Distribution of Chloride, pH, Resistivity, and Sulfate Levels in Backfill for MSE Walls and Implications for Corrosion Testing

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Major Sources of Variability in FMs

Assessed through field, laboratory, and inter-laboratory studies

- pH

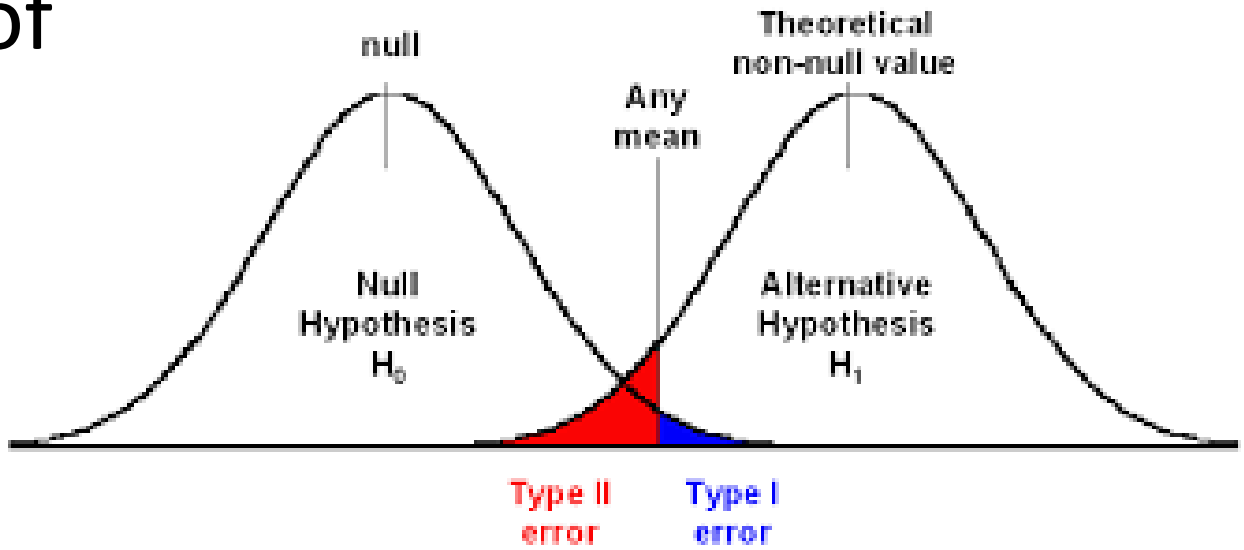
  Condition of electrode, measurement temperature, electrode memory effects, ionic strength of soil
- Minimum Resistivity

  Water content of test slurry, measurement temperature
- Chloride Concentration

  Soil mass, suspended solids or color in sample, incorrect or out-of-date reagents, blank correction
- Sulfate Concentration

  Soil mass, suspended solids or color in sample, incorrect or out-of-date reagents, calibration curve

Development of Operating Characteristic Curves



www.statstodo.com

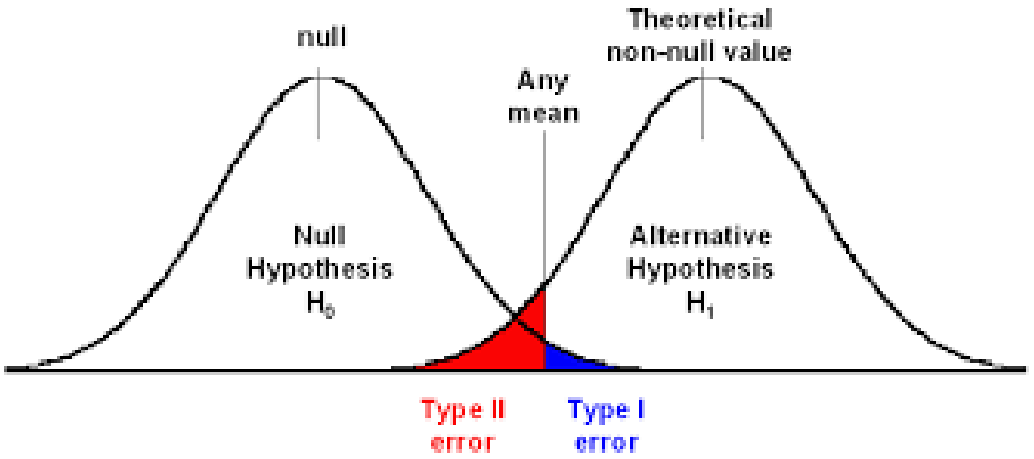
www.six-sigma-material.com

ACTUAL	DECISION: *Reject H_o*	DECISION: *Fail to Reject H_o*
H_o True	Type I Error *Producer Risk* α-Risk False Positive	**Correct Decision** Confidence Interval = 1- α
H_a True	**Correct Decision** **Power = 1- β**	Type II Error *Consumer Risk* β-Risk False Negative

