ESTIMATING PRODUCTION AND BOOSTER PUMP LOCATION FOR LONG DISTANCE PUMPING

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Overview

- Procedure for estimating production
- Spreadsheet logic
- Booster pump evaluation
- Production charts
- Locating booster pumps
- Conclusions

Estimating Production

$$P = AQC_{v\,ave} \quad \text{or} \quad P = AQC_{v\,max}\,DE$$

- P – production
- A – units conversion factor
- Q – average volumetric flow rate
- $C_{v\,ave}$ – average concentration by volume
- $C_{v\,max}$ – maximum concentration by volume
- DE – dredging efficiency (fixed spuds or spud carriage)

Concentration by Volume

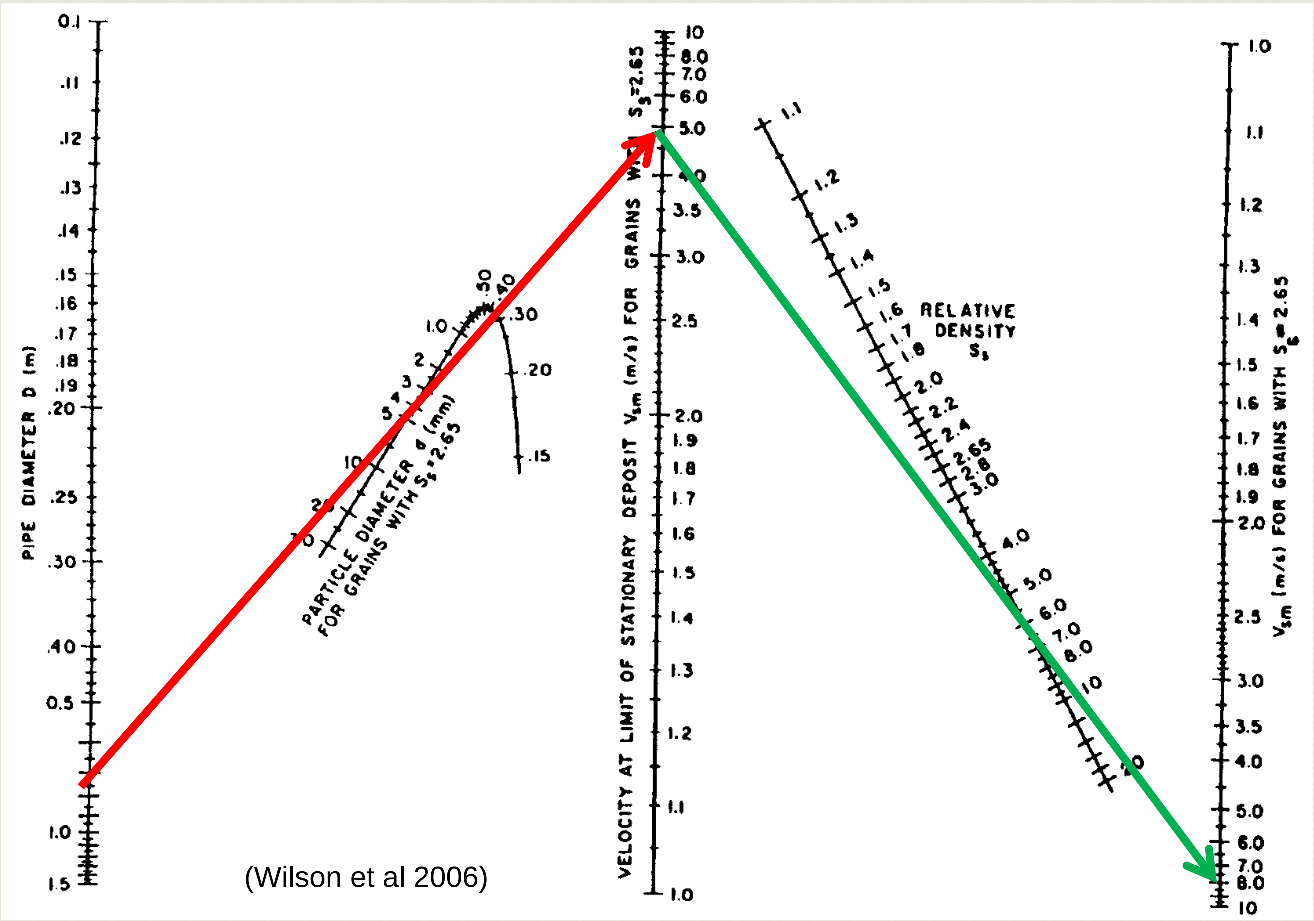
$$C_V = \frac{SG_m - SG_f}{SG_s - SG_f}$$

- SG_m – specific gravity of mixture
- SG_f – specific gravity of fluid
- SG_s – specific gravity of solids or insitu solids

