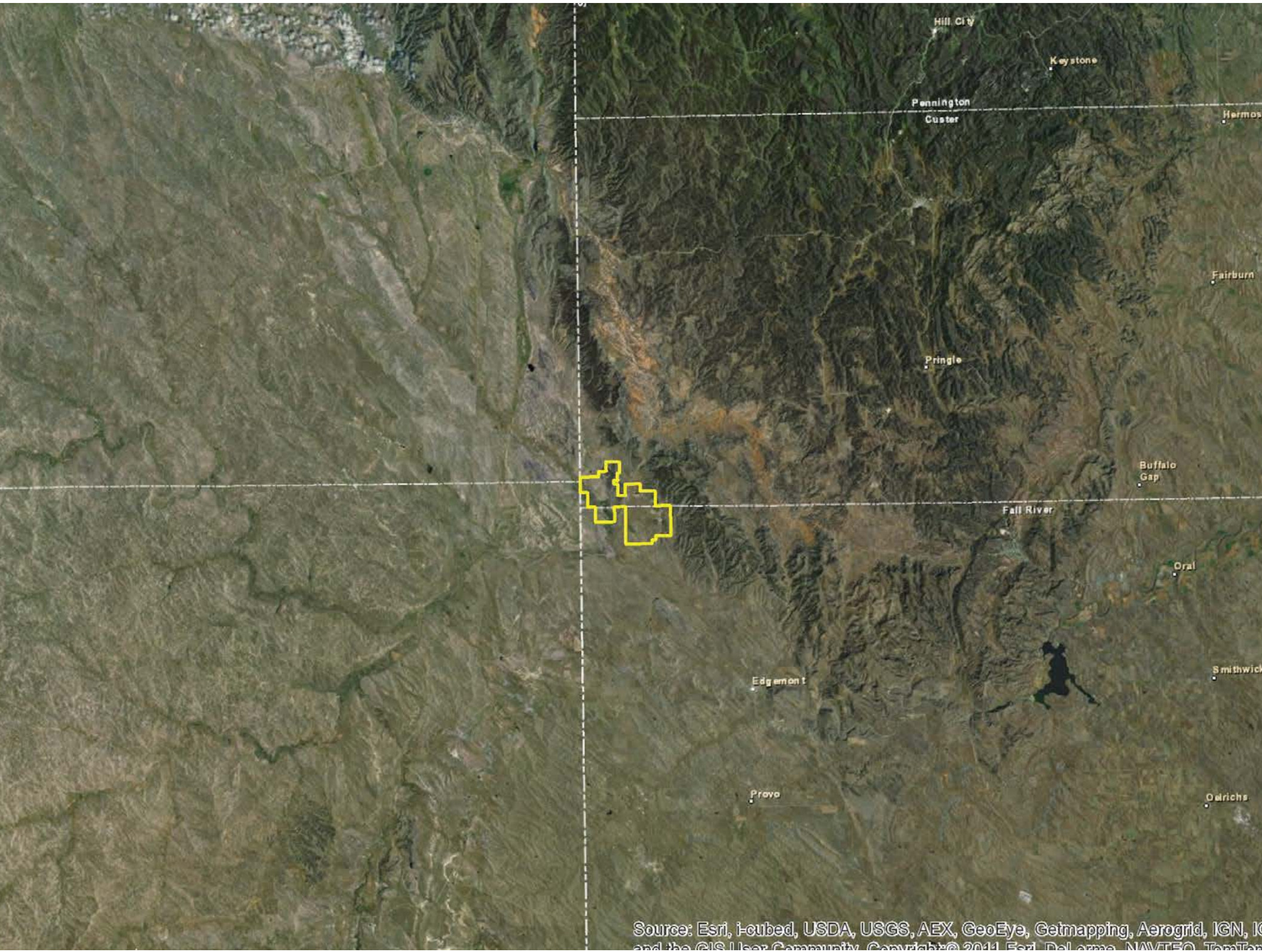
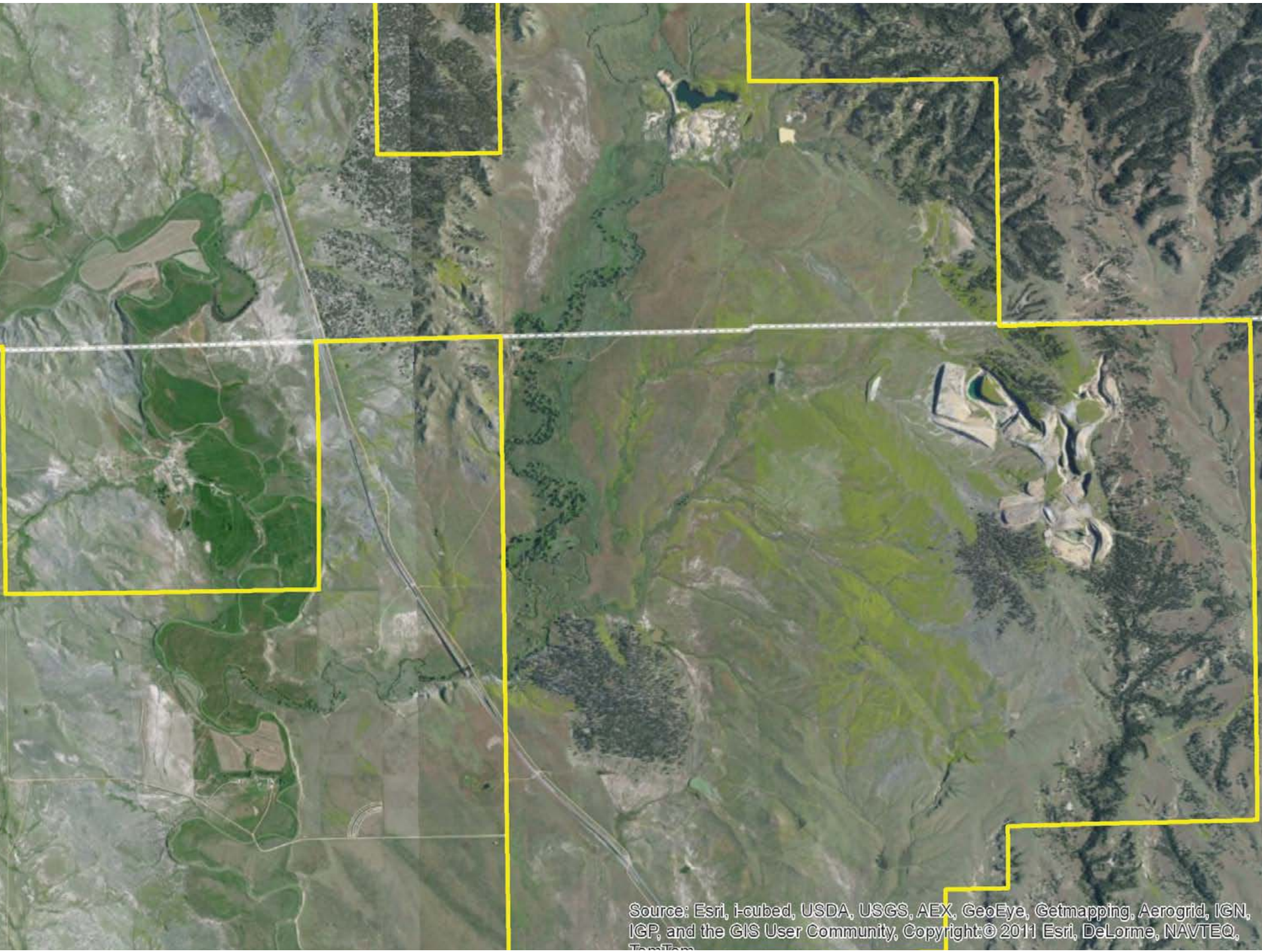
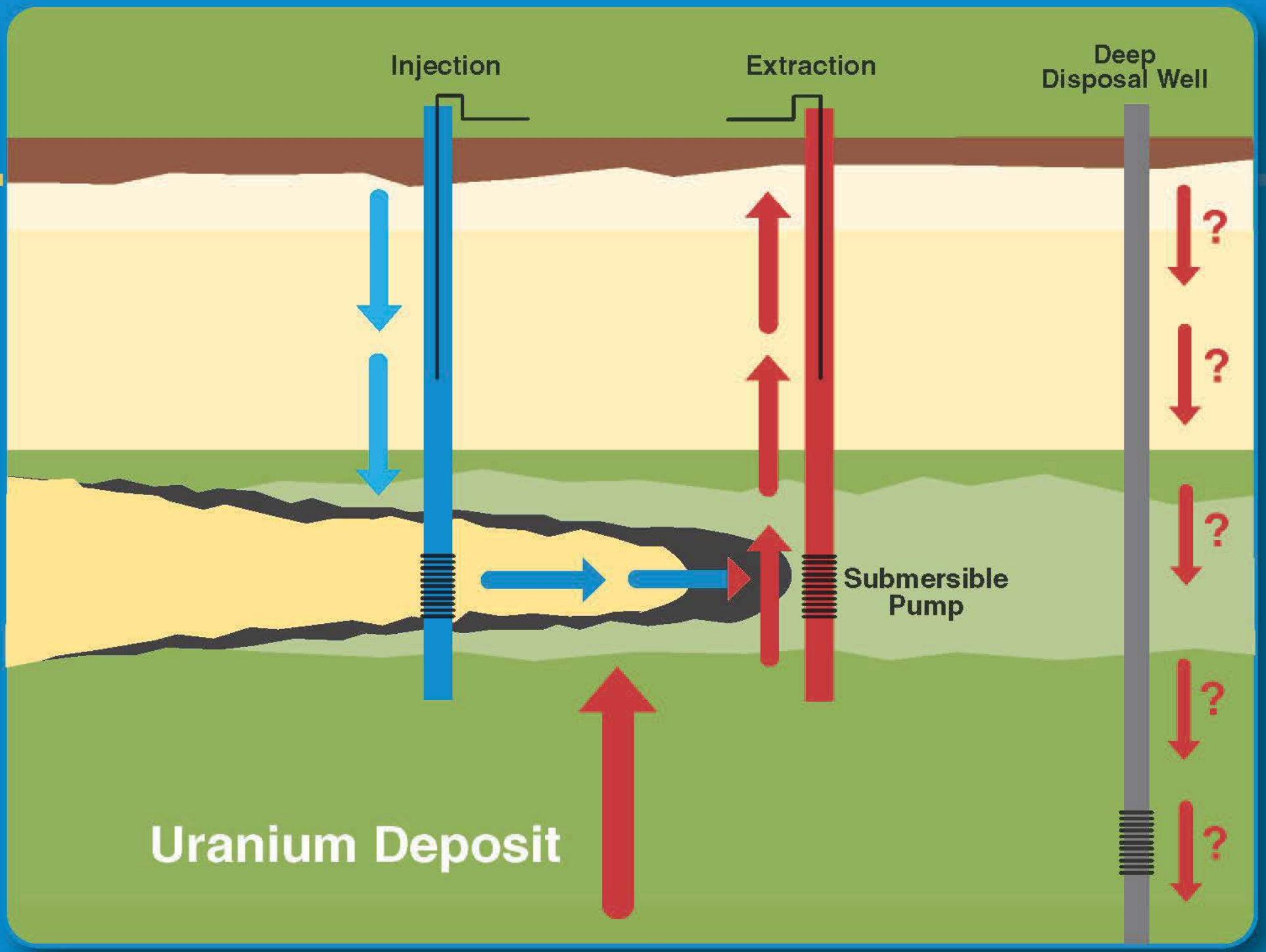
Robert E. Moran, PhD.
Hydrogeology / Geochemistry
Michael-Moran Assoc., LLC
Colorado, U.S.A.
remwater@gmail.com


