# Using Drill Cuttings to Identify Arsenic Risk During Well Construction in Unconsolidated Aquifers

B.J. Bonin, PG WSB and Associates

### **Drill Cuttings**

- What comes up during drilling
- Drilling fluid
  - Water, air
  - □ Clay, barite, polymer, etc.
- Sand and pebbles
- Fluid & fines re-circulate
- Borehole open to erosion until cased
- Cuttings have not been used in Arsenic research despite dominating the available sample set



## Cuttings

- Usually caught with a kitchen strainer
- 1mm grains or larger
- Coated with mud
- Wash away mud



### Process

- Hobbes (1998)
   classified sand in till
- Adapted for use with cuttings
- Photograph cuttings
  - Digital microscope with hard stand to ensure exact frame scale
- Count grains by type



### Arsenic in Groundwater

#### Correlations:

- TDS
- Iron
- Sulfur
- High pH
- Proximity to confining layer
- Drilling method
- Grain size



### Case Study

#### Monticello, MN

#### Belgrade, MN



### Monticello MN



### Monticello, MN Wells 2 and 4

### Well 2

- 250 feet deep
- Confining layer 185-197
- Screened 220 to 250
- 1 ppb Arsenic
- Well 1 is adjacent, also 1 ppb Arsenic
- Samples are 10' intervals

#### Well 4

- 223 feet deep
- Confining layer 101-108
- Screened 174 to 220
- 7 ppb Arsenic
- Test well is adjacent, 8 ppb Arsenic
- Samples are 5' intervals

### **Monticello Wells**

#### Well Log Report - 00236578

http://mdh-agua.health.state.nm.us/cwi/well\_log.asp?wellid=0000236578 Well Log Report - 00449182

http://mdh-agua.health.state.nm.us/cwi/well\_log.asp?wellid=0000449182

236578         County Wight Gual ID         Well LAND BORING Received Date         End of the Update Date Well Address ID         End of the Date Mell Completed Date M	Minnesote Unique Well No.	MINNEBOTA DEPARTMENT OF HEALTH
CONTINUE         Quality         Diministion         REFCORD         Quality         Diministor           WHI Name MONTOCLU 2         Constraints	O2C579 County Weight	WELL AND BORING Entry Date 07/03/1992
Home MontroceLLO 2         Monesois Busites Glapter 600         Monesois Busites Glapter 600         Date Weil Completed           121         25 W         11 ACACA         Berzaion Nutcoul         00 R         .         75 minute         200 R         .	ZJOJIO Quad Monoceno Quad ID 138D	RECORD Received Date
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121     25     W 11     ADACA     Elevation Nethod     75 milute beographic respired 5 ket 0       Weil Addresses     MonTCELLO MN 55552     Defining Fluid     Weil Nydorharburet?     Yes     No       SAND TOP BOL CLAY     Onting Fluid     Weil Nydorharburet?     Yes     No       CANCE GRAVEL     0     12     No AboveScieve 2.8.     Casing Type the lobe of the control Number BOE     Yes     No       COARDE GRAVEL     0     12     No AboveScieve 2.8.     Datameter     Weil Nydorharburet?     Yes     No       COARDE GRAVEL     BROWN     15     15     No 14     No 14     No 200 1.     15     No 200 1.     16	Fownship Range Dir Seotion Subsections Elevation 026 ft.	250 ft. 250 ft. 02/11/1970
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MONTO-ELLO MY 353-2 beologiasi Material Color Hardness From Te Caring Type: Stel Diack of us cation). Joint Vielded Drive Shoer?  Use: Community/Supply PWB10 186012 Source 802 Caring Type: Stel Diack of us cation). Joint Vielded Drive Shoer? Use: Converse of Caring Type: Stel Diack of us cation). Joint Vielded Drive Shoer? AND TO POL CLAY BROWN 185 197 20 Din to 14 ft. bs./ft. 19 In. to 250 ft. Dependied to mt. ft. bt. Sector TSB Make Type: StellAts stell Demeter SkotGause Length Set Setween 15 40 30 220 ft. and 250 ft. Statis Water Level ft. ft. mo Date Messured FMWR01 Diet Determines Under FMWR01 Diet Determines Under Remarks & Loaked by: Minesob Department of Healt Using Numer Vielded Messared FMWR01 Diet Determines Weil Social Diameter Ext Argents: UTM-Nad33, Zoorf5, Melors X: 437800 Y: 501700 Ext and X: 50	Well Address	Drilling Fluid Well Hydrofraotured? Ves No
beologikal Material       Color       Hardness Prom To       Caling Type Bed (bet: or bit cathor) Joint Weides Bottle Back       Interface         OLARDE SAND BOULDERS CLAY STRING.       BLUE       0       12       Ito Above Bed (bet: or bit cathor) Joint Weides Drive Bacet III       Ito Above Bed (bet: or bit cathor) Joint Weides Drive Bacet IIII       Ito Above Bed (bet: or bit cathor) Joint Weides Drive Bacet IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	MONTIGELLO MN 55362	Use CommunitySupply PWSID 1880012 Source 802
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Adda. N.D.211	REMARKS	Casing Protection 12 in. above grade Argrade (Environmental Wells and Borings ONLY) Grouting Information Well Grouted? Yes No
Unique Number Verificasion: Inhomaton hom owner Input Date: 65112000 Bysten: UTM - Nad83, Zonef5, Melers X: 437800 Y: 5017085  Mearest Known Bourse of Contamination	M.G.B. NO.021. Located by: Minnesola Department of Health Method: GPS BA On (averaged)	Grout Naterial: Neat Cement from 0 to ft. 2 yrds.
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County Well Index Online Depart 020070 Printed 9/30/2	Cuttings Yes First Bedrook Aquiter Oust Burled Ales Aquiter Last Birst Gowel (-langed Depth to Bedrook ft.	Abandoned Wells: Des property have any not in use and not sealed well(s)? No Variance Was a winner grented from the MDH for His well? Well Constructor Certification Layner Well Co. 27010 VITUM.R. License Budiness Name Lic. Or Reg. No. Name of Onlier Op CECTO

