Information Support for Groundwater Management in the Wisconsin Central Sands, 2016-2017

A Report to the Wisconsin Department of Natural Resources

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Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin – Stevens Point / Extension

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University of Wisconsin-Stevens Point
Center for Watershed Science and Education

UW Extension
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1. INTRODUCTION

This report summarizes data and information gathering activities that supported groundwater management in the Wisconsin central sands for the period July 2016 through June 2017. The report supplements the previous works of Clancy et al. (2009) and Kraft et al. (2010, 2012a, 2012b, 2014, and 2016), which summarized important hydrologic literature on the central sands, provided documentation for groundwater flow models, and estimated pumping diversions and drawdowns from monitoring data. These previous works concluded groundwater pumping in the central sands is substantially impacting the region's water levels and streamflows, and that the impacts are not explainable by phenomena such as an unprecedented drought. The conclusions about groundwater pumping impacts reinforced prognostic work by Weeks et al. (1965) and Weeks and Stangland (1971), and in turn were reinforced by more recent analyses (Bradbury et al. 2017).

The Wisconsin central sands is an extensive (about 2,506 mi^2), though loosely-defined, region characterized by a thick (often > 100 ft) mantle of coarse-grained sediments overlying low permeability rock, and landforms comprising outwash plains and terminal moraine complexes associated with the Wisconsin Glaciation. The region lies between the headwater streams of the Fox-Wolf and Central Wisconsin Basins, and contains over 100 lakes exceeding 20 acres, and over 600 miles of headwater streams (Figure 1-1 and Figure 1-2).

The central sands contains Wisconsin's greatest density of high capacity wells, about 2,500[1] in the seven counties that this study area overlaps (Figure 1-3). High capacity well pumping in the region amounted to 28-30% of Wisconsin's total; 84-87% was used for agricultural irrigation (for the typical years of 2013 and 2014; WDNR 2015). Other uses (municipal, industrial) are small and limited geographically, but can have locally significant surface water impacts (Clancy et al. 2009). Growth in high capacity irrigation well numbers and pumping has been rapid, minimally managed, and, except for a brief period between the legal decision "*In the matter of two high capacity wells*" of September 2014 (Boldt 2014), and the Wisconsin Department of Natural Resources (WDNR) adoption of a Wisconsin Attorney General's opinion (WDOJ 2016) in June 2016.

Objectives and brief description of how objectives were addressed

The goal of this project was to provide and enhance monitoring support for management decisions regarding groundwater pumping in the Wisconsin central sands. The specific objectives and the work to achieve them is discussed below:

[1] High capacity wells for these purposes are defined as wells with a stated maximum pumping capacity of 70 gallons per minute (gpm) or more. Wells with an unknown maximum were also included if the total annual pumping exceeds 365 days, (or 153 days for irrigation wells) of 70 gpm or more.

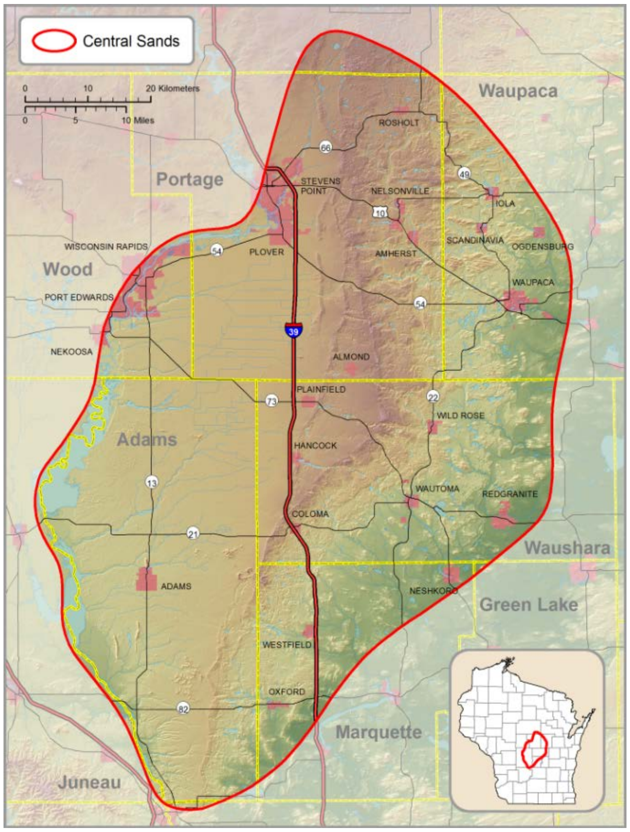

Figure 1-2. The Wisconsin central sands region with selected municipalities and roads.

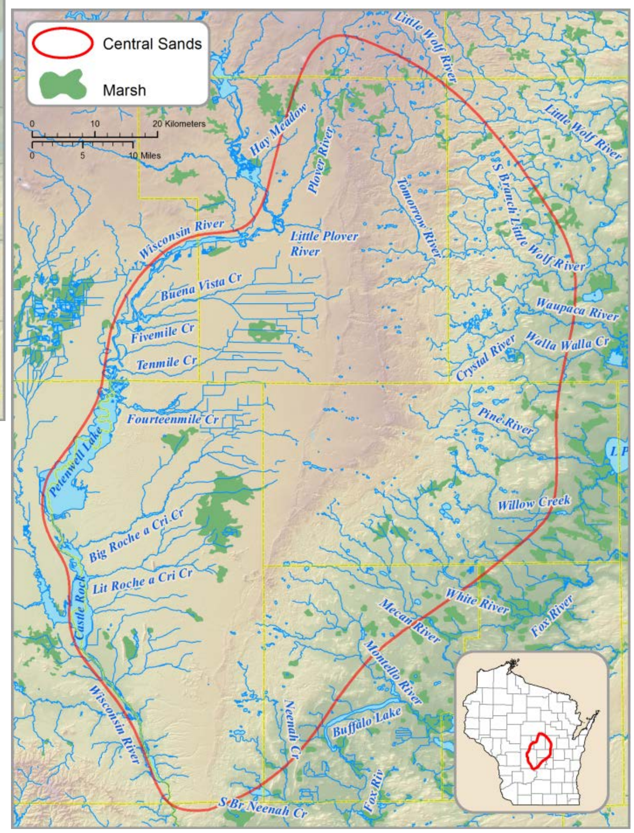

Figure 1-3. Hydrography of the Wisconsin central sands region.

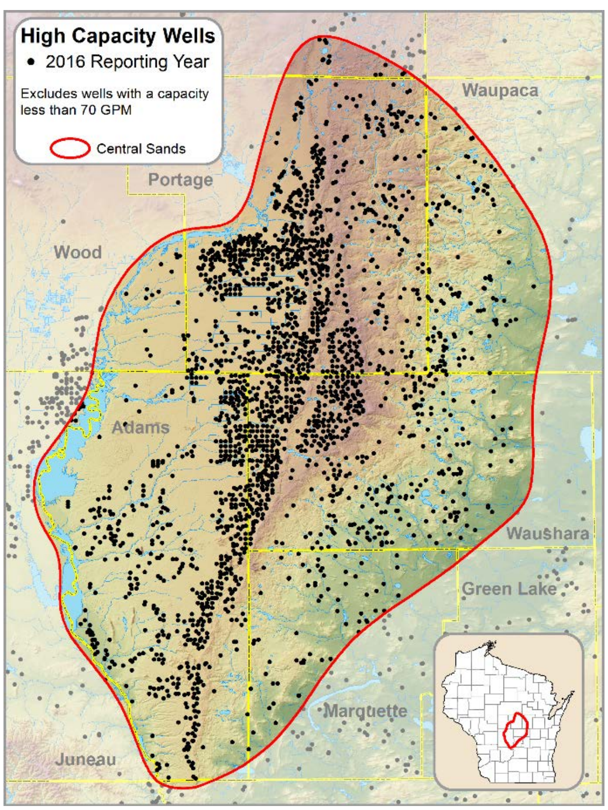

Figure 1-1. Location of high capacity wells in the Wisconsin central sands.

Objective 1. *Continue measuring baseflow at 32 existing stream sites and groundwater elevations at three monitoring wells; provide data to USGS and WDNR for archiving.*

Baseflow measurements proceeded mostly according to plan at the 32 existing stream sites and at three monitoring wells (USGS site names: PT-22/10E/32-1320, PT-23/10E/18-0276, and PT-24/10E/28-1487). Lateral coordinates and elevations for the 32 existing streamflow sites were determined using Real Time Kinematic (RTK) technology.

Baseflow discharges and RTK data have been electronically transferred to WDNR. Groundwater measurements have been uploaded to the USGS database.

Additional detail on baseflow measurements is reported in Section 2. We gratefully acknowledge the loan of a Topcon GR-5 receiver and a FC-200 electronics data collection unit by the USGS Wisconsin Water Science Center in Middleton, WI.

Objective 2. *Select and monitor baseflow monthly at up to 15 new headwaters sites chosen in consultation with WDNR Water Use Section and Monitoring Section.*

The WDNR Water Use Section provided a list of 16 suggestions for new baseflow monitoring sites, of which 15 were chosen for baseflow measurements in 2016-2017 (August 4, 2016 letter from Adam Freihoefer to George Kraft; Appendix A). Additional detail is reported in Section 2.

Objective 3. *Provide training and quality control services for the central sands volunteer baseflow monitoring network.*

A fledgling volunteer monitoring partnership has emerged in the central sands, engaging WDNR, county conservation offices, citizen volunteers, and UW-Stevens Point staff (UWSP). The effort has produced an impressive amount of high-quality data, while demonstrating the challenges of recruitment, keeping volunteers engaged, and producing data at regular measurement intervals (particularly in winters).

Three trainings comprising a half-day, hands-on curriculum were delivered successfully in July 2016, using OTT MF Pro flow meters. The trainings involved three new volunteers from Adams County, a new Adams County staff member, and four new volunteers from Portage County. Two current volunteers in Wood County received refresher training.

Quality control services are discussed in Section 3.

Objective 4. *Recommend 3-5 locations for additional water level monitoring to serve the needs of the WDNR Water Use Section, in consultation with the Wisconsin Groundwater Level Monitoring Network.*

UWSP project staff prepared potential criteria for new monitoring well locations (Appendix B) and reviewed WDNR Water Use Section staff recommendations (Appendix C). These were presented to Department staff in Fall 2016.

2. BASEFLOW MEASUREMENTS ON PRE-EXISTING AND NEW STREAM SITES

New stream baseflow locations

Fifteen new baseflow monitoring sites were selected in consultation with WDNR's Water Use Section and added to the roster of 32 pre-existing sites.

Baseflow measurements

Stream discharges during baseflow periods were measured using velocity-area methods (Turnipseed and Sauer 2010, Rantz et el. 1982, WDNR 2016). Velocities were determined using a SonTek FlowTracker Handheld Acoustic Doppler Velocimeter (SonTek 2007). Baseflow conditions were determined, whenever possible, as a period when at least 5 days had elapsed since precipitation events, and when USGS real time gauges exhibited apparent baseflow conditions.

Results

The 15 new baseflow monitoring sites were added to the inventory which includes the 32 existing active sites for 2016-2017 and a few sites that were measured at one time but discontinued for various reasons (Figure 2-1, Table 2-1).