Hill City
Keystone
Pennington
Custer
Hermos
Fairburn
Pringle
Buffalo
Gap
Fall River
Oral
Edgemont
Smithwick
Provo
Oelrichs
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, I


Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community, Copyright:© 2011 Esri, DeLorme, NAVTEQ,


Injection
Extraction
Deep
Disposal Well
Submersible
Pump
Uranium Deposit
?
?
?
?
?

ERATHEM	SYSTEM	ABBREVIATION FOR STRATIGRAPHIC INTERVAL	STRATIGRAPHIC UNIT	THICKNESS IN FEET	DESCRIPTION
CENOZOIC	QUATERNARY & TERTIARY (?)	QTac	UNDIFFERENTIATED ALLUVIUM AND COLLUVIUM	0 - 50	Sand, gravel, boulder and clay.
		Tw	WHITE RIVER GROUP	0 - 300	Light colored clays with sandstone channel fillings and local limestone lenses.
	TERTIARY	Tui	INTRUSIVE IGNEOUS ROCKS	--	Included rhyolite, latite, trachyte and phonolite.
MESOZOIC	CRETACEOUS	Kps	PIERRE SHALE	1,200 - 2,700	Principal horizon of limestone lenses giving teepee buttes. Dark-gray shale containing scattered concretions. Widely scattered limestone masses giving small teepee buttes. Black fissile shale with concretions.
			NIOBRARA FORMATION	80 - 300 §	Impure chalk and calcareous shale.
			CARLILE SHALE — Turner Sandy Member; Wall Creek Member	350 - 750 §	Light-gray shale with numerous large concretions and sandy layers. Dark-gray shale.
			GREENHORN FORMATION	225 - 380	Impure slabby limestone. Weathers buff. Dark-gray calcareous shale with thin Oman Lake limestone at base.
			GRANEROS GROUP — BELLE FOURCHE SHALE	150 - 850	Gray shale with scattered limestone concretions. Clay spur bentonite at base.
			GRANEROS GROUP — MOWRY SHALE	125 - 230	Light-gray siliceous shale. Fish scales and thin layers of bentonite.
			GRANEROS GROUP — MUDDY SANDSTONE / NEWCASTLE SANDSTONE	0 - 150	Brown to light-yellow and white sandstone.
			GRANEROS GROUP — SKULL CREEK SHALE	150 - 270	Dark-gray to black siliceous shale.
		Kik	INYAN KARA GROUP — FALL RIVER FORMATION	10 - 200	Massive to thin-bedded, brown to reddish-brown sandstone.
			INYAN KARA GROUP — LAKOTA FORMATION — Fuson Shale; Minnewaste Limestone; Chilson Member	10 - 190 0 - 25 25 - 485	Yellow, brown and reddish brown massive to thinly bedded sandstone, pebble conglomerate, siltstone and claystone. Local fine-grained limestone and coal.
	JURASSIC	Ju	MORRISON FORMATION	0 - 220	Green to maroon shale. Thin sandstone.
			UNKPAPA SANDSTONE	0 - 225	Massive fine-grained sandstone.
			SUNDANCE FORMATION — Redwater Member; Lak Member; Hulett Member; Stockade Beaver Member; Canyon Spr Member	250 - 450	Greenish-gray shale, thin limestone lenses. Glauconitic sandstone, red sandstone near middle.
			GYPSUM SPRING FORMATION	0 - 45	Red siltstone, gypsum and limestone.
	TRIASSIC	₸Ps	SPEARFISH FORMATION — Goose Egg Equivalent	375 - 800	Red silty shale, soft red sandstone and siltstone with gypsum and thin limestone layers. Gypsum locally near the base.
PALEOZOIC	PERMIAN	Pmk	MINNEKAHTA LINESTONE	25 - 65 §	Thin to medium-bedded, fine-grained, purplish gray laminated limestone.
		Po	OPECHE SHALE	25 - 150 §	Red shale and sandstone.
		PIPm	MINNELUSA FORMATION *	375 - 1,175 §	Yellow to red cross-bedded sandstone, limestone and anhydrite locally at top. Interbedded sandstone, limestone, dolomite, shale and anhydrite. Red shale with interbedded limestone and sandstone at base.
	PENNSYLVANIAN				
	MISSISSIPPIAN	MDme	MADISON (PAHASAPA) LIMESTONE	< 200 - 1,000 §	Massive light-colored limestone. Dolomite in part. Cavernous in upper part.
	DEVONIAN		ENGLEWOOD FORMATION	30 - 60	Pink to buff limestone. Shale locally at base.
	ORDOVIOAN	Ou	WHITEWOOD (RED RIVER) FORMATION	0 - 235 §	Buff dolomite and limestone.
			WINNIPEG FORMATION	0 - 150 §	Green shale with siltstone.
	CAMBRIAN	O€d	DEADWOOD FORMATION *	0 - 500 §	Massive to thin-bedded buff to purple sandstone. Greenish glauconitic shale flaggy dolomite and flat-pebble limestone conglomerate. Sandstone with conglomerate locally at the base.
PRECAMBRIAN		p€u	UNDIFFERENTIATED IGNEOUS AND METAMORPHIC ROCKS		Schist, slate, quartzite and arkosic grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.

Source: Driscoll et al. (2002)

§ Modified based on drill-hole data

KEY

* **Proposed Injection Zone**

Aquifer

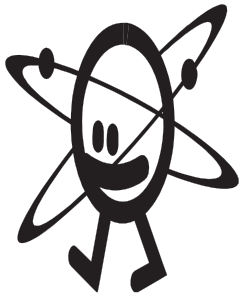
Figure 3-2

Stratigraphic Column of the Black Hills Area

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	30-May-2012
F LENAME	StratColBlackHills.dwg

POWERTECH (USA) INC.



Gaseous $CO_2 + O_2 = H_2CO_3$

H_2CO_3 = CARBONIC ACID

Table 5. Crow Butte (Nebraska) Mine Unit No. 1 Restoration Results (Crow Butte Resources, 2000b). All units in mg/L except for pH (standard units), radium (pCi/L), and specific conductivity (micromho/cm).