Minnesota Unique Well No.	100000				MINNESOTA DEPARTMENT	OF HEALTH	to children		
449182	County 1	Wight			WELL AND BO	RING	Entry Date	07/03/1992	
443102	Quad ID 1	38D			RECORD		Received Date		
					Minnesota Statutes Chap	oter 103/			
Well Name MONTICELLO 4	121 SK124				Well Depth	Depth Complete	ed Date W	ell Completed	
Township Range Dir Seotion Subse	otions Elevation		952 R.		223 ft.	220 ft.	10	18/1988	
	D Elevation	Hathad	7.5 minute	and to be	Drilling Method Non-speci	fled Rolary			
121 25 W 14 ADOD		meulou	S feet)	iah (w					
Well Address					Drilling Fluid	Well Hydrofraotur	red? Yes	No	
MONTICELLO MN 55362					Bentonite	From FL to FL			
					Use CommunitySupply P	WSID 1860012 So	uree 804		
Seological Material NO RECORD	Color	Hardness	From	T0 46	Casing Type Steel (black o	r low carbon) Joint	Welded Drive Shoe	? Ves	
CLAY	GRAY		46	62	NO ADDICIDCION IL				
CLAY & GRAVEL	DK. GRY		62	101	Casing Diameter	Weight	Hole	Diameter	
GRAVEL	RED		101	108	24 in to 45 ft	94.62 lbs	s./R.		
CLAY & GRAVEL	DK. BRN		108	118	24 IL 0 40 IL		124		
GRAVEL	WARED		118	208	18 In. to 176 ft.	70.59 lbs	s./it.		
GRAVEL	VARIED		200	270	Open Hole from ft. to	t.			
ORWEL	WHED		210	443	Soreen YES Make JOHN	NSON Type staini	ess steel		
					Diameter Siot/Ga 18 60	auze Length 46	Set Between 174 ft. and	220 ft.	
					Statio Water Level	ate Measured 100	8/1988		
					DUMPING LOFT A dampin	ad australia			
					67 ft. after 2 hrs.pumping	2400 g.p.m.			
					-				
					Well Head Completion				
					Pitiess adapter manufacturer	BAKER Model			
					Casing Protection II 12 in above grade				
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REMARKS					- Algrede (Environmente	a weis and bonngs o	UNLT)		
M.G.8. NO.2954.					Grouting Information We	Il Grouted?	es 🗆 No		
					Grout Material: Neat Ce	ment fr	om 0 to 118 ft.	10 yrs	
Looated by: Minnesola Department of	fHealth	Method: G	PS SA On (ave	reged)					
Unique Number Verification: Inform	ation from owner	Input Date:	05/11/2000						
System: UTM - Nad83, Zone15, Meter	15	X: 437972	Y: 5015486		Nearest Known Source of C feet direction type	Contamination c			
					Well disinfected upon com	pletion? 🗏 Y	es 🔍 No		
					Pump 🗵 Not installed	Date installed 11/2	3/1988		
					Manufacturer's name	lodel number OE 15	H-7000 HP 75 V	bits <u>440</u>	
					Length of drop Pipe 105 ft.	Capacity2400 g.p.	m Type <u>Turbine</u> k	laterial	
					Abandoned Wells Does pro	operty have any not in	use and not sealed we	ell(s)7 — Y	
					Variance Wese verlence gre	anted from the MDH f	brthisweil? 🗉 Ye	s 🗉 No	
Cuttings Yes					Well Contractor Certification	on			
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art Strat Gauge (slamat	Aquiter Que	ouncel Anco.	Auguster .		Lineare Duris and the	- C - C - C - C - C - C - C - C - C - C	Or Day Ma	theme of the set	
case on all orders (manual)	Depth to Bedr	UUN TL			License Business Nar	ne Lk	C. OF REG. NO.	Name or Drille	
<b>County Well Index</b>	Online I	Report			449182			Printed 9/30/	