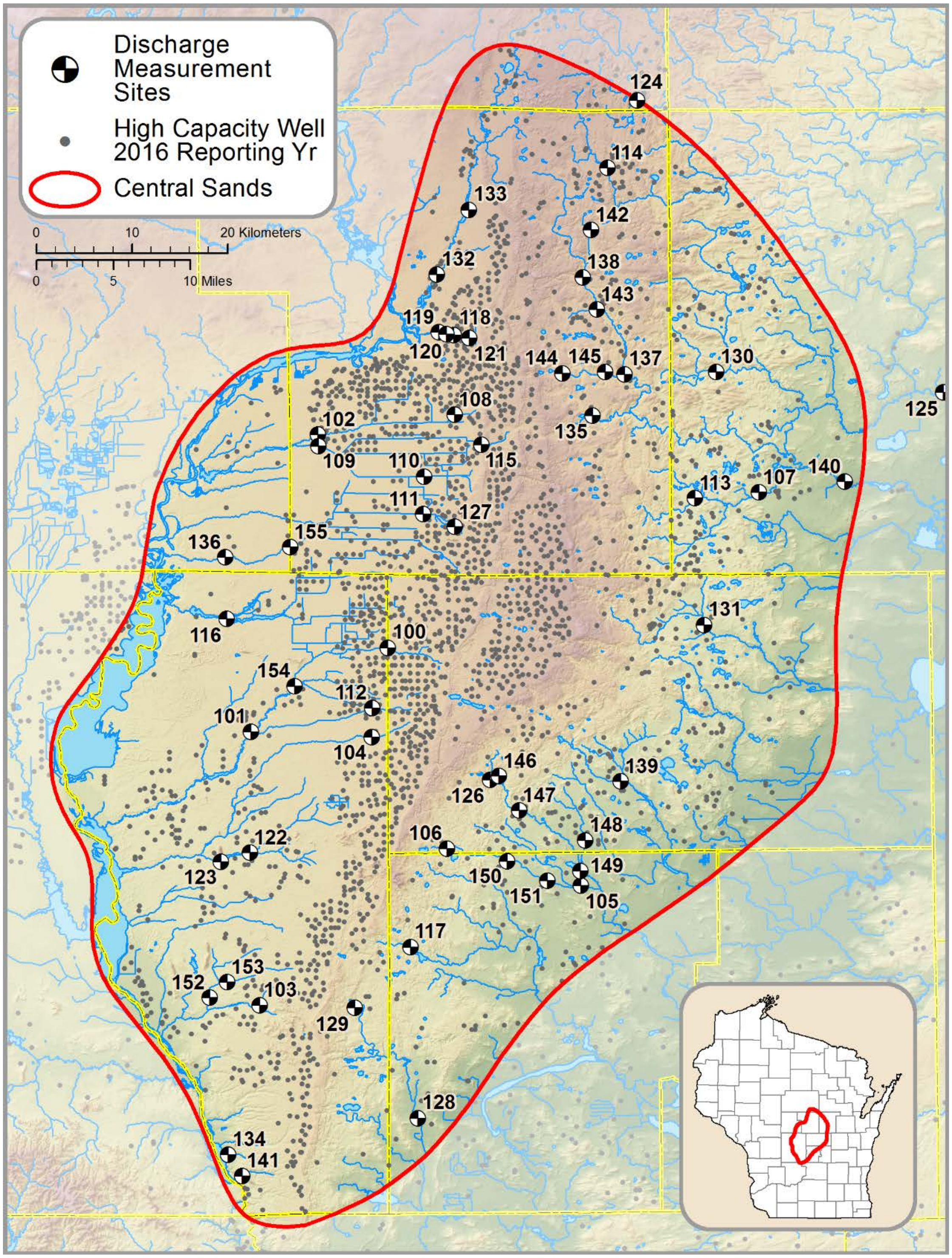

Figure 2-1. Discharge measurement sites from Kraft et al. 2010, most of which were continued for this study and fifteen new sites.

Table 2-1. Baseflow measurement sites. The table includes sites from Kraft et al. (2010), onto which fifteen new sites (Map Locations 142-155) have been added. Sites not included in 2016-2017 efforts are shaded. Also indicated is whether sites had measurements in the USGS Daily or Spot record or in the Fox-Wolf project record (Kraft et al. 2008).

Map Location	Project Site Name	USGS Site Type[1]	USGS Years	Fox-Wolf Site?	Comments
100	Big Roche-A-Cri @ 1st Ave	Near Daily	1963 - 1967		Moved 0.8 Miles Downstream
101	Big Roche-A-Cri @ Brown Deer Ave	At Daily	1963 - 1978		
102	Buena Vista Creek @ 100th Rd	Near Daily	1964 - 1967		Moved 0.4 Miles Upstream
103	Campbell Creek @ A	At Spot	1971		
104	Carter Creek @ G				
105	Chaffee Creek @ 14th	At Spot	1962 - 1988	Y	
106	Chaffee Creek @ CH			Y	
107[2]	Crystal River @ K			Y	
108	Ditch #2 N Fork @ Isherwood	At Spot	1966		
109	Ditch #4 @ 100th Rd	Near Daily	1964 - 1967		Moved 0.9 Miles Upstream
110	Ditch # 4 @ Taft				
111	Ditch #5 @ Taft	At Daily	1964 -1973		
112	Dry Creek @ G				
113	Emmons Creek @ Rustic Road 23	At Daily	1968 - 1974	Y	
114	Flume Creek in Rosholt @ 66	At Spot	1972 - 1976	Y	
115	Four Mile Creek @ JJ&BB				
116[2]	Fourteen Mile Creek @ 13	At Daily	1964 - 1979		
117	Lawrence Creek @ Eagle	Near Daily	1967 - 1973	Y	Moved 0.5 Miles Downstream
118	Little Plover @ Eisenhower	At Spot	1961 - 1963		
119	Little Plover @ Hoover	At Daily	1959 - 1987		
120	Little Plover @ I-39	At Spot	1961 - 1963		
121	Little Plover @ Kennedy	At Daily	1959 - 1976		
122	Little Roche-A-Cri @ 10th Ave.				
123[2]	Little Roche-A-Cri @ Friendship Park	At Spot	1972 - 1976		
124	Little Wolf @ 49	At Daily	1973 - 1979		
125	Little Wolf @ 54	At Daily	1914 -1985		
126	Mecan @ GG	At Spot	1956 - 1988	Y	
127	NB Ten Mile @ Isherwood/Harding				
128	Neenah @ A			Y	
129	Neenah @ G			Y	
130	Peterson Creek @ Q	At Spot	1962 - 1988	Y	
131	Pine River @ Apache			Y	Moved 0.5 Miles Downstream
132	Plover River @ I-39	At Daily	2010-2015		Moved 0.5 Miles Upstream

Table 2-1. Baseflow measurement sites (continued).

Map Location	Project Site Name	USGS Site Type[1]	USGS Years	Fox-Wolf Site?	Comments
133	Plover River @ Y	At Daily	1914 - 1951		
134	Shadduck Creek @ 13				
135	Spring Creek @ Q			Y	
136	Tenmile Creek @ Nekoosa	At Daily	1963 - 2009		
137	Tomorrow @ A			Y	
138	Tomorrow @ River Rd (Clementson)	At Daily	1995	Y	
139	W Branch White River @ 22	At Daily	1963 - 1965	Y	
140	Waupaca River @ Harrington Rd	At Daily	1916 - 1985		
141	Witches Gulch @ 13	Near Spot	1972 - 1973		Moved 0.1 Miles Downstream
142	Poncho Creek @ CTH Z	Near Spot	1994		Moved 0.5 Miles Upstream
143	Stoltenburg Creek @ Cty SS				
144	Bear Creek @ Town Line Road				
145	Bear Creek @ Q				
146	Schmudlack Creek @ Cottonville Ave				
147	Mecan River @ Cumberland Rd				
148	Little Pine Creek @ Czech Ct.				
149	Mecan @ 14th Ave				
150	Chaffee Creek @ B				
151	Chaffee Creek @ 11th Lane				
152	Fairbanks Creek @ Ember Ave				
153	Risk Creek @ Elk Ave				
154	Big Roche-A-Cri @ Beaver Ave				
155	Tenmile Creek @ Cty Rd U/80th Ave				

1. "At" is at the exact USGS site. "Near" is at the specified distance up or down stream.
2. Measurements are potentially affected by a nearby dam.

3. QUALITY ASSURANCE FOR VOLUNTEER BASEFLOW MONITORING SITES

The fledgling volunteer baseflow monitoring effort ("volunteer" is used without distinction for true citizen volunteers as well as for professional county conservation department staff) in the Central Sands has produced substantial amounts of much-needed data with a minimal budget and a great deal of effort by county conservation offices, citizen volunteers, WDNR staff, and UWSP staff (Figure 3-1). The UWSP role included providing quality assurance for volunteer measurements (discussed here) and providing volunteer training (discussed in section 1).

Procedures

The low-budget nature of the volunteer effort pre-ordained that quality assurance efforts would be somewhat chaotic, though in our opinion, still effective. Quality assurance protocols were that UWSP staff measured baseflows at 10% of the universe of volunteer sites per month, and these would then be compared with volunteer measurements taken in the same month. Quality assurance measurements were made without prior knowledge of when, and even if, volunteer measurements would be made at given sites that month. Hence some quality assurance measurements were for naught when a site went unmeasured by volunteers, or provided a poorer basis for comparison when substantial time lag separated quality assurance from volunteer measurements. Large time lags increase the chances that baseflow measurement disparities would result from normal baseflow recession and from precipitation events. Hence, apparent discrepancies between quality assurance and volunteer measurements represent worst-case scenarios. Tighter coordination among volunteers, WDNR project managers, county conservation staff, and UWSP quality assurance staff could provide for a more robust quality assurance effort, but would necessitate larger investments than appear practicable at this time.

Results

Forty quality assurance baseflow measurements at the same number of sites were made during July through November 2016. (Few to no volunteer measurements are made in winter and spring months.) Volunteers and county conservation staff took coincident (within days or weeks) measurements at 23 of the 40 sites, but not at the remaining 17 due to rain events, equipment issues, or lack of volunteer coverage (Table 3-1). Hence 23 quality assurance comparisons can be made. The elapsed time between quality assurance and volunteer measurements averaged 8 days and ranged 4 to 15 days.

Volunteer and quality assurance measurements correlated well (Figure 3-2) and without an evident bias. Discrepancies averaged 12% and generally decreased as baseflows increased. Twelve measurements had discrepancies less than 10%, eight were 10 to 20%, and three were greater than 20%

(Figure 3-3). Larger percentage discrepancies were usually associated with small baseflows; i.e., less than 4 cfs, but absolute differences in this group were small, averaging 0.26 cfs and ranging 0.08 to 0.78. These discrepancies, if real (and not caused by real change in flow conditions between volunteer and quality assurance measurements), are likely tolerable for data usage purposes.

Conclusion

Quality assurance protocols reveal that volunteer measurements represent accurate estimates of actual baseflow, in our opinion. The results of 2016 quality assurance procedures are in line with what has been previously reported (Appendix D).

Quality assurance procedures were somewhat chaotic and inefficient. Problems exist with quality assurance measurements being made when no comparable volunteer measurements were made, and with time lags between volunteer and quality assurance measurements. These could be rectified by greater coordination of volunteer efforts, but at a cost for which there is no funding at this time. It is our opinion that despite some difficulties and inefficiencies, quality assurance protocols were still effective, and indicate good quality baseflow data are being collected by volunteers.

