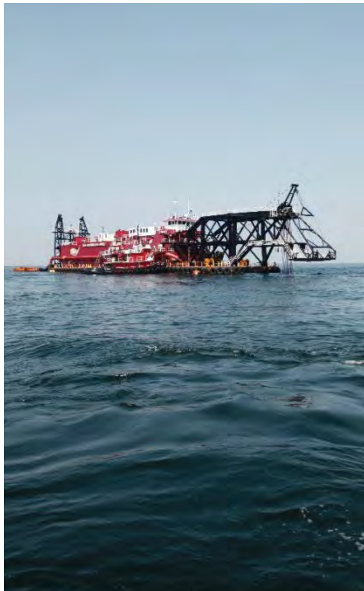


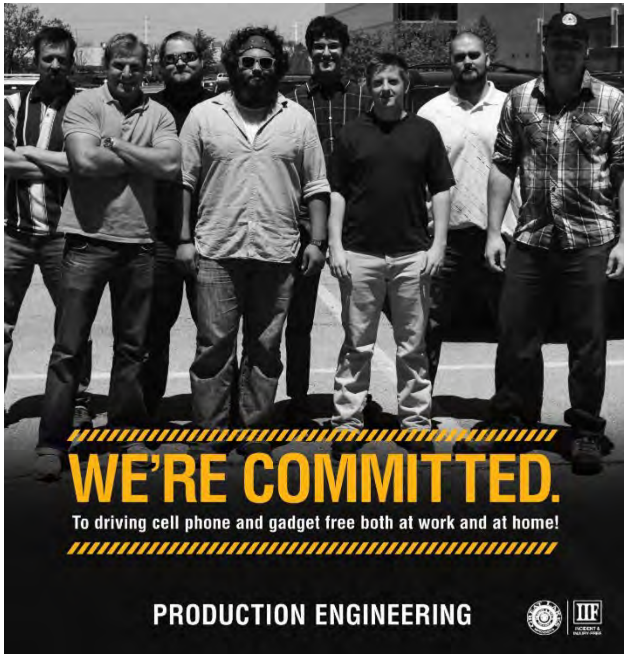
Great Lakes Dredge & Dock Company

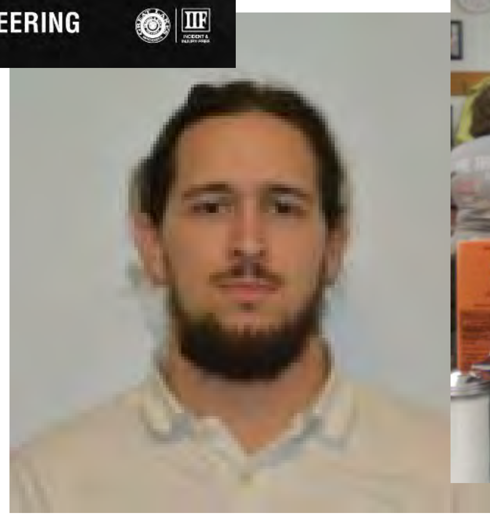
Principles of Production Engineering Models


Robert Ramsdell
Manager of Production Engineering

WEDA Summit & Expo 2019

SAFETY MOMENT





Problem Definition

- Production Engineers must quickly evaluate many scenarios to provide estimated productions and operational guidance
- Scientific theories are often unwieldy and require inputs of little interest to the Engineers.
- Production Engineers need models that bridge the gap:
  - Tractable
  - Discernable
  - Informative