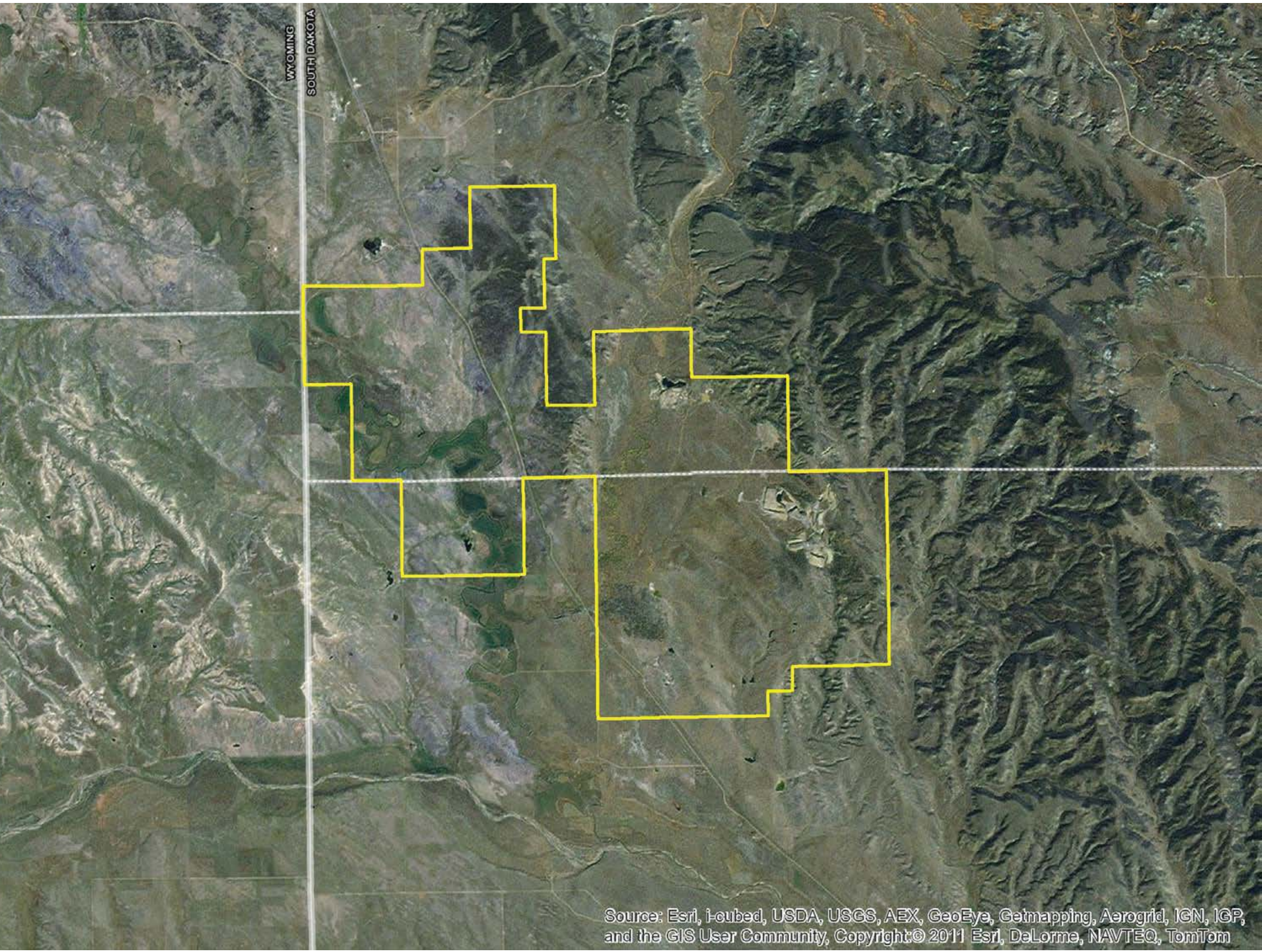
Parameter	Baseline Water Quality	Post-Mining Average Water Quality	Post- Restoration Average Water Quality	Stabilization Period Average Water Quality
Alkalinity	293	875	321	347
Ammonium	0.37	0.277	0.08	0.12
Arsenic	0.002	0.021	0.024	0.017
Barium	0.1	<0.10	<0.10	<0.10
Bicarbonate	344	1068	392	421
Boron	0.93	1.22	0.4	0.46
Cadmium	0.006	<0.01	<0.005	<0.005
Calcium	12.5	88.7	16.0	19.9
Carbonate	7.2	0	<1.0	1.9
Chloride	204	583	124	139
Chromium	<0.03	<0.05	<0.05	<0.05
Copper	0.017	0.035	<0.01	<0.01
Fluoride	0.69	0.41	0.55	0.54
Iron	0.044	0.078	<0.05	0.09
Lead	0.031	<0.05	<0.05	<0.01
Magnesium	3.2	23	4.4	5.3
Manganese	0.11	0.075	0.01	0.02
Mercury	0.001	<0.001	<0.001	<0.001
Molybdenum	0.069	0.487	<0.10	0.10
Nickel	0.034	0.068	<0.05	<0.01
Nitrate	0.05	1.01	<0.10	<0.11
Nitrite	0.01	N/A	<0.10	<0.1
pH	8.5	7.35	7.95	8.18
Potassium	12.5	30.0	13.0	13.2
Radium-226	229.7	786	246.7	303
Selenium	0.003	0.124	0.001	<0.002
Silica	16.7	N/A	13.6	14.4
Sodium	412.2	1117	315	352
Specific Cond.	1947	5752	1620	1787
Sulfate	356.2	1128	287	331
TDS	1170.2	3728	967	1094
Uranium	0.092	12.2	0.963	1.73
Vanadium	0.066	0.96	0.26	0.11
Zinc	0.036	0.038	<0.01	<0.02

N/A means not available

Land Application???

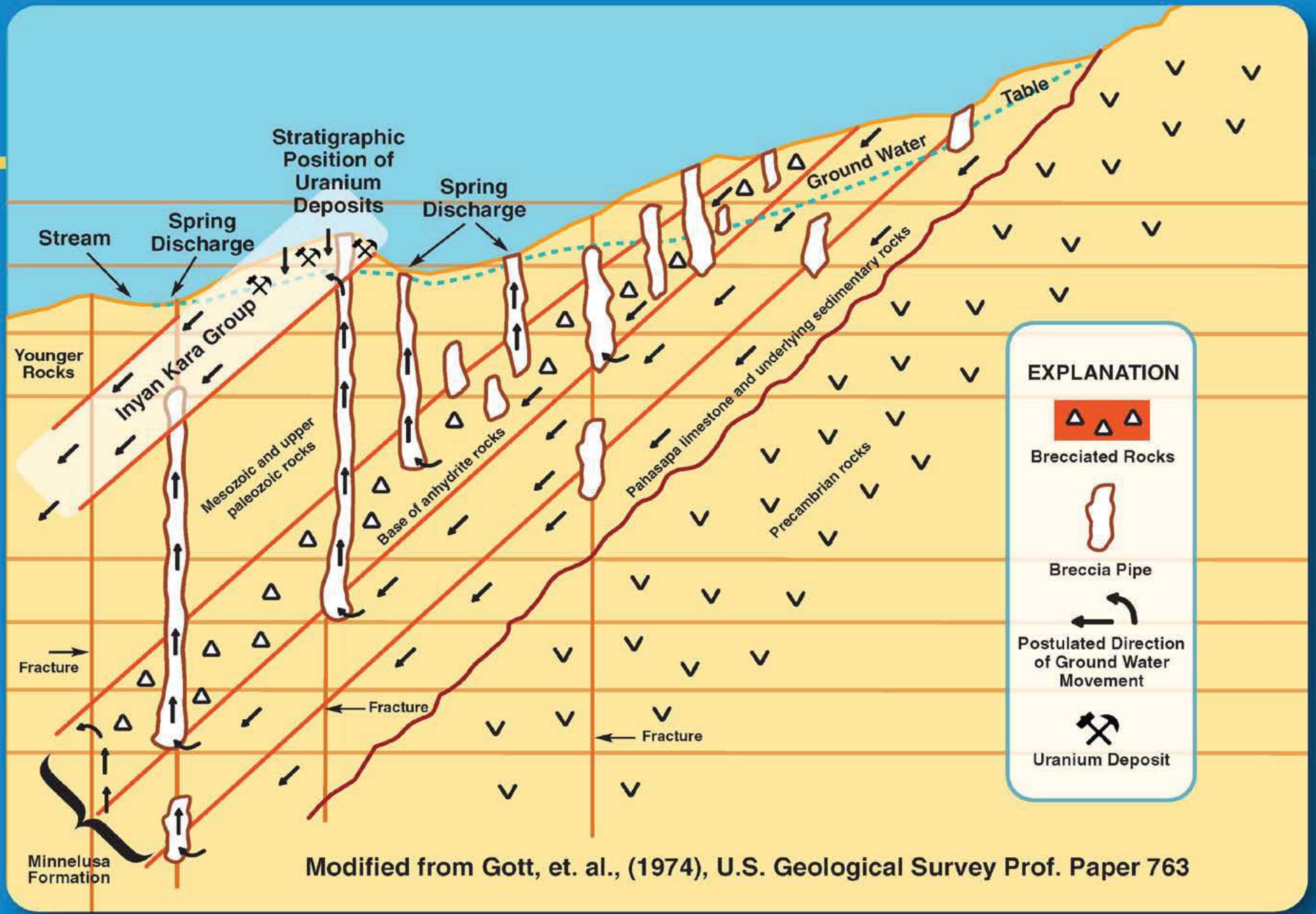
Settling ponds???

NOBODY KNOWS. . .

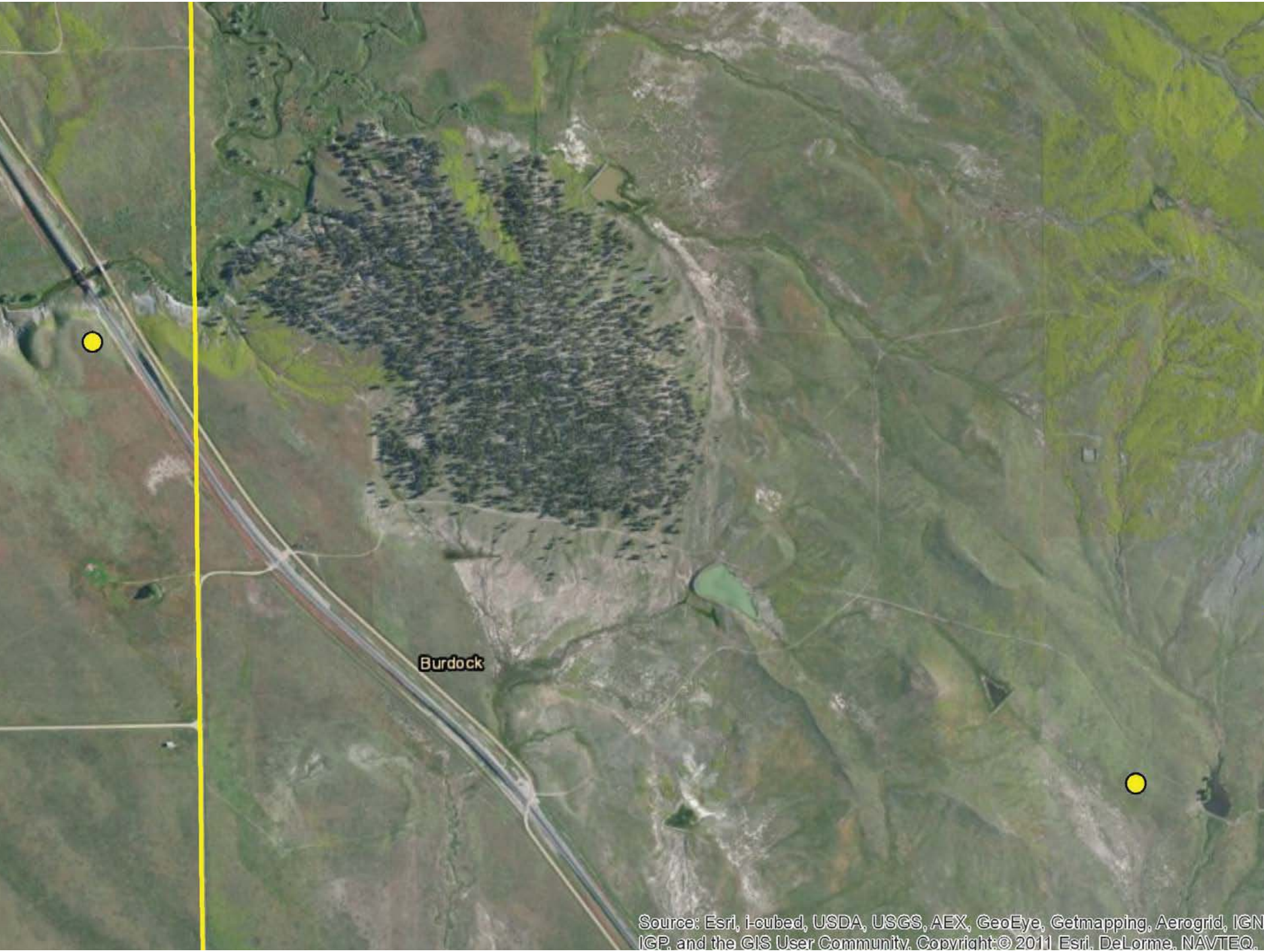

WYOMING
SOUTH DAKOTA
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community, Copyright:© 2011 Esri, DeLorme, NAVTEQ, TomTom

