Groundwater Resources in the Lower Missouri River Basin

Jon Reiten
Lewistown, MT

December 2, 2013

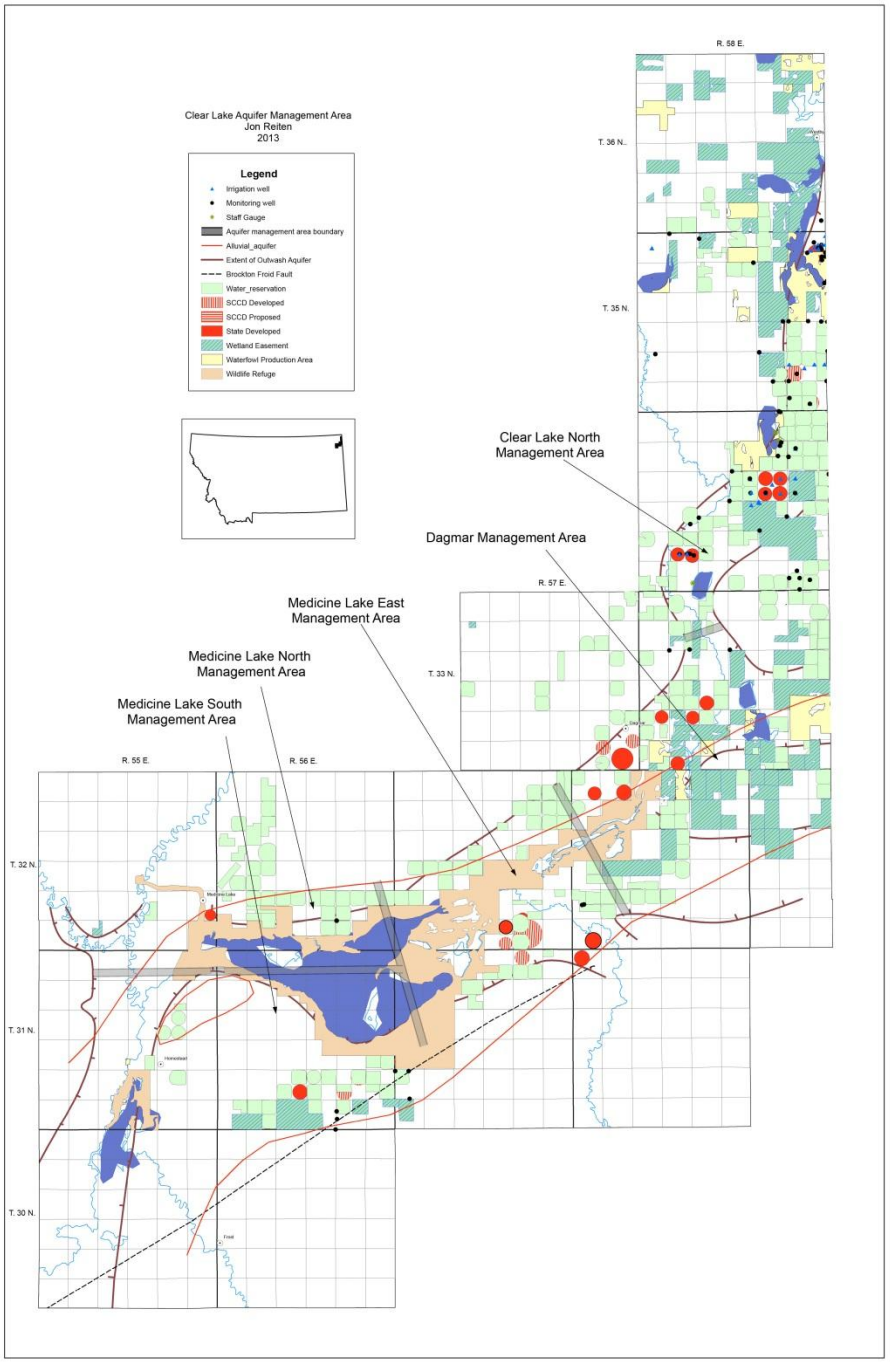
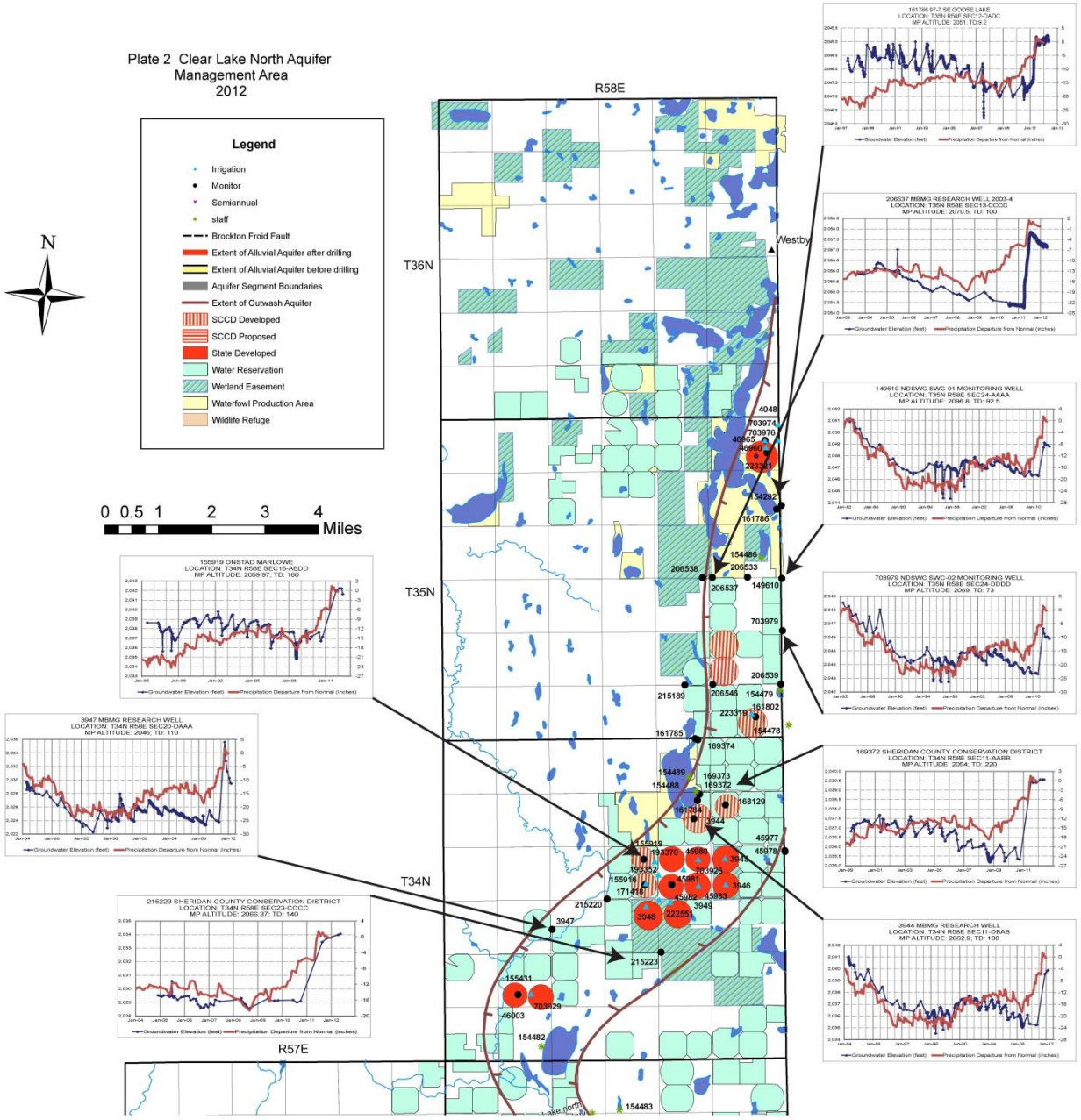
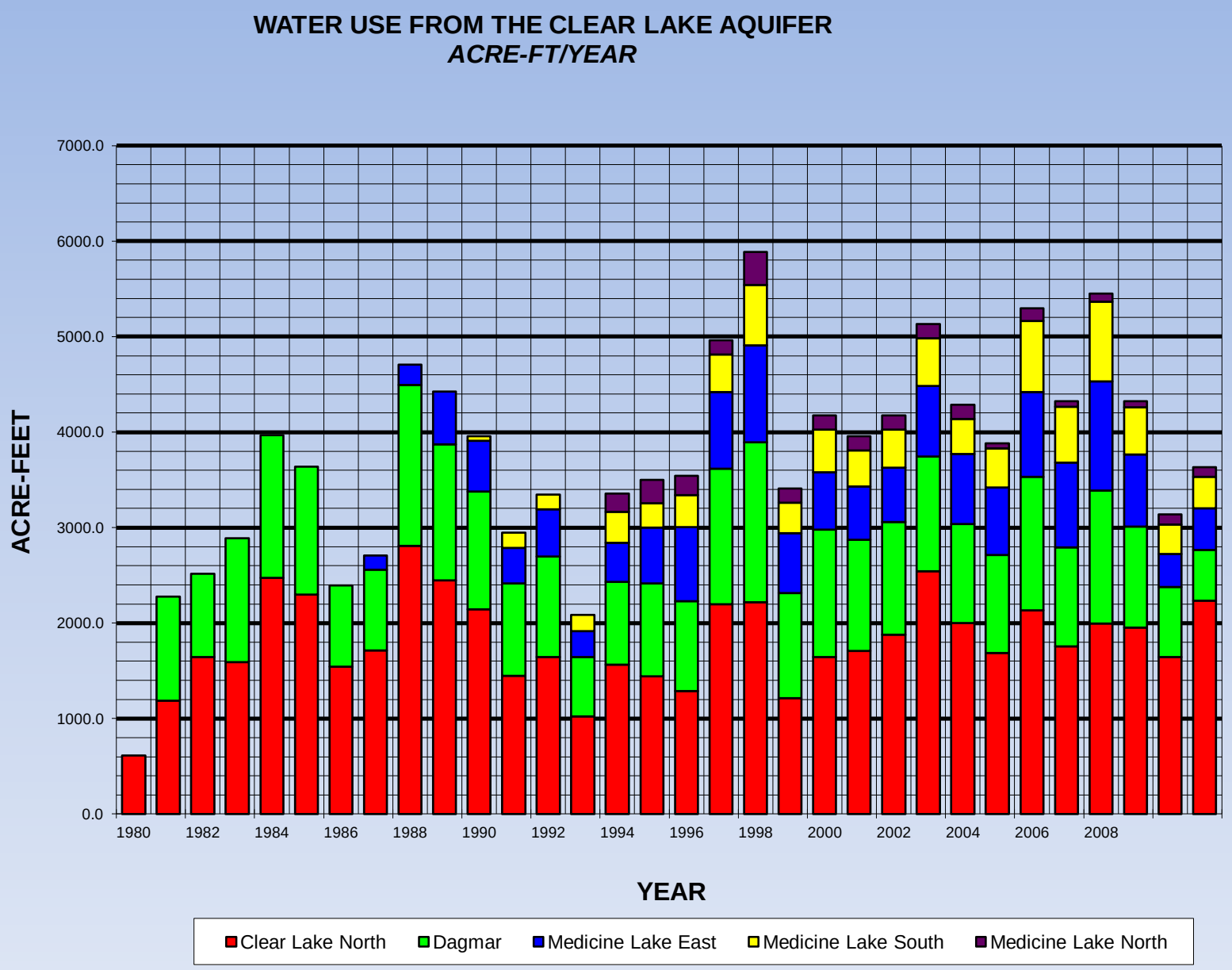

Clear Lake Aquifer Management Area
Jon Reiten
2013
Legend
Irrigation well
Monitoring well
Staff Gauge
Aquifer management area boundary
Alluvial_aquifer
Extent of Outwash Aquifer
Brockton Froid Fault
Water_reservation
SCCD Developed
SCCD Proposed
State Developed
Wetland Easement
Waterfowl Production Area
Wildlife Refuge
Clear Lake North Management Area
Dagmar Management Area
Medicine Lake East Management Area
Medicine Lake North Management Area
Medicine Lake South Management Area
R. 58 E.
R. 57 E.
R. 56 E.
R. 55 E.
T. 36 N.
T. 35 N.
T. 33 N.
T. 32 N.
T. 31 N.
T. 30 N.

Plate 2 Clear Lake North Aquifer Management Area 2012




WATER USE FROM THE CLEAR LAKE AQUIFER
ACRE-FT/YEAR
ACRE-FEET
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
YEAR
Clear Lake North
Dagmar
Medicine Lake East
Medicine Lake South
Medicine Lake North

LOWER YELLOWSTONE GROUND-WATER RESERVATION: WATER-DEVELOPMENT POTENTIAL OF BURIED CHANNEL AQUIFERS IN RICHLAND COUNTY, MONTANA

by

Jon Reiten

Lower Yellowstone Buried Channel Aquifer: DNRC Summary Report, November 2013

BURIED CHANNEL AQUIFERS

--ASSOCIATED WITH YELLOWSTONE VALLEY

--SIDNEY AQUIFER: CITY WELL FIELD IN IRRIGATED VALLEY

--YELLOWSTONE AQUIFER: IN IRRIGATED VALLEY

--WEST CRANE AQUIFER: EDGE OF VALLEY ABOVE IRRIGATION

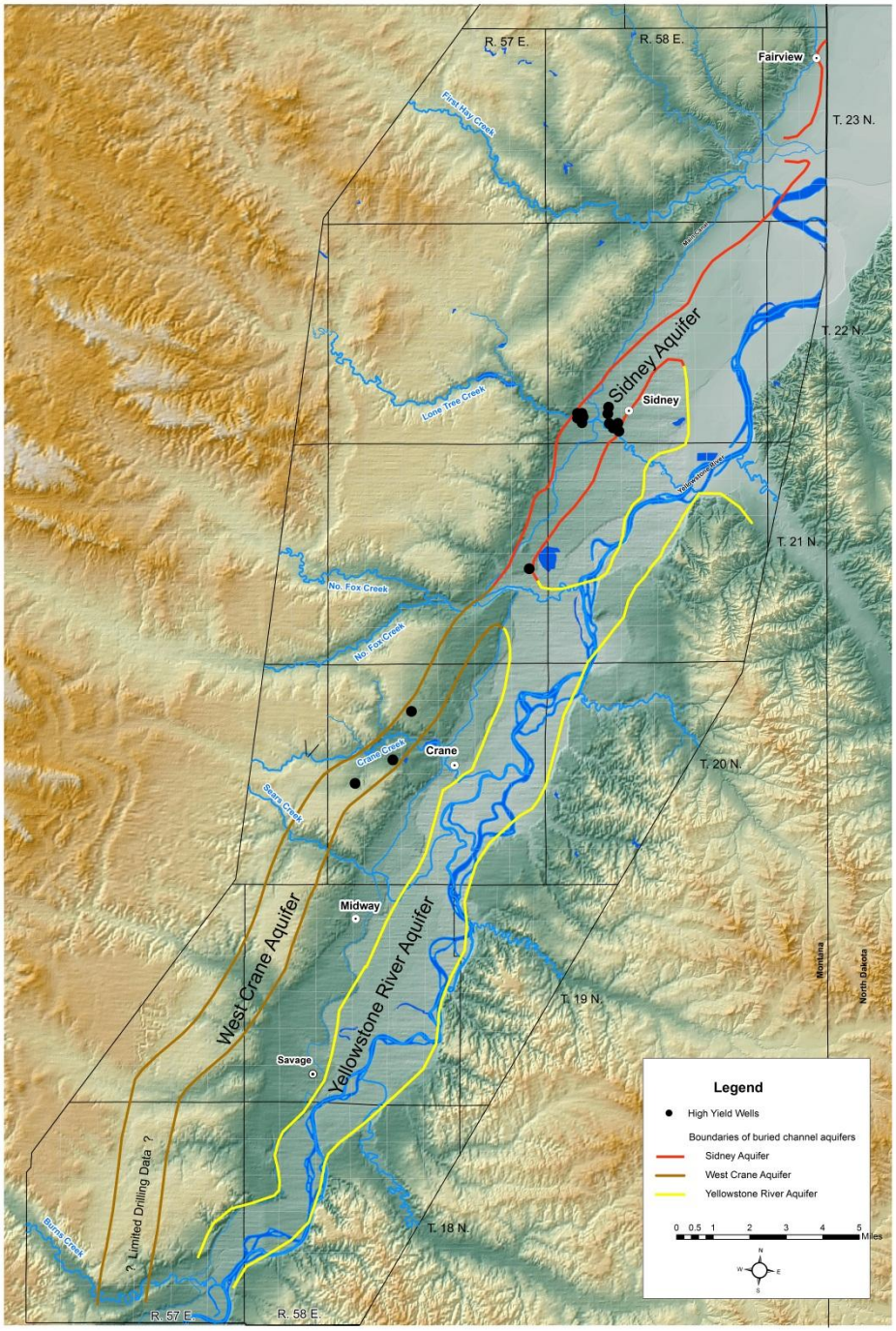
--BURIED CHANNELS TYPICALLY 100 FT DEEP and 1-2 MILES WIDE

--POTENTIAL YIELDS FROM 500 TO >1000 GPM. BEST WHERE CHANNEL IS DEEPEST AND GRAVELS ARE THICKEST

--LOW DISSOLVED SOLIDS BUT USUALLY CONTAINS HIGH IRON CONCENTRATIONS

--

F V E D
Water Man's Greatest Friend
WELL DRILLING
06/26/2013 15:48


R. 57 E.
R. 58 E.
Fairview
T. 23 N.
First Hay Creek
Missouri
T. 22 N.
Sidney Aquifer
Sidney
Lone Tree Creek
Yellowstone River
T. 21 N.
No. Fox Creek
No. Fox Creek
Crane Creek
Crane
T. 20 N.
Burns Creek
Midway
West Crane Aquifer
Yellowstone River Aquifer
T. 19 N.
Montana
North Dakota
Savage
? Limited Drilling Data ?
Burns Creek
T. 18 N.
R. 57 E.
R. 58 E.
Legend
High Yield Wells
Boundaries of buried channel aquifers
Sidney Aquifer
West Crane Aquifer
Yellowstone River Aquifer
0 0.5 1 2 3 4 5 Miles
N
W
E
S