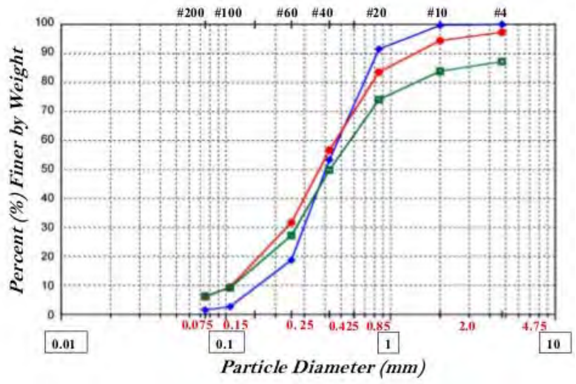
Tractable

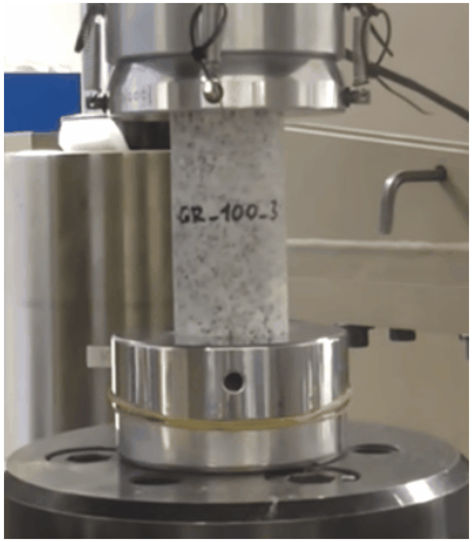
听话的

- the model must be quick to setup and run
- Tools can quickly load standard inputs
- Tools allow for easily changing project-specific inputs and automatically run multiple scenarios that vary in one dimension.

Discernible

能看出的





- uses inputs likely to be known to the engineer
- Parameters describing the soil should be those typically provided for a dredging project
- Tools will provide reasonable default values for parameters not typically tested or provided (e.g. particle shape)
- The tool should also put limits on inputs based on the reasonable expected values and the underlying physics of the system being model

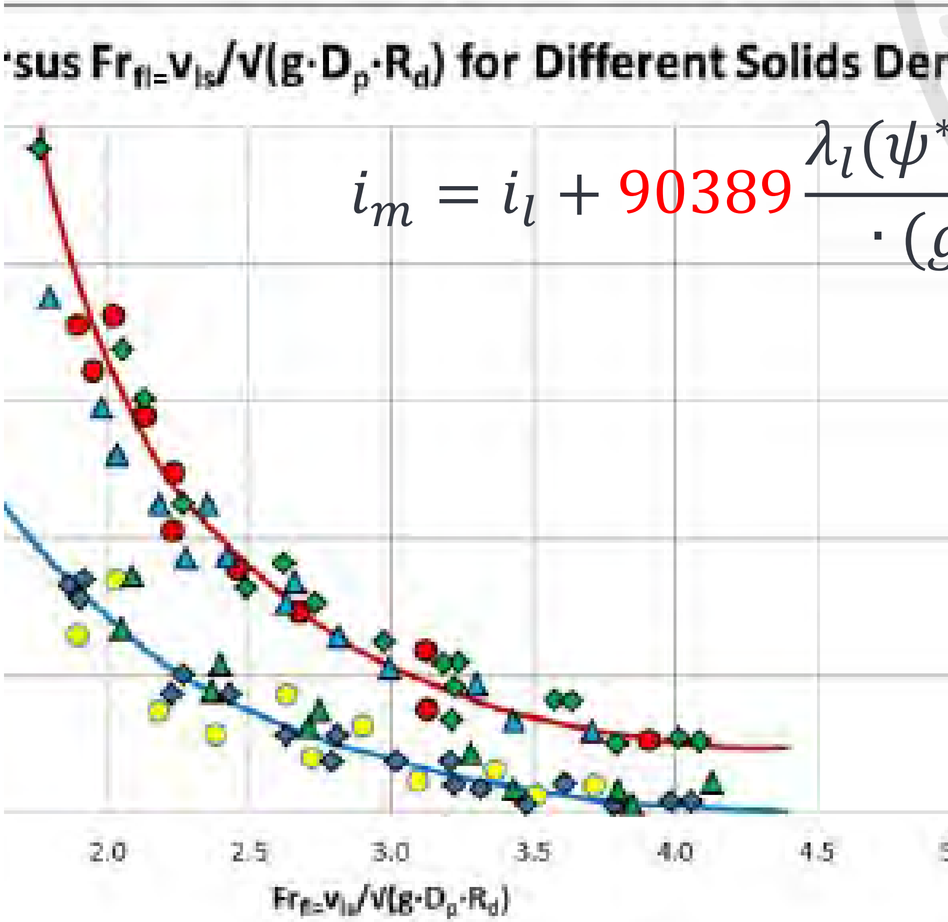
Informative

提供信息的

- provide outputs of direct interest to the Engineer that are valid across a range of typical cases
- capture as inputs those parameters that are significant in the process so that it is most sensitive to those parameters.
- neglect or abstract out parameters that are relatively constant or of minor significance in the process.