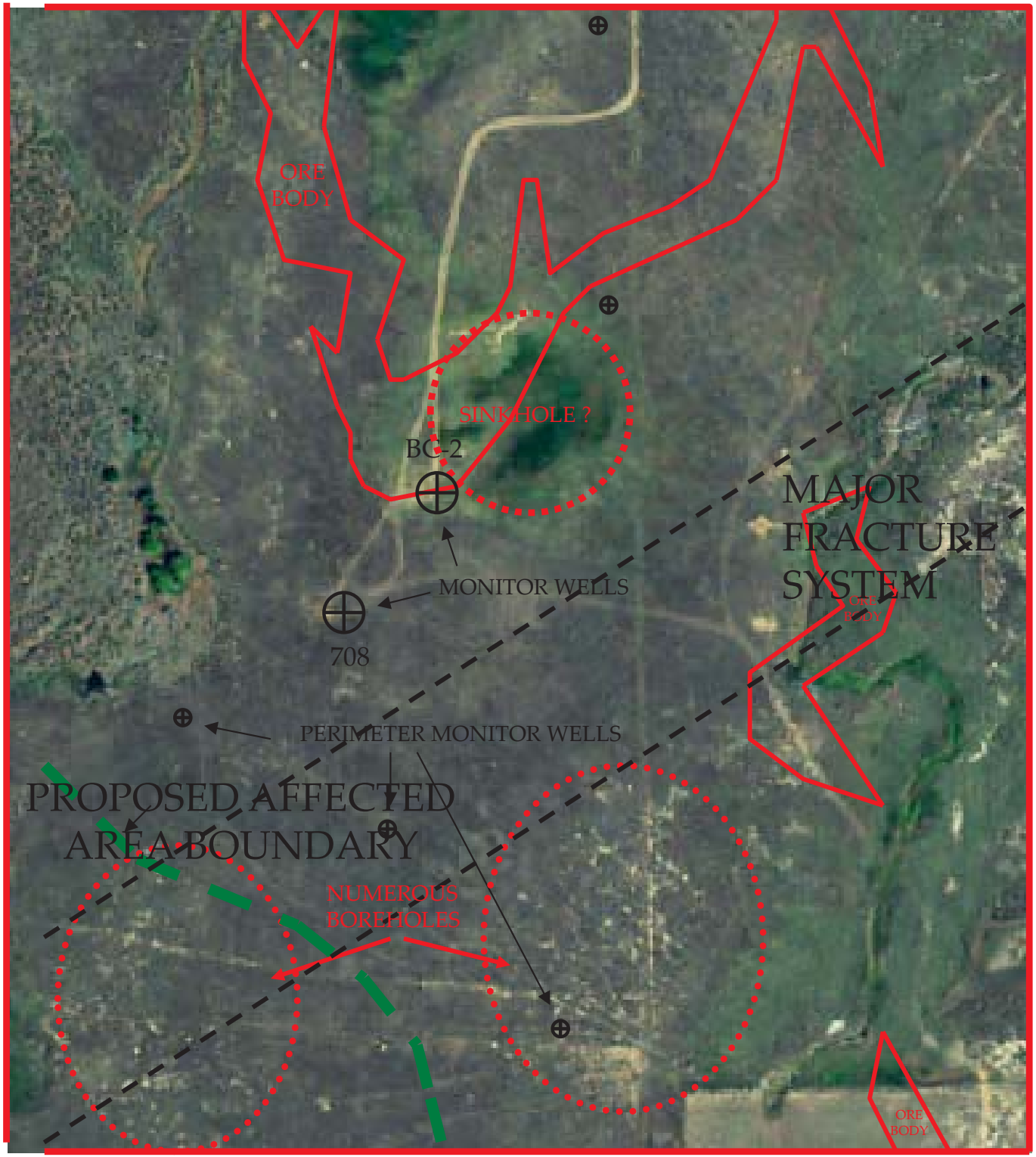
All DB water-bearing zones Hydrogeologically-**interconnected**

- **inter-fingering sediments**
- **fractures**
- **faults**
- **breccia pipes**
- **4,000 to 6,000 boreholes**

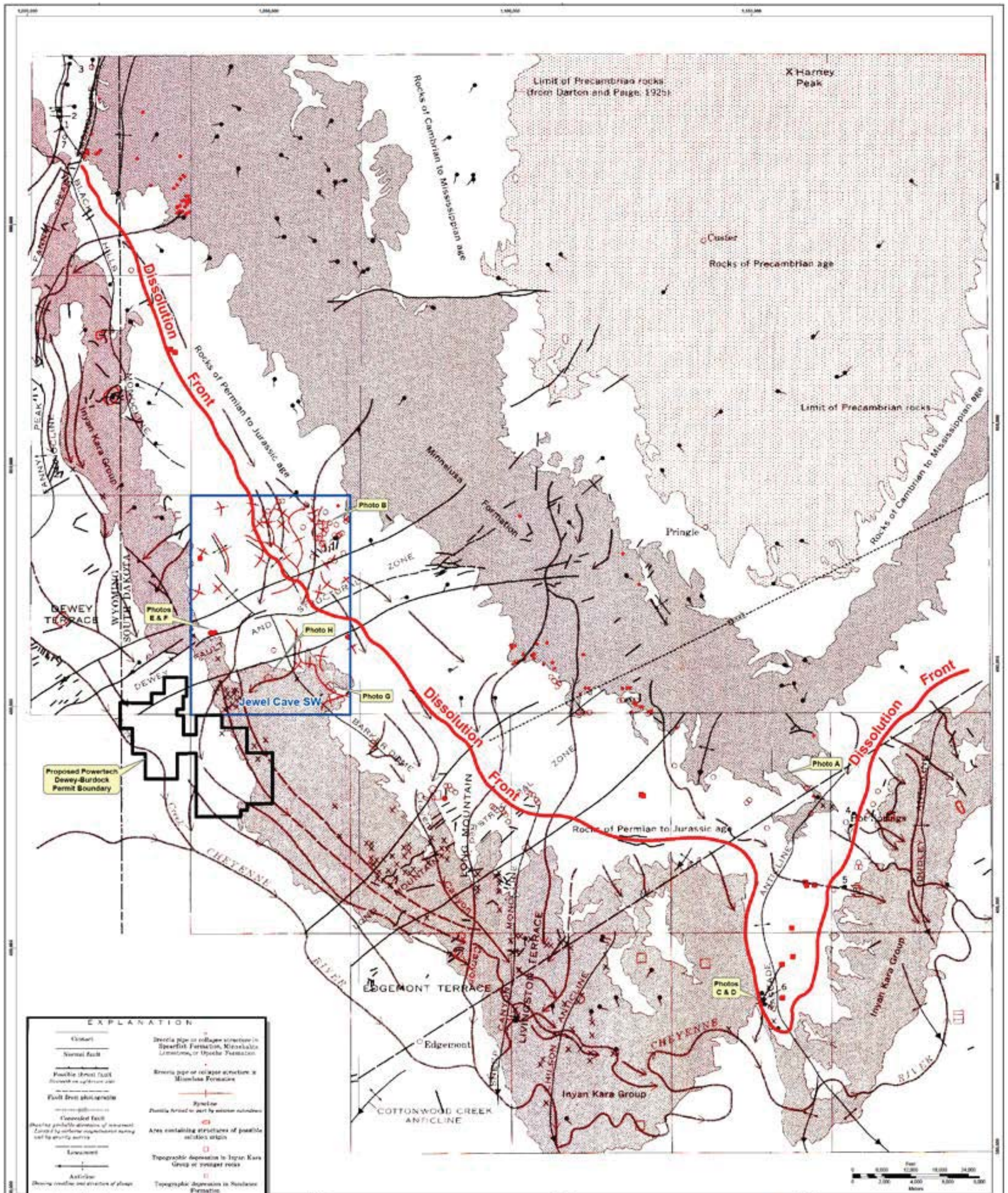


Modified from Gott, et. al., (1974), U.S. Geological Survey Prof. Paper 763


Burdock
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN
IGP, and the GIS User Community. Copyright:© 2011 Esri, DeLorme, NAVTEQ,


ORE BODY
SINKHOLE ?
BC-2
MONITOR WELLS
MAJOR FRACTURE SYSTEM
ORE BODY
708
PERIMETER MONITOR WELLS
PROPOSED AFFECTED AREA BOUNDARY
NUMEROUS BOREHOLES
ORE BODY

ZOOM 2 AREA



Base map and legend shows scanned images taken from:

Stratigraphy of the Inyan Kara Group and Localization of Uranium Deposits, Southern Black Hills, South Dakota and Wyoming, Geological Survey Professional Paper 763, prepared by Garland B. Gott, Don E. Wolcott and C. Gilbert Bowles, US Government Printing Office, 1974, Plate 4, Map Showing Major Tectonic Elements, Minor Fault and Solution Collapse Structures, Springs, Paleostreams, and Uranium Deposits in the Southern Black Hills, South Dakota and Wyoming.

Powertech (USA) Inc.