### **Monticello Wells**

#### Well Log Report - 00236578

http://mdh-agua.health.state.nm.us/cwi/well\_log.asp?wellid=0000236578 Well Log Report - 00449182

http://mdh-agua.health.state.nm.us/cwi/well\_log.asp?wellid=0000449182

County Wight					
226578	WELL AND BORING ENtry Date 07/03/1992				
ZJOJIO Quad ID 138D	RECORD Reserved Date				
	Minnesota Statutes Chapter 103/				
Nell Name MONTICELLO 2	Well Depth Completed Date Well Completed				
Township Range Dir Seotion Subsections Elevation 028 ft.	250 m. 250 m. 02/11/1970				
7.5 minute 121 25 W 11 ACAACA Elevation Method topographic rdp (+) 5 feet)	Dritting Method Non-specified Robry				
Well Address	Drilling Fluid Well Hydrofraotured? Ves No				
MONTICELLO MN 55362	From L to FL				
3eological Material         Color         Hardness         From Ti           SAND YTOP SOL         0         0         12         14           CUAY         BLUE         1.2         14           COARSE GAND BOULDERS CLAYSTRING.         16         11           CLAY         BROWN         165         11	Casing Type Stet (black or low carbon) Joint Weided Drive Shoe? Ves ko AboveBelow 2 ft. Is Casing Diameter Weight Hole Diameter				
COARSE GRAVEL 197 25	20 in. to 14 ft. Ios.π. 19 in. to 250 ft.				
	16 in. to 225 ft. Ibs./ft.				
	Open Hole from ft. to ft.				
	Soreen YEB Make Type stainless steel				
	Diameter Skot/Gauze Length Set Between 16 40 30 220 ft. and 250 ft.				
	Statio Water Level				
	ft. from Date Measured				
	PUNPING LEVEL (below land surface)				
	ft. after hrs.pumping g.p.m.				
	Well Head Completion				
	Pitiess adapter manufacturer Model				
	Casing Protection 12 in. above grade				
	Al-grade (Environmental Wells and Borings ONLY)				
REMARK\$ M.G.8. NO.821.	Grouting Information Well Grouted? 🔲 Yes 👘 No				
	Grout Material: Neat Cement from 0 to ft. 2 yrds.				
Loosted by: Minnesola Department of Health Method: GP8 8A On (averaged) Unique Number Verification: Information from owner Input Date: 05/11/2000					
Bystem: UTM - Nad83, Zone15, Meters X: 437800 Y: 5017096	Nearest Known Source of Contamination feet				
	Well disinfected upon completion? Yes No				
	Pump Not installed Date installed				
	Manufacture's name Model numberHPVolb Length of drop Pipe 1. Gogacity a.g.m Twoe Material				
	Abandoned Wells Does properly have any not in use and not sealed well(s)?				
	No				
	Variance Was a variance granted from the MDH for this well?  Yes No				
Cutings Yes	Well Contractor Certification				
First Bedrook Aquifer Quat. Burled Artes. Aquifer	Layne Well Co. 27010 VIT TUM, R.				
Last Strat Grevel (Harger) Depth to Bedrook ft.	License Business Name Lic. Or Reg. No. Name of Driller				