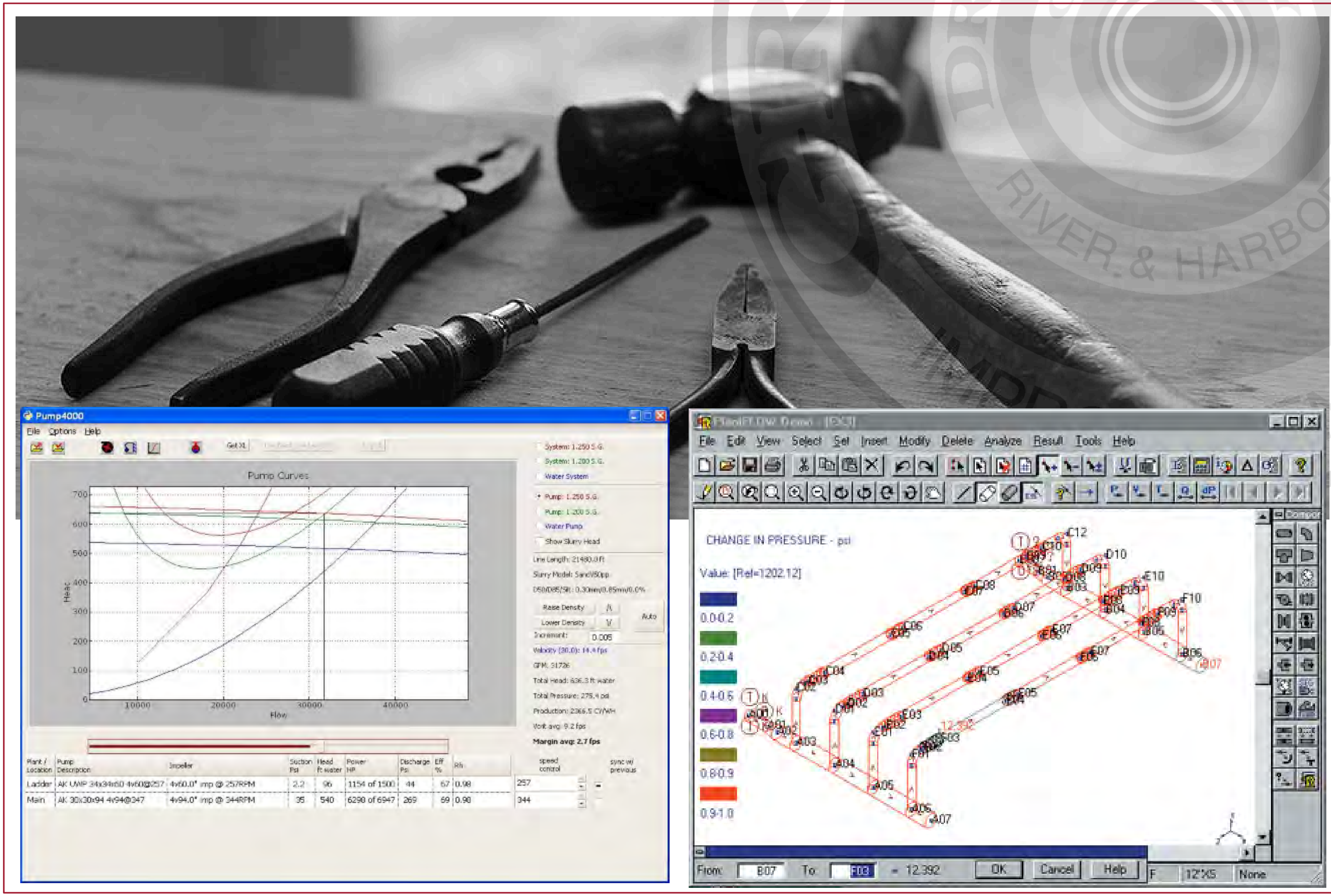
Empirical vs Analytical Models

- The models are usually analytical, empirical, or a combination of each.



