APPENDIX C

CONVEYANCE SYSTEM HEADLOSS CALCULATIONS

CONVEYANCE SYSTEM HEADLOSS CALCULATIONS

PARSONS COMMERCIAL TECHNOLOGY GROUP SYRACUSE, NEW YORK	Slurry Pipeline Hydraulic Analysis Honeywell Onondaga Lake Dredging Project 444853	REV	BY	CHK'D	DATE
		1	AN	MA	6/8/2011
		0	AN	MA	11/16/2010

HYDRAULIC EVALUATION OF THE DREDGE SLURRY PUMPING SYSTEM

ASSUMPTIONS

1) Dredging season 7 months/year 6 days x 24hrs per week
2) Hydraulic calculations performed for dredging in Remediation Area - D with a maximum on water pipe length of 4020 ft
3) Pumping system includes Dredge pump + 4 booster pumps
4) Booster pumps assumed to be Warman MD 36" impeller slurry pump (See Pump Curve tab)
5) Slurry in Remediation Area D - assumed design maximimum slurry SG of 1.11 and d_{50} 0.1 mm ; expected slurry SG of 1.08 and d_{50} 0.1 mm (values based on max design and expected dredge production rates and sediment data)
6) Pressure at BP# 1 inlet is assumed to be a minimum of 15 psi
7) HGL elevation at the dredge is calculated as the sum of 15 psi (BP#1 inlet pressure) + headloss between Dredge and BP#1
8) Pressure at BP# 2 - BP# 4 suction is assumed to be a minimum of 10 psi
9) Discharge head of dredge pump to vary based on the location in the lake
10) C values (friction factor) based on specific gravity of slurry, sediment d_{50} and pipe material (see friction factor tab)
11) Carrier pipe 16" DR 11 HDPE pipe
12) All minor losses assumed at Booster Station
13) Drawings:Slurry Pipeline P&ID 444853-200-D-101 to 444853-D-106- Rev C Issued for Draft Final Design_1/21/11)
14) Drawings: Slurry Pipeline Plan drawings (444853-C-101 to 444853-C-121 Rev C Issued for Draft Final Design_1/21/11)
15) Drawings:Slurry Pipeline Alignment Profile (444853-C-130 Rev A Issued for Draft Final Design_1/21/11)

Constants			
Parameter	Design	Expected	Units
Q_{pump}	5,500	5,500	gpm
C_{HDPE}	135	140	
g	32.2	32.2	ft/sec^2
Sg	1.11	1.08	
% Solids	18%	10%	

Area D Head Loss Calculations for Design of Slurry Pipe - Sg = 1.11 or C = 135

Station (ft)	Ground El. (ft MSL)	Length (ft)	Flow (mgd)	Flow (cfs)	Flow (gpm)	C	Diameter (in.)	Diameter (ft)	Area (sq ft)	Velocity (ft/s)	SG	Headloss (ft of water)	HGL (ft MSL)	Bottom of Pipe (ft MSL)	Pressure (psi)	Comments	Head of pump
-40+20	363	4020	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	160.1	560.0	363	85		
0+00	365	0	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	0.0	399.9	365	15	Booster Pump 1	214.1
0+00	365	400	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	22.0	614.0	365	108		
4+00	369	600	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	22.9	592.0	369	96		
10+00	368	1000	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	38.2	569.1	368	87		
20+00	373	250	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	9.5	531.0	373	68		
22+50	375	350	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	13.4	521.4	375	63		
26+00	373	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	508.1	373	58		
28+00	378	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	500.5	378	53		
30+00	372	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	492.8	372	52		
32+00	369	100	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	3.8	485.2	369	50		
33+00	371	38	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	1.4	481.4	371	48		
33+38	371	0	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	0.0	479.9	371	47	Booster Pump 2	210.1
33+38	371	62	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	12.4	690	371	138		
34+00	366	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	677.6	366	135		
36+00	396	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	670.0	396	118		
38+00	395	100	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	3.8	662.4	395	116		
39+00	406	100	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	3.8	658.6	406	109		
40+00	406	1000	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	38.2	654.7	406	108		
50+00	404	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	616.6	404	92		
55+00	418	300	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	11.4	597.5	418	78		
58+00	408	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	586.1	408	77		
60+00	407	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	578.4	407	74		
65+00	403	100	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	3.8	559.3	403	68		
66+00	407	400	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	15.3	555.5	407	64		
70+00	406	1000	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	38.2	540.3	406	58		
80+00	406	600	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	22.9	502.1	406	41		
86+00	408	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	479.2	408	31		
88+00	415	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	471.6	415	24		
90+00	407	451	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	17.2	464.0	407	24		
94+51	409	0	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	0.0	446.7	409	16	Booster Pump 3	220.3
94+51	409	149	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	18.5	667	409	112		
96+00	376	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	648.5	376	118		
98+00	391	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	640.9	391	108		
100+00	375	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	633.3	375	112		
105+00	380	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	614.2	380	101		
110+00	371	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	595.1	371	97		
115+00	380	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	576.0	380	85		
120+00	373	150	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	5.7	556.9	373	79		
121+50	365	50	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	1.9	551.2	365	80		
122+00	370	750	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	28.6	549.3	370	77		
129+50	370	50	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	1.9	520.7	370	65		
130+00	375	150	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	5.7	518.8	375	62		
131+50	377	450	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	17.2	513.1	377	59		
136+00	373	400	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	15.3	495.9	373	53		
140+00	376	500	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	19.1	480.6	376	45		
145+00	379	150	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	5.7	461.5	379	36		
146+50	371	50	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	1.9	455.8	371	37		
147+00	379	282	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	10.8	453.9	379	32		
149+82	378	0	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	0.0	443.1	378	28	Booster Pump 4	221.9
149+82	378	18	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	14.4	665	378	124		
150+00	378	1000	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	38.2	650.6	378	118		
160+00	378	750	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	28.6	612.5	378	101		
167+50	378	50	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	1.9	583.8	378	89		
168+00	375	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	581.9	375	89		
170+00	384	700	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	26.7	574.3	384	82		
177+00	386	300	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	11.4	547.6	386	70		
180+00	398	800	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	30.5	536.1	398	60		
188+00	447	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	505.6	447	25		
190+00	446	400	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	15.3	498.0	446	22		
194+00	451	100	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	3.8	482.7	451	14		
195+00	432	300	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	11.4	478.9	432	20		
198+00	430	200	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	7.6	467.5	430	16		
200+00	430	650	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	24.8	459.8	430	13		
206+50	435	100	7.9	12.3	5,500	135	12.974	1.08	0.92	13.35	1.11	3.8	435.0	435	0	SCA	

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	Slurry Pipeline Hydraulic Analysis				
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project	1	AN	MA	6/8/2011
SYRACUSE, NEW YORK	444853	0	AN	MA	11/16/2010

HYDRAULIC EVALUATION OF THE DREDGE SLURRY PUMPING SYSTEM

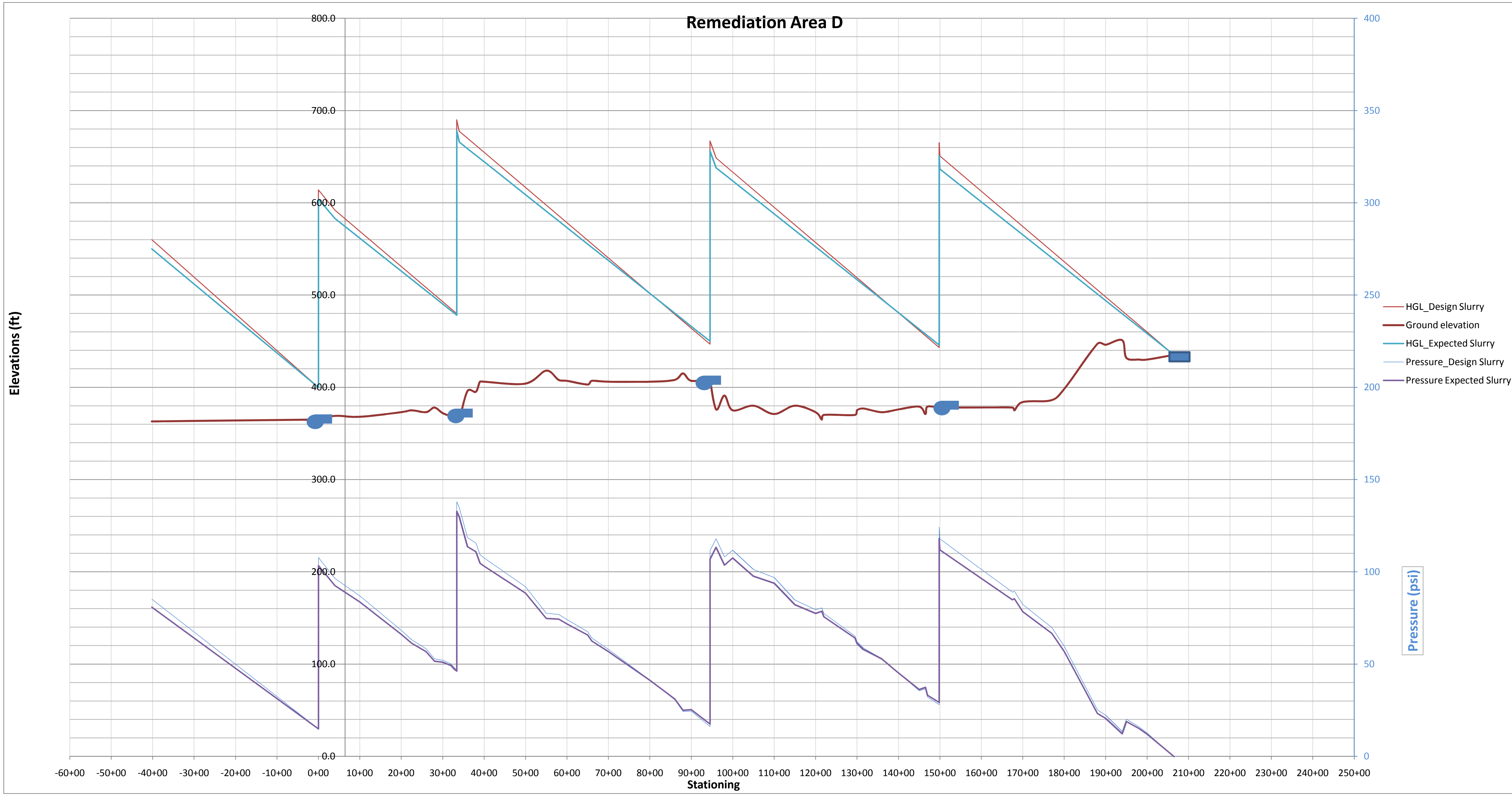
ASSUMPTIONS

1) Dredging season 7 months/year 6 days x 24hrs per week
2) Hydraulic calculations performed for dredging in Remediation Area - D with a maximum on water pipe length of 4020 ft
3) Pumping system includes Dredge pump + 4 booster pumps
4) Booster pumps assumed to be Warman MD 36" impeller slurry pump (See Pump Curve tab)
5) Slurry in Remediation Area D - assumed design maximimum slurry SG of 1.11 and d_{50} 0.1 mm ; expected slurry SG of 1.08 and d_{50} 0.1 mm (values based on max design and expected dredge production rates and sediment data)
6) Pressure at BP# 1 inlet is assumed to be a minimum of 15 psi
7) HGL elevation at the dredge is calculated as the sum of 15 psi (BP#1 inlet pressure) + headloss between Dredge and BP#1
8) Pressure at BP# 2 - BP# 4 suction is assumed to be a minimum of 10 psi
9) Discharge head of dredge pump to vary based on the location in the lake
10) C values (friction factor) based on specific gravity of slurry, sediment d_{50} and pipe material (see friction factor tab)
11) Carrier pipe 16" DR 11 HDPE pipe
12) All minor losses assumed at Booster Station
13) Drawings:Slurry Pipeline P&ID 444853-200-D-101 to 444853-D-106- Rev C Issued for Draft Final Design_1/21/11)
14) Drawings: Slurry Pipeline Plan drawings (444853-C-101 to 444853-C-121 Rev C Issued for Draft Final Design_1/21/11)
15) Drawings:Slurry Pipeline Alignment Profile (444853-C-130 Rev A Issued for Draft Final Design_1/21/11)

Constants			
Parameter	**Design**	**Expected**	**Units**
Q_{pump}	5,500	5,500	gpm
C_{HDPE}	135	140	
g	32.2	32.2	ft/sec^2
Sg	1.11	1.08	
% Solids	18%	10%	

Area D Head Loss Calculations for Expected - Sg of 1.08 - C = 140

Station (ft)	Ground El. (ft MSL)	Length (ft)	Flow (mgd)	Flow (cfs)	Flow (gpm)	C	Diameter (in.)	Diameter (ft)	Area (sq ft)	Velocity (ft/s)	SG	Headloss (ft of water)	HGL (ft MSL)	Bottom of Pipe (ft MSL)	Pressure (psi)	Comments	Head of pump
-40+20	363	4020	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	150.1	550.0	363	81		
0+00	365	0	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	0.0	399.9	365	15	Booster Pump 1	204.1
0+00	365	400	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	21.0	604.0	365	103		
4+00	369	600	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	21.4	583.0	369	93		
10+00	368	1000	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	35.7	561.6	368	84		
20+00	373	250	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	8.9	526.0	373	66		
22+50	375	350	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	12.5	517.0	375	61		
26+00	373	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	504.5	373	57		
28+00	378	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	497.4	378	52		
30+00	372	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	490.3	372	51		
32+00	369	100	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	3.6	483.1	369	49		
33+00	371	38	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	1.4	479.6	371	47		
33+38	371	0	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	0.0	478.2	371	46	Booster Pump 2	199.8
33+38	371	62	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	12.2	678	371	133		
34+00	366	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	665.8	366	130		
36+00	396	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	658.7	396	114		
38+00	395	100	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	3.6	651.5	395	111		
39+00	406	100	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	3.6	648.0	406	105		
40+00	406	1000	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	35.7	644.4	406	103		
50+00	404	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	608.7	404	88		
55+00	418	300	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	10.7	590.9	418	75		
58+00	408	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	580.2	408	74		
60+00	407	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	573.0	407	72		
65+00	403	100	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	3.6	555.2	403	66		
66+00	407	400	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	14.3	551.6	407	62		
70+00	406	1000	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	35.7	537.4	406	57		
80+00	406	600	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	21.4	501.7	406	41		
86+00	408	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	480.3	408	31		
88+00	415	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	473.1	415	25		
90+00	407	451	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	16.1	466.0	407	25		
94+51	409	0	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	0.0	449.9	409	17	Booster Pump 3	206.1
94+51	409	149	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	18.1	656	409	107		
96+00	376	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	637.9	376	113		
98+00	391	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	630.7	391	104		
100+00	375	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	623.6	375	107		
105+00	380	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	605.8	380	98		
110+00	371	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	587.9	371	94		
115+00	380	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	570.1	380	82		
120+00	373	150	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	5.4	552.3	373	77		
121+50	365	50	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	1.8	546.9	365	79		
122+00	370	750	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	26.8	545.1	370	76		
129+50	370	50	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	1.8	518.4	370	64		
130+00	375	150	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	5.4	516.6	375	61		
131+50	377	450	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	16.1	511.2	377	58		
136+00	373	400	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	14.3	495.2	373	53		
140+00	376	500	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	17.8	480.9	376	45		
145+00	379	150	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	5.4	463.1	379	36		
146+50	371	50	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	1.8	457.7	371	37		
147+00	379	282	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	10.1	455.9	379	33		
149+82	378	0	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	0.0	445.9	378	29	Booster Pump 4	205.1
149+82	378	18	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	14.3	651	378	118		
150+00	378	1000	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	35.7	636.7	378	112		
160+00	378	750	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	26.8	601.0	378	96		
167+50	378	50	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	1.8	574.2	378	85		
168+00	375	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	572.4	375	85		
170+00	384	700	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	25.0	565.3	384	78		
177+00	386	300	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	10.7	540.3	386	67		
180+00	398	800	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	28.5	529.6	398	57		
188+00	447	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	501.1	447	23		
190+00	446	400	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	14.3	494.0	446	21		
194+00	451	100	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	3.6	479.7	451	12		
195+00	432	300	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	10.7	476.1	432	19		
198+00	430	200	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	7.1	465.4	430	15		
200+00	430	650	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	23.2	458.3	430	12		
206+50	435	100	7.9	12.3	5,500	140	12.974	1.08	0.92	13.35	1.08	3.6	435.1	435	0	SCA	


Remediation Area D
Elevations (ft)
Pressure (psi)
Stationing
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
400
350
300
250
200
150
100
50
0
-60+00
-50+00
-40+00
-30+00
-20+00
-10+00
0+00
10+00
20+00
30+00
40+00
50+00
60+00
70+00
80+00
90+00
100+00
110+00
120+00
130+00
140+00
150+00
160+00
170+00
180+00
190+00
200+00
210+00
220+00
230+00
240+00
250+00
HGL_Design Slurry
Ground elevation
HGL_Expected Slurry
Pressure_Design Slurry
Pressure Expected Slurry