H_o: Null Hypothesis H_a: Alternative Hypothesis

Type I (α) error: probability of accepting a backfill when it should be rejected.
Type II (β) error: probability of rejecting a backfill when it should be accepted.

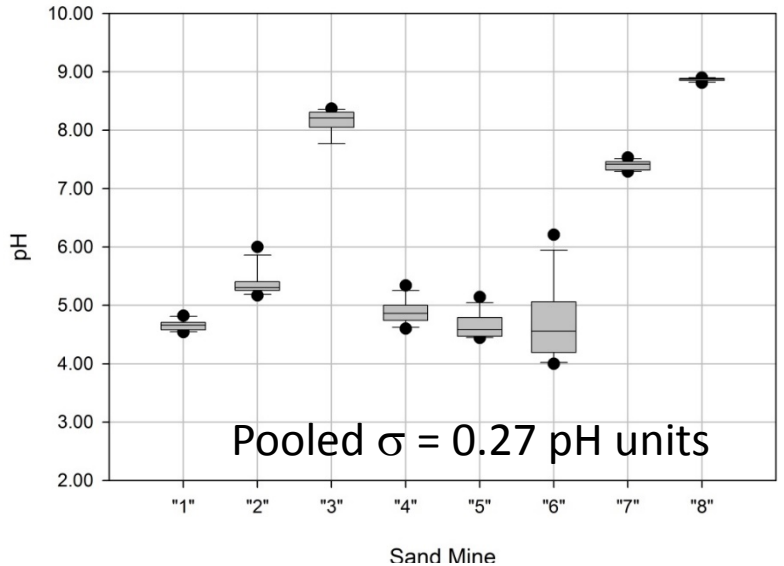
How can we obtain a low Type II (β) error, that is, more power to accept a good backfill?