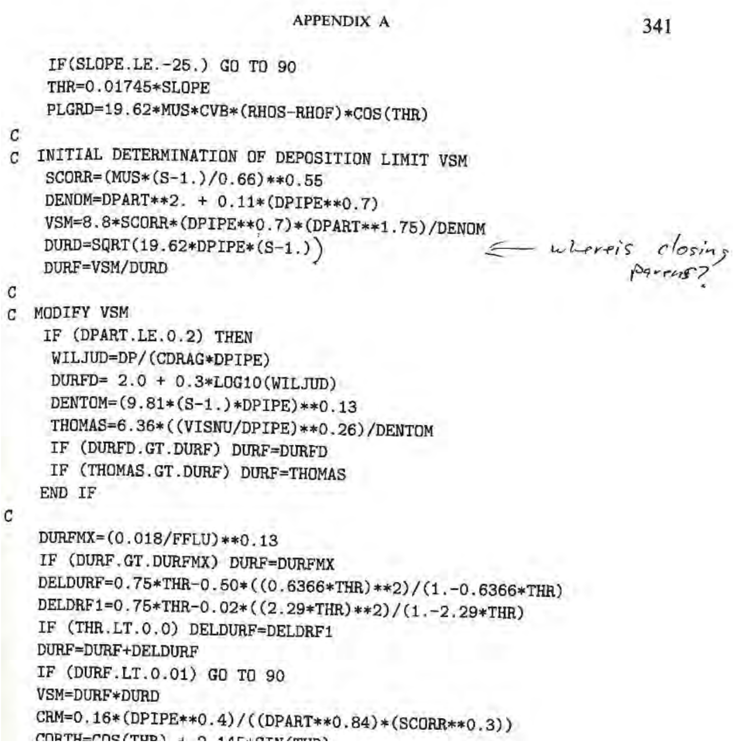
$$i_m = i_l + 90389 \frac{\lambda_l(\psi^* \cdot R_{sd})^{1/2} \cdot (v_l \cdot g)^{2/3}}{\cdot (g \cdot D_p)^{1/2} \cdot (C_{vt})^{1/2}} \cdot \frac{C_{vt}}{V_{ls}}$$

Tools



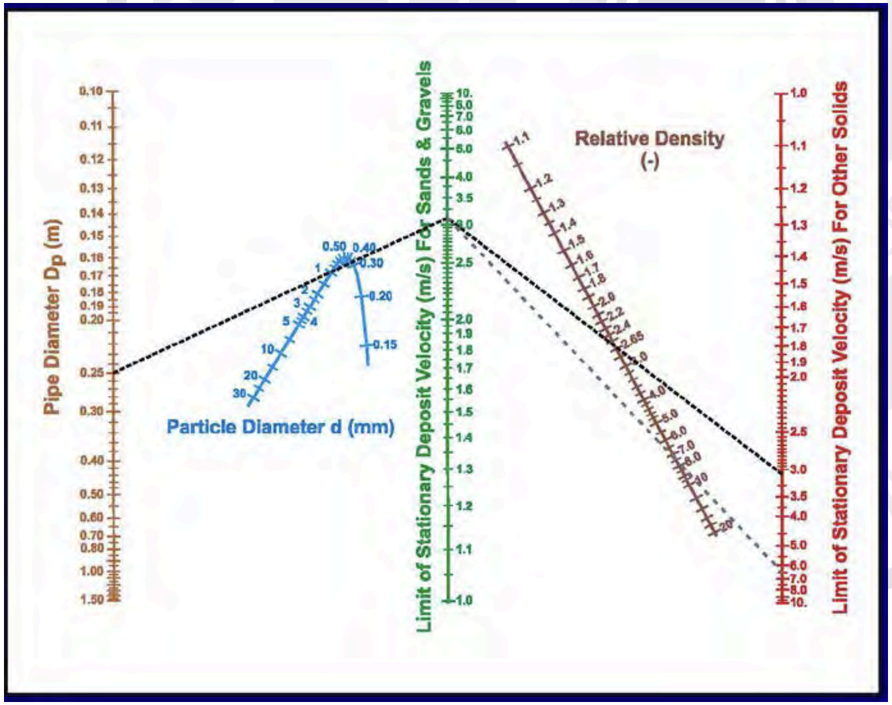
Pump4000
File Options Help
Pump Curves
Head
Flow
CHANGE IN PRESSURE - psi
File Edit View Select Set Insert Modify Delete Analyze Result Tools Help
From: B07 To: F03 = 12.392 OK Cancel Help

