U.S. DoE Project Briefing
June 27, 2006

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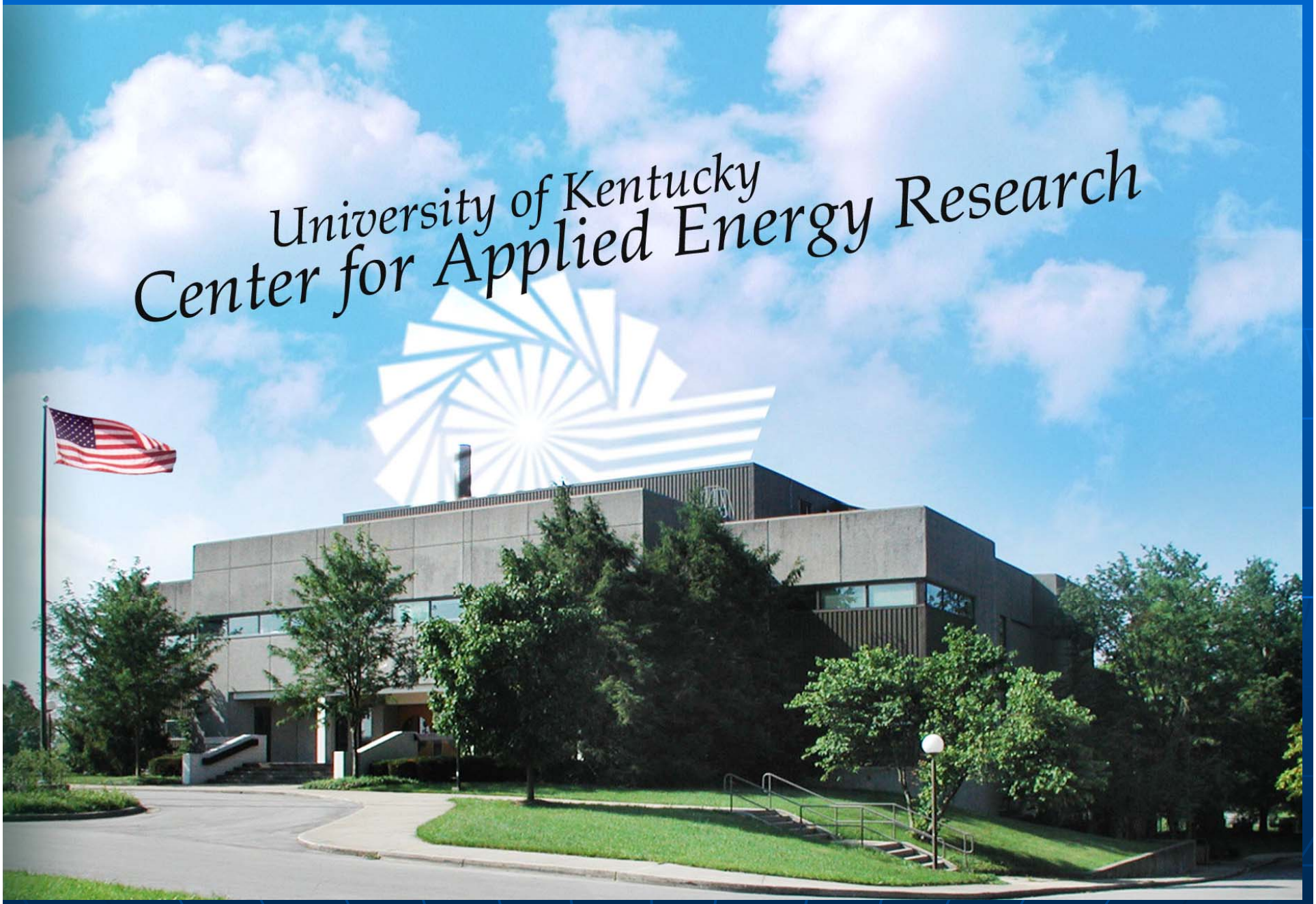
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Coal Combustion in the Ohio Valley

- 32 plants in KY and Ohio River Valley
- ~ 33 GW Rated Capacity
- > 7 million tons of fly ash per year is produced
- Fly ash quality has generally declined due to low NOx burners and co-firing
- Beneficiation needed to control quality

8/10 TOP COAL CONSUMING STATES ARE IN THE OHIO VALLEY

Outline of Presentation

1. Participants and Roles
2. Project Objectives
3. Resource Assessment
4. Circuit Testing in the Field
5. Development of Secondary Classifier
6. Mortar and Paste Results
7. Concrete Results
8. Cement Additive Results
9. Capital and Operating Cost Projections
10. Phase II What's Next

Ghent Participants

- CEMEX, Inc.
  - Technology Owner/Implementer
- E.ON US, LLC (KU)
  - Host Site
- UK CAER
  - Technology Inventor/Developer
- U. S. DoE
  - Technology Implementer

Project Objectives

- Demonstrate and Commercialize An Advanced Ash Beneficiation Technology
  - Increase Quality of Available Ash
    - Achieve High Levels of OPC Substitution
    - Develop New Class of Material
  - Expand Materials Utilization
    - Recover Carbon
    - Recover Aggregate
    - Recover Specialty Products (Cenospheres)

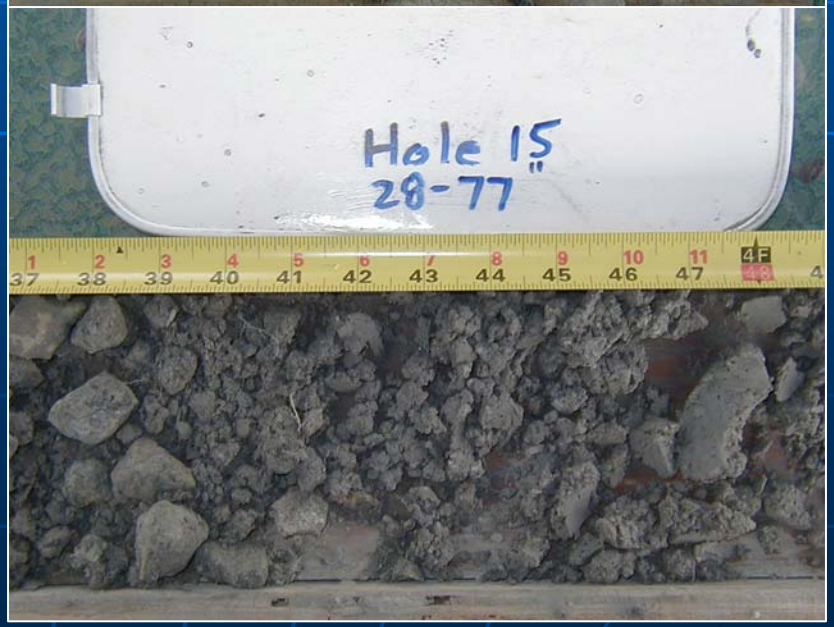
Project Location

*Kentucky Utilities Company
2,200 MW Ghent Power Plant
Carroll County, Kentucky

*A Subsidiary of E.ON US, LLC.

Exploration

Cores



Sample Analysis

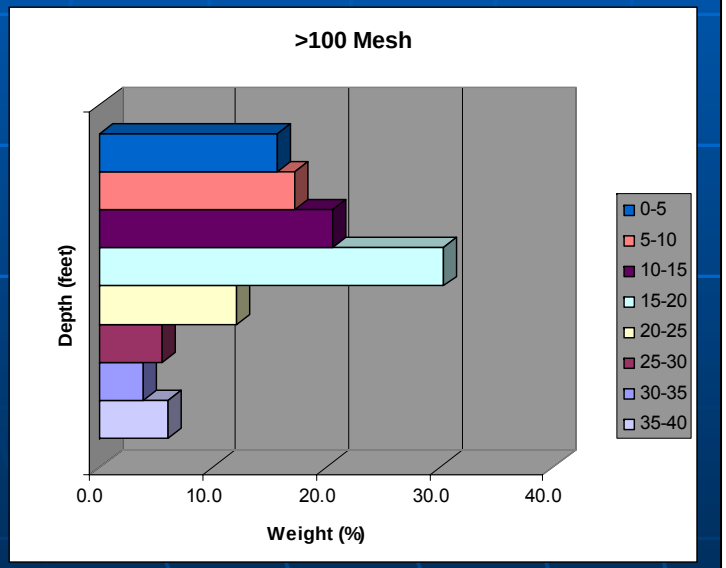
- Core Descriptions
  - 13 vibracores
  - Divided into 381 sample
- Dry-Sieve Analysis
  - No.100 mesh
    - 150 µm
  - 762 samples
- Laser particle-size analy
  - Mean particle-size
    - <100 mesh
  - % <5µm; % <10µm

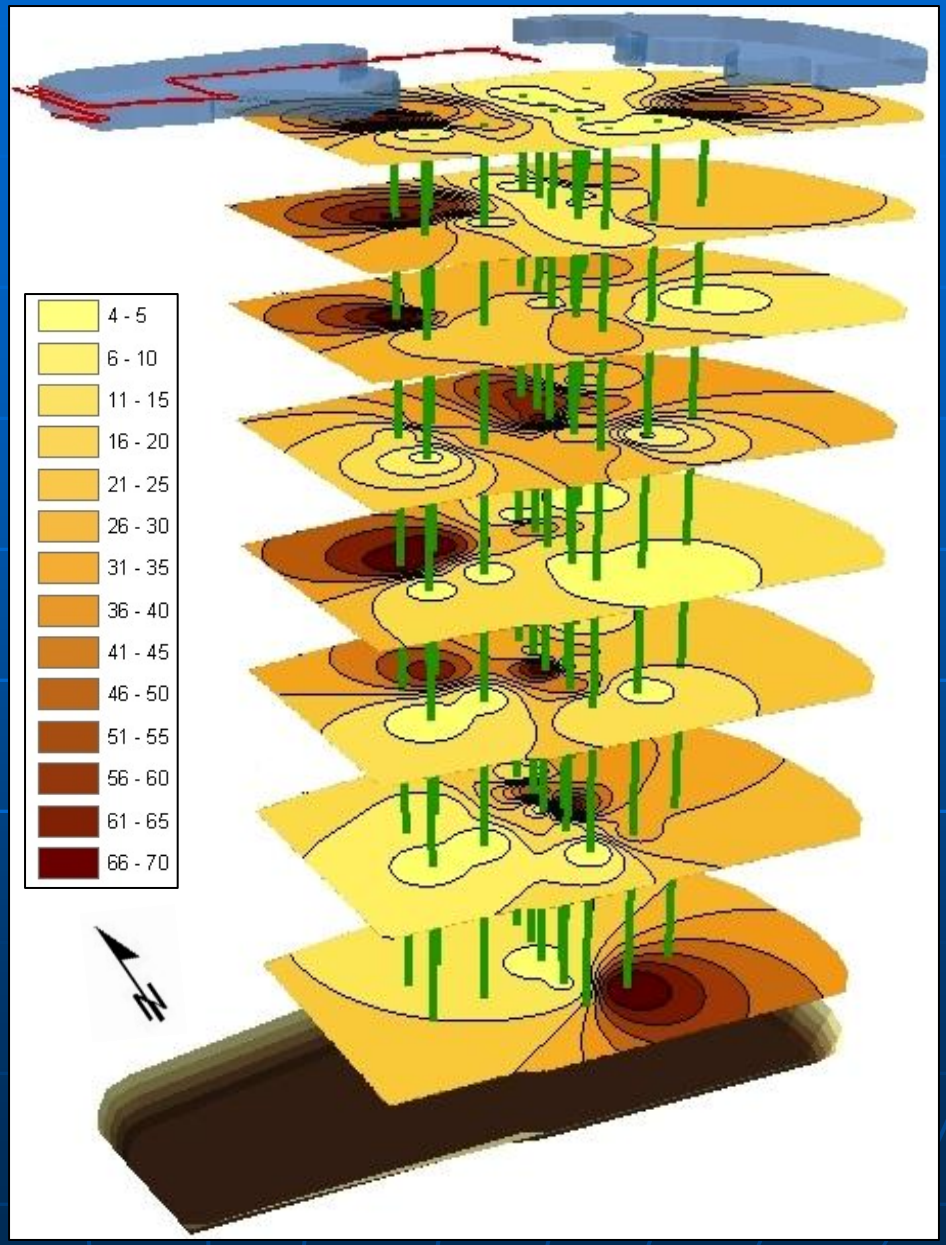
Weight and depth of cored holes

Core #	<100 mesh (kg)	>100 mesh (kg)	Total Depth (ft)
8	5.81	0.31	11.0
9	16.40	1.32	31.0
10	16.27	1.30	37.0
11	14.35	2.25	37.4
12	16.12	2.05	34.0
13	14.87	1.53	34.6
14	16.20	1.79	37.5
15	13.85	2.95	31.4
16	16.79	1.46	33.9
17	15.03	1.33	30.1
18	18.22	1.28	35.8
19	13.86	1.59	30.2
20	6.66	4.33	21.4
Sum	184.43	23.51	405.3
Percent	88.7%	11.3%	

Average weight percent data (>100 mesh)

- Overall coarsening-upward and laterally fining ash





0-5 ft

5-10 ft

10-15 ft

15-20 ft

20-25 ft

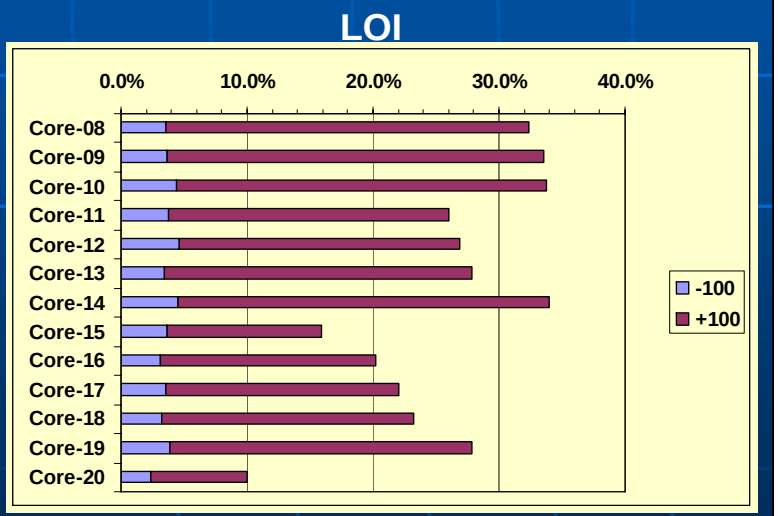
25-30 ft

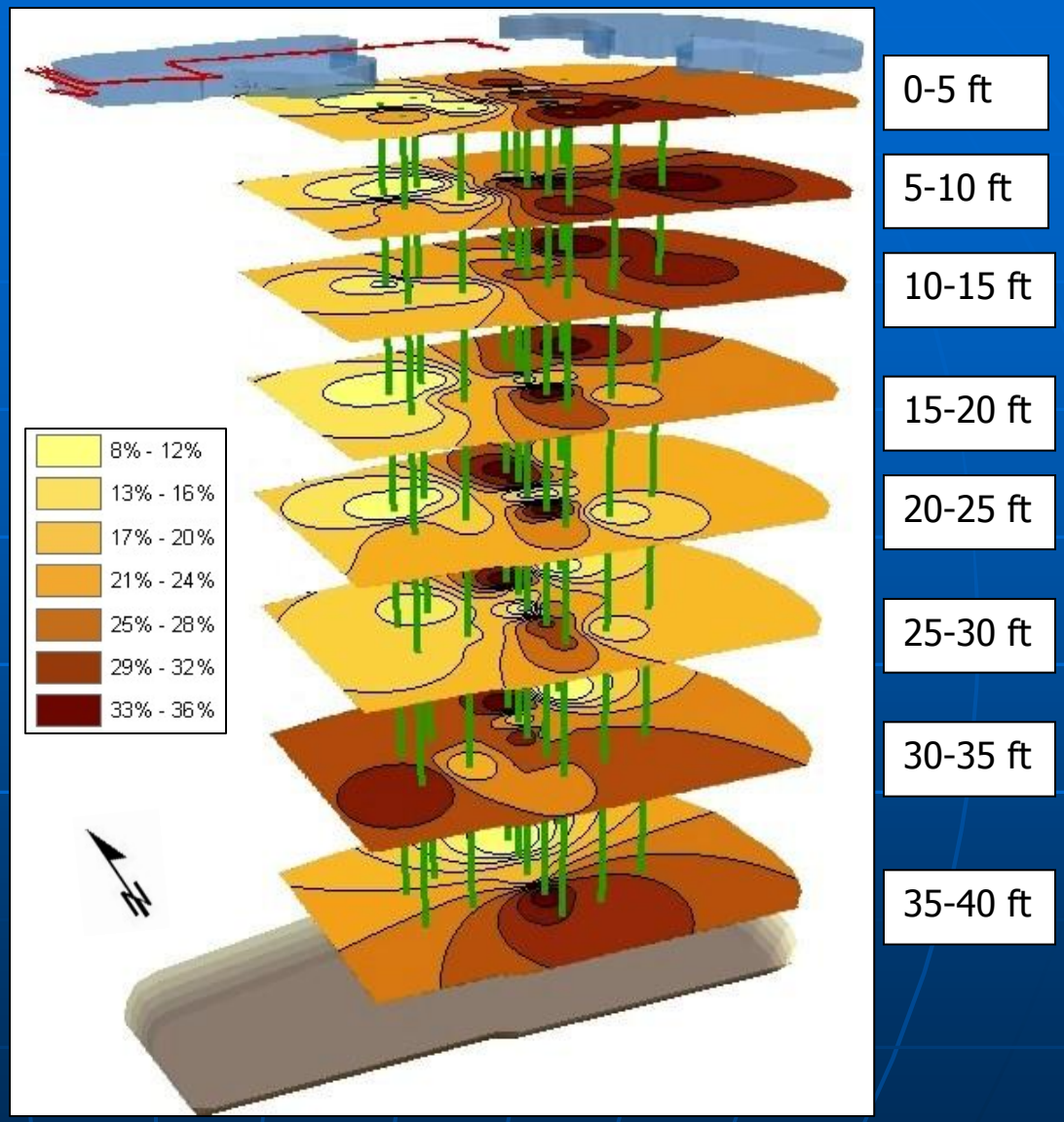
30-35 ft

35-40 ft

Average percent of unburned carbon (>100 mesh)