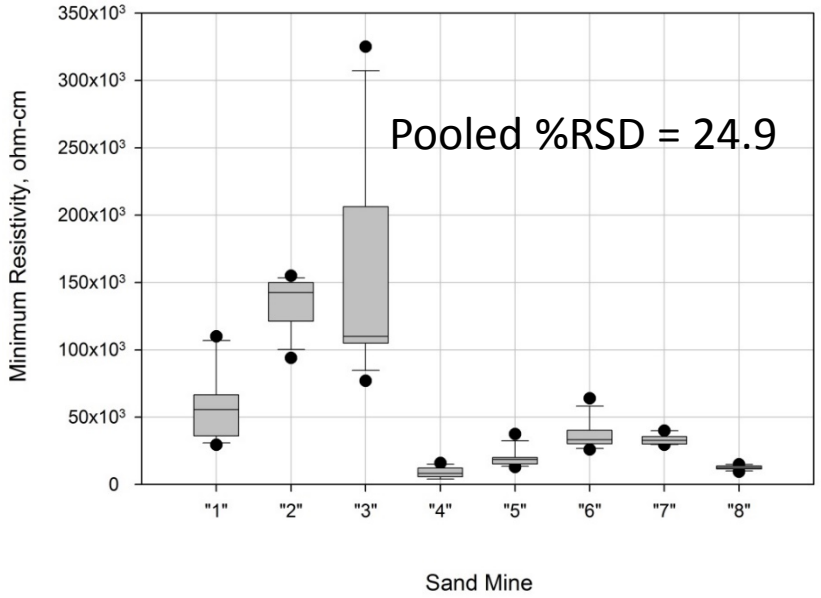


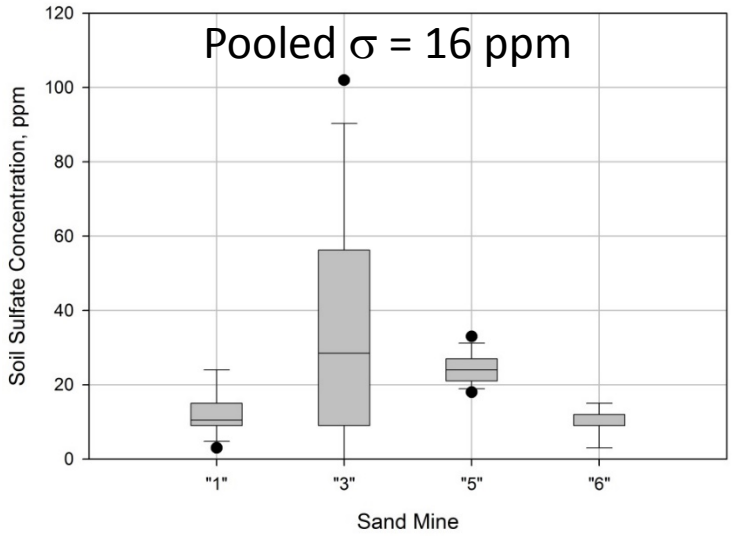
We can

1. Further separate the sample mean from the rejection mean,
2. Reduce the sample variance,
3. Increase the number of samples, which improves the estimate of the sample mean, or
4. Increase the risk of accepting a bad backfill,
5. Reconsider the design or material.

Replicate Study to Estimate Method Test Errors







ANOVA: Variability was much greater between than within samples.

Inter-Laboratory Study to Expand Test Errors for Multiple Laboratories: Minimum Resistivity, Chloride, and Sulfate

Laboratory	Material A		
	Resistivity, ohm-cm	Chloride, ppm	Sulfate, ppm
Average	12,200	7	4
St Dev	1,090	8	4
RSD, %	9.0	110	93

Laboratory	Material B		
	Resistivity, ohm-cm	Chloride, ppm	Sulfate, ppm
Average	2,310	66	67
St Dev	433	12	16
RSD, %	19	18	23

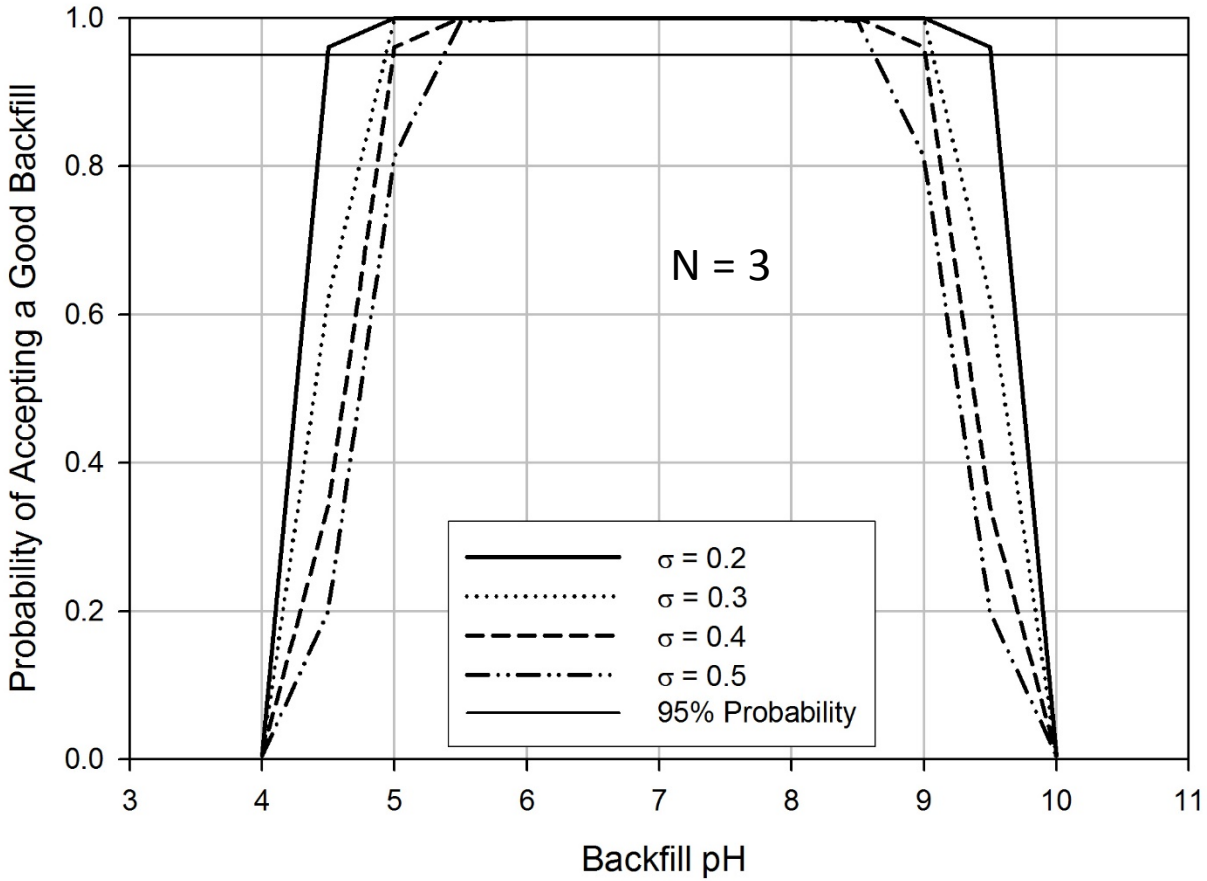
Note: For material A, chloride and sulfate concentrations were below the method detection levels; for material B, chloride and sulfate salts were added to achieved detectable concentrations.