Critical Velocity

$$V_c = \frac{8.8\left[\frac{\mu_s\left(S_s - S_f\right)}{0.66}\right]^{0.55} D^{0.7} d_{50}^{1.75}}{d_{50}^{2} + 0.11 D^{0.7}}$$

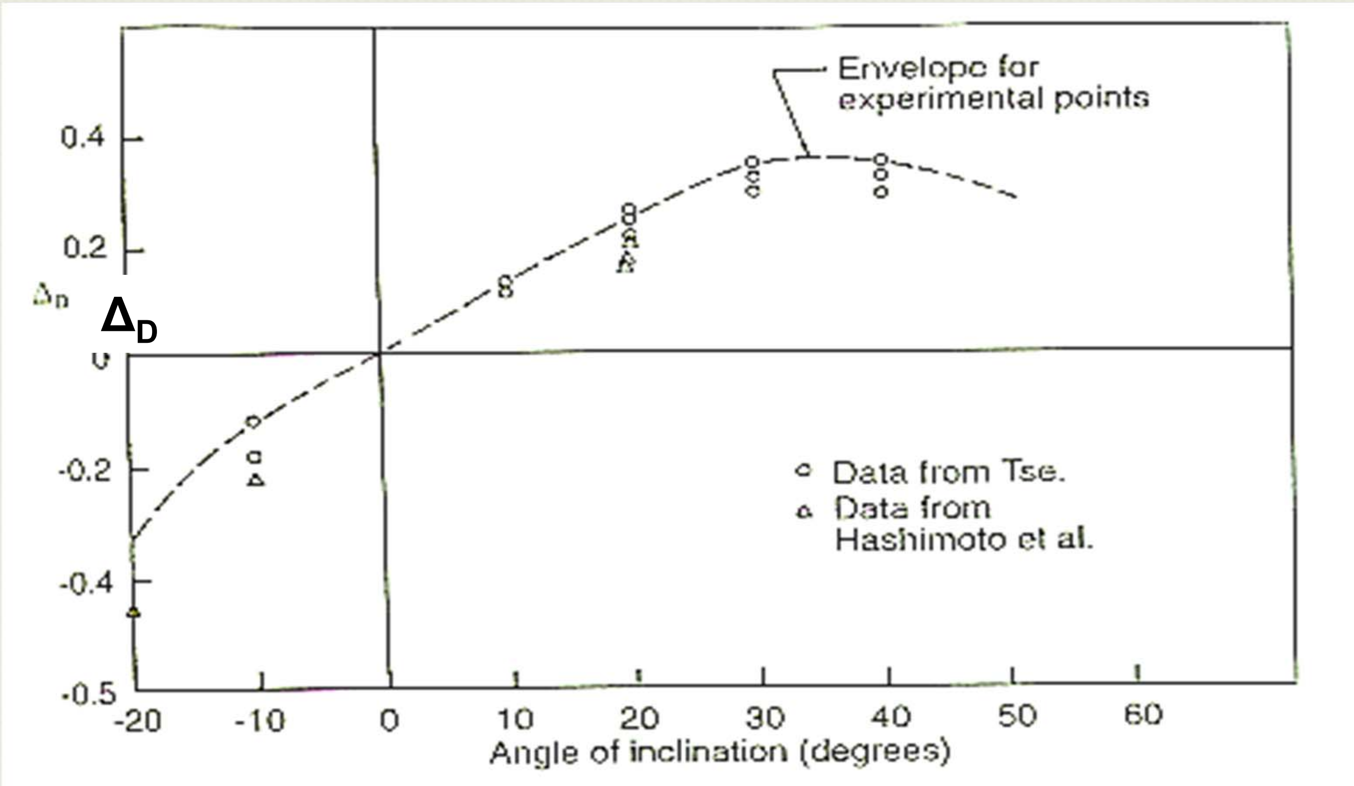
(Matousek 1997)



(Wilson et al 2006)

Effect of Slurry Pipe Inclination on the Critical Velocity (Wilson et al 2006)