06/28/2013 14:18

F V F D
Water
WELL
06/26/2013 15:36

DLS DRILLING, LLC
Miller
06/26/2013 15:53

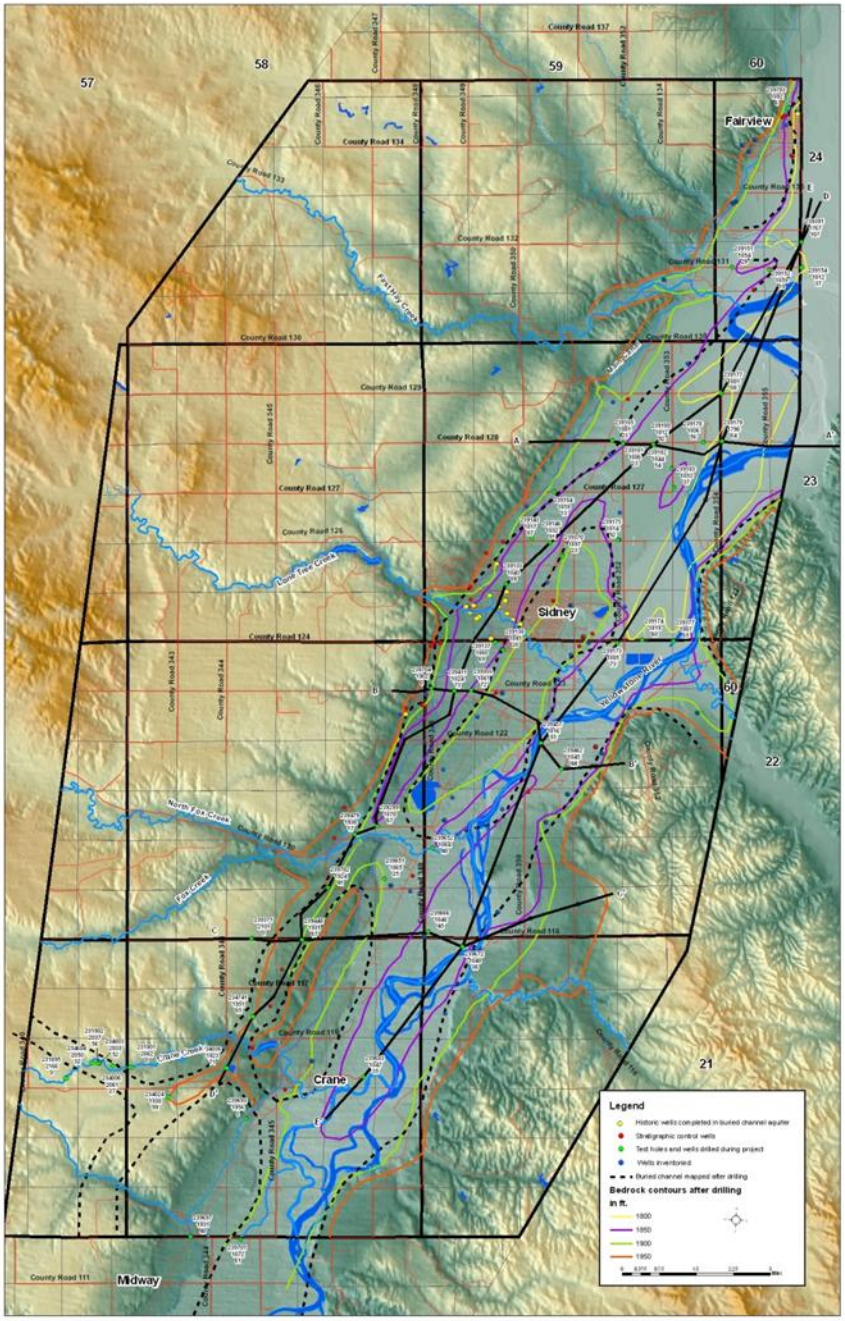
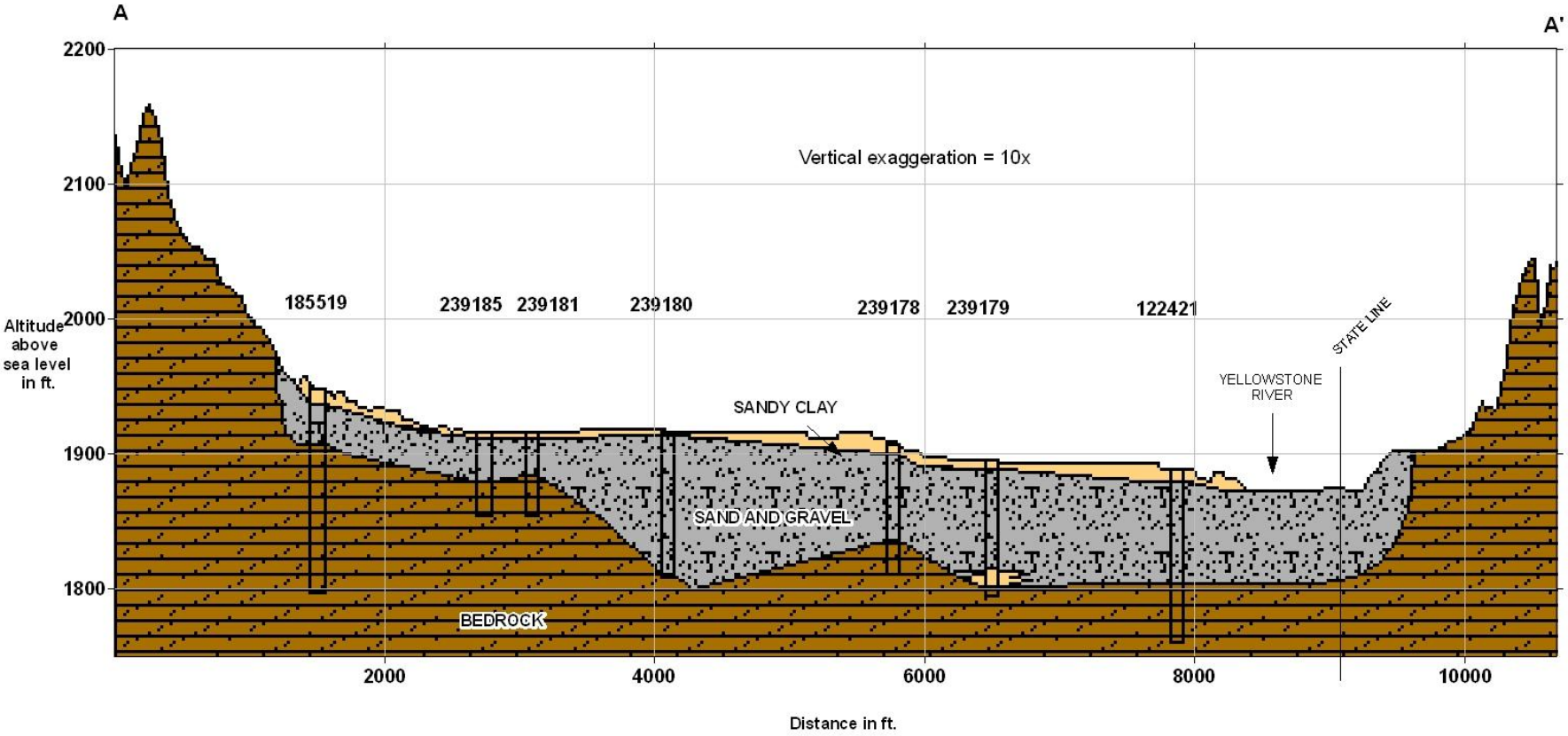
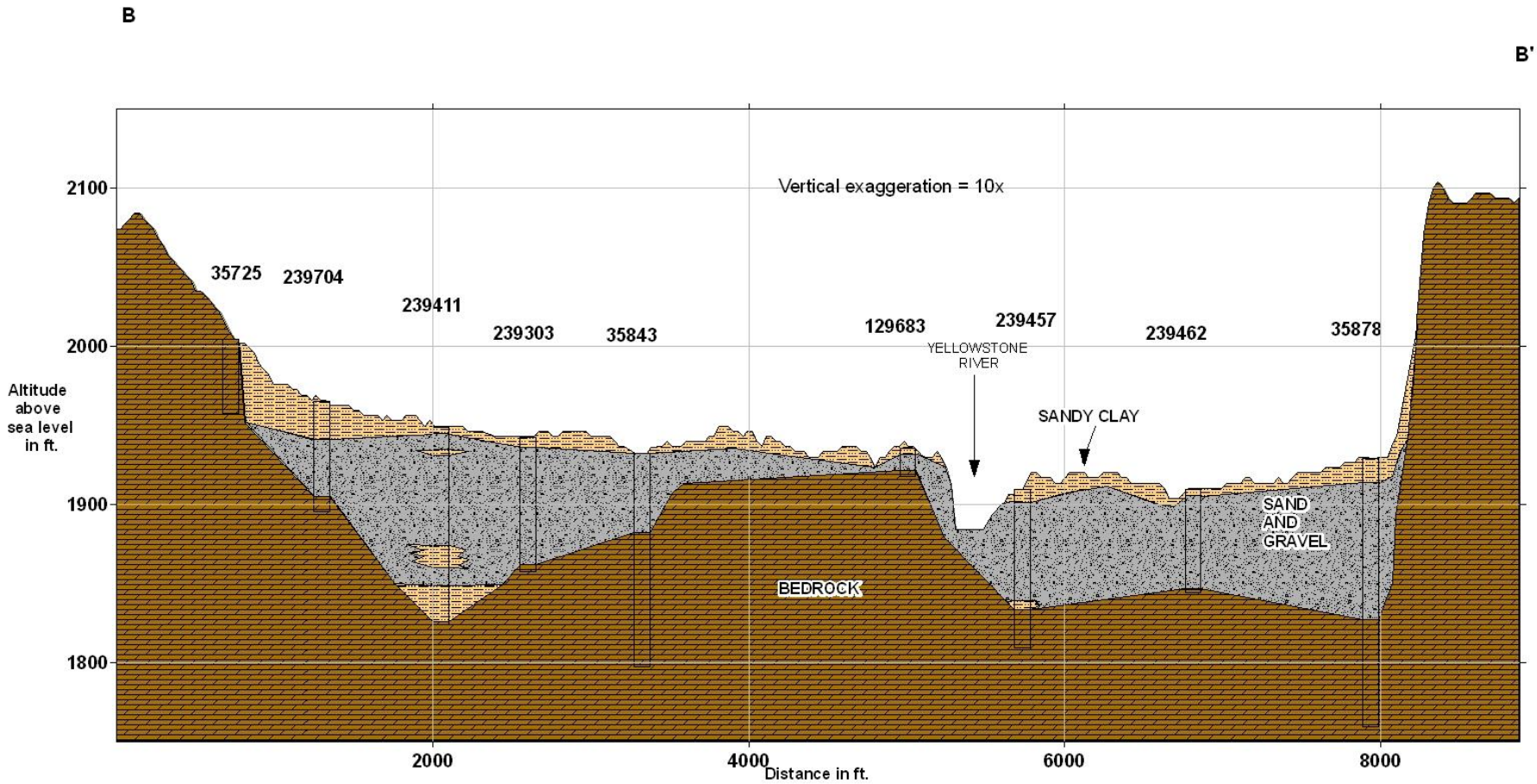
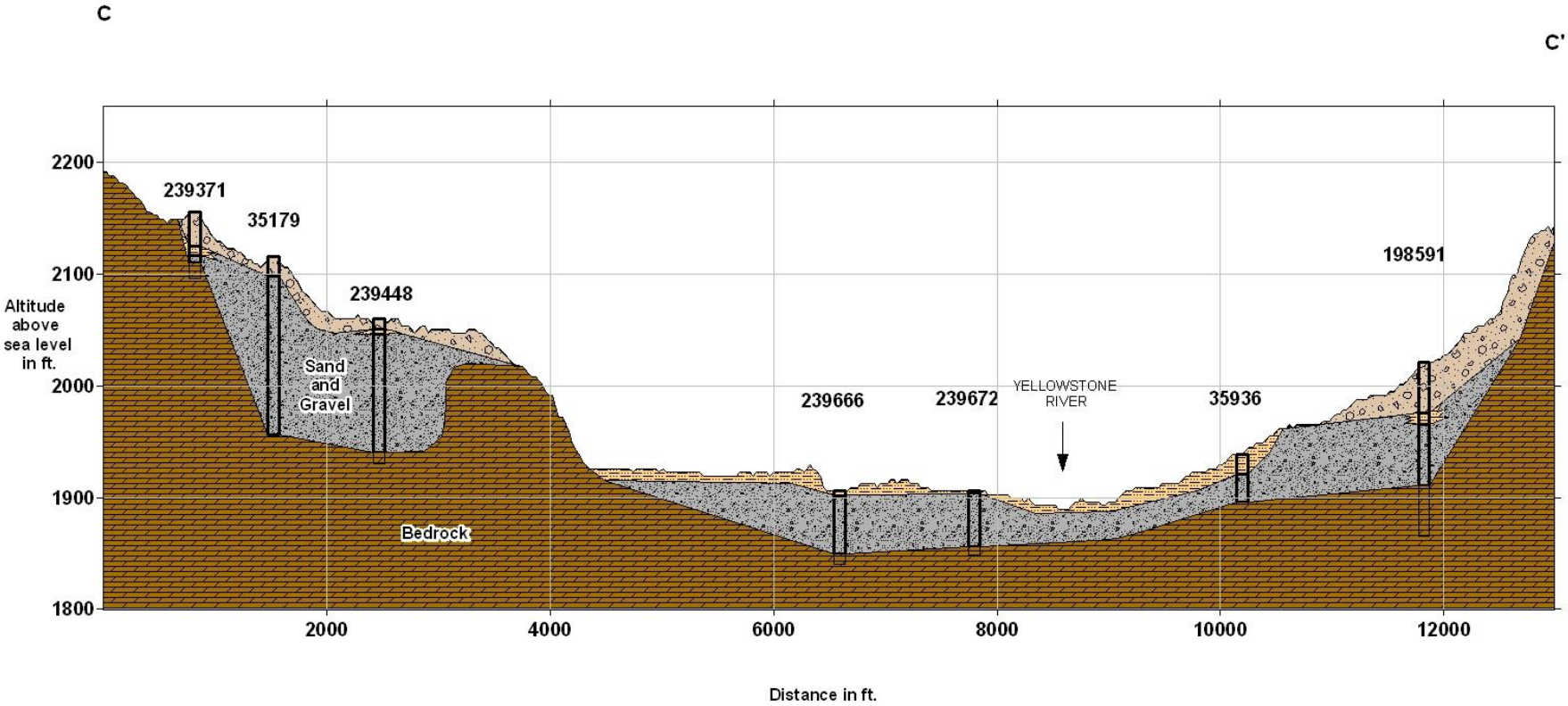


Plate 4. Top of bedrock surface and extent of buried-channel aquifer based on test drilling, fall 2007.


A
A'
2200
2100
2000
1900
1800
Altitude above sea level in ft.
Vertical exaggeration = 10x
185519
239185
239181
239180
239178
239179
122421
STATE LINE
YELLOWSTONE RIVER
SANDY CLAY
SAND AND GRAVEL
BEDROCK
2000
4000
6000
8000
10000
Distance in ft.


B
B'
Vertical exaggeration = 10x
35725
239704
239411
239303
35843
129683
239457
239462
35878
YELLOWSTONE RIVER
SANDY CLAY
SAND AND GRAVEL
BEDROCK
2100
2000
1900
1800
Altitude above sea level in ft.
2000
4000
6000
8000
Distance in ft.


C
C'
2200
2100
2000
1900
1800
Altitude above sea level in ft.
239371
35179
239448
198591
Sand and Gravel
239666
239672
YELLOWSTONE RIVER
35936
Bedrock
2000
4000
6000
8000
10000
12000
Distance in ft.

