

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

B.J. Bonin, PG

WSB and Associates

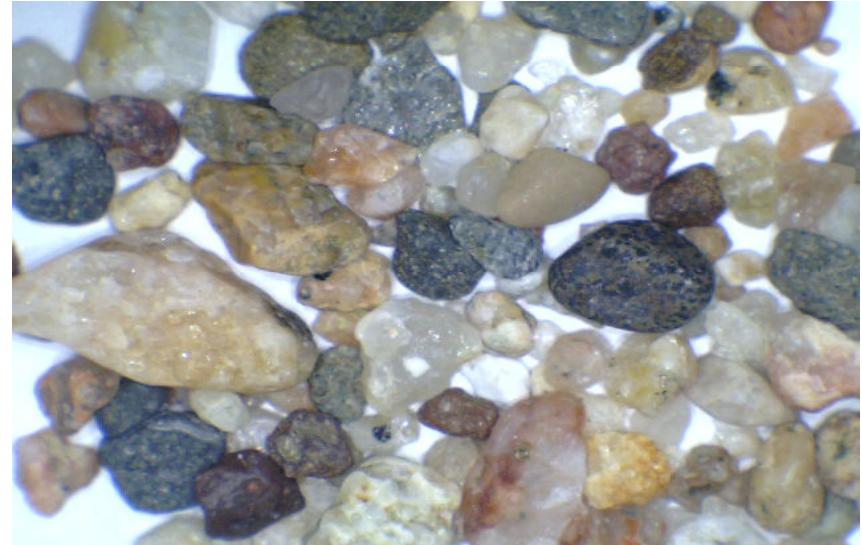
# Drill Cuttings

- 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



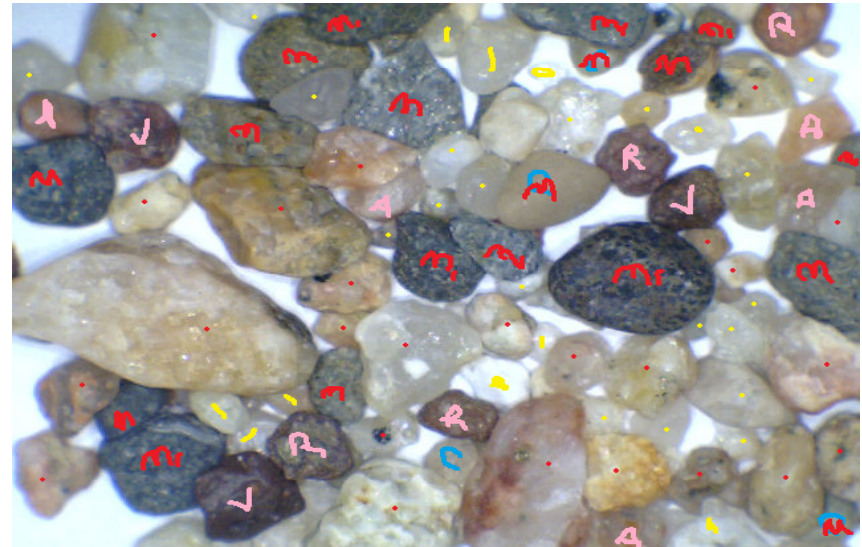
# Cuttings

- 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:

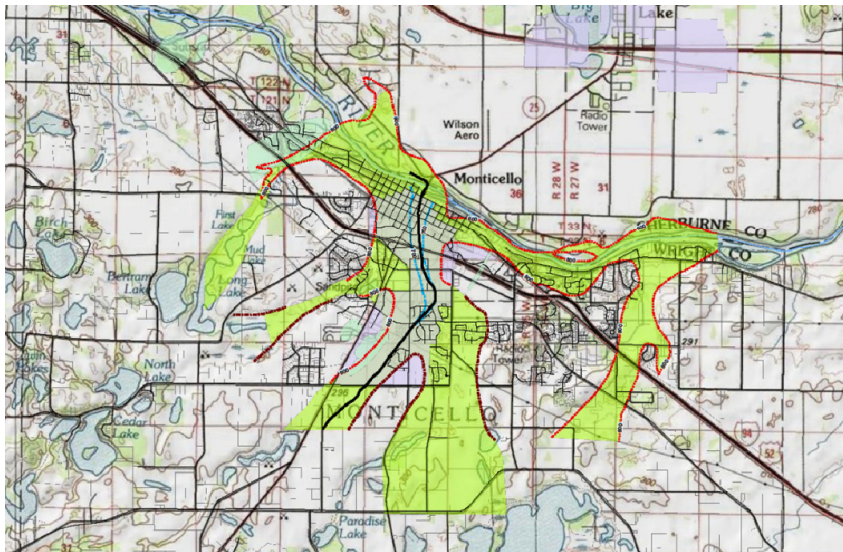
- TDS
- Iron
- Sulfur
- High pH
- Proximity to confining layer
- Drilling method
- Grain size





# Case Study

## Monticello, MN



## Belgrade, MN

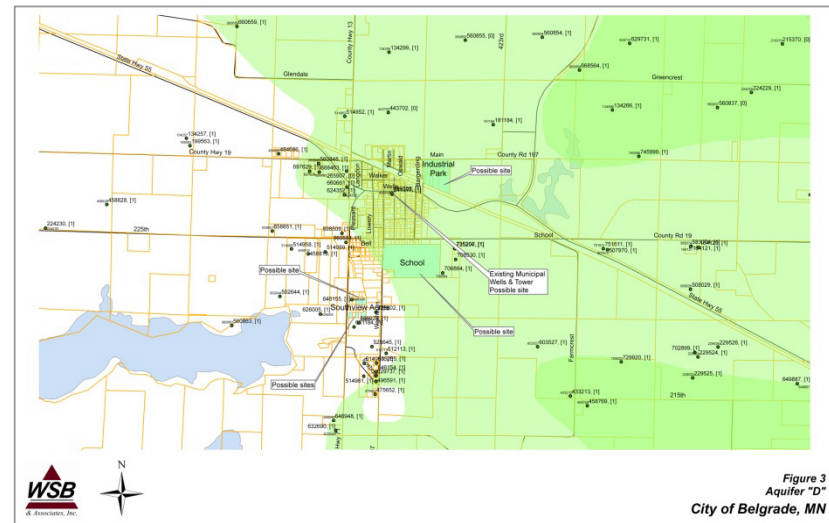
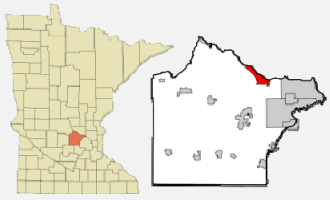
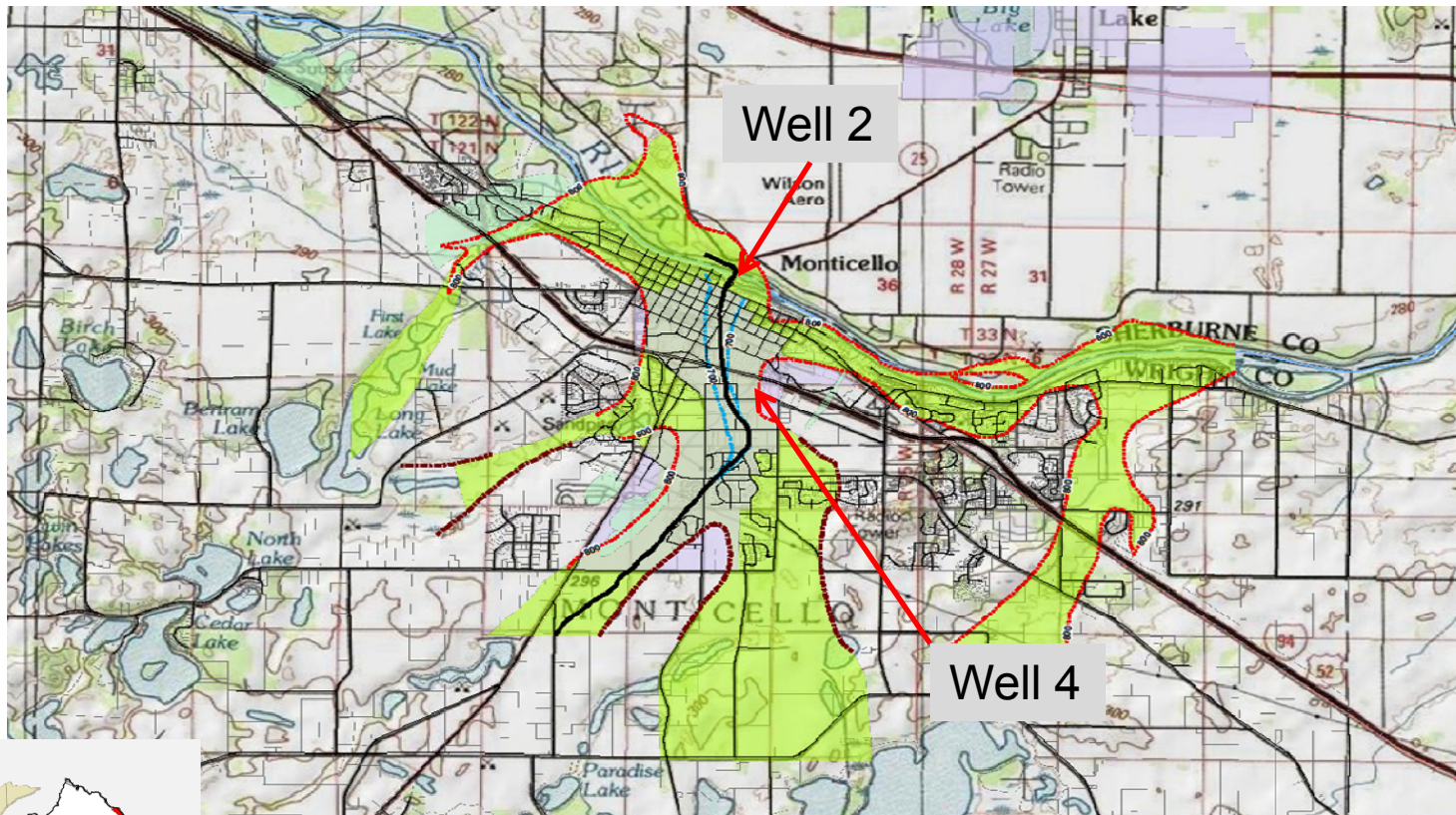