Example: The Wilson demi-macdonald



APPENDIX A 341

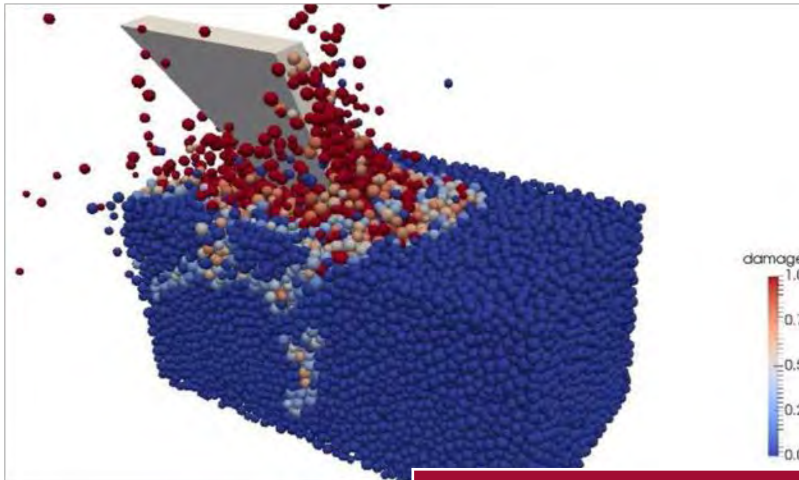
```
      IF(SLOPE.LE.-25.) GO TO 90
      THR=0.01745*SLOPE
      PLGRD=19.62*MUS*CVB*(RHOS-RHOF)*COS(THR)
C
C   INITIAL DETERMINATION OF DEPOSITION LIMIT VSM
      SCORR=(MUS*(S-1.)/0.66)**0.55
      DENOM=DPART**2. + 0.11*(DPIPE**0.7)
      VSM=8.8*SCORR*(DPIPE**0.7)*(DPART**1.75)/DENOM
      DURD=SQRT(19.62*DPIPE*(S-1.))
      DURF=VSM/DURD
C
C   MODIFY VSM
      IF (DPART.LE.0.2) THEN
       WILJUD=DP/(CDRAG*DPIPE)
       DURFD= 2.0 + 0.3*LOG10(WILJUD)
       DENTOM=(9.81*(S-1.)*DPIPE)**0.13
       THOMAS=6.36*((VISNU/DPIPE)**0.26)/DENTOM
       IF (DURFD.GT.DURF) DURF=DURFD
       IF (THOMAS.GT.DURF) DURF=THOMAS
      END IF
C
      DURFMX=(0.018/FFLU)**0.13
      IF (DURF.GT.DURFMX) DURF=DURFMX
      DELDURF=0.75*THR-0.50*((0.6366*THR)**2)/(1.-0.6366*THR)
      DELDRF1=0.75*THR-0.02*((2.29*THR)**2)/(1.-2.29*THR)
      IF (THR.LT.0.0) DELDURF=DELDRF1
      DURF=DURF+DELDURF
      IF (DURF.LT.0.01) GO TO 90
      VSM=DURF*DURD
      CRM=0.16*(DPIPE**0.4)/((DPART**0.84)*(SCORR**0.3))
```