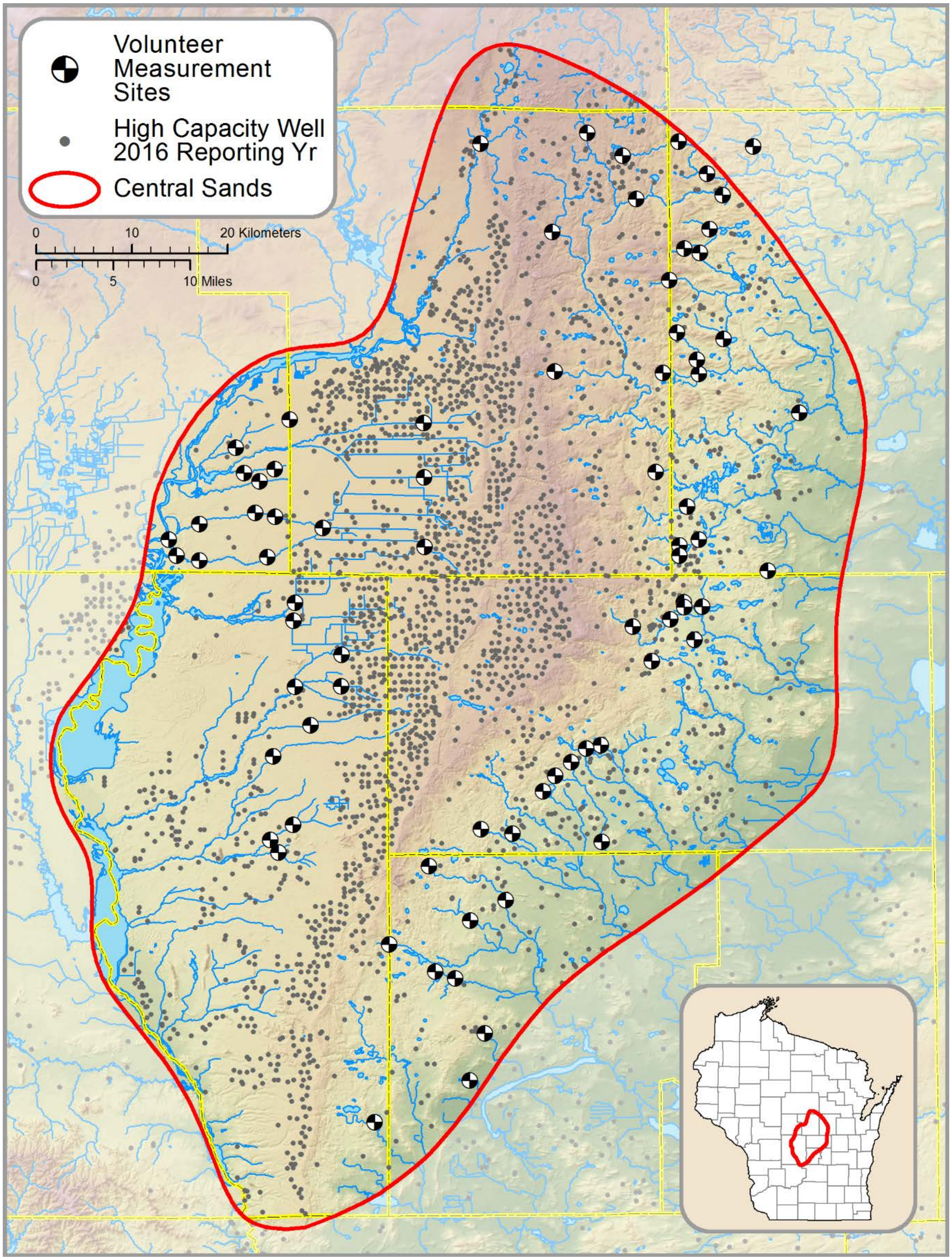

Figure 3-1. Location of volunteer baseflow monitoring sites in the central sands.

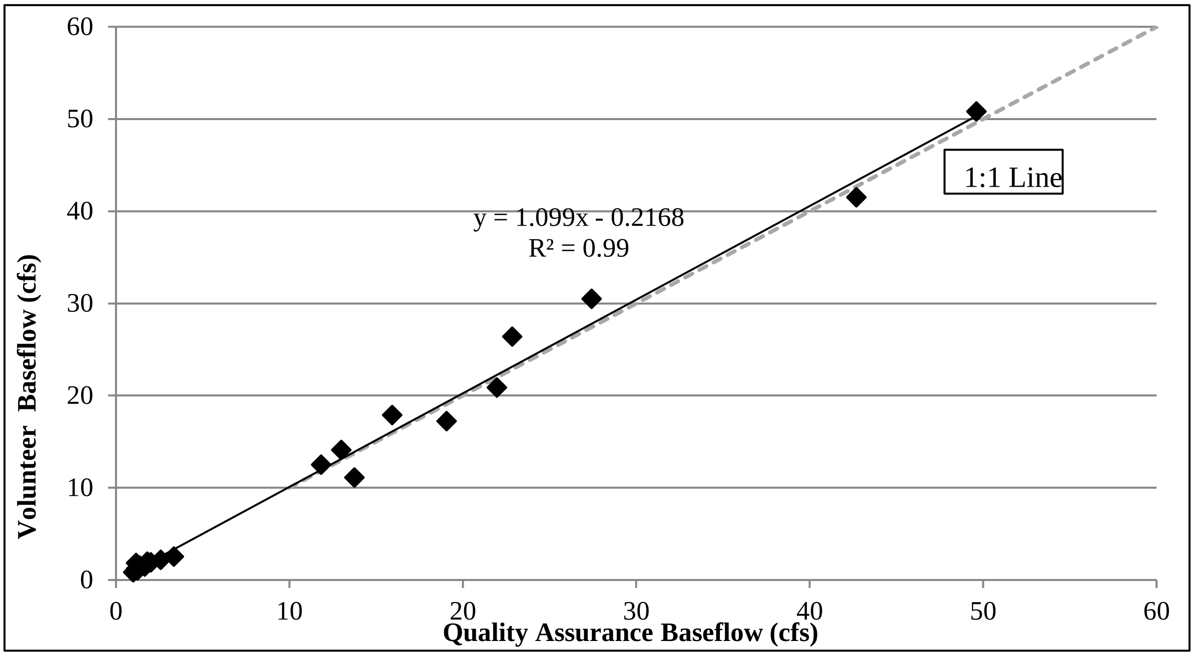

Figure 3-2. Relation of volunteer baseflow measurements with UWSP quality assurance baseflow measurements.

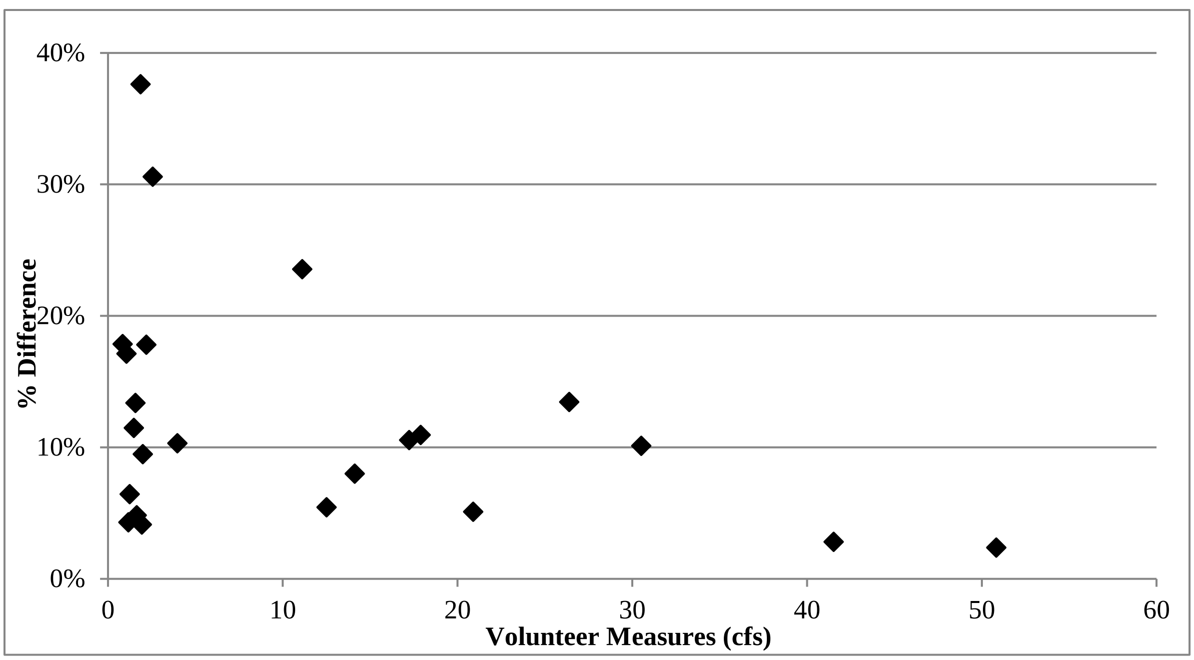

Figure 3-3. 2016 % difference between volunteer and UWSP measurements.

Table 3-1. Comparison of volunteer and UWSP baseflow measurements for 2016. % difference is defined as the absolute value of (larger measurement - smaller measurement)/ smaller measurement.

Station	Volunteer	Volunteer Date	Volunteer Measurement (cfs)	UWSP Date	UWSP Measurement (cfs)	Absolute Difference	% Difference
Kaminski Creek @ CTH A	Waushara County; Waushara Cty Staff	7/11/2016	0.8	7/15/2016	1.0	0.2	18%
Twomile Creek @ Airport Ave	Wood County; Staff	7/19/2016	1.1	7/15/2016	1.2	0.2	17%
Big Roche-A-Cri @ 7th Ave	Adams County; Jay Jocham	7/10/2016	30.5	7/15/2016	27.4	3.1	10%
Chaffee Creek @ 11th Lane	Marquette County	8/18/2016	17.2	8/23/2016	19.1	1.8	11%
Mecan River @ 14th	Marquette County	8/18/2016	50.8	8/23/2016	49.6	1.2	2%
Tenmile Creek @ Cty U	Wood County; Hamm	8/26/2016	17.9	8/22/2016	15.9	2.0	11%
Sevenmile Creek @ 64th	Wood County; Boroski	8/27/2016	1.6	8/22/2016	1.4	0.2	13%
Big Roche-A-Cri @ 7th Ave	Adams County; Jay Jocham	8/12/2016	41.5	8/22/2016	42.7	1.2	3%
Tomorrow River @ Merryland	Portage County; M. Ryan	8/30/2016	2.6	8/18/2016	3.3	0.8	31%
Poncho Ck @ Hwy Z	Portage County; M. Ryan	8/30/2016	1.9	8/18/2016	1.2	0.7	38%
Bear Ck @ Q	Portage County; M. Ryan	8/31/2016	12.5	8/18/2016	11.8	0.7	5%
Buena Vista Ck @ Taft Rd	Portage County; Jen McNelly	8/26/2016	14.1	8/22/2016	13.0	1.1	8%
Stoltenburg Ck @ SS	Portage County; Hinrichs	8/31/2016	1.7	8/18/2016	1.7	0.1	5%
Klawitter @ Edgewood	Marquette County	9/15/2016	1.2	9/20/2016	1.2	0.1	4%
N Br Wedde Ck at B	Waushara County; Waushara Cty Staff	11/1/2016	2.2	10/24/2016	2.6	0.4	18%
S Br Wedde Ck at B	Waushara County; Waushara Cty Staff	11/1/2016	1.5	10/24/2016	1.7	0.2	11%
Schmudlack Ck @ Cottenville	Waushara County; Waushara Cty Staff	11/1/2016	1.9	10/24/2016	2.0	0.1	4%
Chaffee Ck @ 11th Lane	Marquette County	10/10/2016	20.9	10/24/2016	22.0	1.1	5%
Poncho Ck @ Z	Portage County; Mryan	11/2/2016	1.2	10/21/2016	1.2	0.1	6%
Bear Ck @ Q	Portage County; Hinrichs	11/3/2016	11.1	10/20/2016	13.7	2.6	24%
Stoltenburg Ck @ SS	Portage County; Hinrichs	11/3/2016	2.0	10/21/2016	1.8	0.2	10%
Chaffee Ck @ 11th Lane	Marquette County	11/1/2016	26.4	11/16/2016	22.8	3.6	13%
Fivemile Creek @ 48th	Wood County; TA	11/13/2016	4.0	11/15/2016	4.4	0.4	10%

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APPENDIX A

Letter from Adam Freihoefer to George Kraft on Baseflow and Monitoring Well Locations

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WISCONSIN
DEPT. OF NATURAL RESOURCES

August 4, 2016

Dr. George Kraft
Center for Watershed Science and Education
College of Natural Resources, UW - Stevens Point
800 Reserve St.
Stevens Point WI 55581

Subject: Selection of New Sites for Baseflow and Water Level Monitoring

Dear Dr. Kraft:

The purpose of this letter is to convey to you the additional sites identified by the department for potential inclusion in 1) the University of Wisconsin – Stevens Point (UWSP) baseflow monitoring program; and 2) the Wisconsin Groundwater Level Monitoring Network. The selection and commencement of 12-15 monthly monitoring of baseflow monitoring sites and the recommendation of 3-5 groundwater level monitoring sites are both objectives of the FY 17 contract "Monitoring and Modeling Support for Groundwater Management and Policy in the Wisconsin Central Sands".

Baseflow Monitoring Site Selection

The ongoing monthly baseflow monitoring conducted by the UWSP has been very valuable and informative. In examining additional monitoring sites, the department's goal was to identify specific watersheds where additional sites would provide an understanding of the synoptic variation in streamflow. The sites may serve to validate an existing DNR streamflow model, improve our understanding of seasonal and annual variation in baseflow, and assist with the development of future modeling efforts.

