Smart Sewers: Real Time Intelligence and Optimization for South Bend's Sewers



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Introduction



"We have the smartest sewers in the world." Mayor Pete Buttigieg

South Bend, IN named one of the country's 10 Smartest Cities (Cisco Systems)



Built on the South Bend of the St. Joseph River

South Bend Combined Sewer Overflows



• 40 mi²

- 20 mi² Combined
- >1 BG overflow/year
- 77 MGD WWTP
- \$500M LTCP

Goal: More with less = Smart



Key Question: Are we making the MOST out of our EXISTING infrastructure?



Our first answer: We don't know!

South Bend's Solution



Utilize Existing Infrastructure Eliminate DWO's **Prevent Basement Back-Ups** Minimize CSO's to River Maximize Flow to WWTP

Step 1: Turn data into information



CSONet System



- Installed extensive real time monitoring of the combined sewer system
- 120 monitoring points, 5 min data
- 9 control valves
- Focused along river
- Integrated with SCADA and CSONet Website
- Objectives
 - System Characterization
 - Blockage Detection/ DWO Reduction
 - Model Calibration
 - Proactive Maintenance
 - Real Time Control

Condition Based Maintenance Tools



Increased O&M Benefits (Direct)

Use of vactor trucks 50 additional days annually

= \$133K

Clean 2,000 additional catch basins annually

= \$40K

Increase number of sewer inspections by 175%

= \$29K

Same Staff

Total Dynamic Maintenance Value

= \$202,000 Annually

Increased O&M Benefits (Indirect)

Discover and eliminate I/I sources

= 10 MGD decrease

Find and address maintenance hotspots

= Clean what needs to be cleaned when it needs it

Pre-/post-construction monitoring Flood/backup warning system Indirect Value

= \$1.5 M Annually

Dry Weather Overflow Elimination

100% DWO reduction from 2008 to 2011

Number of DWO



Step 2: Bring in the Model



Focus on problem areas

Identify opportunities

Solve discrepancies between the model and RT Data

2005 Calibrated Areas – 003, 006, 11A, 022, 037



Model vs CSOnet Comparison

l eener	Overflow Occurred?		Overflow Duration (hrs)		Peak Depth (ft)		
Park Service Area	CSOnet	2010 Model	CSOnet	2010 Model	CSOnet	2010 Model	Conclusion (Based on Peak Depth)
11A	Y	Y	14.8	26.8	2.6	6.9	Model over estimates
11B	Y	Y	14.7	27.5	4.7	9.0	Model over estimates
010	Y	Y	15.0	16.5	7.3	5.7	Model under estimates
800	Y	Y	15.0	15.0	3.8	3.9	Close
007	Y	Y	15.5	18.5	3.9	2.0	Model under estimates

Targeted Refinement

CSO	LTCP Project Impacted	Combined Acres (Adjusted only)
11A	Leeper Park	187
11B	Leeper Park	239
14	Ice Rink	91
27	Storage Tunnel	399
28	Storage Tunnel	230
31	Ice Rink	<u>161</u>
		1,307

System Acreage 11,863 11% of Area to be Adjusted



2013 Model Update Results

- Installed 11 new flow meters
- Integrated the system in CSONet
- 13 Storms Collected
- Adjusted SWMM model and verified with 9 storms
- Saw an impact on the LTCP
 - Potential Cost Savings
 - Needed Storage Volume Reduction (21%)