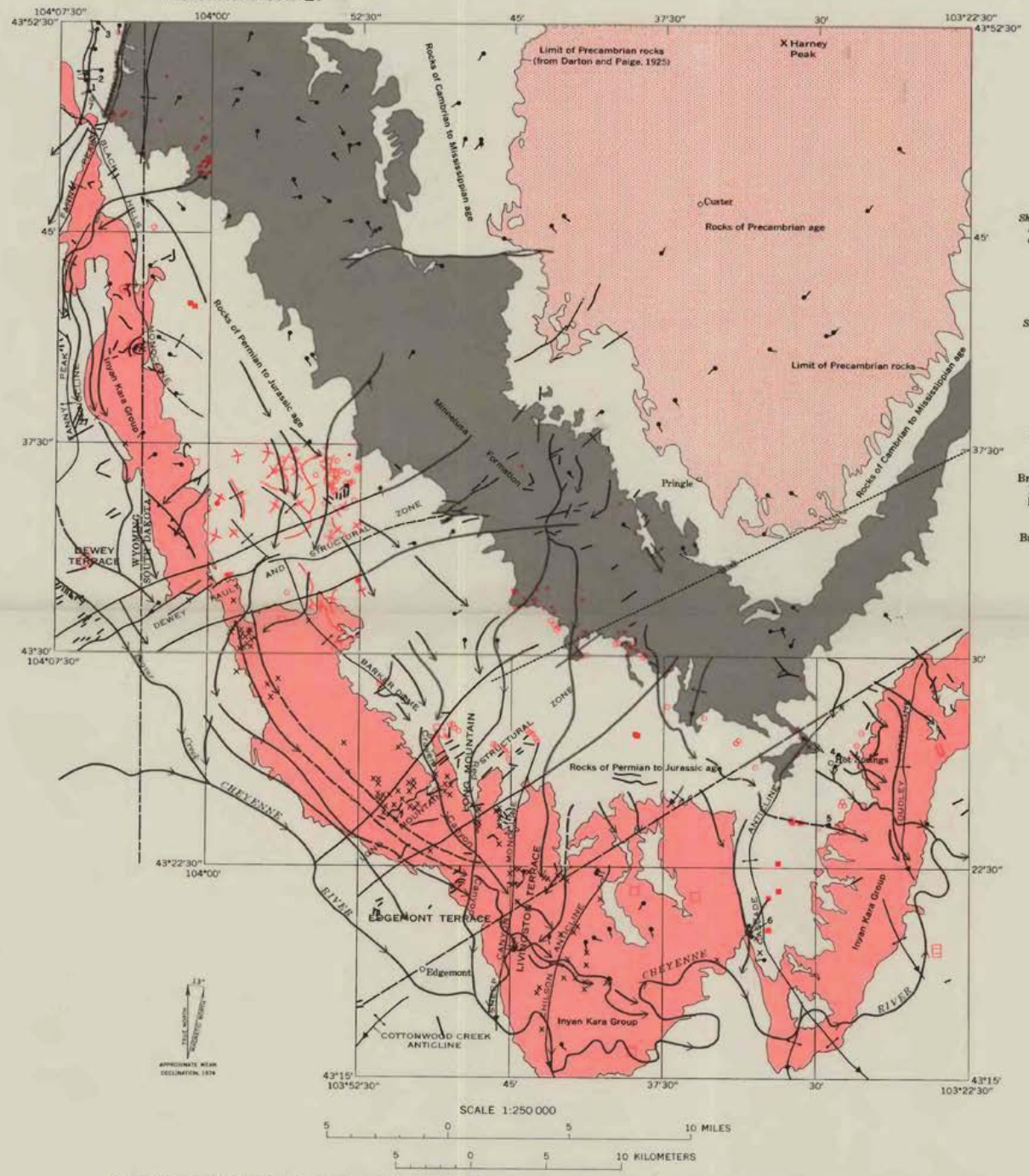
App. 3.2-C Plate 2

Location of Breccia Pipes Proposed by USGS Professional Paper 763

Dewey-Burdock Project

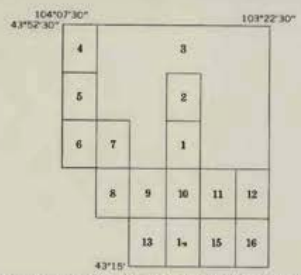
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROFESSIONAL PAPER 763
PLATE 4



EXPLANATION

- Contact
- Normal fault
- Possible thrust fault — *Sawteeth on upthrown side*
- Fault from photographs
- Concealed fault — *Showing probable direction of movement. Located by airborne magnetometer survey and by gravity survey*
- Lineament
- Anticline — *Showing crestline and direction of plunge*
- Syncline — *Showing troughline*
- Monocline — *Showing trace and direction of plunge. Dashed where indefinite*
- Breccia pipe or collapse structure in Inyan Kara Group or Morrison Formation
- Breccia pipe or collapse structure in Sundance Formation
- Breccia pipe or collapse structure in Spearfish Formation, Minnekahta Limestone, or Opeche Formation
- Breccia pipe or collapse structure in Minnelusa Formation
- Syncline — *Possibly formed in part by solution subsidence*
- Area containing structures of possible solution origin
- Topographic depression in Inyan Kara Group or younger rocks
- Topographic depression in Sundance Formation
- Topographic depression in Spearfish Formation or Minnekahta Limestone
- Paleostream of Tertiary and (or) Quaternary age — *Dashed where inferred*
- Uranium deposit — *Some undeveloped prospects in pre-Inyan Kara rocks also shown*
- Spring — *Showing locality number in table 9*
- Water well — *Showing locality number in table 11*



INDEX TO SOURCES OF GEOLOGIC DATA

References are listed in text. Springs located from U.S. Geological Survey topographic maps. Solution collapse structures not mapped in some areas. Uranium deposits shown on geologic maps referenced below.

1. Bowles and Braddock (1963)
2. Redden (1963, pl. 21)
3. Darton and Paige (1925)
4. Brobst and Epstein (1963, pl. 25)
5. Cuppels (1963, pl. 23)
6. Brobst (1961, pl. 5)
7. Braddock (1963, pl. 20)
8. Schnabel (1963, pl. 17)
9. Gott and Schnabel (1963, pl. 12)
10. V. R. Wilmarth, U.S. Geol. Survey unpub. data
11. Wolcott, Bowles, Brobst, and Post (1962)
12. Wolcott (1967, pl. 28)
13. Ryan (1964, pl. 27)
14. Bell and Post (1971, pl. 32)
15. Post (1967, pl. 29)
16. Connor (1963, pl. 11)

MAP SHOWING MAJOR TECTONIC ELEMENTS, MINOR FAULT AND SOLUTION COLLAPSE STRUCTURES, SPRINGS, PALEOSTREAMS, AND URANIUM DEPOSITS IN THE SOUTHERN BLACK HILLS, SOUTH DAKOTA AND WYOMING

537-784 O - 74 (In pocket)

Water Use Comparisons

- Rapid City:
  - **Average Use approx. 7 M gpd (2012)**
- Rapid Valley:
  - **Avg. Use approx. 12.1 M gpd (2012)**
- D-B usage @ 8500 gpm

= 12,240,000 gpd

Madison Application:

289.6 Million gallons per year

Inyan Kara Application:

Gross withdrawal rate of up to 8,500 gpm

@ 8500 gpm = 12,240,000 gpd

= 4.5 Billion gallons per year

= 89.4 Billion gallons over 20 years

Water quality will be degraded

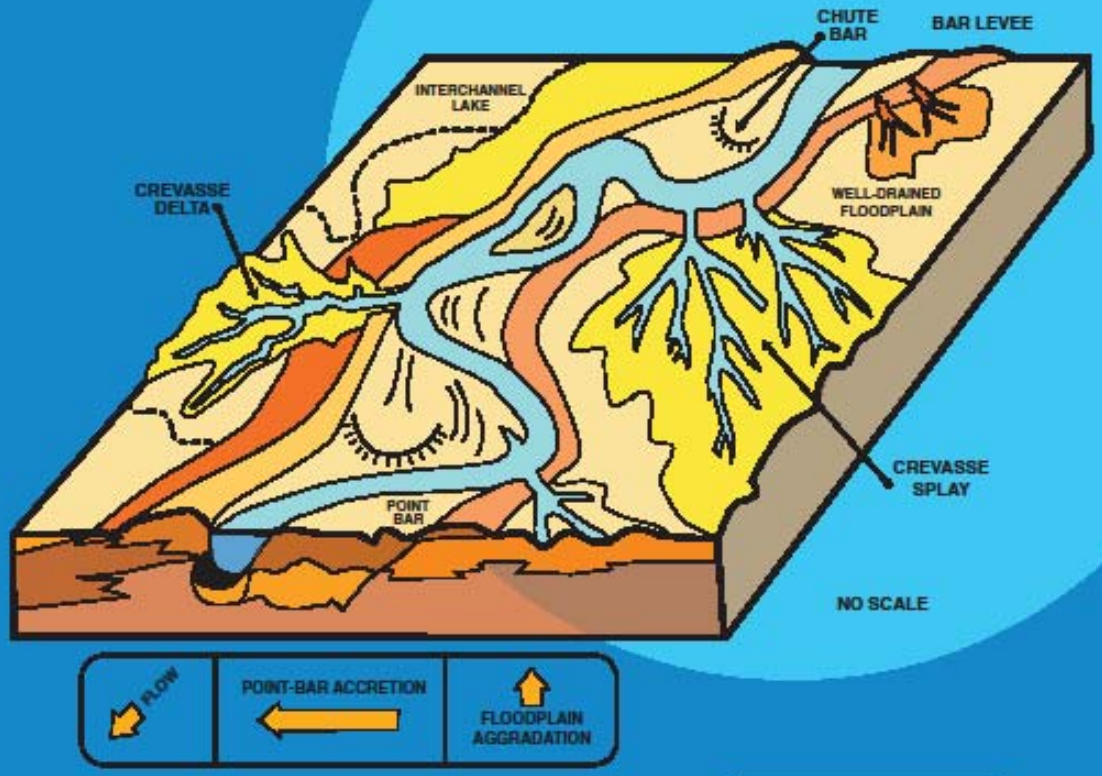
including Madison Water
and waste receiving aquifers