Inter-Laboratory Study to Expand Test Errors for Multiple Laboratories: pH

Material	Average	Standard Deviations		%RSD	
		Within Lab	Between Labs	Within Lab	Between Labs
A	9.19	-	0.07	-	0.80
B	7.07	-	0.72	-	10
C	*7.76*	*0.051*	*0.32*	*0.66*	*4.1*
D	*5.11*	*0.049*	*0.15*	*0.97*	*2.9*

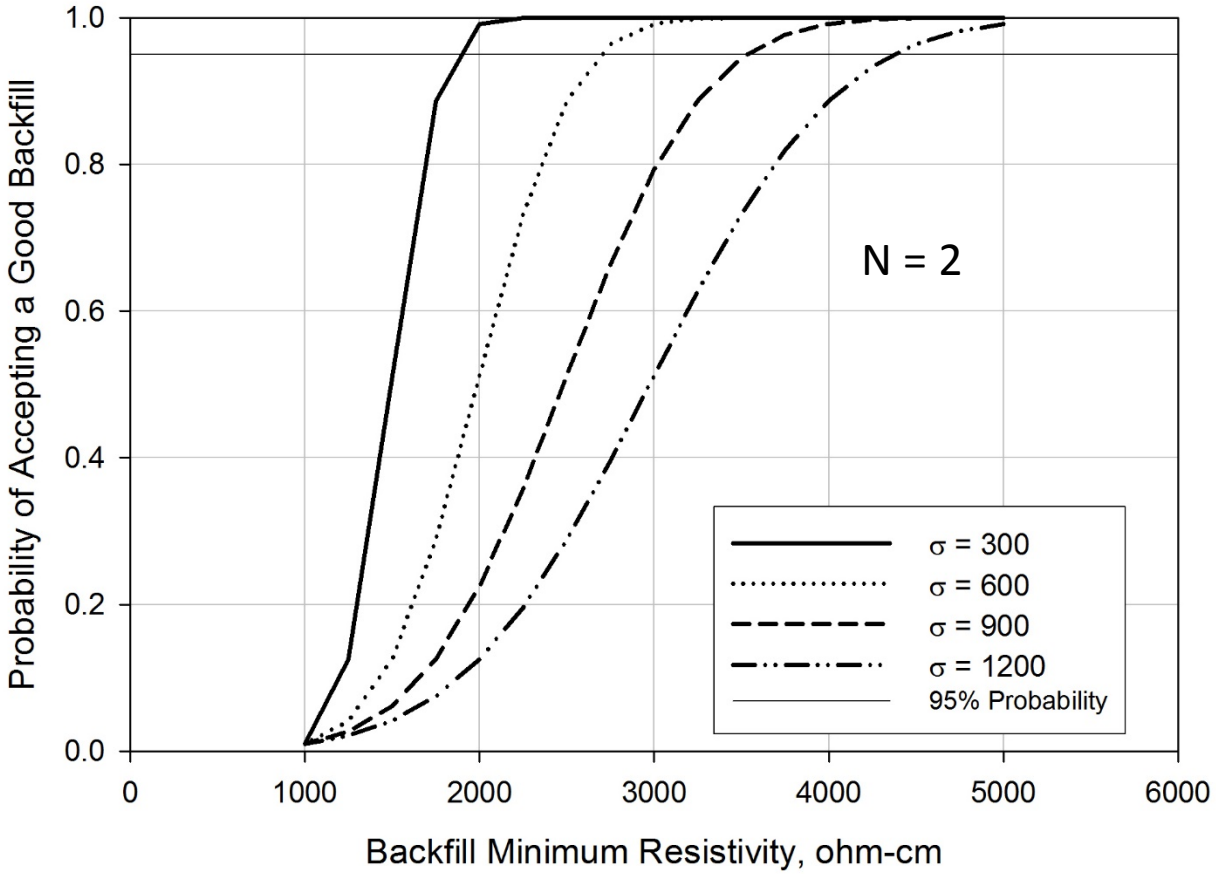
Note: Method procedures were changed for materials C & D.