Step 3: Global Real Time Optimization



Interceptor Utilization

CSOnet - Interceptor Profile File View Tools Help Made Description 1 1.1.1 Int. by CSO 44 (d) 2 1.35.1 Int. by CSO 24(d)		
File View Tools Help Mode Description 1 1.1.1 Int. by CSO 44 (d) 2 1.3a.1 Int. by CSO 24 (d)	Carrier II	CP N
3 G.3a,1 int by CSO 3 (d) 4 13b,1 int, by CSO 3 (d) 5 181 int, by CSO 25 (d) 6 19.3 int, by CSO 25 (d) 8 111.1 int, by CSO 31 (d) 9 1.30.1 int, by CSO 33 (d) 10 1.30.2 int, by CSO 33 (d) 11 G.24.1 int by CSO 33 (d) 12 1.41.1 int, by CSO 33 (d) 13 1.35.1 int, by CSO 33 (d) 14 G.21.3 int by CSO 328 (d) 15 G.21.1 int by CSO 328 (d) 16 G.20.3 int, by CSO 328 (d) 17 1.20.1 int by CSO 42 (d) 16 G.20.3 int, by CSO 42 (d) 17 1.20.1 int by CSO 42 (d) 17 1.20.1 int by CSO 42 (d) 17 1.20.1 int by CSO 42 (d) 18 4.45 4.45 19 1.49 14 4.45 15 G.20.3 16 G.20.3 17 1.20.1		A 25 B A 25 B A 25 B A 25 B A 125 C 1 25 C 1 25 A 125 C 1 25 C 1 25 A 125 C 1 25 C 1 25 A 1 25 1 2
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Regulator Selection

Selection Criteria

- D/S Interceptor Capacity
- Size of existing throttle pipe
- Peak flow in CSO trunkline
- Overflow Volume
- Overflow Frequency
- Maintenance Hotspot
- 9 Regulators Selected
- 26% of Combined Area
- 85% of Total Potential Benefit





Global Real Time Control

- Default is almost closed
- Likelihood of overflow
 - Interceptor Capacity
 - Downstream
 - At "time of impact"
- Calc. Additional Flow
- Compete for Int. Capacity

Open Valve

Valve Installation



- 9 Control Valves
- 12" to 30" diameters
- \$2.2 M
- Completed in Spring, 2011

Start-up

- Communication
- Battery backup
- Valves CCTV verified
- Valves partially open

Modes of Operation



	Manual	Auto
Local	From cabinet	Local Reactive
Remote	From SCADA	Distributed RTC

- Weekly valve exercise
- Fail-Safe
 - UPS opens valve
 - default position
 - 30-50% open

SCADA Integration



Global Real Time Optimization



Overflow duration dropped from 19.5 hrs to 2.3 hrs Overflow volume dropped 76% (0.87 MG to 0.21 MG)

Outcomes

CSO	Overflow Volume Original System	Overflow Volume RTC System	Volume Reduction	Percentage Reduction
003	4.96 MG	3.58 MG	1.36 MG	28%
004	0.10 MG	0.04MG	0.06MG	65%
014	1.41 MG	0.79 MG	0.62 MG	44%
025	0.07 MG	0.06 MG	0.01 MG	15%
026	5.62 MG	0.50 MG	5.12 MG	91%
027	1.40 MG	1.30 MG	0.10 MG	7%
028	0.002 MG	0.001 MG	0.001 MG	36%
030	0.030 MG	0.001 MG	0.029 MG	95%
044	0.17 MG	0.03 MG	0.14 MG	80%
TOTAL	13.67 MG	6.39 MG	7.44 MG	54%

February-June 2012

Annual Overflow Reduction



South Bend CSO Long Term Control Plan Optimization: Comparison of Grey-Only vs. Grey-Green Infrastructure Least-Cost Solutions



Optimization Progress

Objectives of the South Bend LTCP Optimization Project

- Look at many options
- Optimize grey infrastructure and determine most cost-effective conveyance/storage strategy
- Identify Cost Effective LID on a basin level
- Optimize real time controls (RTC) to maximize utilization of existing and future infrastructure
- Prioritize improvement projects to achieve maximum CSO volume reduction within available budget for each planning horizon

Objectives of the South Bend LTCP Optimization Project - LID

- Rooftop Disconnection
- Rain Gardens
- Bioretention Lawn Extensions
- Bioretention Bumpouts
- Porous Paving Systems