1. Hydrogeological Characterization

Inyan Kara Group

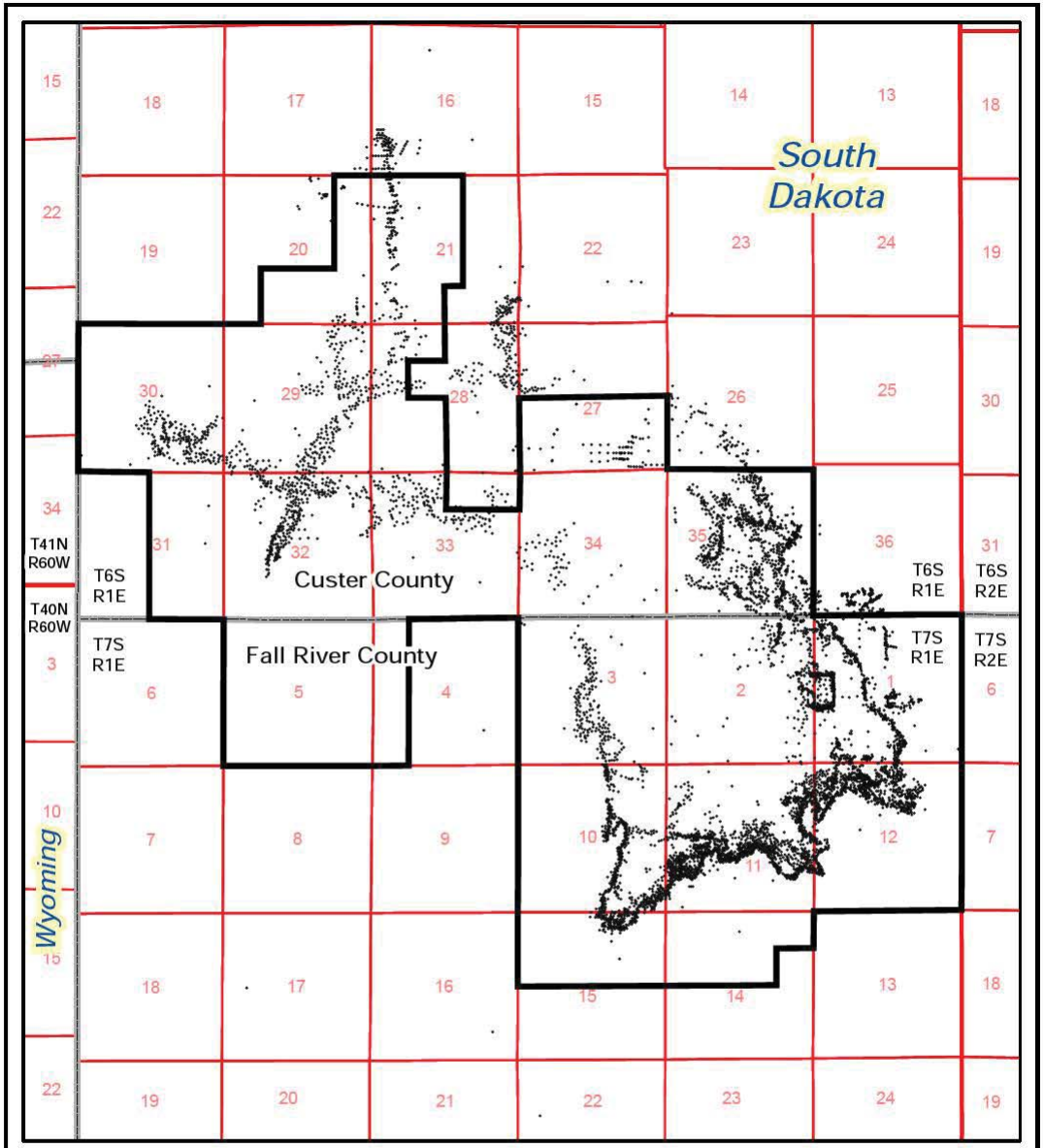
- Fall River, Fuson, Lakota members
- Interbedded sandstone, siltstone, and mudstone
- Alluvial, deltaic marginal marine
- Dips 5-10 degrees, SW
- Depth 0 to >500 ft.
- Overlain by Cretaceous Shales (0-500+ ft.)
- Underlain by Morrison Fm Shale (50-100 ft.)

Modified from RESPEC/Hocking Presentation, March 18-19, 2009, Pierre, SD



DEWEY-BURDOCK

RESPEC CONSULTING & SERVICES



This figure is provided to fulfill the requirements of ARSD 74:29:02:11(1).

Legend

- Permit Boundary
- Drill Hole Locations

Feet
0 2,500 5,000
0 1,000 2,000
Meters

N

Figure 3.2-7

Dewey-Burdock Drill Hole Map

Dewey-Burdock Project

SIGNATURE OF PREPARER	
PREPARER	F. L. Lichnovsky
DATE	24-Sep-2012
FILE	ExploreDrillHoles.mxd

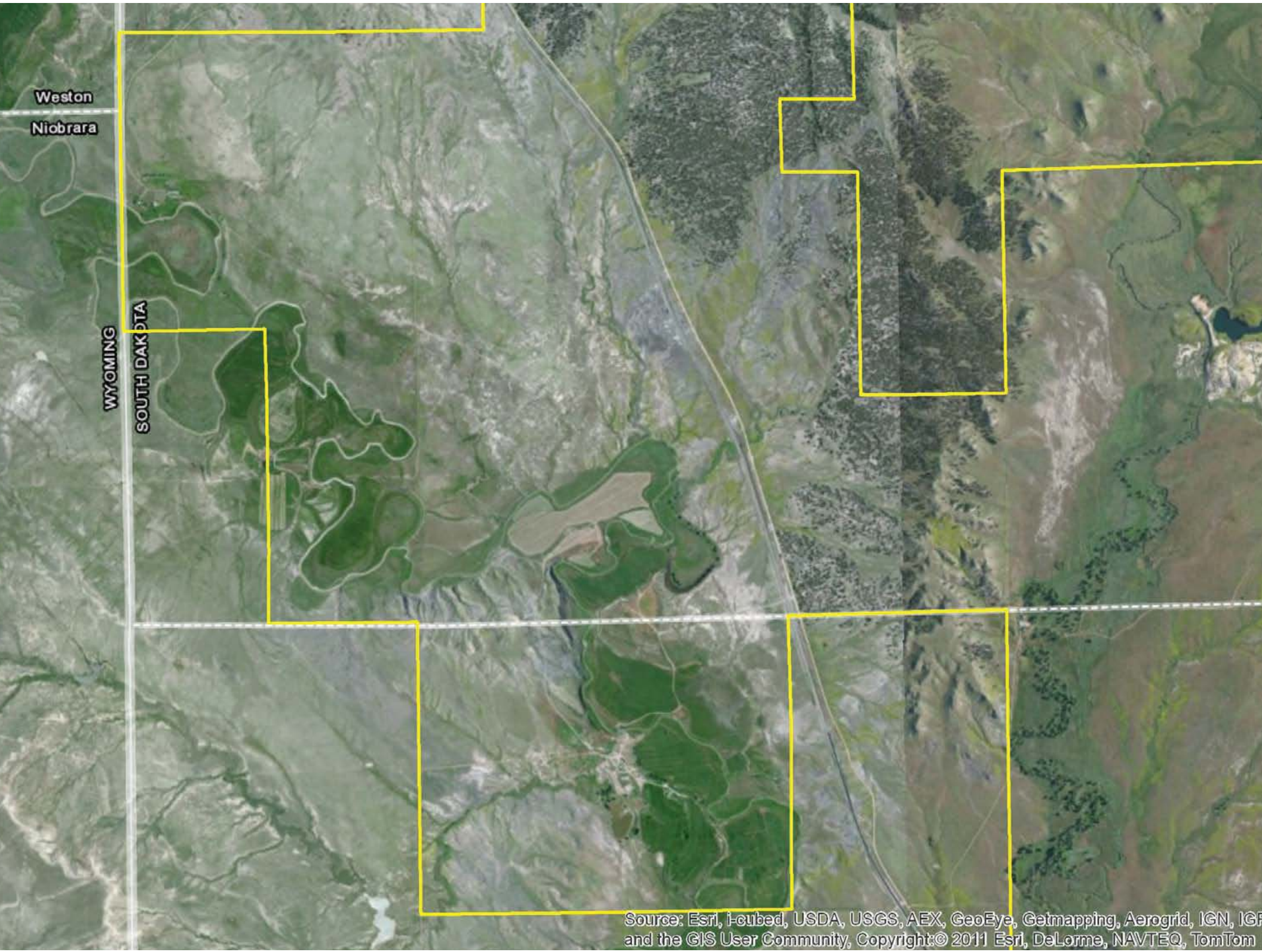
POWERTECH (USA) INC.

LAND APPLICATION OPTION

Total D-B Land Application Volumes:

325,900,000 gallons per yr.

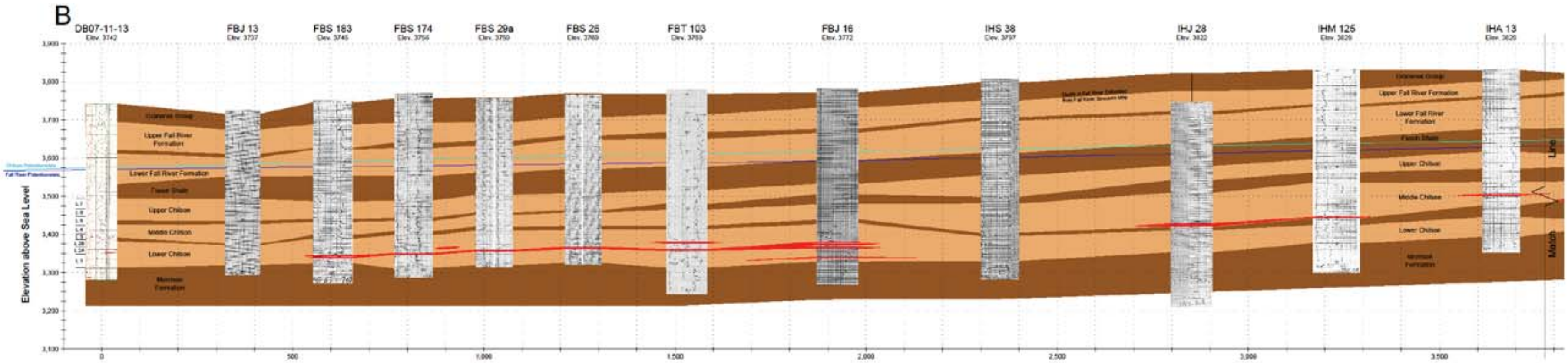
= 325.9 Million gallons per year. [GDP, p.128, 130]