PARSONS		REV	BY	CHK'D	DATE
	Slurry Pipeline Hydraulic Analysis				
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project	1	AN	MA	6/8/2011
SYRACUSE, NEW YORK	444853	0	AN	MA	11/16/2010

HYDRAULIC EVALUATION OF THE DREDGE SLURRY PUMPING SYSTEM

ASSUMPTIONS

1) Dredging season 7 months/year 6 days x 24hrs per week
2) Hydraulic calculations performed for dredging in Remediation Area - E with a maximum in water pipe length of 6260 ft.
3) Pumping system includes Dredge pump + 4 booster pumps
4) Pump assumed to be Warman 36" impeller slurry pump MD
5) Slurry in Remediation Area E - assumed design maximum SG of slurry 1.18 and d_{50} 0.2 mm -expected slurry of SG 1.13 and d_{50} 0.2 mm (values based on design and expected dredge production rates and sediment data)
6) Pressure at BP # 1 suction assumed to be will be a minimum of 15 psi
7) HGL elevation at the dredge is calculated as the sum of 15 psi (BP#1 inlet pressure) + headloss between Dredge and BP#1
8) Pressure at pump suction will be a minimum of 10 psi
9) Speed and discharge head of dredge pump to vary based on the location in the lake
10) C values (friction factor) based on specific gravity of slurry, sediment d_{50} and pipe material (See friction factor tab)
11) Carrier pipe 16" DR 11 HDPE pipe
12) All minor losses assumed at Booster Station
13) Drawings:Slurry Pipeline P&ID 444853-200-D-101 to 444853-D-106- Rev C Issued for Draft Final Design_1/21/11)
14) Drawings: Slurry Pipeline Plan drawings (444853-C-101 to 444853-C-121 Rev C Issued for Draft Final Design_1/21/11)
15) Drawings:Slurry Pipeline Alignment Profile (444853-C-130 Rev A Issued for Draft Final Design_1/21/11)

Constants			
Parameter	Design	Expected	Units
Q_{pump}	5,500	5,500	gpm
C_{HDPE}	127	132	
g	32.2	32.2	ft/sec^2
SG	1.18	1.13	

Area E Head Loss Calculations for Design of Slurry Pipe - Sg = 1.18 or C = 127																	
Station	Ground El.	Length	Flow	Flow	Flow	C	Diameter	Diameter	Area	Velocity		Headloss	HGL	Bottom of Pipe	Pressure		Head of
(ft)	(ft MSL)	(ft)	(mgd)	(cfs)	(gpm)		(in.)	(ft)	(sq ft)	(ft/s)	SG	(ft of water)	(ft MSL)	(ft MSL)	(psi)	Comments	pump
-62+60	363	6260	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	274.1	674.0	363	135		
0+00	365	0	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	0.0	399.9	365	15	Booster Pump 1	229.3
0+00	365	400	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	23.8	629.2	365	114		
4+00	369	600	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	25.6	605.4	369	102		
10+00	368	1000	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	42.7	579.8	368	92		
20+00	373	250	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	10.7	537.1	373	71		
22+50	375	350	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	15.0	526.4	375	65		
26+00	373	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	511.4	373	60		
28+00	378	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	502.9	378	54		
30+00	372	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	494.3	372	53		
32+00	369	100	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	4.3	485.8	369	50		
33+00	371	38	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	1.6	481.5	371	48		
33+38	371	0	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	0.0	479.9	371	47	Booster Pump 2	238.0
33+38	371	62	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	12.6	717.9	371	150		
34+00	366	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	705.3	366	147		
36+00	396	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	696.7	396	130		
38+00	395	100	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	4.3	688.2	395	127		
39+00	406	100	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	4.3	683.9	406	120		
40+00	406	1000	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	42.7	679.6	406	118		
50+00	404	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	636.9	404	101		
55+00	418	300	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	12.8	615.5	418	85		
58+00	408	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	602.7	408	84		
60+00	407	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	594.2	407	81		
65+00	403	100	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	4.3	572.8	403	73		
66+00	407	400	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	17.1	568.5	407	70		
70+00	406	1000	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	42.7	551.4	406	63		
80+00	406	600	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	25.6	508.7	406	44		
86+00	408	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	483.1	408	32		
88+00	415	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	474.5	415	26		
90+00	407	451	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	19.3	466.0	407	25		
94+51	409	0	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	0.0	446.7	409	16	Booster Pump 3	245.5
94+51	409	149	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	19.2	692.2	409	122		
96+00	376	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	673.0	376	128		
98+00	391	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	664.5	391	118		
100+00	375	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	655.9	375	121		
105+00	380	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	634.6	380	110		
110+00	371	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	613.2	371	105		
115+00	380	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	591.9	380	92		
120+00	373	150	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	6.4	570.5	373	85		
121+50	365	50	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	2.1	564.1	365	86		
122+00	370	750	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	32.0	562.0	370	83		
129+50	370	50	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	2.1	529.9	370	69		
130+00	375	150	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	6.4	527.8	375	66		
131+50	377	450	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	19.2	521.4	377	62		
136+00	373	400	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	17.1	502.1	373	56		
140+00	376	500	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	21.4	485.1	376	47		
145+00	379	150	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	6.4	463.7	379	36		
146+50	371	50	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	2.1	457.3	371	37		
147+00	379	282	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	12.0	455.1	379	33		
149+82	378	0	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	0.0	443.1	378	28	Booster Pump 4	247.7
149+82	378	18	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	14.5	690.8	378	135		
150+00	378	1000	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	42.7	676.3	378	129		
160+00	378	750	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	32.0	633.6	378	111		
167+50	378	50	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	2.1	601.6	378	97		
168+00	375	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	599.4	375	97		
170+00	384	700	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	29.9	590.9	384	89		
177+00	386	300	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	12.8	561.0	386	76		
180+00	398	800	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	34.2	548.2	398	65		
188+00	447	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	514.0	447	29		
190+00	446	400	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	17.1	505.4	446	26		
194+00	451	100	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	4.3	488.3	451	16		
195+00	432	300	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	12.8	484.1	432	22		
198+00	430	200	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	8.5	471.3	430	18		
200+00	430	650	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	27.8	462.7	430	14		
206+50	435	100	7.9	12.3	5,500	127	12.974	1.08	0.92	13.35	1.18	4.3	434.9	435	0	SCA	

PARSONS		REV	BY	CHK'D	DATE
	Slurry Pipeline Hydraulic Analysis				
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project	1	AN	MA	6/8/2011
SYRACUSE, NEW YORK	444853	0	AN	MA	11/16/2010

HYDRAULIC EVALUATION OF THE DREDGE SLURRY PUMPING SYSTEM

ASSUMPTIONS

1) Dredging season 7 months/year 6 days x 24hrs per week
2) Hydraulic calculations performed for dredging in Remediation Area - E with a maximum in water pipe length of 6260 ft.
3) Pumping system includes Dredge pump + 4 booster pumps
4) Pump assumed to be Warman 36" impeller slurry pump MD
5) Slurry in Remediation Area E - assumed design maximum SG of slurry 1.18 and d_{50} 0.2 mm -expected slurry of SG 1.13 and d_{50} 0.2 mm (values based on design and expected dredge production rates and sediment data)
6) Pressure at BP # 1 suction assumed to be will be a minimum of 15 psi
7) HGL elevation at the dredge is calculated as the sum of 15 psi (BP#1 inlet pressure) + headloss between Dredge and BP#1
8) Pressure at pump suction will be a minimum of 10 psi
9) Speed and discharge head of dredge pump to vary based on the location in the lake
10) C values (friction factor) based on specific gravity of slurry, sediment d_{50} and pipe material (See friction factor tab)
11) Carrier pipe 16" DR 11 HDPE pipe
12) All minor losses assumed at Booster Station
13) Drawings:Slurry Pipeline P&ID 444853-200-D-101 to 444853-D-106- Rev C Issued for Draft Final Design_1/21/11)
14) Drawings: Slurry Pipeline Plan drawings (444853-C-101 to 444853-C-121 Rev C Issued for Draft Final Design_1/21/11)
15) Drawings:Slurry Pipeline Alignment Profile (444853-C-130 Rev A Issued for Draft Final Design_1/21/11)

Constants			
Parameter	Design	Expected	Units
Q_{pump}	5,500	5,500	gpm
C_{HDPE}	127	132	
g	32.2	32.2	ft/sec^2
SG	1.18	1.13	

Area E Head Loss Calculations for expected - Sg = 1.13 - C = 132																		
Station (ft)	Ground El. (ft MSL)	Length (ft)	Flow (mgd)	Flow (cfs)	Flow (gpm)	C	Diameter (in.)	Diameter (ft)	Area (sq ft)	Velocity (ft/s)	SG	Headloss (ft of water)	HGL (ft MSL)	Bottom of Pipe (ft MSL)	Pressure (psi)	Comments	Head of pump
-62+60	363	6260	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	255.7	655.0	363	126		
0+00	365	0	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	0.0	399.3	365	15	Booster Pump 1	210.7
0+00	365	400	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	22.6	610.0	365	106		
4+00	369	600	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	23.9	587.4	369	94		
10+00	368	1000	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	39.8	563.5	368	84		
20+00	373	250	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	9.9	523.7	373	65		
22+50	375	350	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	13.9	513.8	375	60		
26+00	373	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	499.9	373	55		
28+00	378	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	491.9	378	49		
30+00	372	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	484.0	372	48		
32+00	369	100	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	4.0	476.0	369	46		
33+00	371	38	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	1.5	472.0	371	44		
33+38	371	0	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	0.0	470.5	371	43	Booster Pump 2	230.5
33+38	371	62	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	12.5	701	371	143		
34+00	366	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	688.5	366	140		
36+00	396	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	680.6	396	123		
38+00	395	100	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	4.0	672.6	395	120		
39+00	406	100	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	4.0	668.6	406	114		
40+00	406	1000	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	39.8	664.7	406	112		
50+00	404	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	624.9	404	95		
55+00	418	300	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	11.9	605.0	418	81		
58+00	408	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	593.1	408	80		
60+00	407	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	585.1	407	77		
65+00	403	100	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	4.0	565.2	403	70		
66+00	407	400	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	15.9	561.2	407	67		
70+00	406	1000	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	39.8	545.3	406	60		
80+00	406	600	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	23.9	505.6	406	43		
86+00	408	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	481.7	408	32		
88+00	415	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	473.7	415	25		
90+00	407	451	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	17.9	465.8	407	25		
94+51	409	0	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	0.0	447.8	409	17	Booster Pump 3	230.2
94+51	409	149	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	18.7	678	409	116		
96+00	376	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	659.3	376	123		
98+00	391	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	651.3	391	113		
100+00	375	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	643.4	375	116		
105+00	380	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	623.5	380	105		
110+00	371	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	603.6	371	101		
115+00	380	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	583.7	380	88		
120+00	373	150	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	6.0	563.8	373	82		
121+50	365	50	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	2.0	557.8	365	83		
122+00	370	750	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	29.8	555.9	370	80		
129+50	370	50	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	2.0	526.0	370	67		
130+00	375	150	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	6.0	524.0	375	64		
131+50	377	450	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	17.9	518.1	377	61		
136+00	373	400	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	15.9	500.2	373	55		
140+00	376	500	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	19.9	484.3	376	47		
145+00	379	150	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	6.0	464.4	379	37		
146+50	371	50	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	2.0	458.4	371	38		
147+00	379	282	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	11.2	456.4	379	33		
149+82	378	0	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	0.0	445.2	378	29	Booster Pump 4	229.8
149+82	378	18	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	14.4	675	378	128		
150+00	378	1000	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	39.8	660.6	378	122		
160+00	378	750	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	29.8	620.8	378	105		
167+50	378	50	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	2.0	591.0	378	92		
168+00	375	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	589.0	375	92		
170+00	384	700	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	27.8	581.0	384	85		
177+00	386	300	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	11.9	553.2	386	72		
180+00	398	800	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	31.8	541.3	398	62		
188+00	447	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	509.4	447	27		
190+00	446	400	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	15.9	501.5	446	24		
194+00	451	100	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	4.0	485.6	451	15		
195+00	432	300	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	11.9	481.6	432	21		
198+00	430	200	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	8.0	469.7	430	17		
200+00	430	650	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	25.9	461.7	430	13		
206+50	435	100	7.9	12.3	5,500	132	12.974	1.08	0.92	13.35	1.13	4.0	435.8	435	0	SCA	

Remediation Area E
Elevations (ft)
Pressure (psi)
Stationing
800
700
600
500
400
300
200
100
0
400
350
300
250
200
150
100
50
0
-70+00 -60+00 -50+00 -40+00 -30+00 -20+00 -10+00 0+00 10+00 20+00 30+00 40+00 50+00 60+00 70+00 80+00 90+00 100+00 110+00 120+00 130+00 140+00 150+00 160+00 170+00 180+00 190+00 200+00 210+00 220+00 230+00 240+00 250+00
Ground Elevation
HGL_Design Slurry
HGL_Expected Slurry
Pressure_Design Slurry
Pressure Expected Slurry

PARSONS		REV	BY	CHK'D	DATE
	Slurry Pipeline Hydraulic Analysis				
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project	1	AN	MA	6/8/2011
SYRACUSE, NEW YORK	444853	0	AN	MA	11/16/2010

Assumptions:

1)Pressure at BP # 1 suction is 15 psi

System Data (REM D)

	Length	Flow	Flow	C	Diameter	Diameter	Area	Velocity	Minor Loss		Headloss
	(ft)	(gpm)	(ft^3/s)		(in.)	(ft)	(sq ft)	(ft/s)	K	SG	(ft of water)
System BP#1- SCA	20650	0	0.0	135	12.974	1.08	0.92	0.00	15.60	1.11	36.10
	20650	500	1.1	135	12.974	1.08	0.92	1.21	15.60	1.11	45.79
	20650	1000	2.2	135	12.974	1.08	0.92	2.43	15.60	1.11	71.16
	20650	1500	3.3	135	12.974	1.08	0.92	3.64	15.60	1.11	110.53
	20650	2000	4.5	135	12.974	1.08	0.92	4.85	15.60	1.11	163.07
	20650	2500	5.6	135	12.974	1.08	0.92	6.07	15.60	1.11	228.26
	20650	3000	6.7	135	12.974	1.08	0.92	7.28	15.60	1.11	305.69
	20650	3500	7.8	135	12.974	1.08	0.92	8.49	15.60	1.11	395.05
	20650	4000	8.9	135	12.974	1.08	0.92	9.71	15.60	1.11	496.09
	20650	4500	10.0	135	12.974	1.08	0.92	10.92	15.60	1.11	608.59
	20650	5000	11.1	135	12.974	1.08	0.92	12.14	15.60	1.11	732.35
	20650	5500	12.3	135	12.974	1.08	0.92	13.35	15.60	1.11	867.22
	20650	6000	13.4	135	12.974	1.08	0.92	14.56	15.60	1.11	1013.04
	20650	6500	14.5	135	12.974	1.08	0.92	15.78	15.60	1.11	1169.68
	20650	7000	15.6	135	12.974	1.08	0.92	16.99	15.60	1.11	1337.03
	20650	7500	16.7	135	12.974	1.08	0.92	18.20	15.60	1.11	1514.96

System data (REM D)