Operating Characteristic (OC) Curve for pH



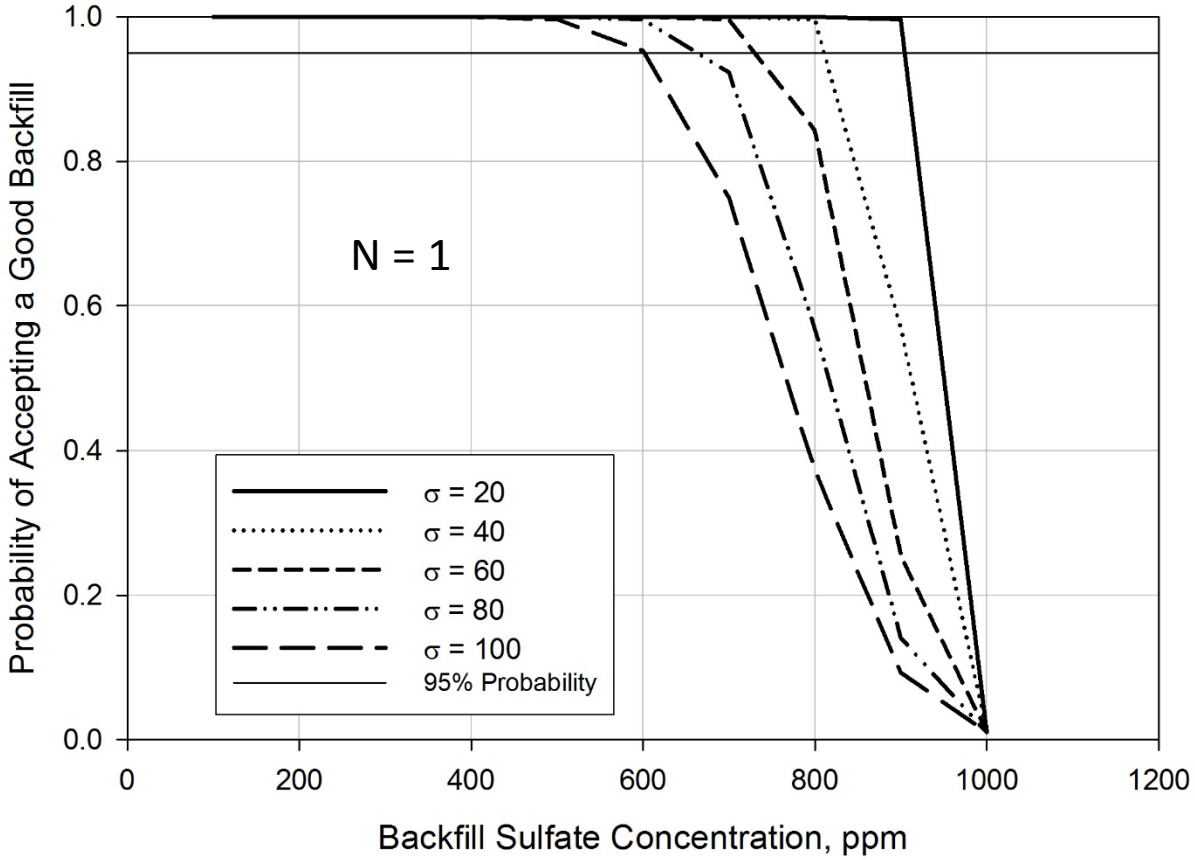
Estimated test error was 0.30 pH units. For N = 3 samples, the probability of accepting a good backfill ($5 \leq pH \leq 9$) was 95% or better for a test error that was at or below 0.40 pH units.