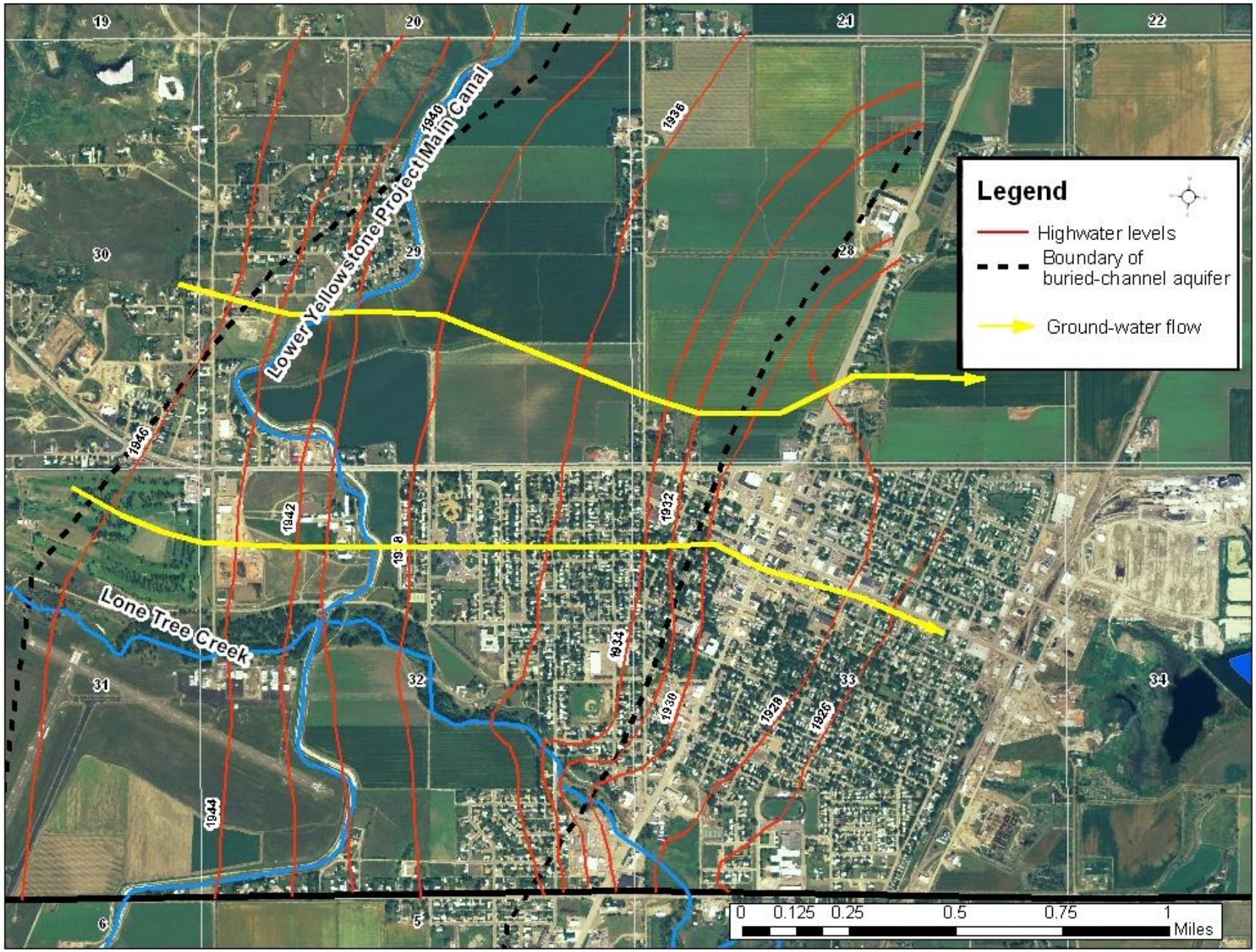
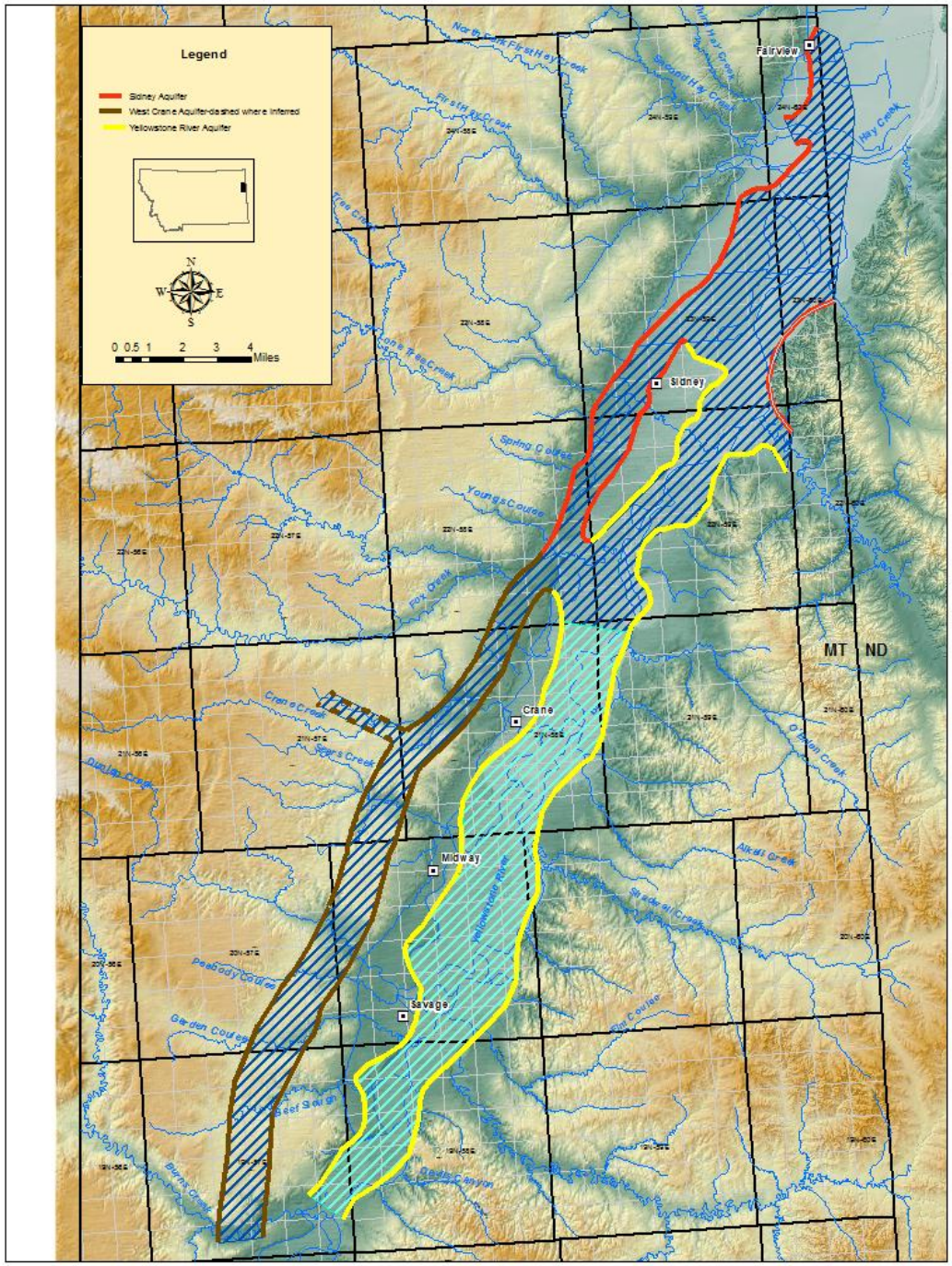
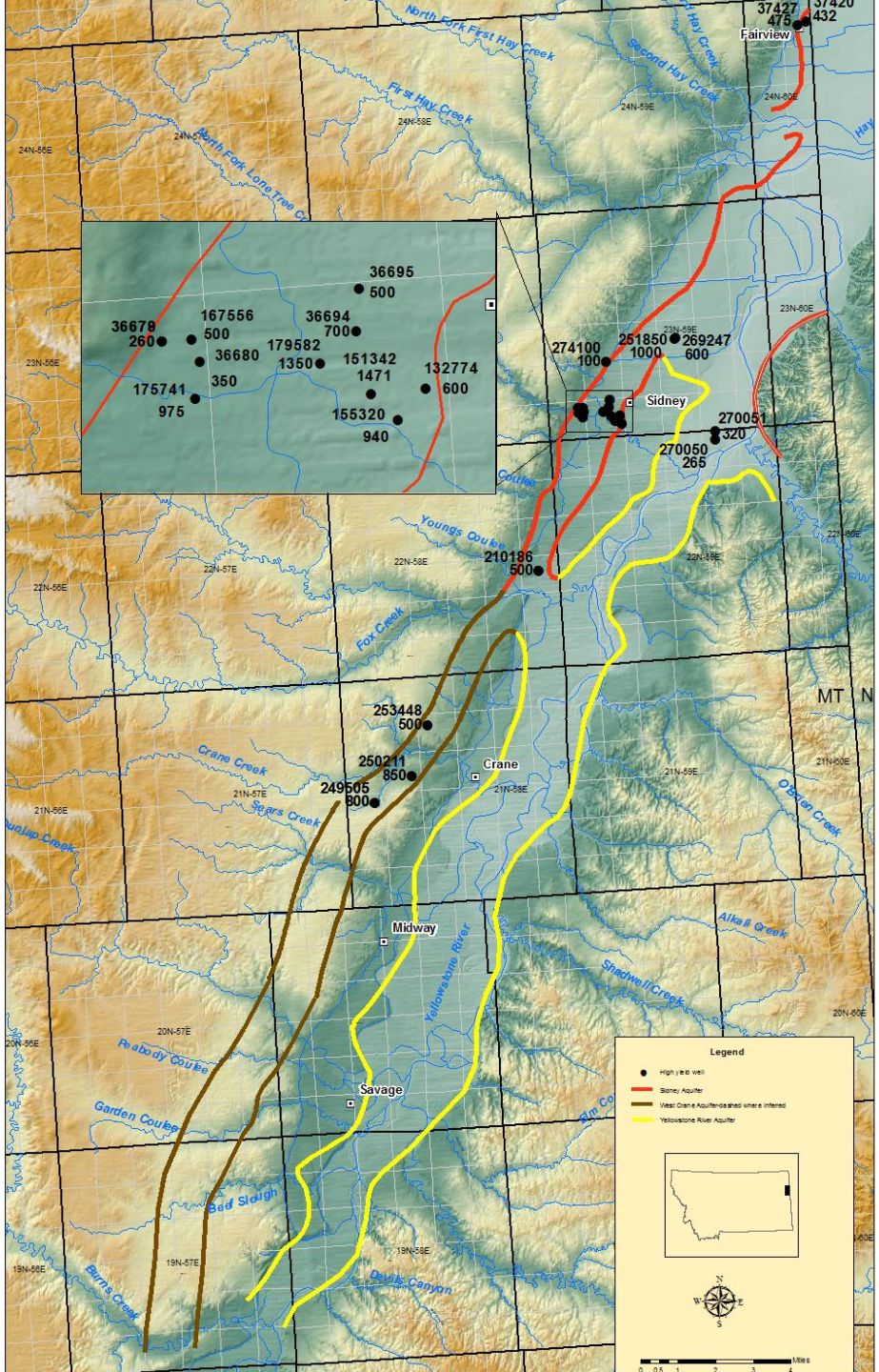
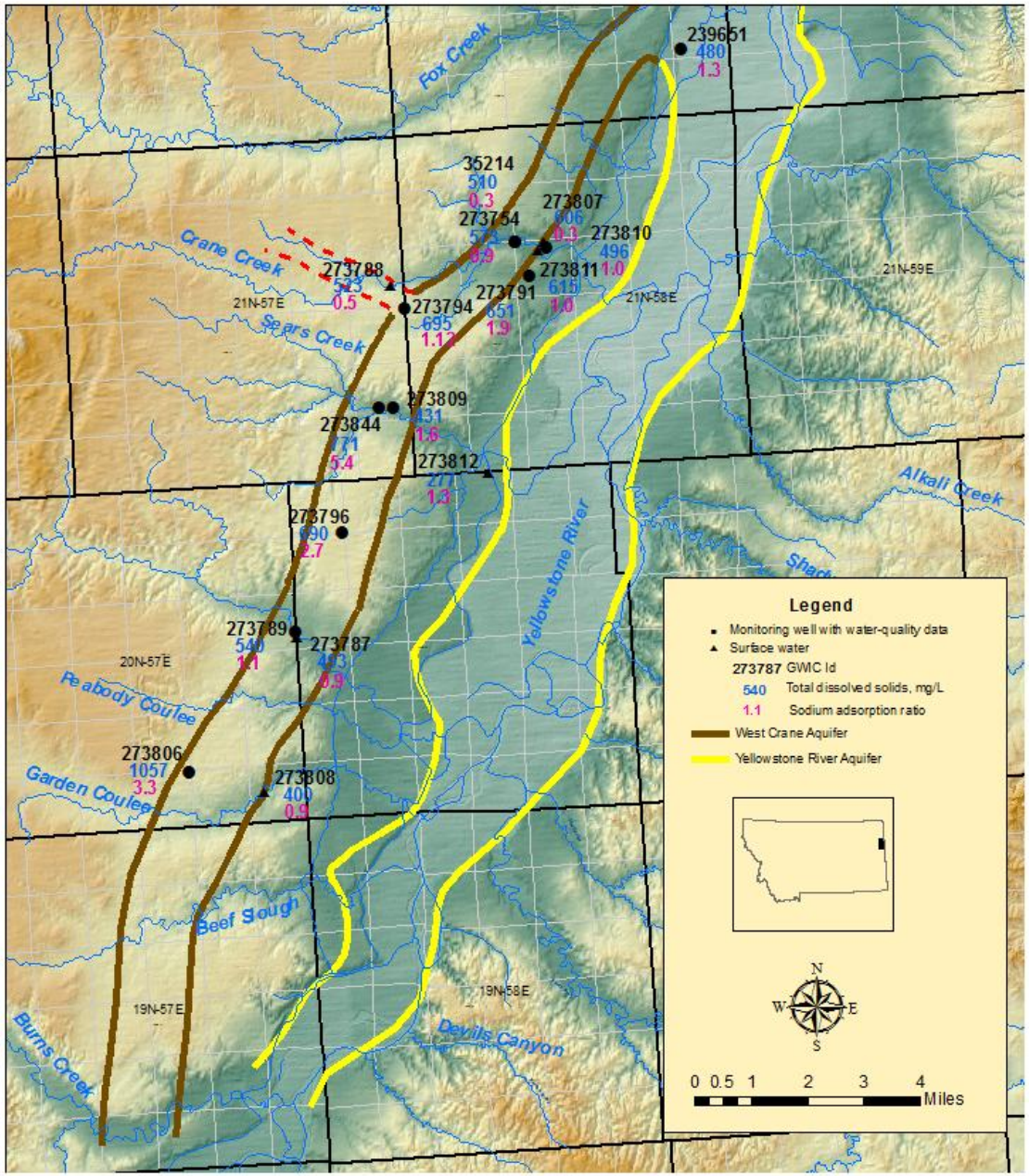


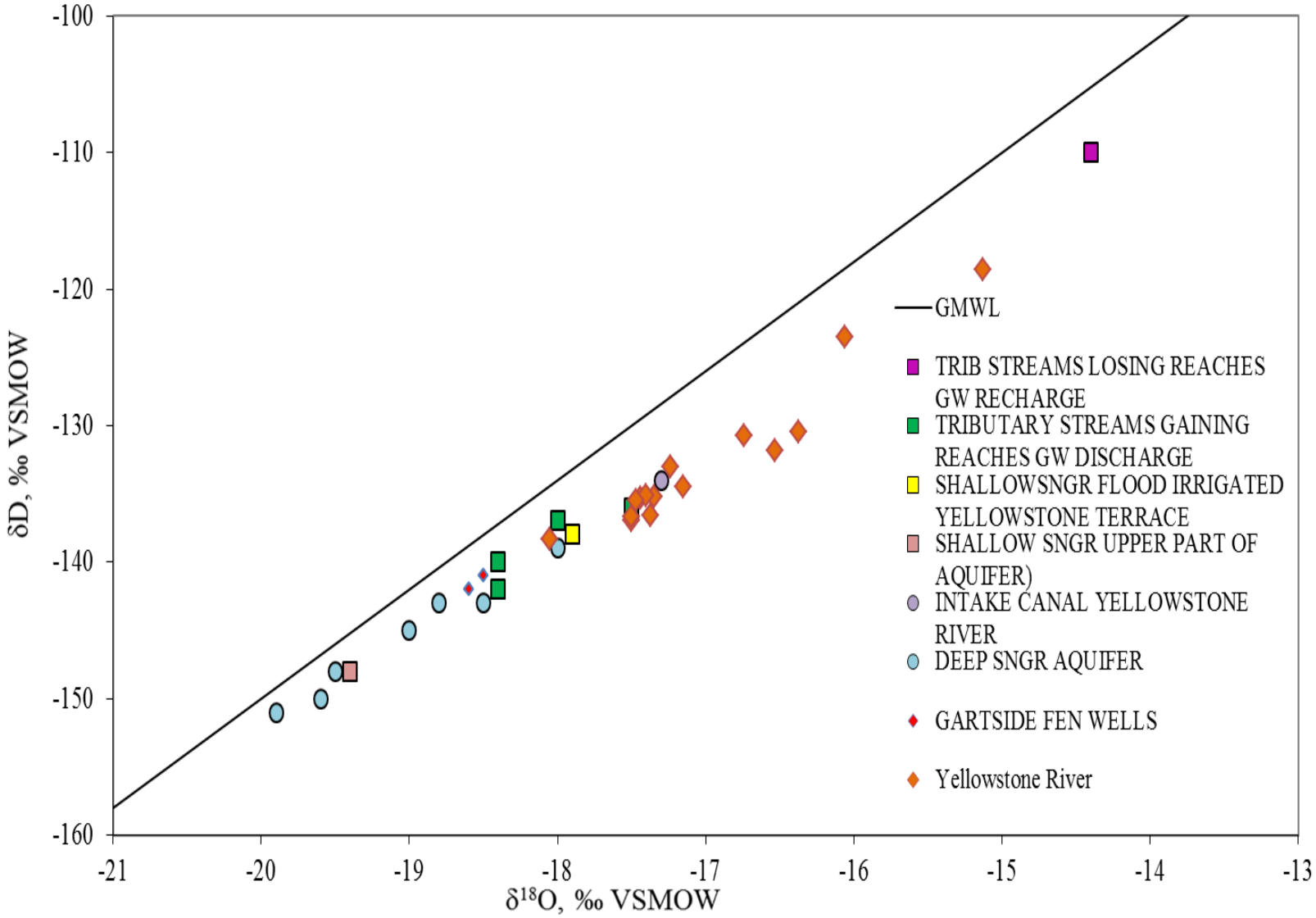
Figure 12. Potentiometric surface map of the Sidney area based on generally high water levels, October 1995.


Legend
Sidney Aquifer
West Crane Aquifer-dashed where inferred
Yellowstone River Aquifer
N
W
E
S
0 0.5 1 2 3 4
Miles
Fairview
Sidney
Crane
Midway
Savage
MT
ND
North Fork First Hay Creek
First Hay Creek
Second Hay Creek
Hay Creek
Lone Tree Creek
Spring Coulee
Youngs Coulee
Fox Creek
Crane Creek
Sears Creek
Dunlap Creek
O'Brien Creek
Alkali Creek
Shadwell Creek
Yellowstone River
Peabody Coulee
Garden Coulee
Beef Slough
Burns Creek
Devils Canyon
Fim Coulee

AQUIFER	PRODUCTION WELL	TRANSMISSIVITY ft^2/day	HYDRAULIC CONDUCTIVITY ft/day	STORAGE COEFFICIENT
Sidney	CW7 (M:36694)	37,500	500	0.004
Sidney	CW5 (M:36690)	15,000	500	0.05
Sidney	CW8 (M:132774)	36,500	450	0.006
Sidney	CW9 (M:36695)	34,700	500	0.007
Sidney	CW10 (M:155320)	63,500	650	not calculated
Sidney	CW11 (M:151342)	38,600	600	not calculated
Sidney	NMN (M:36648)	23,500	470	0.0002
Sidney	NMS (M:36649)	23,200	460	0.0007
Yellowstone	Sid Lagoon (270050)	13,500	216	0.15
Yellowstone	Sid Lagoon (270051)	13,800	225	0.15
West Crane	Bradley (253448)	31,450	425	0.16
West Crane	Jonsson (249505)	45,000	450	0.15
West Crane	Wyman (250211)	36,000	400	0.15


Fairview
37427
475
37420
432
North Fork First Hay Creek
First Hay Creek
Second Hay Creek
North Fork Lone Tree Cr
36695
500
36679
260
167556
500
36694
700
36680
350
179582
1350
151342
1471
132774
600
175741
975
155320
940
274100
100
251850
1000
269247
600
Sidney
270051
320
270050
265
Youngs Coulee
210186
500
Fox Creek
MT
253448
500
250211
850
249505
800
Crane Creek
Crane
Sears Creek
Dunlap Creek
Obrien Creek
Alkali Creek
Midway
Yellowstone River
Shadwell Creek
Peabody Coulee
Savage
Garden Coulee
Bad Slough
Burns Creek
Devils Canyon
Legend
High yield well
Sidney Aquifer
West Crane Aquifer-dashed where inferred
Yellowstone River Aquifer
Miles


Fox Creek
239651
480
1.3
35214
510
0.3
273807
606
0.3
273754
573
0.9
273810
496
1.0
273811
615
1.0
Crane Creek
273788
543
0.5
273791
651
1.9
273794
695
1.12
21N-57E
21N-58E
21N-59E
Sears Creek
273809
431
1.6
273844
471
5.4
273812
271
1.3
Alkali Creek
273796
690
2.7
Yellowstone River
Shark
273789
540
1.1
273787
493
0.9
20N-57E
Peabody Coulee
273806
1057
3.3
Garden Coulee
273808
400
0.9
Beef Slough
19N-57E
19N-58E
Burns Creek
Devils Canyon
Legend
Monitoring well with water-quality data
Surface water
273787 GWIC Id
540 Total dissolved solids, mg/L
1.1 Sodium adsorption ratio
West Crane Aquifer
Yellowstone River Aquifer
N
W
E
S
0 0.5 1 2 3 4
Miles


-100
-110
-120
-130
-140
-150
-160
δD, ‰ VSMOW
-21
-20
-19
-18
-17
-16
-15
-14
-13
δ18O, ‰ VSMOW
GMWL
TRIB STREAMS LOSING REACHES GW RECHARGE
TRIBUTARY STREAMS GAINING REACHES GW DISCHARGE
SHALLOWSNGR FLOOD IRRIGATED YELLOWSTONE TERRACE
SHALLOW SNGR UPPER PART OF AQUIFER)
INTAKE CANAL YELLOWSTONE RIVER
DEEP SNGR AQUIFER
GARTSIDE FEN WELLS
Yellowstone River