C	cost Item	Capital Cost (\$M) C	O&M cost (\$M) (Total Cost (\$M)
C S	Conveyance (incl RTC, Lift Stations & Relining)	212.58	6.97	219.55
S T	Storage (Tanks & Linear 7/S)	164.79	41.22	206.01
Green Infrastructure		8.99	0.79	9.78
Т	otal Project Cost	386.36	48.98	435.33
Performance Violation Penalty Cost		-	-	209.17
Т	otal Solution Fitness	-	-	644.50
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Green Infrastructure

Total Project Cost

Conveyance





С	ost Item	Capital Cost (\$M) (O&M Cost (\$M) (Total Cost (\$M)		
C S	onveyance (incl RTC, Lift tations &Relining)	217.79	7.23	225.02		
S T	torage (Tanks & Linear /S)	136.04	30.76	166.81		
G	reen Infrastructure	12.85	1.11	13.97		
Τ	otal Project Cost	366.68	39.11	405.79		
P P	erformance Violation enalty Cost	-	-	19.27		
Т	Total Solution Fitness-425.06•Best solution in 3rd generation•Total of 600 trial solutions evaluated•Actual processing time: 0:48 hours (104 cores)					
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Cos	st Item	Capital Cost (\$M) (O&M Cost (\$M) C	Total cost (\$M)
Cor Stat	iveyance (incl RTC, Lift tions &Relining)	165.77	4.37	170.14
Stor T/S	rage (Tanks & Linear)	147.91	34.46	182.37
Gre	en Infrastructure	8.58	0.76	9.34
Tota	al Project Cost	322.27	39.60	361.86
Per Per	formance Violation alty Cost	-	-	45.89
Tota	al Solution Fitness •Best solution	in 5 th gene	- ration	407.75
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Conveyance (incl RTC, L Stations &Relining)	ift 153.15	4.02	157.17
Storage (Tanks & Linear T/S)	139.10	34.84	173.94
Green Infrastructure	14.82	1.26	16.07
Total Project Cost	307.06	40.12	347.18
Performance Violation Penalty Cost	-	-	10.89
Total Solution Fitness •Best solution	- n in 10 th gene	- eration	358.07
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Total Project Cost