Figure 3  
Aquifer "D"  
City of Belgrade, MN

# 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://mnh-agna.health.state.mn.us/cwi/well\\_log.asp?wellid=0000236578](http://mnh-agna.health.state.mn.us/cwi/well_log.asp?wellid=0000236578)

Well Log Report - 00449182

[http://mnh-agna.health.state.mn.us/cwi/well\\_log.asp?wellid=0000449182](http://mnh-agna.health.state.mn.us/cwi/well_log.asp?wellid=0000449182)

Minnesota Unique Well No. <b>236578</b>		County Monticello	Weight 1380	MINNESOTA DEPARTMENT OF HEALTH <b>WELL AND BORING RECORD</b>		Entry Date 07/03/1992	Update Date 08/31/2009	Received Date
Well Name MONTICELLO 2		Township Range Dir Section Subsections Elevation 121 25 W 11 ACACA Elevation Method 7.5 minute topographic map (+/- 5 feet)		Well Depth 250 ft.	Depth Completed 250 ft.	Date Well Completed 02/11/1970		
Well Address MONTICELLO MN 55362		Drilling Fluid --		Well hydrofractured? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No From Ft. to Ft.		Use: Community Supply PW9 ID 1600012 Source 002		
Geological Material SANDY TOP SOIL CLAY COARSE SAND BOULDERS CLAY STRING. CLAY COARSE GRAVEL		Color BLUE BROWN	Hardness 0 12 16 185 185 197 197 250	Casing Type No Above/Below 2 ft.	Casing Diameter 20 in. to 14 ft.	Weight lbs./ft.	Joint Welded 19 in. to 250 ft.	Drive Shoe? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Open Hole from ft. to ft.		Sieve YES Make Type stainless steel		Diameter 3 in./Gauge Length Set Between		16 40 30 220 ft. and 250 ft.		
Static Water Level ft. from Date Measured		PUMPING LEVEL (below land surface) ft. after hrs. pumping g.p.m.		Well Head Completion Fits adapter manufacturer Model <input type="checkbox"/> Casing Protection <input type="checkbox"/> 12 in. above grade <input type="checkbox"/> Above (Environmental Wells and Springs ONLY)		Grouting Information Well Grouted? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Grout Material: Neat Cement from 0 to ft. 2 yds.		
REMARKS M.G.S. NO. 021.		Located by: Minnesota Department of Health Method: GPS BA On (averaged) Unique Number Verification: Information from owner Input Date: 05/11/2000 System: UTM - Nad83, Zone 15, Meters X: 437800 Y: 5017090		Nearest Known Source of Contamination _ft. _direction _type Well disinfected upon completion? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		Pump <input checked="" type="checkbox"/> Not Installed Date Installed 11/03/1988 Manufacturer's name Model number HP_Volt Length of drop pipe ft. Capacity g.p.m. Type Material		
Cuttings Yes First Bedrock Last Strat. Gravel (Hager)		Aquifer Quat. Buried Artes. Aquifer Depth to Bedrock ft.		Abandoned Wells Does property have any not in use and not sealed well(s)? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		Variance Was a variance granted from the MDH for this well? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		
County Well Index Online Report		236578		Lynn Well Co. 72010 VITUM, R. License Business Name Lic. Or Reg. No. Name of Driller		Printed 9/30/2011 HE-01205-07		

Minnesota Unique Well No. <b>449182</b>		County Monticello	Weight 1380	MINNESOTA DEPARTMENT OF HEALTH <b>WELL AND BORING RECORD</b>		Entry Date 07/03/1992	Update Date 08/31/2009	Received Date
Well Name MONTICELLO 4		Township Range Dir Section Subsections Elevation 121 25 W 14 ADCBBB Elevation Method 7.5 minute topographic map (+/- 5 feet)		Well Depth 223 ft.	Depth Completed 220 ft.	Date Well Completed 10/18/1988		
Well Address MONTICELLO MN 55362		Drilling Fluid Bentonite		Well hydrofractured? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No From Ft. to Ft.		Use: Community Supply PW9 ID 1600012 Source 004		
Geological Material NO RECORD CLAY CLAY & GRAVEL GRAVEL CLAY & GRAVEL GRAVEL CLAY GRAVEL		Color GRAY DK. GRY RED DK. BRN VARIED GRAY VARIED	Hardness 0 45 46 62 62 101 101 108 108 118 118 208 200 210 210 223	Casing Type No Above/Below ft.	Casing Diameter 24 in. to 46 ft.	Weight 94.62 lbs./ft.	Joint Welded 18 in. to 176 ft.	Drive Shoe? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Open Hole from ft. to ft.		Sieve YES Make JOHNSON Type stainless steel		Diameter 3 in./Gauge Length Set Between		18 60 46 174 ft. and 220 ft.		
Static Water Level 30 ft. from Land surface Date Measured 10/18/1988		PUMPING LEVEL (below land surface) 87 ft. after 2 hrs. pumping 3400 g.p.m.		Well Head Completion Fits adapter manufacturer BAKER Model <input type="checkbox"/> Casing Protection <input checked="" type="checkbox"/> 12 in. above grade <input type="checkbox"/> Above (Environmental Wells and Springs ONLY)		Grouting Information Well Grouted? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Grout Material: Neat Cement from 0 to 118 ft. 10 yds.		
REMARKS M.G.S. NO. 2954.		Located by: Minnesota Department of Health Method: GPS BA On (averaged) Unique Number Verification: Information from owner Input Date: 05/11/2000 System: UTM - Nad83, Zone 15, Meters X: 437972 Y: 5015486		Nearest Known Source of Contamination _ft. _direction _type Well disinfected upon completion? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		Pump <input checked="" type="checkbox"/> Not Installed Date Installed 11/03/1988 Manufacturer's name Model number GE 15H7000 HP 7.5 Volt 440 Length of drop pipe 105 ft. Capacity 3400 g.p.m. Type Turbine Material		
Cuttings Yes First Bedrock Last Strat. Gravel (Hager)		Aquifer Quat. Buried Artes. Aquifer Depth to Bedrock ft.		Abandoned Wells Does property have any not in use and not sealed well(s)? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		Variance Was a variance granted from the MDH for this well? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		
County Well Index Online Report		449182		Renner E.H. Well 71015 SIGAFOOS, B. License Business Name Lic. Or Reg. No. Name of Driller		Printed 9/30/2011 HE-01205-07		

# Monticello Wells

Well Log Report - 00236578

[http://mxdh-agua.health.state.mn.us/cwi/well\\_log.asp?wellid=0000236578](http://mxdh-agua.health.state.mn.us/cwi/well_log.asp?wellid=0000236578)

Well Log Report - 00449182

[http://mxdh-agua.health.state.mn.us/cwi/well\\_log.asp?wellid=0000449182](http://mxdh-agua.health.state.mn.us/cwi/well_log.asp?wellid=0000449182)

