PUMP SYSTEMS INC.
"THE PROBLEM SOLVERS"
http://www.pumpsystems.com

Main Office and Service Center
530 25th Ave E, PO Box 1940, Dickinson, ND 58602
(800) 437-8076 • (701) 225-4494 • Fax (701) 225-0320

SolarBee®
Reservoir and Pond Circulators
"Cleaner Water at Less Cost"
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CASE STUDY OF WWTF AT DICKINSON, ND FOR THE YEARS 1996 - 2002

Summary

Between 1998 and 2002, a total of 20 solar-powered circulators were installed into the lagoons at the City of Dickinson WWTF. *

(* These machines were all developed, manufactured, and installed by Pump Systems, Inc. In Sep. 2001 PSI named this technology its **"**SolarBee**"** brand of solar circulators.)

The WWTF had a long history of being plagued with problems of **high ammonia levels** and **high energy costs**.

There have been substantial documented improvements:

-- **Ammonia is down**, so that irrigation as a necessary means of water disposal has dropped from **73%** of the influent to **2%** of the influent..

-- System **horsepower** requirements dropped from **500 hp** to virtually **0 hp**.

-- Water being treated and discharged has increased from **12%** of the influent to **62%**,of the influent

-- Evaporation from the lagoons has increased from **14%** of the influent to an estimated **45%** of the influent.

-- Discharged water is meeting all NPDES permit requirements **without the use of the Overland Flow system**.

-- **Discharges** can be made at **high flow rates** and **without opening the upstream Patterson Lake Dam** to increase the flow of the Heart River.

-- **Odor control** has been achieved, with shorter ice-out odor events and fewer wind and seasonal turnover odor events.

-- Water **clarity**, **aesthetics**, and **overall quality** has improved, as evidenced by a significant **increase of wildlife** at all lagoons.

Current and Design Loading Conditions

	Actual conditions	Design conditions
Population:	16,000	30,000
Influent flow rate, MGD:	1.40	2.85
Influent BOD_5, lbs:	1,870	3665

NPDES Effluent Discharge Limits :

	30 Consecutive Day Period	7 Consecutive Day Period
BOD_5 :	25 mg/l	45 mg/l
TSS :	30 mg/l	45 mg/l
Fecal Coliforms :	200/100ml	400/100ml
pH :	6.0-9.0	6.0-9.0
Oil & Grease :	Visual inspection	Visual inspection
Ammonia (NH_3) :	Discharge rate is limited to: Z = (25 Q x 0.85) / (1.5 X + 4.6Y - 31), where Q = Heart River flow in cfs, and X = Effluent BOD in mg/l, and Y = Effluent NH_3 in mg/l, and Z = Effluent flow in cfs.	

System Description In 1998, Before The Solar Circulators

Flow Path:

Pretreatment	2 Aeration Cells	Cell 1 & Cell 2	Cell 3	Cell 4	Overland Flow
bar screen grit removal	in parallel each: 600,000 cu. ft 60 hp splasher 10 ft deep	in parallel each: 43 acres 3.0 ft op. depth 5 ft max depth 42 MG volume (total 84 MG vol.)	58 acres 10.0 ft op. depth 12 ft max depth 151 MG volume	29.7 acres 1-18 ft op. depth 20 ft max depth 145 MG volume	31 acres 2500 gpm pump 6000 ft of piping Reed Canary grass (Used to help meet ammonia limits.)

Irrigation systems: Center pivot, 2 flood systems, 3 traveling gun systems, several solid-set sprinkler systems, overland flow system
Before installation of the solar powered circulators, irrigation was needed to dispose of well over 50% of the water.

System horsepower: 500 installed horsepower, including 120 hp of aeration used continuously year round, 235 hp of miscellaneous irrigation pumps, 55 hp of overland flow pumps, a 60 hp lift station to lift the water to the aerated cells, and a 30 hp transfer pump.

Operational considerations: The ammonia limit combined with low river flow caused intensive management and water disposal problems.
The irrigation systems had to be kept operating at all costs, and hay removed quickly, to be able to dispose of enough water.
There were high energy costs for aeration and pumping, and high labor costs associated with the irrigation systems.
Only 12% of the water could be discharged to the Heart River, and only by opening the upstream dam for dilution river flow.
River bank erosion was developing from the irrigation; alternatives studied in 1998 included a $10+M mechanical plant.

System Description by 2002, After The Final Highflow SB10000 (10,000 gpm) SolarBees Were Installed.