With respect to the aforementioned goal, we appreciate the input provided by you and Dave Mechenich prior to, and during our teleconference on July 25, 2016. As we agreed during the July 25 discussion, the department completed an analysis of existing streamflow monitoring and water use data. The department reviewed previous streamflow monitoring data collected within the Central Sands region by UWSP as well as other data sources including United States Geological Survey (USGS) continuous gage data, and volunteer streamflow monitoring. The department examined streamflow monitoring relative to several variables including all relevant existing monitoring locations, and regions of existing and potential groundwater withdrawal. The attached map shows watersheds shaded in proportion to relative numbers of new and pending high-capacity wells, and shows the locations of existing streamflow monitoring sites, as well as the proposed future monitoring sites listed below.

Tomorrow/Waupaca River

1. Poncho Creek at Cty Z
2. Stoltenburg Creek at Cty SS
3. Bear Creek at Town Line Road
4. Bear Creek at Cty Q
5. Tomorrow River at Cty A

Mecan/Little Pine River

6. Schmudlack Creek at Cottonville Ave.
7. Mecan River at Cumberland Rd or 11th Ave (whichever is more suitable)
8. Little Pine River at Czech Ct.
9. Mecan River at 14th Ave.

Chaffee Creek

10. Chaffee Creek at Cty B
11. Chaffee Creek at 11th Ave.
12. Chaffee Creek at 14th Ave.

Campbell Creek

13. Fairbanks Creek at Ember Ave.
14. White Creek at Evergreen Ave.

Other

15. Big Roche a Cri at Beaver Ave.
16. Tenmile Creek at U

The department's selected sites represent a small departure from specific language in the contract, in that not all locations are on headwaters streams. As we discussed, our needs have evolved to include synoptic data along key streams to help us understand how flow increases downstream relative to modeled predictions. This letter also serves as documentation of that slight change in direction in this project.

The project contract specifies that "up to 15 new stream sites" be selected. The list above includes 16 sites because we anticipate the possibility that not all of the sites identified may be suitable for baseflow monitoring. Therefore we encourage you to review the list to eliminate any sites that aren't suitable. If there are more than a few unsuitable sites, please suggest other nearby sites on the same stream to replace the unsuitable sites.

Water Level Monitoring Site Recommendations

The project contract states that UWSP will recommend 3-5 new locations for water level monitoring. During the July 25, 2016 teleconference the department introduced their analysis of existing groundwater level monitoring relative to regions of existing and potential groundwater withdrawal and proximity to baseflow and streamflow measuring sites. The results of that analysis, as shown in the attached map and defined in the list below, provide UWSP with 10 potential sites to consider when recommending the most beneficial sites to be added to the Wisconsin Groundwater Level Monitoring Network.

Water Level Monitoring Sites

1. Tomorrow River State Trail – Parking Lot
2. Tomorrow River State Trail – East
3. Wolf Lake - Parking lot
4. Long Lake – Shallow Well
5. Long Lake – Deep Well
6. Weymouth Lake - PfldTC
7. Bohn Lake
8. Ice Age Trail – near Hancock
9. Mecan Springs
10. Chaffee Creek

Also related to water level monitoring, the project contract states that "[UWSP] would draft a proposal by November 1, 2016 for constructing or refurbishing monitoring infrastructure to be submitted to the 2017 Joint Solicitation. If the proposal is selected for funding, we anticipate monitoring well installation in August 2017." Subsequent discussions between the department and UWSP have determined that both parties would prefer that the construction or refurbishing of monitoring wells be conducted through the Wisconsin Geological and Natural History Survey and USGS. Therefore this letter also serves to eliminate the drafting of a well construction and refurbishing proposal from the project objectives.

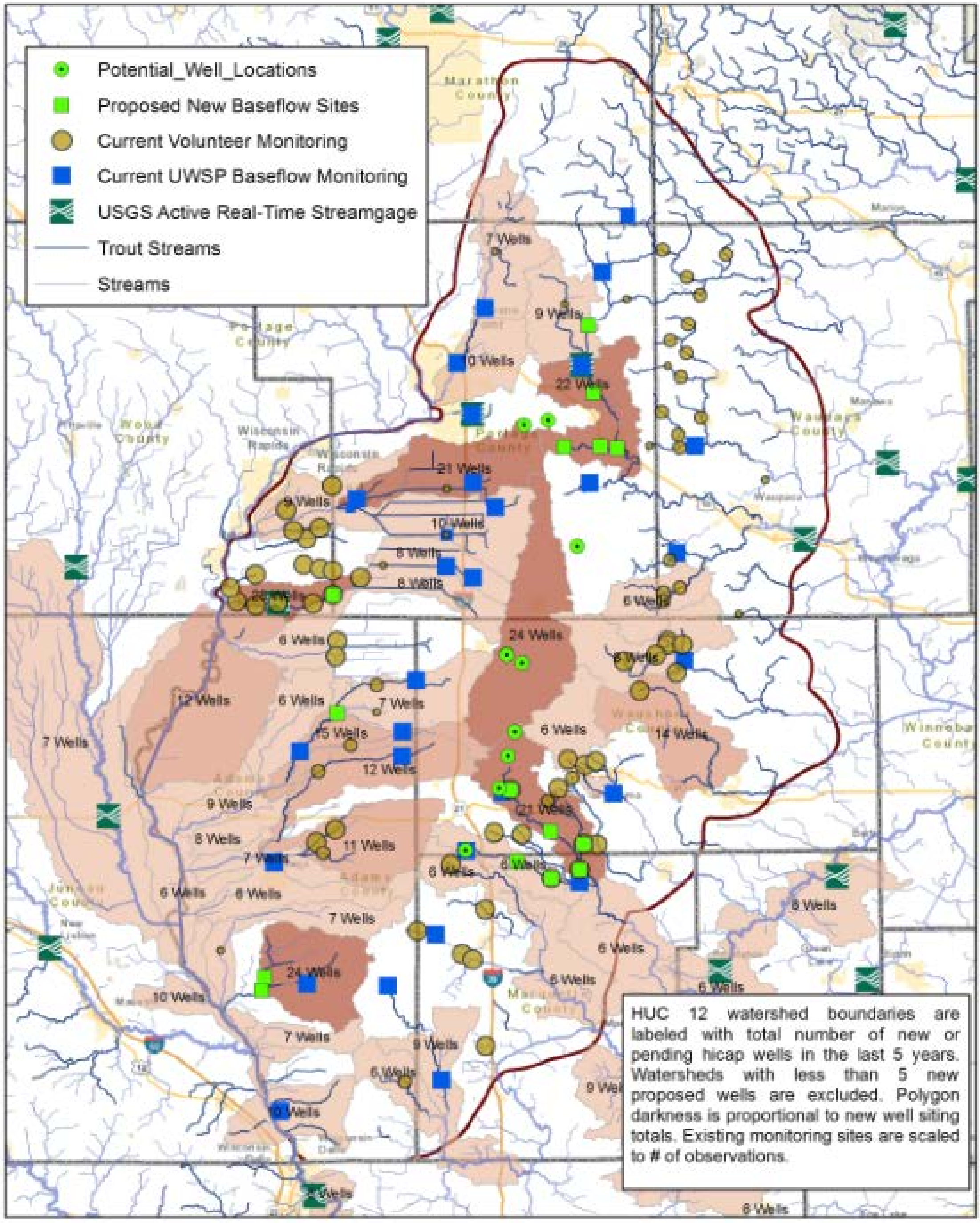
To assist with your review of the monitoring sites proposed above, geospatial files are included with this letter. The files contain the locations and attributes of the proposed baseflow monitoring and groundwater level monitoring sites. We look forward to continuing this important work together.

Sincerely,

Adam Freihoefer

Adam Freihoefer, Chief
Water Use Section

Proposed Baseflow and Water Level Monitoring Sites



Date: 08/04/2016

APPENDIX B

Materials Prepared by George Kraft and David Mechenich for Discussion and Presentation to WDNR Water Use Section Staff on Potential Monitoring Well Locations

Dated July 7 2016

MONITORING WELL LOCATION CRITERIA

What criteria might be useful in helping to decide where additional monitoring wells are needed and should be placed???

Some potential criteria might include these:

- Setting some up as reference sites, where levels are subject only to changes in weather and pumping or land use change.

- The locales are more sensitive to ups and downs caused by weather and pumping?

- Monitoring conditions in areas well developed for pumping (though the change wrought by that pumping might not be apparent because groundwater levels are already in equilibrium with pumping).

- Monitoring conditions in areas where pumping is rapidly expanding so as to catch the transient period of pumping development)

- Where are we already monitoring?

- Where do we have existing wells and data that we haven't used in some time, can we use this existing infrastructure?

With that being said, attached are some imageries that might help guide our discussion.

In order:

- Irrigation high cap wells completed pre and post 2010, which gives us a sense of the degree of development and what areas are expanding rapidly.

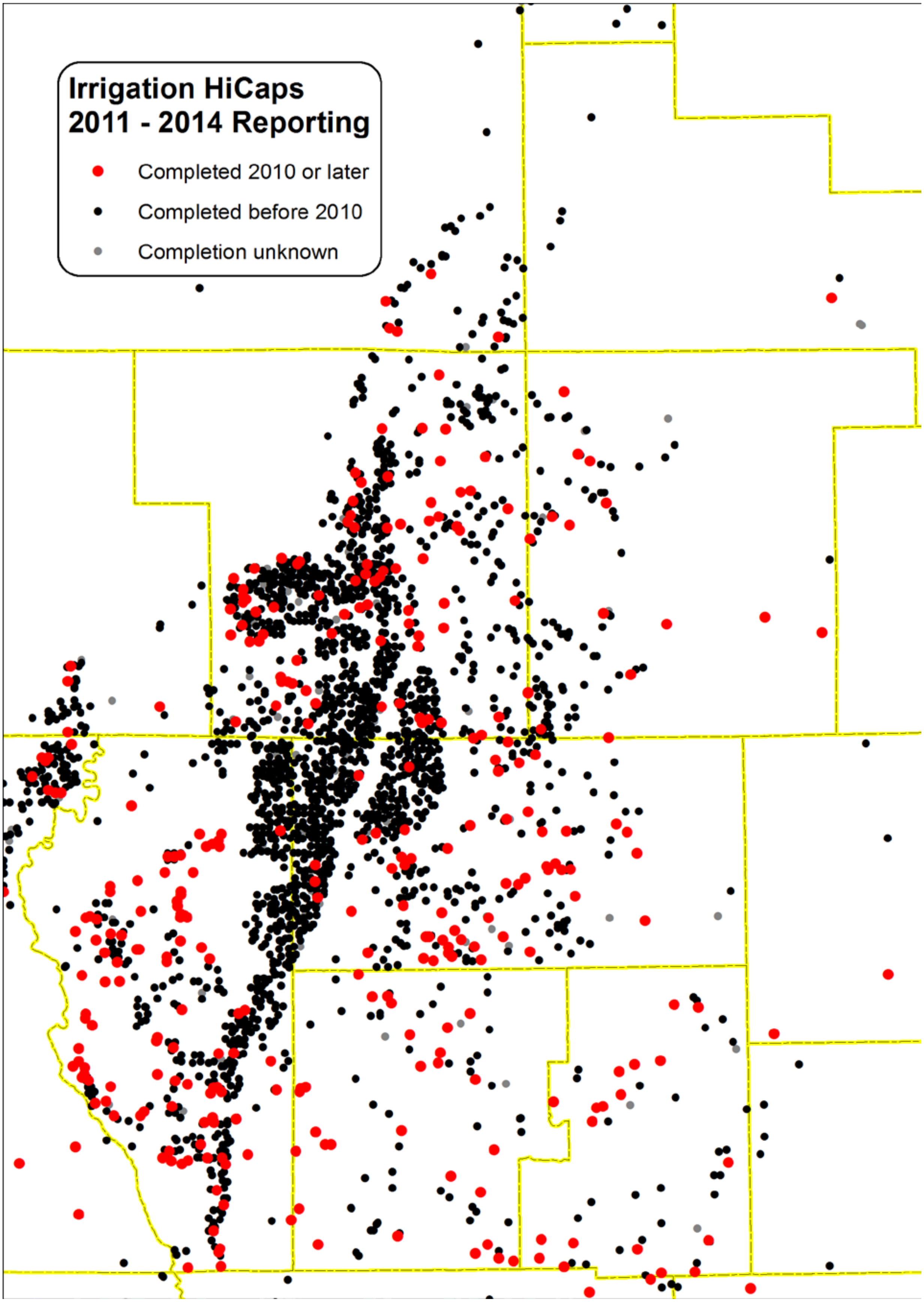
- Recharge sensitivity map, defined as the change in water level per inch change in recharge rate. Areas with low sensitivity fluctuate little.