Minnesota Unique Well No.		County		Weight		MINNESOTA DEPARTMENT OF HEALTH		Entry Date	
<b>236578</b>		Monticello		138D		<b>WELL AND BORING RECORD</b>		07/03/1992	
Well Name MONTICELLO 2		Township Range Dir Section Subsections Elevation		Well Depth		Depth Completed		Date Well Completed	
121 25 W 11 ACACA Elevation Method		7.5 minute topographic map (+/- 5 feet)		250 ft.		250 ft.		02/11/1970	
Well Address		MONTICELLO MN 55362		Drilling Fluid		Well Hydrofractured? <input type="checkbox"/> Yes <input type="checkbox"/> No		Expected Depth	
Geological Material		Color Hardness From To		Casing Type		Steel (black or low carbon) Joint Welded Drive Shoe? <input type="checkbox"/> Yes <input type="checkbox"/> No		Above/Below 2 ft.	
SANDY TOP SOIL. CLAY. COARSE SAND BOULDERS CLAY STRING. CLAY. COARSE GRAVEL		BLUE BROWN		12 16 16 185 185 197 197 250		No Above/Below 2 ft.		Casing Diameter Weight Hole Diameter	
				20 in. to 14 ft.		16 in. to 226 ft.		lbs./ft. 19 in. to 250 ft.	
				16 in. to 226 ft.				lbs./ft.	
REMARKS		M.G.S. NO. 821.		Grouting Information		Well Grouted? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		Grout Material: Neat Cement from 0 to ft. 2 yds.	
Located by: Minnesota Department of Health		Method: GPS BA On (averaged)		Nearest Known Source of Contamination		_ft. _direction _type		Well disinfected upon completion? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Unique Number Verification: Information from owner		Input Date: 05/11/2000		Pump		<input type="checkbox"/> Not Installed Date Installed		Manufacturer's name Model number HP_Volt	
System: UTM - Nad83, Zone 15, Meters		X: 437800 Y: 5017090		Abandoned Wells		Does properly have any not in use and not sealed well(s)? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		Well Contractor Certification	
County Well Index Online Report		<b>236578</b>		License Business Name		LIC. OR REG. NO.		Name of Driller	
								Printed 9/30/2011 HE-01205-07	

Minnesota Unique Well No.		County		Weight		MINNESOTA DEPARTMENT OF HEALTH		Entry Date	
<b>449182</b>		Monticello		138D		<b>WELL AND BORING RECORD</b>		07/03/1992	
Well Name MONTICELLO 4		Township Range Dir Section Subsections Elevation		Well Depth		Depth Completed		Date Well Completed	
121 25 W 14 ADC888 Elevation Method		7.5 minute topographic map (+/- 5 feet)		223 ft.		220 ft.		10/18/1988	
Well Address		MONTICELLO MN 55362		Drilling Fluid		Well Hydrofractured? <input type="checkbox"/> Yes <input type="checkbox"/> No		Expected Depth	
Geological Material		Color Hardness From To		Casing Type		Steel (black or low carbon) Joint Welded Drive Shoe? <input type="checkbox"/> Yes <input type="checkbox"/> No		Above/Below 2 ft.	
NO RECORD. CLAY & GRAVEL. GRAVEL. CLAY & GRAVEL. GRAVEL. CLAY. GRAVEL		GRAY DK. GRY. RED DK. BRN. VARIOED GRAY VARIOED		46 62 101 108 118 208 210 223		No Above/Below 2 ft.		Casing Diameter Weight Hole Diameter	
				24 in. to 46 ft.		18 in. to 176 ft.		94.62 lbs./ft. 70.59 lbs./ft.	
				18 in. to 176 ft.				lbs./ft.	
REMARKS		M.G.S. NO. 2954.		Grouting Information		Well Grouted? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		Grout Material: Neat Cement from 0 to 118 ft. 10 yds.	
Located by: Minnesota Department of Health		Method: GPS BA On (averaged)		Nearest Known Source of Contamination		_ft. _direction _type		Well disinfected upon completion? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	
Unique Number Verification: Information from owner		Input Date: 05/11/2000		Pump		<input checked="" type="checkbox"/> Not Installed Date Installed 11/03/1988		Manufacturer's name Model number HP_Volt	
System: UTM - Nad83, Zone 15, Meters		X: 437972 Y: 5015486		Abandoned Wells		Does properly have any not in use and not sealed well(s)? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		Well Contractor Certification	
County Well Index Online Report		<b>449182</b>		License Business Name		LIC. OR REG. NO.		Name of Driller	
								Printed 9/30/2011 HE-01205-07	

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



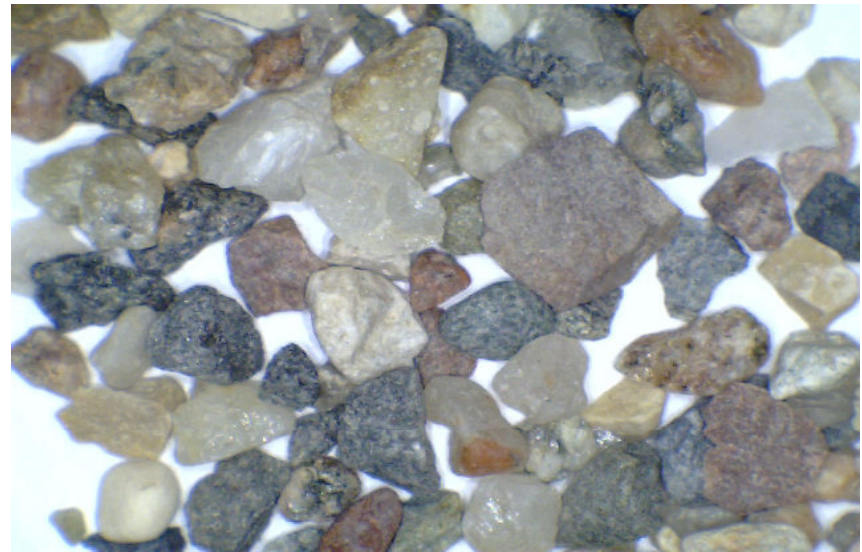
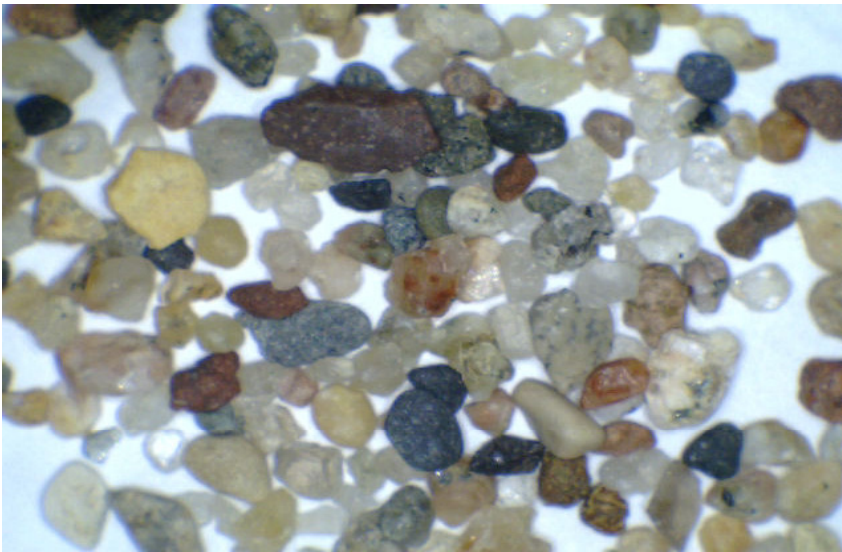
Look for differences in:

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

# Compare Materials

**Well 2 210 - 220 feet**

**Well 4 210 - 215 feet**





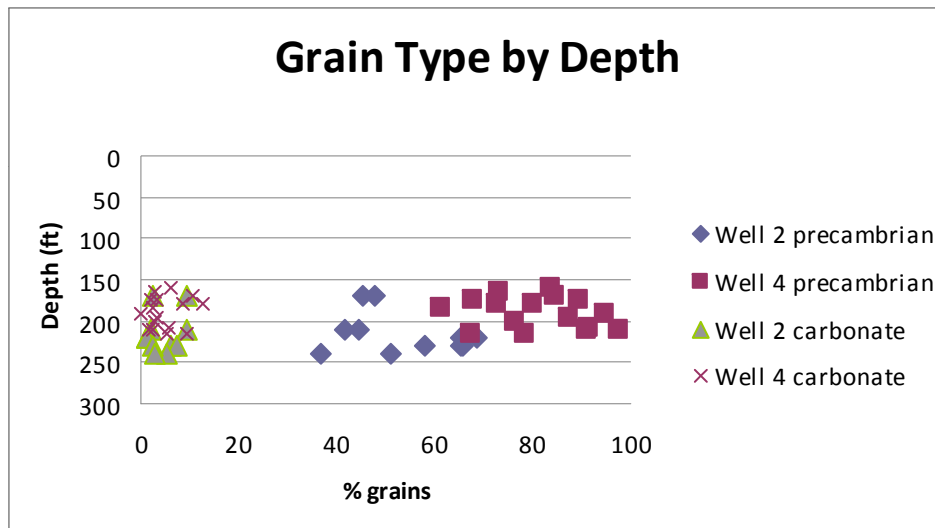
# Compare Materials

**Well 2 – 220 - 230 feet**

**Well 4 – 215 - 220 feet**

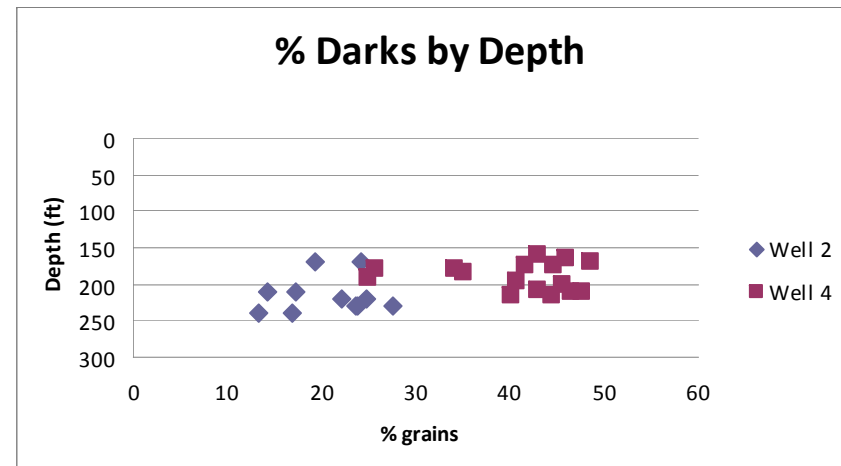
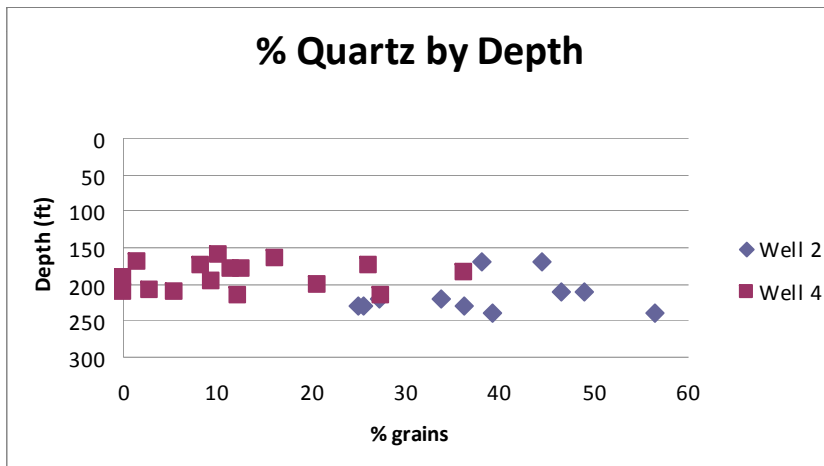


# Compare Materials

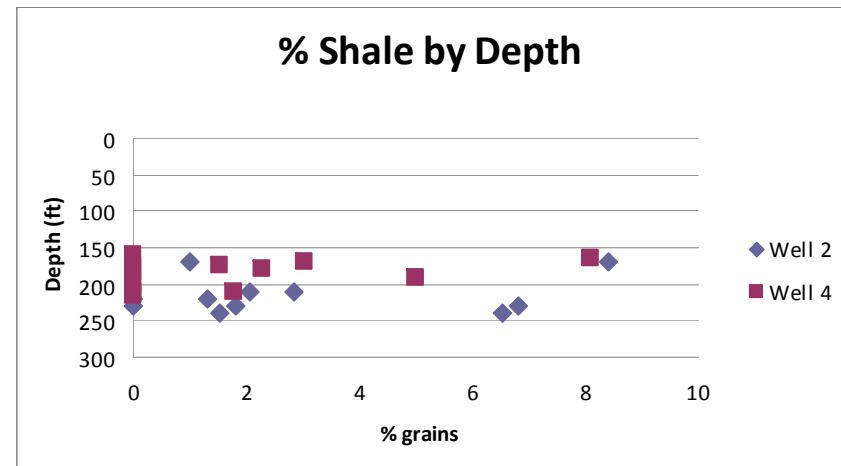
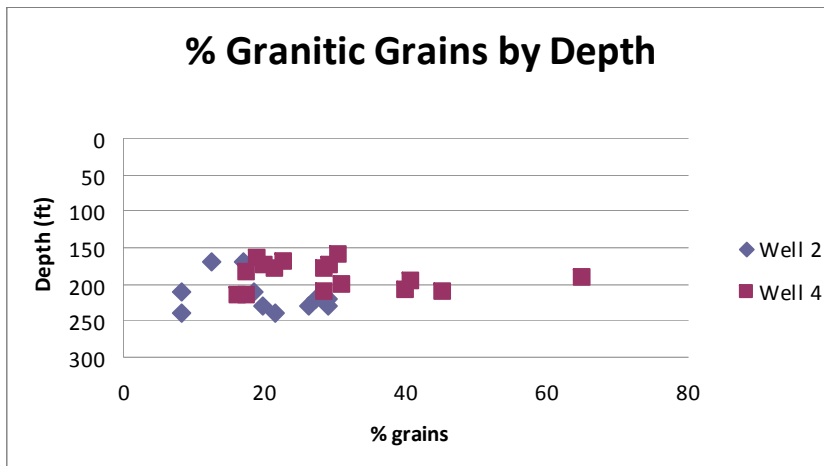


- Grain size
- Composition
- Depositional environment
- Provenance
- Drilling Method
- Drilling Fluid