- Increased unburned carbon concentrations in the distal end of the pond





Resource Estimates

Polygon	Area	Thickness	Volume	Tonnage Factor	tons ash
	(sq ft)	(ft)	(cu ft)	(cu ft/ton)	(total)
1	40560	40	1622400	29.8	54443
2	47970	40	1918800	29.8	64389
3	29725	40	1189000	29.8	39899
4	9944	40	397760	29.8	13348
5	44720	40	1788800	29.8	60027
6	20790	40	831600	29.8	27906
7	29415	40	1176600	29.8	39483
8	47841	40	1913640	29.8	64216
9	55963	40	2238520	29.8	75118
10	140476	40	5619040	29.8	188558
11	45674	40	1826960	29.8	61307
12	50180	40	2007200	29.8	67356
13	78470	40	3138800	29.8	105329
14	43000	40	1720000	29.8	57718
15	46368	40	1854720	29.8	62239
16	55796	40	2231840	29.8	74894
Drilled Estimate	**786,892**	**40**	**31,475,680**	**29.8**	**1,056,231**
Pond Estimate	**5,227,000**	**40**	**209,080,000**	**29.8**	**7,016,107**

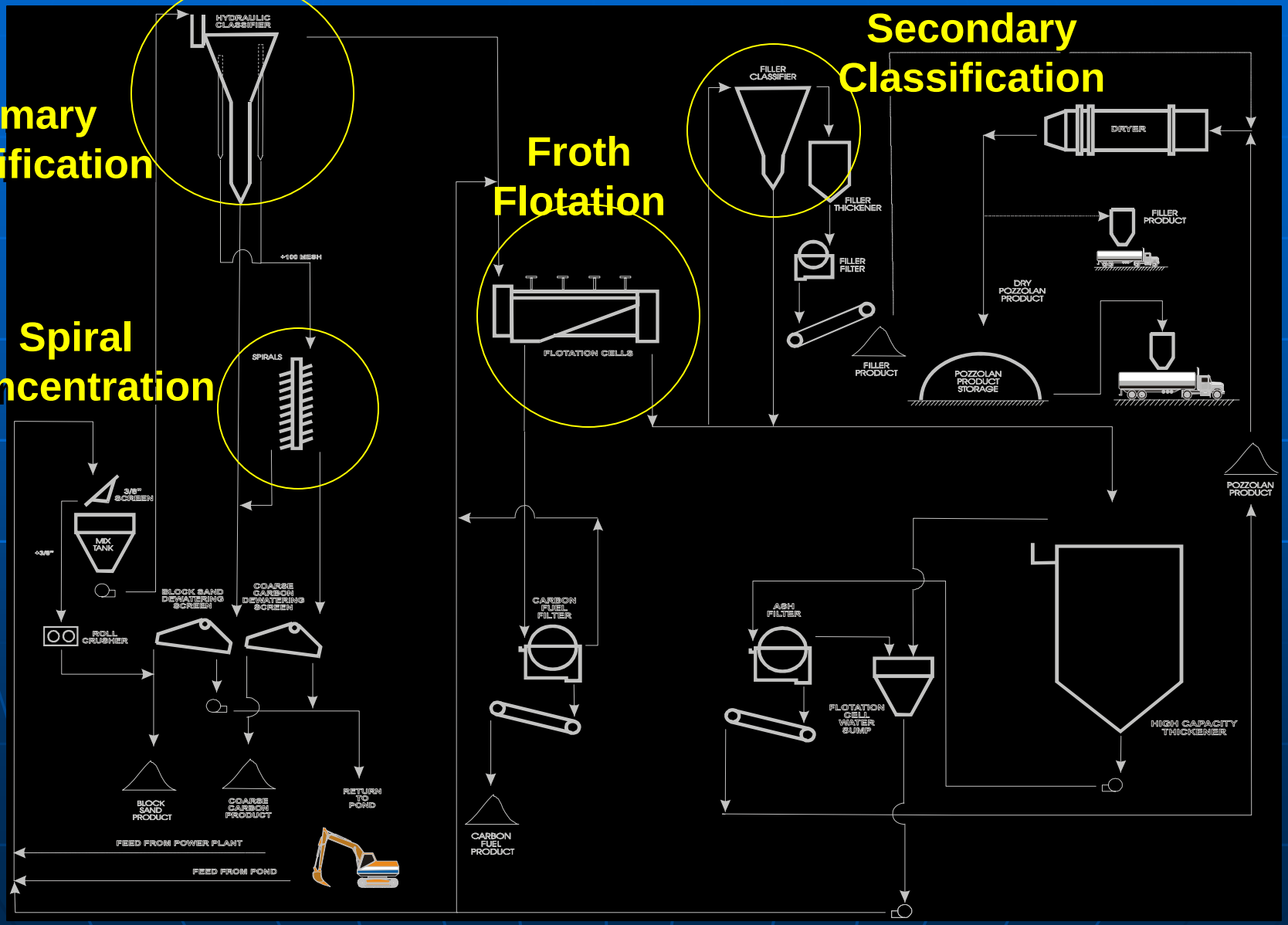
Resource Estimates (cont.)

Average Grade (% <5µm)	tons (% <5µm)	Average Grade (% <10µm)	tons (% <10µm)	Average Grade (fine C)	tons (fine C)	Average Grade (coarse C)	tons (coarse C)
0.15	8166	0.26	14155	0.037	2014	0.22	11977
0.15	9658	0.26	16741	0.037	2382	0.22	14166
0.15	5985	0.26	10374	0.037	1476	0.22	8778
0.15	2002	0.26	3470	0.037	494	0.22	2936
0.15	9004	0.26	15607	0.037	2221	0.22	13206
0.15	4186	0.26	7256	0.037	1033	0.22	6139
0.15	5922	0.26	10266	0.037	1461	0.22	8686
0.15	9632	0.26	16696	0.037	2376	0.22	14128
0.15	11268	0.26	19531	0.037	2779	0.22	16526
0.15	28284	0.26	49025	0.037	6977	0.22	41483
0.15	9196	0.26	15940	0.037	2268	0.22	13488
0.15	10103	0.26	17512	0.037	2492	0.22	14818
0.15	15799	0.26	27386	0.037	3897	0.22	23172
0.15	8658	0.26	15007	0.037	2136	0.22	12698
0.15	9336	0.26	16182	0.037	2303	0.22	13693
0.15	11234	0.26	19472	0.037	2771	0.22	16477
0.15	**158,435**	**0.26**	**274,620**	**0.037**	**39,081**	**0.22**	**232,371**
0.15	**1,052,416**	**0.26**	**1,824,188**	**0.037**	**259,596**	**0.22**	**1,543,544**

Purpose of Field Testing

- Generate large quantities of products for evaluation
  - several tons
- Evaluate flowsheet options
  - 4 flowsheet configurations
- Develop Guidance for Commercial Scale-up

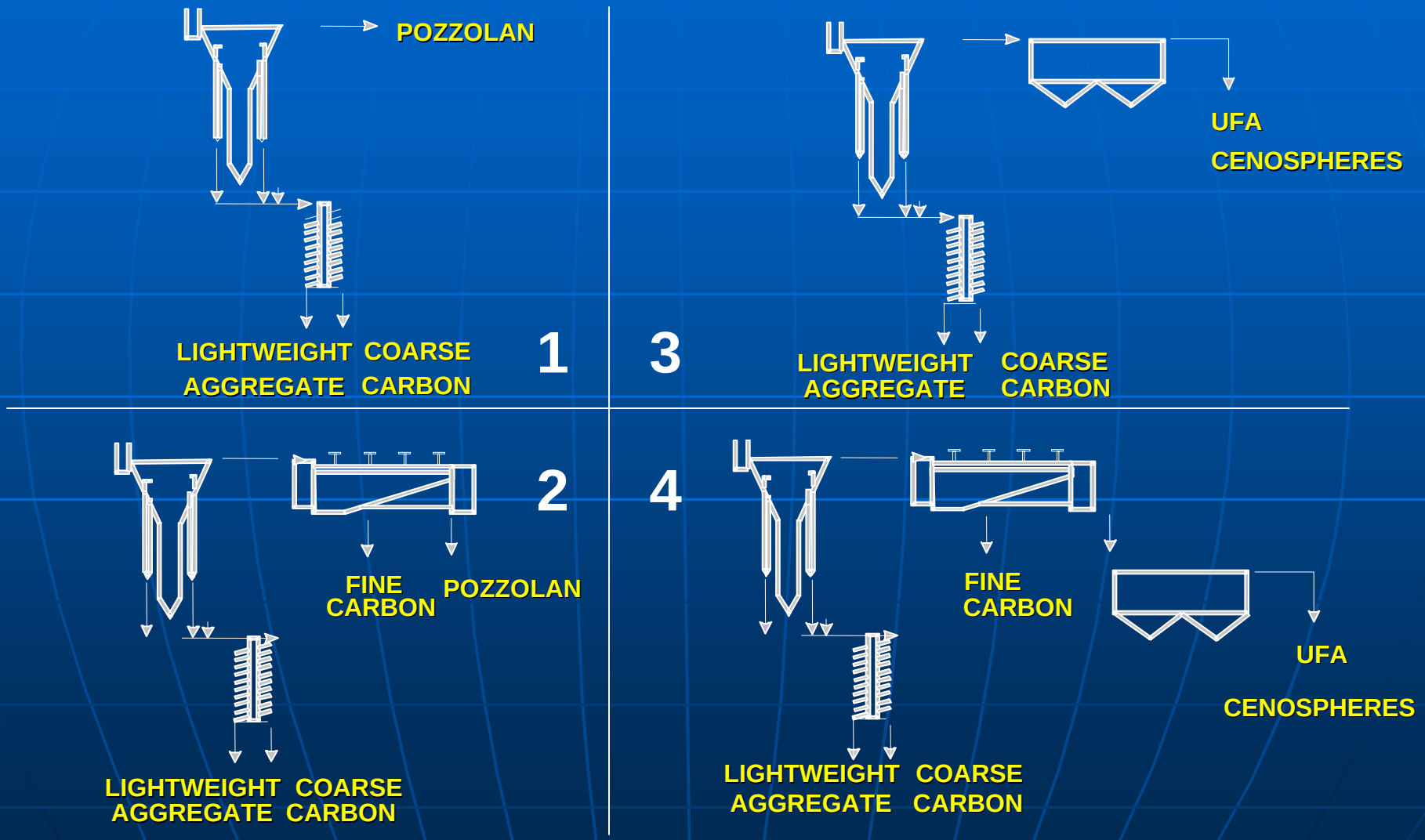
General Process Flowsheet



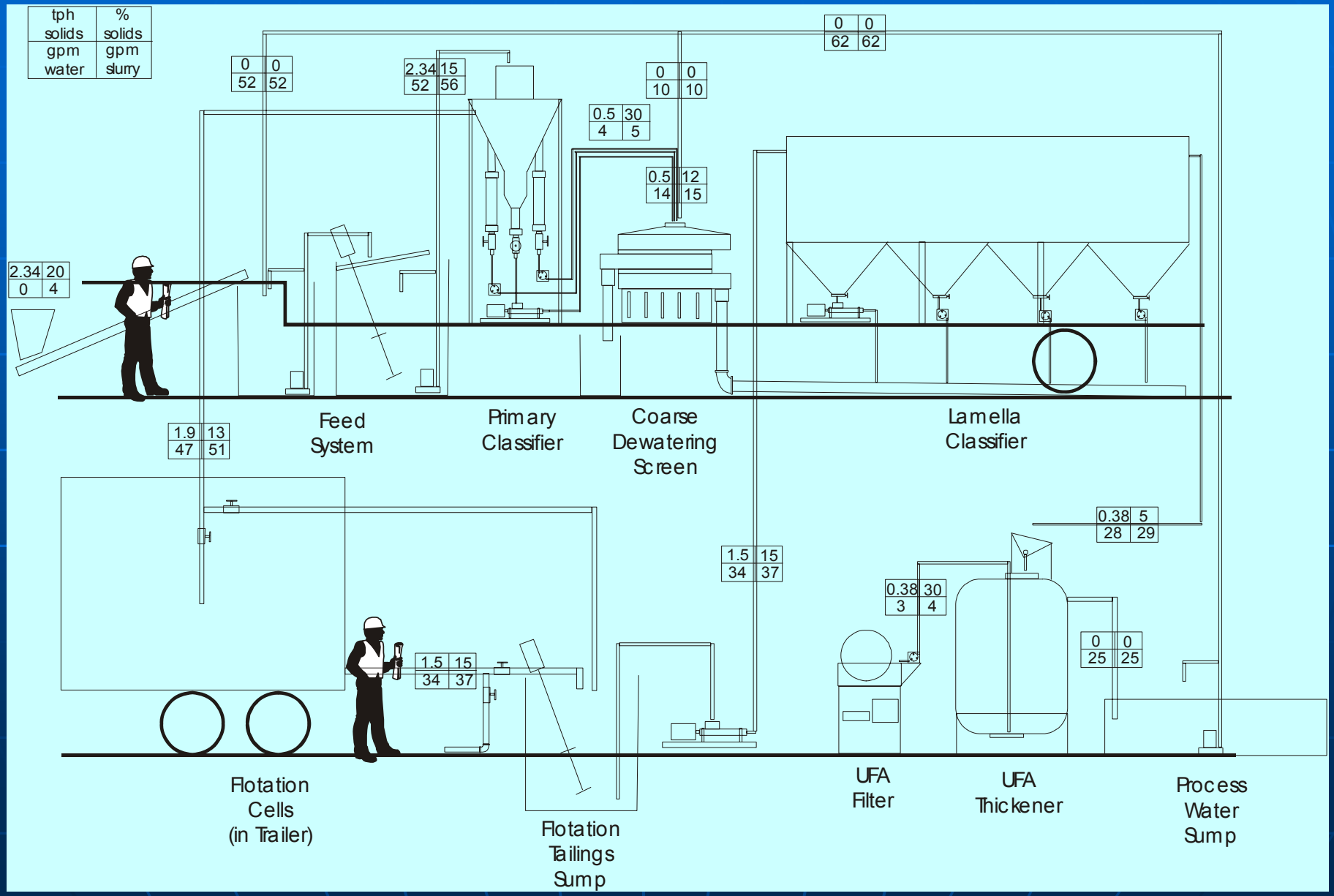
Purpose of Unit Processes

- Primary Classification
  - Efficiently reject +100 mesh
- Spiral Concentration
  - Recover coarse (+100 mesh) carbon fuel
  - Recover coarse lightweight aggregate
- Froth Flotation
  - Recover fine (-100 mesh) carbon fuel
  - Produce low LOI pozzolan
- Secondary Classification
  - Recover UFA (-10 micron) filler

Flowsheet Options



Field Testing Plant

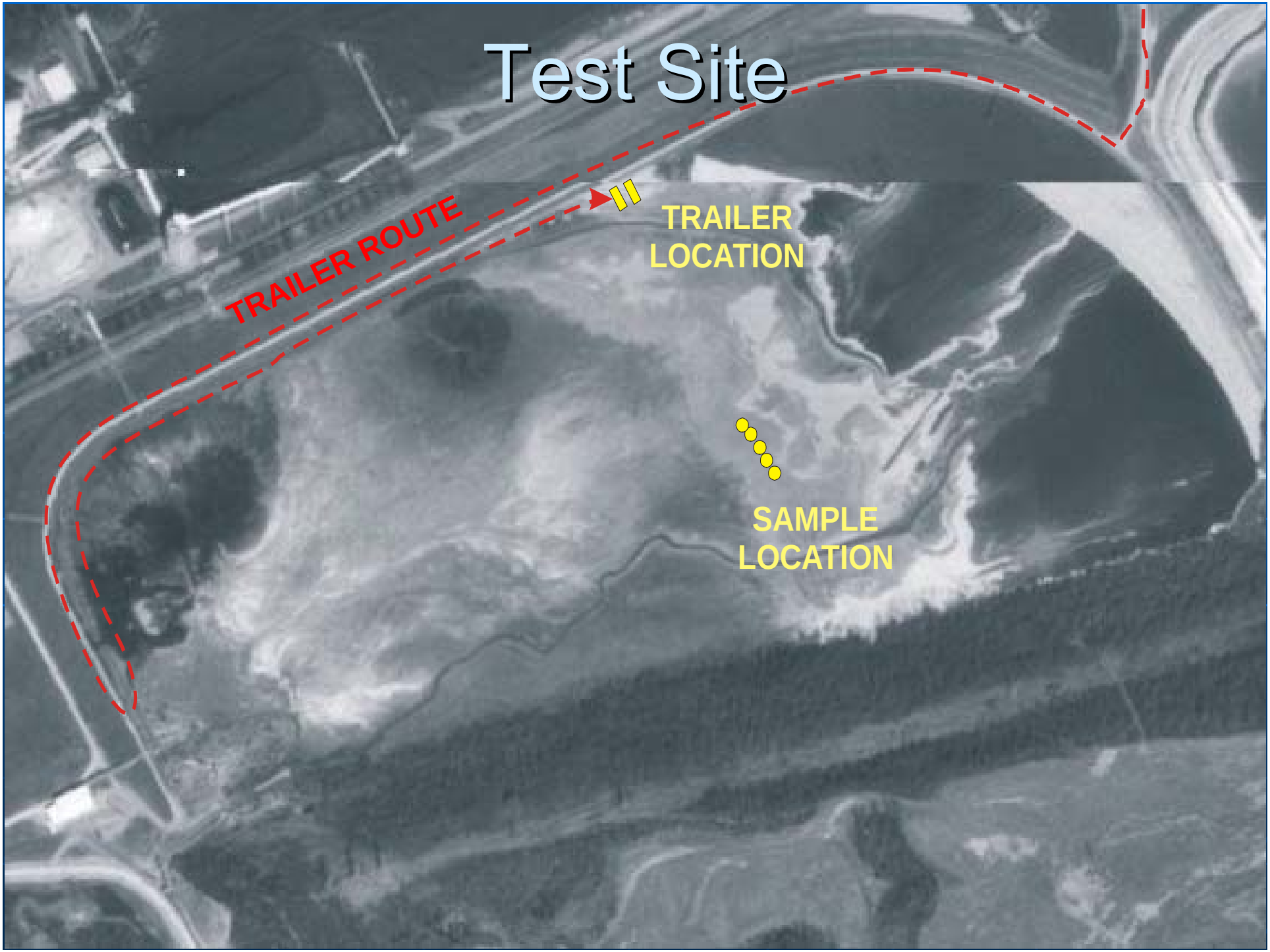


UK

Primary Classifier
Secondary Classifier
Floatation Cells
De-watering Screen
Thickener
Filter
Feed System
UK
UNIVERSITY OF KENT
CENTER FOR
APPLIED ENERGY RESEARCH