	Length	Flow	Flow	C	Diameter	Diameter	Area	Velocity	Minor Loss		Headloss
	(ft)	(gpm)	(ft^3/s)		(in.)	(ft)	(sq ft)	(ft/s)	K	SG	(ft of water)
Booster Pump # 1	3338	0	0.00	135	12.974	1.08	0.92	0.00	2.42	1.11	80.00
	3338	500	1.11	135	12.974	1.08	0.92	1.21	2.42	1.11	81.56
	3338	1000	2.23	135	12.974	1.08	0.92	2.43	2.42	1.11	85.66
	3338	1500	3.34	135	12.974	1.08	0.92	3.64	2.42	1.11	92.01
	3338	2000	4.46	135	12.974	1.08	0.92	4.85	2.42	1.11	100.49
	3338	2500	5.57	135	12.974	1.08	0.92	6.07	2.42	1.11	111.00
	3338	3000	6.68	135	12.974	1.08	0.92	7.28	2.42	1.11	123.49
	3338	3500	7.80	135	12.974	1.08	0.92	8.49	2.42	1.11	137.91
	3338	4000	8.91	135	12.974	1.08	0.92	9.71	2.42	1.11	154.21
	3338	4500	10.03	135	12.974	1.08	0.92	10.92	2.42	1.11	172.35
	3338	5000	11.14	135	12.974	1.08	0.92	12.14	2.42	1.11	192.31
	3338	5500	12.25	135	12.974	1.08	0.92	13.35	2.42	1.11	214.07
	3338	6000	13.37	135	12.974	1.08	0.92	14.56	2.42	1.11	237.58
	3338	6500	14.48	135	12.974	1.08	0.92	15.78	2.42	1.11	262.85
	3338	7000	15.60	135	12.974	1.08	0.92	16.99	2.42	1.11	289.83
	3338	7500	16.71	135	12.974	1.08	0.92	18.20	2.42	1.11	318.53
Booster Pump # 2	6113	0	0.00	135	12.974	1.08	0.92	0.00	3.62	1.11	-33.20
	6113	500	1.11	135	12.974	1.08	0.92	1.21	3.62	1.11	-30.35
	6113	1000	2.23	135	12.974	1.08	0.92	2.43	3.62	1.11	-22.91
	6113	1500	3.34	135	12.974	1.08	0.92	3.64	3.62	1.11	-11.37
	6113	2000	4.46	135	12.974	1.08	0.92	4.85	3.62	1.11	4.02
	6113	2500	5.57	135	12.974	1.08	0.92	6.07	3.62	1.11	23.11
	6113	3000	6.68	135	12.974	1.08	0.92	7.28	3.62	1.11	45.78
	6113	3500	7.80	135	12.974	1.08	0.92	8.49	3.62	1.11	71.94
	6113	4000	8.91	135	12.974	1.08	0.92	9.71	3.62	1.11	101.51
	6113	4500	10.03	135	12.974	1.08	0.92	10.92	3.62	1.11	134.42
	6113	5000	11.14	135	12.974	1.08	0.92	12.14	3.62	1.11	170.63
	6113	5500	12.25	135	12.974	1.08	0.92	13.35	3.62	1.11	210.07
	6113	6000	13.37	135	12.974	1.08	0.92	14.56	3.62	1.11	252.72
	6113	6500	14.48	135	12.974	1.08	0.92	15.78	3.62	1.11	298.52
	6113	7000	15.60	135	12.974	1.08	0.92	16.99	3.62	1.11	347.44
	6113	7500	16.71	135	12.974	1.08	0.92	18.20	3.62	1.11	399.45
Booster Pump # 3	5531	0	0.00	135	12.974	1.08	0.92	0.00	4.62	1.11	-3.60
	5531	500	1.11	135	12.974	1.08	0.92	1.21	4.62	1.11	-1.00
	5531	1000	2.23	135	12.974	1.08	0.92	2.43	4.62	1.11	5.83
	5531	1500	3.34	135	12.974	1.08	0.92	3.64	4.62	1.11	16.43
	5531	2000	4.46	135	12.974	1.08	0.92	4.85	4.62	1.11	30.57
	5531	2500	5.57	135	12.974	1.08	0.92	6.07	4.62	1.11	48.12
	5531	3000	6.68	135	12.974	1.08	0.92	7.28	4.62	1.11	68.97
	5531	3500	7.80	135	12.974	1.08	0.92	8.49	4.62	1.11	93.04
	5531	4000	8.91	135	12.974	1.08	0.92	9.71	4.62	1.11	120.25
	5531	4500	10.03	135	12.974	1.08	0.92	10.92	4.62	1.11	150.56
	5531	5000	11.14	135	12.974	1.08	0.92	12.14	4.62	1.11	183.90
	5531	5500	12.25	135	12.974	1.08	0.92	13.35	4.62	1.11	220.23
	5531	6000	13.37	135	12.974	1.08	0.92	14.56	4.62	1.11	259.52
	5531	6500	14.48	135	12.974	1.08	0.92	15.78	4.62	1.11	301.73
	5531	7000	15.60	135	12.974	1.08	0.92	16.99	4.62	1.11	346.83
	5531	7500	16.71	135	12.974	1.08	0.92	18.20	4.62	1.11	394.78
Booster Pump 4	5668	0	0.00	135	12.974	1.08	0.92	0.00	4.94	1.11	-8.10
	5668	500	1.11	135	12.974	1.08	0.92	1.21	4.94	1.11	-5.43
	5668	1000	2.23	135	12.974	1.08	0.92	2.43	4.94	1.11	1.58
	5668	1500	3.34	135	12.974	1.08	0.92	3.64	4.94	1.11	12.46
	5668	2000	4.46	135	12.974	1.08	0.92	4.85	4.94	1.11	26.99
	5668	2500	5.57	135	12.974	1.08	0.92	6.07	4.94	1.11	45.02
	5668	3000	6.68	135	12.974	1.08	0.92	7.28	4.94	1.11	66.44
	5668	3500	7.80	135	12.974	1.08	0.92	8.49	4.94	1.11	91.16
	5668	4000	8.91	135	12.974	1.08	0.92	9.71	4.94	1.11	119.12
	5668	4500	10.03	135	12.974	1.08	0.92	10.92	4.94	1.11	150.25
	5668	5000	11.14	135	12.974	1.08	0.92	12.14	4.94	1.11	184.51
	5668	5500	12.25	135	12.974	1.08	0.92	13.35	4.94	1.11	221.85
	5668	6000	13.37	135	12.974	1.08	0.92	14.56	4.94	1.11	262.22
	5668	6500	14.48	135	12.974	1.08	0.92	15.78	4.94	1.11	305.59
	5668	7000	15.60	135	12.974	1.08	0.92	16.99	4.94	1.11	351.93
	5668	7500	16.71	135	12.974	1.08	0.92	18.20	4.94	1.11	401.20

		Head from Single Pump			Four Booster in Series Combined Head		
	GPM	700 RPM	600 RPM	500 RPM	700 RPM	600 RPM	500 RPM
WARMAN DSC - 36	0	255	187	130	1020	748	520
	1000	257	189	131	1028	756	524
	2000	259	190	132	1036	760	528
	3000	258	189	130	1032	756	520
	4000	256	187	129	1024	748	516
	5000	254	185	125	1016	740	500
	6000	250	181	123	1000	724	492
	7000	247	177	119	988	708	476
	8000	242	173	115	968	692	460

PARSONS	Slurry Pipeline Hydraulic Analysis	REV	BY	CHK'D
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project			
SYRACUSE, NEW YORK	444853	0	AN	MA

Assumptions:
1)Pressure at BP # 1 suction is 15 psi

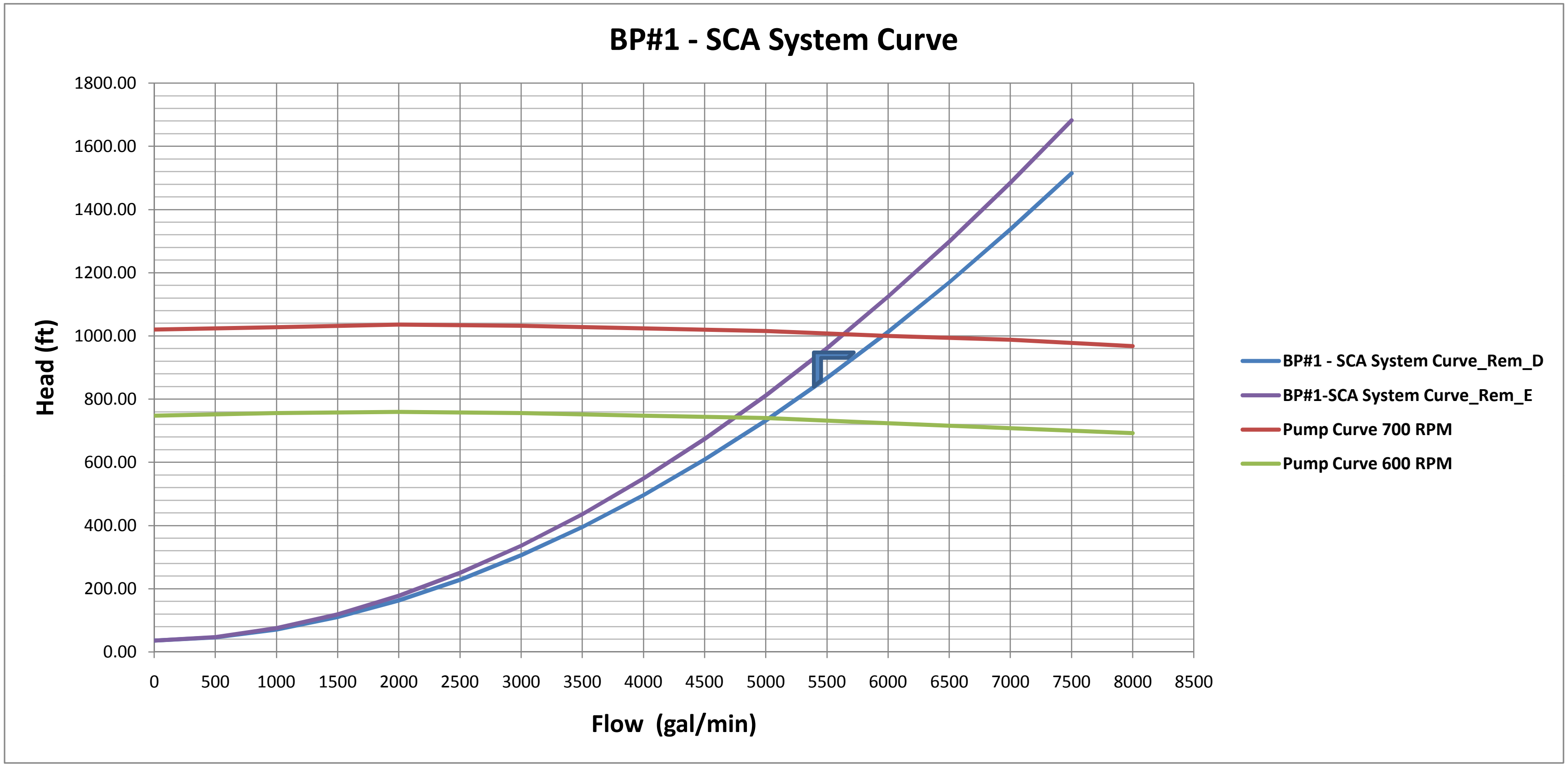
System Data (REM E)

	Length (ft)	Flow (gpm)	Flow (ft^3/s)	C	Diameter (in.)	Diameter (ft)	Area (sq ft)	Velocity (ft/s)	Minor Loss K	SG	Headloss (ft of water)
System BP#1- SCA	20650	0	0.00	127	12.974	1.08	0.92	0.00	15.60	1.18	36.10
	20650	500	1.11	127	12.974	1.08	0.92	1.21	15.60	1.18	46.90
	20650	1000	2.23	127	12.974	1.08	0.92	2.43	15.60	1.18	75.19
	20650	1500	3.34	127	12.974	1.08	0.92	3.64	15.60	1.18	119.05
	20650	2000	4.46	127	12.974	1.08	0.92	4.85	15.60	1.18	177.58
	20650	2500	5.57	127	12.974	1.08	0.92	6.07	15.60	1.18	250.18
	20650	3000	6.68	127	12.974	1.08	0.92	7.28	15.60	1.18	336.41
	20650	3500	7.80	127	12.974	1.08	0.92	8.49	15.60	1.18	435.91
	20650	4000	8.91	127	12.974	1.08	0.92	9.71	15.60	1.18	548.40
	20650	4500	10.03	127	12.974	1.08	0.92	10.92	15.60	1.18	673.63
	20650	5000	11.14	127	12.974	1.08	0.92	12.14	15.60	1.18	811.39
	20650	5500	12.25	127	12.974	1.08	0.92	13.35	15.60	1.18	961.49
	20650	6000	13.37	127	12.974	1.08	0.92	14.56	15.60	1.18	1123.78
	20650	6500	14.48	127	12.974	1.08	0.92	15.78	15.60	1.18	1298.10
	20650	7000	15.60	127	12.974	1.08	0.92	16.99	15.60	1.18	1484.31
	20650	7500	16.71	127	12.974	1.08	0.92	18.20	15.60	1.18	1682.30

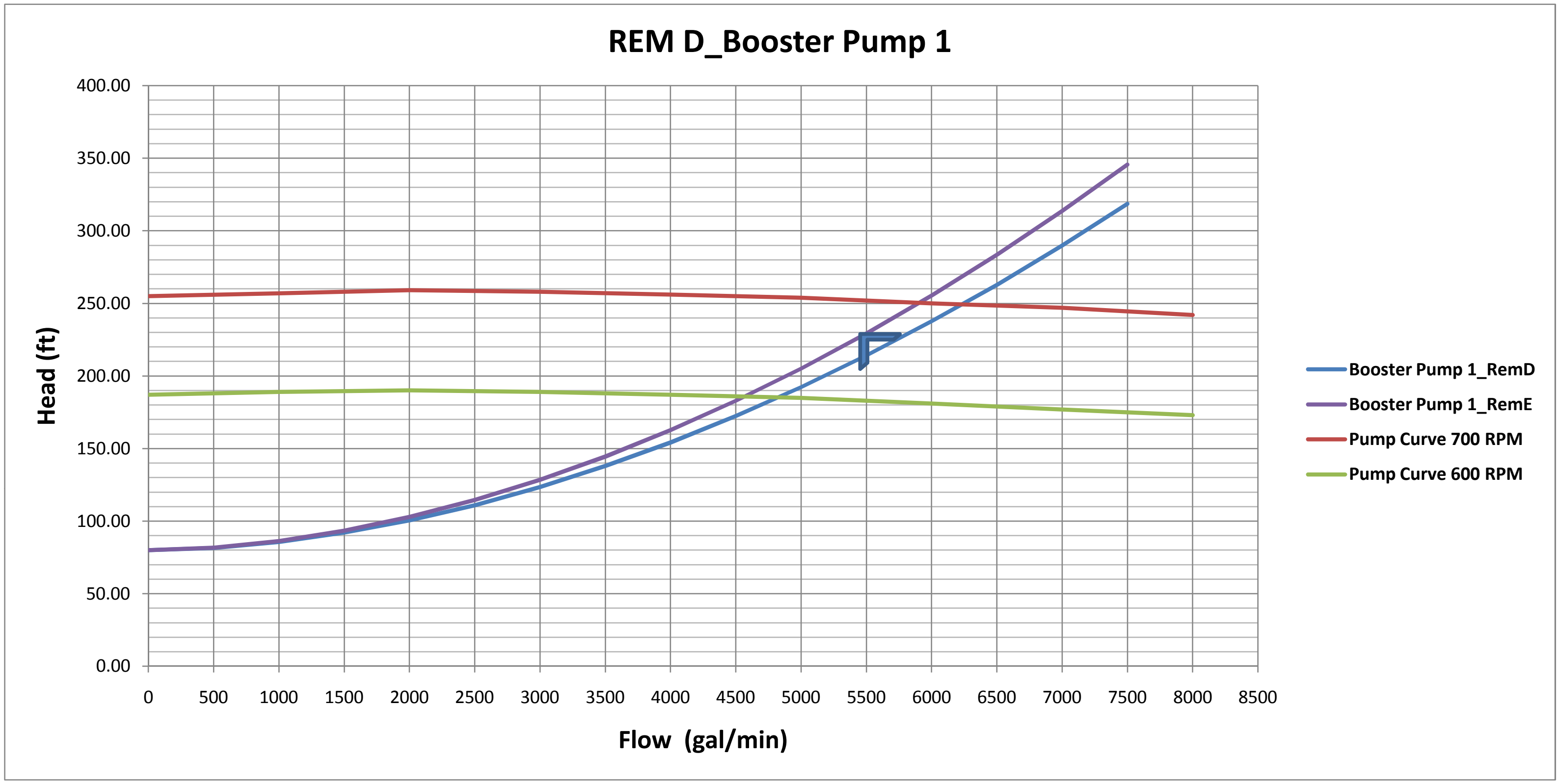
System data (REM E)