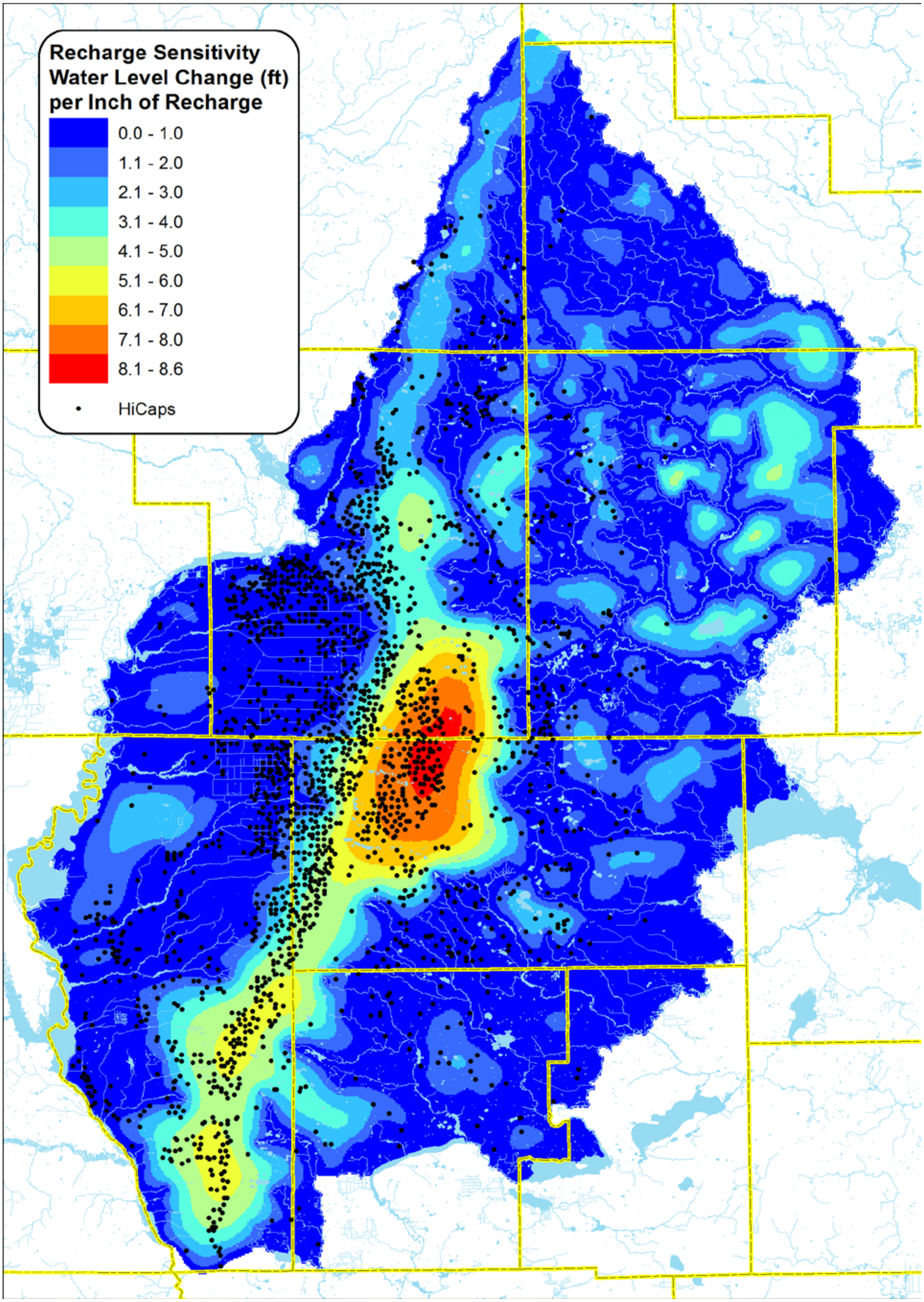
- Two drawdown maps. One assumes that the irrigation impact is a 2" net consumption on an average size field (103.6 acres) coming from each irrigation well (about 752,000 gallon per year pump rate). The second "spatially weighted" also assumes a 2" consumption, but scales the field size associated with each well by the reported pumping amount.

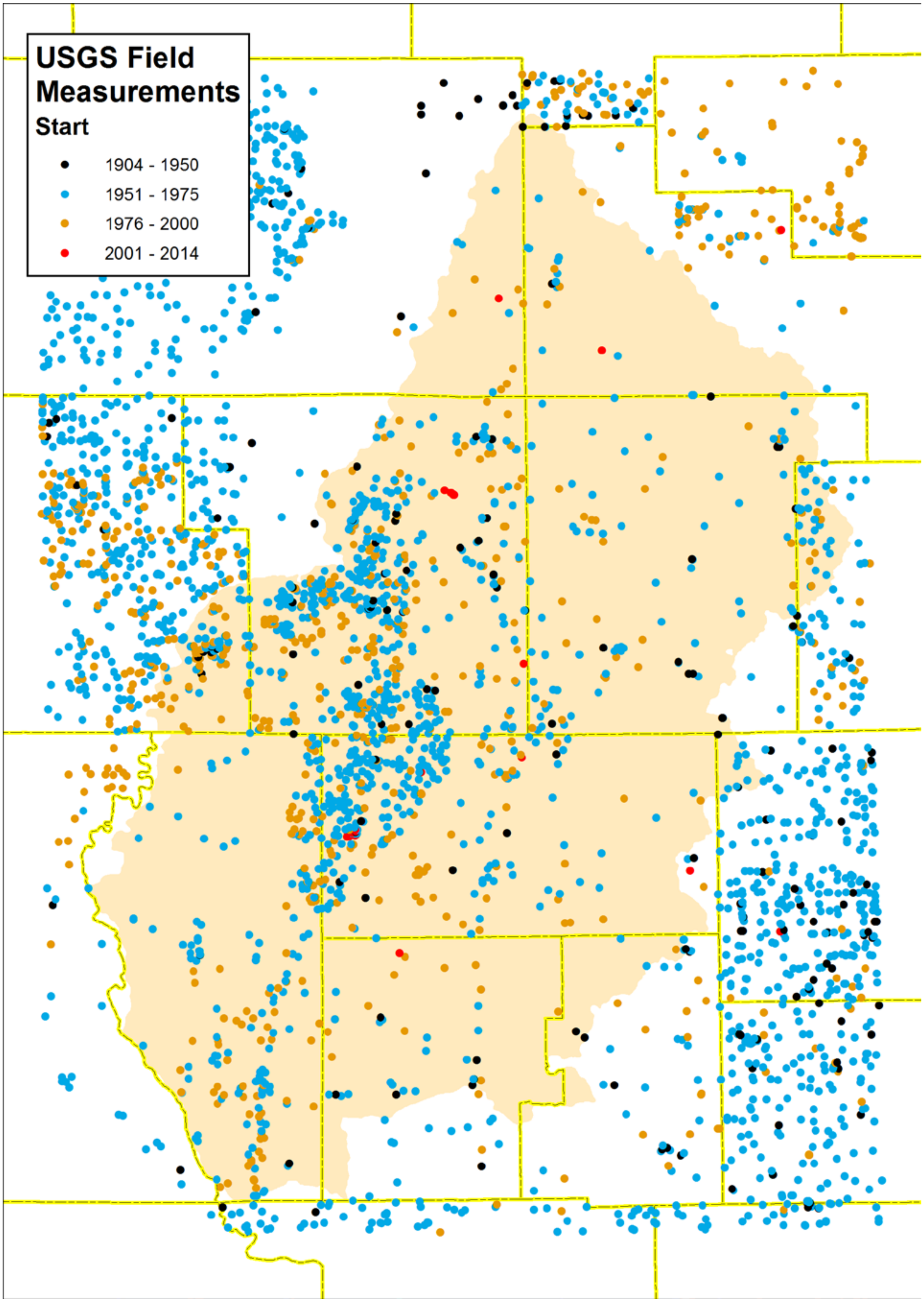
- Two maps of USGS groundwater level field measurements; first measurement and last measurement at each well.

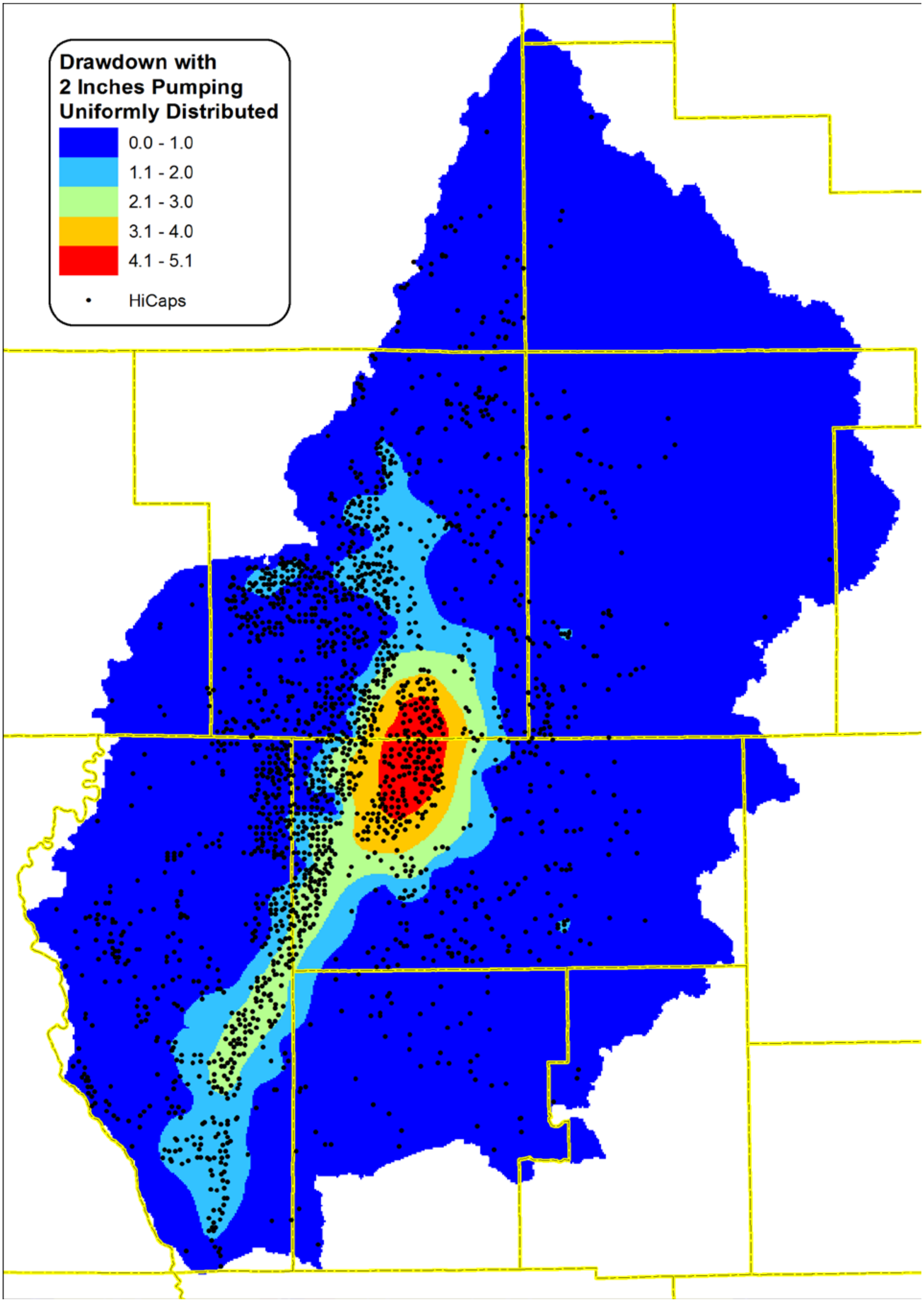
- One map of USGS field measurements with number of observations at each point.