Van Interior
6 x 2' x 2' x 2' Denver Cells

Test Site



Feed Sample Preparation

Excavation

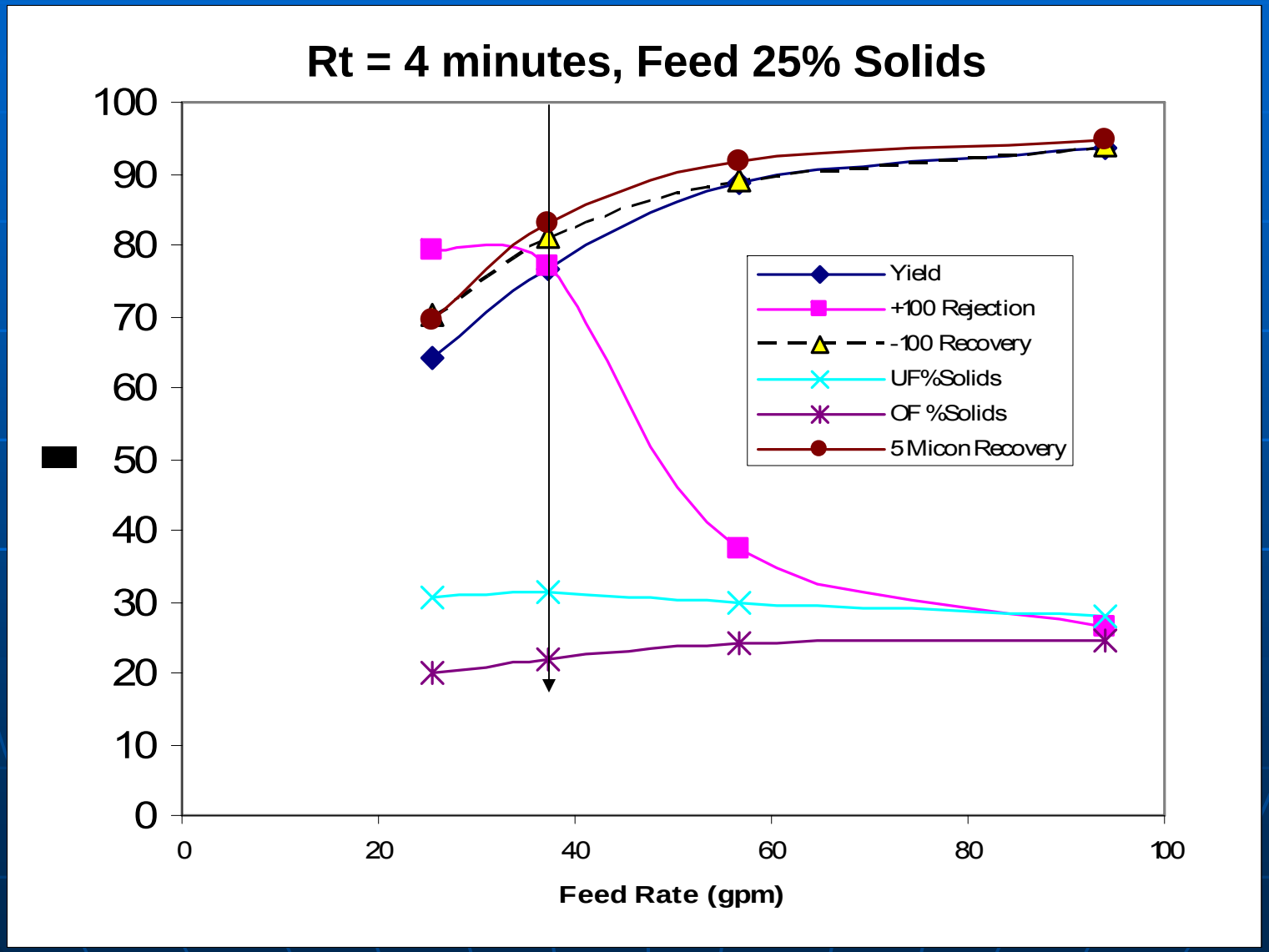
Hauling

Screening
@ 3/8”

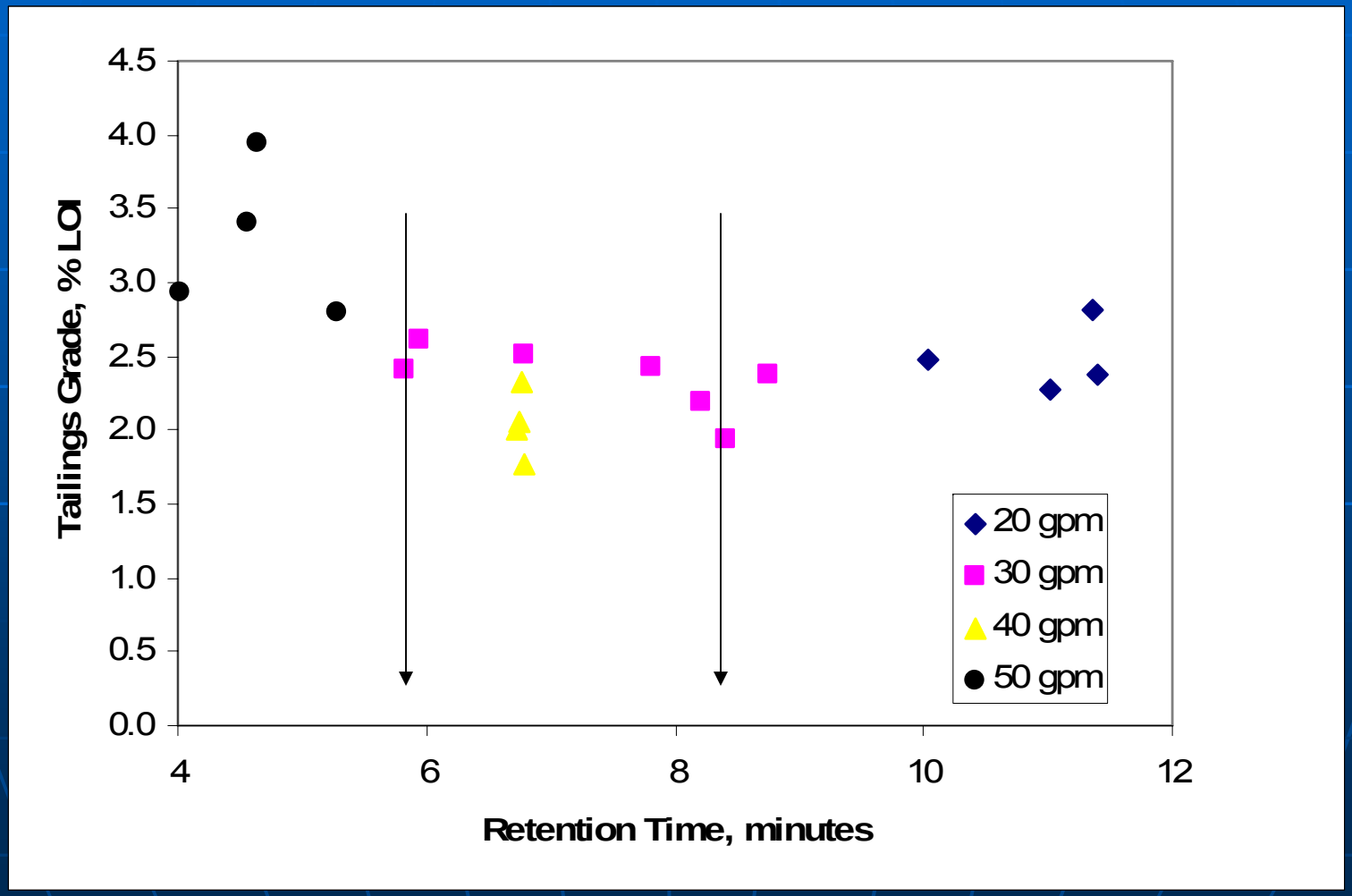
170 ton Stockpile

Flowsheet Testing

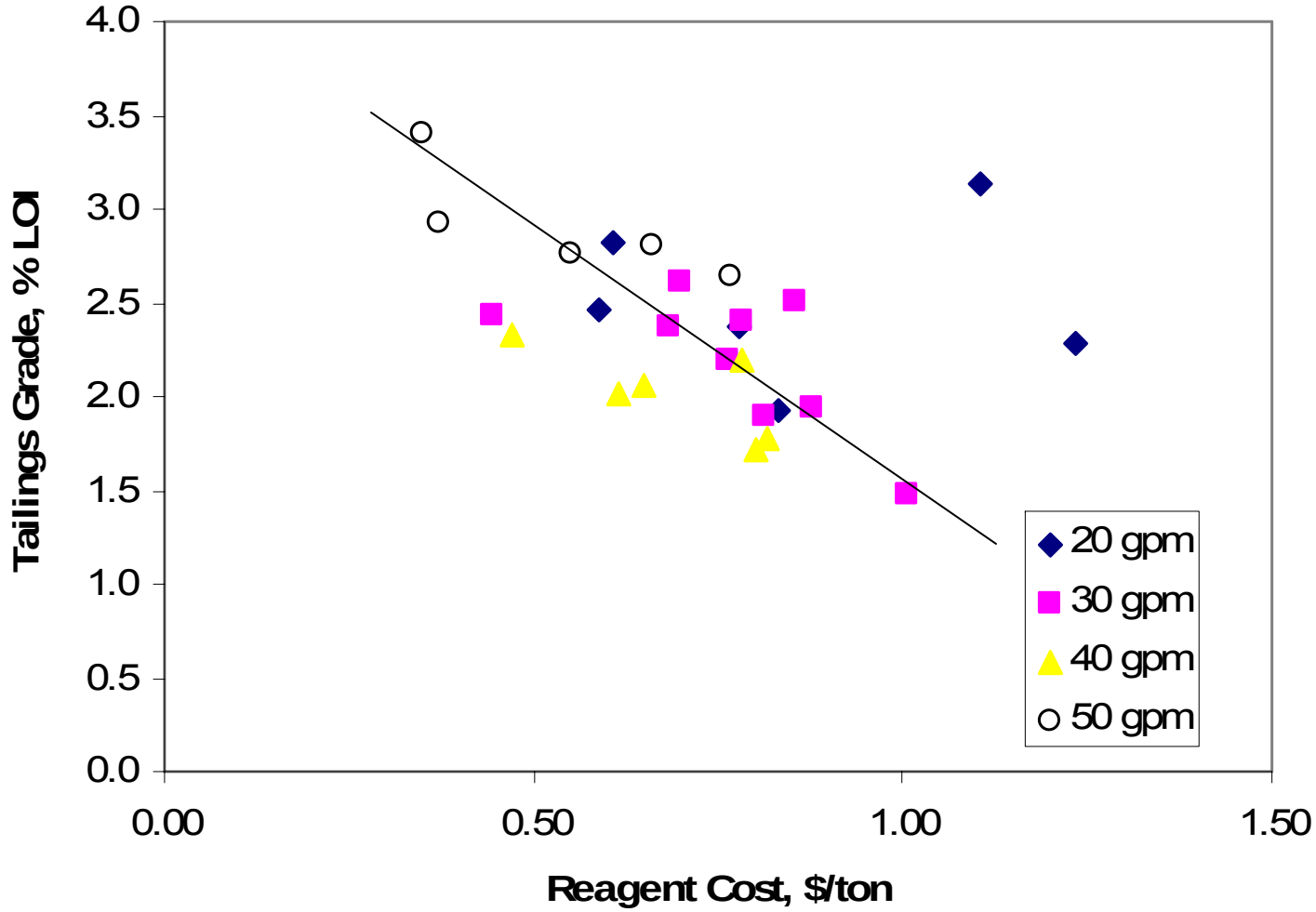
Primary Classifier



Flotation Retention Requirements



Flotation Chemical Costs



Secondary Hydraulic Classification

STOKES LAW

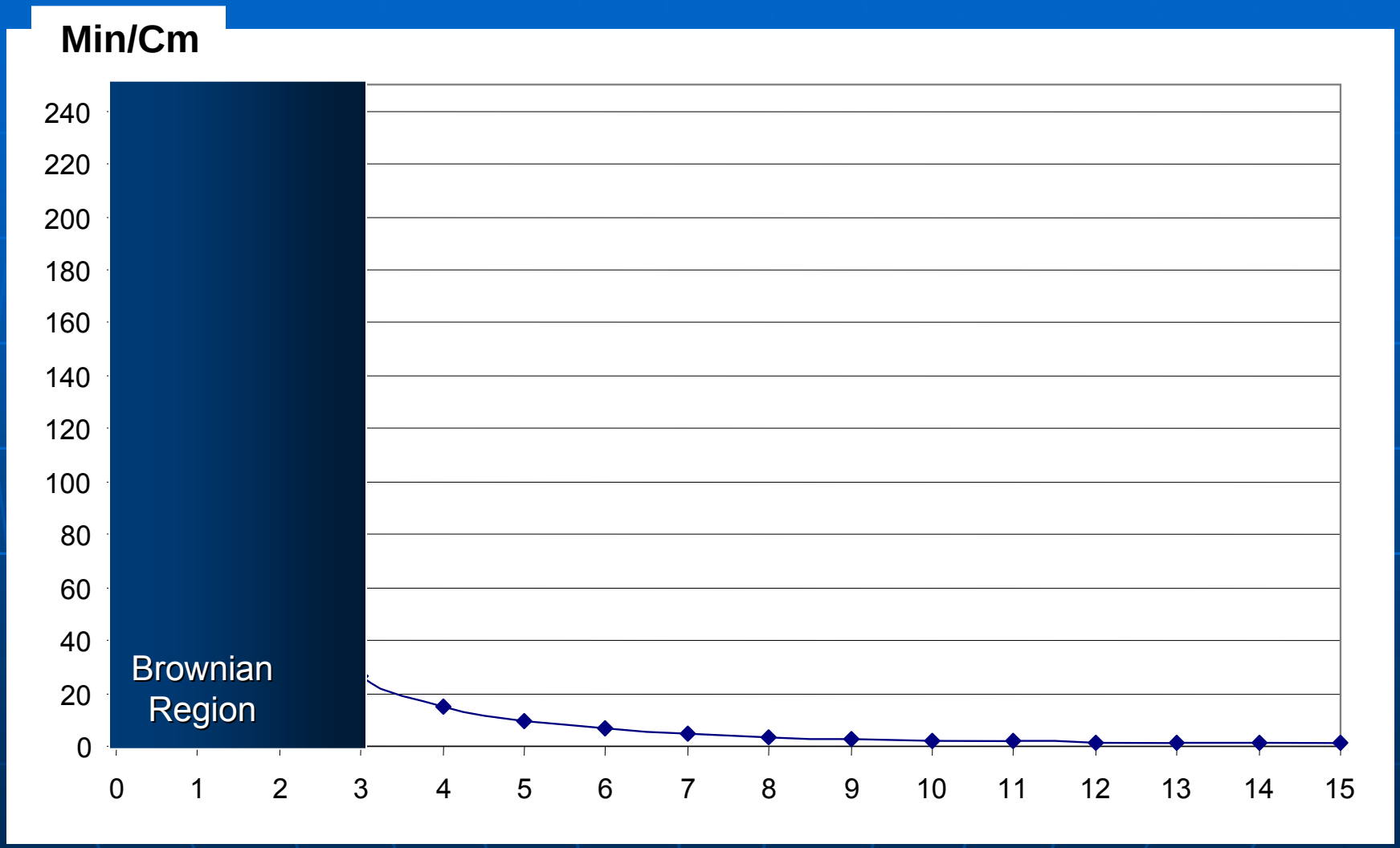
$$V_p = G\,(\rho_s - \rho)\,D^2 / 18\mu$$

where:

- V_p = rising or settling velocity of discrete particle
- G = gravity constant
- ρ_s = density of particle
- ρ = density of carrier fluid
- D = diameter of discrete particle
- μ = viscosity of carrier fluid

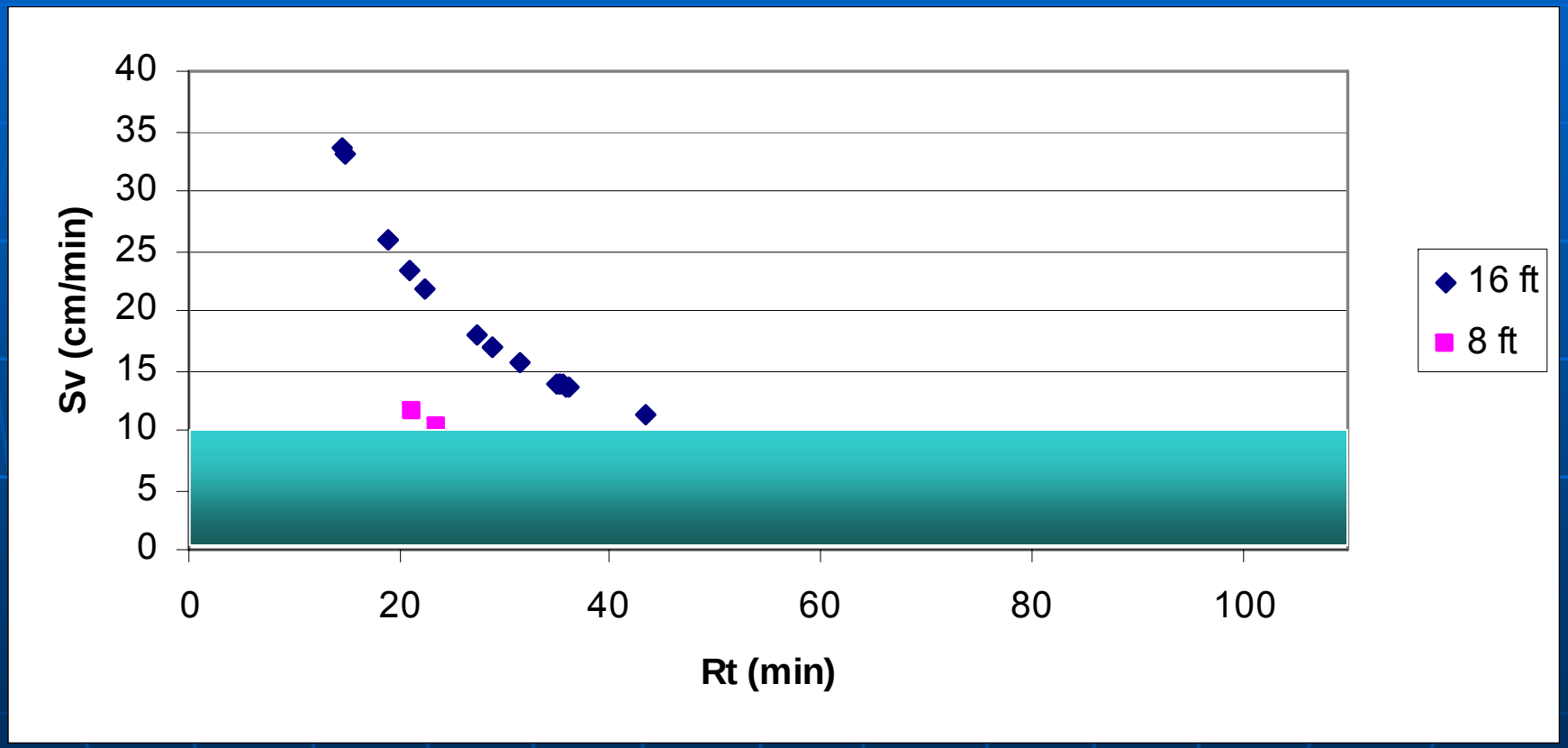
Stokes Law Assumes <u>Laminar Flow</u> and that <u>Particles Do Not Interact !</u>