	Length (ft)	Flow (gpm)	Flow (ft^3/s)	C	Diameter (in.)	Diameter (ft)	Area (sq ft)	Velocity (ft/s)	Minor Loss K	SG	Headloss (ft of water)
Booster Pump # 1	3338	0	0.00	127	12.974	1.08	0.92	0.00	2.42	1.18	80.00
	3338	500	1.11	127	12.974	1.08	0.92	1.21	2.42	1.18	81.74
	3338	1000	2.23	127	12.974	1.08	0.92	2.43	2.42	1.18	86.31
	3338	1500	3.34	127	12.974	1.08	0.92	3.64	2.42	1.18	93.39
	3338	2000	4.46	127	12.974	1.08	0.92	4.85	2.42	1.18	102.83
	3338	2500	5.57	127	12.974	1.08	0.92	6.07	2.42	1.18	114.55
	3338	3000	6.68	127	12.974	1.08	0.92	7.28	2.42	1.18	128.46
	3338	3500	7.80	127	12.974	1.08	0.92	8.49	2.42	1.18	144.51
	3338	4000	8.91	127	12.974	1.08	0.92	9.71	2.42	1.18	162.66
	3338	4500	10.03	127	12.974	1.08	0.92	10.92	2.42	1.18	182.87
	3338	5000	11.14	127	12.974	1.08	0.92	12.14	2.42	1.18	205.09
	3338	5500	12.25	127	12.974	1.08	0.92	13.35	2.42	1.18	229.31
	3338	6000	13.37	127	12.974	1.08	0.92	14.56	2.42	1.18	255.48
	3338	6500	14.48	127	12.974	1.08	0.92	15.78	2.42	1.18	283.60
	3338	7000	15.60	127	12.974	1.08	0.92	16.99	2.42	1.18	313.64
	3338	7500	16.71	127	12.974	1.08	0.92	18.20	2.42	1.18	345.58
Booster Pump # 2	6113	0	0.00	127	12.974	1.08	0.92	0.00	3.62	1.18	-33.20
	6113	500	1.11	127	12.974	1.08	0.92	1.21	3.62	1.18	-30.02
	6113	1000	2.23	127	12.974	1.08	0.92	2.43	3.62	1.18	-21.72
	6113	1500	3.34	127	12.974	1.08	0.92	3.64	3.62	1.18	-8.85
	6113	2000	4.46	127	12.974	1.08	0.92	4.85	3.62	1.18	8.32
	6113	2500	5.57	127	12.974	1.08	0.92	6.07	3.62	1.18	29.60
	6113	3000	6.68	127	12.974	1.08	0.92	7.28	3.62	1.18	54.88
	6113	3500	7.80	127	12.974	1.08	0.92	8.49	3.62	1.18	84.04
	6113	4000	8.91	127	12.974	1.08	0.92	9.71	3.62	1.18	116.99
	6113	4500	10.03	127	12.974	1.08	0.92	10.92	3.62	1.18	153.68
	6113	5000	11.14	127	12.974	1.08	0.92	12.14	3.62	1.18	194.03
	6113	5500	12.25	127	12.974	1.08	0.92	13.35	3.62	1.18	237.98
	6113	6000	13.37	127	12.974	1.08	0.92	14.56	3.62	1.18	285.50
	6113	6500	14.48	127	12.974	1.08	0.92	15.78	3.62	1.18	336.53
	6113	7000	15.60	127	12.974	1.08	0.92	16.99	3.62	1.18	391.04
	6113	7500	16.71	127	12.974	1.08	0.92	18.20	3.62	1.18	448.99
Booster Pump # 3	5531	0	0.00	127	12.974	1.08	0.92	0.00	4.62	1.18	-3.60
	5531	500	1.11	127	12.974	1.08	0.92	1.21	4.62	1.18	-0.70
	5531	1000	2.23	127	12.974	1.08	0.92	2.43	4.62	1.18	6.91
	5531	1500	3.34	127	12.974	1.08	0.92	3.64	4.62	1.18	18.71
	5531	2000	4.46	127	12.974	1.08	0.92	4.85	4.62	1.18	34.46
	5531	2500	5.57	127	12.974	1.08	0.92	6.07	4.62	1.18	53.99
	5531	3000	6.68	127	12.974	1.08	0.92	7.28	4.62	1.18	77.20
	5531	3500	7.80	127	12.974	1.08	0.92	8.49	4.62	1.18	103.98
	5531	4000	8.91	127	12.974	1.08	0.92	9.71	4.62	1.18	134.26
	5531	4500	10.03	127	12.974	1.08	0.92	10.92	4.62	1.18	167.98
	5531	5000	11.14	127	12.974	1.08	0.92	12.14	4.62	1.18	205.07
	5531	5500	12.25	127	12.974	1.08	0.92	13.35	4.62	1.18	245.48
	5531	6000	13.37	127	12.974	1.08	0.92	14.56	4.62	1.18	289.18
	5531	6500	14.48	127	12.974	1.08	0.92	15.78	4.62	1.18	336.13
	5531	7000	15.60	127	12.974	1.08	0.92	16.99	4.62	1.18	386.28
	5531	7500	16.71	127	12.974	1.08	0.92	18.20	4.62	1.18	439.60
Booster Pump 4	5668	0	0.00	127	12.974	1.08	0.92	0.00	4.94	1.18	-8.10
	5668	500	1.11	127	12.974	1.08	0.92	1.21	4.94	1.18	-5.12
	5668	1000	2.23	127	12.974	1.08	0.92	2.43	4.94	1.18	2.69
	5668	1500	3.34	127	12.974	1.08	0.92	3.64	4.94	1.18	14.80
	5668	2000	4.46	127	12.974	1.08	0.92	4.85	4.94	1.18	30.97
	5668	2500	5.57	127	12.974	1.08	0.92	6.07	4.94	1.18	51.04
	5668	3000	6.68	127	12.974	1.08	0.92	7.28	4.94	1.18	74.87
	5668	3500	7.80	127	12.974	1.08	0.92	8.49	4.94	1.18	102.38
	5668	4000	8.91	127	12.974	1.08	0.92	9.71	4.94	1.18	133.48
	5668	4500	10.03	127	12.974	1.08	0.92	10.92	4.94	1.18	168.11
	5668	5000	11.14	127	12.974	1.08	0.92	12.14	4.94	1.18	206.21
	5668	5500	12.25	127	12.974	1.08	0.92	13.35	4.94	1.18	247.72
	5668	6000	13.37	127	12.974	1.08	0.92	14.56	4.94	1.18	292.61
	5668	6500	14.48	127	12.974	1.08	0.92	15.78	4.94	1.18	340.84
	5668	7000	15.60	127	12.974	1.08	0.92	16.99	4.94	1.18	392.35
	5668	7500	16.71	127	12.974	1.08	0.92	18.20	4.94	1.18	447.13

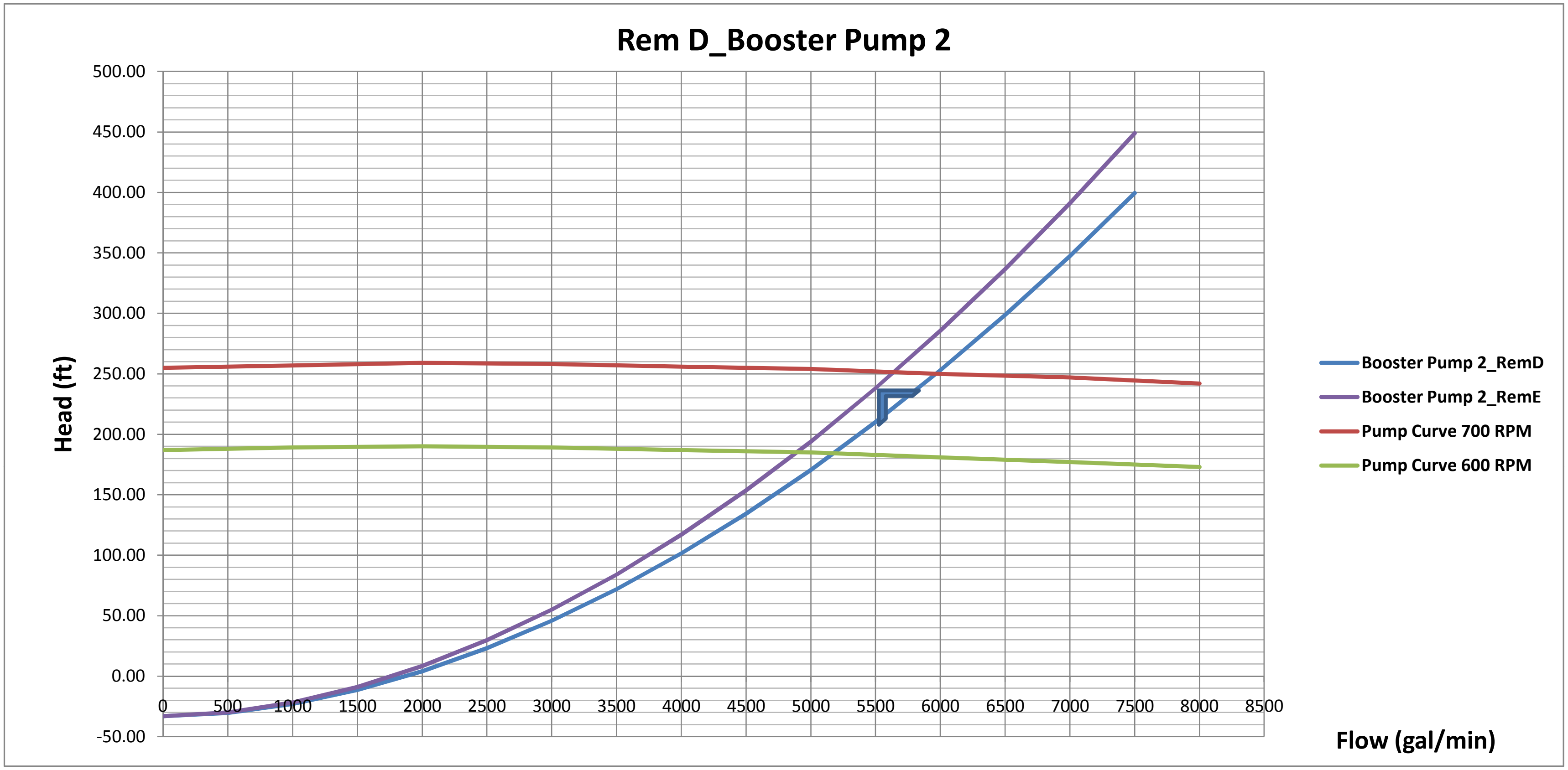
		Head from Single Pump			Four Booster in Series Combined Head		
	GPM	700 RPM	600 RPM	500 RPM	700 RPM	600 RPM	500 RPM
WARMAN DSC - 36	0	255	187	130	1020	748	520
	1000	257	189	131	1028	756	524
	2000	259	190	132	1036	760	528
	3000	258	189	130	1032	756	520
	4000	256	187	129	1024	748	516
	5000	254	185	125	1016	740	500
	6000	250	181	123	1000	724	492
	7000	247	177	119	988	708	476
	8000	242	173	115	968	692	460

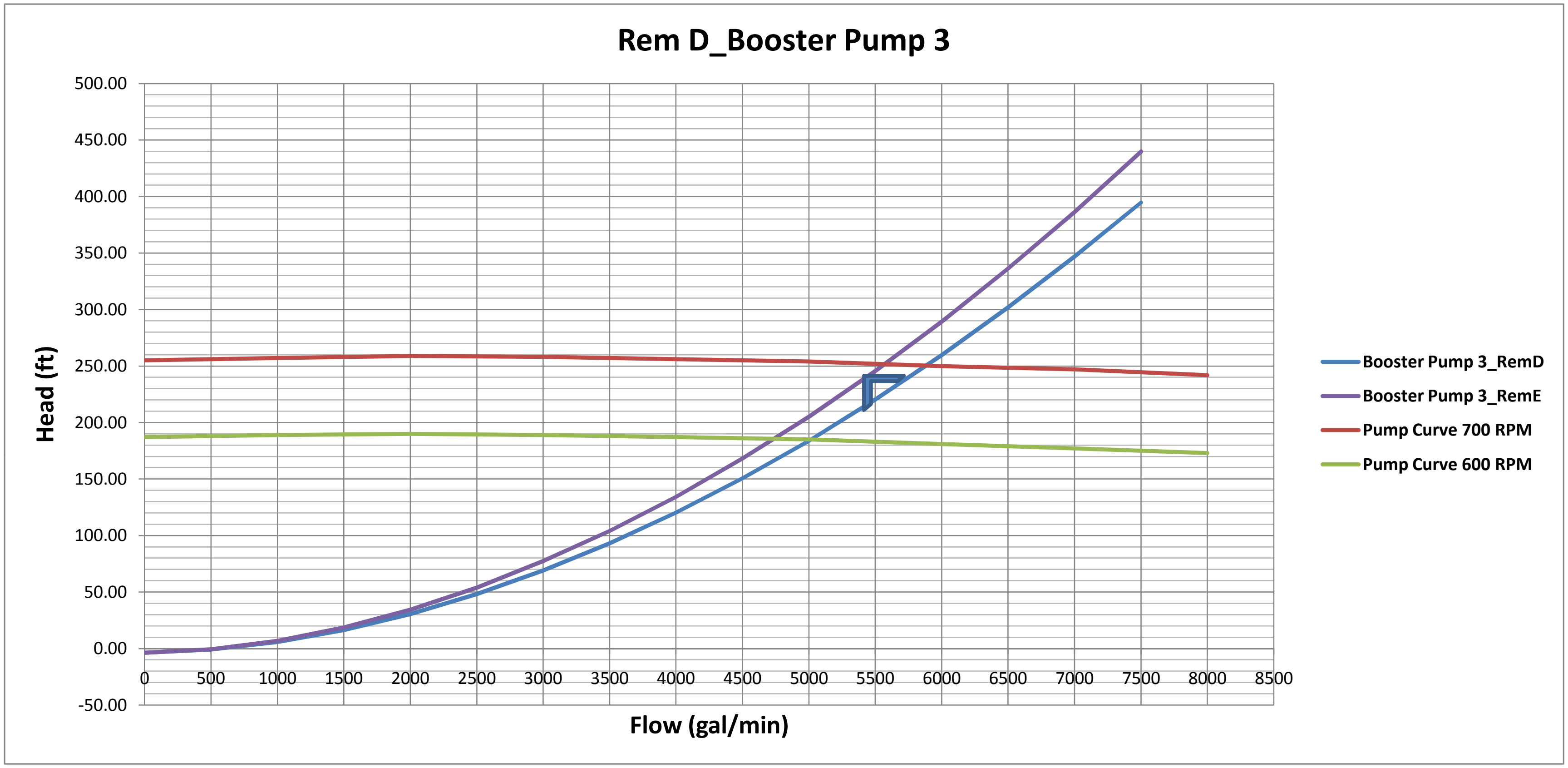


BP#1 - SCA System Curve
Head (ft)
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Flow (gal/min)
BP#1 - SCA System Curve_Rem_D
BP#1-SCA System Curve_Rem_E
Pump Curve 700 RPM
Pump Curve 600 RPM

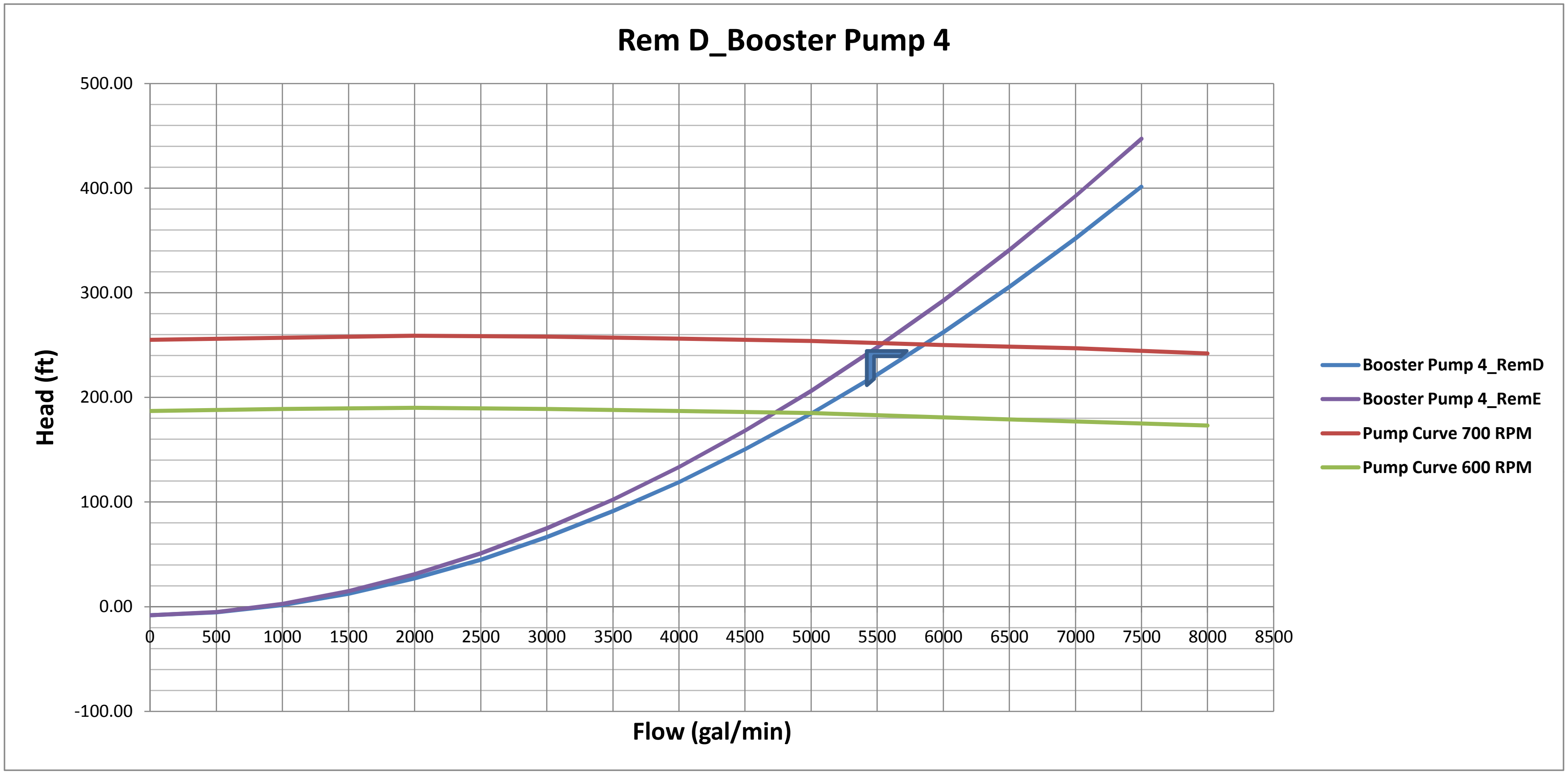


REM D_Booster Pump 1
Head (ft)
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Flow (gal/min)
Booster Pump 1_RemD
Booster Pump 1_RemE
Pump Curve 700 RPM
Pump Curve 600 RPM