# Compare Materials



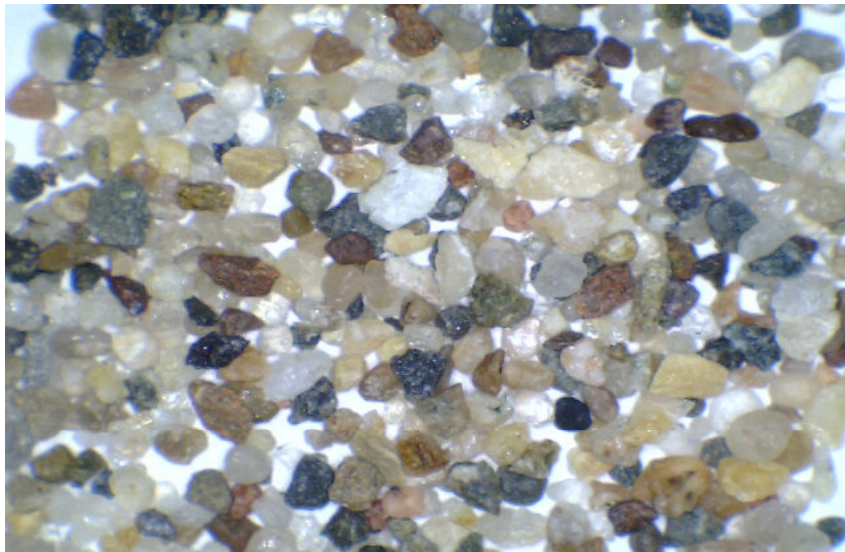
# Compare Materials



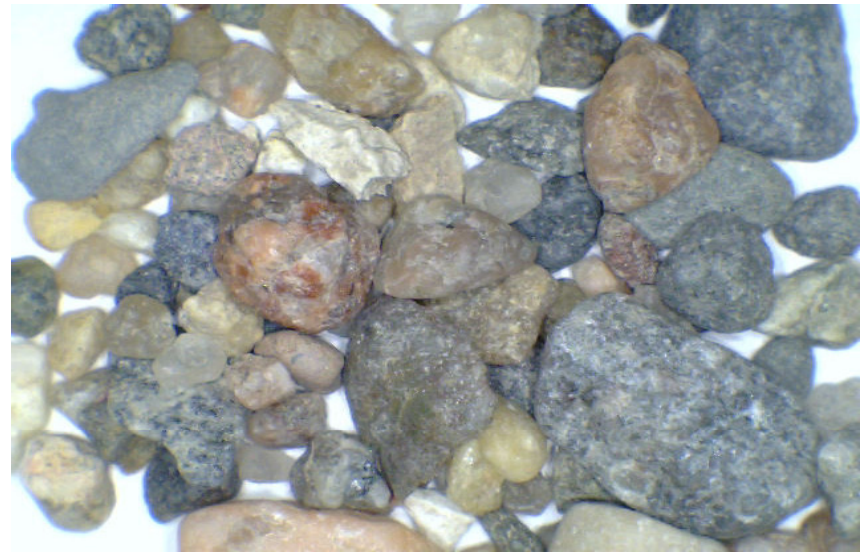


# Strata Comparison

**Well 2 – 170 feet**

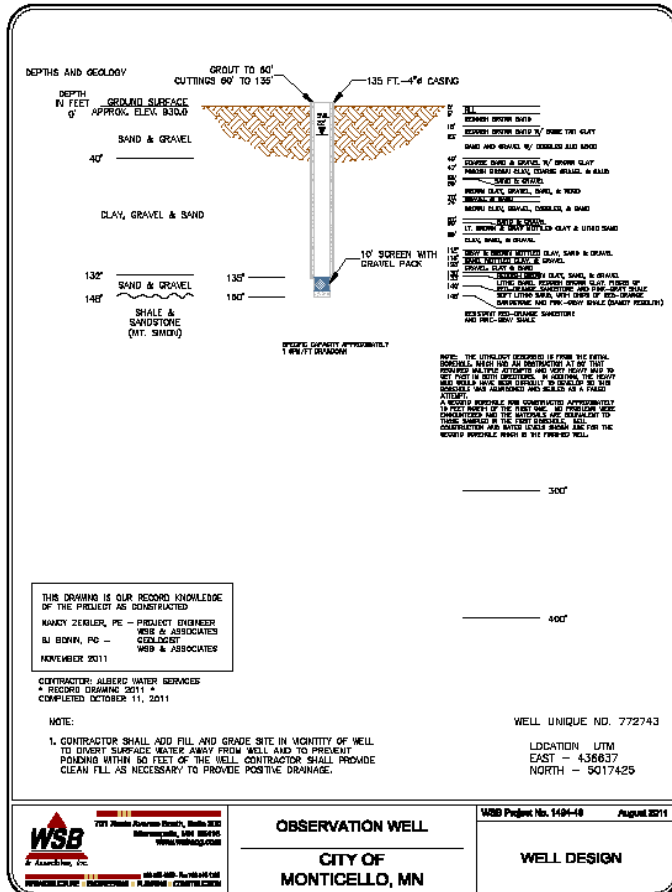


**Well 4 – 195 feet**





# New Well



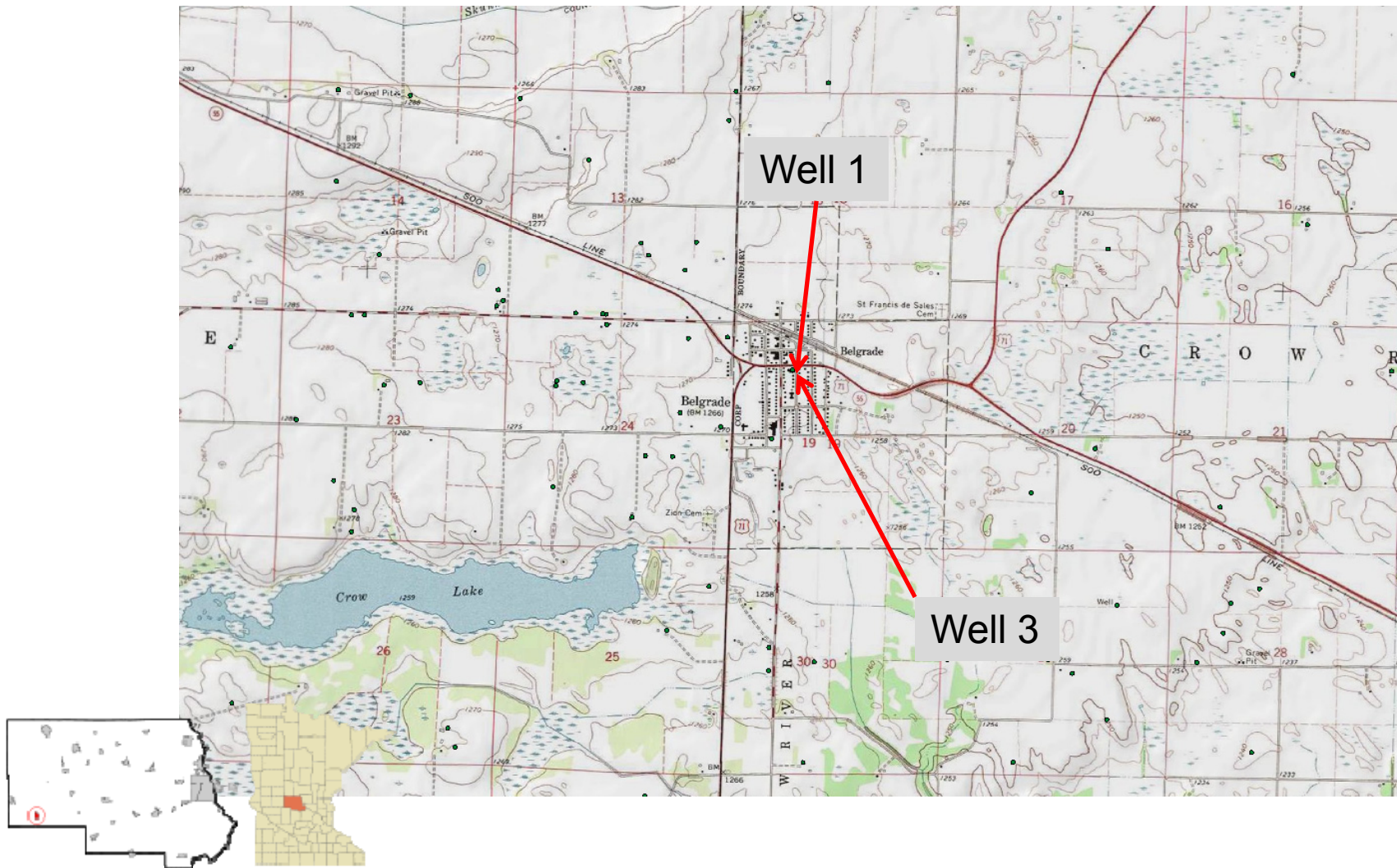
OBSERVATION WELL  
CITY OF  
MONTICELLO, MN

