By: SWPTSA

Denitrifying Woodchip Bioreactor

What is a Bioreactor?

- A structure containing a carbon source installed to intercept subsurface drain (tile) flow or ground water, and reduce the concentration of nitrate-nitrogen.

How does a Bioreactor Work?

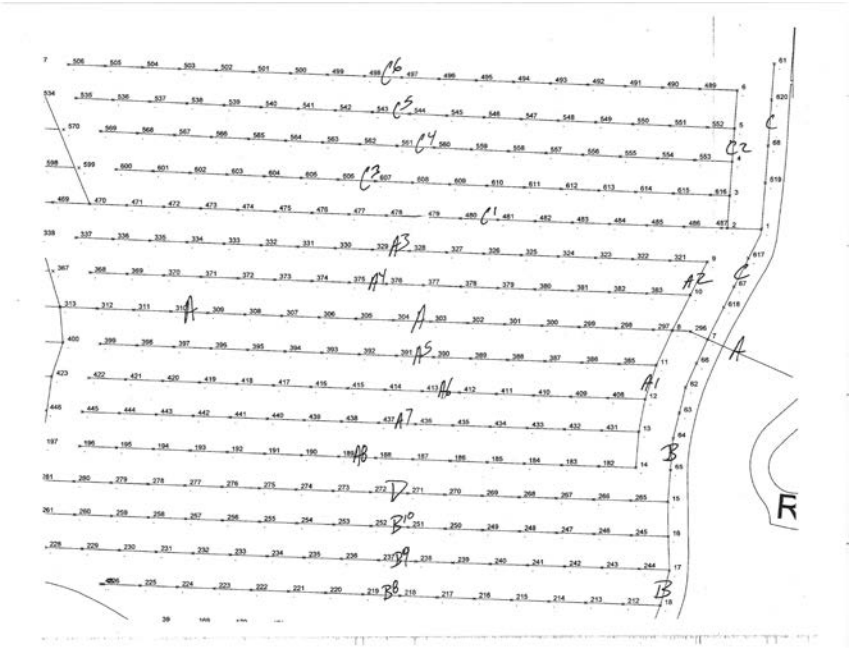
- Organisms in the soil colonize the woodchips
  - Turns woodchips into other organic material
  - "Eat" the carbon of woodchips, "breathes" the nitrates from the tile water
- Microorganism take in the nitrates and they release nitrogen gas
- Nitrate is removed from tile water and clean water returns to the tile system

2 Ways to Design a Bioreactor

- Using the peak flow rate from the tile entering the Bioreactor
- Use the drainage coefficient and the drained area (acres) of the tile system entering the Bioreactor

What you need to design using the peak flow rate of the tile

TILE MAPS



TILE CUT SHEETS

04/16/12

LINE: B10

FI #	STA.	ELEV.	PIPE EL.	CUT	GRD. BRK.	GRD.	SIZE
16	0	981.14	976.74	4.4	0.1	0.1	
245	75	981.05	976.82	4.23		0.1	
246	150	980.8	976.9	3.9		0.1	
247	225	980.45	976.98	3.47		0.1	
248	300	980.74	977.06	3.68		0.1	
249	375	980.91	977.14	3.77		0.1	
250	450	981.1	977.22	3.88		0.1	
251	525	981.28	977.3	3.98	0.3	0.3	
252	600	981.38	977.53	3.85		0.3	
253	675	981.68	977.76	3.92		0.3	S
254	750	981.91	977.99	3.92	0.1	0.1	
255	825	981.93	978.07	3.86		0.1	
256	900	982.03	978.15	3.88		0.1	
257	975	982.13	978.23	3.9		0.1	
258	1050	982.07	978.31	3.76		0.1	
259	1125	982.22	978.39	3.83		0.1	
260	1200	982.35	978.47	3.88		0.1	
261	1275	982.33	978.55	3.78		0.1	
262	1350	982.5	978.63	3.87		0.1	
263	1425	982.49	978.71	3.78		0.1	
264	1500	982.6	978.79	3.81		0.1	
42	1569	982.37	978.86	3.51		0.1	

04/16/12

LINE: C

FI #	STA.	ELEV.	PIPE EL.	CUT	GRD. BRK.	GRD.	SIZE
7	0	980.14	973.84	6.3	0.1	0.1	8" = 246
618	71	980.1	973.91	6.19		0.1	
67	118	979.99	973.96	6.03		0.1	
617	183	979.83	974.03	5.8		0.1	
1C1	246	979.9	974.09	5.81	0.7	0.7	
619	341	979.33	974.75	4.58		0.7	
68	416	979.27	975.28	3.99		0.7	5" = 337
620	508	979.54	975.92	3.62	1.4	1.4	
61	583	980.6	976.97	3.63		1.4	