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



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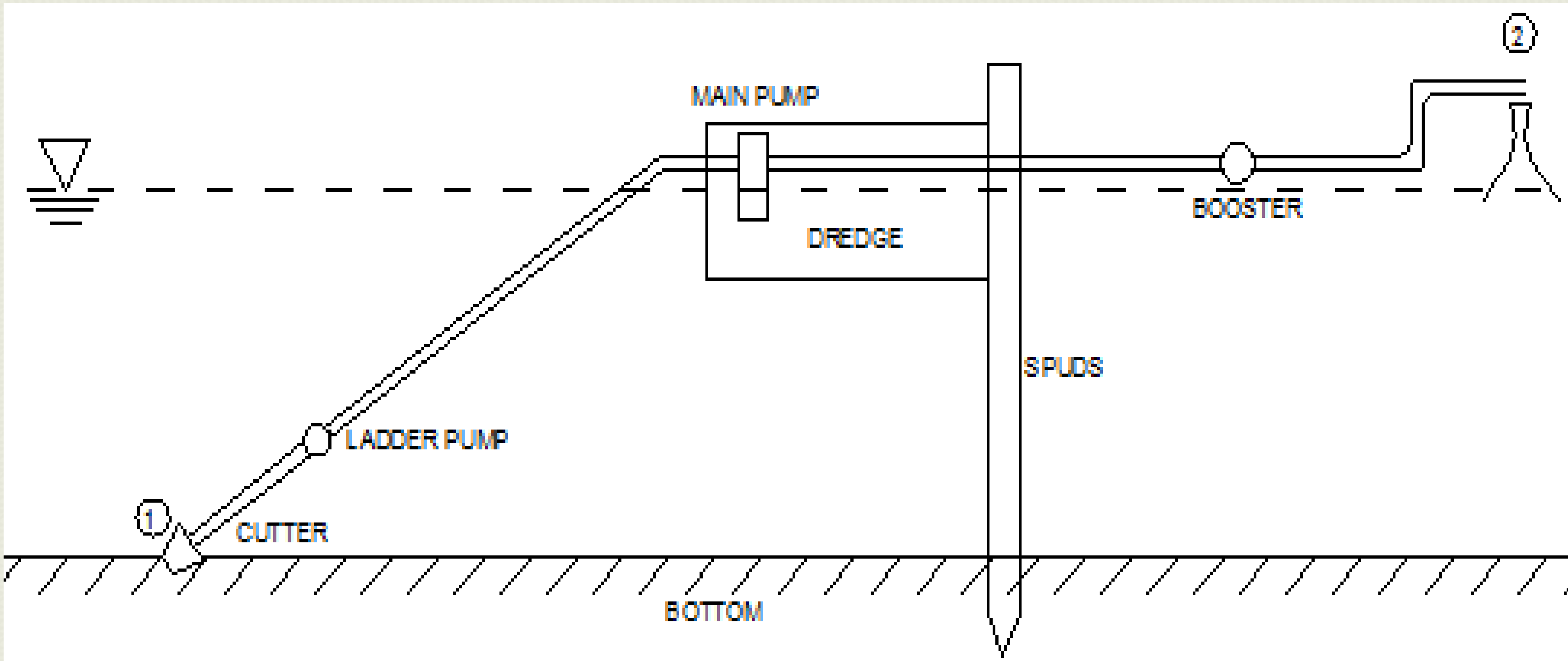
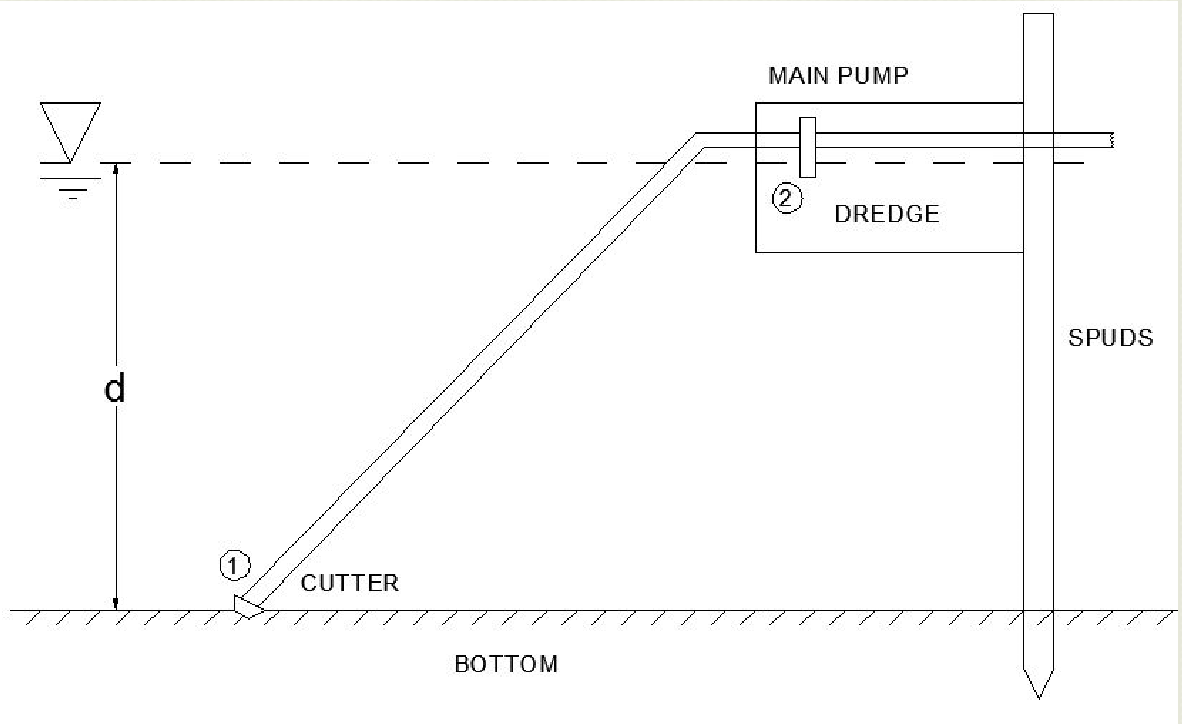
Evaluating System Head



$$\frac{p_1}{\gamma_m} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma_m} + \frac{V_2^2}{2g} + z_2 + h_L$$