Stokes Law Settling Time



Diameter (Microns)

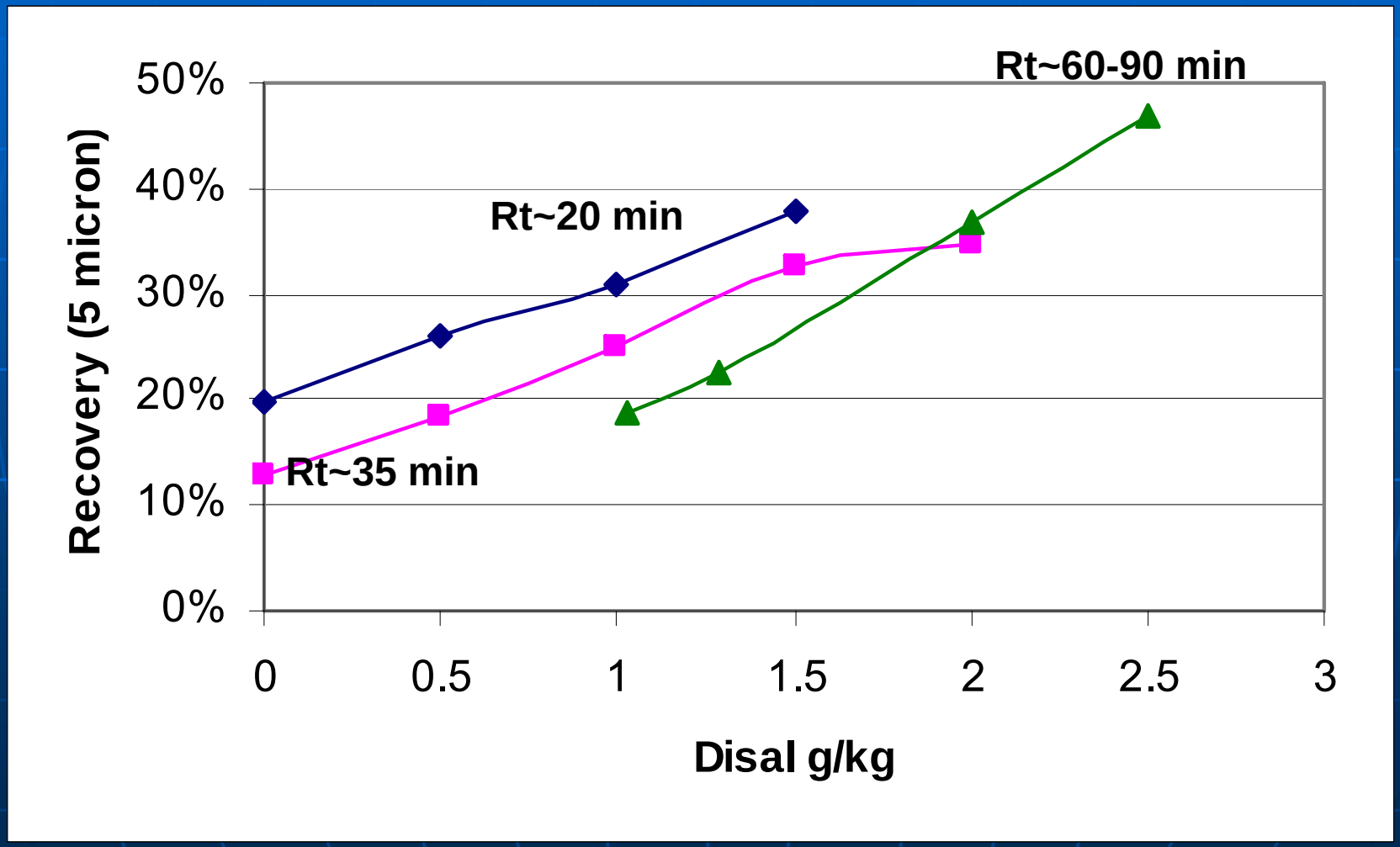
Classifier Rt-Sv Configurations



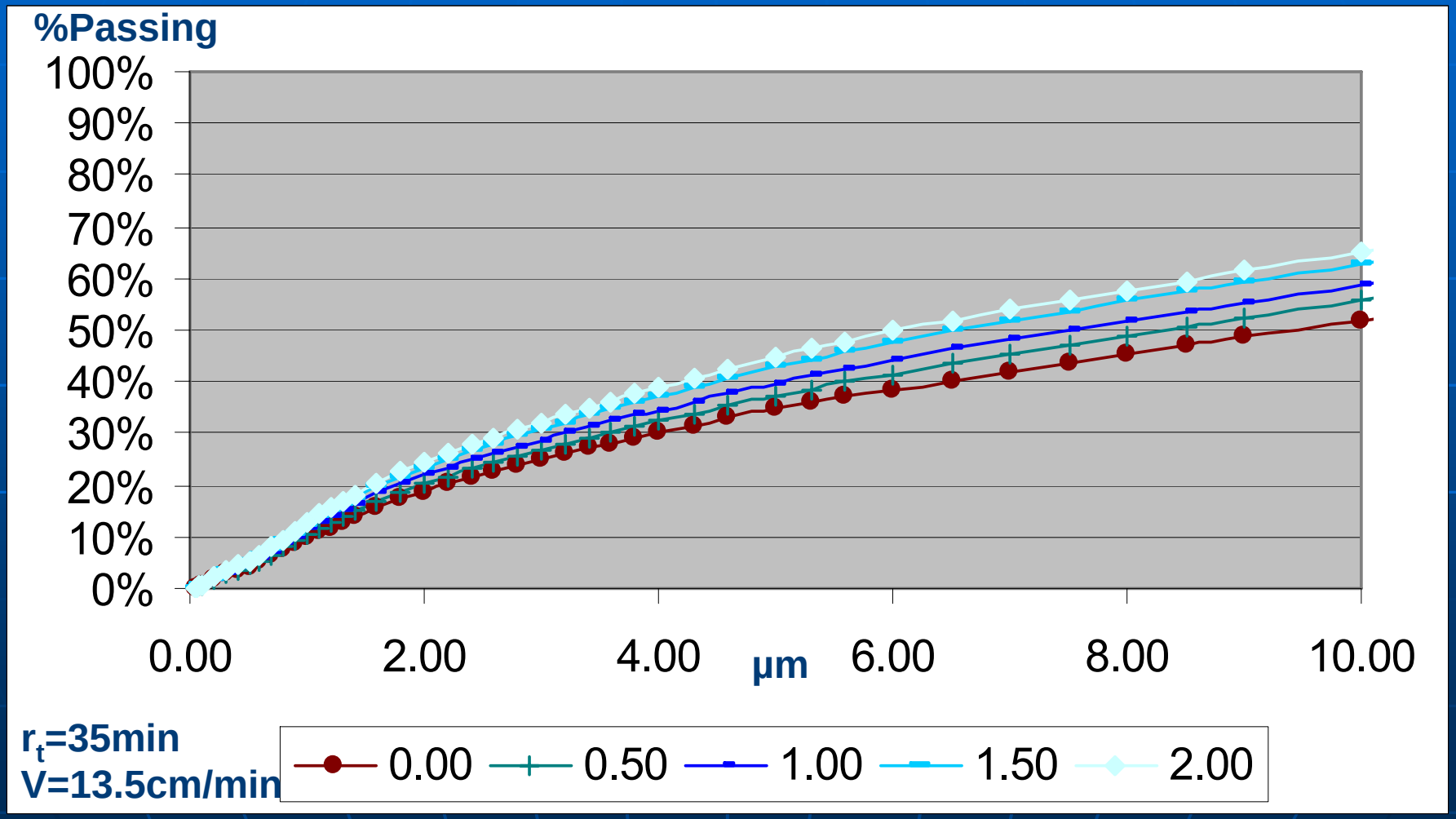
Rt = Q/V Sv = Q/A

Hydraulic Classifier Configurations

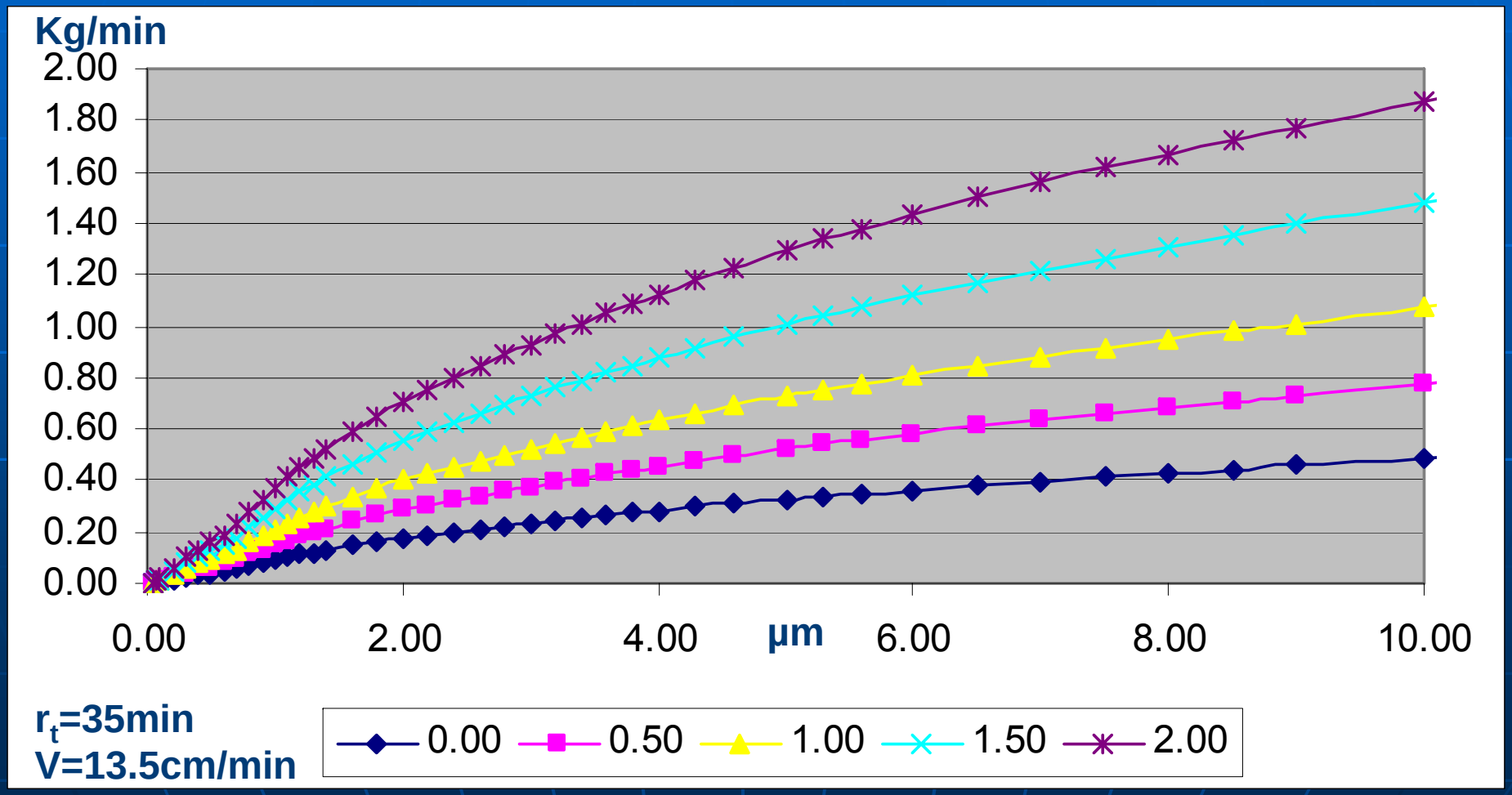
Disal Dosage vs Recovery



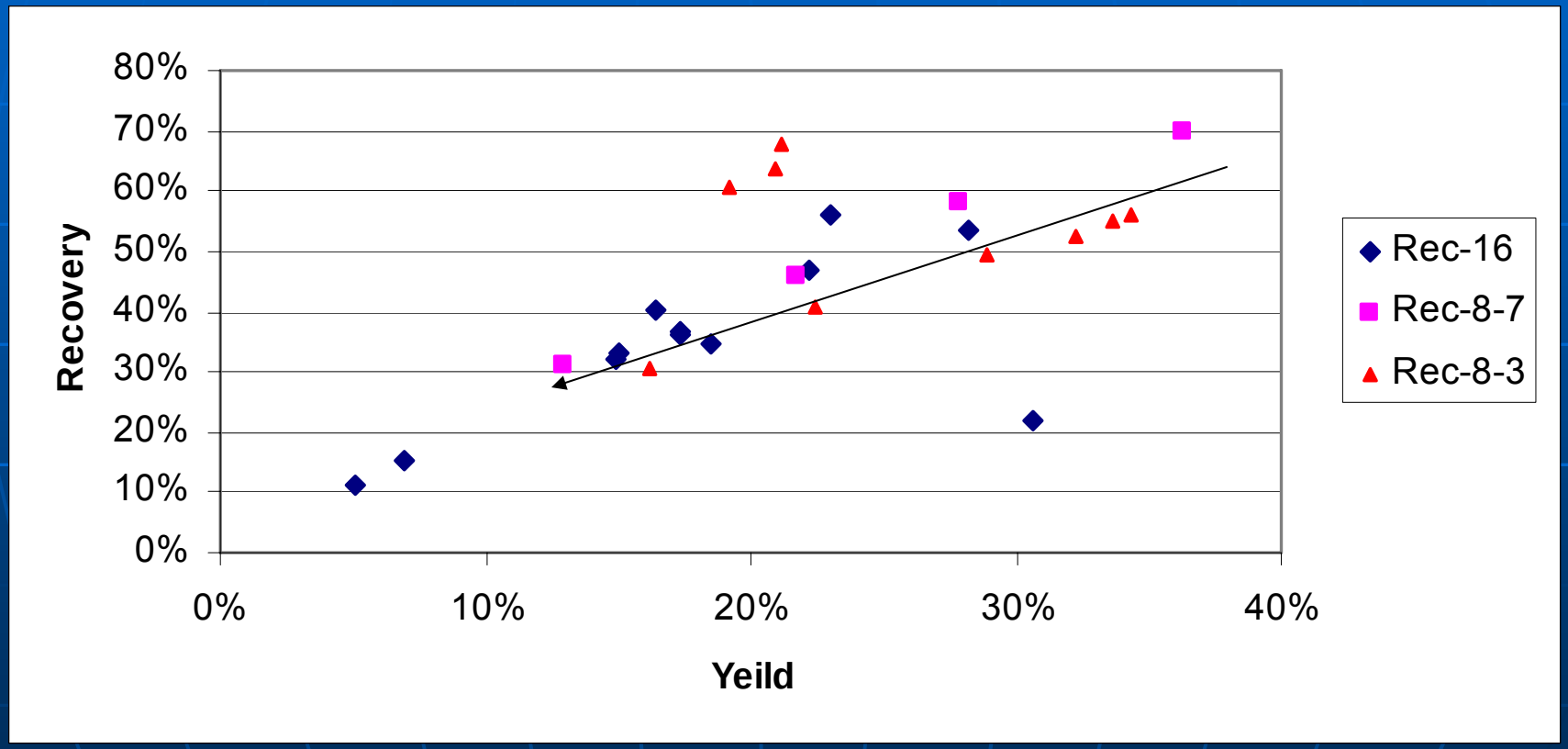
Affect of Dispersant Dosage on Particle Size