Rem D_Booster Pump 2
Head (ft)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Flow (gal/min)
Booster Pump 2_RemD
Booster Pump 2_RemE
Pump Curve 700 RPM
Pump Curve 600 RPM



Rem D_Booster Pump 3
Head (ft)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Flow (gal/min)
Booster Pump 3_RemD
Booster Pump 3_RemE
Pump Curve 700 RPM
Pump Curve 600 RPM


Rem D_Booster Pump 4
500.00
400.00
300.00
200.00
100.00
0.00
-100.00
Head (ft)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Flow (gal/min)
Booster Pump 4_RemD
Booster Pump 4_RemE
Pump Curve 700 RPM
Pump Curve 600 RPM

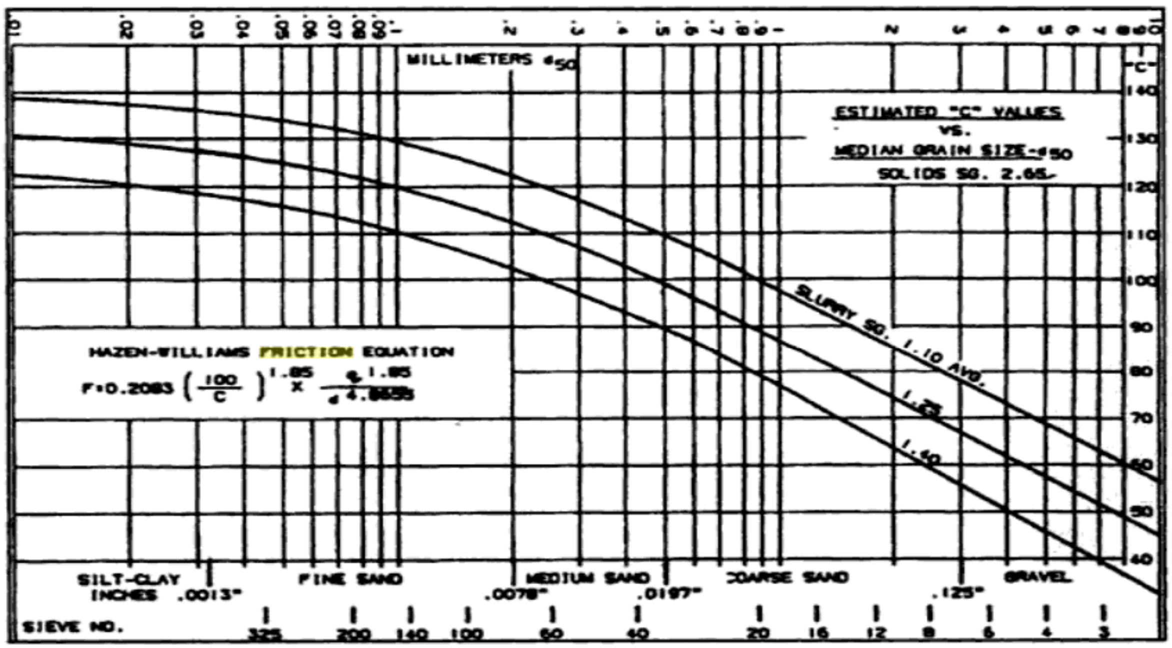


FIGURE 7.31 Constant *C* for Hazen-Williams equation. *Turner, 1984*)

Note- Friction factor has been corrected for pipe material. A clean water C value of 150 is assumed for HDPE pipe. Figure 7.31 assumes a clean water C value of 140 in steel pipe.

PARSONS COMMERCIAL TECHNOLOGY GROUP SYRACUSE, NEW YORK	Slurry Pipeline Hydraulic Analysis Honeywell Onondaga Lake Dredging Project 444853	REV	BY	CHK'D	DATE
		0	AN	MA	6/8/2011

References:
1) Minor loss coefficients Haested Methods (Advanced Distribution Modelling and Management) & Flow of Fluids-Through Valves, Pipes, And Fittings (Crane.Co)
2) Slurry Pipeline P&ID 444853-200-D-101 to 444853-D-106- Rev C Issued for Draft Final Design_1/21/11)
3) Slurry Pipeline Plan drawings (444853-C-101 to 444853-C-121 Rev C Issued for Draft Final Design_1/21/11)
3) Slurry Pipeline Alignment Profile (444853-C-130 Rev A Issued for Draft Final Design_1/21/11)

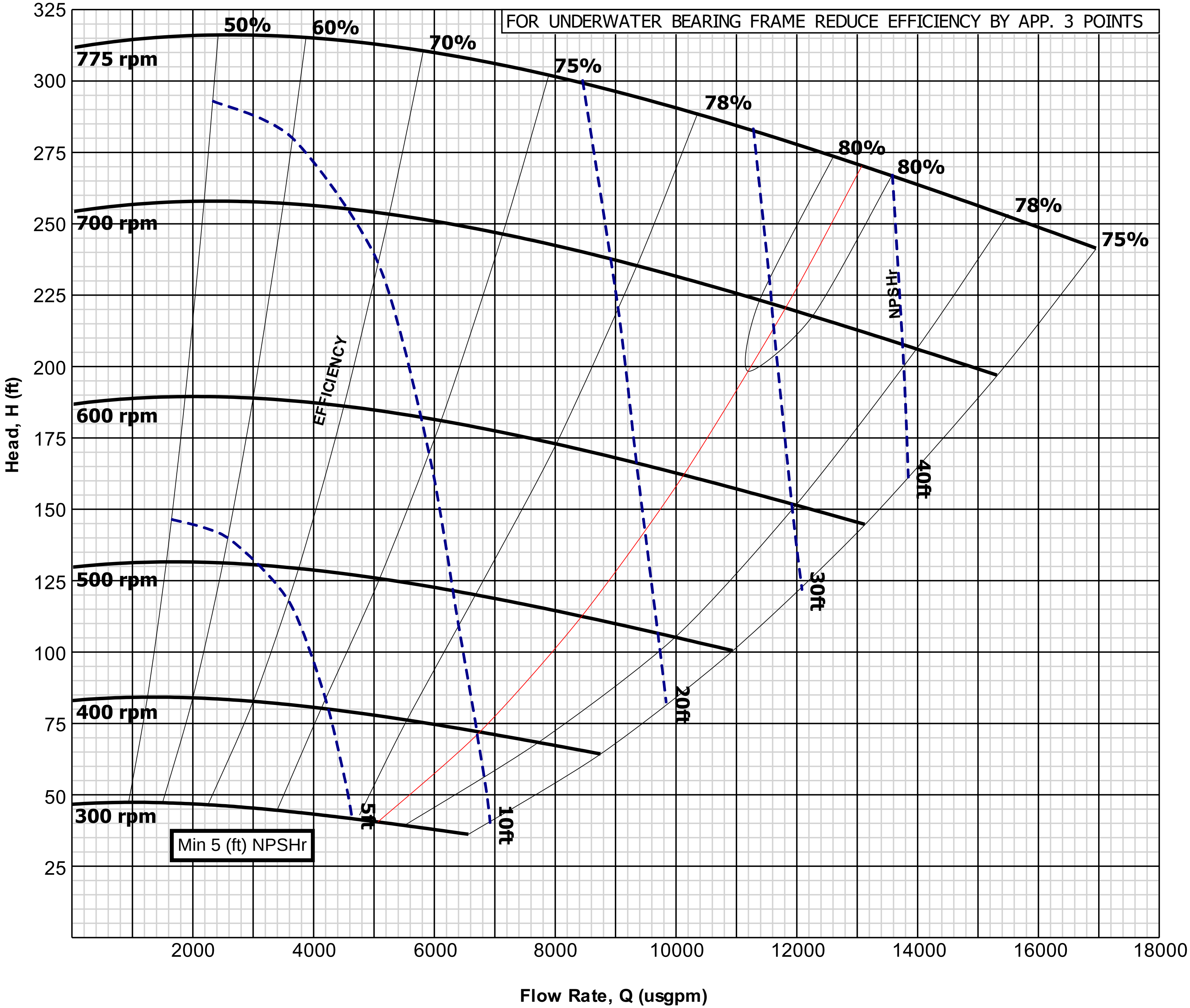
Assumed Minor Losses Coefficient	
Type	**k_l**
Wide-Radius Bend	0.20
Knife Gate Valve (fully open)	0.40
Sudden Enlargement	0.1
Sudden Contraction	0.1
Pipe Exit	1

Total Minor Loss Coefficients per Reach			
Reach	**Total k_l per Reach**	**Velocity (ft/s)**	**Minor Loss K (ft)**
Dredge - Booster	2.42	13.35	6.7
BP#1 - BP#2	2.42	13.35	6.7
BP#2 - BP#3	3.62	13.35	10.0
BP#3 - BP#4	4.62	13.35	12.8
BP#4 - SCA	4.94	13.35	13.7

WARMAN®
Centrifugal Slurry Pumps

DSC - 36

CURVE SHOWS APPROXIMATE PERFORMANCE FOR CLEAR WATER (ANSI/HI 1.6-2000 Centrifugal Pump Test Standard unless otherwise specified). For media other than water, corrections must be made for density, viscosity and/or other effects of solids. WEIR MINERALS reserves the right to change pump performance and/or delete impellers without notice. Frame suitability must be checked for each duty and drive arrangement. Not all frame alternatives are necessarily available from each manufacturing centre.



Dredging Supply Company, Inc.

Pump

Metal Casing

Impeller

Vanes	4
Vane ø	36.0"
Type	Closed
Part No	**Material**
MD10145	Metal
MD10451	Metal

Frame (Coupled Rating - HP)

MD8003H	536
MD10003	1307

Seal

Gland Sealed Pump

Liner (Norm Max r/min)

Unlined	775

Min Passage Size

5.7" Max Sphere

Curve

Revision	2
Revision Notes	B
Reference	

Madison Test 051221, SLC Test May 2006

Last Issued	Jan 06
Issued	May 08

TYPICAL PUMP PERFORMANCE CURVE

T-12107/B

PARSONS	Slurry Pipeline Hydraulic Analysis	REV	BY	CHK'D	DATE
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project				
SYRACUSE, NEW YORK	444853	0	AN	MA	6/8/2011

HYDRAULIC EVALUATION OF THE DREDGE SLURRY PUMPING SYSTEM

ASSUMPTIONS

1) Dredging season 7 months/year 6 days x 24hrs per week
2) Hydraulic calculations performed for dredging in Remediation Area - A with a maximum on-water pipe length of 2800 ft
3) Hydraulic analysis is performed for length between dredge and BP#3
4) Dredge pump assumed to be Warman MD 40" impeller slurry pump (See Pump Curve tab)
5) Slurry in Remediation Area A - assumed design maximum slurry SG of 1.16 and d_{50} 0.07 mm ; expected slurry SG of 1.11 and d_{50} 0.07 mm (values assumed based on max design and expected dredge production rates and sediment data)
6) Pressure at BP #3 inlet is set to be a minimum of 15 psi
7) HGL elevation at the dredge is calculated as the sum of 15 psi (BP#3 inlet pressure) + headloss between Dredge and BP#3
8) Discharge head of dredge pump to vary based on the location in the lake
9) C values (friction factor) based on specific gravity of slurry, sediment d_{50} and pipe material (see friction factor tab)
10) Carrier pipe 16" DR 11 HDPE pipe
11) All minor losses assumed at Booster Station
13) Drawings:Slurry Pipeline P&ID 444853-200-D-101 to 444853-D-106- Rev C Issued for Draft Final Design_1/21/11)
14) Drawings: Slurry Pipeline Plan drawings (444853-C-101 to 444853-C-121 Rev C Issued for Draft Final Design_1/21/11)
15) Drawings:Slurry Pipeline Alignment Profile Remediation Area 'A' Spur(444853-C-133 Rev A _6/3/11)

Constants			
Parameter	**Design**	**Expected**	**Units**
Q_{pump}	5,500	5,500	gpm
C_{HDPE}	137	142	
g	32.2	32.2	ft/sec^2
Sg	1.16	1.11	
% Solids	22%	16%	

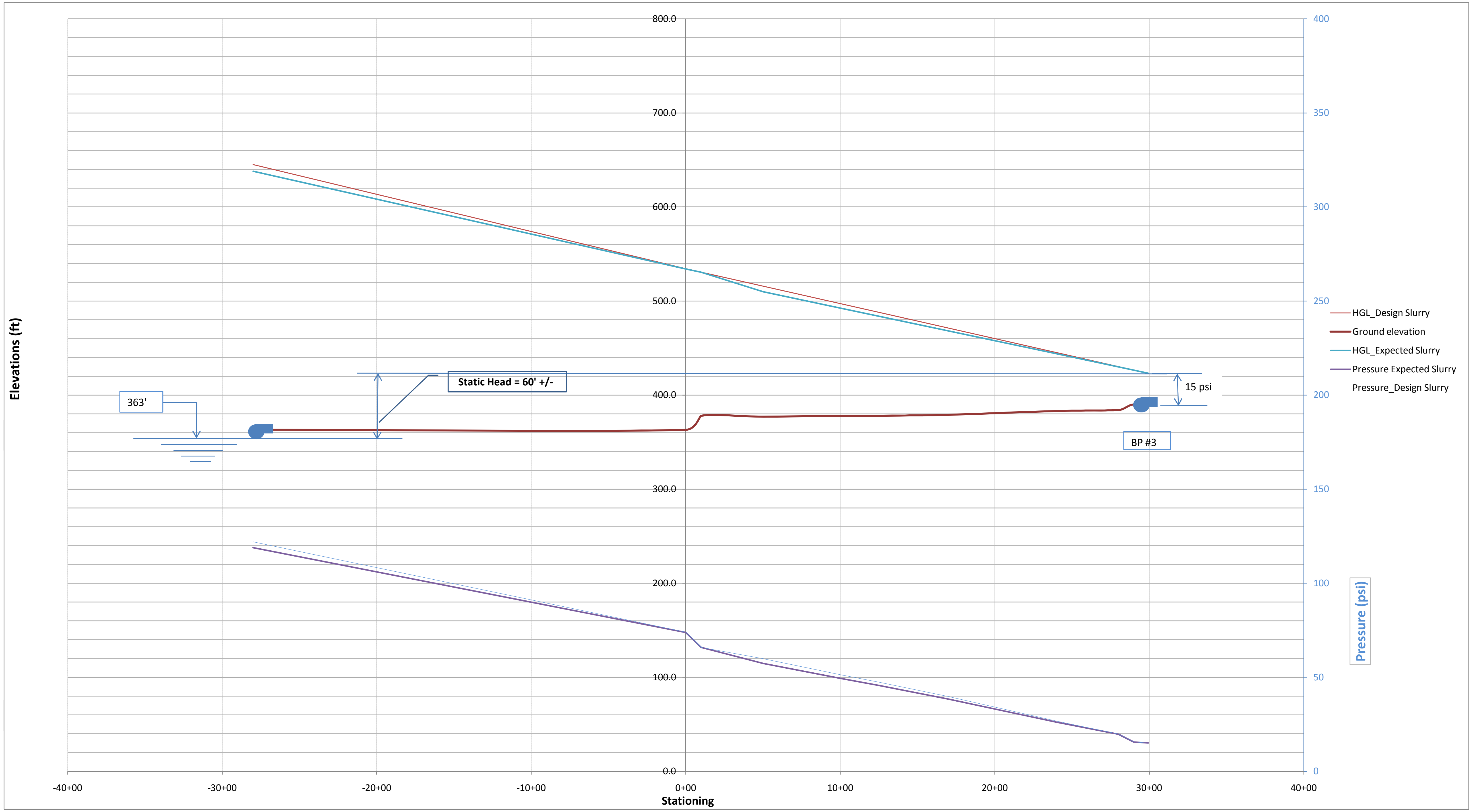
Area A Head Loss Calculations for Design of Slurry Pipe - Sg = 1.16 or C = 137