Evaluating Available Net Positive Suction Head (NPSH)



$$\text{Available NPSH} = \frac{p_a}{\gamma_m} - \frac{p_v}{\gamma_m} + \frac{d}{SG_m} - z_2 - h_L$$

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Unit (US Unit = 1, SI Unit = 2)	1				PUMP RPM		390	
INPUT	(US UNITS)		(SI UNITS)		PUMP CURVE (US and SI UNIT)			
DREDGE/PUMP VALUES	UNIT	VALUE	UNIT	VALUE	Q [gpm]	Q [m3/s]	H [ft]	H [m]
Dredging Depth	ft	5.00E+01	m	1.52E+01	30000	1.89E+00	420	1.28E+02
Dike Height	ft	1.00E+01	m	3.05E+00	40000	2.52E+00	398	1.21E+02
Vapor Pressure	lb/in^2	2.56E-01	N/m^2	1.77E+03	50000	3.15E+00	380	1.16E+02
Pressure (abs)	lb/in^2	1.47E+01	N/m^2	1.01E+05	60000	3.79E+00	365	1.11E+02
Pump Location below waterline	ft	3.00E+00	m	9.14E-01	70000	4.42E+00	352	1.07E+02
Minimum Flowrate	GPM	2.00E+04	m^3/s	1.26E+00	80000	5.05E+00	339	1.03E+02
Maximum Flowrate	GPM	8.00E+04	m^3/s	5.05E+00				
Density of Water (ρ_w)	$slug/ft^3$	1.94E+00	kg/m^3	1.00E+03	NPSH REQUIRED (US and SI UNIT)			
Gravity Acceleration (g)	ft/s^2	3.22E+01	m/s^2	9.81E+00	Q [gpm]	Q [m3/s]	H [ft]	H [m]
SOLID	UNIT	VALUE	UNIT	VALUE	30000	1.89E+00	11	3.35E+00
Shape Factor Hartman (ψ)	-	7.80E-01	-	7.80E-01	40000	2.52E+00	13	3.96E+00
Shape Factor Wilson (K)	-	2.60E-01	-	2.60E-01	50000	3.15E+00	16	4.88E+00
Diameter (d_{85})	inch	0.00E+00	mm	0.00E+00	60000	3.79E+00	20	6.10E+00
Diameter (d_{50})	inch	9.84E-03	mm	2.50E-01	70000	4.42E+00	25	7.62E+00
	ft	8.20E-04	m	2.50E-04	80000	5.05E+00	30	9.14E+00