Flow Path:

Pretreatment	Cell 1	Cell 2	Cell 3	Cell 4	Overland Flow
bar screen	Primary cell	Secondary cell	Storage cell	Storage cell	(used very little for
grit removal	100% of flow	In series	In series	In series	prior hay contract)
	Diffused inlet				31 acres
(Both of the former	10 circulators	6 circulators	3 circulators	1 circulator	2500 gpm pump
aeration cells are	43 acres	43 acres	58 acres	29.7 acres	6000 ft of piping
being bypassed)	3.5 ft op. depth	3.5 ft op. depth	10.0 ft op. depth	1-18 ft op. depth	Reed Canary grass
	5 ft max depth	5 ft max depth	12 ft max depth	20 ft max depth	
	42 MG volume	42 MG volume	151 MG volume	145 MG volume	

Irrigation systems: All but abandoned, by 2002 only 2% of the water was disposed of by irrigating, just enough to fulfill a small hay-supply contract.

System horsepower: All 500 hp eleiminated, transfer pumps are still in place in case higher-than-gravity flows are ever desirable.

Operational considerations: Smooth operation in 2002, about the same as in 2001. Final water quality data will be availbable by year end.
By 2001, 62% of the water could be discharged directly into the Heart River without any dilution water needed from the dam.
The high effluent water quality allowed for discharge rates much higher than the river flow rates.
Cell 3 and Cell 4 both regularly meet the discharge limits during the summer months, without dilution water from the dam.
In some months, even Cell 1 and 2 were nearly able to be discharged directly into the river without dilution water.
The system has low management and labor needs, and appears capable of handling much higher loading than it needs to.

Bold figures are from NPDES Discharge Monitoring Report (DMR).

From 1996 to 1999, the DMR discharges were from the Overland Flow. In 2001 and 2001, MDR discharges were from Cell 4 except where indicated.

In 1998 and prior years, more than 50% of the water was drawn from Cells 1,2, and 3, for irrigation, and only about 12% was treated and discharged.

By 2001, almost all use of irrigation and the Overland Flow was eliminated, and the cells processed 98% of the water and met permit requirements.

BOD5, mg/l

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1997 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1998 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1999 60 hp aer **Overland flow f/ NH3** less irrigation	2000 60 hp aer **Ov. flow not needed** less irrigation	2001 45 hp aer **Ov. flow not needed** little irrigation
January					(6 solar circulators	
February					installed in cell 2)	
March						6
April						**9.3**
May DMR data	**9**	**11.5**				**7.5**
May cell 3	12			**9.2**		
May cell 4	23	12				
May overland flow	9	17				
June DMR data	**12.3**	**15.75**				**7.7**
June cell 3					63	
June cell 4	12	17	(1 solar circulator	(6 solar circulators	10	
June overland flow	12.1	17	installed in cell 4)	installed in cell 1)		
July					**8.8**	
August					**9.5**	
September						**7**
October cell 3			**6.5**			**4.25**
October cell 4			**6.33**	**7.0**	**6**	
November			(3 solar circulators	**6**	**6**	
December			installed in cell 3)			

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TSS, mg/l

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1997 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1998 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1999 60 hp aer **Overland flow f/ NH3** less irrigation	2000 60 hp aer **Ov. flow not needed** less irrigation	2001 45 hp aer **Ov. flow not needed** little irrigation
January					(6 solar circulators	
February					installed in cell 2)	
March						1
April						**9.2**
May DMR data	**8**	**24.5**		**14**		**10.5**
May cell 3	73					
May cell 4	12	25				
May overland flow	8	10				
June DMR data	**7.66**	**20.25**				**19**
June cell 3			(1 solar circulator	(6 solar circulators	101	
June cell 4	8	10	installed in cell 4)	installed in cell 1)	7	
June overland flow	8	10				
July					**8.6**	
August					**13.5**	
September						**18**
October cell 3			**37**			**14.75**
October cell 4			**18**	**14**	**5**	
November			(3 solar circulators	**5**	**5**	
December			installed in cell 3)			

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pH, average

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1997 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1998 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1999 60 hp aer **Overland flow f/ NH3** less irrigation	2000 60 hp aer **Ov. flow not needed** less irrigation	2001 45 hp aer **Ov. flow not needed** little irrigation
January					(6 solar circulators	
February					installed in cell 2)	
March						7.3
April						**7.8**
May DMR data	**7.8**	**8.4**				**8.0**
May cell 3	7.9					
May cell 4	7.68	8.4		**8.0**		
May overland flow	8.31	7.29				
June DMR data	**7.75**	**8.05**	(1 solar circulator	(6 solar circulators		**7.67**
June cell 3			inst. in cell 4)	installed in cell 1)	7.99	
June cell 4	7.64	7.29			8.4	
June overland flow	7.6	7.29				
July					**8.16**	
August					**8.44**	
September						**7.65**
October cell 3			**8.15**			**7.84**
October cell 4			**8.48**	**8.47**	**8.28**	
November			(3 solar circulators	**8.43**	**8.1**	
December			installed in cell 3)			