449182	County Quad Quad ID	Wright Monticello 138D			WELL AND BO RECORD Minnesota Statutes Chap	RING Entry Upd: Rece ter 103/	y Date 07/03/1992 ate Date 08/31/2009 ived Date
Vell Name MONTICELLO 4	107 - 22	12			Well Death	Depth Completed	Date Well Completed
Township Range Dir Section Subse	otions Elevati	ion	952 ft.		222 .	220 R.	10/18/1988
121 25 W 14 ADCB	BB Elevati	ion Nethod	7.5 minute topographic r	ap (+)-	Drilling Method Non-specif	led Rotary	
Well Address				_	- 14 - 14		
MONTICELLO MN 55362					Bentonte	Well Hydro raotured? From L to Ft.	Yes No
and and and Marked at	Onlas	Handaran	-	-	use commenter pro	Hold 1000012 Bourde	
NO RECORD	Color	Hardness	n	45	Casing Type Steel (block or	low carbon) Joint Weld	ed Drive Shoe? Yes
CLAY	GRAY		46	62	No Above/Below ft.		
CLAY & GRAVEL	DK. GRY		62	101	Casing Diameter	Weight	Hole Diameter
GRAVEL	RED		101	108	74 in to 45 *	94.62 lbs /#	
CLAY & GRAVEL	DK. BRN		108	118	24 R. 00 46 R.		
DL AY	WARIED		118	208	18 in. to 176 ft.	70.59 lbs./ft.	
3RAVEL	VARIED		210	223	Open Hole from ft. to f	L	
	erec.		210		Soreen YES Make JOHN	ISON Type stainless st	el
					Diameter Siot/Ga 18 60	uze Length Se 46 1	tBetween 74 ft. and 220 ft.
					Statio Water Level		
					30 ft. from Land surface D	ate Measured 10/18/1988	
					PUMPING LEVEL (below las	nd surface)	
					67 ft. after 2 hrs. pumping	2400 g.p.m.	
					Well Head Completion		
					Pitiess adapter manufacturer	BAKER Model	
					mana		
					Casing Protection	12 in. above grade	
					Al-grade (Environmental	Wells and Borings ONLY)	
REMARKS A.G.8. NO.2954.					Grouting Information Wel	Grouted? 🗵 Yes	No
					Grout Material: Neat Ce	ment from (	to 118 ft. 10 yrd
Looated by: Minnesola Department Unique Number Verification: Inform	of Health Lation from own	Method: G er Input Date:	PS SA On (ave 05/11/2000	raged)			
Bystem: UTM - Nad83, Zone15, Mete	NS .	X: 437972	Y: 5015486		Nearest Known Source of C feetdirectiontype	ontamination	
					Well disinfected upon com	pletion? 🔲 Yes	No
					Pump 🗵 Not installed	Date installed 11/23/1988	
					Manufacturer's name M	odel number OE 15H-700	HP 75 Volts 440
					Length of drop Pipe 105 ft.	Capacity2400 g.p.m	Type Turbine Material
					Abandoned Wells Does pro	perty have any not in use a	nd not sealed well(s)? 📃 🛛
					Variance Wese verlence gre	nted from the MDH for this	well? 🗉 Yes 🗐 No
Cuttings Yes					Well Contractor Certificatio	•	
first Bedrook	Aquifer C	ust Buried Artes.	Aquifer		Renner E.H. Well	710	15 8IGAF008, 0
and Black Description and					the second se		
astatrat Grever (Harger)	Depth to B	edrook ft.			LICENSE BUSINESS NOT	LIC. OF N	eg. No. Name of Units