Station	Ground El.	Length	Flow	Flow	Flow	C	Diameter	Diameter	Area	Velocity		Headloss	HGL	Bottom of Pipe	Pressure		Head of
(ft)	(ft MSL)	(ft)	(mgd)	(cfs)	(gpm)		(in.)	(ft)	(sq ft)	(ft/s)	SG	(ft of water)	(ft MSL)	(ft MSL)	(psi)	Comments	pump
-28+00	363	2800	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	110.7	645.0	363	122		282.0
0+00	363	100	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	3.7	534.3	363	74		
1+00	378	400	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	14.9	530.6	378	66		
5+00	377	500	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	18.6	515.8	377	60		
10+00	378	250	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	9.3	497.2	378	51		
12+50	378	450	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	16.7	487.9	378	47		
17+00	379	700	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	26.0	471.2	379	40		
24+00	383	400	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	14.9	445.2	383	27		
28+00	384	50	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	1.9	430.4	384	20		
28+50	387	50	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	1.9	428.5	387	18		
29+00	390	93	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	3.5	426.6	390	16		
29+93	388	0	7.9	12.3	5,500	137	12.974	1.08	0.92	13.35	1.16	0.0	423.2	388	15		

Area D Head Loss Calculations for Expected - Sg of 1.11 - C = 142

Station	Ground El.	Length	Flow	Flow	Flow	C	Diameter	Diameter	Area	Velocity		Headloss	HGL	Bottom of Pipe	Pressure		Head of
(ft)	(ft MSL)	(ft)	(mgd)	(cfs)	(gpm)		(in.)	(ft)	(sq ft)	(ft/s)	SG	(ft of water)	(ft MSL)	(ft MSL)	(psi)	Comments	pump
-28+00	363	2800	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	104.0	638.0	363	119		275.0
0+00	363	100	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	3.5	534.0	363	74		
1+00	378	400	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	20.6	530.5	378	66		
5+00	377	500	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	17.4	509.9	377	57		
10+00	378	250	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	8.7	492.5	378	49		
12+50	378	450	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	15.6	483.9	378	46		
17+00	379	700	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	24.3	468.2	379	38		
24+00	383	400	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	13.9	443.9	383	26		
28+00	384	50	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	1.7	430.0	384	20		
28+50	387	50	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	1.7	428.3	387	18		
29+00	390	93	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	3.2	426.5	390	16		
29+93	388	0	7.9	12.3	5,500	142	12.974	1.08	0.92	13.35	1.11	0.0	423.3	388	15		

Remediation Area A



PARSONS		REV	BY	CHK'D	DATE
	Slurry Pipeline Hydraulic Analysis				
COMMERCIAL TECHNOLOGY GROUP	Honeywell Onondaga Lake Dredging Project				
SYRACUSE, NEW YORK	444853	0	AN	MA	6/8/2011

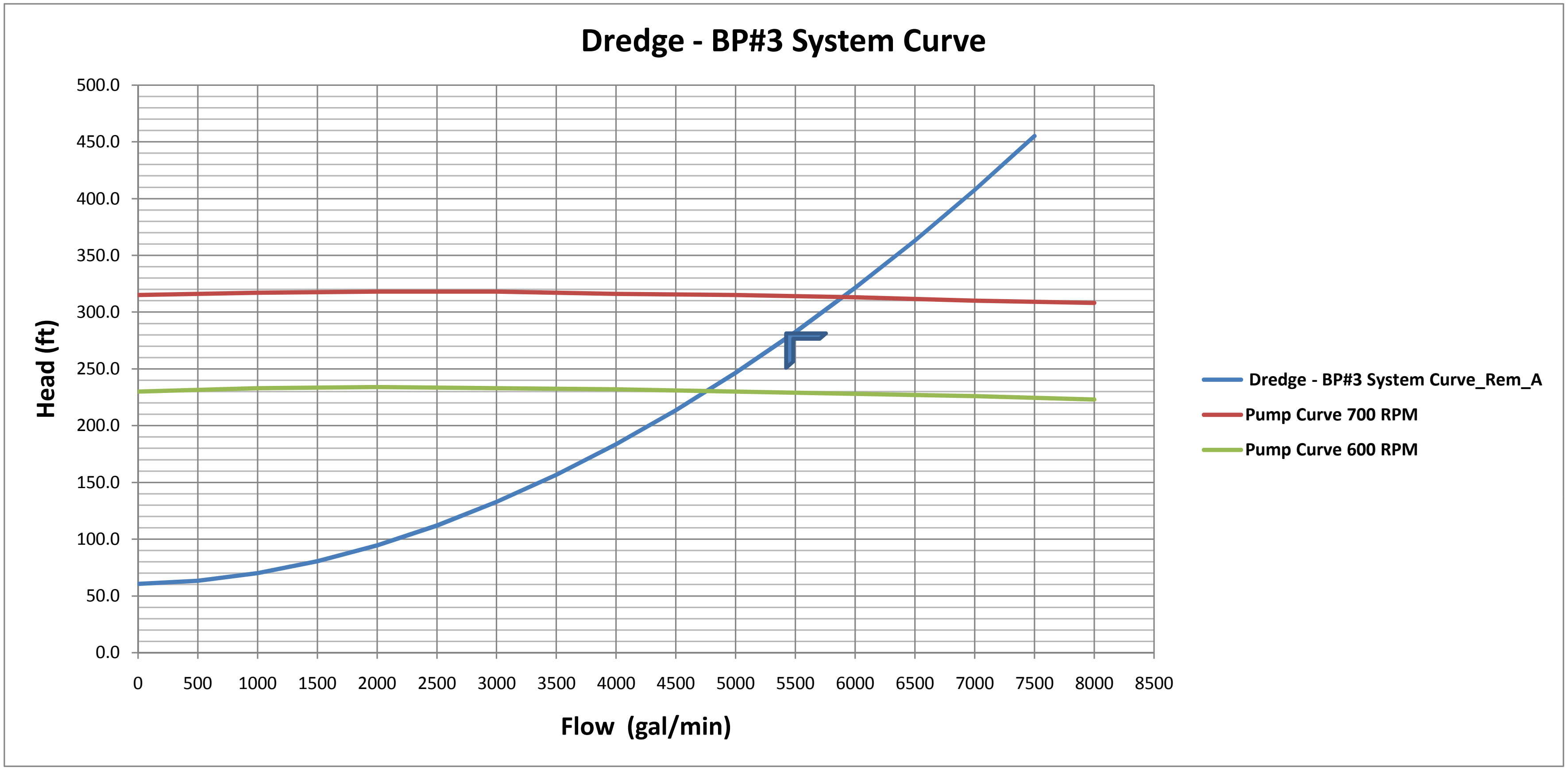
Assumptions:

1)Minimum pressure at BP #3 suction set at **15** psi

System Data (REM A)

	Length (ft)	Flow (gpm)	Flow (ft^3/s)	C	Diameter (in.)	Diameter (ft)	Area (sq ft)	Velocity (ft/s)	Minor Loss K	SG	Headloss (ft of water)	Total Head (ft of water)
Dredge - BP#3	5793	0	0.00	137	12.974	1.08	0.92	0.00	2.42	1.16	26.00	60.6
	5793	500	1.11	137	12.974	1.08	0.92	1.21	2.42	1.16	28.60	63.2
	5793	1000	2.23	137	12.974	1.08	0.92	2.43	2.42	1.16	35.40	70.0
	5793	1500	3.34	137	12.974	1.08	0.92	3.64	2.42	1.16	45.94	80.6
	5793	2000	4.46	137	12.974	1.08	0.92	4.85	2.42	1.16	59.99	94.6
	5793	2500	5.57	137	12.974	1.08	0.92	6.07	2.42	1.16	77.41	112.1
	5793	3000	6.68	137	12.974	1.08	0.92	7.28	2.42	1.16	98.08	132.7
	5793	3500	7.80	137	12.974	1.08	0.92	8.49	2.42	1.16	121.93	156.6
	5793	4000	8.91	137	12.974	1.08	0.92	9.71	2.42	1.16	148.89	183.5
	5793	4500	10.03	137	12.974	1.08	0.92	10.92	2.42	1.16	178.88	213.5
	5793	5000	11.14	137	12.974	1.08	0.92	12.14	2.42	1.16	211.87	246.5
	5793	5500	12.25	137	12.974	1.08	0.92	13.35	2.42	1.16	247.81	282.5
	5793	6000	13.37	137	12.974	1.08	0.92	14.56	2.42	1.16	286.65	321.3
	5793	6500	14.48	137	12.974	1.08	0.92	15.78	2.42	1.16	328.37	363.0
	5793	7000	15.60	137	12.974	1.08	0.92	16.99	2.42	1.16	372.92	407.6
	5793	7500	16.71	137	12.974	1.08	0.92	18.20	2.42	1.16	420.27	454.9

		Head from Dredge Pump	
WARMAN DSC - 40	GPM	700 RPM	600 RPM
	0	315	230
	1000	317	233
	2000	318	234
	3000	318	233
	4000	316	232
	5000	315	230
	6000	313	228
	7000	310	226
	8000	308	223


Dredge - BP#3 System Curve
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Head (ft)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Flow (gal/min)
Dredge - BP#3 System Curve_Rem_A
Pump Curve 700 RPM
Pump Curve 600 RPM

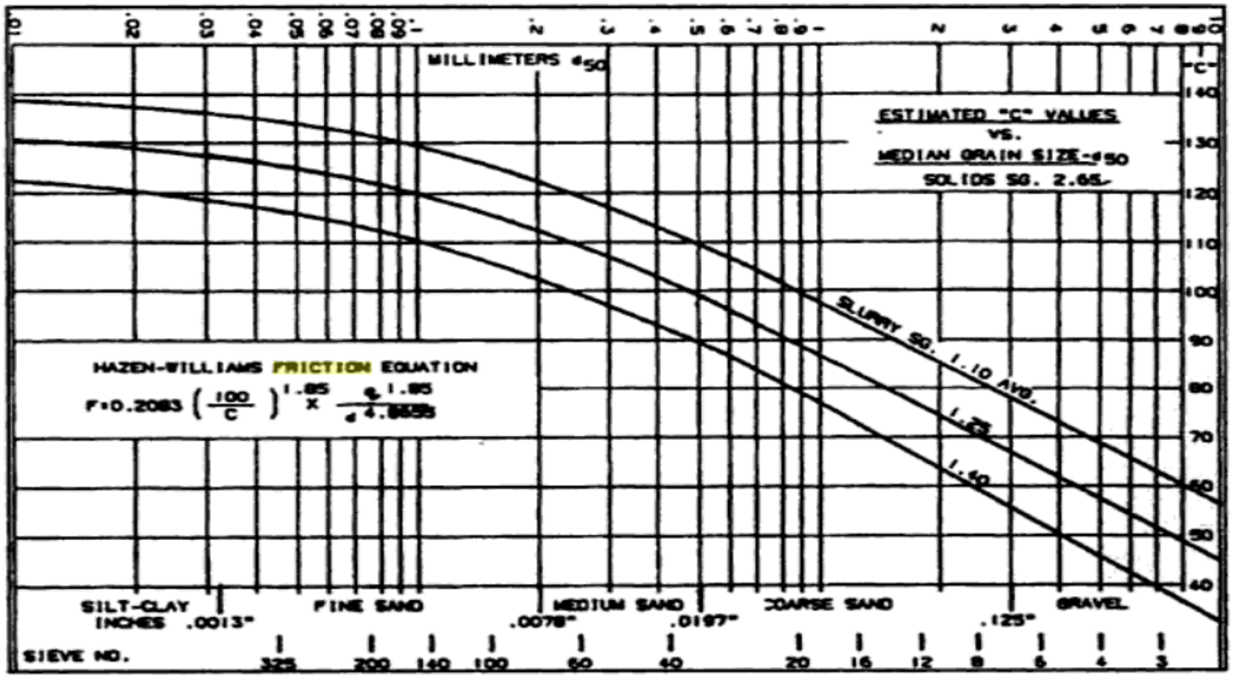


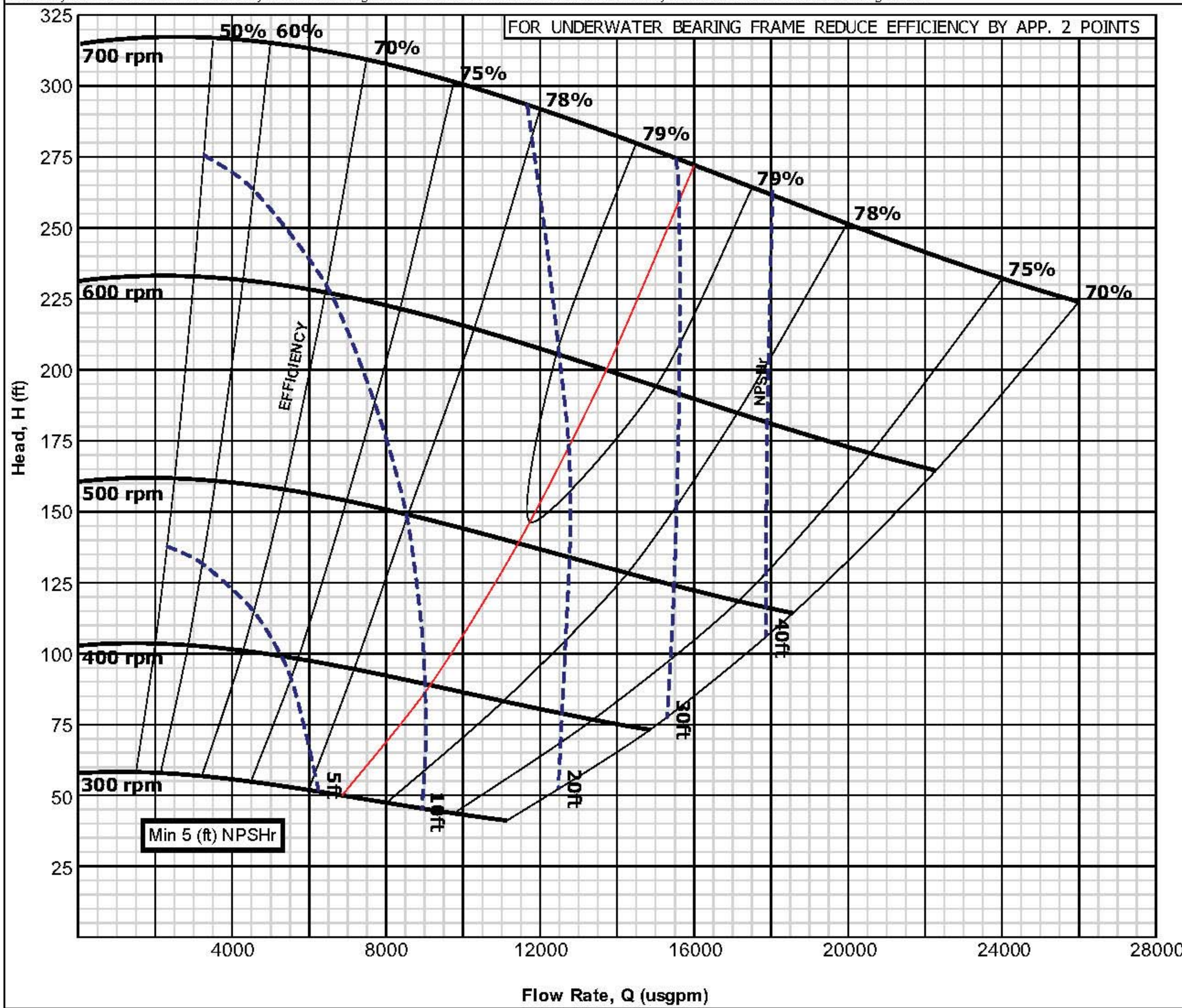
FIGURE 7.31 Constant *C* for Hazen-Williams equation. *Turner, 1984*)

Note- Friction factor corrected for pipe material. A clean water C value of 150 is assumed for HDPE pipe. Figure 7.31 assumes a clean water C value of 140 for steel pipe.

WARMAN®
Centrifugal Slurry Pumps

DSC - 40

CURVE SHOWS APPROXIMATE PERFORMANCE FOR CLEAR WATER (ANSI/HI 1.6-2000 Centifugal Pump Test Standard unless otherwise specified). For media other than water, corrections must be made for density, viscosity and/or other effects of solids. WEIR MINERALS reserves the right to change pump performance and/or delete impellers without notice. Frame suitability must be checked for each duty and drive arrangement. Not all frame alternatives are necessarily available from each manufacturing centre.



Dredging Supply Company, Inc.