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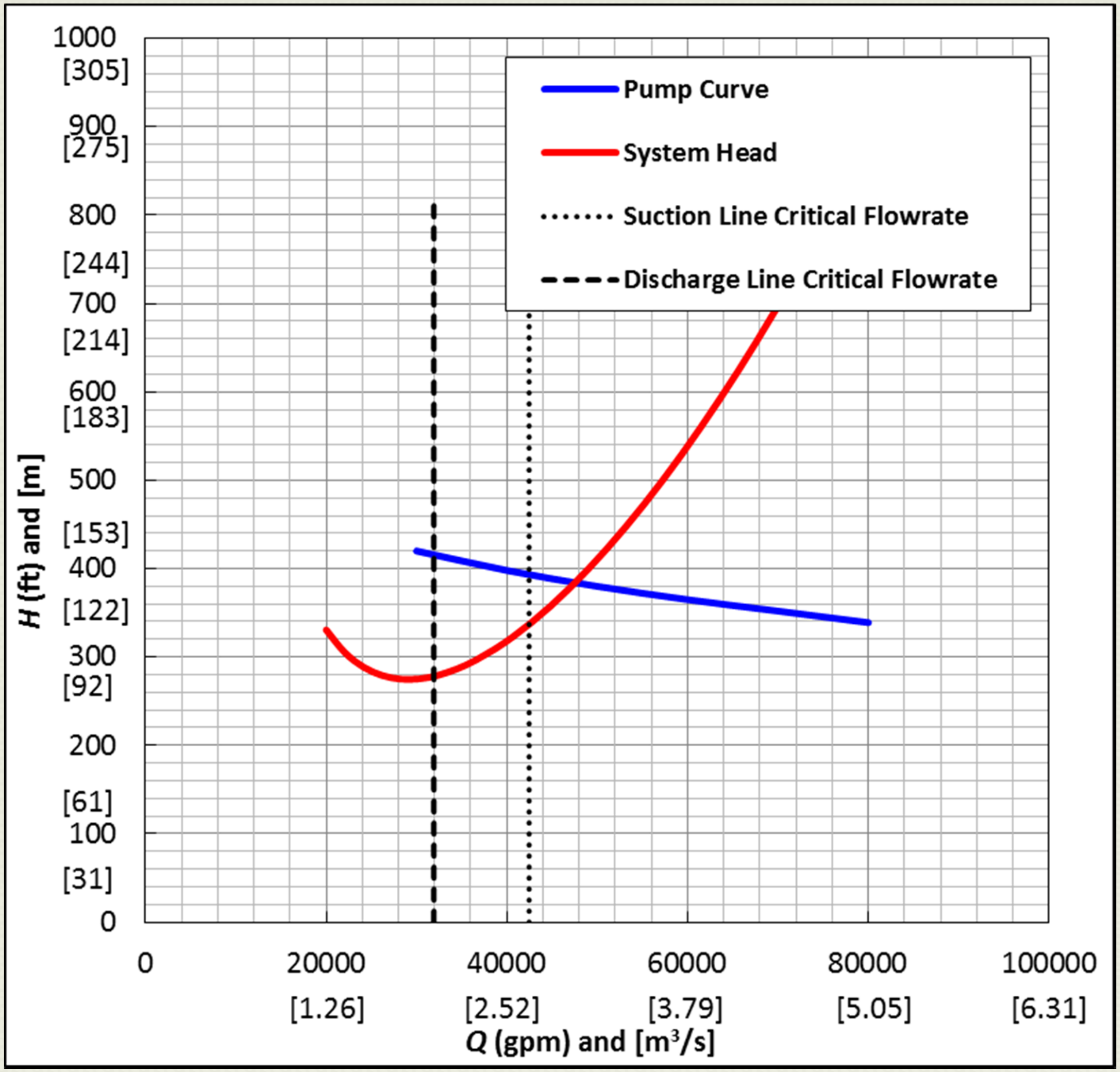
Specific Gravity (SG_s)	-	2.65E+00	-	2.65E+00
Density (ρ_s)	$slug/ft^3$	5.14E+00	kg/m^3	2.65E+03
Coeff Mechanical Friction (μ_s)	-	4.40E-01	-	4.40E-01
FLUID (Sea water)	UNIT	VALUE	UNIT	VALUE
Specific Gravity (SG_f)	-	1.00E+00	-	1.00E+00
Density (ρ_f)	$slug/ft^3$	1.94E+00	kg/m^3	1.00E+03
Dynamic Viscosity (μ_f)	$lb\text{-}s/ft^2$	2.34E-05	$N\text{-}s/m^2$	1.12E-03
Kinematic Viscosity (ν_f)	ft^2/S	1.21E-05	m^2/S	1.12E-06
MIXTURE	UNIT	VALUE	UNIT	VALUE
Specific Gravity (SG_m)	-	1.50E+00	-	1.50E+00
SUCTION PIPELINE	UNIT	VALUE	UNIT	VALUE
Length (L)	ft	9.00E+01	m	2.74E+01
Diameter (D)	inch	3.40E+01	mm	8.64E+02
	ft	2.83E+00	m	8.64E-01
AREA (A)	ft^2	6.31E+00	m^2	5.86E-01
e	ft	1.50E-04	mm	4.57E-08
e/D	-	5.29E-05	-	5.29E-05
Inclination	deg.	0.00E+00	deg.	0.00E+00
Minor Loss Coeff (K)	-	1.50E+00	-	1.50E+00
DISCHARGE PIPELINE	UNIT	VALUE	UNIT	VALUE
Length (L)	ft	2.00E+04	m	6.10E+03
Diameter (D)	inch	3.00E+01	mm	7.62E-04
	ft	2.50E+00	m	7.62E-01
AREA (A)	ft^2	4.91E+00	m^2	4.56E-01
e	ft	1.50E-04	mm	4.57E-08
e/D	-	6.00E-05	-	6.00E-05
Inclination	deg.	0.00E+00	deg.	0.00E+00
Minor Loss Coeff (K)	-	7.00E+00	-	7.00E+00