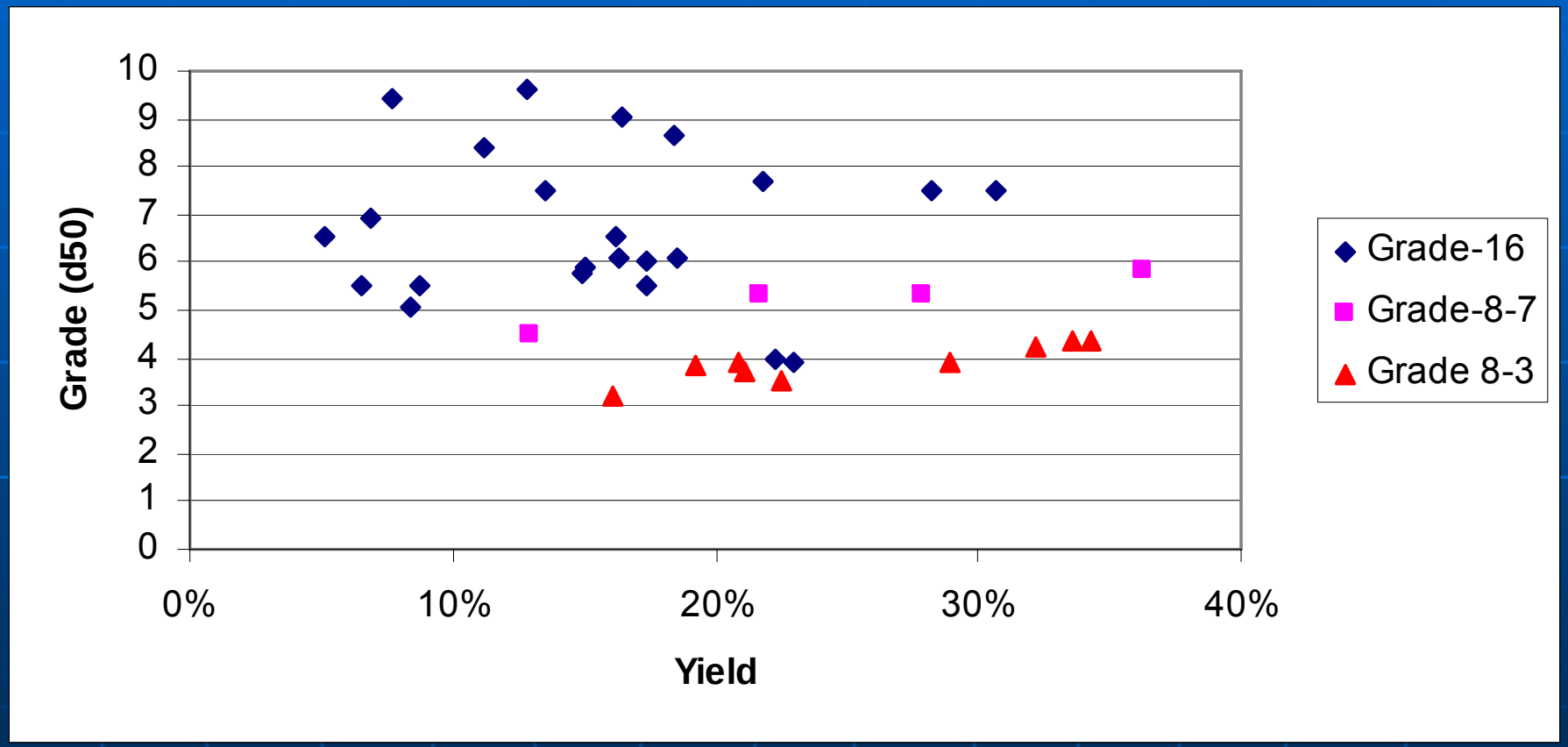
Affect of Dispersant Dosage on Mass Flow