Pump	
	Metal Casing
Impeller	
Vanes	4
Vane ø	40"
Type	Closed
Part No	**Material**
MD12145	Metal
MD12451	Metal
Frame (Coupled Rating - HP)	
MD8003H	536
MD10003	1307
Seal	
	Gland Sealed Pump
Liner (Norm Max r/min)	
Unlined	700
Min Passage Size	
	6.4" Max Sphere
Curve	
Revision	0
Reference	
Madison Test 080416	
Issued	May 08

TYPICAL PUMP PERFORMANCE CURVE

T-14127

SLURRY PIPELINE CRITICAL VELOCITY ANALYSIS

Critical Velocity Calculation Methodology

1) Various empirical formulas for critical velocity exist in the literatures. Several formulas were evaluated in the critical velocity analysis.

2) Critical velocity calculation was performed for slurry from Remediation Area E. Based on Parsons Sediment data Remediation Area E had the largest d50 and will have the greatest slurry solids concentration by weight as compared to all other remediation areas (see Appendix F for sediment data and Appendix E for production rates).

3) Critical velocity calculation was performed for the average slurry production rate of 18.5% solids by weight.

4) Critical velocity analysis was performed for a d50 of 0.11 mm obtained from Remediation Area E sediment data.

5) A second analysis was performed for the settling portion of the slurry. Sizes greater than 0.075 mm was assumed to constitute the settling portion of the slurry. Based on the sediment data and the PSD curve developed from the sediment data (see Figure 1) a d50 of 0.2 mm was used for the settling portion of the slurry for Remediation Area E.

6) Slurry concentration for the settling portion of the slurry was obtained by multiplying the solids concentration of the slurry during average production rate with the settling fraction (1-0.433=0.567) which was obtained from the sediment data.

7) Critical velocity for horizontal pipe was derived using three methods.

8) Method (1) Critical velocity for narrow graded slurry using Durand's formula (Eqn 7.18, Herbich, 2000; Eqn 4.2, Abulnaga, 2002) and Durand velocity factor versus particle size curve (Figure 4-7, Abulnaga, 2002 also shown in Figure 2 of this calculation.

9) Method (2) Critical velocity for broad graded slurry was obtained using Modified Durands and Schillers formula (Eqn 4.4 Abulnaga, 2002).

10) Method (3) Critical velocity for broad graded slurry was obtained using Wilsons Nomograph. (Figure 3, Wilson, 2006) also shown as Figure 3 in this calculation.

11) Critical velocity for inclined pipe was calculated using equation 7.81 (Herbich, 2000), Figure 8.1 (Wilson, 2006) also shown as Figure 4 of this calculation, and using critical velocity for narrow graded slurry obtained from Step 8.

12) A maximum inclination of 8% of the pipeline was used based on pipeline profile drawing 444853-200-130. Long distance pipe inclinations were considered for inclined critical velocity calculations. All short distance inclines e.g., under roads and rail crossings were assumed to have turbulent conditions within the pipeline to keep the solids in suspension.

PARSONS COMMERCIAL TECHNOLOGY GROUP SYRACUSE, NEW YORK	Title:	Slurry Pipeline Critical Velocity Analysis
	Project:	Honeywell Onondaga Lake Dredging Project
	Number:	444853

REV	ISSUE	BY	CHK'D	DATE
1	Final	AN	MA	6/8/2011
0	Draft Final	AN	MA	1/7/2011

Equations		
C_w - Conc. (by weight) (Eq. 7-76, Herbich, 2000)	$C_w = \frac{SG_s(SG_m - SG_f)}{SG_m(SG_s - SG_f)}$	**Eqn -1**
C_v- Conc. (by volume) (Eq. 7-77, Herbich, 2000)	$C_v = \frac{SG_m}{SG_s}(C_w)$	**Eqn 2**
Modified $F_{L,d50}$ Eq. 4.4 Albuga	$F_{L,d_{50}} = \left[\left(1.3 \times C_v^{\;0.125}\right) \times \left(1 - \exp^{(-6.9 \times d_{50})}\right)\right]$	**Eqn 4**
$V_{c,hor}$ - Critical Velocity (Eq. 7-79, Herbich, 2000) (Eq. 4.2, Albuga, 2004)	$V_{c,hor} = F_L\left[2g\left(\frac{SG_s - SG_f}{SG_f}\right)D\right]^{1/2}$	**Eqn 3**
$V_{c,inc}$ - Inclined Critical Velocity (Eq. 7-81,Herbich, 2000)	$V_{c,inc} = V_{c,hor} + \Delta_D\left(\sqrt{2g(SG_s - 1)D}\right)$	**Eqn 5**

Symbol	Description
F_L	Coefficient that is a function of slurry concentration by volume
D	Inside diameter of of pipe in feet
g	Acceleration due to gravity in ft/sec^2
Δ_D	Factor affecting angle of inclination on durand deposition parameter (Fig 7.29, Herbich 2000)
C_w	Slurry concentration by weight
C_v	Slurry concentration by volume
SG_s	Specific gravity of solids
SG_f	Specific gravity of the carrier fluid (i.e., water), assumed to be 1.0
SG_m	Specific gravity of slurry

Constants		
Parameter	**Rem E (Total)**	**Rem E_settling**
d_{50}	**0.11**	**0.2**
C_w	18.5%	10.5%
g	32.2	32.2
SG_s	2.58	2.58
SG_f	1.0	1.00

Parameter	Rem E (Total)	Rem E_settling	
d_{50}	**0.11**	**0.2**	
SG_m	1.13	1.07	Eqn 1
C_v	8.1%	4.3%	Eqn 2
$F_{L\_Narrow\ Graded}$ (d_{50} = 0.2-mm)	-	1.07	Fig 2
$F_{L\_Narrow\ Graded}$ (d_{50} = 0.11-mm)	0.96	-	Fig 2
$F_{L\_Broad\ Graded}$ (d_{50}= 0.2-mm)	-	0.66	Eqn 4
$F_{L\_Broad\ Graded}$(d_{50}= 0.11-mm)	0.50	-	Eqn 4
Δ_D	0.1	0.1	Fig 4

	Critical Velocity for Various Particle Diameters							
	HDPE Rating	**D_{nom} (in.)**	**ID (in.)**	**$V_{c,hor}$ (ft/sec) Durand *Narrow Graded Slurry***	**$V_{c,hor}$ (ft/sec) Durand *Broad Graded Slurry***	**$V_{c,hor}$ (ft/sec) Wilson**	**$V_{c,inc}$ (ft/sec)**	**$V_{Pipeline}$**
Rem Area E (0.11 mm)	DR 11	16	12.974	10.1	5.3	< 6.2	11.1	13.5
Rem Area E (0.2 mm)	DR 11	16	12.974	11.2	6.9	8.9	12.3	13.5

Figure 1 Dredge Area Particle Size Distribution

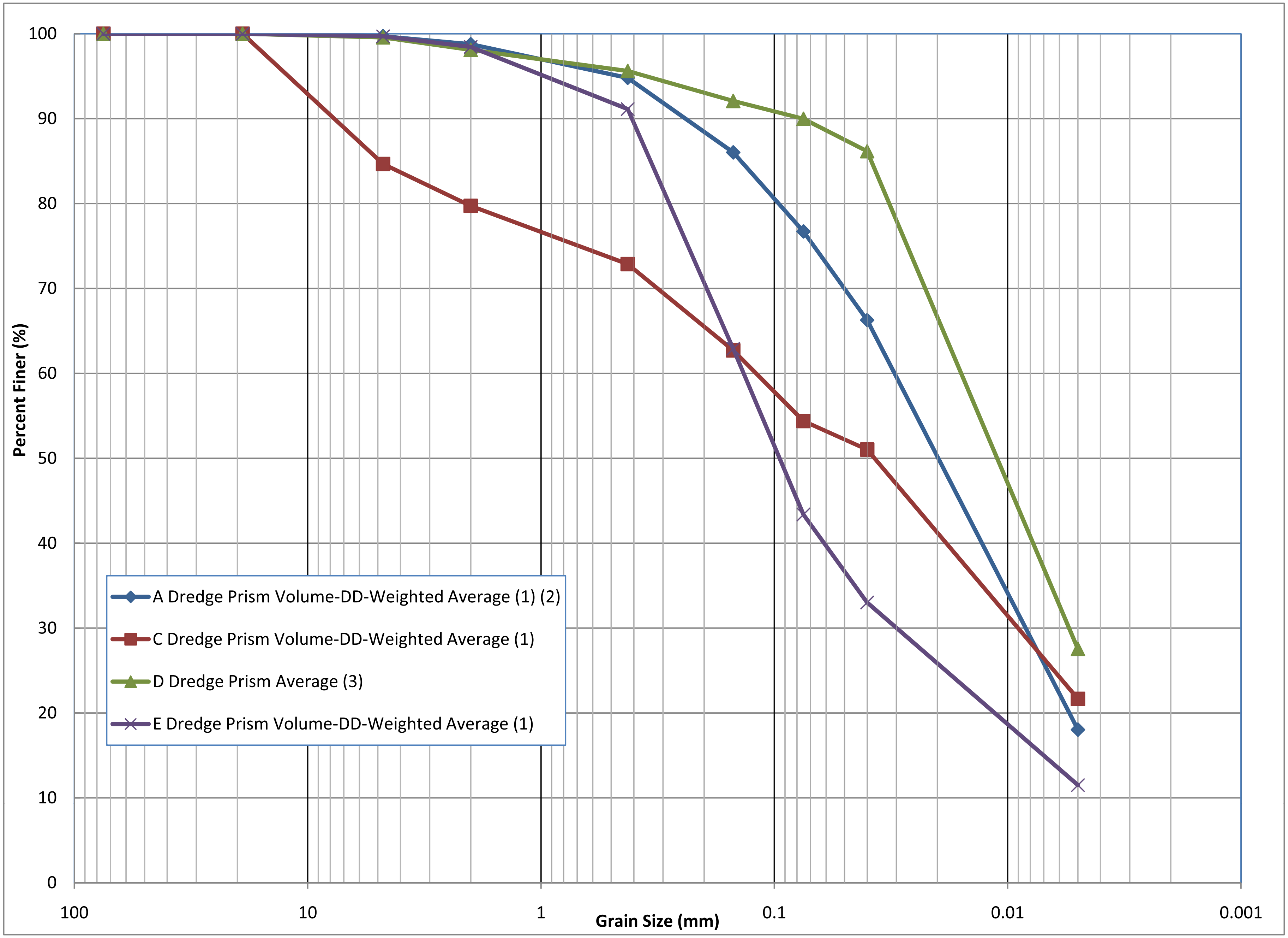


Figure 2 Durand Velocity Factor Versus Particle Size

Durand velocity factor versus particle size.
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Slurry Systems Handbook
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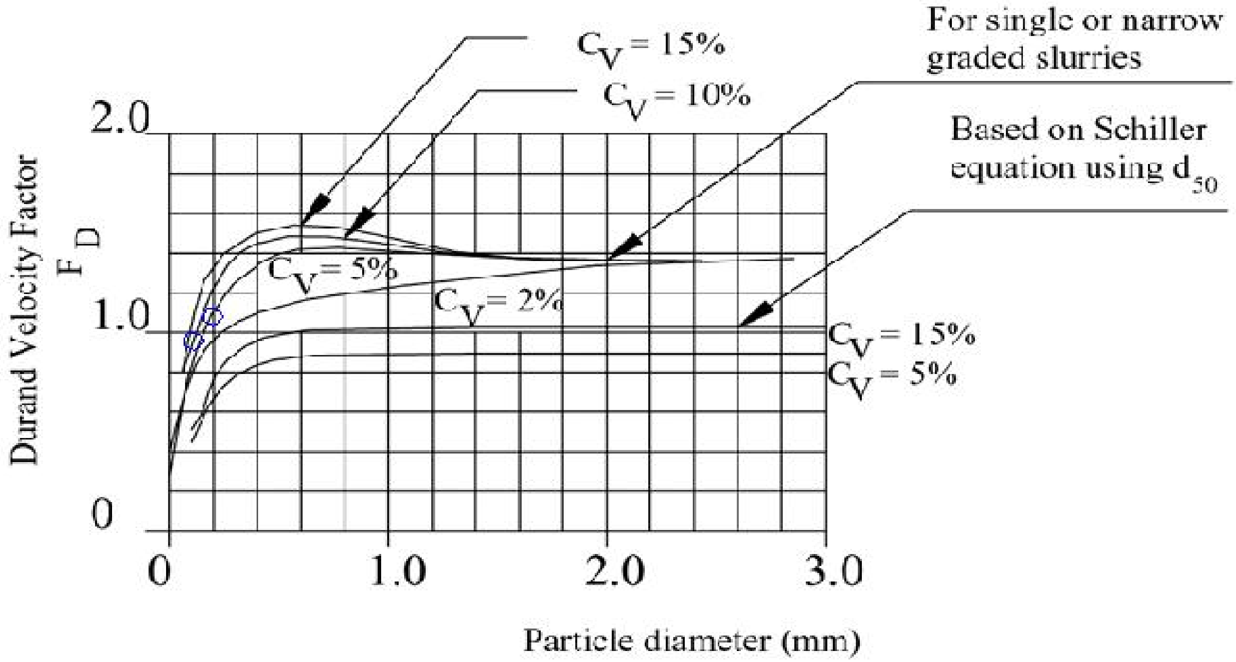

Figure 3. Nomograph for determining deposit velocity.

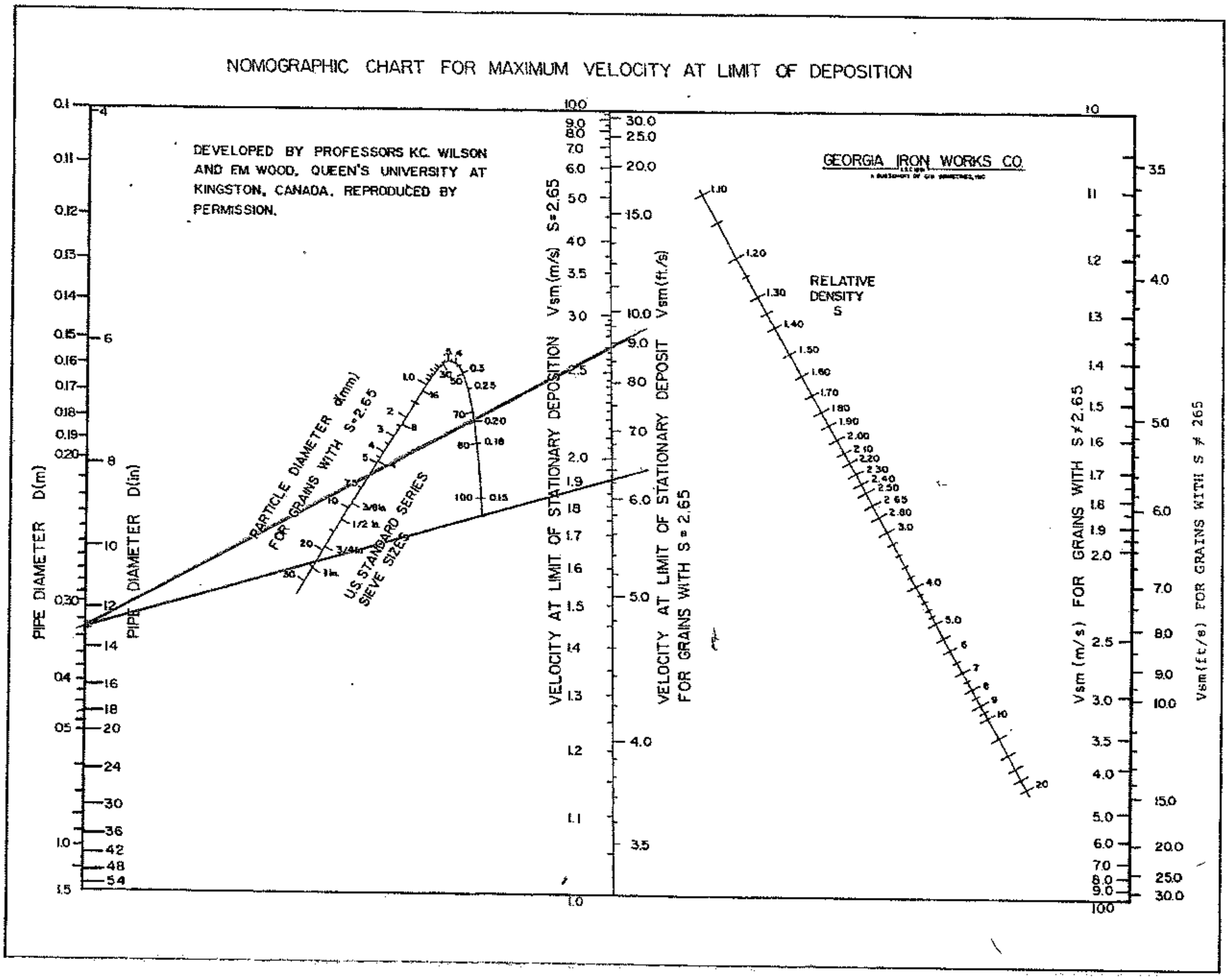

Figure 4 Effect of Angle of Inclination on Durand Deposition Parameter

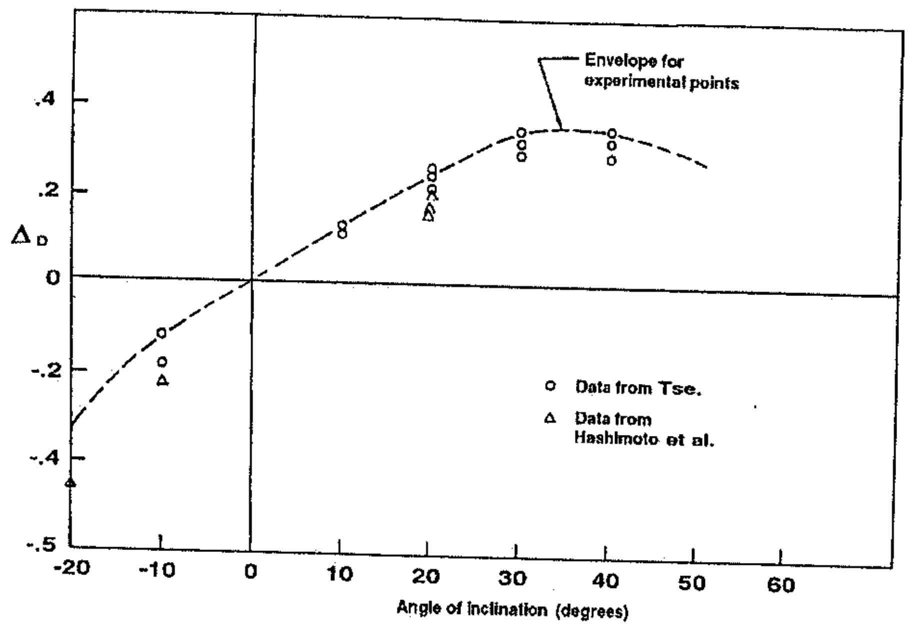

Figure 8.2. Effect of angle of inclination on Durand deposition parameter, after Wilson and Tse (1984)

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S = ratio of density of solids to density of liquid
C_{vb} = volume fraction solids in the bed

(When USCS units are used, express density in slugs/ft^3 rather than lbm/ft^3).