Pump and System Head Intersections



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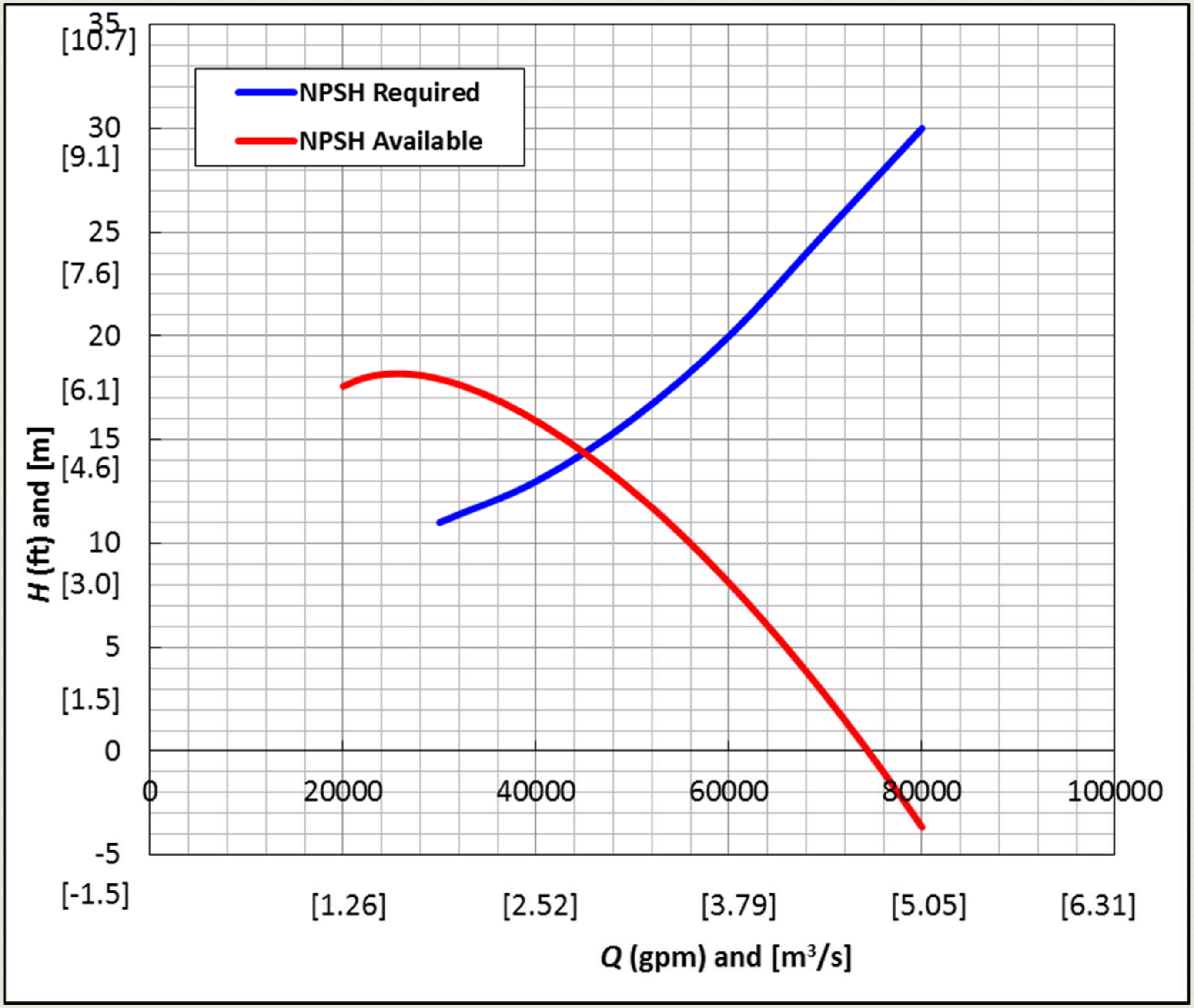
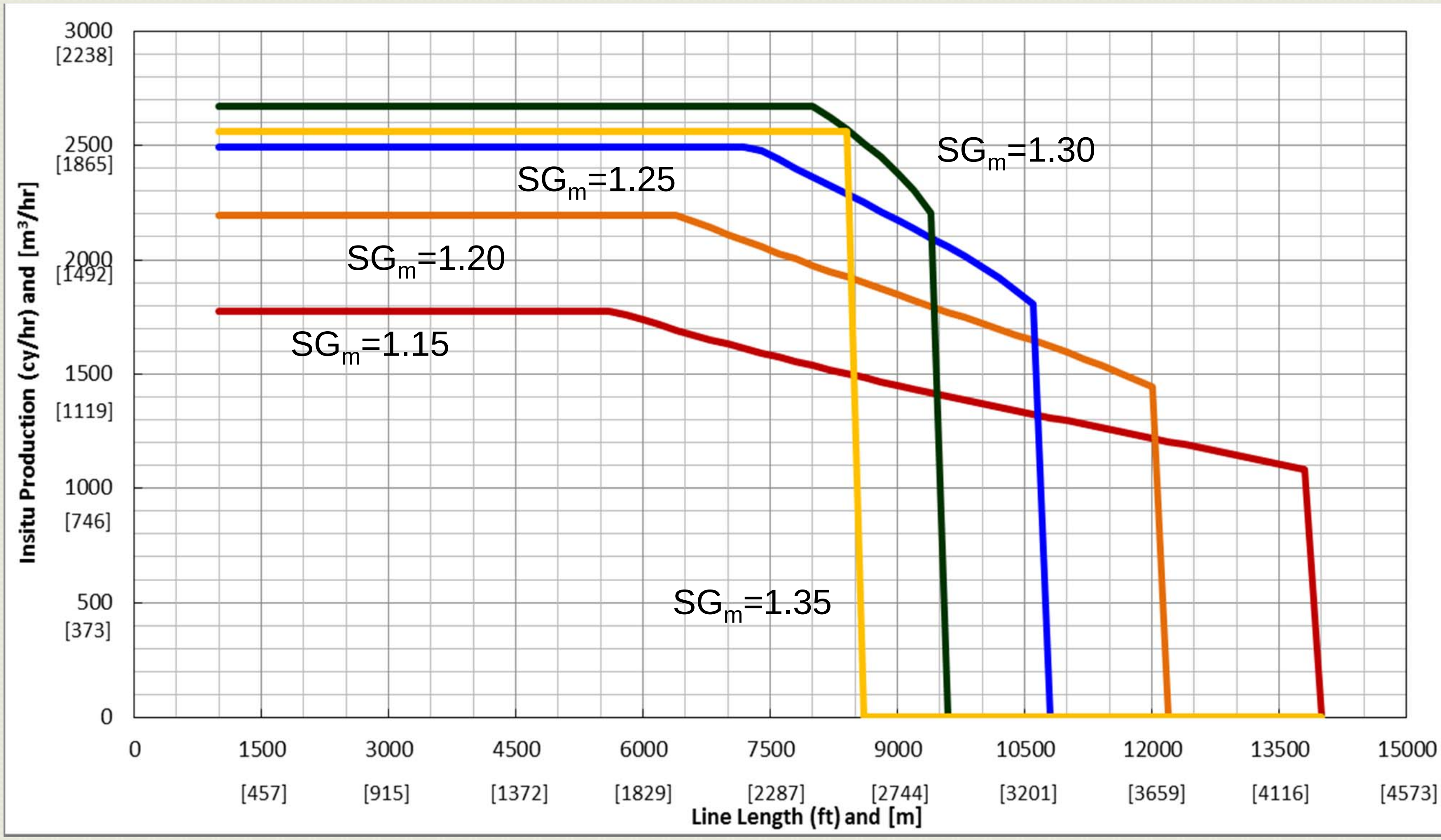
NPSH$_R$ & NPSH$_A$ Intersections