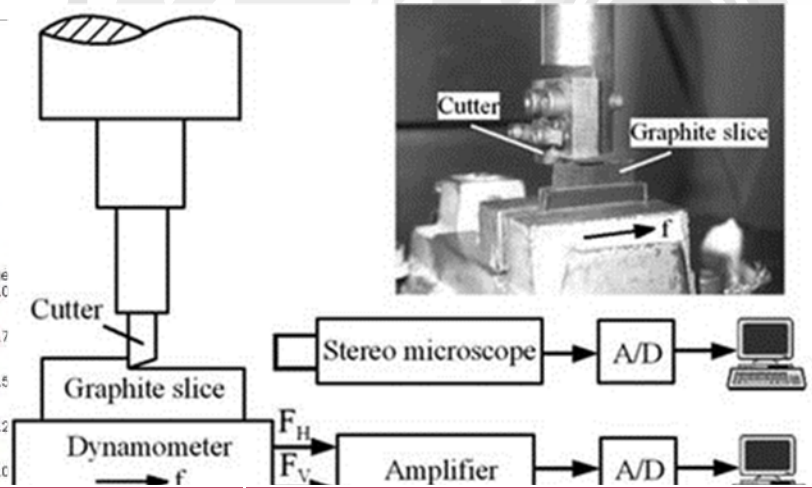



"The computer output, although manageable for detailed studies, soon becomes <u>unwieldy for the designer concerned with many alternative proposals</u>. Moreover, the conservative designer may be <u>content to know only the maximum velocity at the limit of deposition, Vsm</u>, since maintaining the velocity above this value ensures that deposition will not occur.

(Wilson et al, 2008, page 109)

Scientific Models: Helmons, 2019





Simulations require between 17 hours with a standard laptop and an estimated 20 min with a dedicated GPU

Normal stiffness (MPa)	Calibration by user
Shear stiffness (MPa)	Calibration by user
Normal strength (MPa)	Calibration by user
Shear strength (MPa)	Calibration by user
Bond radius multiplier (-)	Calibration by user
Friction coefficient (-)	Calibration by user
Mean particle size (mm)	Determined by user (computational demand vs. (minimum) level of detail)
Effective stress coefficient (-)	Calibration by user
Fluid viscosity (Pa-s)	Direct from field
Numerical damping (-)	Constant, so far
Boundary criterion (-)	Determined by user
Smoothing length (mm)	Closely related to particle size
Timestep (s)	Closely related other properties

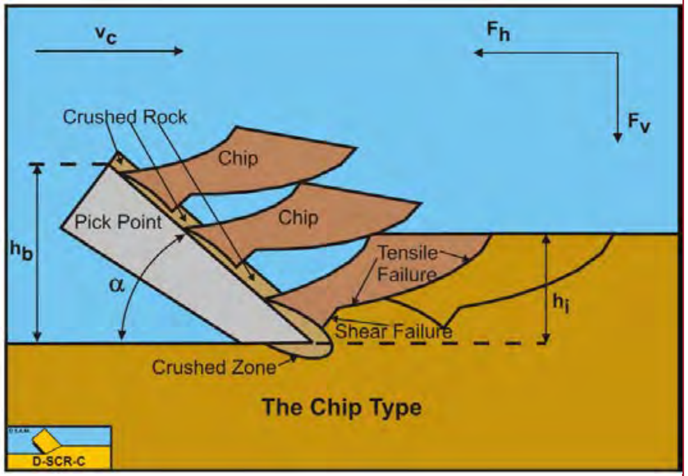
Scientific Models: Rock Cutting (Miedema 2017)

UCS (MPa)	**Measure (Unconfined or triaxial tests)**
BTS (MPa)	Measure (Brazilian Tensile Test)
Permeability (m^2)	Measure
Hydrostatic pressure (MPa)	Known from water depth
Bulk modulus pore fluid (GPa)	Standard value
Type of rock	e.g. limestone, sandstone
Poisson ratio (-)	Measure / rule of thumb
Young's modulus (Pa)	Measure / rule of thumb
Shape of the tool	e.g. height, angle, width of blade, sharpness, wear flats, etc.
Cutting depth (m)	These vary with cutting process and operating parameters of the tools being investigated.
Cutting velocity (m/s)	
Rake angle (°)	
Clearance angle (°)	
Friction coefficient tool-rock (-)	Measured