WSD Project No. 1404-10 August 2011  
WELL DESIGN

2011-08-10 09:00:00 AM: 01-10-11 10:00:00 AM: 01-10-11 10:00:00 AM: 01-10-11 10:00:00 AM



# 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



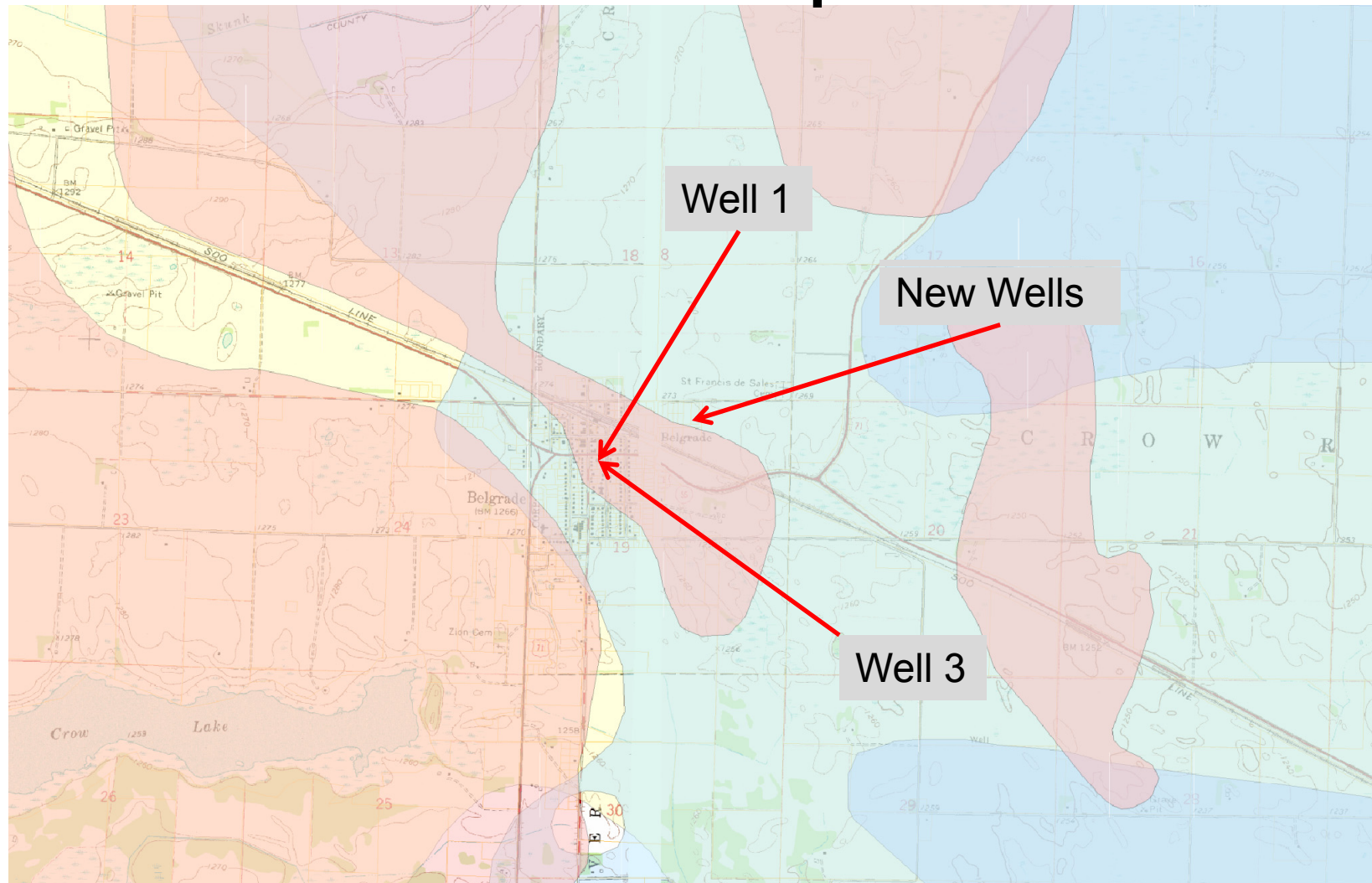


# Aquifer Characteristics

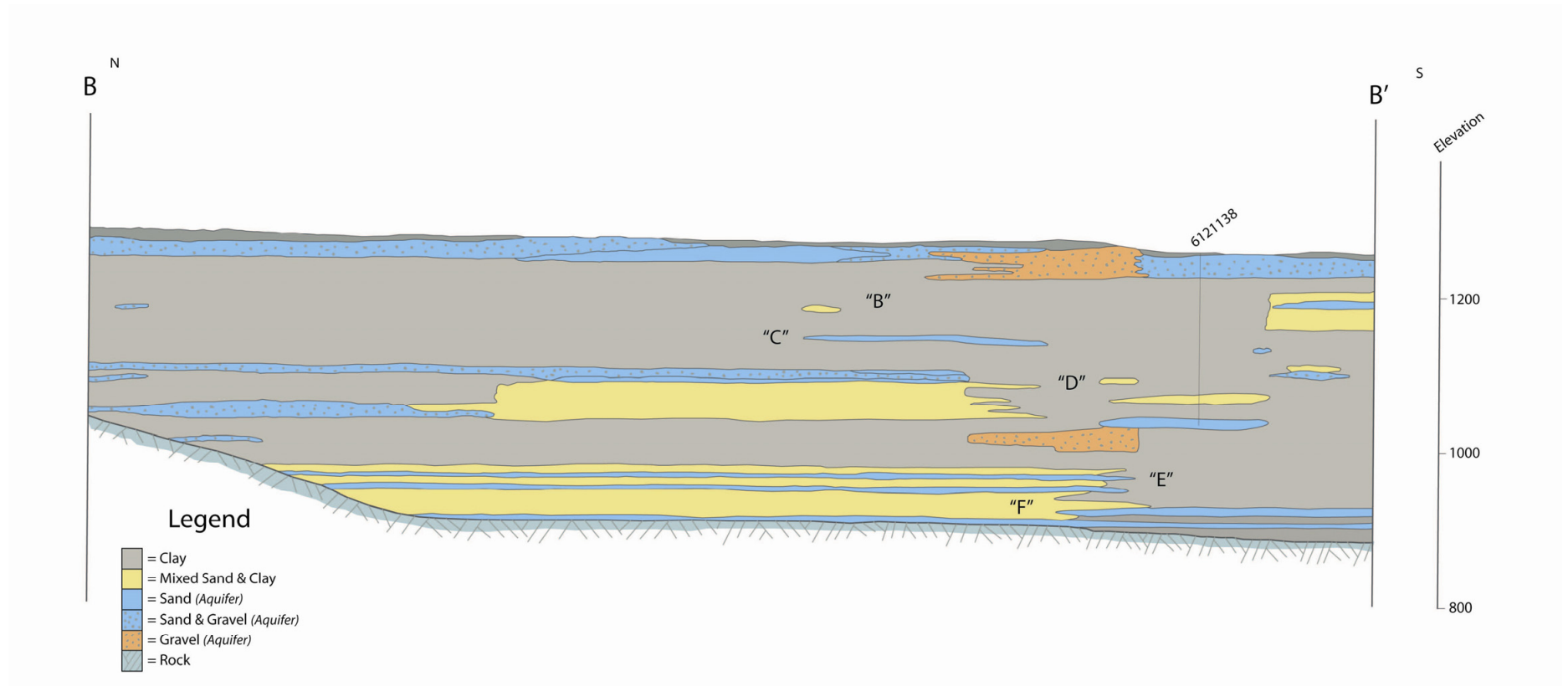
Aquifer:	Depth range	Average thickness	Fe	Mn	TDS	SO4	As
B	20-80	20	2.52 ppm	192 ppb	350 ppm	5.3 ppm	
C	110-150	20	3.8 ppm	120 ppb	390 ppm	7.9 ppm	30-50 ppb
D	160-200	15	1.38 ppm	43 ppb	380 ppm	13.3 ppm	1-10 ppb
E	180-250	20	2.77 ppm	125 ppb	447 ppm	46.9 ppm	1-10 ppb
F	230-270	15	3.12 ppm	77 ppb	376 ppm	29.3 ppm	


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

Muni # 1

Route to:  
(1) \_\_\_\_\_  
(2) \_\_\_\_\_  
(3) \_\_\_\_\_  
(4) \_\_\_\_\_

OFFICE MEMORANDUM

File: \_\_\_\_\_

Location: Belgrade, Stearns Co  
(City, Village, Township, Section, Range, County, etc.)

Subject: Municipal Well # 1

By Whom: Byron Adams Date: 1-13-87

Investigation  Office  Field  Hearing  Meeting  Phone

Items to be Covered: (1) Those present and/or those interviewed  
(2) Situation  
(3) Further action, follow-up, recommendations

Spoke with Cnie (854.5333) at McCarthy Well Co. Bloomington about Muni Well # 1, they drilled in Belgrade.

He relayed the well log geology to me over the phone.

Thickness (ft.)	Material	Thickness	Material
0-2'	Top Soil	(19')	120'-139' Sandy Shale
(23')	2-25' Yellow Sand	(32')	139'-171' Firm Sandy Shale
(10')	35'-35' Grey Sand	(5')	171'-176' Shale + Gravel
(8')	35'-43' Firm muddy Sand	(2')	176'-178' Rock - Lime rock
(17')	43'-60' Hard Sandy Shale	(13')	178'-191' Soft Sandy Shale + Gravel
(2')	60'-62' Hard Pan	(21')	191'-209' Hard Shale + Gravel
(1')	62'-63' Soft Sand		
(25')	63'-88' Soft Sandy Shale	(200'-209')	Backfilled Grout
(1')	88'-89' Hard Pan		
(1')	89'-90' Shale	Screened	160'-200'
(11')	90'-101' Soft Sandy Shale + Gravel		
(3')	101'-104' Hard Sandy Shale		
(16')	104'-120' Soft Sandy Shale		

0-00273-02 (8/79)