What you need to design using the peak flow rate of the tile

TILE TYPE

- Concrete
- Clay
- Plastic
- Dual-wall
- PVC

TILE GRADE

- From cut sheets
- Probing and surveying

What you need to design using the peak flow rate of the tile

CALCULATE FLOW (NOMOGRAPH)

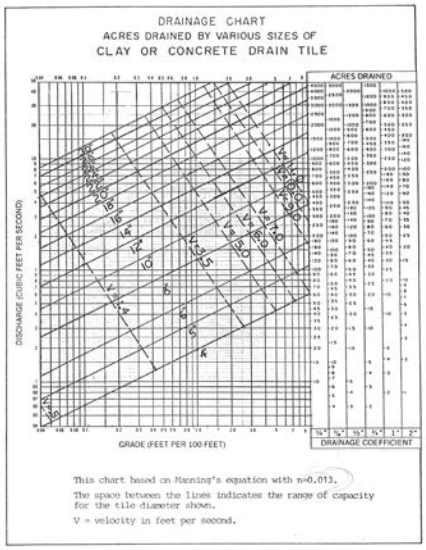
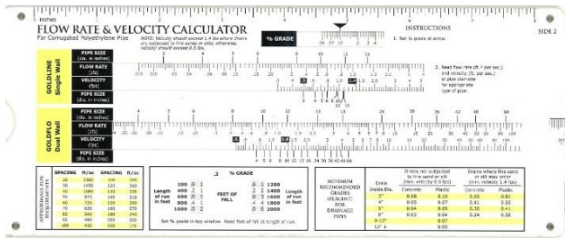


Figure 4-8. Drainage Chart for Clay and Concrete Tile.

4-17

CALCULATE FLOW (SLIDE RULE)



Calculate flow (equation)

Manning's Equation:

$$Q = \frac{0.000614\ d^{8/3}\ s^{1/2}}{n}$$

What you need to design using the designed Drainage Coefficient and Drained Area of the tile system

TILE MAPS

DESIGNED DRAINAGE COEFFICIENT

DRAINAGE GUIDE DATA FOR MINNESOTA

SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
BROWNSDALE SERIES	MN0432		5	36	57	44	37	29	0-9	CL-ML,CL	0.6-2.0	5.6-7.3	0-3.0	>60
			5	48	74	59	50	39	9-26	CL	0.6-2.0	4.5-6.5		
BROWNTON SERIES	MN0008													
BULLWINKLE SERIES	MN0469													
BURKHARDT SERIES	WI0050													
BURNSVILLE SERIES	MN0240													
BURR SERIES	MN0332													
BUSE SERIES MODERATE PERMEABILITY	MN0142													
BUSE SERIES MODERATELY SLOW PERM	MN0317													
BUSE SERIES STONY	MN0310		7						0-7	ML,CL	0.6-2.0	6.6-8.4	>6.0	>60
									0-7	CL	0.6-2.0	6.6-8.4		
									7-60	CL	0.2-0.6	7.4-8.4		
CALCO SERIES	IA0075		3	36	98	77	64	50	0-16	CH,CL	0.6-2.0	7.4-8.4	1.0-3.0	>60
			3	48	127	101	85	67	0-16	CL,CL-ML	0.6-2.0	7.4-8.4		
									16-44	CL,CH	0.6-2.0	7.4-8.4		
									44-60	CL	0.6-2.0	7.4-8.4		

SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4
BROWNSDALE SERIES	MN0432		5	36	57	44	37	29
			5	48	74	59	50	39
BROWNTON SERIES	MN0008		5	36	76	56	45	33
			5	48	103	80	67	52
BULLWINKLE SERIES	MN0469		1					
			2					
			5	36	123	98	84	67
			5	48	149	120	103	82

Design of a Bioreactor

- Follow the Minnesota NRCS Interim Conservation Practice Standard, Denitrifying Bioreactor 747
- Design according to design flow rate, permeability of woodchips, and desired hydraulic retention time

Sizing the Bioreactor

- Design to treat the base flow using:
  - Drainage coefficient – minimum of 0.125 inches
  - Bioreactor Flow Rate/Peak Flow Rate from Tile – minimum of 20%
  - Retention Time – minimum of 4 hours
- Design to remove 50-80% of nitrate load:
  - According to the Performance Curve for Illinois Drainage Guide, Recommended Load Density (Ld): 1.6 – 4.4 acres/100 sq. ft. of bioreactor
  - Using equation: (100 * CA)/Ld = Bioreactor Surface Area
    - Example: (100 * 21.5 ac.)/ 3.6 = 600 sq. ft.
- Recommended Width of Bioreactor – 5 to 20 ft.
  - Area / Width = Length
    600 sq. ft. / 10 ft = 60 ft