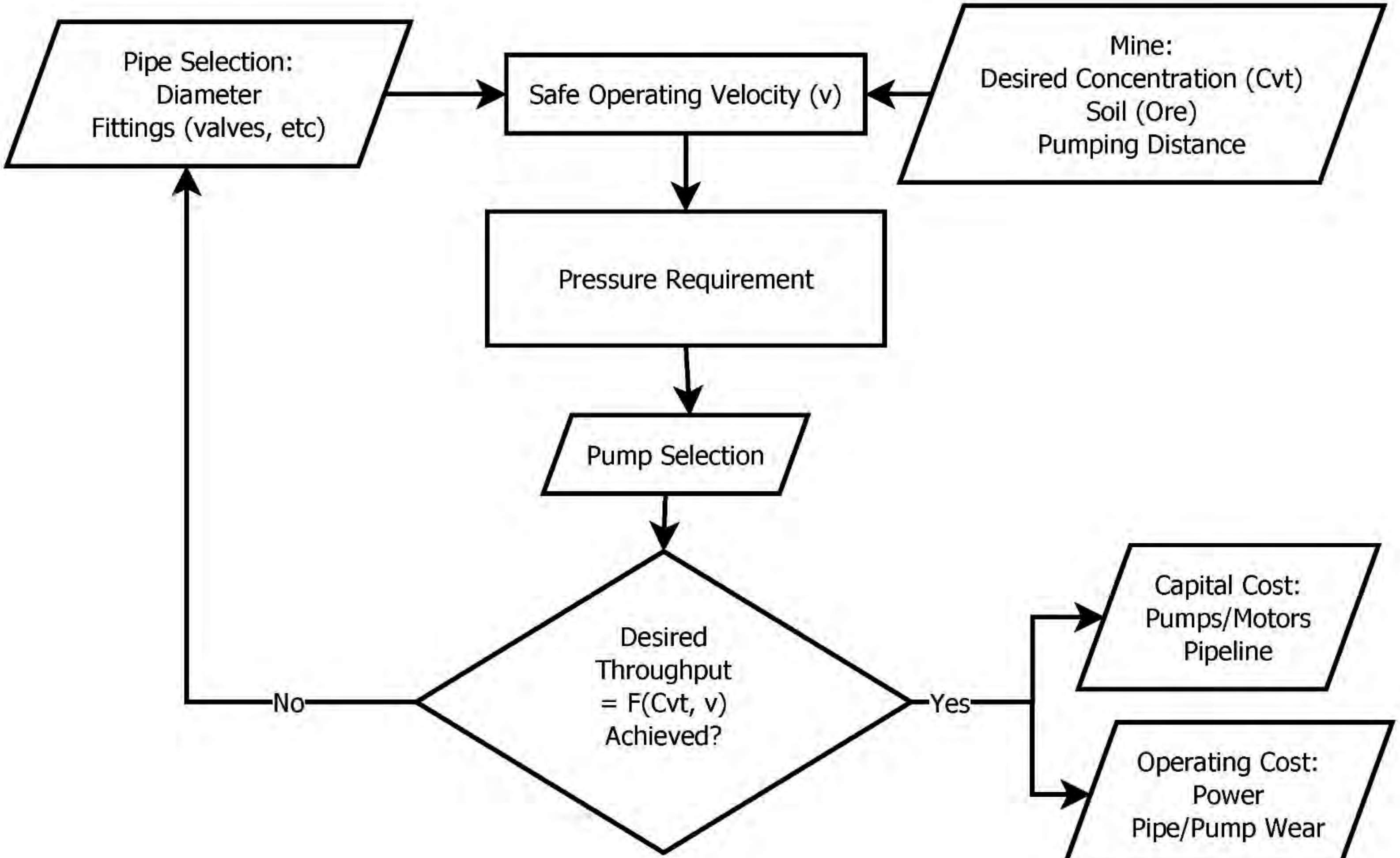
$$Q_{cut} = \frac{P_{avail} * h_i * w}{F_h}$$

$$F_h = \frac{\lambda_s * c * h_i * w * \cos(\varphi) * \sin(\alpha + \delta)}{\sin(\beta) * \sin(\alpha + \beta + \delta + \varphi)}$$