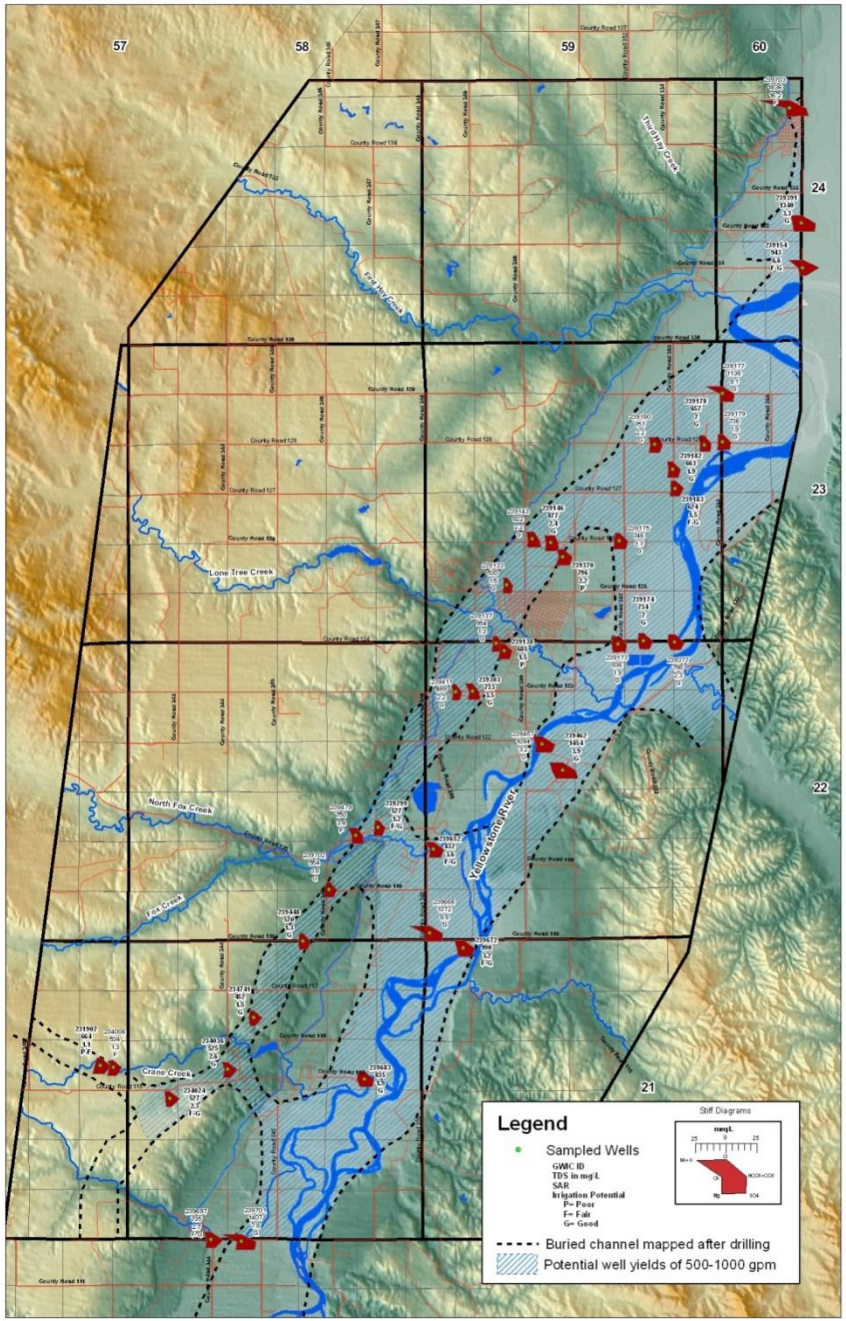
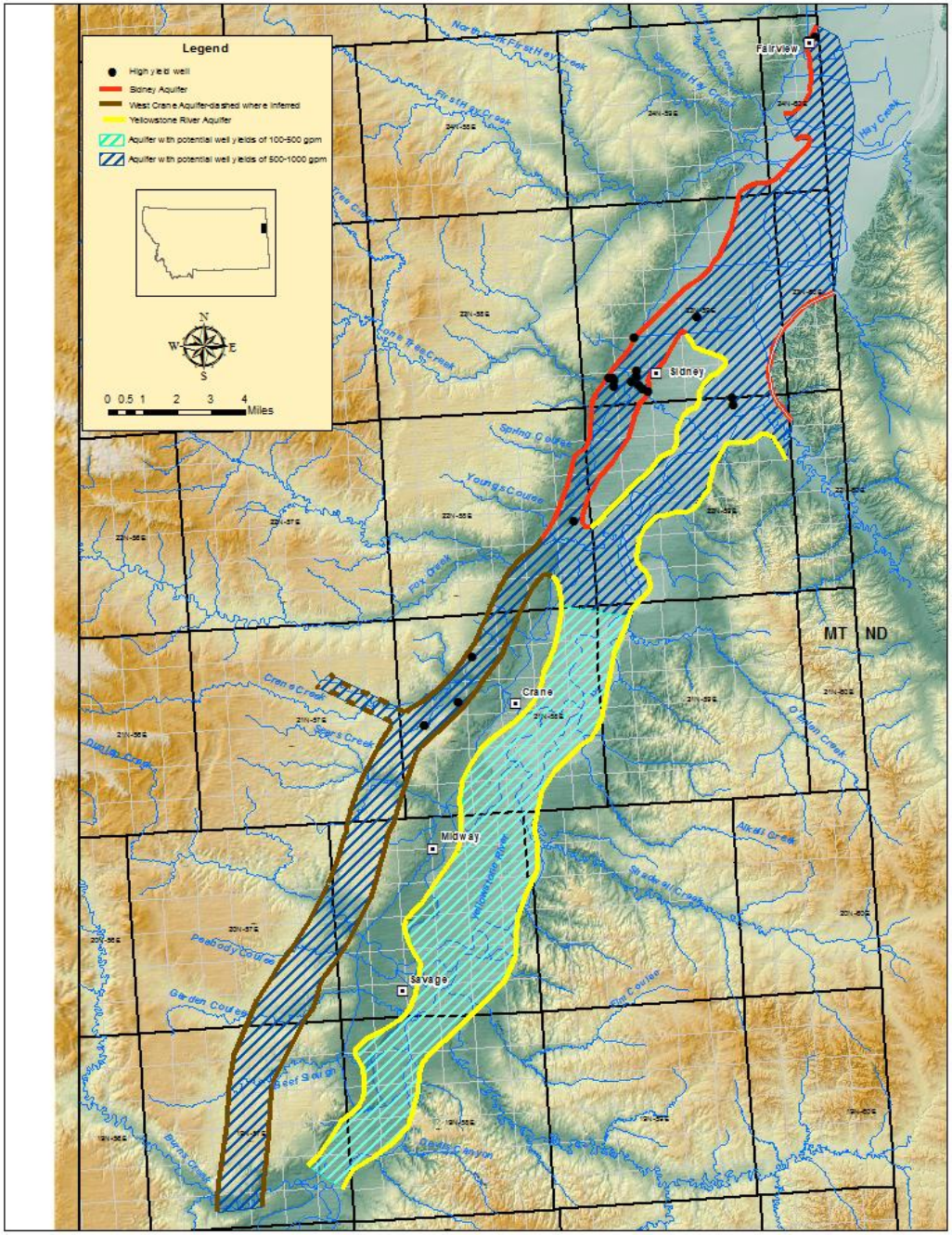


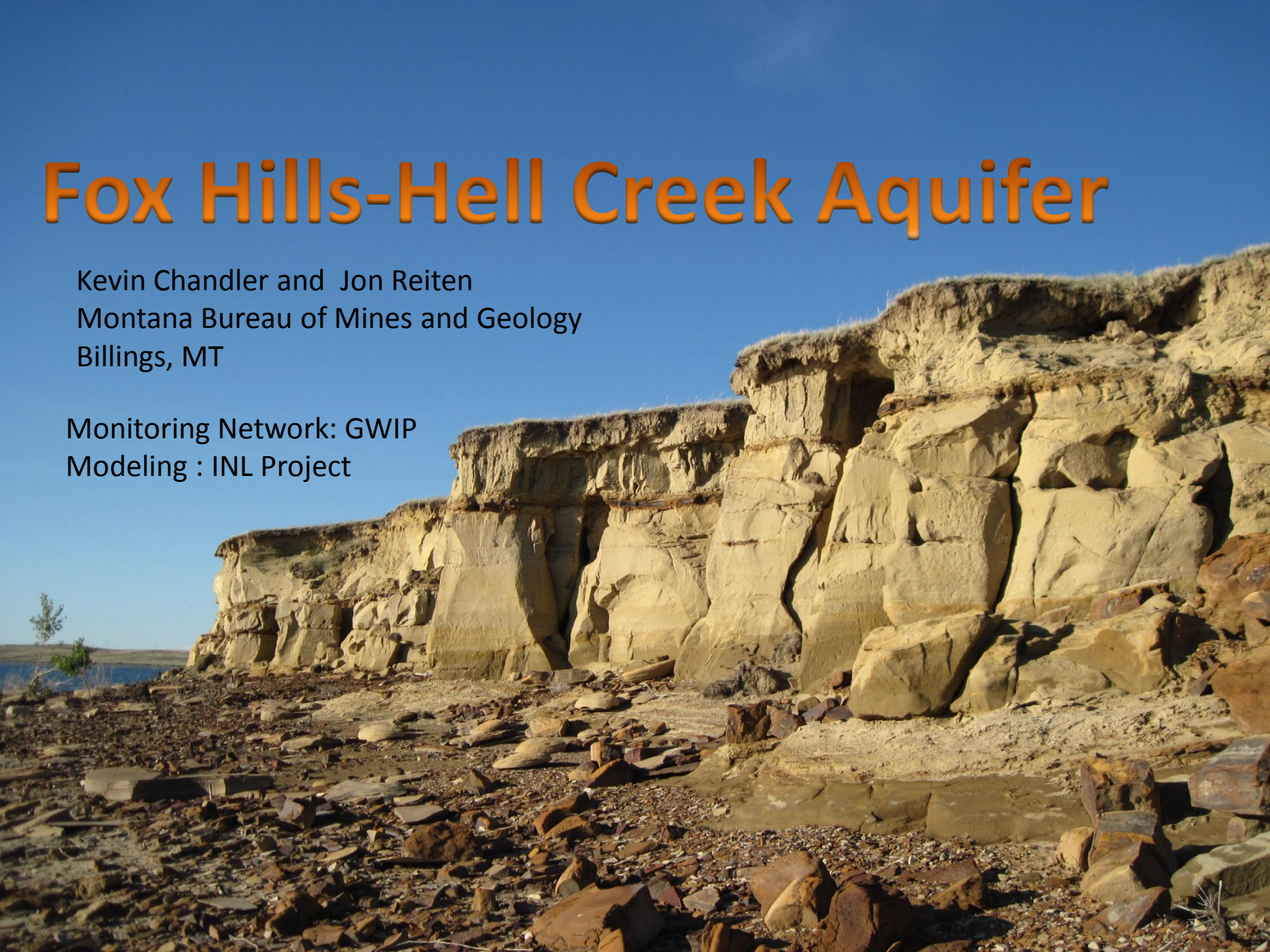
Plate 6. Water quality and aquifer development potential in the Lower Yellowstone Valley based on recently completed wells.


Legend
High yield well
Sidney Aquifer
West Crane Aquifer-dashed where inferred
Yellowstone River Aquifer
Aquifer with potential well yields of 100-500 gpm
Aquifer with potential well yields of 500-1000 gpm
N
W
E
S
0 0.5 1 2 3 4
Miles
Fairview
Sidney
Crane
Midway
Savage
MT
ND
North Fork First Hay Creek
First Hay Creek
Second Hay Creek
Hay Creek
Lone Tree Creek
Spring Coulee
Youngs Coulee
Fox Creek
Crane Creek
Sears Creek
Dunlap Creek
O'Brien Creek
Alkali Creek
Shadwell Creek
Yellowstone River
Peabody Coulee
Garden Coulee
Beef Slough
Burns Creek
Devils Canyon

Fox Hills-Hell Creek Aquifer

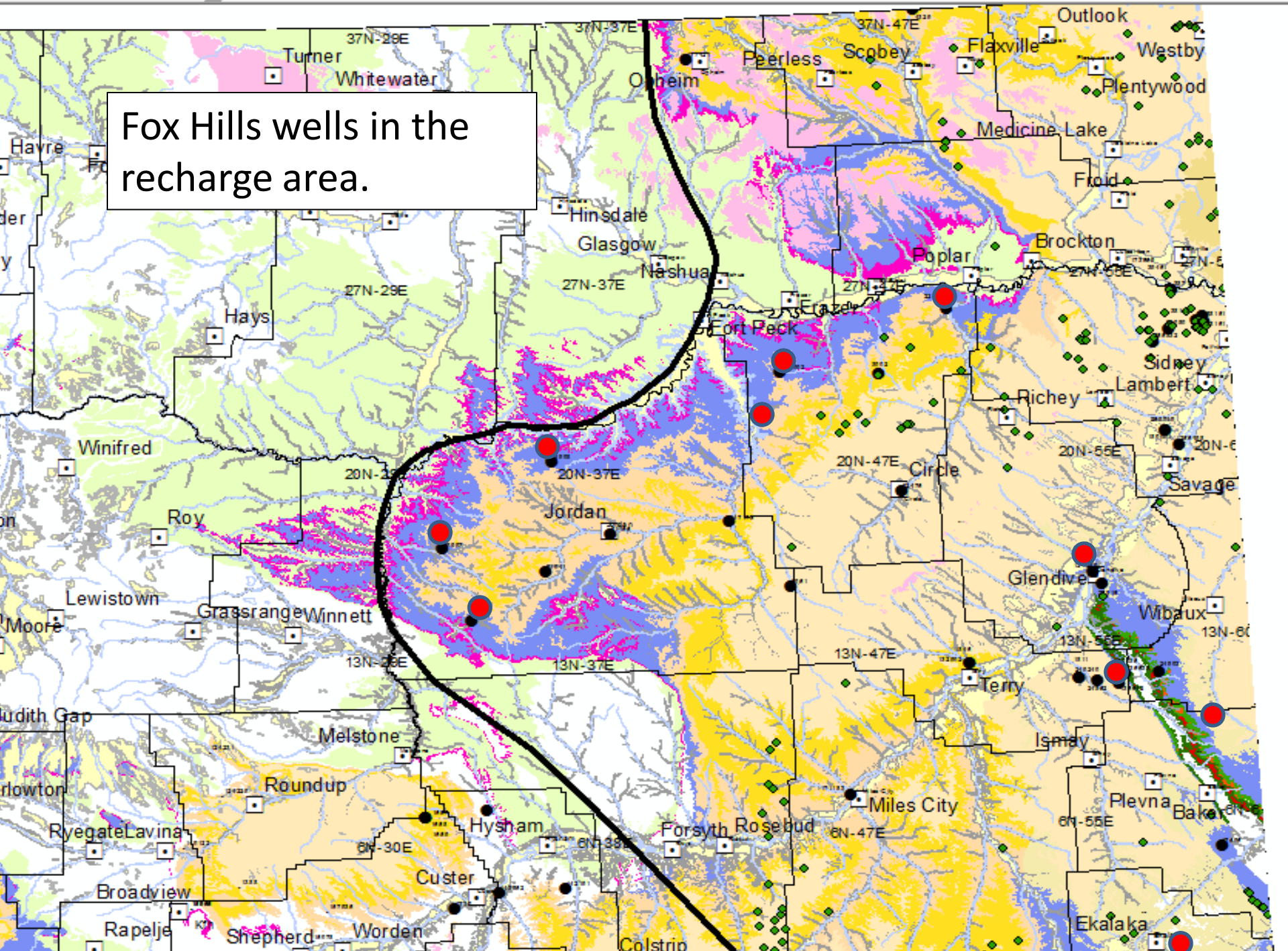
Kevin Chandler and Jon Reiten
Montana Bureau of Mines and Geology
Billings, MT

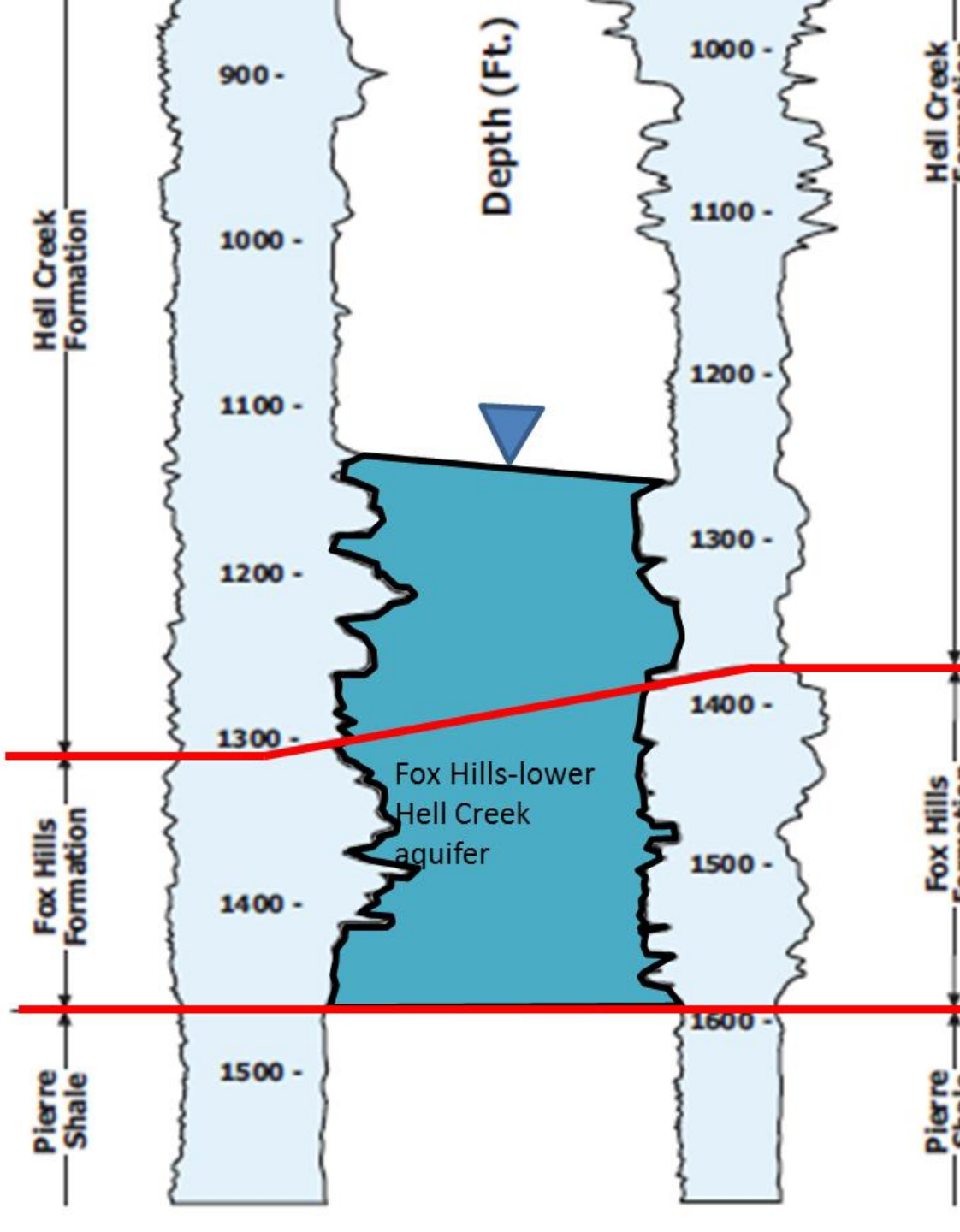
Monitoring Network: GWIP
Modeling : INL Project



Fox Hills/Hell Creek Aquifer Study

- Recent increase in Fox Hills/Hell Creek aquifer monitoring started in February of 2011 with funding from MBMG Groundwater Investigation Program.
- In 2012 a joint project between Idaho National Laboratory and MBMG provided additional funding.
- Data loggers were installed in recharge and discharge areas to collect data on current aquifer conditions
- Data from Montana's Ground Water Information Center (GWIC) and North Dakota's State Water Commission were compiled to evaluate long-term trends.