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Green Infrastructure

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	Cost Item		Capital Cost (\$M) (O&M Cost (\$M) (Total Cost (\$M)
	Conveyance (incl RTC, Lift Stations &Relining) Storage (Tanks & Linear T/S)		147.36	3.36	150.72
			142.39	32.11	174.51
	Green Infrastructure		10.43	0.91	11.35
	Total Project	Cost	300.18	36.39	336.57
	Performance Violation Penalty Cost		-	-	0.00
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5			124.	.94	28.61	153.55
T/S) Green Infrastructure		19.	.34	1.69	21.04	
Total Project Cost		290.	72	33.72	324.44	
Performance Violation Penalty Cost		-		-	0.00	
Total Solution Fitness •Best solution i		- in 20 th (aene	- eration	324.44	
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Сс	ost Item	Capital Cost (\$M) (O&M Cost (\$M) C	Total cost (\$M)
Co Sta	onveyance (incl RTC, Lift ations &Relining)	142.84	3.28	146.12
Sto T/S	orage (Tanks & Linear S)	132.41	30.00	162.41
T/S) Green Infrastructure		14.92	1.30	16.23
То	tal Project Cost	290.17	34.59	324.76
Performance Violation Penalty Cost		-	-	0.00
То	tal Solution Fitness	-	-	324.76
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Conveyance (incl RTC, Lift Stations & Relining) Storage (Tanks & Linear T/S) Green Infrastructure 14.40 1.21 15.62 Total Project Cost 298.33 35.89 334.22 Performance Violation Penalty Cost 0.00 Total Solution Fitness 334.22 •Best solution in 30^{th} generation •Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores)	(Cost Ite	m	Capi Cost (tal (\$M) C	O&M Cost (\$M) C	Total ost (\$M)
Storage (Tanks & Linear T/S) 136.44 31.20 167.63 Green Infrastructure 14.40 1.21 15.62 Total Project Cost 298.33 35.89 334.22 Performance Violation Penalty Cost - 0.00 Total Solution Fitness 0.00 •Best solution in 30 th generation •Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores) $^{700}_{0}$ $^{600}_{0}$ $^{$	(Conveyance (incl RTC, Lift Stations & Relining) Storage (Tanks & Linear T/S)		, Lift 147	.49	3.48	150.97
Green Infrastructure 14.40 1.21 15.62 Total Project Cost 298.33 35.89 334.22 Performance Violation Penalty Cost - 0.00 Total Solution Fitness 334.22 •Best solution in 30 th generation •Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores) 700 600 600 600 600 600 600 600	_			ar 136	.44	31.20	167.63
Total Project Cost298.3335.89334.22Performance Violation Penalty Cost0.00Total Solution Fitness334.22•Best solution in 30th generation •Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores)700 600 	(Green In	frastructure	14	.40	1.21	15.62
Performance Violation Penalty Cost - 0.00 Total Solution Fitness - 334.22 •Best solution in 30 th generation •Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores)		Total Pro	oject Cost	298	.33	35.89	334.22
Total Solution Fitness - 334.22 •Best solution in 30 th generation •Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores) 700 600 500 400 500 600 500 600		Performa Penalty (ance Violation Cost	-		-	0.00
•Total of 6,000 trial solutions evaluated •Actual processing time: 7:27 hours (104 cores)		Total So	•Best solut	s - tion in 30 th	gene	- eration	334.22
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С	ost Item	Capital Cost (\$M)	O&M Cost (\$M) C	Total Sost (\$M)			
C S	onveyance (incl RTC, Lif tations &Relining)	^t 141.26	3.22	144.48			
S T	torage (Tanks & Linear /S)	114.79	26.60	141.39			
G	Freen Infrastructure	18.74	1.63	20.37			
Т	otal Project Cost	274.79	31.45	306.24			
P P	erformance Violation enalty Cost	-	-	0.00			
Т	otal Solution Fitness	-	-	306.24			
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Solution Fitness

Conveyance

Penalty Cost

Green Infrastructure

Co	ost Item	Capital Cost (\$M) C	O&M Cost (\$M) (Total Cost (\$M)
Co Sta	onveyance (incl RTC, Lift ations &Relining)	145.68	3.37	149.05
Sto T/S	orage (Tanks & Linear S)	118.16	27.65	145.81
Gr	een Infrastructure	19.11	1.68	20.78
То	tal Project Cost	282.94	32.70	315.64
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То	tal Solution Fitness	-	-	315.64
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Storage

Total Project Cost



Cost Item	Capital Cost (\$M) (O&M Cost (\$M) (Total Cost (\$M)		
Conveyance (incl RTC, Lift Stations & Relining)	140.32	3.20	143.52		
Storage (Tanks & Linear T/S)	114.77	26.92	141.70		
Green Infrastructure	20.55	1.76	22.31		
Total Project Cost	275.64	31.89	307.53		
Performance Violation Penalty Cost	-	-	0.00		
Total Solution Fitness307.53•Best solution in 75th generation					
•Total of 15,000 tri	ial solutions	s evaluate	d		
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Cost Item	Capital Cost (\$M)	O&M Cost (\$M)	Total Cost (\$M)
Conveyance (incl RTC, Li Stations &Relining)	ft 133.60	3.09	136.69
Storage (Tanks & Linear T/S)	105.72	25.34	131.06
Green Infrastructure	24.77	2.13	26.90
Total Project Cost	264.10	30.56	294.66
Performance Violation Penalty Cost	-	-	0.00
Total Solution Fitness	-	-	294.66
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Cost Item	C	Capital Cost (\$M) (O&M Cost (\$M) (Total Cost (\$M)
Conveyance (incl Stations &Relining	RTC, Lift g)	128.11	2.95	131.06
Storage (Tanks & T/S)	Linear	106.47	25.68	132.16
Green Infrastructu	ure	24.92	2.14	27.07
Total Project Cos	st	259.51	30.78	290.28
Performance Viol Penalty Cost	ation -	-		0.00
Total Solution Fi	tness -	-		290.28
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Solution Fitness