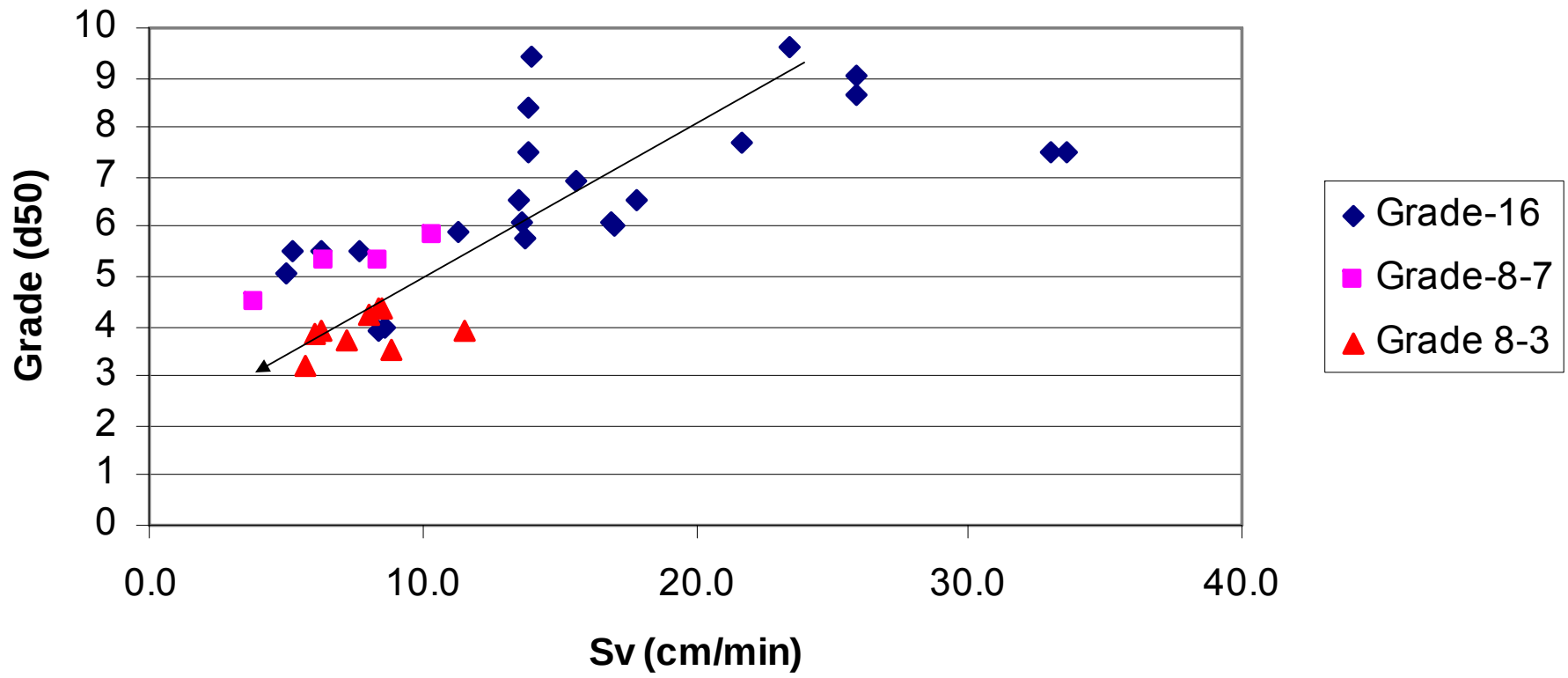
Yield-Recovery Data
Disal ≥2 mg/kg



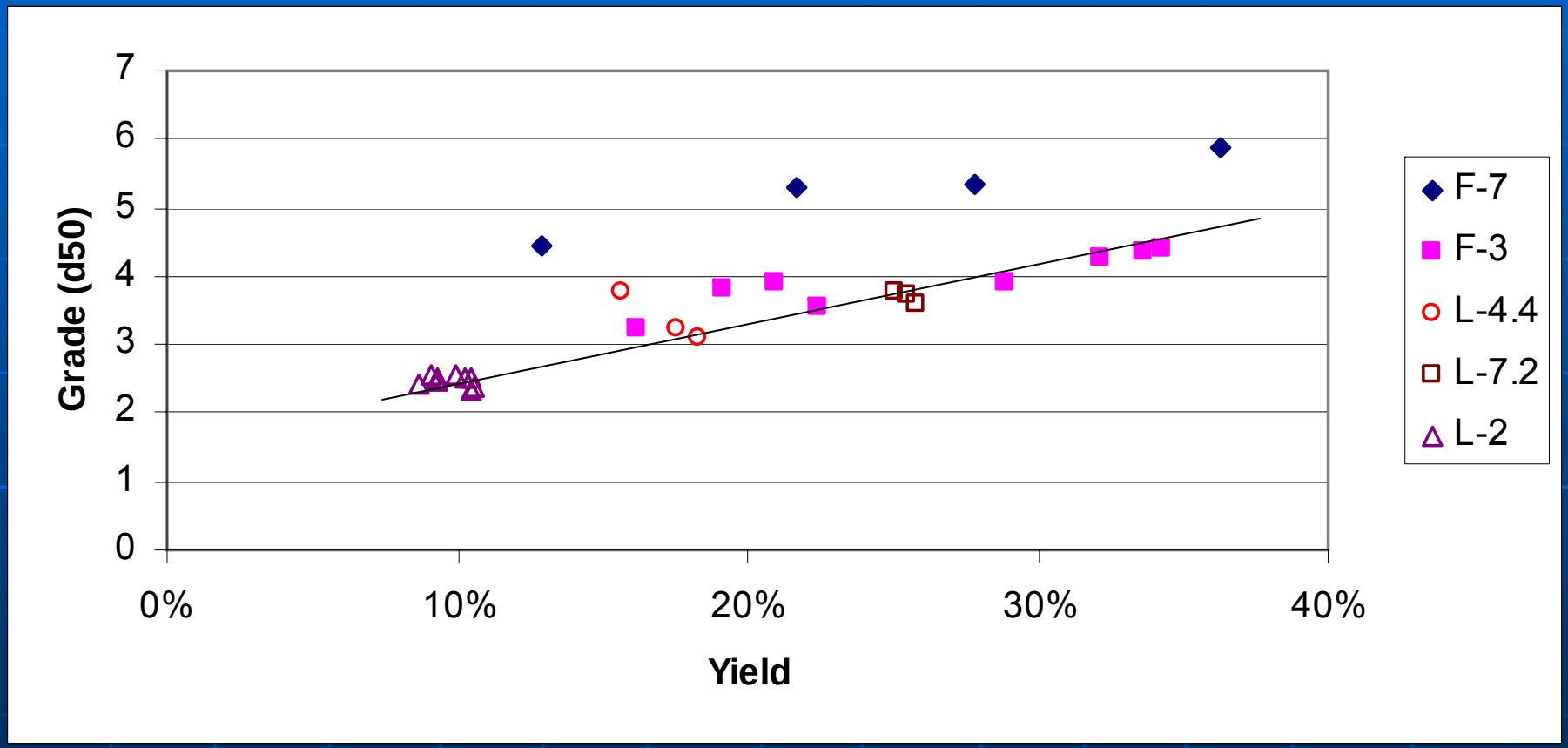
Grade/Yield All Field Data



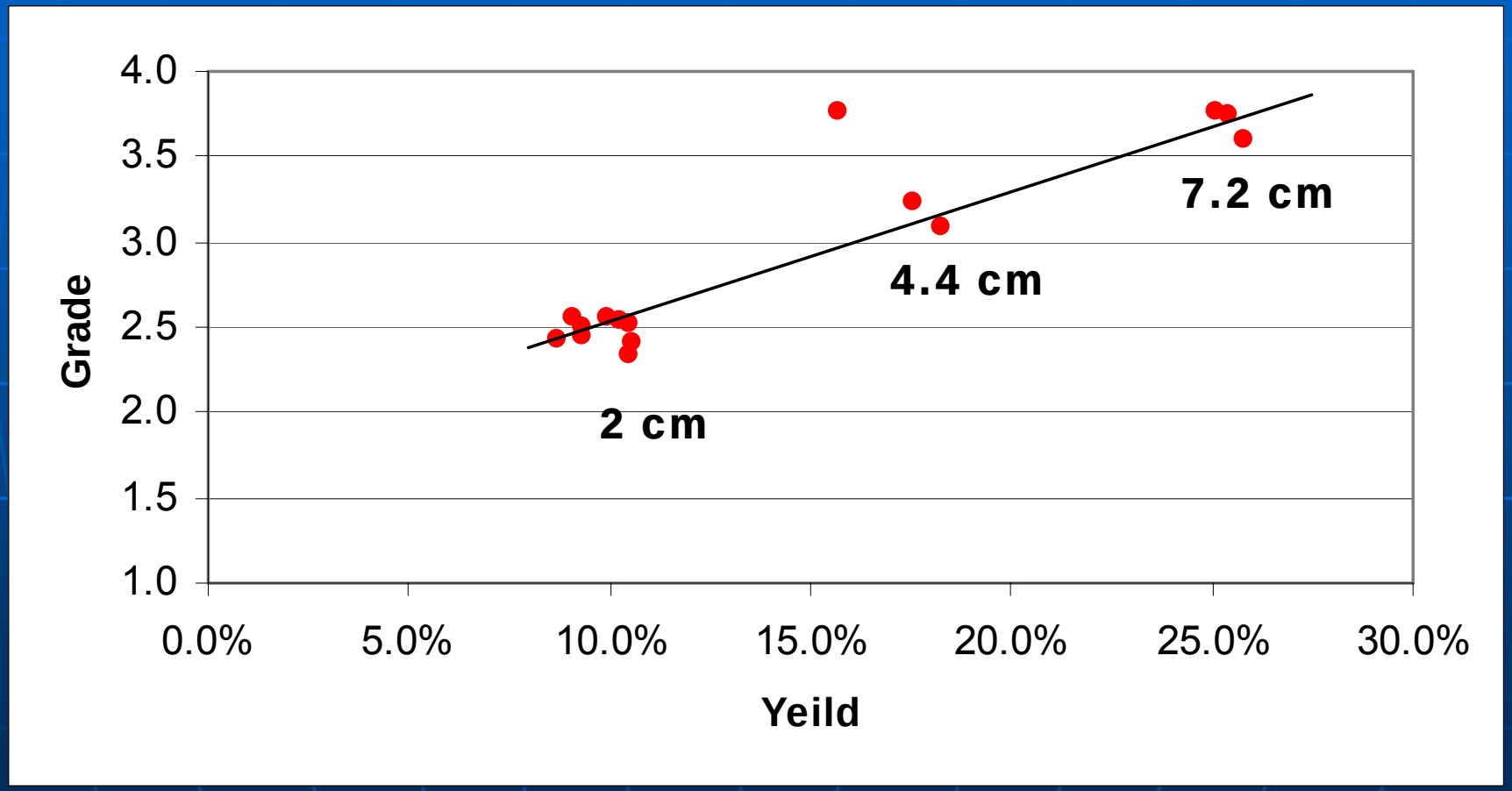
Grade vs. Superficial Velocity



Lab and Field Results

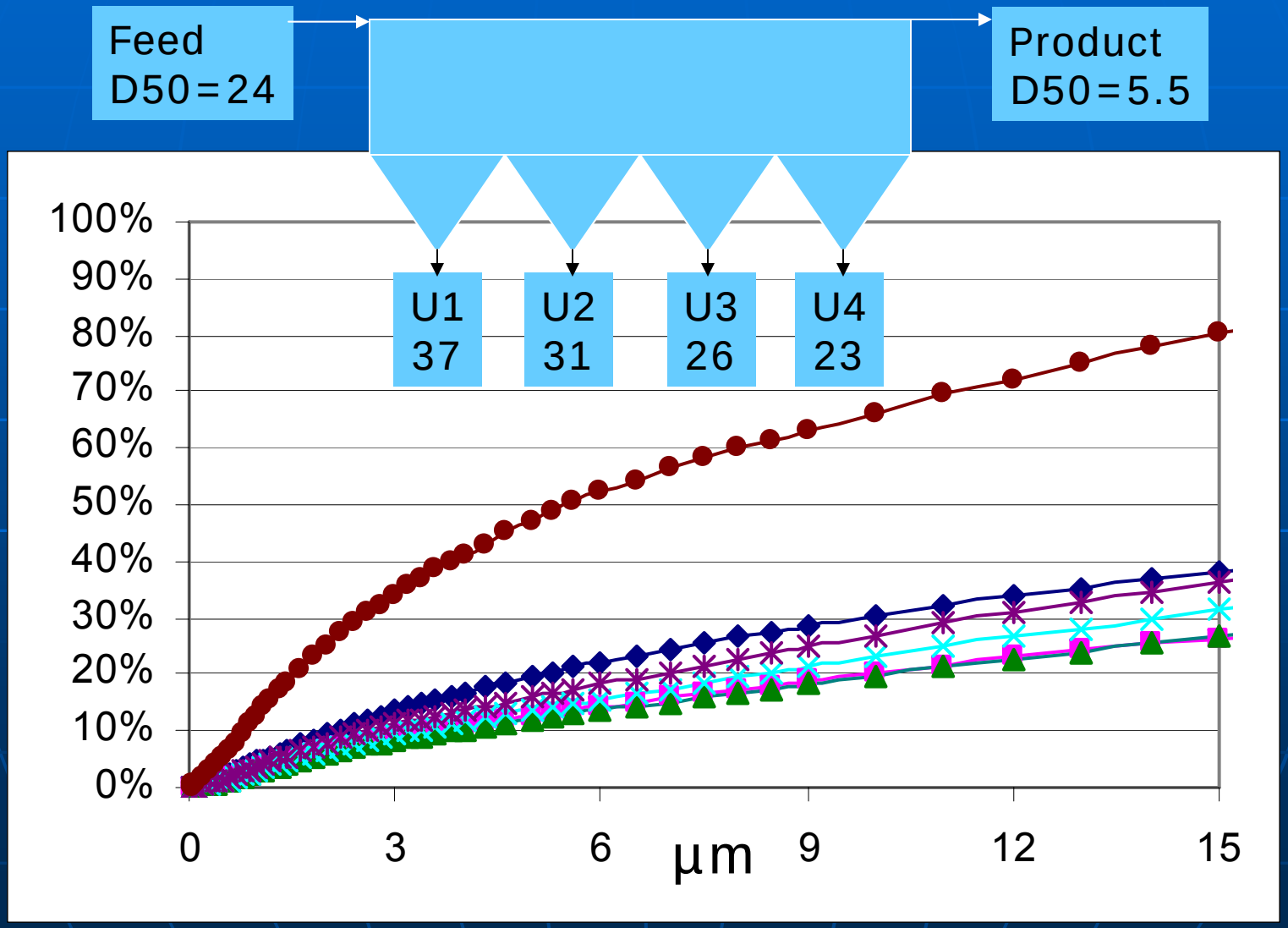


Affect of Lamellae Spacing

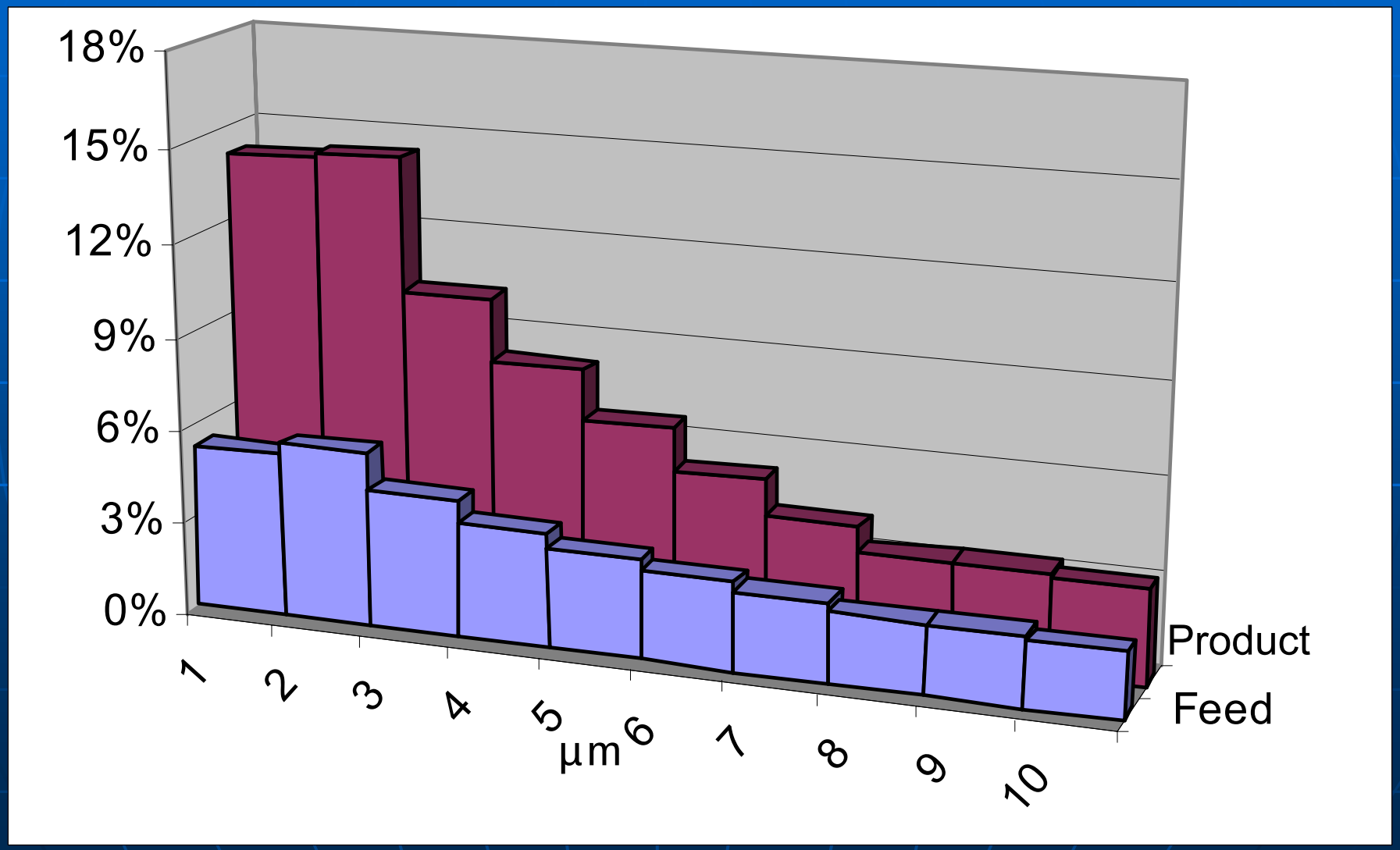


Lab data, Sv and Rt held constant at 39 min and 4.1 cm/sec

Secondary Classification Results



Secondary Classification Results

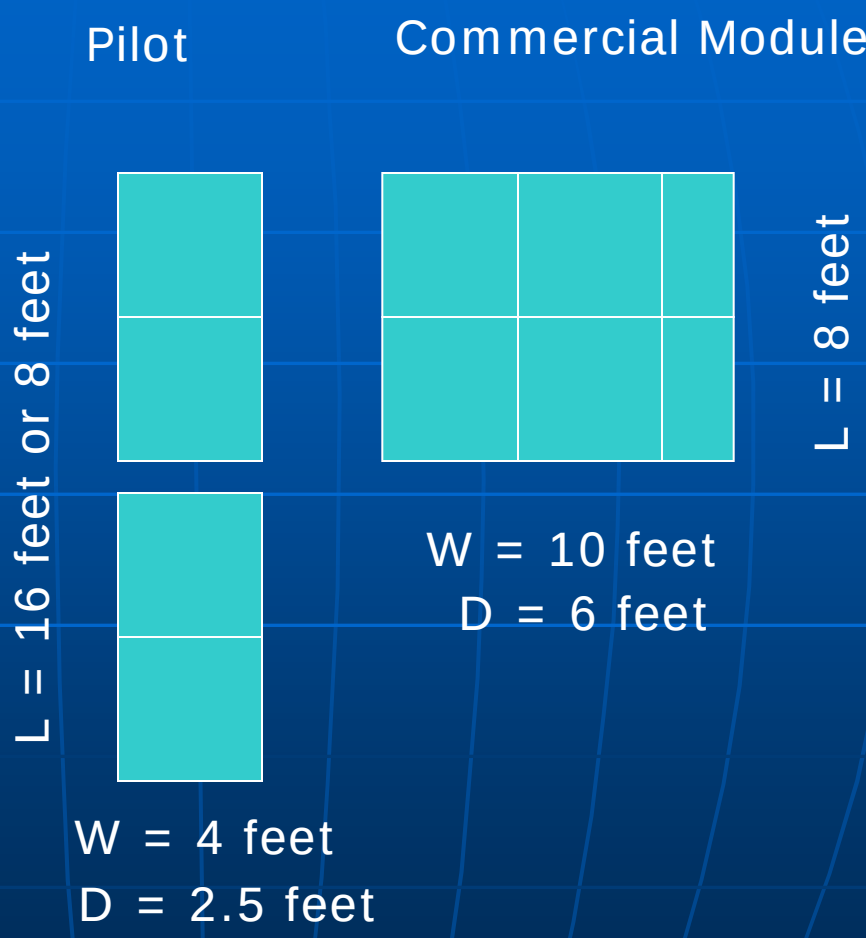


Lamellae Classifier Parameters: Ghent Ash

- Sv: less than 10 cm/min
- Retention Time: ~30 or Less minutes
- NSF Dosage: ~2.0 to 2.5 g/Kg
  - Based on Feed Solids
  - 40% liquid solution (Disal)
- Lamellae Spacing: ~3-4 cm
- Dry Underflow (60% Solids)
- Product:
  - D_{50} = ~4.5 µm
  - Yield = ~30% of Feed Solids

Scale Up

Feed = 15% solids
Slurry = 125 gal/min
= 470 l/min
Solids = 5 ton/hr
Rt = 29 min
Sv = 9 cm/min



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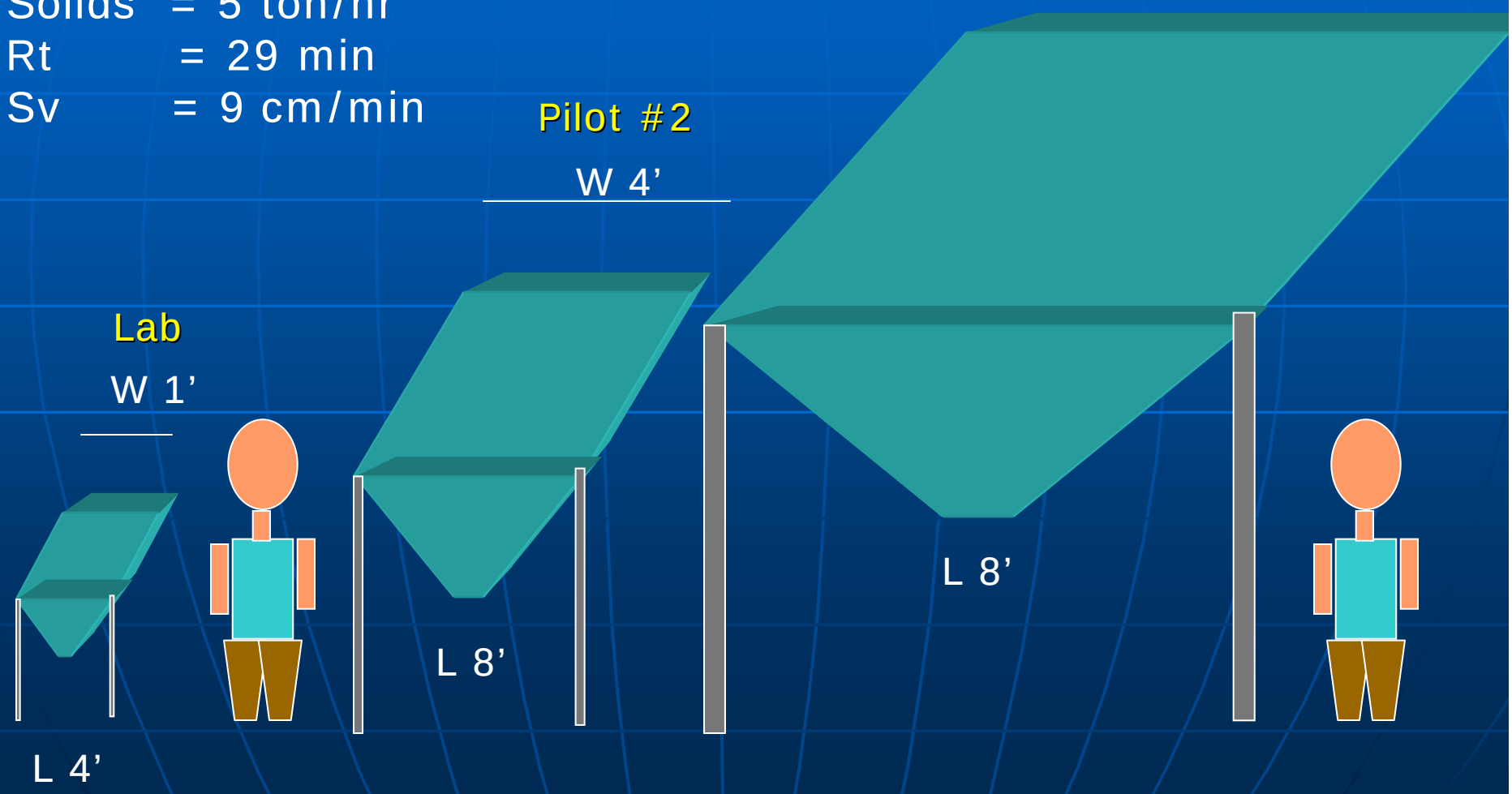
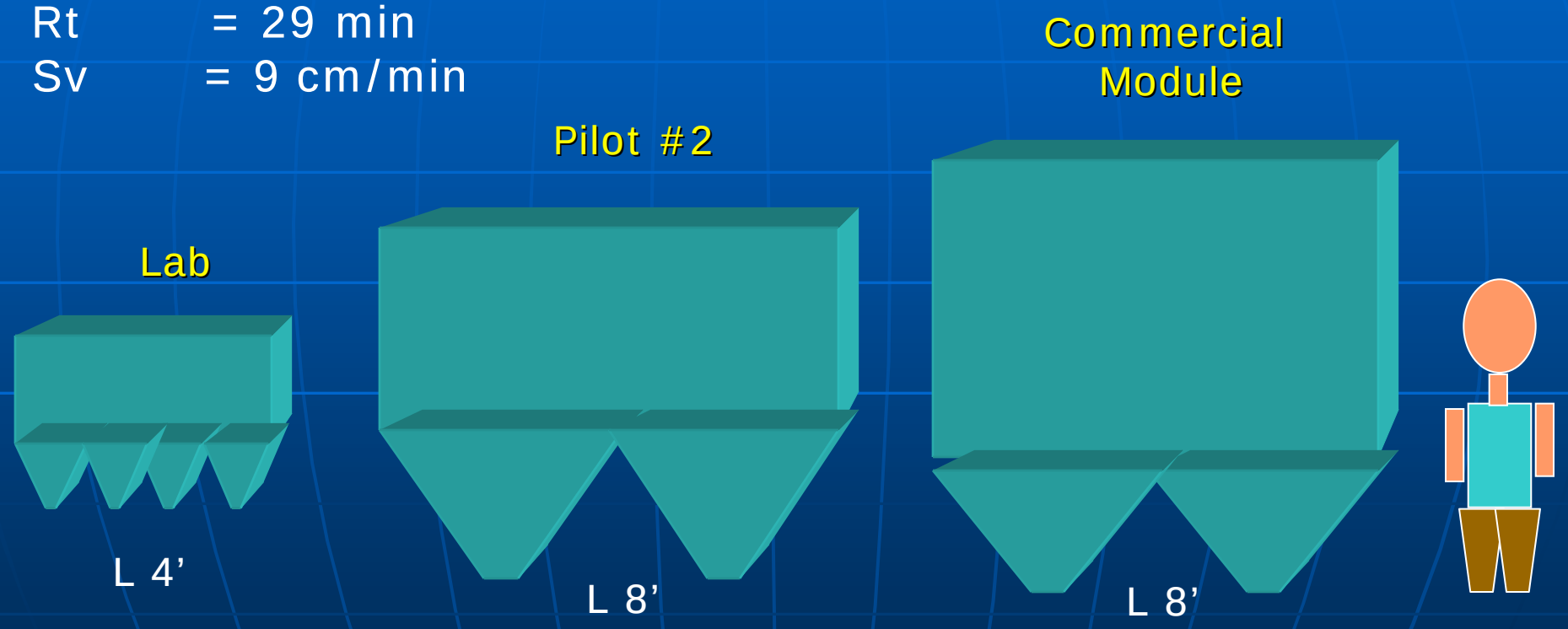


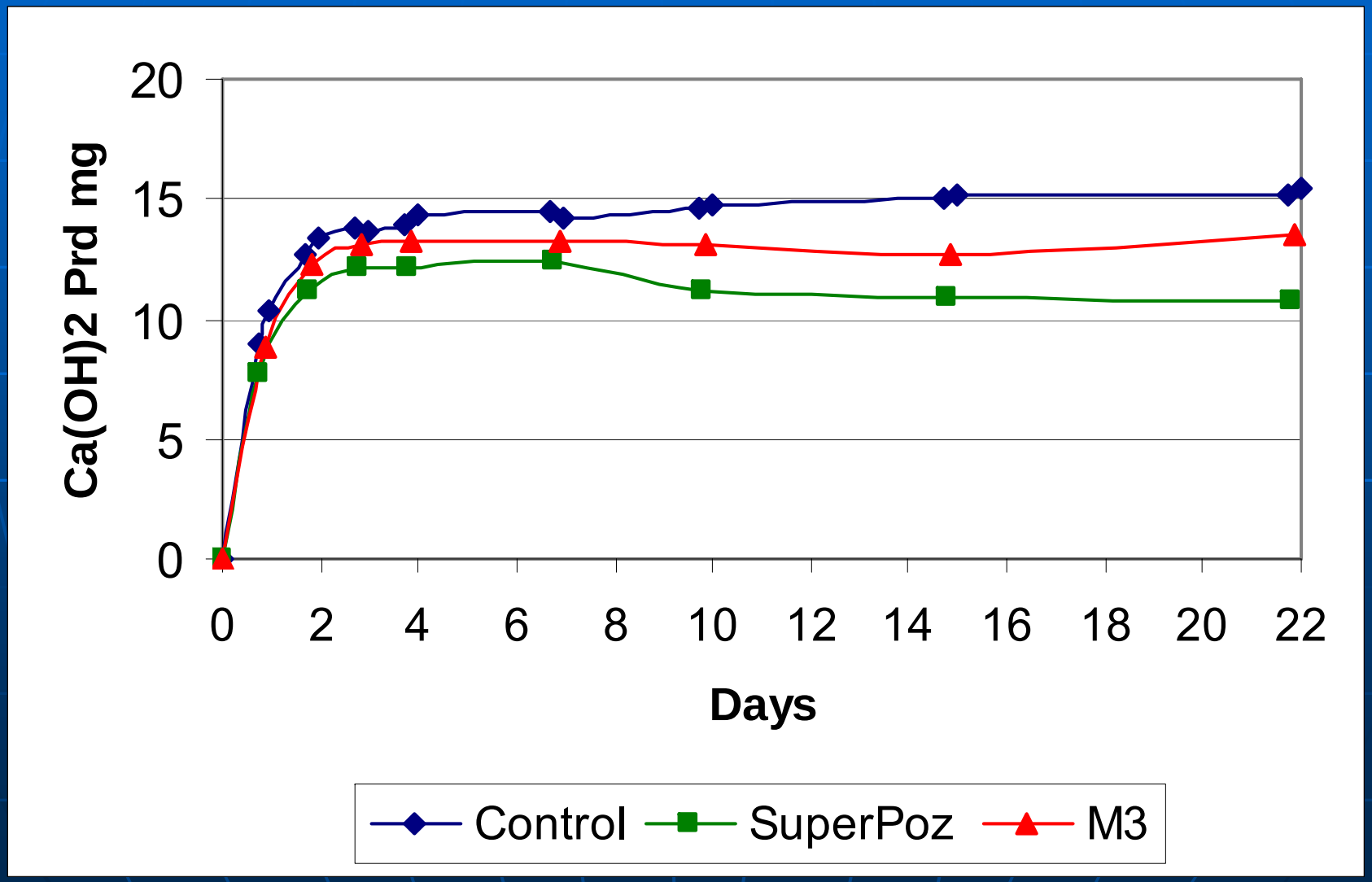
Scale Up of Technology

Feed = 15% solids
Slurry = 125 gal/min
= 470 l/min
Solids = 5 ton/hr
Rt = 29 min
Sv = 9 cm/min