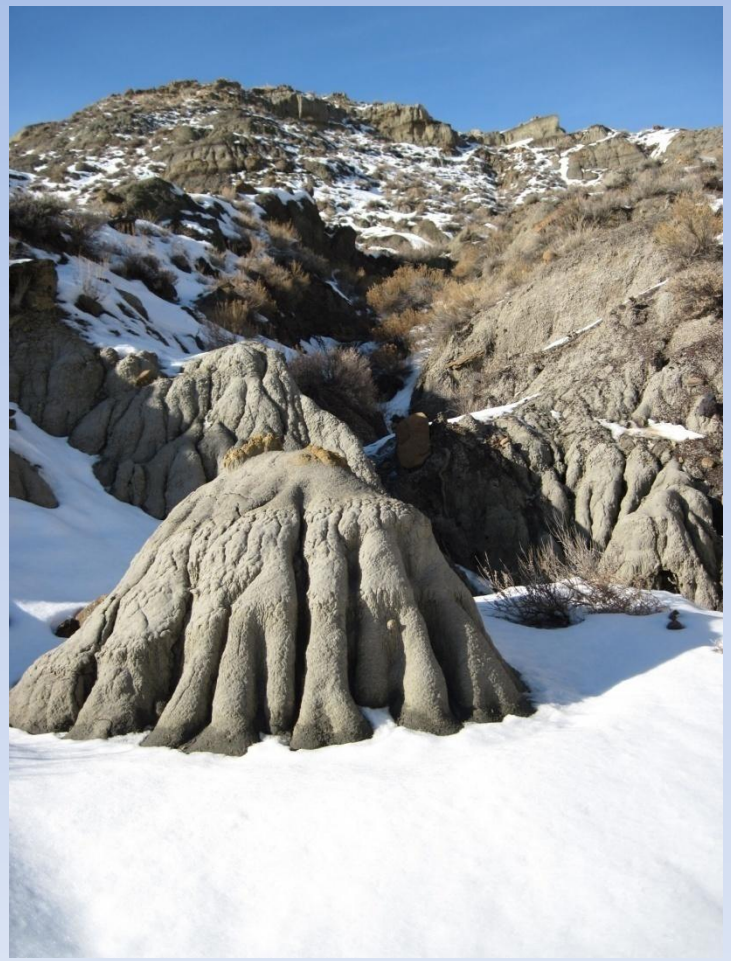

Fox Hills wells in the recharge area.
Turner
Whitewater
Havre
Hinsdale
Glasgow
Nashua
Hays
Winifred
Roy
Lewistown
Grassrange
Winnett
Moore
Judith Gap
Melstone
Roundup
Hysham
Custer
Broadview
Rapelje
Shepherd
Worden
Colstrip
Forsyth
Rosebud
Miles City
Terry
Ismay
Plevna
Baker
Ekalaka
Glendive
Wibaux
Circle
Jordan
Fort Peck
Poplar
Brockton
Richey
Lambert
Sidney
Savage
Peerless
Scobey
Flaxville
Outlook
Westby
Plentywood
Medicine Lake
Froid
37N-28E
37N-37E
37N-47E
27N-28E
27N-37E
20N-37E
20N-47E
20N-55E
13N-37E
13N-47E
6N-30E
6N-47E
6N-55E

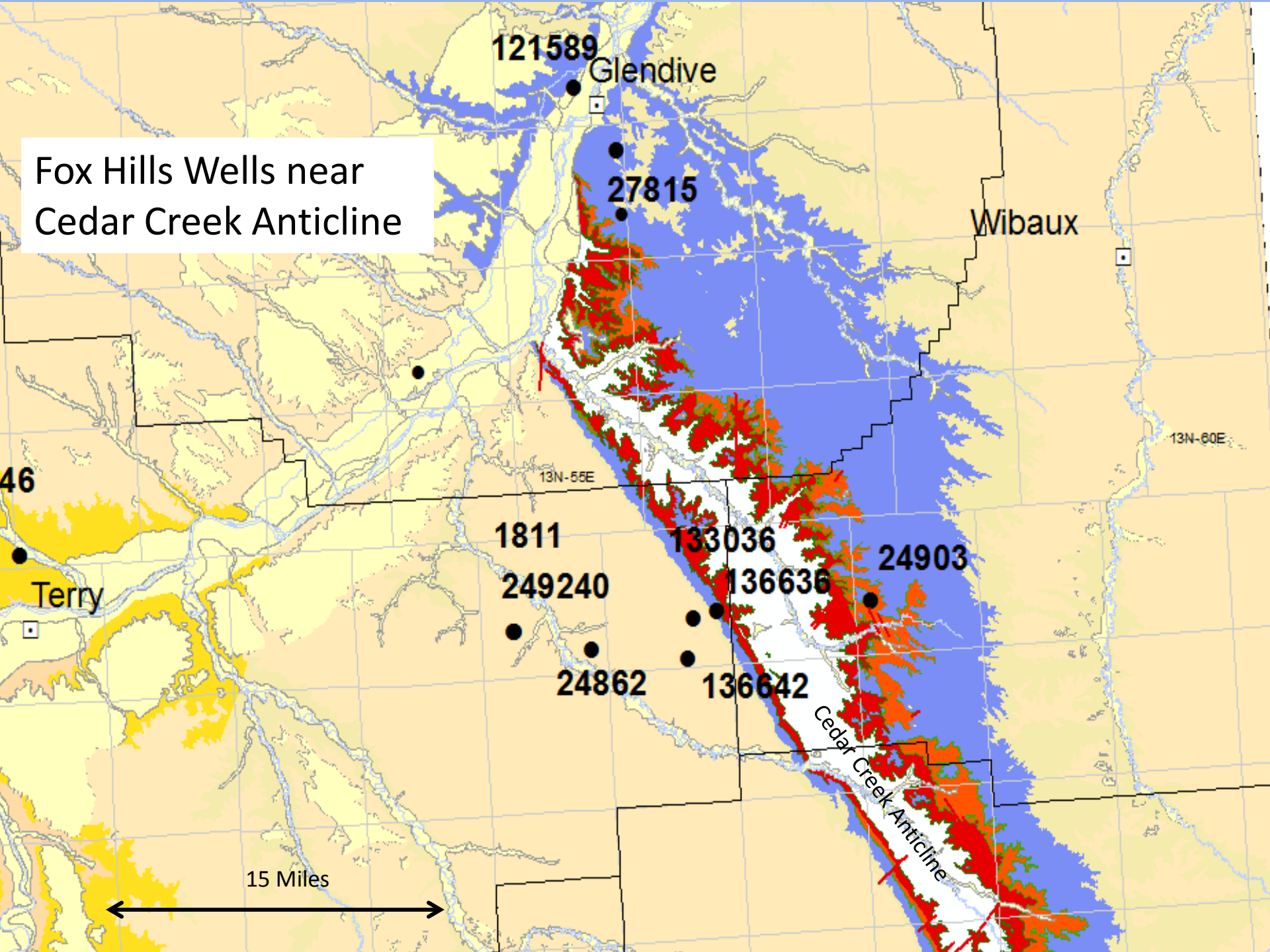

Hell Creek Formation
Fox Hills Formation
Pierre Shale
900 -
1000 -
1100 -
1200 -
1300 -
1400 -
1500 -
Depth (Ft.)
1000 -
1100 -
1200 -
1300 -
1400 -
1500 -
1600 -
Fox Hills-lower Hell Creek aquifer
Hell Creek
Fox Hills
Pierre

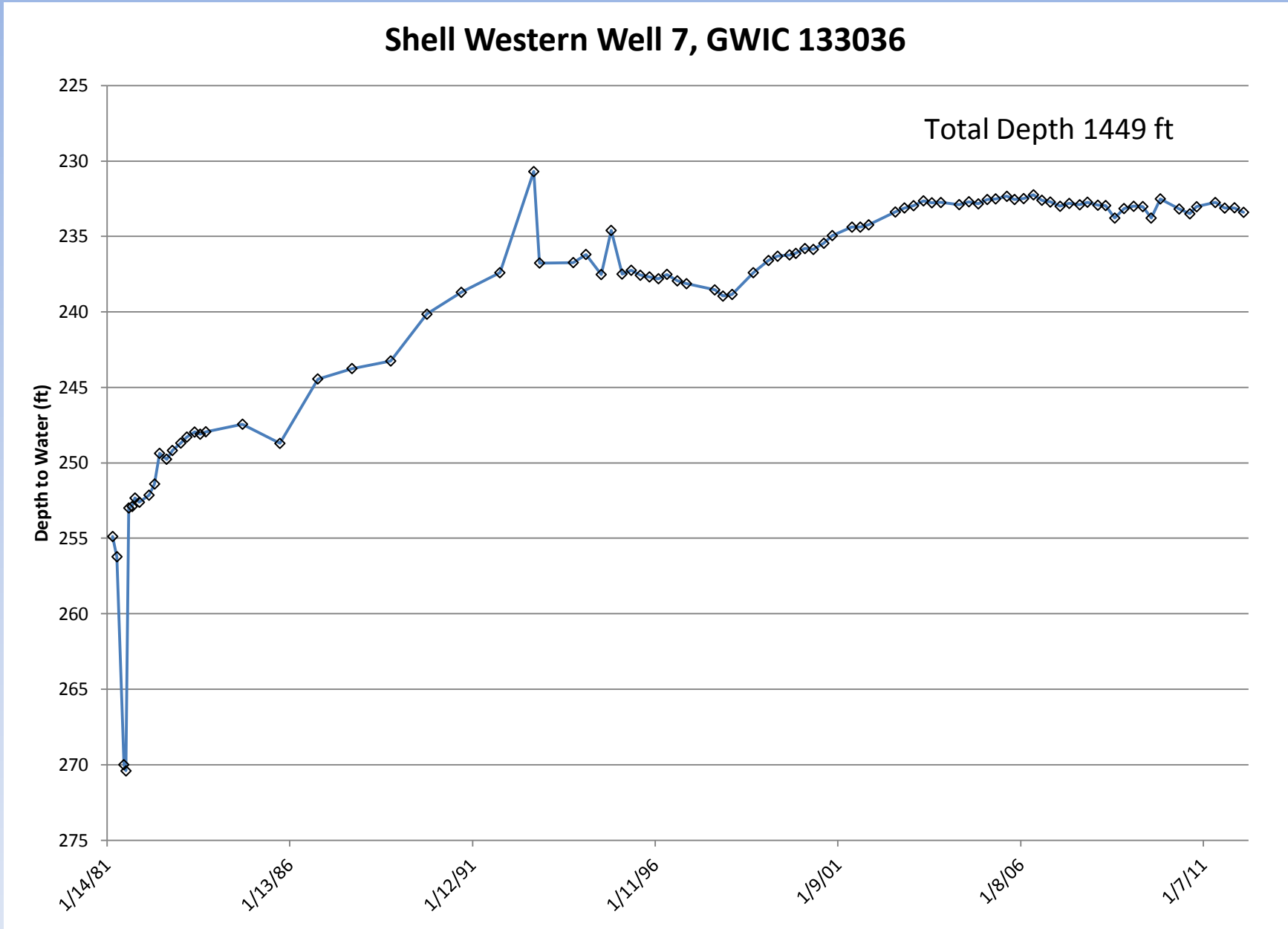
Fox Hills Recharge Area at the northeast side of the Cedar Creek Anticline

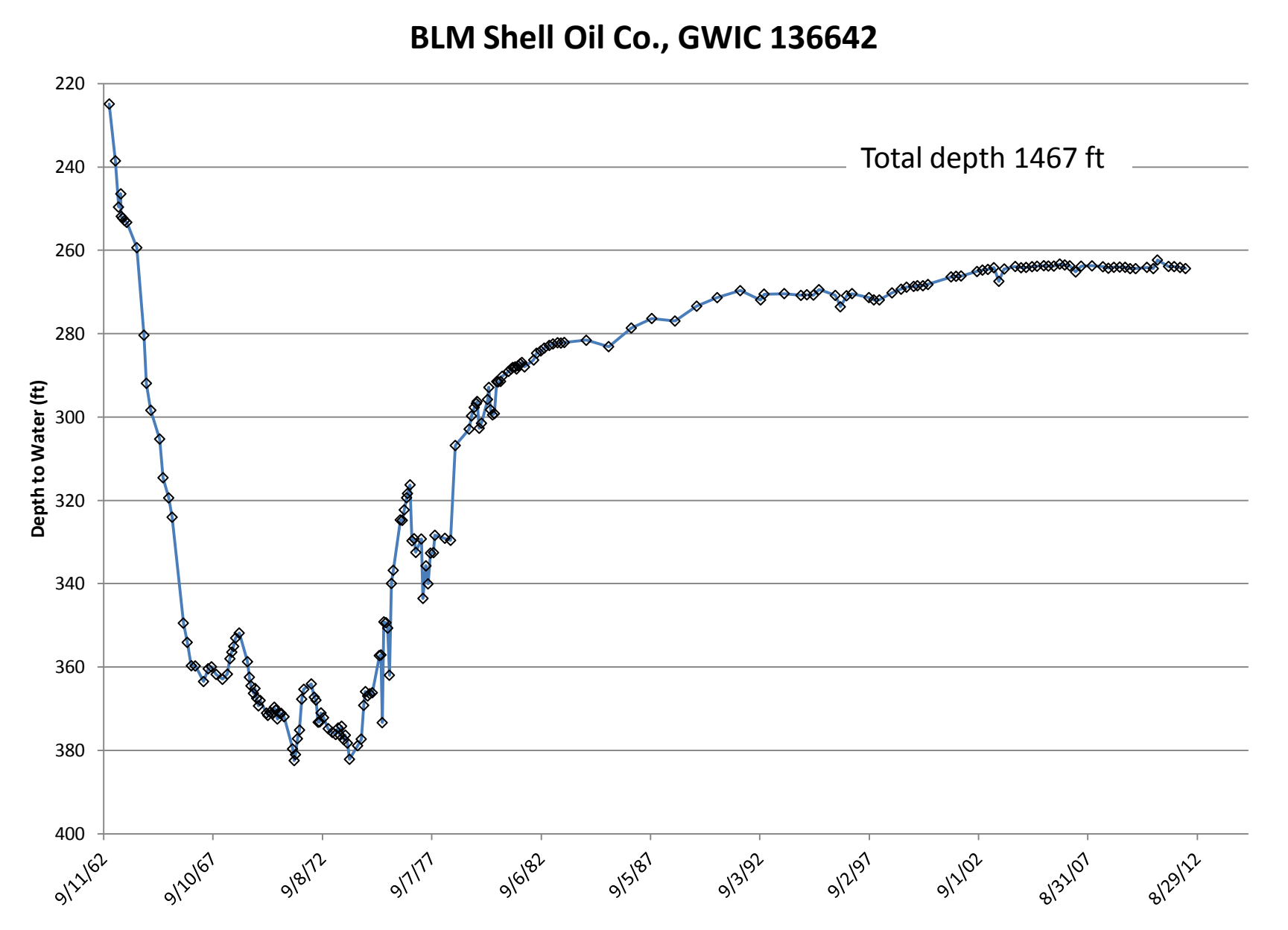
Hell Creek and Fox Hills at the west side of the Cedar Creek anticline, looking northwest towards Glendive
Hell Creek
Fox Hills

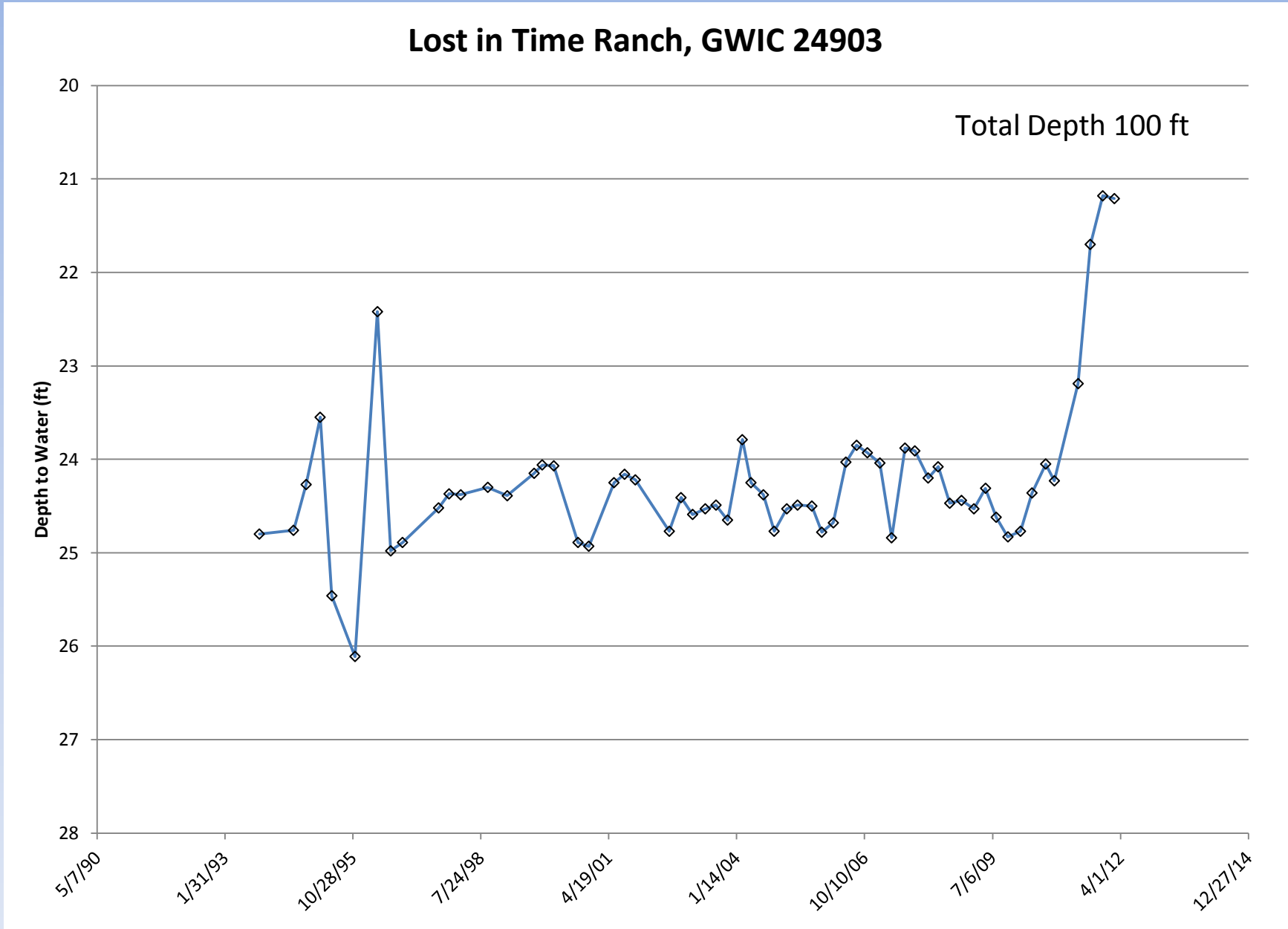
Poorly cemented soft sandstone of the Fox Hills Formation soaking up melt water, January 17th 2013 along the southwest side of the Cedar Creek anticline.



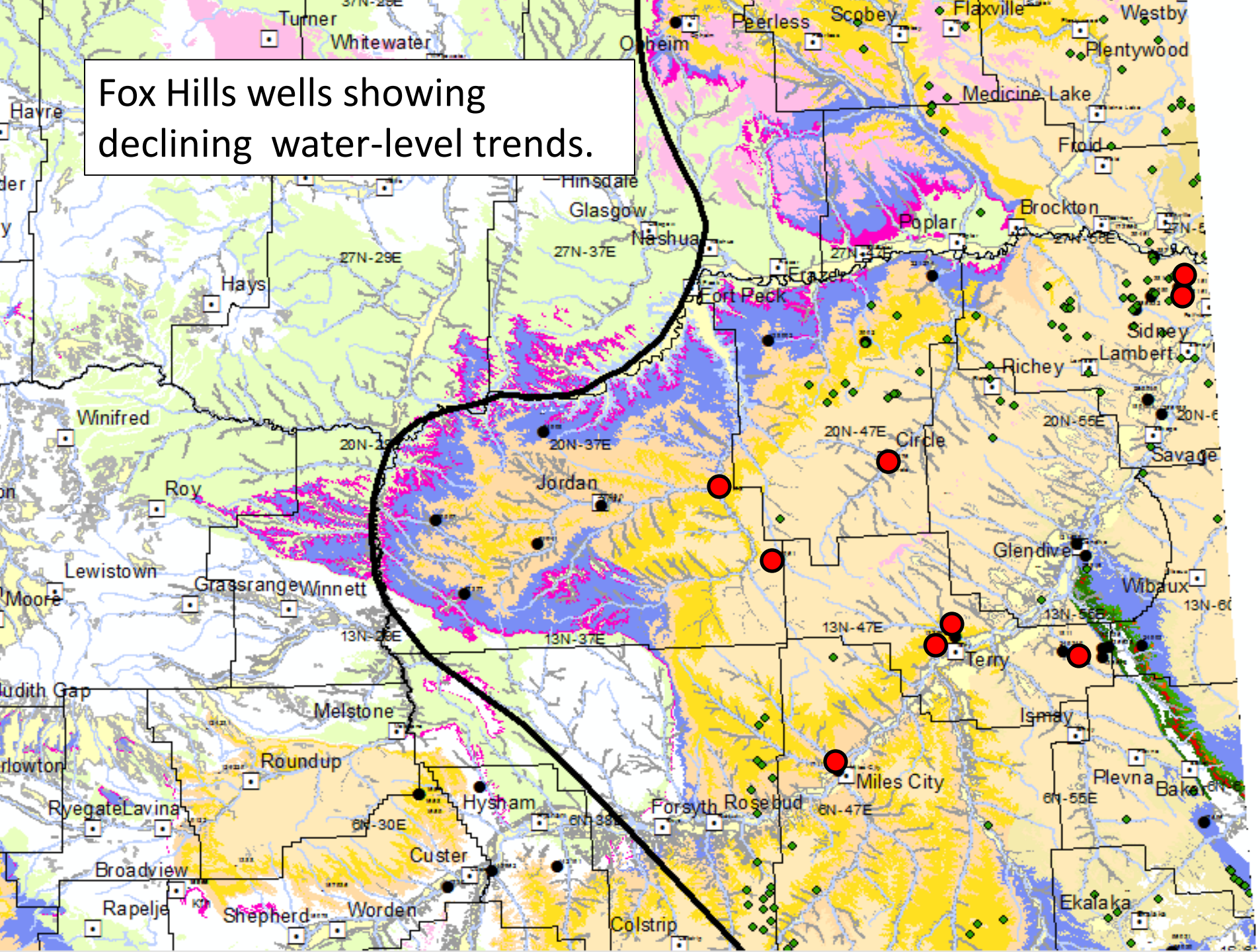

Fox Hills Wells near
Cedar Creek Anticline
121589
Glendive
27815
Wibaux
13N-60E
13N-55E
46
Terry
1811
133036
24903
249240
136636
24862
136642
Cedar Creek Anticline
15 Miles