# Both appear to be the same aquifer – why does Arsenic concentration differ?



Look for differences in:

- Provenance
- Materials
- Grain counts (size equivalent)
- Drilling method
- Drilling fluid

#### Well 2 210 - 220 feet Well 4 210 - 215 feet



#### Well 2 – 220 - 230 feet Well 4 – 215 - 220 feet





- Grain size
- Composition
- Depositional environment
- Provenance
- Drilling Method
- Drilling Fluid





### Strata Comparison

#### Well 2 – 170 feet

#### Well 4 – 195 feet



### New Well





### Belgrade, MN



### Aquifers

- "Water Table" aquifer (Well 2)
- 5 buried confined aquifers around Belgrade
- Named by letter (B through F), B is shallow, F is deepest
- Aquifers vary in water quality

### **Aquifer Characteristics**

Aquifer:	Depth range	Average thickness	Fe	Mn	TDS	SO4	As
В	20-80	20	2.52 ppm	192 ppb	350 ppm	5.3 ppm	
С	110-150	20	3.8 ppm	120 ppb	390 ppm	7.9 ppm	30-50 ppb
D	160-200	15	1.38 ppm	43 ppb	380 ppm	13.3 ppm	1-10 ppb
F	180-250	20	2 77 ppm	125 nnh	447 nnm	46 9 ppm	1-10 ppb
F	230-270	15	3 12 ppm	77 ppb	376 ppm	29.3 ppm	1.10.000

From USGS Water Resources Investigation Report 88-4124

### **Confined Aquifers**



### **Confined Aquifers**



### Belgrade, MN Wells 1 and 3

### Well 1

- 209 feet deep
- Confining layer 35-120
- Confining layer 139-171
- Screened 160 to 200
- 1 ppb Arsenic
- Well 3 is adjacent
- Sealed 2011

### Well 3

- 139 feet deep
- Confining layer 30-119
- Screened 123 to 135
- 38+ ppb Arsenic
- Well 1 is adjacent
- Sealed 2011

### **Belgrade Wells**

Well Log Report - 00496508

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Σι (i Σιle;	
Location: Oelarade Steams Co	
(city, tillage, Township, Section, Range, County, etc.)	- :
subject: <u>Murricipal Well # 1</u>	1
By Moon: Byren Adams Date: 1-13-82	<b>-</b>
Investigation X Conference Field Reprise	<u> </u>
i Items to be Covered: (1) Those procerts	X
(2) Situation	
Seale	
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Belgrade.	<u>`</u>
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Thickness Material The phone aver The phone	<u></u>
thickness material	
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1 2-35 yellow Stand (35') 139'- 171' Ein Sandy St 6	<u> </u>
(10) 95-35 Grey Sand (5') 171-176' Shale + Could	<u>1</u> ·
(8') 35-43' Firm Muddy Sent (a) 171' 170' Pitt	<del>.</del>
(17) 43'-60' Hard Sade State (2) 110-118 KOCK - Lime rac	<u>K</u> .
(2') 60-11' 11 (2) Soft Sandy Shaler (1) 178-191 Soft Sandy Shaler (	Travel
(1) (2) (2) (2) And (2) (2) 191 - 209 Hard Shale + Gri	avel
C - 65 Soft Sand	
(15 / 63-88 Soft Sandy Shale (200-209' Rackel (6.0)	-
Front Hard Par	-
(1) 89-90' Shale Screenet 162-2001	
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[(3)] Internet and the transformed and the the the second	_
(16') with and marked Shall	
154-100 Soft Strong Shale	
(1°00/273-01 (8/79)	