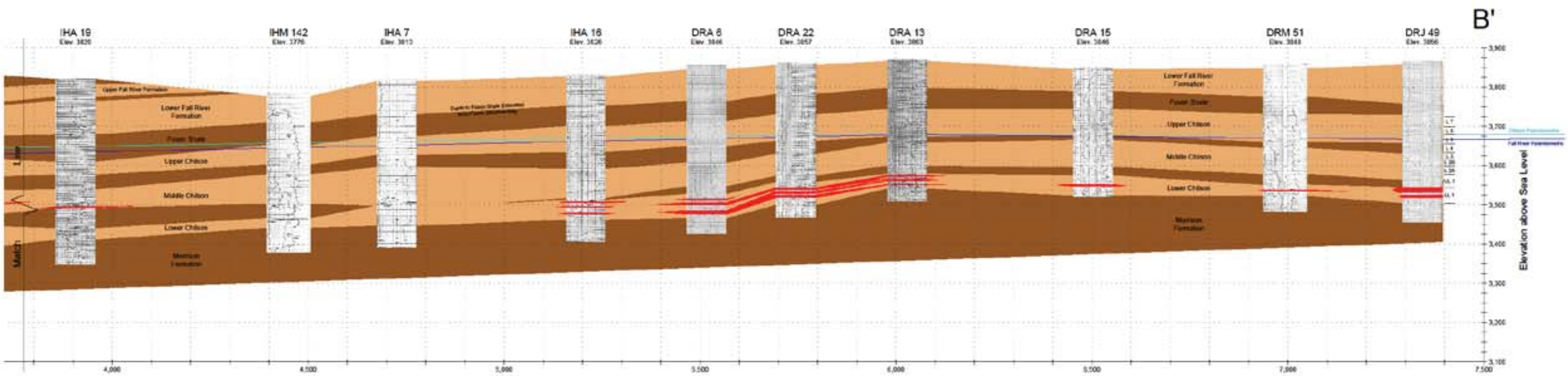

Weston
Niobrara
WYOMING
SOUTH DAKOTA
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP
and the GIS User Community, Copyright:© 2011 Esri, DeLorme, NAVTEQ, TomTom

Parameter	Units	U.S.A. (EPA)			Canada					South Dakota			
		Drinking Water Standard[5]	Fresh Water Aquatic Life Acute Guideline[1]	Fresh Water Aquatic Life Chronic Guideline[1]	Drinking Water Guideline[3]	Irrigation Guideline[2]	Livestock Guideline[2]	Fresh Water Aquatic Life Acute Guideline[4, 6]	Fresh Water Aquatic Life Chronic Guideline[4, 6]	Drinking Water Standard	Agricultural	Fresh Water Aquatic Life Acute Guideline	Fresh Water Aquatic Life Chronic Guideline
pH	Units	6.5-8.5[7]		6.5-9	6.5-8.5				6.5-9.0	6.5-8.5[2]			
Alpha, Gross		15 pCi/L			0.5 Bq/L								
Beta, Gross		4 mrem/yr			1.0 Bq/L								
Aluminum	µg/l	50-200[7]	750	87	<100-200	5000	5000		5.0-100				
Ammonia (N)	mg/l		2.9 to 5.0	0.26-1.8					0.017-190[10]				
Antimony	µg/l	6.0			6.0					5.6[1]			
Arsenic	µg/l	10	340	150	10	100	25		5.0	10[3, 2]			
Boron	mg/l				5.0	0.5-6.0	5.0	29	1.5				
Cadmium	µg/l	5.0	2.0	0.25	5.0	5.1	80		0.018[11]	5.0[1]		2.0	0.25
Chloride	mg/l	250[7]	860	230	≤250[9]	100-900		640	120	250[2]		860	230
Chromium (tot)	µg/l	100	16-570	11-74	50	4.9-8.0	50		1.0-8.9	100[3]		16-570	11-74
Chromium (hex)	µg/l		16	11		8.0	50		1.0			16	11
Chlorine	mg/l	4.0[13]	0.019	0.011	See[16]			0.0005[17]		4.0[1]		19	11
Copper	mg/l	1.0[7]-1.3[8]	0.013[12]	0.009[12]	≤1.0[9]	0.2-1.0	0.5-5.0		0.002[11]				
Cyanide (total)	µg/l		22	5.2	200					140[1]		22	5.2
Cyanide (free)	µg/l	200							5.0	200[2, 3]			

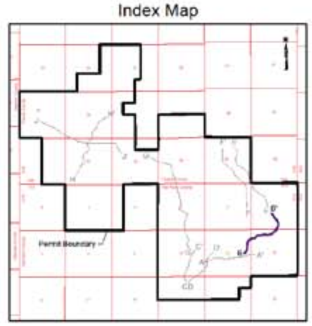
Parameter	Units	U.S.A. (EPA)			Canada					South Dakota			
		Drinking Water Standard[5]	Fresh Water Aquatic Life Acute Guideline[1]	Fresh Water Aquatic Life Chronic Guideline[1]	Drinking Water Guideline[3]	Irrigation Guideline[2]	Livestock Guideline[2]	Fresh Water Aquatic Life Acute Guideline[4, 6]	Fresh Water Aquatic Life Chronic Guideline[4, 6]	Drinking Water Standard	Agricultural	Fresh Water Aquatic Life Acute Guideline	Fresh Water Aquatic Life Chronic Guideline
Fecal Coliform	MPN/ 100 ml	See[14]				100				<2.2[2]			
Tot. Coliform	MPN/ 100 ml	See[15]			0	1000				0 (MCLG)[3]			
Fluoride	mg/l	2.0[7]-4.0			1.5	1.0	1.0-2.0		0.12	4.0[2, 3]			
Iron	mg/l	0.3[7]		1.0	≤0.3[9]	5.0			0.3				
Lead	µg/l	15[8]	65	2.5	10	200	100		1.0[11]	15[1]		65	2.5
Manganese	mg/l	0.05[7]			≤0.05[9]	0.2							
Mercury	µg/l	2.0	1.4	0.77	1.0		3.0		0.026	0.050[1]		1.4	0.77
Molybdenum	mg/l					0.01-0.05	0.50		0.073				
Nickel	mg/l		0.47	0.052		0.2	1.0		0.025[11]	610 µg/l[1]		470 µg/l	52 µg/l
Nitrate	mg/l	10			45; 10 as N		100	550	13	10			
Nitrite	mg/l	1.0			3.2; 1.0 as N[9]		10		0.060	1.0			
Phenols	mg/l						0.002		0.004	21,000 µg/l			
Radium	pCi/L	5.0			0.5					5.0[2]			
Selenium	mg/l	0.05		0.005	0.01	0.02-0.05	0.05		0.001	0.05 µg/l[2]		170 µg/l[1]	4.6 µg/l[1]
Silver	mg/l	0.10[7]	0.0032						0.0001	0.10[2]		3.2 µg/l[1]	
Sodium	mg/l				≤200[9]								

Parameter	Units	U.S.A. (EPA)			Canada					South Dakota			
		Drinking Water Standard[5]	Fresh Water Aquatic Life Acute Guideline[1]	Fresh Water Aquatic Life Chronic Guideline[1]	Drinking Water Guideline[3]	Irrigation Guideline[2]	Livestock Guideline[2]	Fresh Water Aquatic Life Acute Guideline[4, 6]	Fresh Water Aquatic Life Chronic Guideline[4, 6]	Drinking Water Standard	Agricultural	Fresh Water Aquatic Life Acute Guideline	Fresh Water Aquatic Life Chronic Guideline
Sulfate	mg/l	250[7]			≤500[9]		1000			500[2]			
Sulfide	mg/l			0.002	≤0.05[9]								
TDS	mg/l	500[7]	250	250	≤500[9]	500-3500	3000			1,000[2]			
Thallium	mg/l	0.002							0.0008	.24 µg/l[1]			
Turbidity	UNT	0.3-5.0 NTU			≤0.1-1.0 NTU[9]			8-80 NTU					
Uranium	µg/l	30			20	10	200	33	15	30[2]			
Vanadium						0.1	0.1						
Zinc	mg/l	5[7]	0.12	0.12	≤5.0[9]	1.0-5.0	50		0.03	7400 µg/l[1]			





Index Map



Legend

- Ore
- Confining Clays and Shale
- Sand

Horizontal Scale = Vertical Scale

Feet: 0 50 100 200 300 400

Meters: 0 25 50 100

REVISIONS				
#	DRAWN	CHECKED	APPROVED	DATE

Powertech (USA) Inc.

Plate 3.2-14

Cross Section B - B'