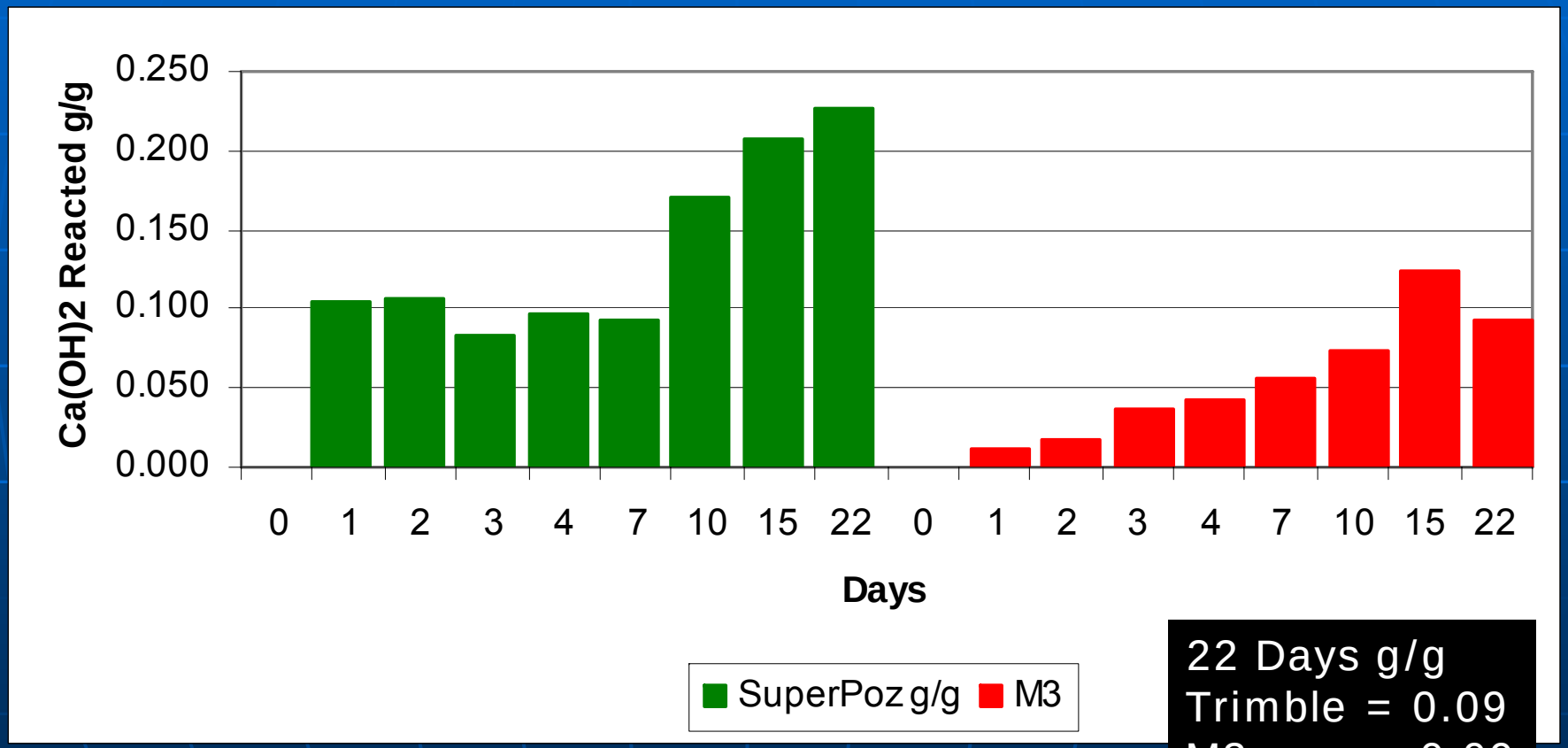


Mortar and Paste Results

$Ca(OH)_2$ Measured



$Ca(OH)_2$ Reacted

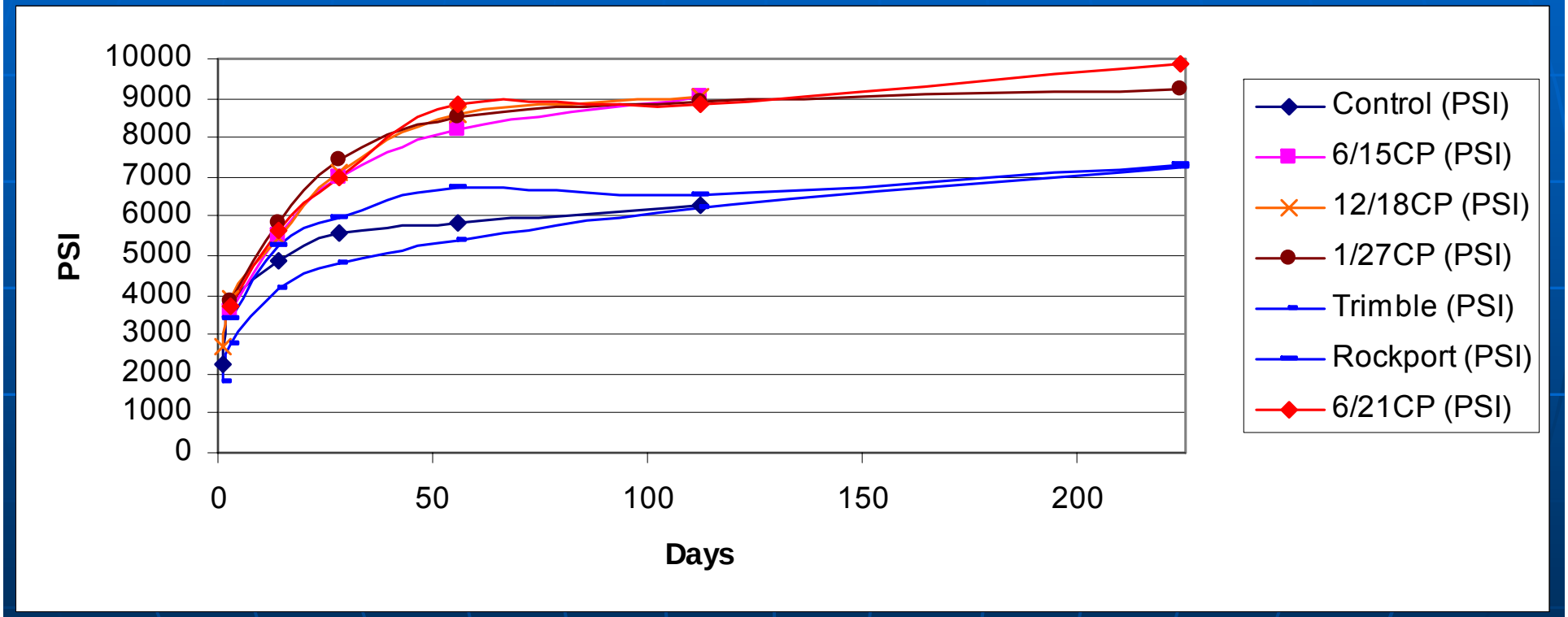


22 Days g/g
Trimble = 0.09
M3 = 0.09
SP 1 = 0.23
SP 2 = 0.23

Water Demand and Fineness Data

	Water %	D_{50}	Fineness (cm^2/g)
Underflow Product	95	11	-
Ghent Lab Products (20%)	93	3.0-6.0	8850-13400
Ghent Lab Products (40%)	87-89	-	-
Ghent Field Products (10%)	96-97	-	-
Ghent Field Products (20%)	93-95	4.5-5.5	9680-10700
Ghent Econosizer Product (20%)	93	20.3	4570
Ghent Flotation Product (20%)	93	20.3	4430
Mill Creek Product (20%)	97	4.4	11110
Coleman Product (20%)	96	7.3	7370
Trimble (10%)	99	-	-
Trimble (20%)	98	25.8	3270
Rockport (20%)	95	13.1	6770
Mill Creek (20%)	97	17.8	4580
Micron3 (20%)	91	3.0	14600

Mortar Data: Lab Ash



Mortar Data: Field Ash

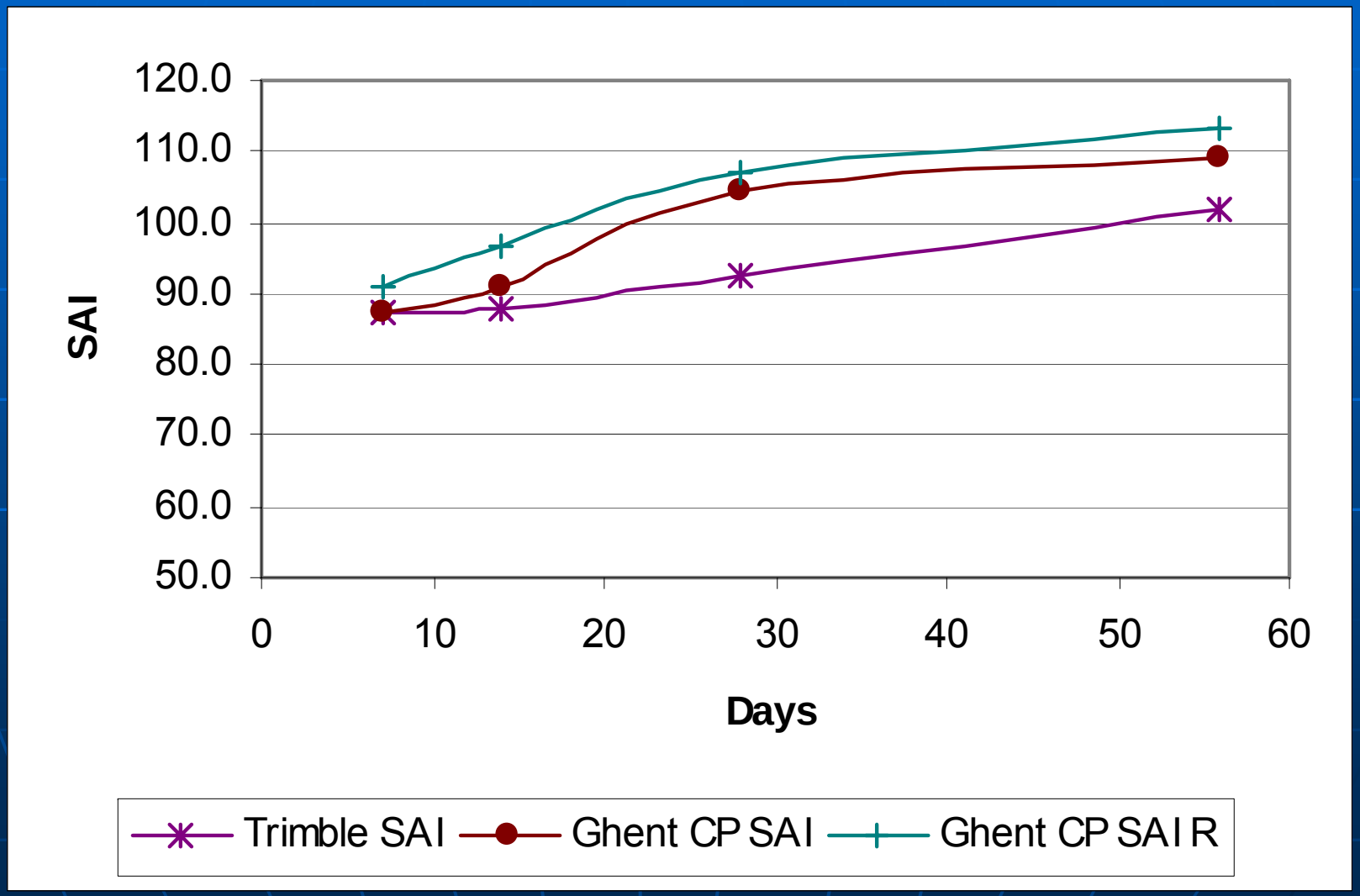
Time (days)	1day	7day	28day	56day
Control (PSI)	2509	4683	5597	6117
#78 (SAI)	95	95	116	121
#82 (SAI)	89	95	116	127
#85 (SAI)	94	99	123	125
#86 (SAI)	95	103	121	121
6/21 (SAI)	96	98	123	132
2.5 µm (SAI)	104	106	134	138

Product Evaluations in Mortar

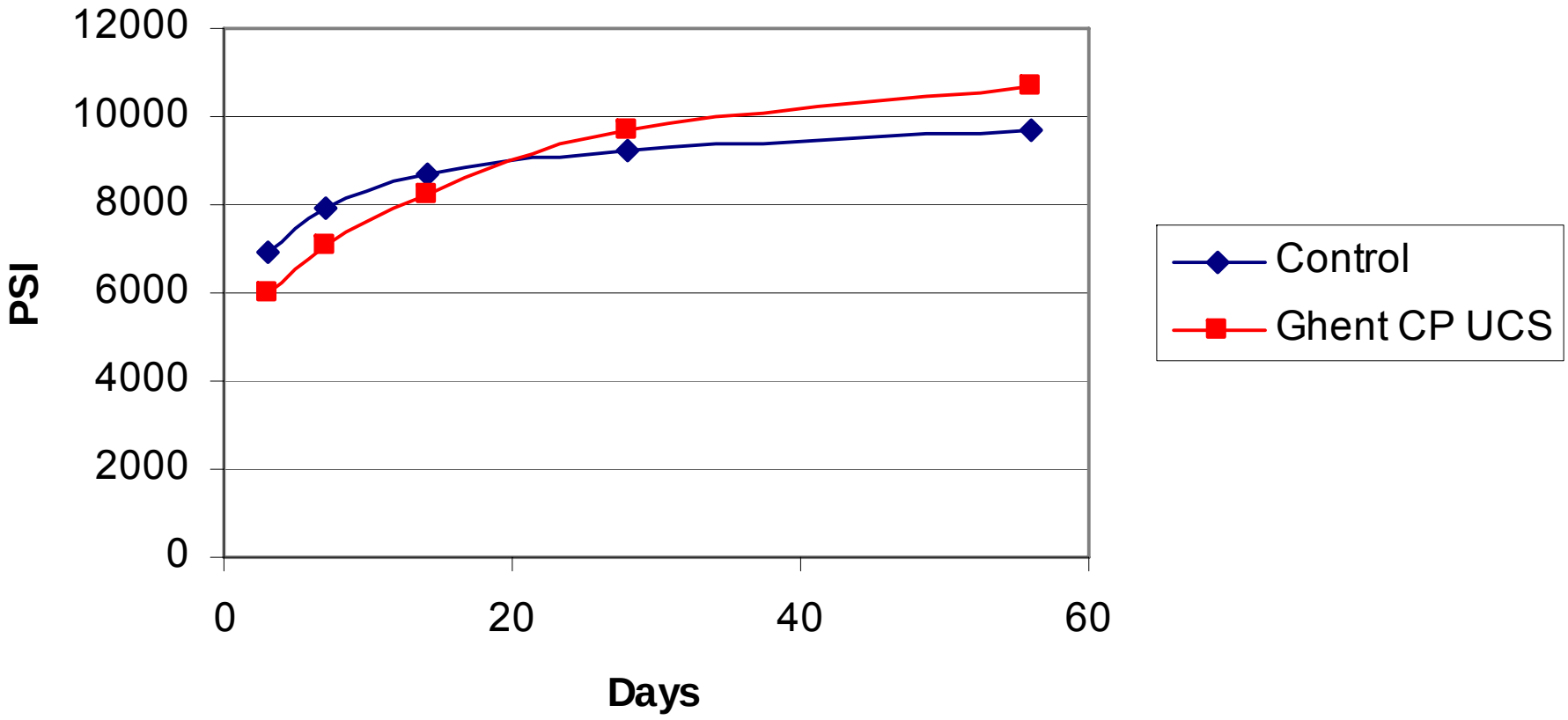
		Flowsheet 1	Flowsheet 2	Flowsheet 3	Flowsheet 4
Product		EP	FP	UFA	FUFA
d50	microns	14.3	19.2	3.2 - 6.0	4.8 - 5.5
Water Reduction	%	96	97 - 98	93 - 95	93 - 95
S.A.I. @20% Substitution	% of Control				
	7 Day	85	80 - 85	102 - 110	102 - 107
	28 Day	100	93 - 100	129 - 135	122 - 129
	56 Day	130	103	132 - 140	126 - 133
Mortar Air	ul of AEA To Constant 16% air	620	500	700 - 1600	820 - 1180