Sizing the Bioreactor

- Check flow rate through bioreactor versus flow rate through tile using Darcy's Law:
  - 20% minimum
  - q = K * i * A
    - K=hydraulic conductivity (ft/s) (woodchips, 0.15)
    - i=hydraulic gradient (head drop per length of reactor)
    - A=cross-sectional flow area perpendicular to flow (sq. ft.) (width * average flow depth)
      - Example : q = 0.15 ft/s * (1 ft/60 ft) * (10 ft * 3.5 ft) = 0.088 cfs
      - Compare to flow rate of tile (0.33 cfs)
        - 0.088/0.33 *100 = 26.5% (meets requirement)

Sizing the Bioreactor

- Check Hydraulic Retention Time (HRT, seconds)
  - 4 hours minimum
  - HRT= (Length * width * average depth * porosity of woodchips)/ flow rate
    - HRT = (60 ft * 10 ft * 3.5 ft * 0.7) / 0.088 cfs
    - HRT = 16,705 sec. or 4.6 hours (meets requirements)

General Layout

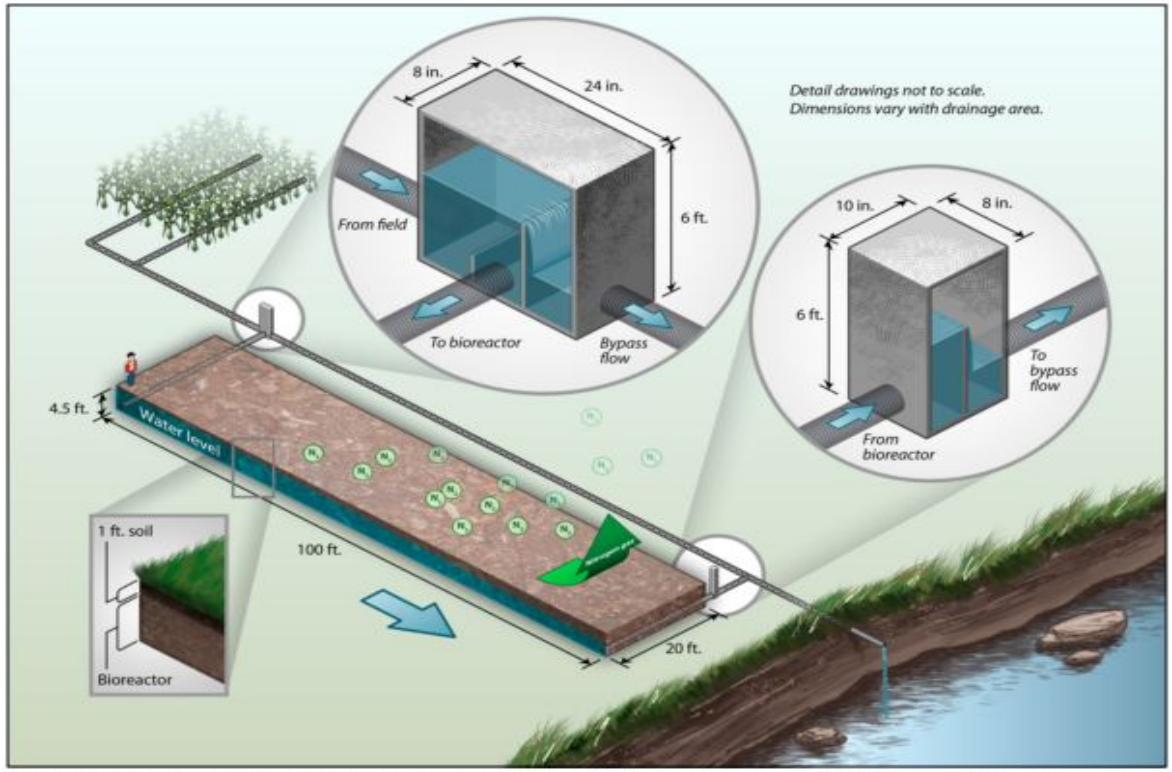


Diagram courtesy of Matt Helmers and Laura Christianson, Iowa State University. Illustration by John Peterson.

Installation Guidelines

Excavate trench with a flat bottom

Install Geotextile

Install Water Control Structure

Install Tile Manifolds

Install Woodchips

Install Geotextile Over Top

Cover Bioreactor with Fill Material

Other Considerations

- Put a fence around the Bioreactor
- Backfill trench with a mound
- Put hole in bottom stop log of outlet control box – no stagnant water
- Adjust the stop logs
  - After harvest – 6 inches below the ground surface
  - Two weeks before planting – 12 to 24 inches above tile flow line
  - Two weeks after the end of spring field work – 24 to 36 inches above tile flow line

Advantages Vs Disadvantages

Advantages

- Low cost
- Simple Design
- Small Area Needed
- Good Design Life
- Good Nitrate Reduction
- Cost Sharable

Disadvantage

- Replace woodchips
- Potential unintended consequences
  - Methyl Mercury
  - Nitrous Oxide

Questions

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