For 0.7 mm (mesh 24) sand with water in a 90 mm (3.5 in) pipe, Wilson measured λ = 0.35 and concluded that the assumptions of hydrostatic distribution of the granular pressure were correct.

4-3-2 The Transitional Velocity V_3 or Speed for Minimum Pressure Gradient

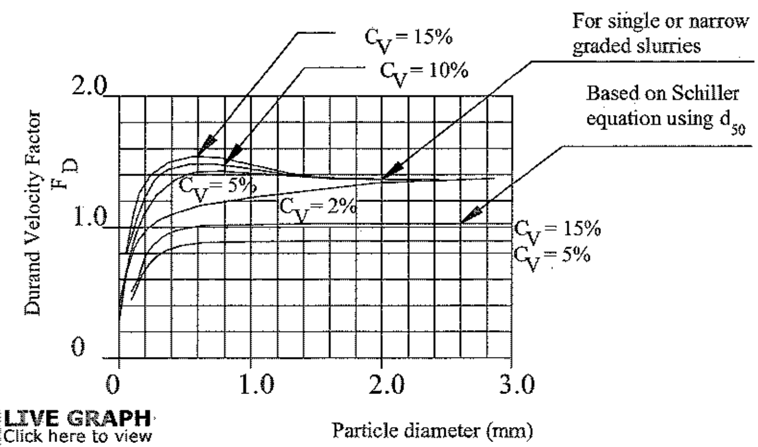
The transitional velocity V_3 is extremely important because it is the speed at which the pressure gradient is at a minimum. Although there is evidence that solids start to settle at slower speeds in complex mixtures, operators and engineers often referred to transitional velocity as the speed of deposition.

Durand and Condolios (1952) derived the following equation for uniformly sized sand and gravel:

$$V_D = V_3 = F_L\{2 \cdot g \cdot D_i[(\rho_s - \rho_L)/\rho_L]\}^{1/2} \tag{4-2}$$

where
F_L = is the Durand factor based on grain size and volume concentration
V_3 = the critical transition velocity between flow with a stationary bed and a heterogeneous flow
D_i = pipe inner diameter (in m)
g = acceleration due to gravity (9.81 m/s)
ρ_s = density of solids in a mixture (kg/m^3)
ρ_L = density of liquid carrier

The Durand factor F_L is typically represented in a graph for single or narrow graded particles, as in Figure 4-7 after the work of Durand (1953). However, since most slurries



LIVE GRAPH
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FIGURE 4-7 Durand velocity factor versus particle size—comparison between the conventional values for single graded slurries and Schiller's equation using d_{50} for wide graded slurry.

are mixtures of particles of different sizes, this plot is considered too conservative. The Durand velocity factor has been refined by a number of authors.

In an effort to represent more diluted concentrations, Wasp et al. (1970) proposed including a ratio between the particle diameter and the pipeline diameter. Wasp proposed the use of a modified factor F_L' so that

$$V_D = V_3 = F_L'\left[2gD_i\frac{\rho_S - \rho_L}{\rho_L}\right]^{1/2}\left[\frac{d_p}{D_i}\right]^{1/6} \tag{4-3}$$

Schiller and Herbich (1991) proposed the following equation for the Durand velocity factor based on the d_{50} of the particles:

$$F_L = \{(1.3 \times C_v^{0.125})[1 - \exp(-6.9\, d_{50})]\} \tag{4-4}$$

where d_{50} is expressed in mm.

Some reference books define a Froude number as $Fr = F_L \cdot \sqrt{2}$. The particle size d_{50} is the statistically determined particle size below which half (or 50%) would be equal or smaller to that set size. The following example illustrates the concept of d_{50}.

Example 4-1
A sample of slurry is sieved for particle size. The data is collected in the laboratory (see Table 4-1). Plot the data on a logarithmic graph and determine the d_{50}.

Solution
The data is plotted in Figure 4-6; the d_{50} is determined to be 145 μm.

Example 4-2
A slurry mixture has a d_{50} of 300 μm. The slurry is pumped in a 30 in pipe with an ID of 28.28″. The volumetric concentration is 0.27. Using Equations 4-4 and 4-2, determine the speed of deposition for a sand–water mixture if the specific gravity of sand is 2.65.

Solution in SI Units
From Equation 4-4:

$$F_L = (1.3 \times 0.27^{0.125})(1\text{-exp}(-6.9 \times 0.3))$$

$$F_L = 1.1 \times 0.8738$$

$$F_L = 0.964$$

From Equation 4-2 the deposition velocity is

$$V_3 = 0.964\,(2 \times 9.81 \times 28.25 \times 0.0254 \times 1.65)^{1/2}$$

$$V_3 = 4.64 \text{ m/s}$$

TABLE 4-1 Data for Example 4-1

Particle size (μm)	425	300	212	150	106	75	53	45	38	–38
Cumulative passing (%)	97.2	87.1	68.3	51.3	35.9	20.5	14.5	11.8	10.8	—

HANDBOOK OF DREDGING ENGINEERING

John B. Herbich, Ph.D., P.E.

W. H. Bauer Professor Emeritus
Ocean Engineering Program
Director Emeritus, Center for Dredging Studies
Department of Civil Engineering
Texas A&M University
College Station, Texas
and
Vice President
Consulting and Research Services, Inc.
Wailuku, Hawaii

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mixture, differs appreciably from head loss, in feet of water, for flow of water at the corre sponding flow conditions. At velocities greater than the critical velocity, homogeneou flows may be expected. Durand[13] also concluded that for homogeneous flow the hea losses for sand-water mixtures are similar to head losses for water, provided the head lo is expressed in feet of mixture.

Newitt, et al.[15] made the same conclusions as O'Brien and Folsom[12] and Durand[13] an suggested that

$$\frac{i_m - i}{C_v i} = \frac{\rho_s}{\rho_w} - 1 \qquad (7.1$$

where i_m = gradient of piezometric head line for mixture
i = gradient of piezometric head line for water
C_v = sediment concentration by volume
ρ_s = density of the sediment
ρ_w = density of water

However, as reported by Shen,[10] the numerical value of Eq. (7.17) is approximately which is greater than $(\rho_s/\rho_w) - 1$ for sand with a mean particle size of 0.02 mm. Similar the left-hand side of Eq. (7.17) is less than $(\rho_s/\rho_w) - 1$ for sand with mean particle size 0.096 mm for velocities greater than 5.5 ft/s.

Several investigators, including Homayounfar,[23] Zandi,[24] and Herbich and Vallentine have found that head losses for coal-water and silt-clay-water mixtures were lower th the head losses for water at the corresponding conditions. Shen suggests that the homog neous flow with sediments slightly larger than the fine sediments required for truly hom geneous flow may be assumed to have approximately the same head losses as t homogeneous flows.

Heterogeneous Regime and Saltation Flow

The heterogeneous flow regime is most important from an economic point of view. In t regime the sediment is nonuniformly distributed, as shown in Fig. 7.7*b*. Head losses will higher in flow with a moving bed, as depicted schematically in Fig. 7.7*c*.

Durand and Condolios[11] conducted extensive experimental studies on the transportati of solids in the heterogeneous regime and the equations presented are valid only for fl with no net deposition of solids at the bottom of the pipe. They defined the limiting depo velocity as

$$V_c = F_L \left[2gd \left(\frac{\rho_s}{\rho_w} - 1 \right) \right]^{1/2} \qquad (7.1$$

where F_L = constant = $f(C, d_g)$.

F_L is given in Fig. 7.8*a* for the range of concentration of solids by volume (C_v) as a fu tion of grain diameter. It will be noted that for particles having a grain size greater than 2 m the concentration has no effect, and F_L is approximately equal to 1.34.

Limiting deposit velocities for sand (S.G. = 2.62) and coal (S.G. = 1.5) are shown Table 7.5.

Durand and Condolios[11] presented an equation for flow based on test results as follo

$$\frac{i_m - i}{C_v i} = 81 \left[\frac{gd\,(\rho_s/\rho_w - 1)}{V^2} \left(\frac{1}{\sqrt{C_D}} \right) \right]^{1.5} \qquad (7.$$

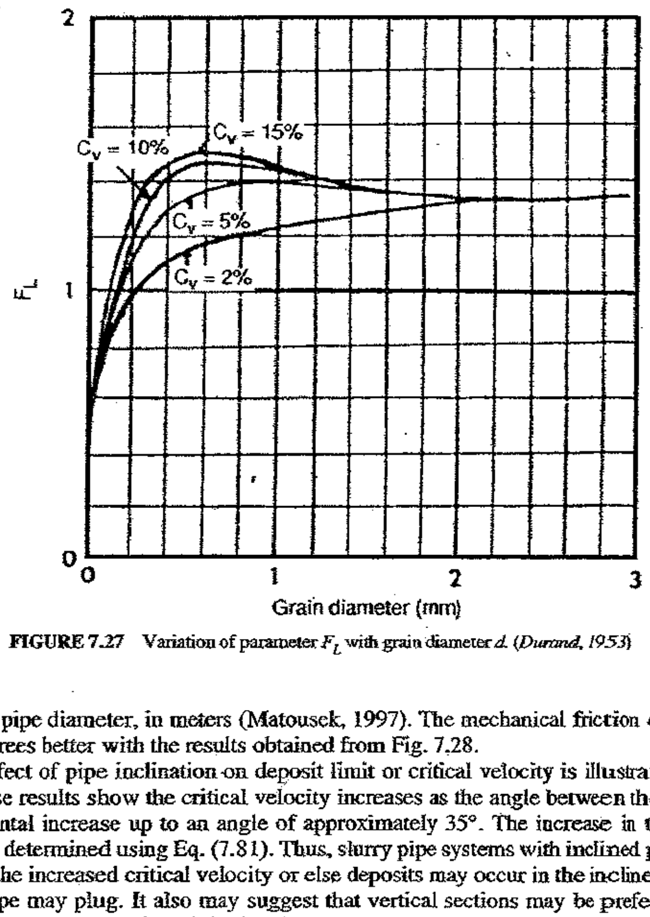

FIGURE 7.27 Variation of parameter F_L with grain diameter *d*. *(Durand, 1953)*

the inside pipe diameter, in meters (Matousek, 1997). The mechanical friction coefficient of 0.44 agrees better with the results obtained from Fig. 7.28.

The effect of pipe inclination on deposit limit or critical velocity is illustrated in Fig. 7.29. These results show the critical velocity increases as the angle between the pipe and the horizontal increase up to an angle of approximately 35°. The increase in the critical velocity is determined using Eq. (7.81). Thus, slurry pipe systems with inclined pipes must allow for the increased critical velocity or else deposits may occur in the inclined sections and the pipe may plug. It also may suggest that vertical sections may be preferable over short inclines to prevent deposit in the pipe. Thus

$$V_c\,(\text{inclined}) = V_c\,(\text{horizontal}) + \Delta_D\left[\sqrt{2g\,(S_s - 1)\,D}\right] \tag{7.81}$$

Heterogeneous to Homogeneous Flow

Wilson, et al. (1992) proposed that the ratio d/D could be used as an indicator of transition from heterogeneous to homogeneous flow. When $d/D > 0.018$, the flow is fully stratified (homogeneous), and when $d/D < 0.015$, the flow is partially stratified (heterogeneous). Both types of slurry flow can occur for the region $0.015 < d/D > 0.018$. The transition velocity (V_{th}) between homogeneous and heterogeneous regimes is also approximated by

$$V_{th} = (1800\,gdv_t)^{1/3} \tag{7.82}$$

where g is the acceleration of gravity, d is the median grain diameter, and v_t is the terminal velocity.

Hazen and Williams Equation

Another equation that is often used in the dredging industry is the Hazen-Williams equation:

$$H = 0.2083\left(\frac{100}{C}\right)^{1.85}\left(\frac{Q^{1.85}}{D^{4.8655}}\right) \tag{7.85}$$

where H is friction head, in feet of freshwater per 100 feet of pipe; D is inside diameter of the pipe, in inches; Q is flow, in gallons per minute; and C is a constant describing pipe roughness determined from Fig. 7.31.

Durand

For saltation flow [$d_{50} > 0.001$ in (0.025 mm)], the head loss per unit length of pipe [feet of water/feet of pipe (meters of water/meters of pipe)] may be expressed as

$$i_m = 66\,C_v i\left(\frac{\rho_s}{\rho_w} - 1\right)\frac{gD}{V^2} + i \tag{7.86}$$

where i_m is the head loss due to mixture per unit pipe length [feet of water/feet of pipe (meters of water/meters of pipe)], i is the head loss due to water per unit length of pipe [feet of water/feet of pipe (meters of water/meters of pipe)], C_v is the sediment concentration by volume, D is the internal pipe diameter, V is the average slurry velocity, ρ_s and ρ_w are the density of slurry and water, respectively; and g is the gravitational acceleration.

The Durand and Condolios (1952) equation for estimating the head loss in a pipe with heterogeneous flow is

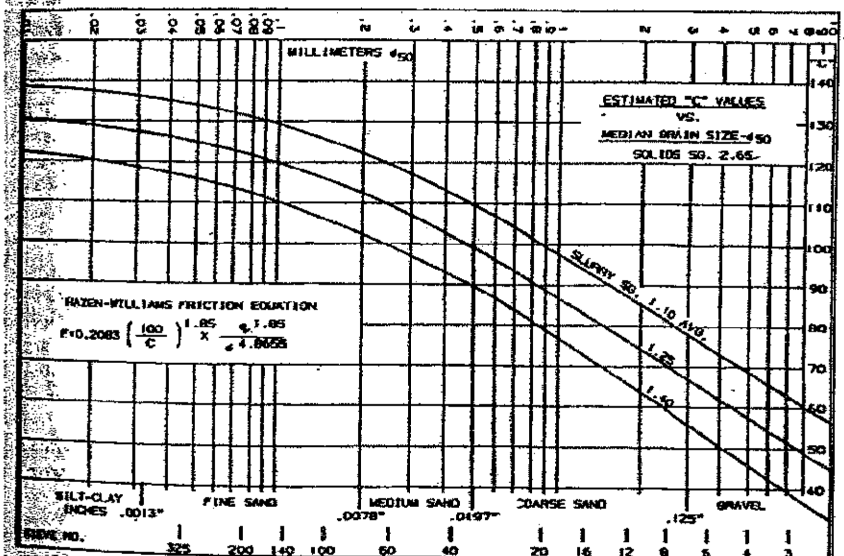

FIGURE 7.31 Constant C for Hazen-Williams equation. *Turner, 1984*)

K.C. Wilson, G. R. Addie,
A. Sellgren and R. Clift

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