- One map of USGS Real Time measurements.

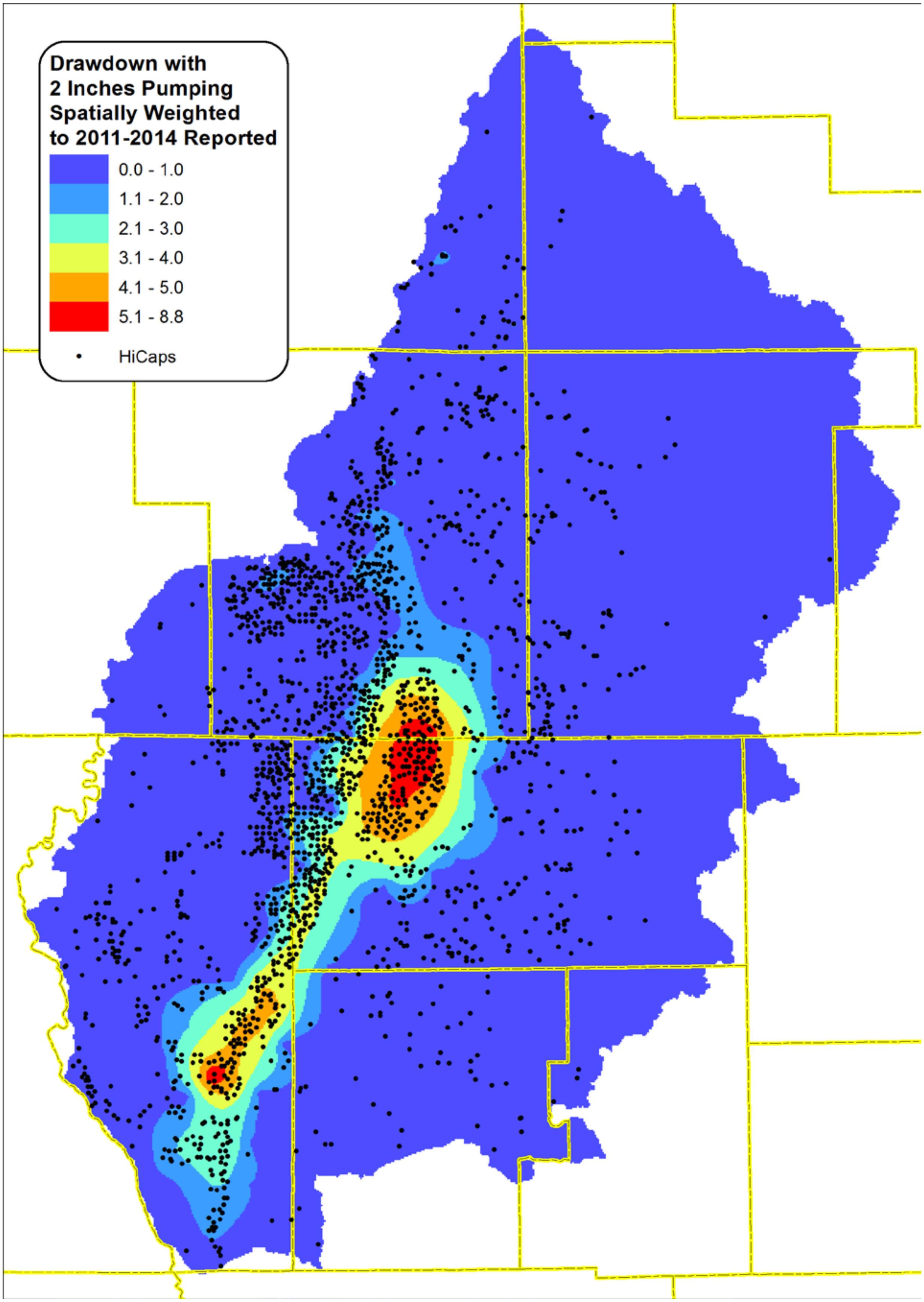

Irrigation HiCaps
2011 - 2014 Reporting
Completed 2010 or later
Completed before 2010
Completion unknown


Recharge Sensitivity
Water Level Change (ft)
per Inch of Recharge
0.0 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 8.6
HiCaps

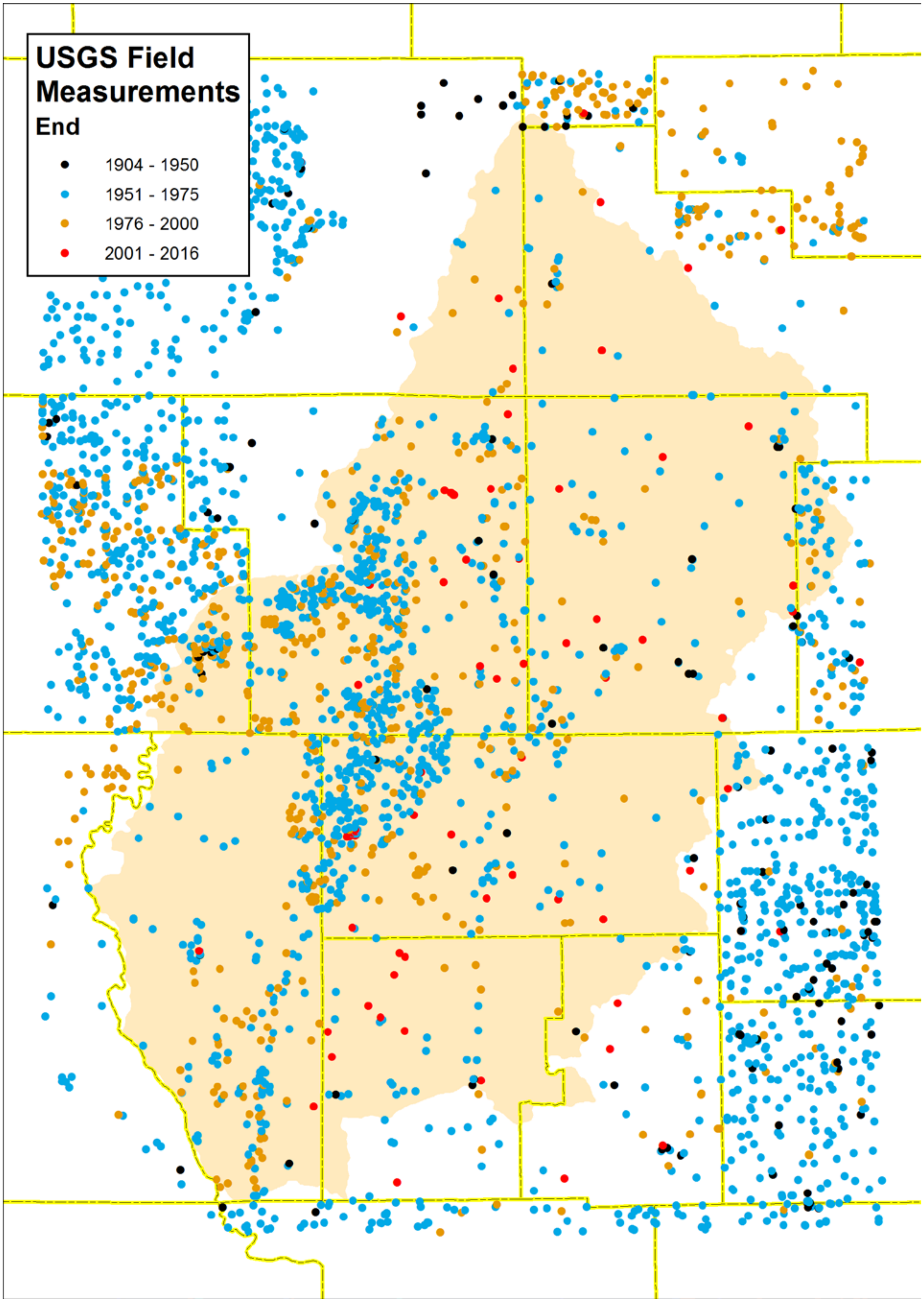

USGS Field Measurements
Start
1904 - 1950
1951 - 1975
1976 - 2000
2001 - 2014

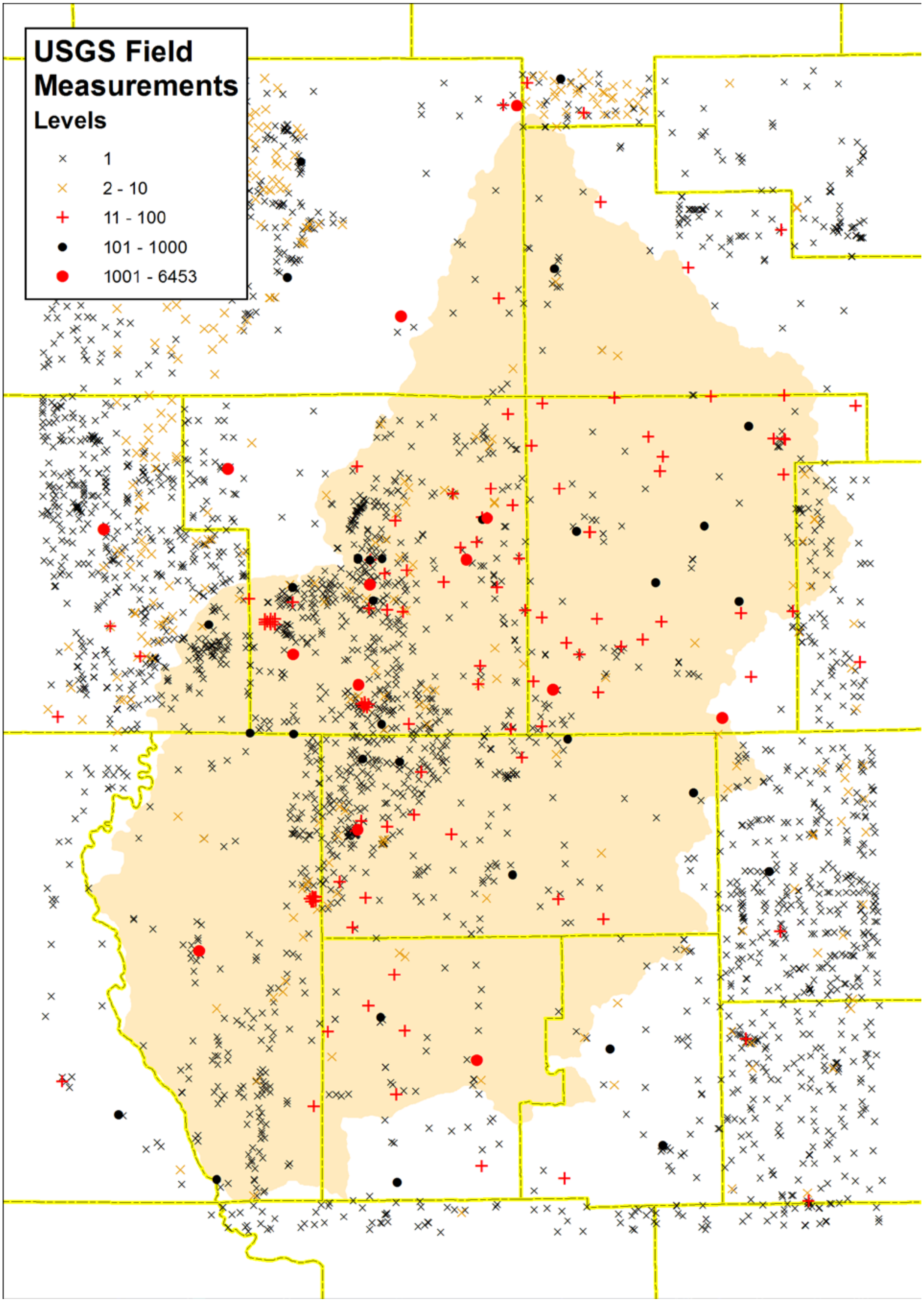


Drawdown with
2 Inches Pumping
Uniformly Distributed
0.0 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.1
HiCaps



Drawdown with
2 Inches Pumping
Spatially Weighted
to 2011-2014 Reported
0.0 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 8.8
HiCaps


USGS Field Measurements
End
1904 - 1950
1951 - 1975
1976 - 2000
2001 - 2016


USGS Field Measurements
Levels
1
2 - 10
11 - 100
101 - 1000
1001 - 6453

APPENDIX C

Materials Drafted Prepared for Discussion with WDNR Water Use Section on DNR Suggestions for Potential Monitoring Well Locations

MONITORING WELL LOCATION RECOMMENDATIONS **SEPTEMBER 26 2016**

GEORGE KRAFT

[Objective 4. *Recommend 3-5 locations for additional water level monitoring to serve the needs of the WDNR Water Use Section, in consultation with the Wisconsin Groundwater Level Monitoring Network.*]

Summary

DNR staff requested comments on 10 potential well locations. These were recommended as higher, medium, and lower priority thusly:

Tomorrow River Trail (wells 1 and 2) - “higher priority” for one well at one or the other location.
Wolf Lake (well 3) – “lower priority” due to redundancy with a nearby regularly monitored USGS well.
Long Lake (wells 4 and 5) and Weymouth Lake (well 6) - “lower priority” due to existing wells with a current monitoring history.
Bohn Lake and Ice Age (wells 7 and 8) – “medium priority” for one or the other; measurements will be correlated and information fairly redundant with the Hancock monitoring well.
Mecan Spring and Chaffee Creek (well 9 and 10) – “low priority.” Not that useful in a regional context.