Conveyance

Penalty Cost

Green Infrastructure

Co	ost Item	Capital Cost (\$M) C	O&M Cost (\$M) (Total Cost (\$M)
Co Sta	nveyance (incl RTC, Lift ations &Relining)	130.93	3.03	133.96
Sto T/S	orage (Tanks & Linear S)	105.37	25.46	130.83
Gr	een Infrastructure	24.83	2.13	26.96
То	tal Project Cost	261.13	30.63	291.76
Pe Pe	rformance Violation nalty Cost	-	-	0.00
То	tal Solution Fitness •Best solution i	- n 150 th ger	- neration	291.76
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Storage

Total Project Cost



C	ost Item	Capital Cost (\$M) C	O&M Cost (\$M) (Total Cost (\$M)
Co St	onveyance (incl RTC, Lift tations &Relining)	128.11	2.95	131.06
St T/	torage (Tanks & Linear 'S)	106.47	25.68	132.16
G	reen Infrastructure	24.92	2.14	27.07
Тс	otal Project Cost	259.51	30.78	290.28
Pe Pe	erformance Violation enalty Cost	-	-	0.00
Тс	otal Solution Fitness •Best solution i	n 200 th ger	- neration	290.28
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Generations

Green Infrastructure

Storage

Total Project Cost

Penalty Cost

Solution Fitness

Conveyance



	Cost Item	Capital Cost (\$M) C	O&M Cost (\$M) (Total Cost (\$M)
	Conveyance (incl RTC, Lift Stations & Relining)	128.40	2.99	131.39
	Storage (Tanks & Linear T/S)	105.96	25.58	131.54
	Green Infrastructure	24.95	2.15	27.10
	Total Project Cost	259.31	30.72	290.03
	Performance Violation Penalty Cost	-	-	0.00
	Total Solution Fitness	-	-	290.03
	 Best solution i 	n 250 th gen	eration	
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Green Infrastructure

Conveyance

Total Project Cost



Comparison of Total Project Costs

Cost Item	Baseline Solution (\$M)					
		No LID/RTC (\$M)	No LID (\$M)	Optimized Solution (\$M)	LID 50% Effective (\$M)	No RGBO ³ (\$M)
Conveyance	149.83	114.40	114.40	114.40	114.40	114.40
Pump Station ¹	-	1.25	1.25	1.25	1.25	1.25
Linear Storage	42.66	13.96	13.96	13.96	13.96	13.96
Storage Tank	99.80	123.62	116.82	63.28	95.81	96.68
Relining	13.04	3.51	3.51	2.18	2.67	2.56
RTC	-	-	2.67	2.67	2.67	2.67
Green Technology/LID ²	-	-	-	27.39	19.04	15.06
Total Construction Cost	305.34	256.75	252.62	225.13	249.80	246.58
Eng'g/Legal/Admin (20%)	61.07	51.35	50.52	45.03	49.96	49.32
Total Capital Cost	366.40	308.10	303.14	270.16	299.76	295.90
Present Worth O&M	45.61	42.02	40.84	29.40	37.45	35.92
TOTAL PROJECT COST	412.01	350.11	343.98	299.56	337.21	331.82
Savings on Baseline Cost	(\$M) (%)	61.90 15%	68.04 17%	112.46 27%	74.80 18%	80.19 19%

Layout of Optimized Solutions showing Storage Volumes for Three Scenarios



Prioritization of Projects for Maximum Impendit of Projects for Maximum



Priority 4

Next Steps

- Develop CSO communications dashboard
- Increase logic aggressiveness to further reduce CSOs
- Fine tune and evaluate RT-DSS effectiveness
- Compare RT-DSS, Model, and DMR CSO volume reporting
- Review entire LTCP to realize more savings

Questions?