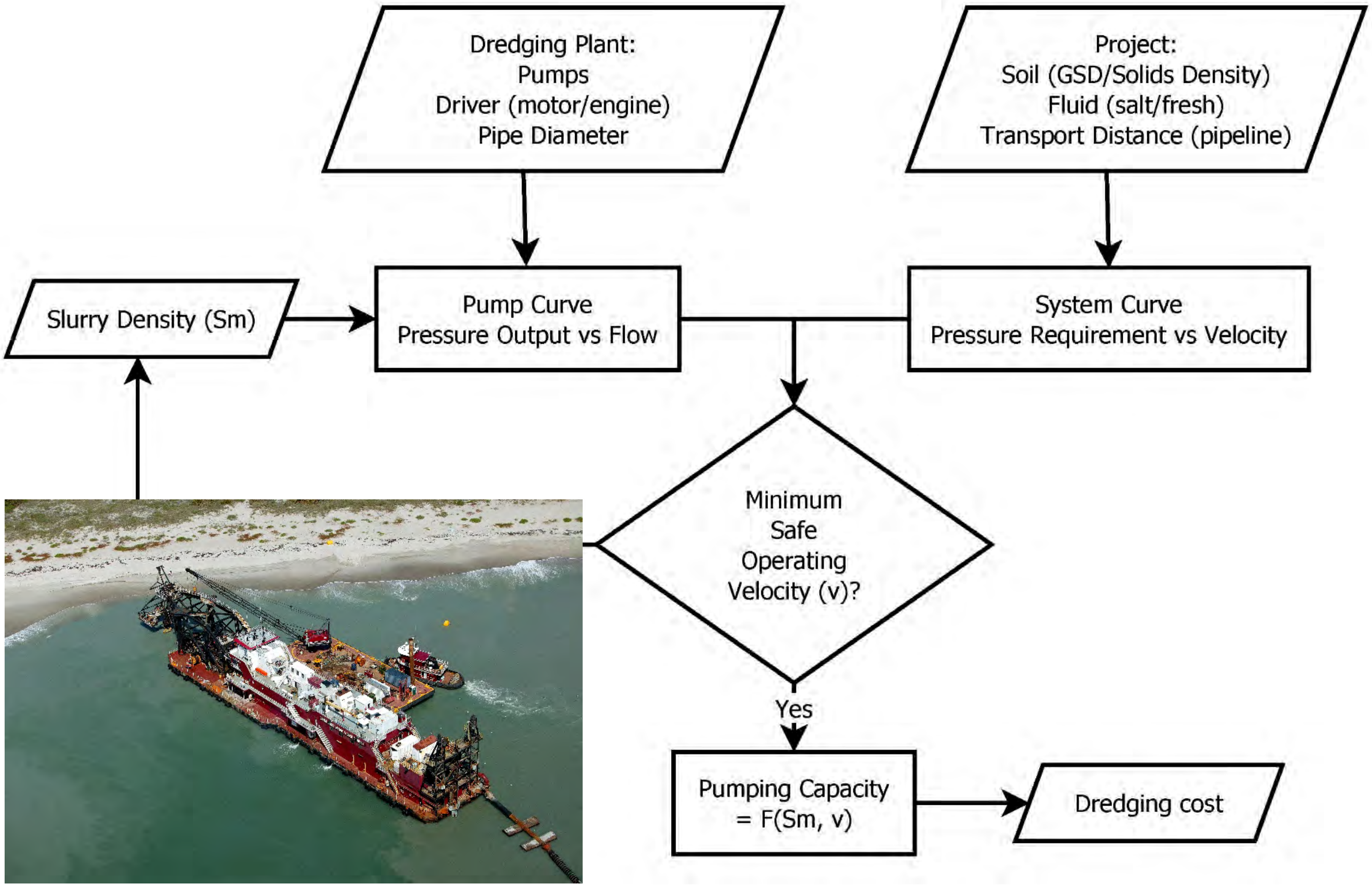
$$c = \frac{UCS}{2} * \left(\frac{1 - \sin(\varphi)}{\cos(\varphi)}\right)$$



Design Engineering: Mine Pumping System



Production Engineering: Pumping Capacity



Simulations

- Require faster (more abstract) models, to allow running many time steps per second
- Time–consuming to setup and run
- Useful for:
  - Training
  - Modelling dynamic behavior
  - Modelling random interactions

Production Engineers need to provide good estimates of dredge production and operational guidance. The models they use must meet the three requirements that the models be tractable, discernable and informative.

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