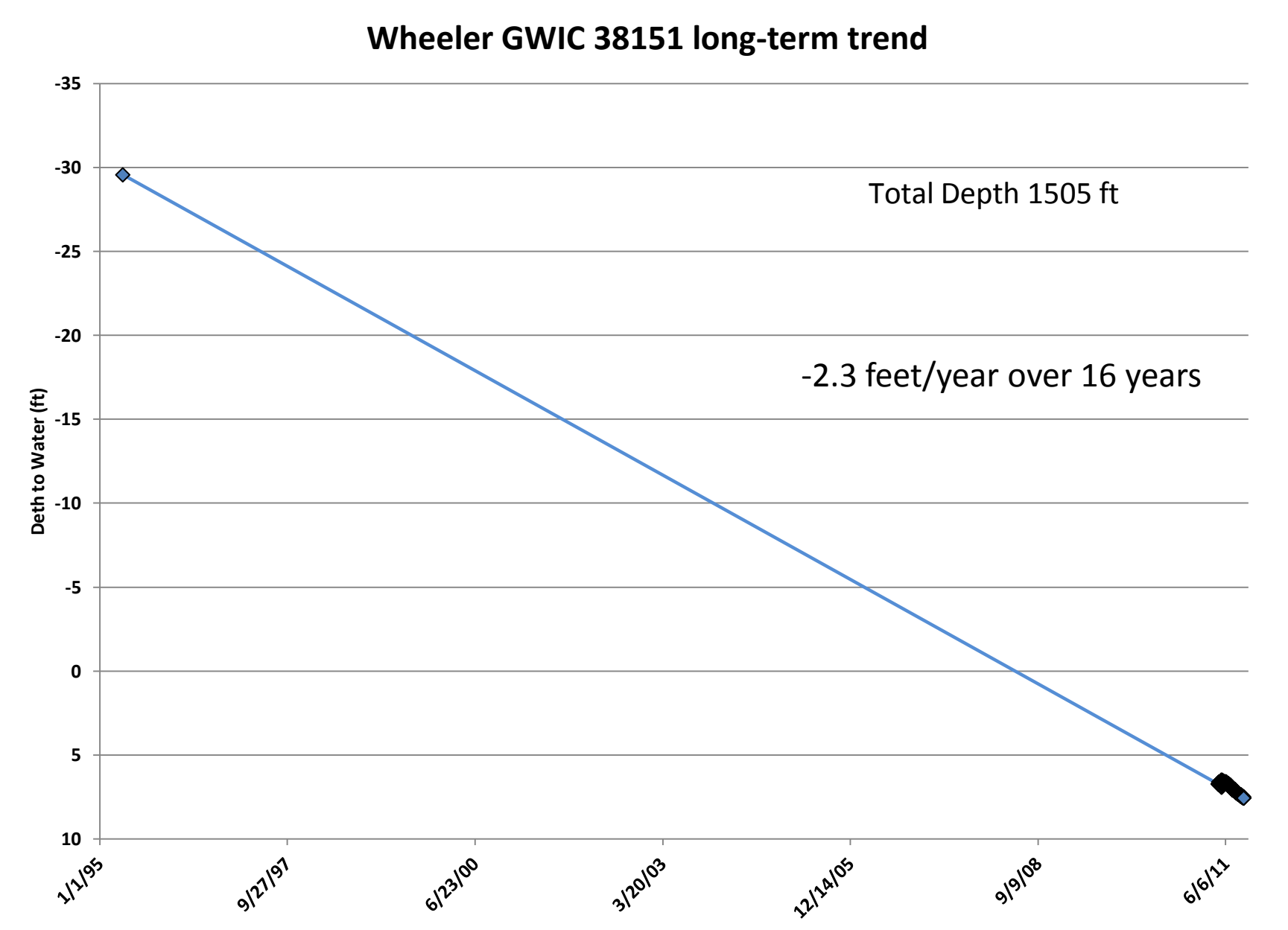

Shell Western Well 7, GWIC 133036
Total Depth 1449 ft
Depth to Water (ft)
225
230
235
240
245
250
255
260
265
270
275
1/14/81
1/13/86
1/12/91
1/11/96
1/9/01
1/8/06
1/7/11


BLM Shell Oil Co., GWIC 136642
Total depth 1467 ft
Depth to Water (ft)
220
240
260
280
300
320
340
360
380
400
9/11/62
9/10/67
9/8/72
9/7/77
9/6/82
9/5/87
9/3/92
9/2/97
9/1/02
8/31/07
8/29/12

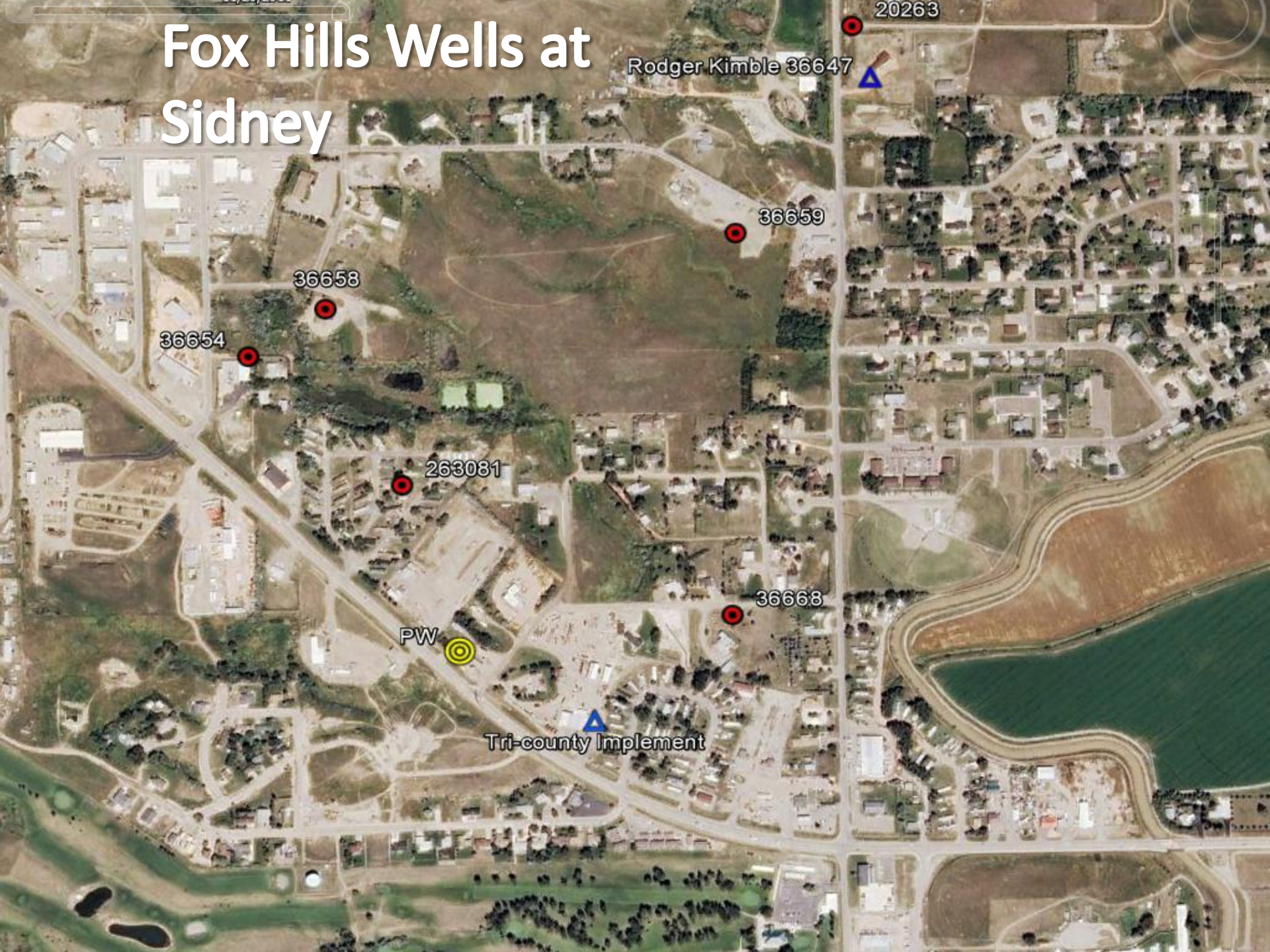

Lost in Time Ranch, GWIC 24903
Total Depth 100 ft
Depth to Water (ft)
20
21
22
23
24
25
26
27
28
5/7/90
1/31/93
10/28/95
7/24/98
4/19/01
1/14/04
10/10/06
7/6/09
4/1/12
12/27/14

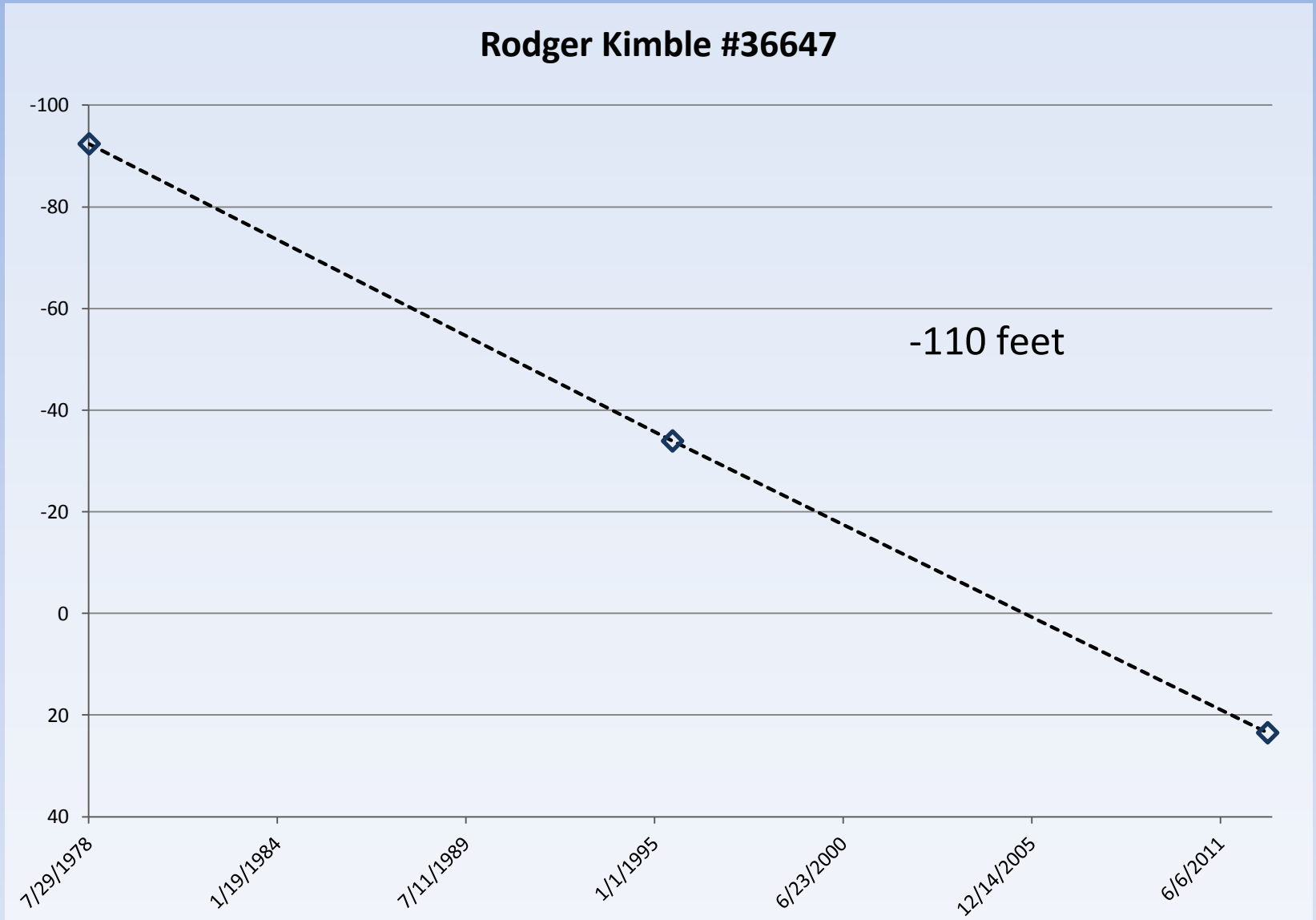
Recharge area near Fort Peck
Reservoir???

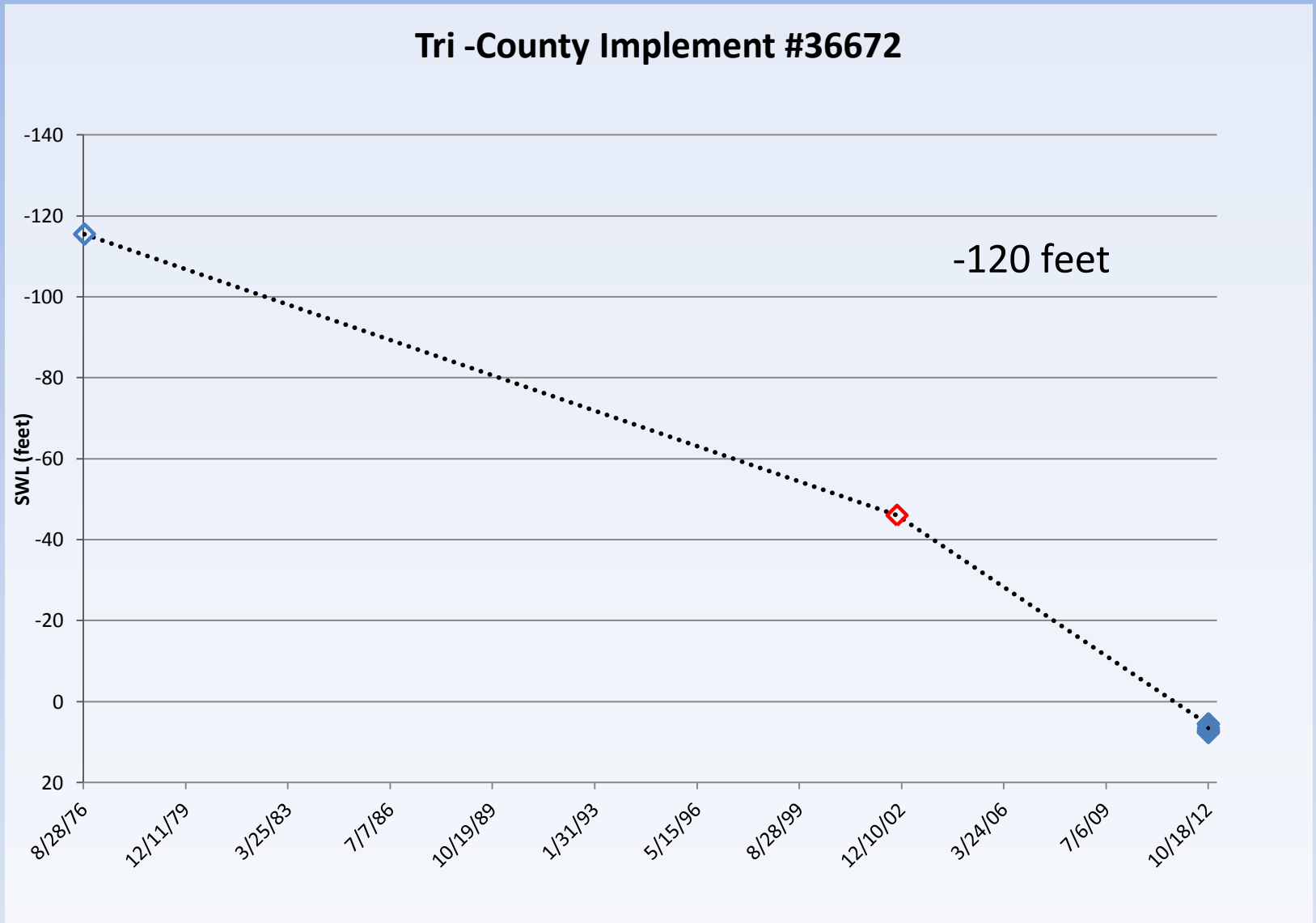

Fox Hills wells showing declining water-level trends.
Turner
Whitewater
Opheim
Peerless
Scobey
Flaxville
Westby
Plentywood
Medicine Lake
Havre
Froid
Hinsdale
Glasgow
Nashua
Brockton
Poplar
27N-29E
27N-37E
Hays
Frazer
Fort Peck
Sidney
Lambert
Richey
Winifred
20N-37E
20N-47E
Circle
20N-55E
Savage
Roy
Jordan
Glendive
Lewistown
Grassrange
Winnett
Moore
Wibaux
13N-37E
13N-47E
Terry
Judith Gap
Melstone
Ismay
Roundup
Miles City
Plevna
Baker
Ryegate
Lavina
Hysham
Forsyth
Rosebud
6N-30E
6N-47E
6N-55E
Custer
Broadview
Rapelje
Shepherd
Worden
Colstrip
Ekalaka

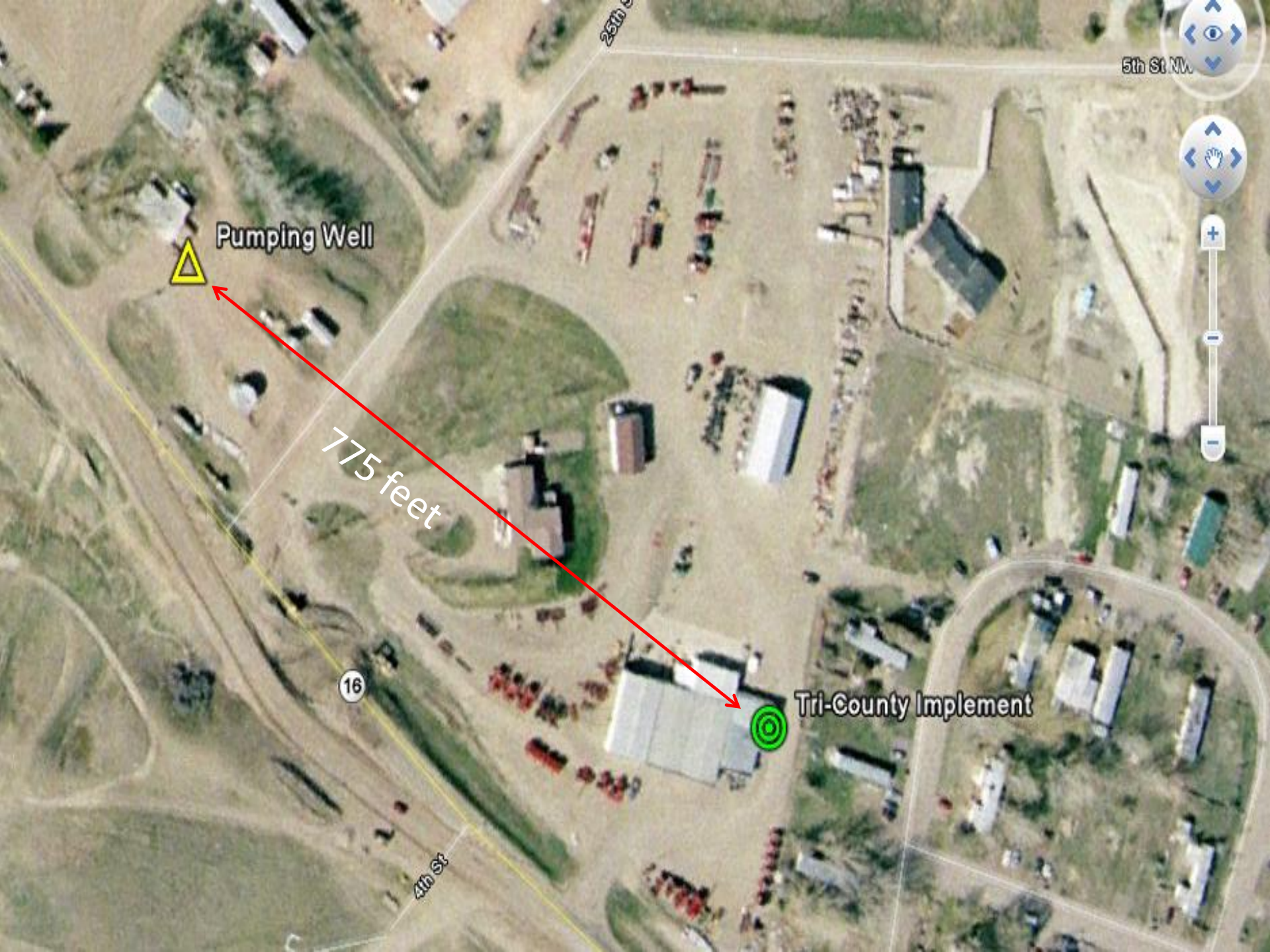

Wheeler GWIC 38151 long-term trend
Total Depth 1505 ft
-2.3 feet/year over 16 years
Deth to Water (ft)
-35
-30
-25
-20
-15
-10
-5
0
5
10
1/1/95
9/27/97
6/23/00
3/20/03
12/14/05
9/9/08
6/6/11