OC Curve for Minimum Resistivity



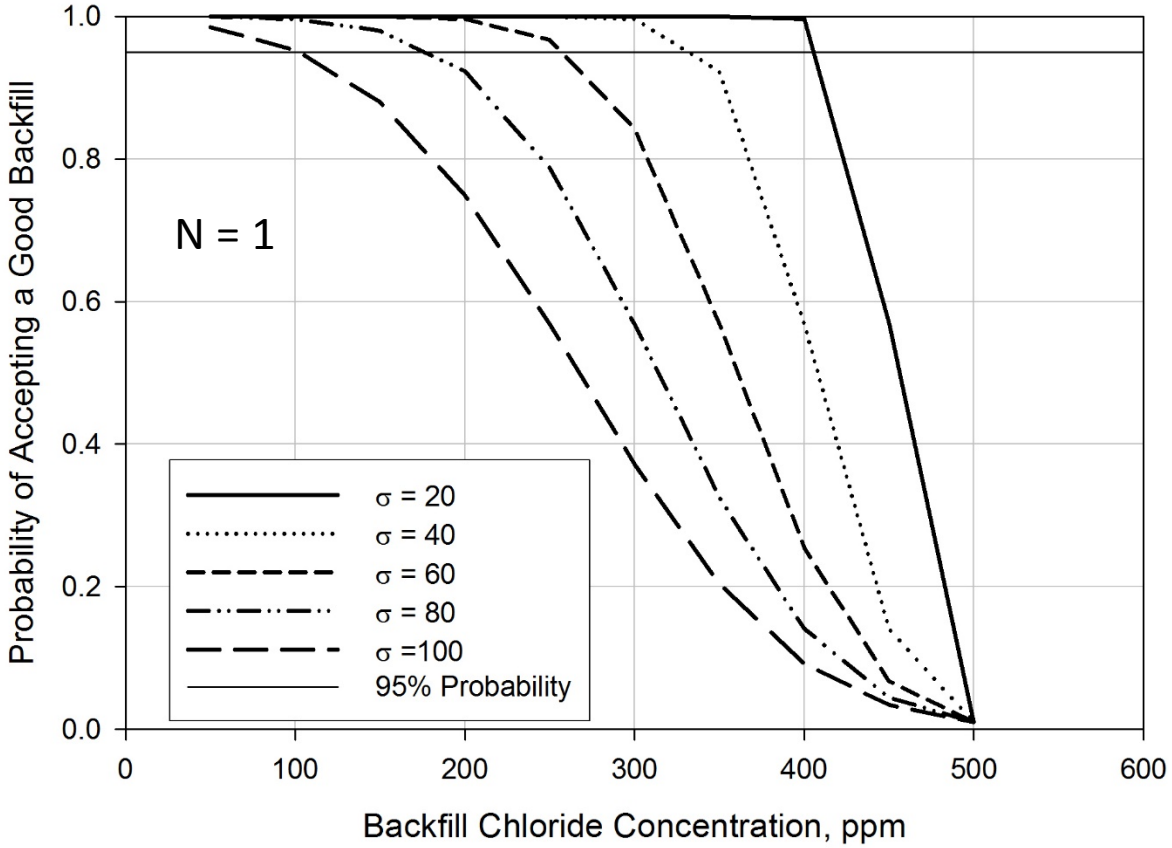
Estimated test error was 900 ohm-cm. For N = 2 samples and a revised acceptance level of 4,000 ohm-cm, the probability of accepting a good backfill was 95% or better for a test error that was at or below 900 ohm-cm.

OC Curve for Sulfate Concentration



Estimated test error was 22 ppm. For N = 1 samples and an acceptance level of 200 ppm, the probability of accepting a good backfill was 95% or better for a test error as high as 200 ppm.

OC Curve for Chloride Concentration



Estimated test error was 12 ppm (inter-laboratory study only). For N = 1 samples and an acceptance level of 100 ppm, the probability of accepting a good backfill was 95% or better for a test error as high as 100 ppm.

Recommendations

- Revise the FMs for pH, minimum resistivity, chloride, and sulfate;
- Increase the number of independent samples per soil type for pH and minimum resistivity;
- Increase the acceptance limit for minimum resistivity from 3,000 to 4,000 ohm-cm;
- Conduct operator training and laboratory audits of corrosion FMs;
- Conduct a Florida-wide inter-laboratory study of revised FMs within a year of implementation; and
- Re-evaluate the FMs for chloride and sulfate after a two-year data collection period.