Minnessele Unique Weil No. 496508 Guad Belgranie Guad ID 143A	MINNESOTA DEPARTMENT OF HEALTH WELL AND BORING Entry Date 0900/1992 Update Date 0922/2012 RECORD Received Date Minnesota Statutus Chapter 109/
Well Name BELGRADE 3 Township Range Dir Section Subsections Elevation 1265 ft.	Well Depth Depth Completed Date Well Completed
123 34 W 19 BACCED Elevation Method tooographic mat	Drilling Method Non-specified Rotary
(+/- 5 teel)	
BELGRADE MN 56312	Drilling Fluid Well Hydrofractured? Yes No Bentonite From FL to FL
Geological Material Color Hardness From To TOP SOIL BLACK SOFT 0 1	Use Abendoned Status Seeled Casing Type Steel (block or low carbon) Joint Unknown Drive Shoe?
SARDY CLAY         YELLOW         M.S.D.F.I         1         4         3           SARDY CLARSE         YELLOW         WEDILM         4         3 <td>res 12 No Adovection 25 m. Casing Diameter Weight Hole Diameter 20 in. to 26 ft. Ios./ft. 12 in. to 123 ft. Ios./ft. DearNie for ft. Io ft.</td>	res 12 No Adovection 25 m. Casing Diameter Weight Hole Diameter 20 in. to 26 ft. Ios./ft. 12 in. to 123 ft. Ios./ft. DearNie for ft. Io ft.
FINE SAND ROCKY         80         81           SANDY CLAY         GRAY         M.SOFT         81           SANDY CLAY         GRAY         M.SOFT         81           ROCKY CLAY         GRAY         M.SOFT         81           SANDY SILTY CLAY         GRAY         M.SOFT         108           SANDY SILTY CLAY         GRAY         NOFT         108           SANDY CLAY         GRAY         M.SOFT         113           SANDY CLAY         GRAY         M.SOFT         113           SANDY CLAY         GRAY         HARD         113           SONDY CLAY         INT         114         117           SUBLY         GRAY         117         119           MCK         HARD         119         119	Somen YES Make JOHNSON Type skinless sked Diameter Slot/Gauze Length Set Between 12 60 12 123 ft. and 135 ft.
SAND & SIGNS OF WOOD         SOFT         120         12           SILTY CLAY         BLACK         M.SOFT         121         12           SAND - FINE         VARIED         MEDIUM         123         13           CLAY         YALLOW         VARIED         MEDIUM         123         13           CLAY         GRAY         YELLOW         HARD         135         13	Static Water Level 182 ft. from Land surface Dele Messured 11/18/1991 PMWPNG EURE (Delow Land surface) 93.7 ft. efter hrs. pumping 230 q.p.m.
	Well Head Completion Pless adapter menufacturer MONITOR Model 7PS121 Casing Potection 12 in. above grade
REMARKS SEALED 4-7-2011 BY 1551; PREVIOUS USE: PC	Grouting Information Well Grouted?
Located by: Minnesola Geological Method: Diglizzed - scale 1:24,000 or larger Survey (Diglizing Table)	Grout Material: Neat Cement from 0 to 113 ft. 0
Verification: Informetion from owner System: UTM - Ned83, Zone15, Meters X: 343377 Y: 5035170	Neurest Known Source of Contamination <u>75</u> feet E_direction <u>Septic tankidrain field</u> type
	ven exercuteur up016000pet001: 155 0 No Pump Ø Na Installed Date Installed 11022091 Manufacture's name UUCLER. Model number <u>9557</u> HP 15 Volts 230 Langth of drop Fipe <u>156</u> L. Capacity_a.p.m. Type <u>Submersible</u> Method <u>Steel</u> Match of law perfort.
	Abandoned Wells Does property have any not in use and not sealed well(s)?
	Variance Was a variance granted from the MDH for this well? Yes No Well Contractor Certification
First Bedrock Aquifer Quot. Buried Artes. Aquifer Last Strat clay-groy Depth to Bedrock ft.	Ervin Well Co. 65252 ERVIN, B. License Business Name Lic. Or Reg. No. Name of Driller
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### **Belgrade Wells**





### **USGS** Test Wells





- Grain size
- Composition
- Depositional environment
- Provenance
- Drilling Method
- Drilling Fluid





#### TH 10 Aquifer C TH 10 Aquifer D



#### TH 42 Aquifer C TH 42 Aquifer D



### Conclusions

- Identifying high arsenic aquifer by cuttings appears possible in Monticello, MN,
- but not in Belgrade, MN using the archived samples.
- Much more work needs to be done, as aquifer conditions change over time and space.
- Investigate drilling methods in addition to materials drilled.



### Questions?

- Thanks:
  - Minnesota Geological Survey
  - □ Cities of Monticello and Belgrade
  - Minnesota Department of Health

#### References

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