CONCRETE DATA

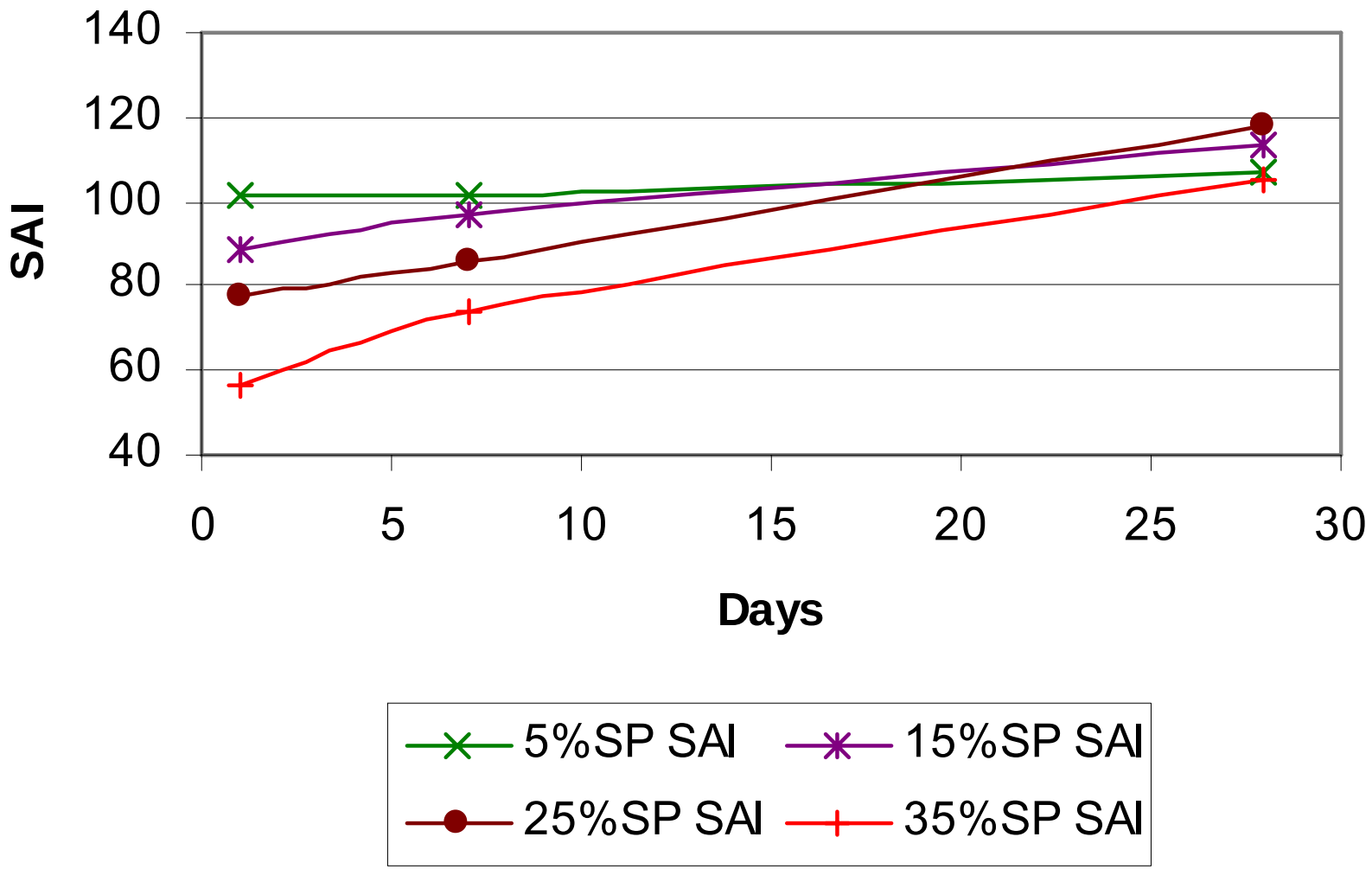
Concrete SAI Comparison Pavement Mix



Concrete Strength
HPC Mix



SAI as Function of Concentration

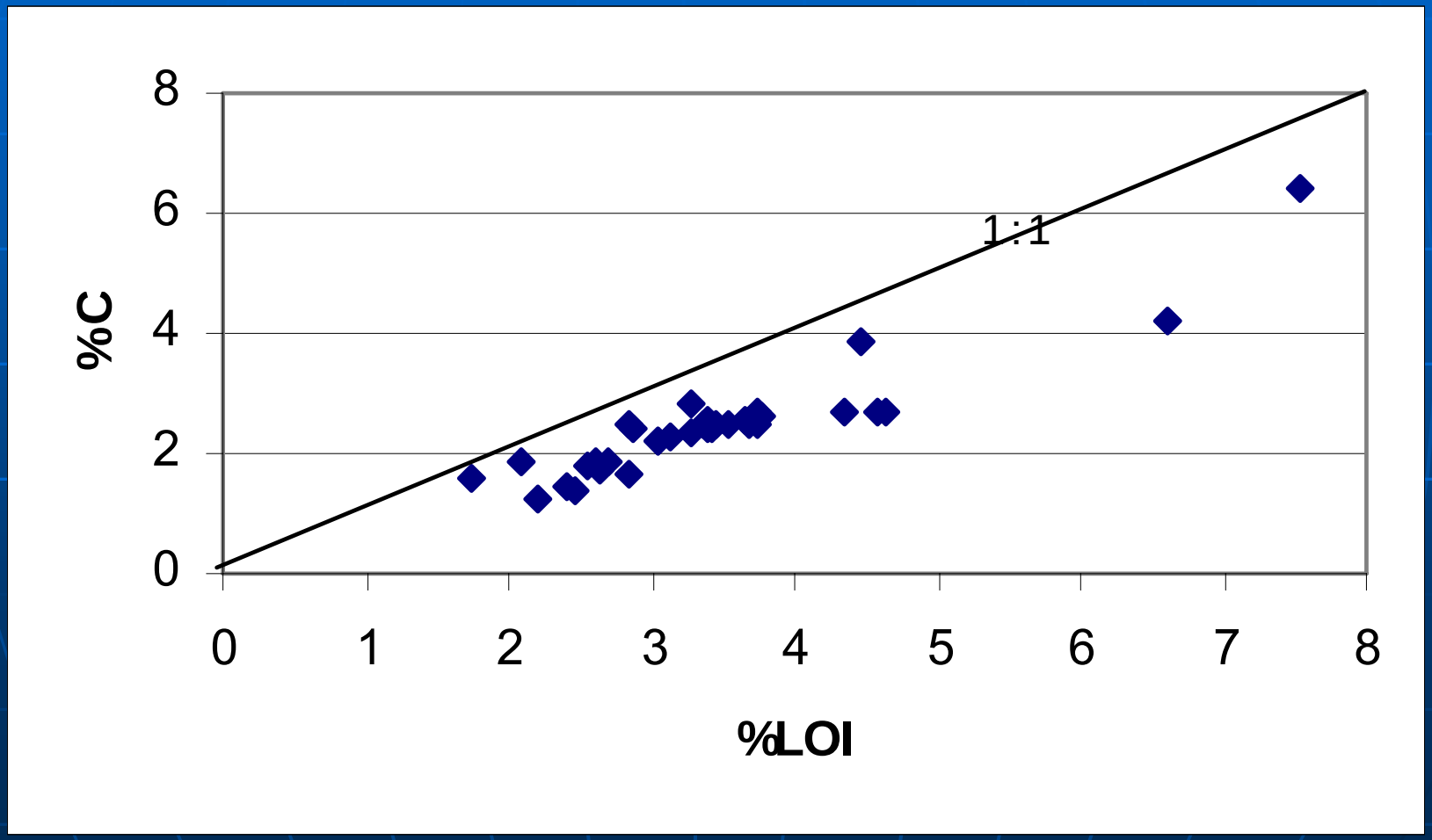


Comparison of Ghent SP SAI with Convention Class F

Time days	25% *HF SAI	25% *PG SAI	25%SP SAI	35%SP SAI
1	-	-	77.7	56.9
7	71.7	71.1	86.1	73.5
28	*81.4*	*80.2*	*118.1*	*105.3*
56	91.8	91.7	-	-

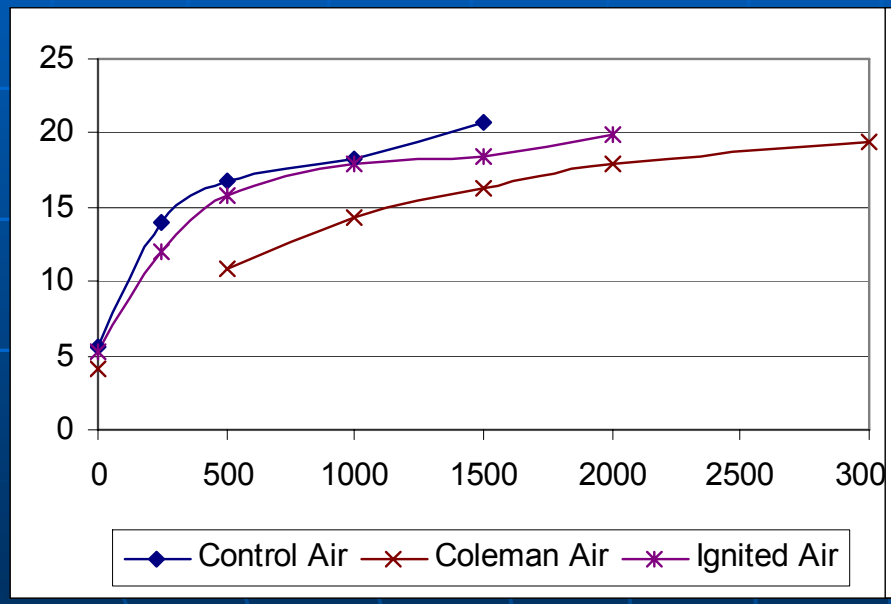
**Data for HF and PG averaged over 1 year, 12 replications*
Courtesy of LaFarge Corp.

Carbon vs LOI

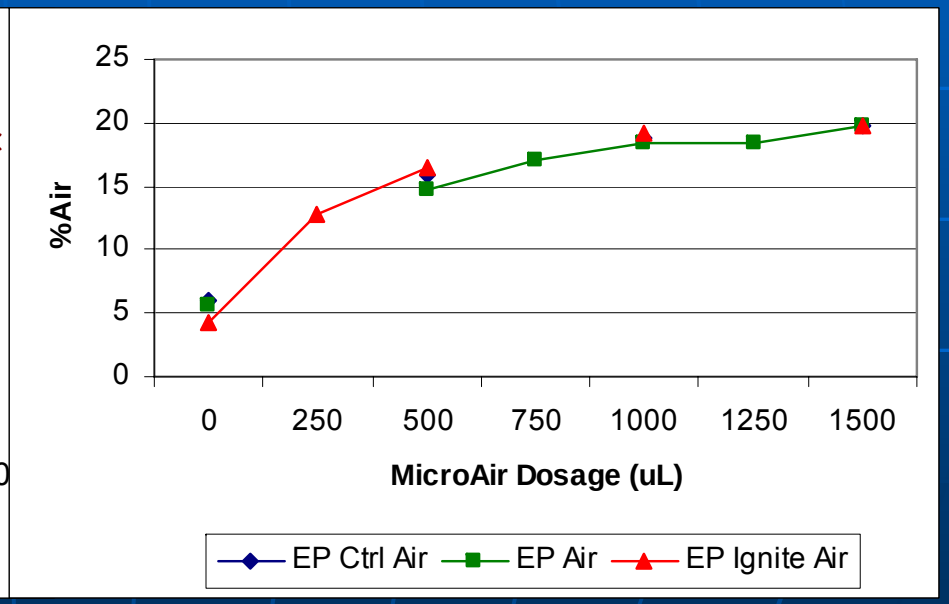


Effect of Pond Carbon on Air

Coleman



Ghent



Chloride Permeability

Concrete Mix	RCP (coulombs)	ASTM Chloride Rating
Control	2418	Moderate
F Ash 20%	1200	Low
Ghent CP 20%	426	Very Low
Ghent CP 40%	150	Very Low

Concrete Tensile and Flexural Strength at 56 days

Sample	Flexural PSI	Flexural Dev	Tensile PSI	Tensile Dev
Control	890	19.1	613	27.7
Trimble	930	4.9	526	70.3
Ghent CP	1056	35.4	625	38.3

Evaluation of SuperPozz as a Process Addition

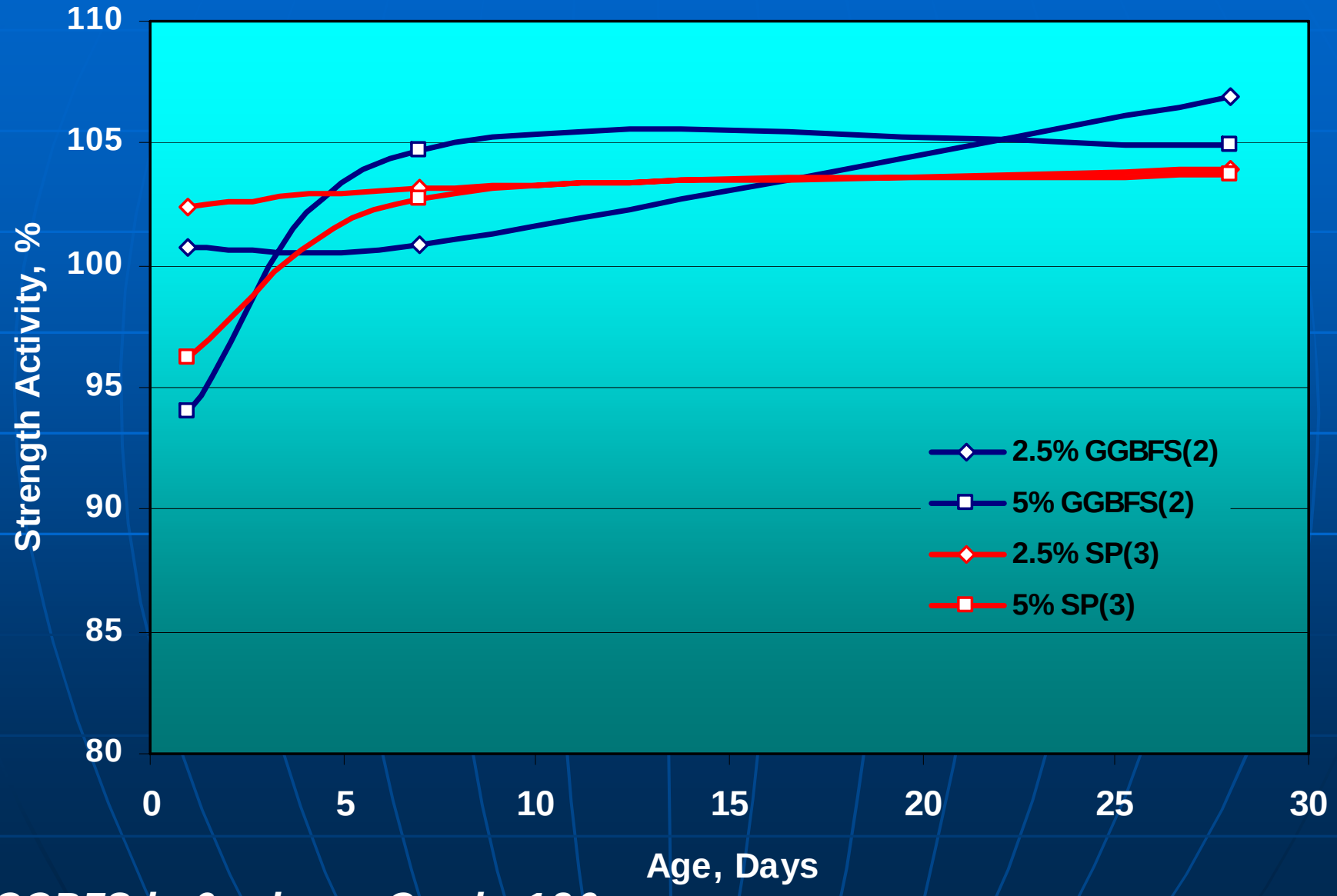
Ghent UFA

Dewatered to 65-70% solids slurry which will be pumpable and stable

Properties:

- D50: 3 – 5 µm
- density: ~2.41
- LOI: 3 %
- Carbon: 1 – 2

SuperPozz vs. GGBFS*



GGBFS is 6 micron Grade 120

Results of Mortar Testing

GGBFS and SP slightly improved the 1 day strength activity at 2.5% substitution; at 5%, strength was 94 – 96% relative to control

SP consistently exhibits higher 1 day strength activity relative to GGBFS at 2.5% and 5%

GGBFS and SP similar in 28 day strength activity at 2.5% and 5%, which ranged between 104 – 107%

Advantages for Kiln

Extend clinker, increase production capacity with a minor capital investment

Lower cost relative to ground granulated blast furnace slag (FOB cement plant)

Early and ultimate strength improved at 2.5% substitution rate

Improved grinding efficiency*

Reduced CO_2 Emission

**Grinding efficiency of the mills should be improved due to the finely divided state and spherical morphology of the fly ash; grinding addition rate should also decrease*

Advantages for Project

- Simplify Project Startup
  - Greatly Reduced Marketing Issues
- Eliminate Need for Dryer*
  - Greatly Reduced Capital Cost

** Slurry will contribute 1.1 – 1.3% water relative to the clinker, which will be part of the cooling water*

Recommendations

Conduct an industrial trial with 2.5% SuperPozz according to ASTM C465 guidelines

Conduct mortar and concrete testing of industrially ground cement at CAER and Cemex USA

Field Testing: Conclusions

- Reasonable Scale Up Factors.
- Modest Reagent Costs.
- Recovery of High Quality Products.
  - Excellent Fineness.
  - High Strength Index.
- Reasonable Capital Costs.

Comparisons for 50 tph Design Basis

	Flowsheet	1	2	3	4
Unit Processes	Primary Classification	X	X	X	X
	Spiral Concentration	X	X	X	X
	Froth Flotation		X		X
	2nd Classification			X	X
Total Installed Equipment Cost		$3.24M	$4.00M	$3.44M	$4.21M
Additive Cost	$/feed ton	0.029	0.622	1.08-1.35	1.52-1.75
	$/product ton (pozzolan or UFA)	0.033	0.828	3.88-4.48	4.58-5.52
Pozzolan	tph	46.5	43.7	-	-
	% LOI	3.5	2.3	-	-
	% Moisture	20	20	-	-
UFA	tph	-	-	14.0	13.1
	% LOI	-	-	2.5	<3
	% Moisture	-	-	30	30
Coarse Carbon	tph	0.4	0.4	0.4	0.4
	Btu/lb (dmf)	5400	5400	5400	5400
Fine Carbon	tph	-	2.8	-	2.8
	Btu/lb (dmf)	-	2700	-	2700

Operating Costs 50 tph Basis

Plant Operating Costs

Floesheet	1	2	3	4
Maintenance ($0.30/Feed ton)	$61,590	$61,590	$61,590	$61,590
Power	$87,355	$132,224	$103,139	$147,015
Fuel (Drying)	$0	$0	$0	$0
Desel Fuel	$50,960	$50,960	$50,960	$50,960
Labor	$246,170	$246,170	$246,170	$246,170
Chemicals/Flotation	$6,384	$150,887	$0	$0
Chemicals/UFA	$0	$0	$178,931	$167,428
Loader Lease	$36,000	$36,000	$36,000	$36,000
Tot. Plant Oper. Cost	**$488,459**	**$677,832**	**$676,790**	**$709,163**
10% Oper. Contingency	**$48,846**	**$67,783**	**$67,679**	**$70,916**
Total Operating Cost	**$537,305**	**$745,615**	**$744,469**	**$780,080**

Costs Per Ton Product mix

Flowsheet	1 (100% Poz)	2 (100%Poz)	3 (100%UFA)	4 (100%UFA)
Maintenance ($0.30/Feed ton)	$0.32	$0.34	$1.06	$1.13
Power	$0.45	$0.73	$1.77	$2.70
Fuel (Drying)	$0.00	$0.00	$0.00	$0.00
Desel Fuel	$0.26	$0.28	$0.88	$0.94
Labor	$1.27	$1.35	$4.23	$4.52
Chemicals/Flotation	$0.03	$0.83	$0.00	$0.00
Chemicals/UFA	$0.00	$0.00	$3.07	$3.07
Loader Lease	$0.19	$0.20	$0.62	$0.66
Tot. Plant Oper. Cost	**$2.53**	**$3.73**	**$11.62**	**$13.01**
10% Oper. Contingency	**$0.25**	**$0.37**	**$1.16**	**$1.30**
Total Operating Cost	**$2.78**	**$4.10**	**$12.78**	**$14.31**

Phase II

- Submit Continuation, 7/1/06
- Cemex Review of Data, 7/6/06
- Down-select Flowsheet, 9/1/06
- USDoE Review of Continuation Complete 9/1/06

Task 2, 6 Months

Subtask 2.1 Preliminary Plant Design, 3 Months

2.1.1 Flow Diagrams

2.1.1.1 Water Balance

2.1.1.2 Solids Balance

2.1.2 Preliminary Plant Design

2.1.2.1 Plant Sizing

2.1.2.2 Final Preliminary Design

2.1.2.3 Equipment List

2.1.2.4 Design Review and Comment

Subtask 2.2 Detailed Engineering Design, 3 Months

2.2.1 A&E Selection

2.2.2 Detailed Design Drawings

2.2.3 Cost Estimate