Production Chart

[34 in (0.86 m) suction, 30 in (0.76 m) discharge, depth =50 ft (15.2 m), DE=0.75, SGs=2.0, d50=0.25mm]



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Pipeline/Slurry Parameters

Configuration 1		Configuration 2		Configuration 3	
Suction Diameter m [in]	0.86 (34)	Suction Diameter m [in]	0.86 (34)	Suction Diameter m [in]	0.86 (34)
Discharge Diameter m [in]	0.76 (30)	Discharge Diameter m [in]	0.76 (30)	Discharge Diameter m [in]	0.76 (30)
Dredging Depth m [ft]	15.2 (50)	Dredging Depth m [ft]	15.2 (50)	Dredging Depth m [ft]	15.2 (50)
Dredge Efficiency	0.75	Dredge Efficiency	0.75	Dredge Efficiency	0.75
SG Slurry	1.15	SG Slurry	1.20	SG Slurry	1.25
SG Insitu Solids	2.00	SG Insitu Solids	2.00	SG Insitu Solids	2.00
Grain Size, d50 [mm]	0.25	Grain Size, d50 [mm]	0.25	Grain Size, d50 [mm]	0.25

Configuration 4		Configuration 5	
Suction Diameter m [in]	0.86 (34)	Suction Diameter m [in]	0.86 (34)
Discharge Diameter m [in]	0.76 (30)	Discharge Diameter [in]	0.76 (30)
Dredging Depth m [ft]	15.2 (50)	Dredging Depth m [ft]	15.2 (50)
Dredge Efficiency	0.75	Dredge Efficiency	0.75
SG Slurry	1.30	SG Slurry	1.35
SG Insitu Solids	2.00	SG Insitu Solids	2.00
Grain Size, d50 [mm]	0.25	Grain Size, d50 [mm]	0.25