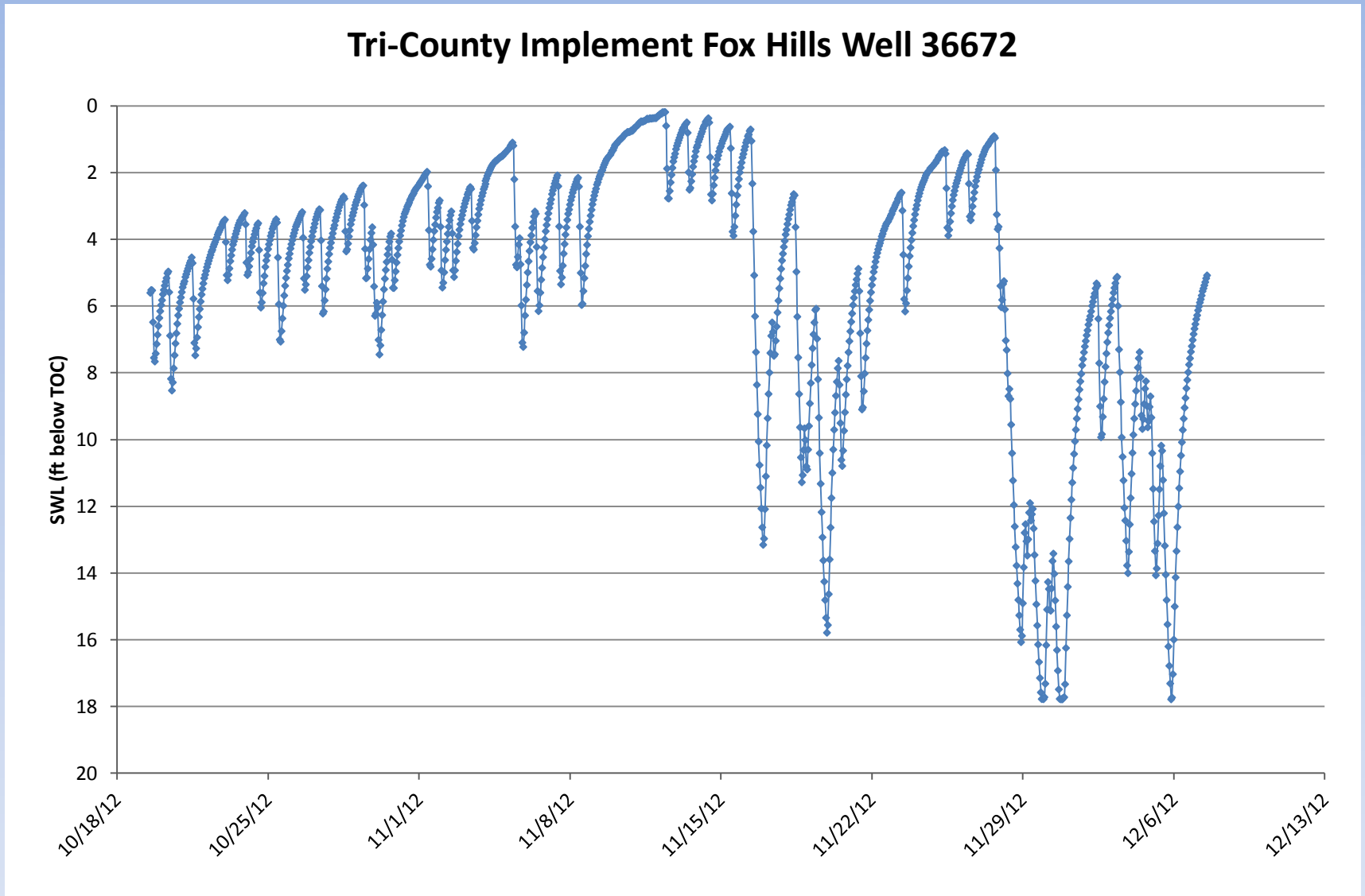
Fox Hills Wells at Sidney



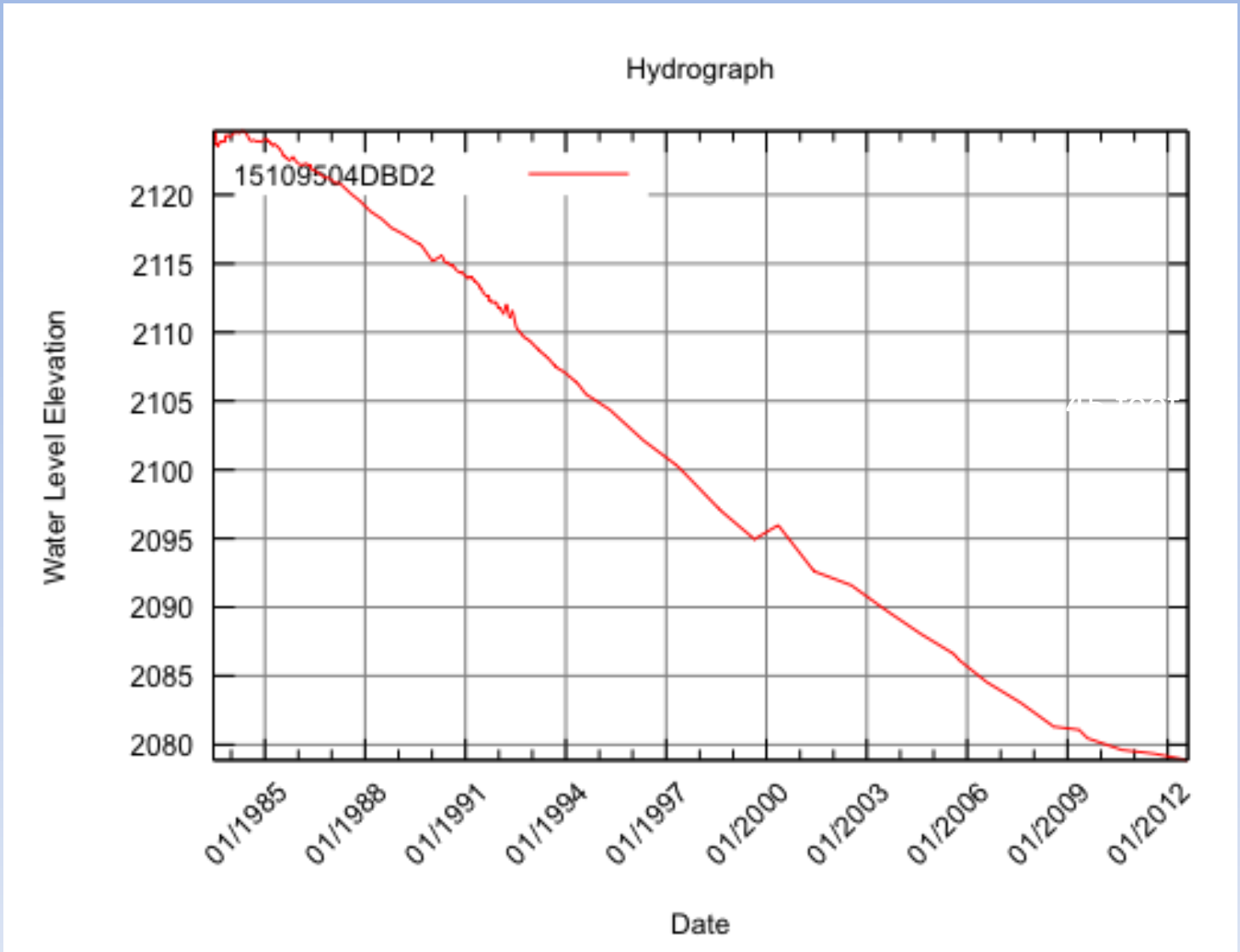

Rodger Kimble #36647
-100
-80
-60
-40
-20
0
20
40
-110 feet
7/29/1978
1/19/1984
7/11/1989
1/1/1995
6/23/2000
12/14/2005
6/6/2011


Tri -County Implement #36672
-120 feet
SWL (feet)
-140
-120
-100
-80
-60
-40
-20
0
20
8/28/76
12/11/79
3/25/83
7/7/86
10/19/89
1/31/93
5/15/96
8/28/99
12/10/02
3/24/06
7/6/09
10/18/12


Pumping Well
775 feet
Tri-County Implement
16
4th St
5th St NW


Tri-County Implement Fox Hills Well 36672
SWL (ft below TOC)
0
2
4
6
8
10
12
14
16
18
20
10/18/12
10/25/12
11/1/12
11/8/12
11/15/12
11/22/12
11/29/12
12/6/12
12/13/12

ND Well McKenzie County, 63 miles east of Sidney

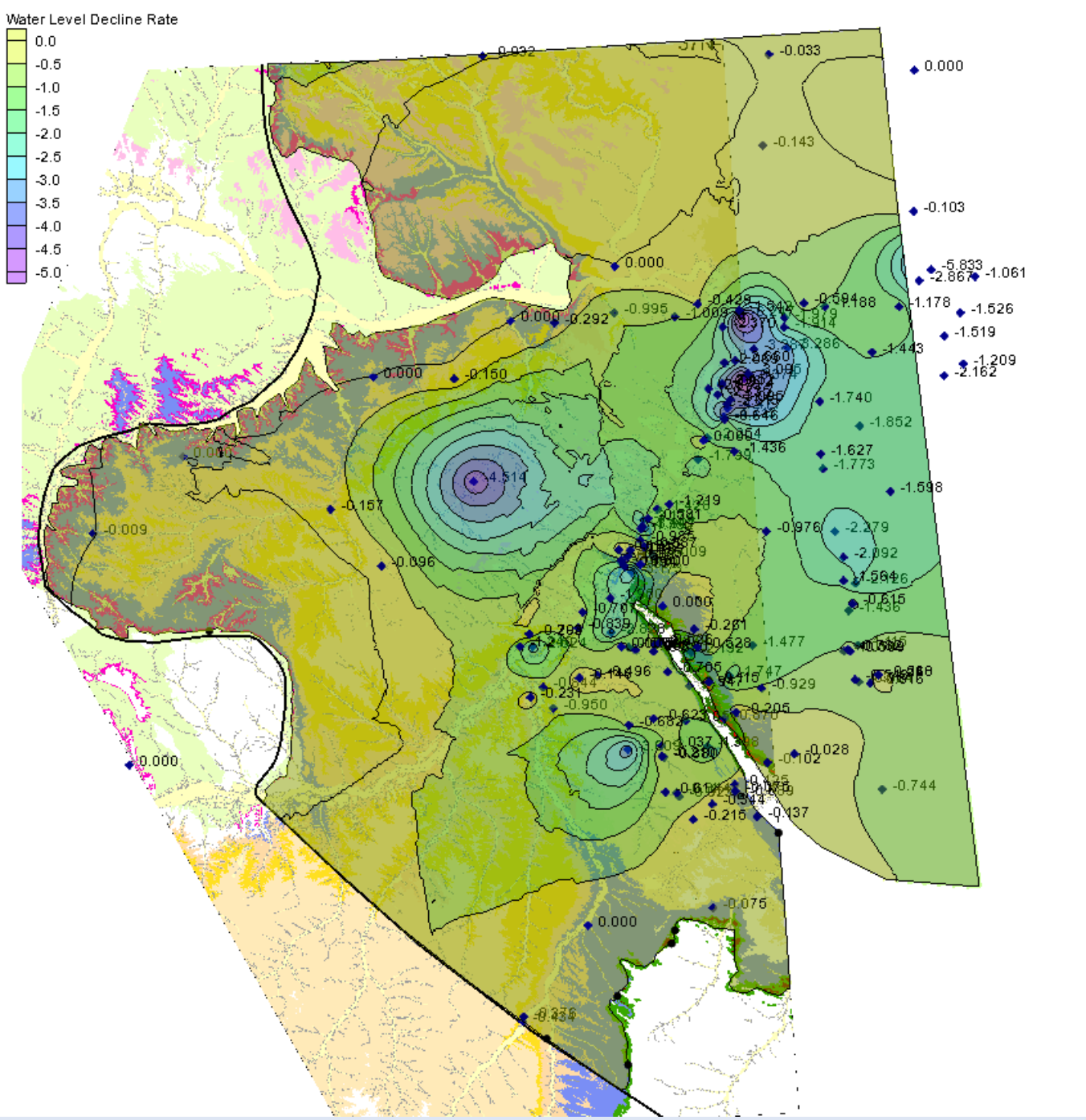


From ND State Water Commission

Numerical Modeling of the Fox Hills/Hell Creek Aquifer

- The goals of the MODFLOW based groundwater flow model are to:
  - Estimate and simulate pre-decline water levels
  - Simulate current water levels
  - Use transient simulations to determine the current level of use given a range of recharge rates.
  - Simulate the water-level changes with increased use.

Interpolated Water-level Decline Rates feet/year



Summary of the Study Findings

- Wells in the recharge area and in areas with little use show no significant water-level decline.
- The recharge area wells monitored show slow response to recharge if any.
- The greatest water-level declines occur along Yellowstone River corridor from Miles City to North Dakota.
- Water levels in many wells have declined at rates similar to those measured in North Dakota.
- Wells in the discharge areas show little seasonal water-level change.

Agriculture
+ Industrial Uses
RECHARGE
Fox Hills/Hell Creek
Water Balance ?

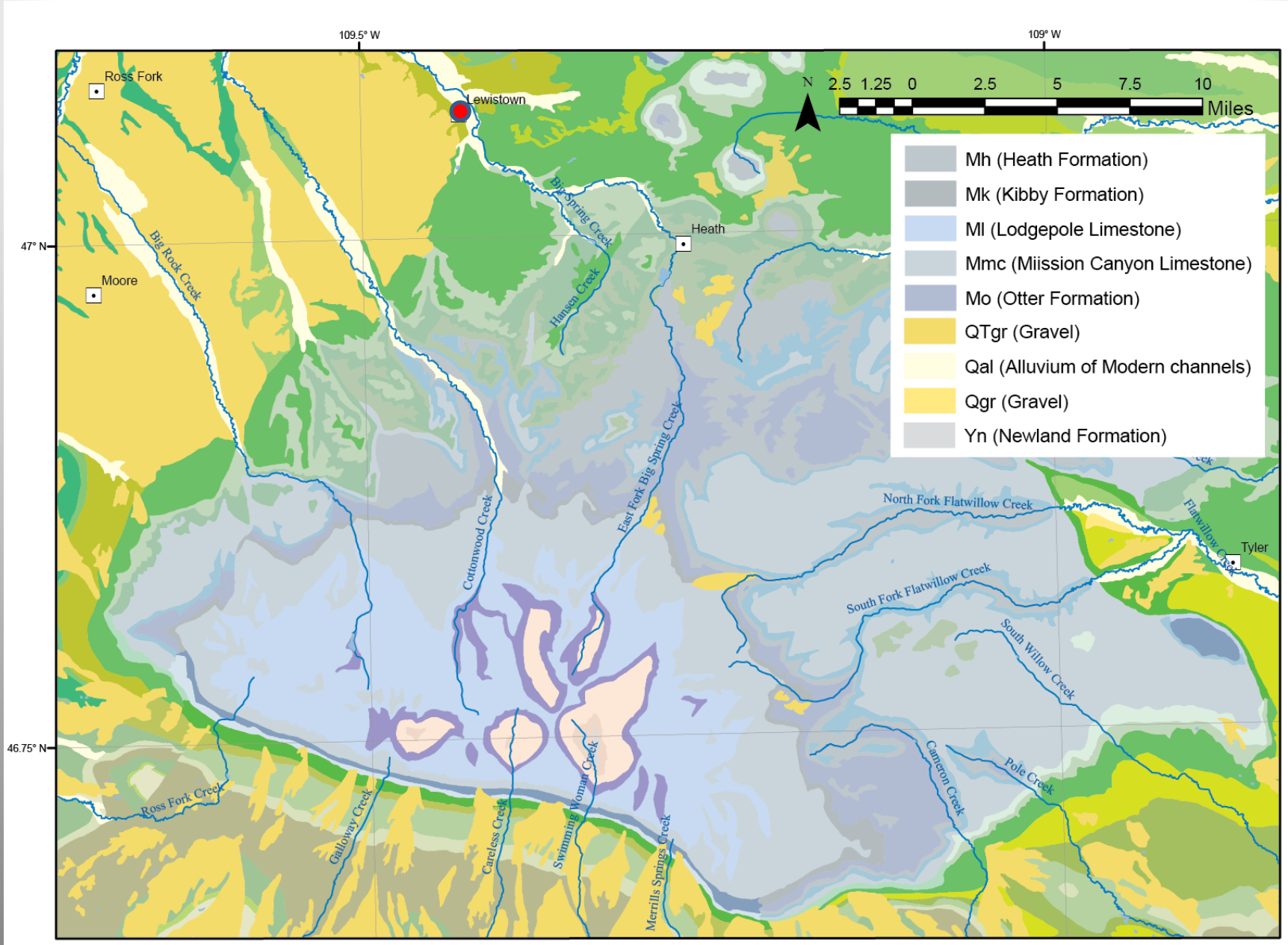
Questions?

Thanks to :
Kimberly Fischer and the ND State Water Commission
Julie Goss and Richland County Conservation District
MBMG GWIP Program and INL for funding.