Three different locations were suggested as “higher priority” for new well installation (11. Eastern Adams County in the high drawdown corridor; 12. NW Adams County / SE Wood County in an area of expansion interest; 13. Town of New Hope, Rhinehart Lake area, an area of expanding irrigation pumping), and two existing monitoring well locations were suggested for incorporation into a monitoring network (14. East of Amherst, 15. NE Portage County, and select monitoring wells around Long and Plainfield Lakes).

Considerations for Assessing Monitoring Locations

UWSP staff previously put forward several considerations for where new monitoring wells might be located (in no particular order):

1. Reference locations. Places where water levels are subject only to weather drivers and not to pumping influences. This consideration is driven by the erosion of the value of current long-term reference sites due to the expansion of irrigation pumping in their vicinity (Amherst Junction, Nelsonville) or their removal (Wild Rose).

2. Areas highly sensitive to changes in weather and pumping. These are places where water level changes have a large amplitude. This generally pushes monitoring locations away from discharge areas. These locales would also be more helpful as future model head targets.

3. Highly impacted areas. I.e., areas where pumping is already well developed. The change wrought by pumping might not be apparent, because groundwater levels are likely close to an equilibrium with pumping.

4. Areas where pumping is rapidly expanding; so as to catch the transient period of pumping development and allows future impacts to be quantified,

5. Locales removed from current monitoring locations; i.e., avoid duplication.

6. Use existing wells with previous history when available and useful.

WDNR staff put forth a few others. Among them:

7. Locales that are preferably state lands, or possibly other public land.

8. Locales with some particular interest (Long Lake, Chaffee Creek).

9. Delineate the location of the regional groundwater divide.

Imagery for decision support

UWSP staff generated various maps to help visualize potentially important information regarding these considerations (attached).

Kraft Comments on Suggested locations

DNR staff laid out deployments of 10 potential well locations, which might represent seven unique installations (i.e., alternate locations appear to have been provided for siting a single well).

An accompanying spreadsheet illustrates some pros and cons of each of the proposed sites with respect to other monitoring, sensitivity to weather / pumping, and stage of impact development.

To summarize:

Wells 1 & 2, Tomorrow River Trail. These locations are only 3-4 miles from existing monitoring wells, and from that perspective would seem to be a lower priority. BUT both are in an area where substantial irrigation could occur, and the consequences could be severe (see Kraft et al. 2014). The location is sensitive to weather and pumping influences. From a documentation of potential degradation perspective, this site rates high. **HIGHER PRIORITY FOR A SINGLE WELL.**

Well 3. Wolf Lake. Located only 1.5 miles W of USGS well 441958089183601; one measurement in in 1994, monthly to semiannually since 2007. Also 3.5 miles W of USGS 441900089164501 (often dry). **LOWER PRIORITY BECAUSE DUPLICATIVE.**

Locations 4/5. Long Lake. A deep and shallow well were proposed. The transient period of groundwater decline has likely mostly passed this location. Area is highly sensitive to weather/pumping. Many other wells already exist in this vicinity. I suggest that if the desire to learn something about Long

Lake is important, it should be done with this in mind rather than as a part of a regional long-term monitoring project. **LOWER PRIORITY. INVESTIGATE USING THE PLETHORA OF WELLS THAT ALREADY EXIST IN THE LONG LAKE VICINITY, AS WELL AS THE MONITORING WELL PRESENT NEAR PLAINFIELD LAKE.**

Location 6. Weymouth Lake. Duplicative with 4/5. **SAME AS ABOVE.**

Location 7. Bohn Lake. Five miles from the existing Hancock well, with a somewhat smaller drawdown. Water levels here are likely highly correlated with Hancock. Sensitivity is high. Transient period has likely mostly passed. **MEDIUM PRIORITY**

Location 8. Ice Age Trail. Duplicative with the above. One or the other. **MEDIUM PRIORITY.**

Location 9 Mecan Spring, and 10 Chaffee Creek. Water levels are pretty insensitive to weather and pumping as they are adjacent to surface waters. If the desire is to learn something about these areas, I suggest it be done a little more comprehensively and as a separate project rather than just tossing in a new monitoring well. **LOWER PRIORITY.**

Additional suggestions for DNR consideration

Location 11. Eastern Adams County in the southern part of the high drawdown corridor. No monitoring currently exists in this part of the large drawdown area of the central sands. **HIGHER PRIORITY**

Location 12. NW Adams County / SE Wood County. An area of expansion interest. Installing monitoring now would catch the transient pumping change. Or if the area did not become developed it would be useful as a reference location. Moderate sensitivity area. **HIGHER PRIORITY**

Location 13. Town of New Hope, Rhinehart Lake area. An area of expansion interest. Installing monitoring now would catch the transient pumping change. Or if the area did not become developed it would be useful as a reference location. Moderate sensitivity area. **HIGHER PRIORITY**

Location 14. East of Amherst, Elkins Rd. and Co. Rd. B. An existing active USGS well there might make for a good reference well. Lower sensitivity. Perhaps area will not receive lots of irrigation development. **EXISTING WELL IS PRESENT, SUGGEST ADDING IT TO A DNR NETWORK.**

Location 15. Far NE Portage County. USGS 443921089152001. Might be useful as a reference well. Little development at present. Subject to seasonal irrigation effects, but out of the way of the large irrigation area. **EXISTING WELL IS PRESENT, SUGGEST ADDING IT TO A DNR NETWORK.**

Attached Imagery

- Irrigation high cap wells completed pre and post 2010, which gives us a sense of the degree of development and what areas are expanding rapidly.

- Recharge sensitivity map, defined as the change in water level per inch change in recharge rate. Areas with low sensitivity fluctuate little.

- Two drawdown maps. One assumes that the irrigation impact is a 2” net consumption on an average size field (103.6 acres) coming from each irrigation well (about 752,000 gallon per year pump rate). The second “spatially weighted” also assumes a 2” consumption, but <u>scales the field size associated with each well</u> by the reported pumping amount.

- Two maps of USGS groundwater level field measurements; first measurement and last measurement at each well.

- One map of USGS field measurements with number of observations at each point.

- One map of USGS Real Time measurements.

APPENDIX D

Summaries of Quality Assurance for Volunteer Baseflow Sites in 2013 and 2014

Quality Assurance for Volunteer Baseflow Monitoring Sites in 2013

Jessica Haucke
February 19 2014

In 2013 five central Wisconsin counties organized volunteers to measure baseflows in select streams. The UWSP role included providing volunteer training and quality assurance for volunteer measurements. A comparison of quality assurance measurements and volunteer measurements is made in this report.

Twenty two comparisons were made between August 2013 and October 2013 (Table 1). As volunteer and UWSP efforts were not coordinated, the time between volunteer and UWSP measurements was as little as one and as much as 19 days.

Of the 22 sets of comparison measurements:

1. Fourteen had differences under 10%.
2. Three of with differences > 10% had discharges $\leq$ 2cfs and small absolute differences (< 0.3 cfs).
3. Four with differences > 10% had substantial time between the volunteer measurement and UWSP measurements during which flow conditions likely changed, as judged by changes in discharge at a nearby daily USGS gauge.
4. One comparison (34.9 and 39.4 cfs) had a difference of 13% for a stream with large discharge (> 30 cfs) and only a day of separation between measurements.

We conclude that the UWSP and volunteer quality assurance comparisons generally agreed well, with either a small percentage error or a small absolute error. No highly erroneous discharge errors (say, a factor of 2) were observed. In cases where apparent disagreement was substantial, actual changes in discharge between measurements over time is the likely cause. The largest disagreement observed at a stream with a robust discharge over a short time interval was 13%. Signs of systematic error and blunder in the volunteer monitoring data were absent.

Table 2. Comparison of volunteer and UWSP baseflow measurements for 2013. % difference is defined as the absolute value of (larger measurement - smaller measurement)/ smaller measurement.

Station	Volunteer	Volunteer Date	Volunteer Measurement	UWSP Date	UWSP Measurement	Absolute Difference (cfs)	% Difference
14 Mile @ Aniwa Rd	Adams; Dennis Poehler	8/23/2013	2.2	8/16/2013	2.3	0.1	4
7mile @ Cty Rd Z	Wood; Rob	8/1/2013	5.6	8/16/2013	4.1	1.5	36
Big Roche-A-Cri @ Cty Rd W	Adams; Jay Jocham	8/20/2013	9.7	8/16/2013	10.3	0.6	6
Bird Creek @ Bicentennial Rd	Waushara; Ralph Shemanski	8/17/2013	0.4	8/20/2013	0.4	0.0	3
Caves Creek @ CH	Marquette Cty Staff	8/29/2013	6.5	8/19/2013	6.5	0.0	0
Comet Creek @ Mud Lake Rd	Waupaca Cty Staff	7/30/2013	22.8	8/16/2013	17.3	5.5	32
W Branch White River @ Lake Dr.	Waushara; Ralph Shemanski	8/18/2013	6.2	8/20/2013	6.4	0.2	3
Allen Creek @ 6th Rd	Marquette Cty Staff	9/24/2013	4.6	9/12/2013	4.6	0.0	0
Buckner Creek @ 4th Ave	Adams; Jay Jocham	9/19/2013	1.9	9/11/2013	1.8	0.1	5
Kaminski Creek @ CTH A	Waushara Cty Staff	9/26/2013	0.4	9/7/2013	0.6	0.2	50
Klawitter Creek @ Edgewood Ct	Marquette Cty Staff	9/24/2013	0.5	9/12/2013	0.6	0.1	19
Little Roche-A-Cri Creek @ Cypress Ave	Adams; Gary Lueck	9/2/2013	3.1	9/11/2013	3.3	0.2	7
Mecan River @ 14th Ave	Marquette Cty Staff	9/27/2013	51.5	9/11/2013	48.9	2.6	5
North Branch Wedde Creek @ Cty Rd B	Waushara; Adam Rigden	9/6/2013	1.9	9/7/2013	1.9	0.0	2
Peterson Creek @ CTH B	Waupaca; Jim Hlaban	9/23/2013	5.7	9/7/2013	5.8	0.2	3
Bestul Creek @ Cty Hwy G	Waupaca; Jim Hlaban	10/30/2013	1.5	10/14/2013	1.7	0.2	14
Carter Creek @ 8th Ct	Adams Cty Staff	10/10/2013	0.0	10/10/2013	0.0	0.0	0
Klawitter Creek @ Cty Rd J	Marquette Cty Staff	10/29/2013	2.7	10/10/2013	2.8	0.1	3
Lunch Creek @ Czech Ct	Waushara; JS	10/29/2013	9.5	10/17/2013	12.3	2.7	29
Radley Creek @ Hwy 22	Waupaca Cty Staff	10/19/2013	15.4	10/14/2013	15.0	0.5	3
South Branch Wedde Creek @ 7th Ct	Waushara Cty Staff	10/27/2013	1.2	10/17/2013	1.5	0.2	20
Tenmile @ Rangeline Rd	Wood; Borski	10/10/2013	34.9	10/11/2013	39.4	4.5	13

Quality Assurance for Volunteer Baseflow Monitoring Sites in 2014

Jessica Haucke
November 12 2014

Five central sands Wisconsin counties organized volunteers to measure baseflows in select streams. The UWSP role included providing volunteer training and quality assurance for volunteer measurements. UWSP staff made quality assurance checks of baseflow measurements at 10 of all volunteer sites. A comparison of quality assurance measurements and volunteer measurements is made in this report.