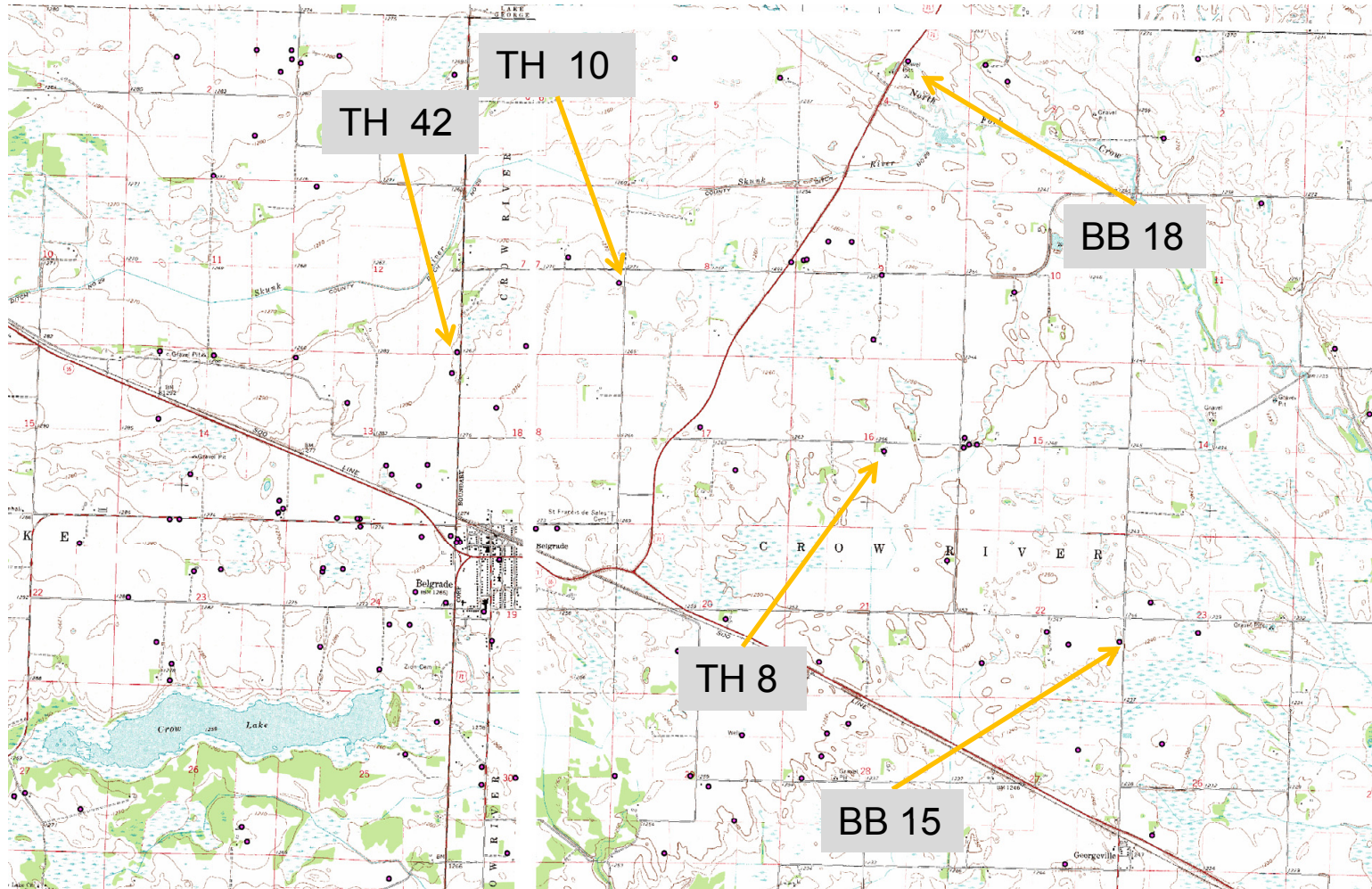
Well Log Report - 00496508

Page 1 of 1

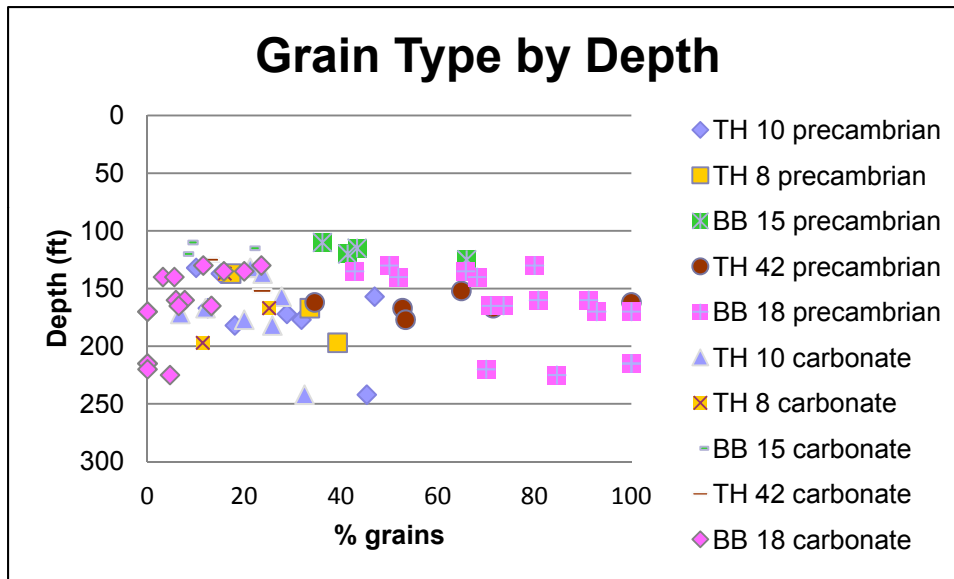
Minnesota Unique Well No. <b>496508</b>		County Belgrade	Stearns Belgrade	MINNESOTA DEPARTMENT OF HEALTH <b>WELL AND BORING RECORD</b>		Entry Date 09/08/1992
Quadrant 143A		Elevation Method 7.5 minute topographic map (+/- 5 feet)		Update Date 08/22/2012		Received Date
Well Name BELGRADE3		Well Depth 139 ft.	Depth Completed 135 ft.	Date Well Completed 11/22/1991		
Township Range Dir Section Subsections Elevation 123 34 W 19 BACCD Elevation Method		Drilling Method Non-specified Rotary				
Well Address BELGRADE MN 56312		Drilling Fluid Benitic		Well Hydrofractured? <input type="checkbox"/> Yes <input type="checkbox"/> No From FL to FL		
Geological Material		Use Abandoned Status Sealed		Casing Type Steel (black or low carbon) Joint Unknown Drive Shoe? <input type="checkbox"/>		
Color Hardness From To		Casing Diameter Weight Hole Diameter		20 in. to 26 ft. lbs./ft.		
TOP SOIL BLACK SOFT 0 1		12 in. to 123 ft. lbs./ft.		Open Hole from ft to ft		
SANDY CLAY YELLOW M.SOFT 1 4		Screen YES Make JOHNSON Type stainless steel		Diameter Slot/Gauze Length Set Between		
SAND-COARSE YELLOW MEDIUM 4 30		Diameter 12 Slot/Gauze 60 Length 123 Set Between 123 ft. and 135 ft.		Static Water Level 18.2 ft. from Land surface Date Measured 11/18/1991		
SANDY CLAY GRAY SOFT 30 43		PUMPING LEVEL (below land surface) 93.7 ft. after hrs pumping 230 g.p.m.		Well Head Completion Pipes adapter manufacturer MONITOR Model 7PS121		
CLAY GRAY M.HARD 43 58		Well Head Completion <input type="checkbox"/> Casing Protection <input type="checkbox"/> 12 in. above grade <input type="checkbox"/> Above (Environmental Wells and Borings ONLY)		Grouting Information Well Grouted? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		
SANDY CLAY - STIFF ROCKY GRAY M.HARD 58 77		Grout Material: Neat Cement from 0 to 113 ft. 0		Nearest Known Source of Contamination 75 feet E direction Septic tank/drain field type		
SANDY CLAY SILTY GRAY SOFT-1 77 79		Well Head Completion <input type="checkbox"/> Abandoned Wells Does properly have any rd in use and not sealed well(s)? <input type="checkbox"/>		Well disinfected upon completion? <input type="checkbox"/> Yes <input type="checkbox"/> No		
FINE SAND ROCKY GRAY M.SOFT 80 81		Variance Was a variance granted from the MDH for this well? <input type="checkbox"/> Yes <input type="checkbox"/> No		Well Contractor Certification Ervin Well Co. 65252 ERVIN, B. License Business Name Lic. Or Reg. No. Name of Driller		
SANDY CLAY GRAY M.SOFT 88 95		Well Contractor Certification Ervin Well Co. 65252 ERVIN, B. License Business Name Lic. Or Reg. No. Name of Driller		Printed 9/17/2012 HE-01285-07		
ROCKY CLAY GRAY M.HARD 95 108		County Well Index Online Report		496508		
SANDY SILTY CLAY GRAY SOFT 108 113		496508		496508		
SANDY CLAY GRAY M.SOFT 113 117		496508		496508		
SILTY CLAY FINE GRAY 117 119		496508		496508		
ROCK HARD 119 120		496508		496508		
SAND & SIGNS OF WOOD BLACK SOFT 120 121		496508		496508		
SILTY CLAY VARIED M.SOFT 121 122		496508		496508		
SAND - FINE VARIED MEDIUM 123 135		496508		496508		
CLAY YELLOW M.HARD 135 137		496508		496508		
CLAY GRAY M.SOFT 137 139		496508		496508		