Sustainable Water Supplies from the Madison Aquifer, Central Montana

Montana Bureau of Mines and Geology

Lewistown area geology



Field Work
Near Big Springs

Stream Flows

8-10-12

Big Springs
116 CFS

Lehman Spring
41 CFS

Does not include city use

Samples

Water quality Samples

Big Spring samples

200345 -- sampled 7/15/2011 1:47:00 PM
1983Q0249 -- sampled 6/8/1983 8:00:00 AM
1972Q5010 -- sampled 10/25/1972
1967Q5010 -- sampled 4/7/1967
1966Q5001 -- sampled 1/1/1966
1959Q5001 -- sampled 4/1/1959
1939Q5001 -- sampled 4/3/1939
1935Q5001 -- sampled 9/14/1935
1934Q5001 -- sampled 1/9/1934

Lehman Spring samples

200346 -- sampled 7/15/2011 2:40:00
1938Q5001 -- sampled 4/18/1938

Middle Spring at Big Springs Fish Hatchery

202955 -- sampled 10/19/2012 3:50:00 PM

Oxygen and Deuterium Isotopes

Used to determine groundwater recharge sources

Precipitation is influenced by meteorological processes and particularly by the temperature, elevation, and latitude of the rain or snowfall event. (processing data)

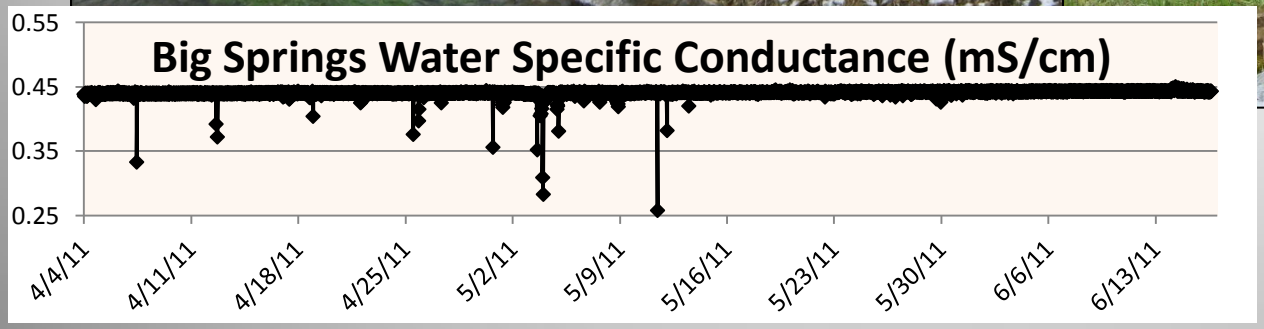
Tritium

Tritium concentrations in groundwater can be used to differentiate relative ages of groundwater and identify potential recharge sources.
The age of groundwater is defined as the time elapsed since the water was last in contact with the atmosphere and entered the aquifer. (processing data)

Manta data logger
Specific conductance hourly

Big Springs

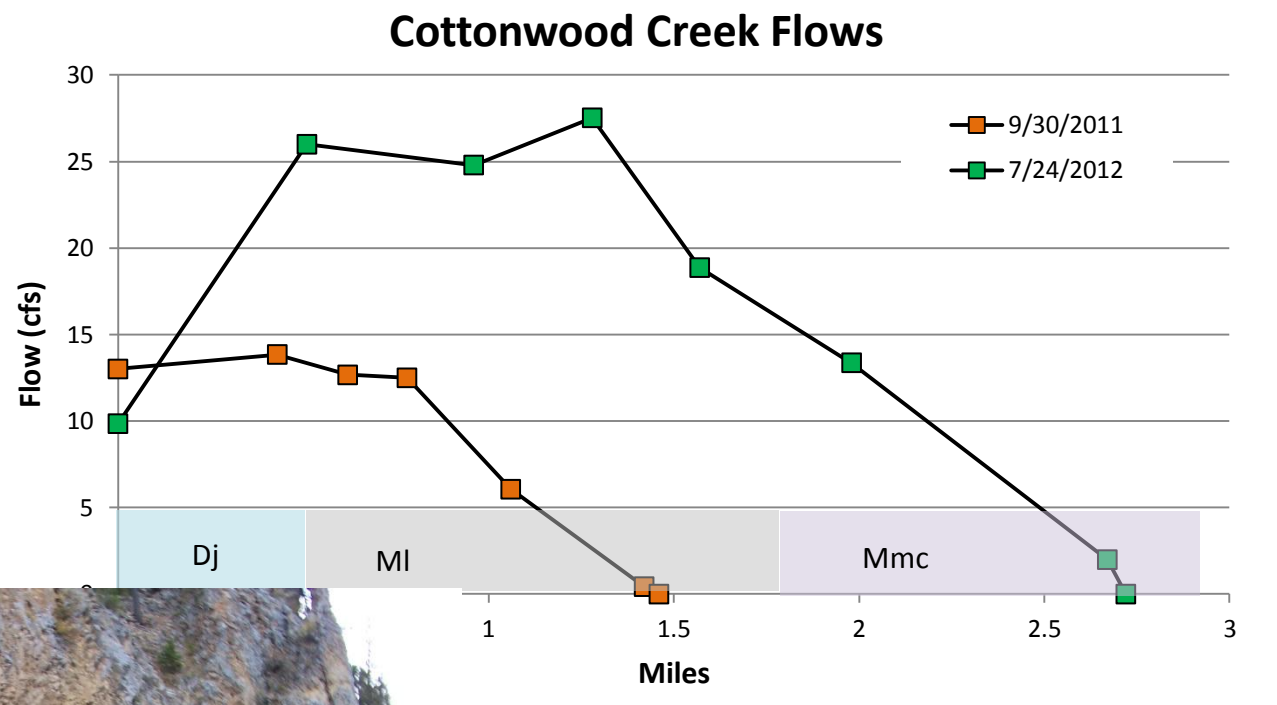
Lehman Spring



Specific conductance stayed constant throughout the period of record. The point drops are probably due to fresh water coming into the system from precipitation events.

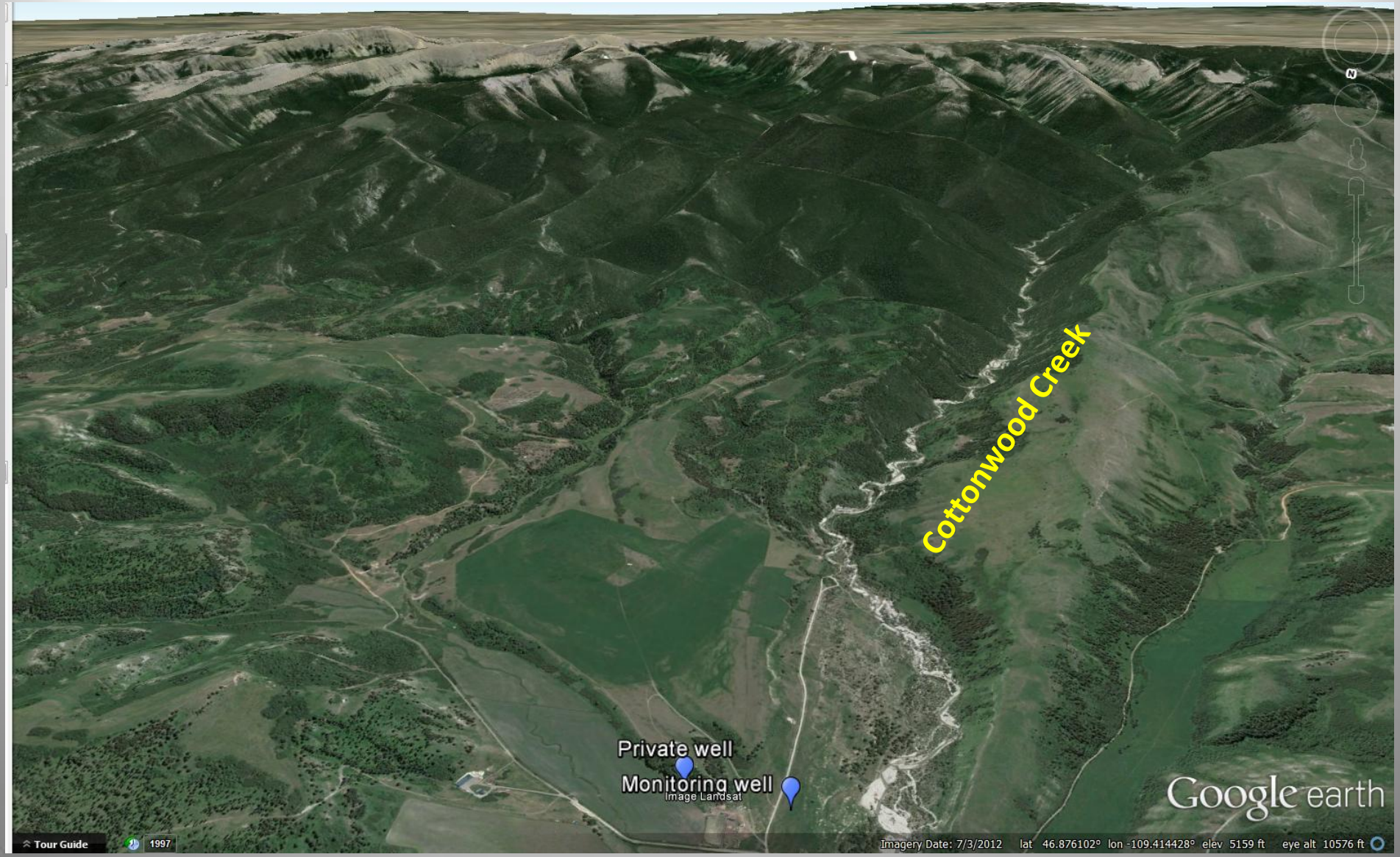
Cottonwood Creek Area

Stream flows



Monitoring well location

S

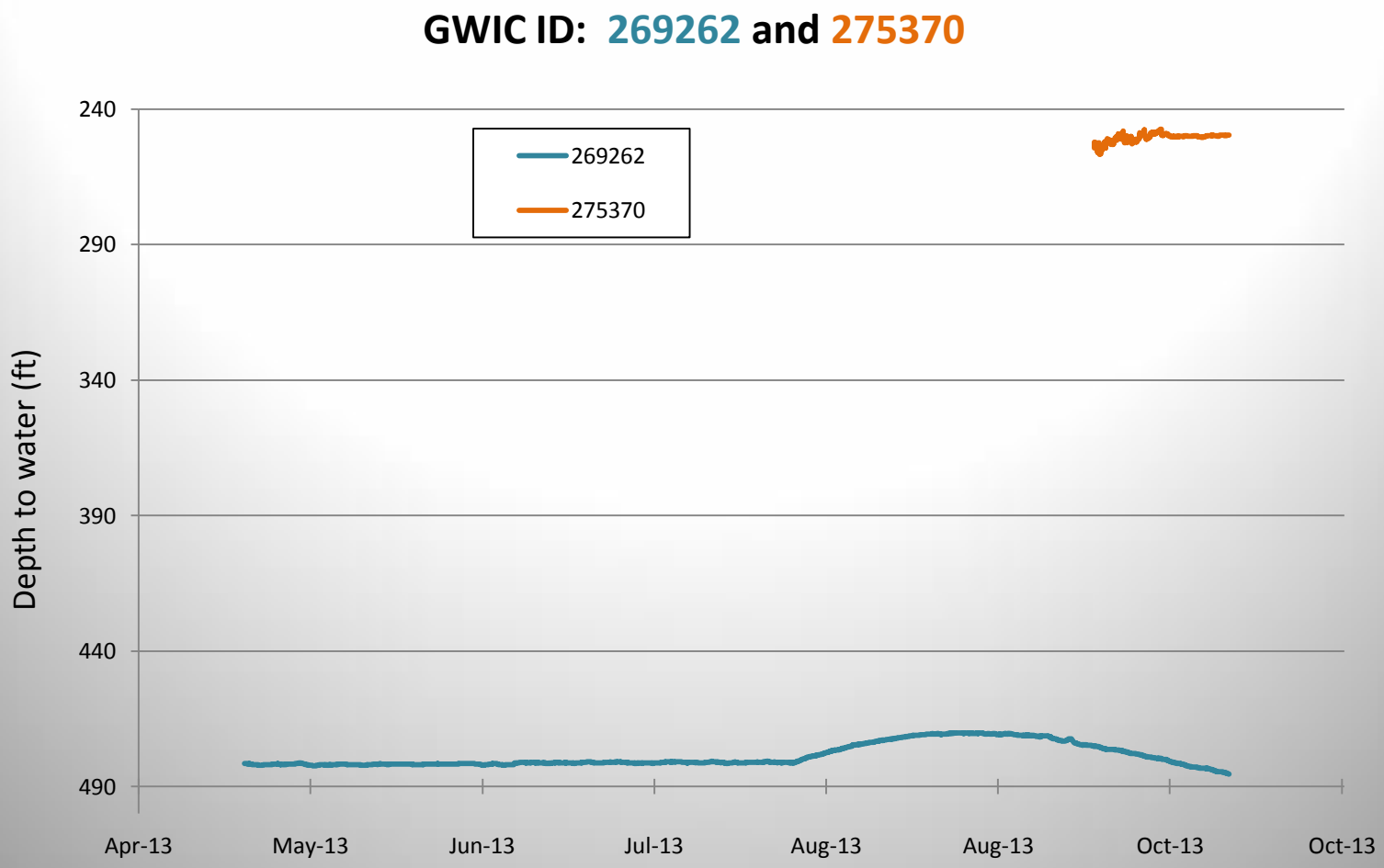


Monitor Well Installation at the Base of the Big Snowy Mountains

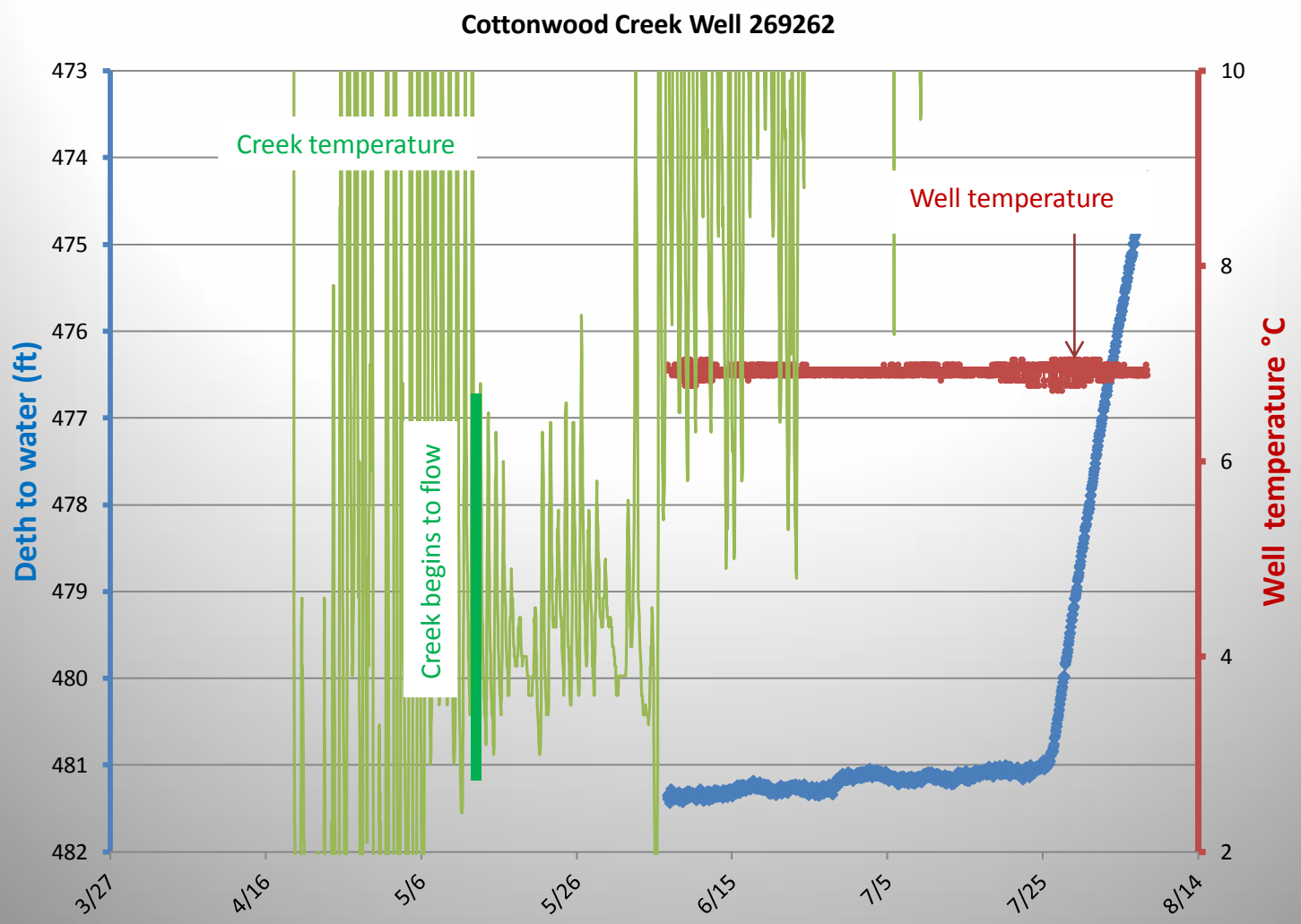
From	To	Description
0	2	TOP SOIL
2	8	WASHED GRAVEL
8	27	BROWN CLAY AND GRAVEL
27	55	WASHED GRAVEL SOME SAND
55	58	BROWN AND ORANGE WEATHERED SANDSTONE
58	61	RED SANDSTONE
61	70	RED SHALE
70	74	TAN SANDSTONE 5 GPM
74	110	RED SHALE
110	120	TAN SHALE
120	125	TAN SANDSTONE 30 GPM
125	189	RED SHALE
189	200	DARK GRAY LIMESONE
200	500	VARIOUS LIMESTONES

Lost circulation ~415

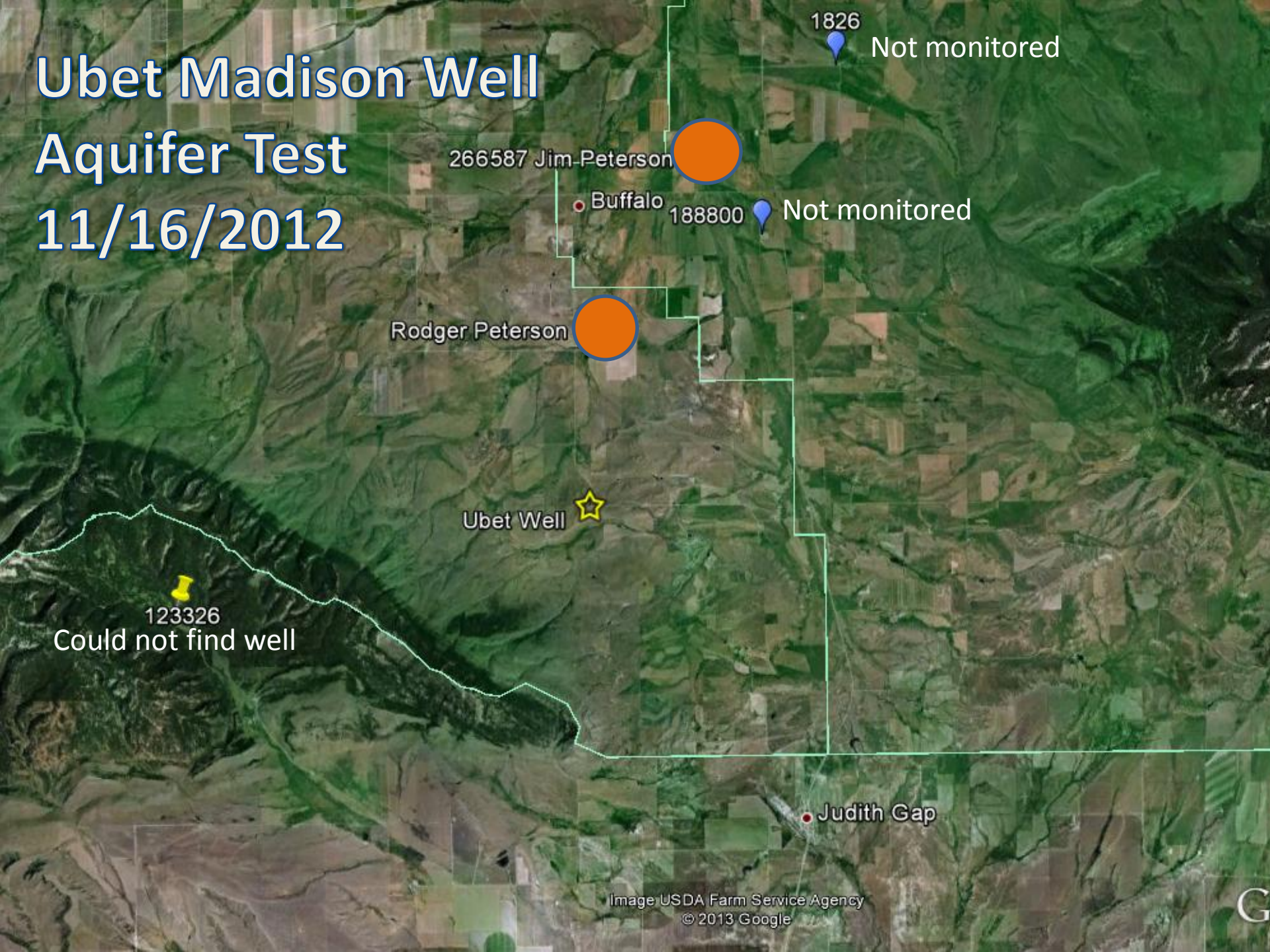
Dual completion well



Temperature comparisons of Cottonwood Creek and monitoring well



Central Montana Regional Water Authority

Ubet (test well)

Ubet Madison Well Aquifer Test 11/16/2012