Spreadsheet Buttons for Ladder and Booster Pumps

HEAD LOSS

MAIN PUMP OPERATION FLOWRATE (gpm)	
Flowrate (gpm)	44801

LADDER PUMP

LADDER PUMP	
Head (ft)	100

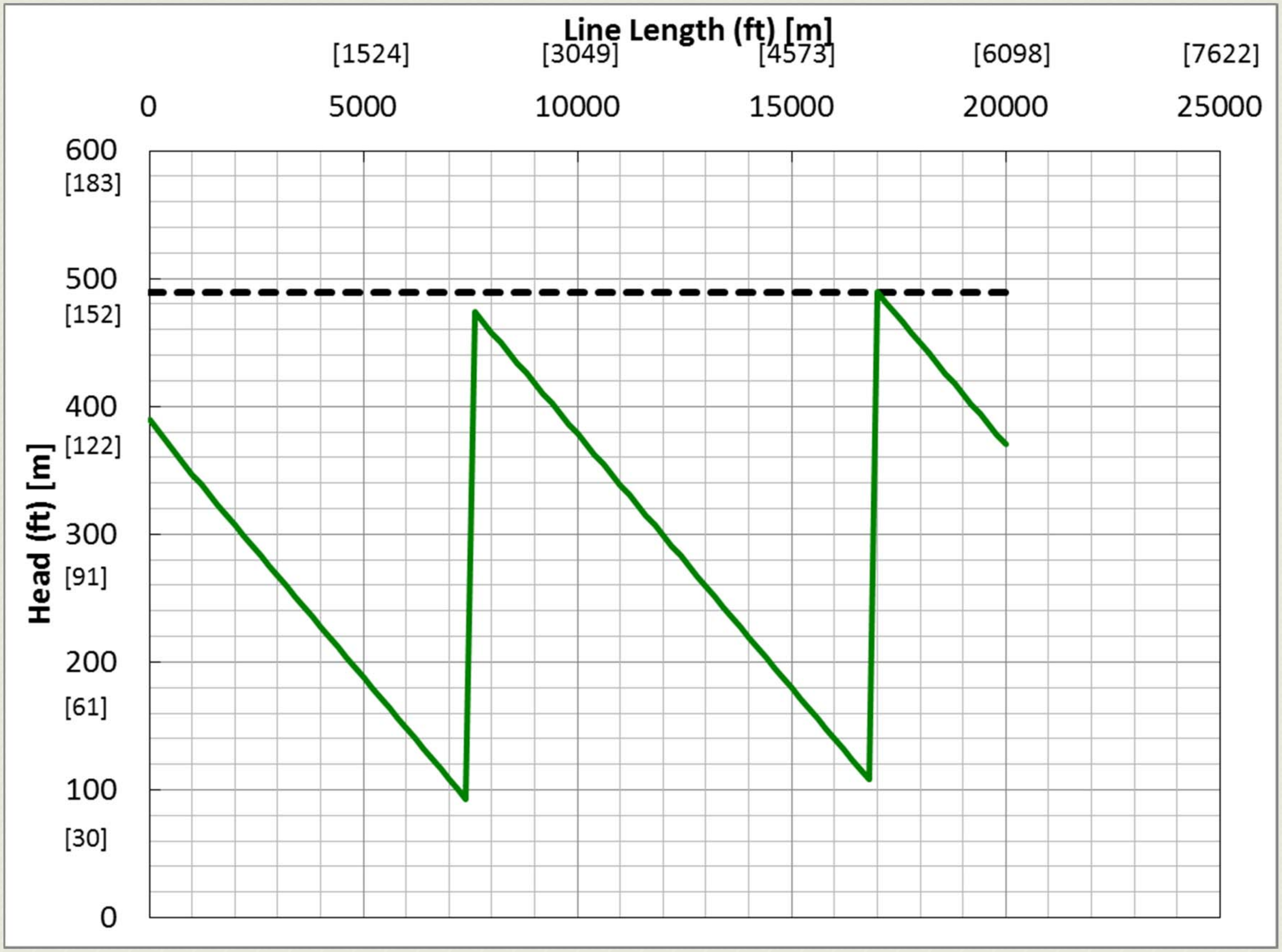
BOOST PUMP I

BOOST PUMP I			
Position (ft)	7500	Head (ft)	389

BOOST PUMP II

BOOST PUMP II			
Position (ft)	17000	Head (ft)	389

Booster Pump Locations



Summary and Conclusions

- Production is evaluated as a function of pump flowrate, concentration by volume, and dredging efficiency.
- Head loss is determined using the Wilson et al (1997) approach.
- Intersection of the system and the pump head curve are determined using macros in the Excel spreadsheet to determine the operating point at a given pipeline length.
- System and pump head curves must exceed the critical velocity in the discharge line.
- Location of required booster pumps is determined by when the losses in the pipeline reach approximately 30.5 m (100 ft) of water and this value can be changed by the user.
- Excel spreadsheet software is a useful tool for estimating production as a function of pipeline length and assisting in the location of booster pumps.

Reference for Manuscript

- Randall, R. E., Yeh, P. “Estimating Dredge Production and Booster Pump Location,” *Proceedings of the World Dredging Congress XIX*, Paper, Brussels, Belgium, June 3-6, 2013.

Thank you

Courtesy of Great Lakes Dredge and Dock