Twenty one quality assurance comparisons were made between May 2014 and October 2014 (Table 1). All 21 baseflow comparisons were made within hours to 21 days (Figure 1). In addition, twenty citizen volunteer sites that went unmeasured by citizen volunteers were also measured by UWSP.

Of the 21 quality assurance comparisons, 10 had differences less than 10 and 15 had differences less than 20 (Figure 2). Of the 11 sets of comparisons with a difference over 10 :

1. Five had discharges ≤ 3.1cfs and small absolute differences (< 0.3 cfs) (Figure 3).

2. Two with substantial differences (17 and 41) had substantial time (17 and 14 days, respectively) between comparison measurements, during which flow conditions likely changed, as judged by a nearby daily USGS gauge.

3. One comparison (7.1 vs. 8.8 cfs) had a large difference of 24 and only 6 days of separation between measurements. No extenuating circumstances for the difference were evident.

4. One comparison (1.6 vs. 3.3 cfs, a difference of 112) with only 4 days of time separation had installation of a new culvert between measurements, which may have altered flow conditions.

5. Two comparisons for streams of large discharge (49.4 vs. 55.0 and 82.4 vs. 94.3) had differences of 11 and 15 when measured on the same day.

We conclude that the quality assurance comparisons made by UWSP and volunteers generally agreed well within data quality needs. The two sites with highly erroneous discharge errors (112 and 200) had plausible explanations for the high error as explained above. Measurements taken from May to July in Adams and Wood Counties had the greatest fluctuations, which we believe was due to high amounts of precipitation. Signs of systematic error and blunder in the volunteer monitoring data were absent.

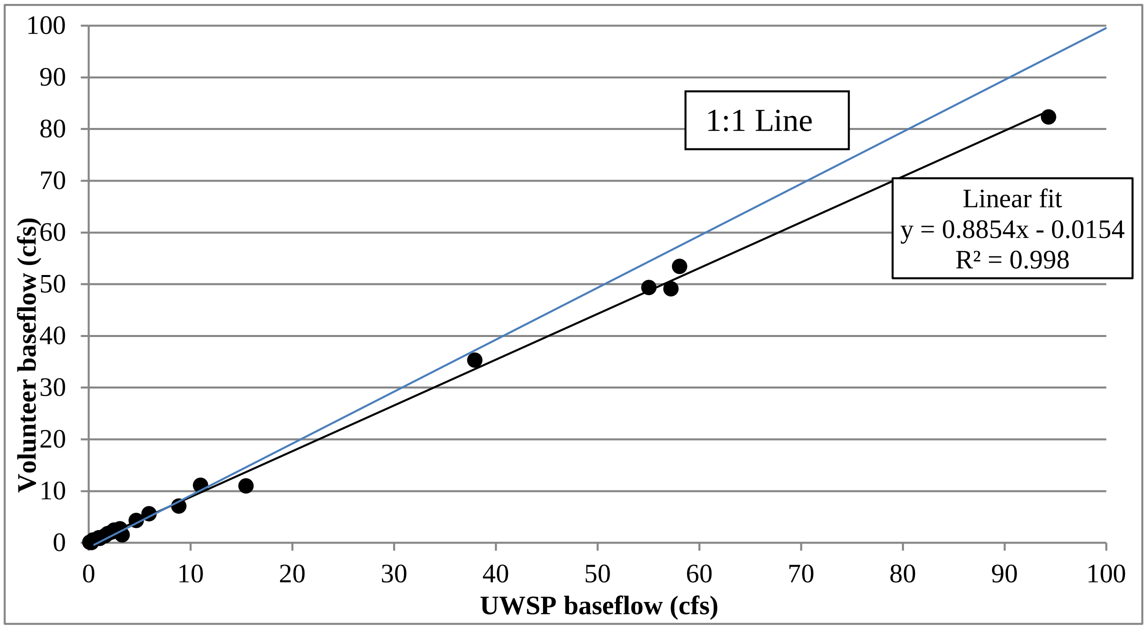


Figure 8. Relation of volunteer baseflow measurements with UWSP baseflow measurements.

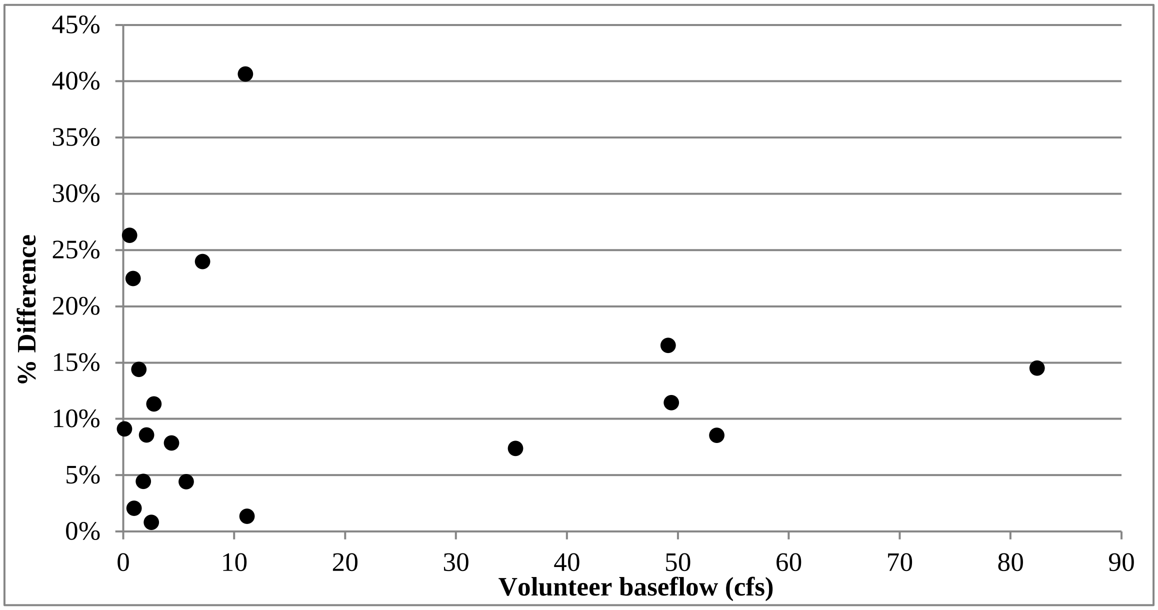


Figure 9. % difference between volunteer and UWSP measurements by volunteer baseflow. Not included are two sites where the difference was over 100%.

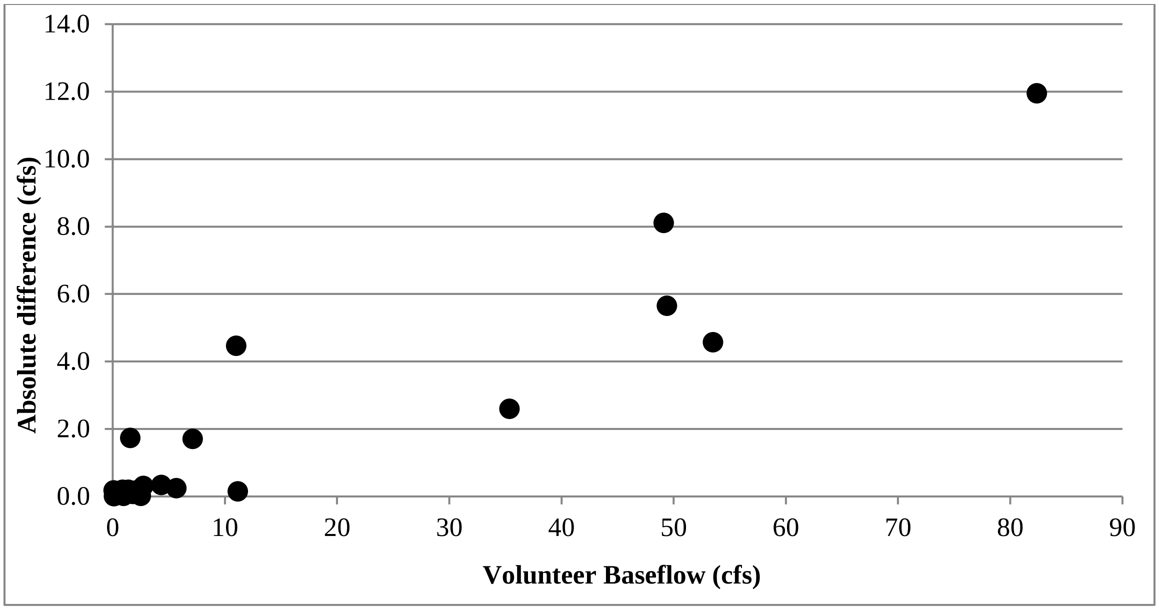


Figure 3. Absolute difference between volunteer and UWSP measurements by volunteer baseflow.

Table 3. Comparison of volunteer and UWSP baseflow measurements for 2014. Difference is defined as the absolute value of (larger measurement - smaller measurement)/ smaller measurement.

Station	Volunteer	Volunteer Date	Volunteer Measurement	UWSP Date	UWSP Measurement	Absolute Difference	Difference
West Branch Little Pine Creek	Waushara Cty	5/23/2014	2.5	5/19/2014	2.5	0.0	1
Schmudlack Creek	Waushara Cty	5/23/2014	1.4	5/19/2014	1.6	0.2	14
Bloody Run @ 64th Street	Wood Cty	5/19/2014	1.6	5/23/2014	3.3	1.7	112
Bloody Run @ 64th Street	Wood Cty	6/30/2014	0.9	6/26/2014	1.1	0.2	22
10Mile @ Evergreen	Wood Cty; Brian Hamm	6/26/2014	49.4	6/26/2014	55.0	5.7	11
10Mile @ Wilderness	Wood Cty; Brian Hamm	6/26/2014	82.4	6/26/2014	94.3	12.0	15
Big Roche-A-Cri @ 7th Ave	Adams Cty; Jay Jocham	6/7/2014	49.1	6/24/2014	57.2	8.1	17
14 Mile @ Aniwa Rd	Adams Cty; Dennis Poehler	6/11/2014	11.0	6/26/2014	15.5	4.5	41
10Mile @ Cty Rd U/80th St	Wood Cty; Brian Hamm	7/18/2014	35.4	7/18/2014	38.0	2.6	7
Little Roche-A-Cri Creek @ Czech/8th Ave	Adams Cty; Gary Lueck	7/28/2014	7.1	7/22/2014	8.8	1.7	24
Bower Creek @ Brown Deer	Waushara Cty	7/27/2014	1.0	7/21/2014	1.0	0.0	2
Lawrence Creek @ 1st Ave	Marquette Cty; Pat Kilby	7/11/2014	11.2	7/22/2014	11.0	0.2	1
2Mile @ Cty Rd U/80th Ave	Wood Cty; Staff	8/14/2014	0.1	8/15/2014	0.1	0.0	9
Bloody Run @ 32nd Street	Wood Cty; Staff	8/14/2014	1.8	8/15/2014	1.9	0.1	4
Pine Creek @ 17th Dr. (off Apache Dr.)	Waushara Cty	9/3/2014	0.6	8/13/2014	0.4	0.2	26
Willow Creek @ 18th Rd	Waushara Cty	9/3/2014	0.1	9/24/2014	0.3	0.2	200
N Davies @ 21st Ave	Waushara Cty	9/3/2014	2.1	9/24/2014	2.3	0.2	9
Sannes Creek @ Peterson Rd	Waupaca Cty	9/29/2014	5.7	9/29/2014	5.9	0.3	4
Twomile Creek @ Airport Ave	Wood Cty; Staff	9/25/2014	4.3	9/25/2014	4.7	0.3	8
Sevenmile @ 64th Street	Wood Cty; Borski	9/19/2014	2.7	9/25/2014	3.1	0.3	11
Mecan @ 14th Ave	Marquette Cty; Pat Kilby	10/20/2014	53.5	10/22/2014	58.1	4.6	9