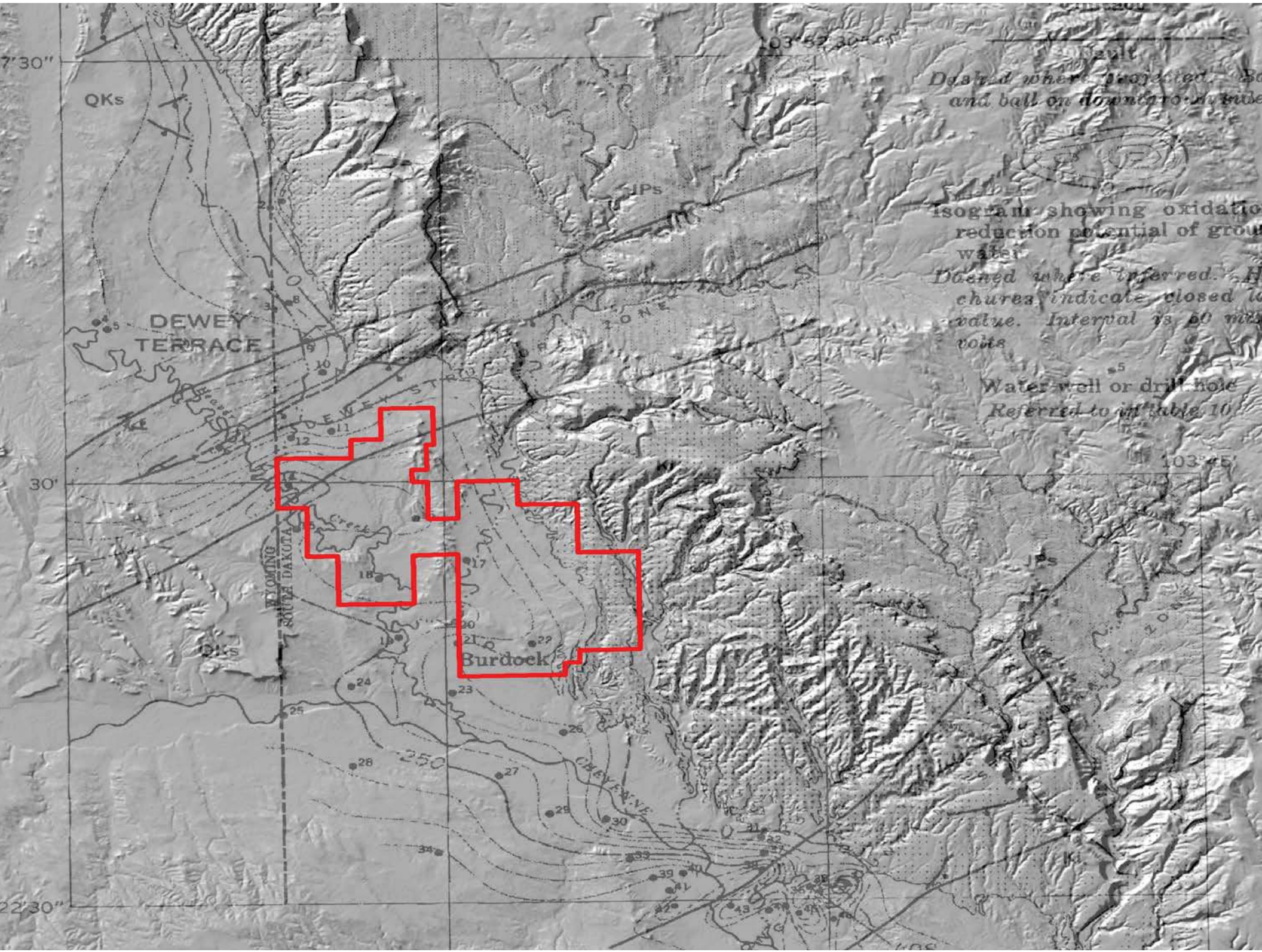
Dewey Burdock Project

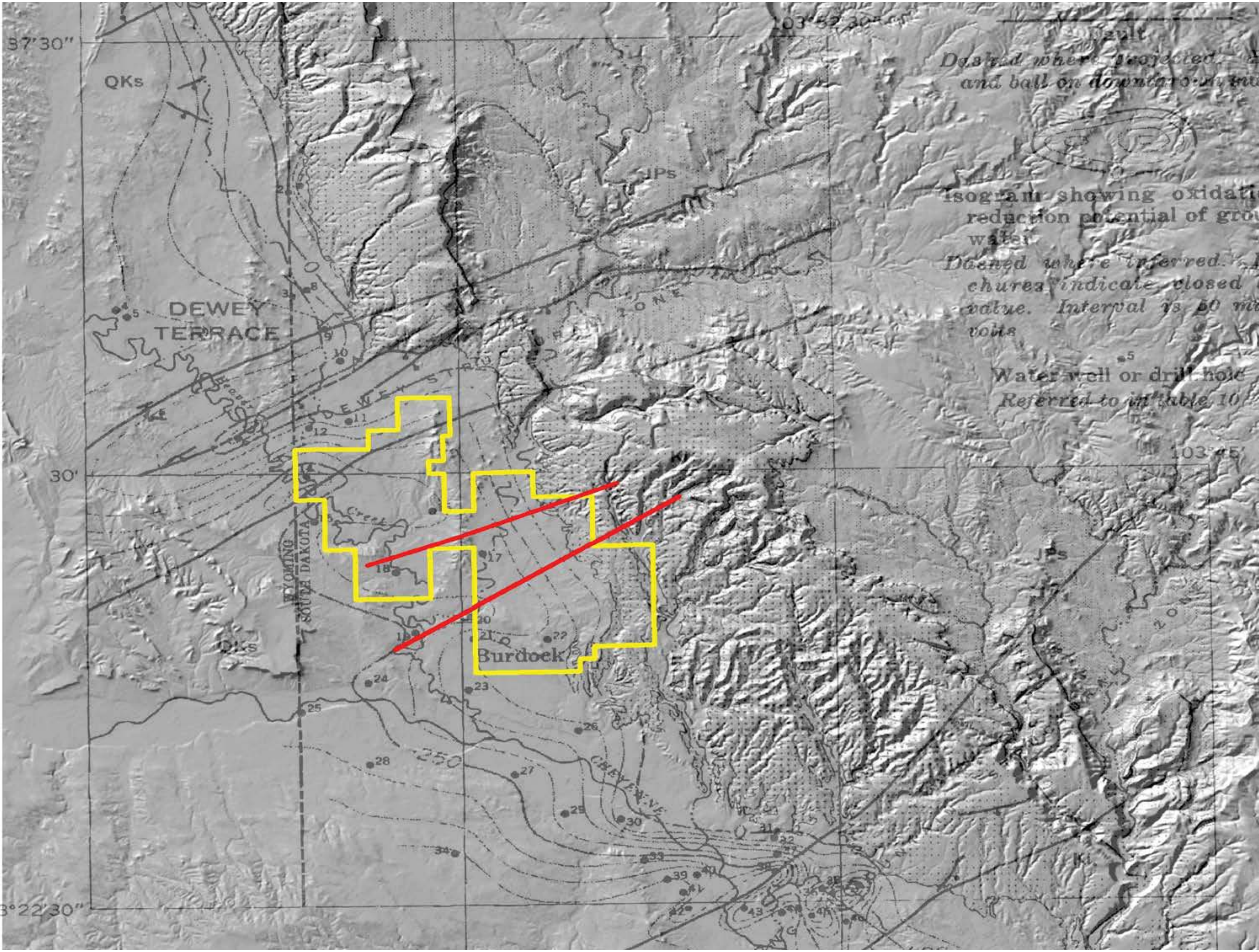
12-Sep-2012 | 12-Sep-2012

R. Lichnovsky

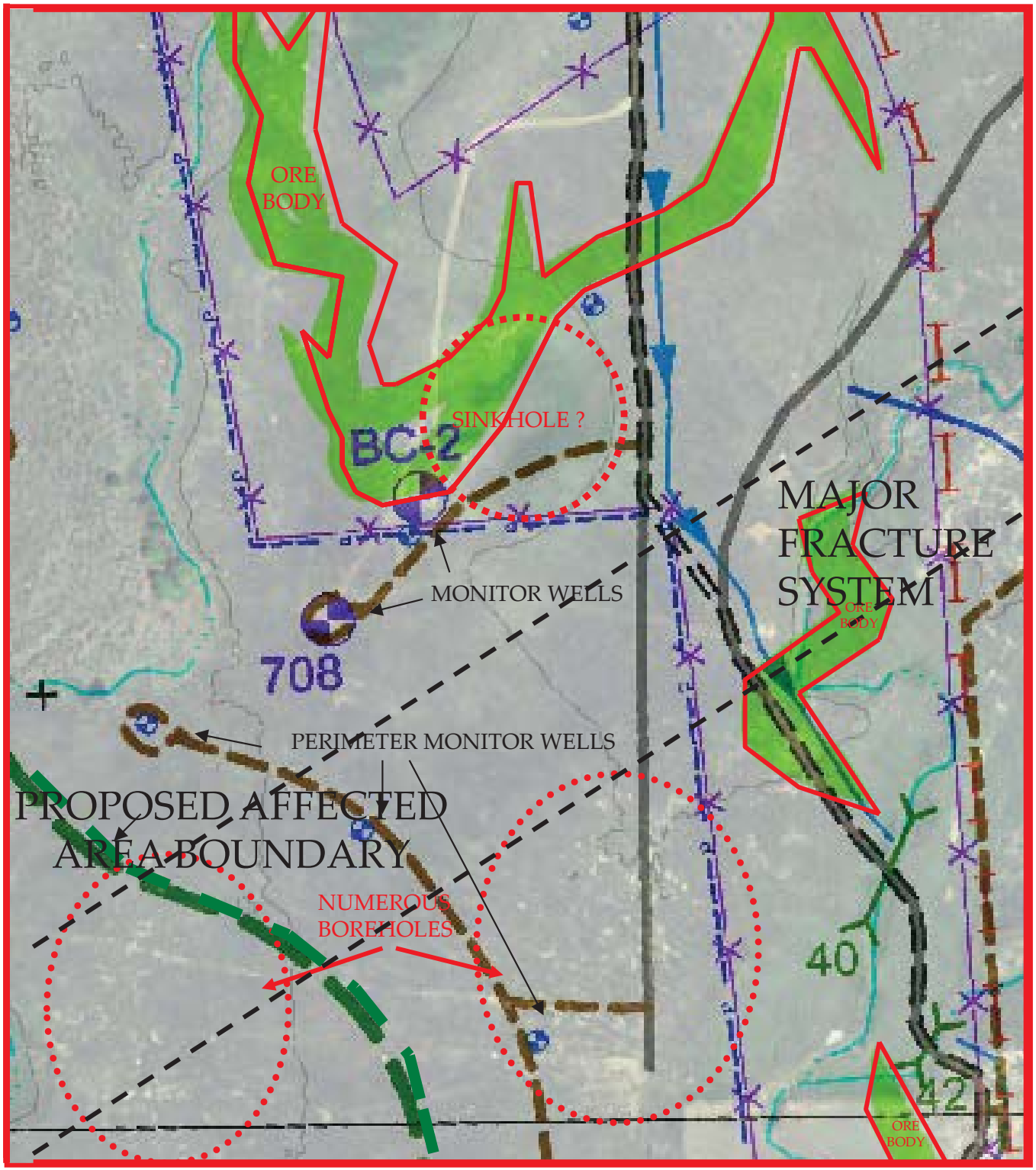
F. L. Lichnovsky

NAD 27, South Dakota State Plane South (feet)


7'30"
QKs
DEWEY TERRACE
JPs
Fault
Isogram showing oxidatio
reduction potential of grou
water
Water well or drill hole
Referred to in Table 10
103°25'
30'
22'30"
Burdock
250



DEWEY
TERRACE
QKs
JPs
Burdock
WYOMING
SOUTH DAKOTA
CHEYENNE
Isogram showing oxidation reduction potential of ground water
Water well or drill hole


ORE BODY
SINKHOLE ?
BC-2
MAJOR FRACTURE SYSTEM
MONITOR WELLS
708
PERIMETER MONITOR WELLS
PROPOSED AFFECTED AREA BOUNDARY
NUMEROUS BOREHOLES
40
42
ORE BODY
ORE BODY

ZOOM 2 AREA

Local Hydrostratigraphic Units: Dewey-Burdock Project Area