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Ammonia, mg/l

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1997 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1998 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1999 60 hp aer **Overland flow f/ NH3** less irrigation	2000 60 hp aer **Ov. flow not needed** less irrigation	2001 45 hp aer **Ov. flow not needed** little irrigation
January					(6 solar circulators	
February					installed in cell 2)	
March						2.31
April						**13.18**
May DMR data	**12.05**	**16.8**		**11.12**		**7.95**
May cell 3	9.8					
May cell 4	24.8	17.6				
May overland flow	13.8	12.7				
June DMR data	**10.64**	**9.74**				**13.23**
June cell 3					15.8	
June cell 4	16.7	11.6			8.47	
June overland flow	11	7	(1 solar circulator	(6 solar circulators		
July			inst. in cell 4)	installed in cell 1)	**8.85**	
August					**3.193**	
September						**4.89**
October cell 3			**0.206**			**7.8**
October cell 4			**4.2**	**0.973**	**4.21**	
November			(3 solar circulators	**1.465**	**4.87**	
December			installed in cell 3)			

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Fecals, CFU/100ml (10 in minimum measurable)

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	**1997** 120 hp aer., **Overland flow f/ NH3** ext. irrigation	**1998** 120 hp aer., **Overland flow f/ NH3** ext. irrigation	**1999** 60 hp aer **Overland flow f/ NH3** less irrigation	**2000** 60 hp aer **Ov. flow not needed** less irrigation	**2001** 45 hp aer **Ov. flow not needed** little irrigation
January					(6 solar circulators	
February					installed in cell 2)	
March						< 10
April						(no data,lab error)
May DMR data	**70**	**<10**		**<10**		**<10**
May cell 3	< 10					
May cell 4	< 10	< 10				
May overland flow	70	160				
June DMR data	**23**	**87**				**13**
June cell 3						
June cell 4			(1 solar circulator	(6 solar circulators		
June overland flow		160	inst. in cell 4)	installed in cell 1)		
July					**<10**	
August					**14**	
September						**15**
October cell 3			**<10**			**32**
October cell 4			**16.7**	**<10**	**<10**	
November			(3 solar circulators	**<10**		
December			installed in cell 3)			

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Water Discharged, millions of gallons

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1997 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1998 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1999 60 hp aer **Overland flow f/ NH3** less irrigation	2000 60 hp aer **Ov. flow not needed** less irrigation	2001 45 hp aer **Ov. flow not needed** little irrigation
January					(6 solar circulators	
February					installed in cell 2)	
March						
April						**74**
May DMR data	**7.6**	**17.4**		**44.9**		**8**
May cell 3						
May cell 4						
May overland flow						
June DMR data	**51.4**	**50**				**47.8**
June cell 3						
June cell 4			(1 solar circulator	(6 solar circulators		
June overland flow			inst. in cell 4)	installed in cell 1)		
July					**22.1**	
August					**28**	
September						**94**
October cell 3			**49.1**			**91.5**
October cell 4			**13.2**	**10**	**73**	
November			(3 solar circulators	**20.3**	**4**	
December			installed in cell 3)			

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Water Disposal Summary, millions of gallons

	1996 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1997 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1998 120 hp aer., **Overland flow f/ NH3** ext. irrigation	1999 60 hp aer **Overland flow f/ NH3** less irrigation	2000 60 hp aer **Ov. flow not needed** less irrigation	2001 45 hp aer **Ov. flow not needed** little irrigation
Amount discharged:	**59**	**67.4**	**62.3**	**75.2**	**127.1**	**315.3**
Estimated evaporation * :	71	71	71	120	230.7	230.7
Estimated irrigation:	381	372.6	377.7	315.8	153.2	15
Total water disposed of ^ :	511	511	511	511	511	561

* Average lagoon evaporation in western ND is estimated at 15 inches per year. Dickinson has 174 acres of lagoons.
Irrigation figures are PSI and city estimates. By 2001 the 16 circulators, at 10.8 acre average spacing, appear to have increased the evaporation rate from 15" per year to 59" per year.

^ Average inflow is 1.4 MGD, or 511 MG/year.
In 2001, the year ended with the system water volume being approximately 50 million gallons less than in 2000., so the total water disposed of was 561 million.