# USGS Test Wells

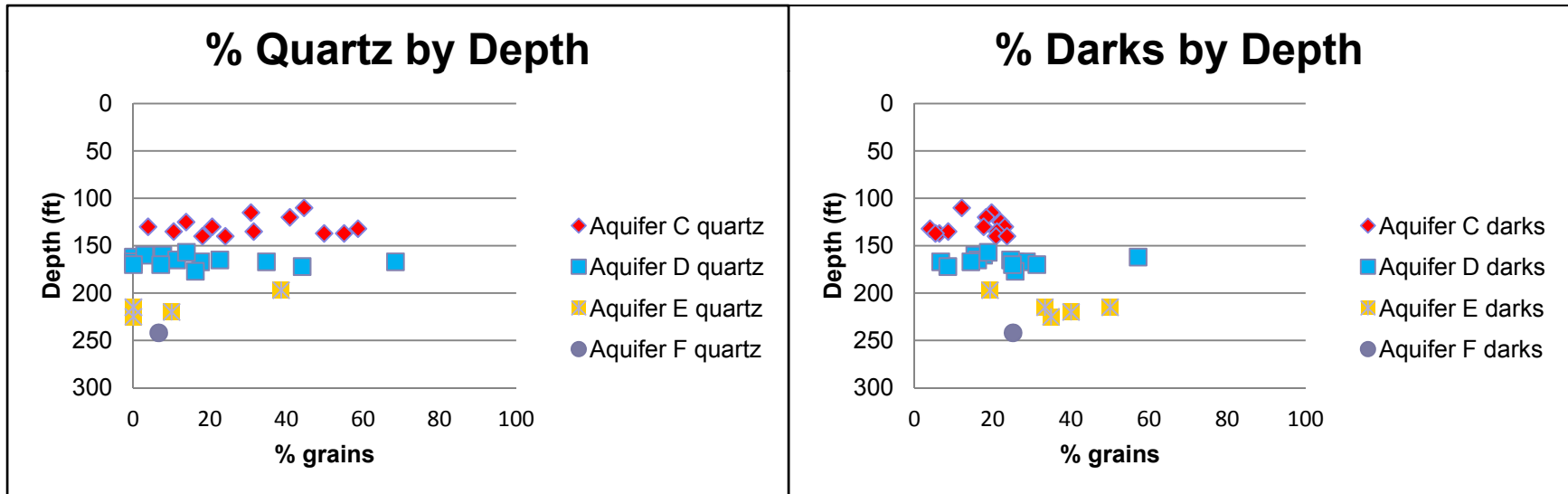


# Compare Materials



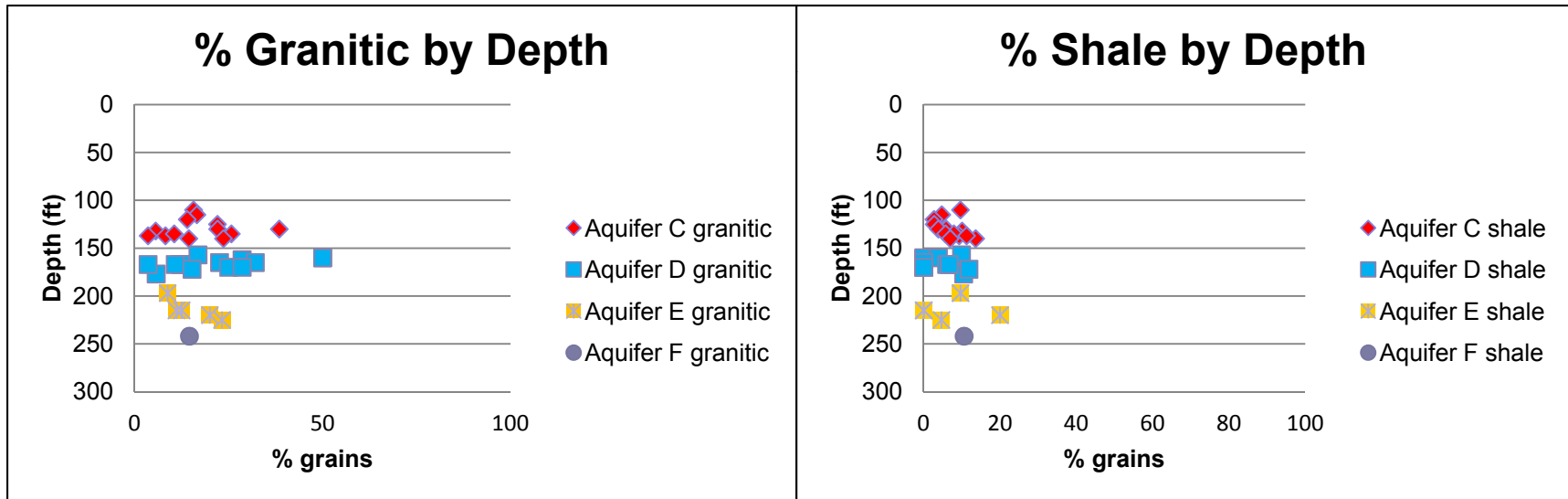
- Grain size
- Composition
- Depositional environment
- Provenance
- Drilling Method
- Drilling Fluid

# Compare Materials



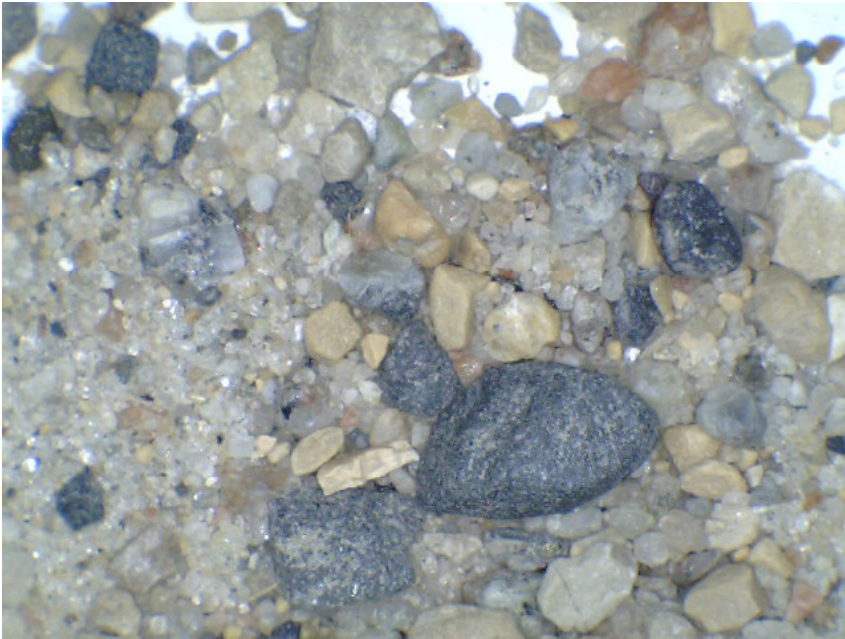


# Compare Materials



# Compare Materials

**TH 10 Aquifer C**

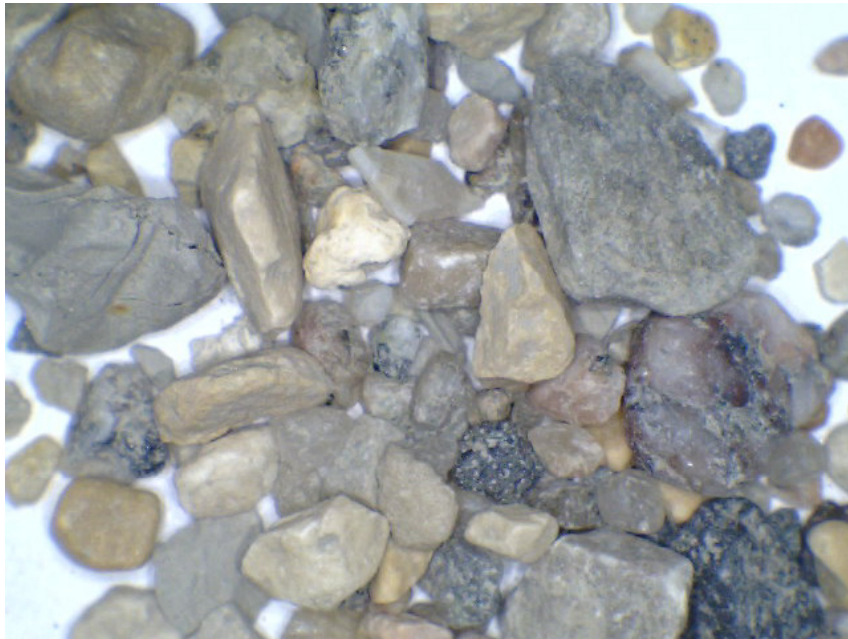


**TH 10 Aquifer D**



# Compare Materials

**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

- Hobbs, Howard C. (1998). Use of 1-2 Millimeter Sand-Grain Composition in Minnesota Quaternary Studies *in* Patterson, C.J. and Wright, H.E., Jr., eds., Contributions to Quaternary Studies in Minnesota: Minnesota Geological Survey Report of Investigations 49, pp. 193-208.
- Erickson, Mindy L. (2011). Personal Communication.
- Delin, Geoffrey N. (1990). Geohydrology and Water Quality of Confined Drift Aquifers in the Brooten – Belgrade Area, West – Central Minnesota, U.S. Geological Survey Water Resources Investigations Report 88-4124, 145 p.