



A Methodology for Estimating Health Indices for Cable Systems in the Field

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Subcommittee F
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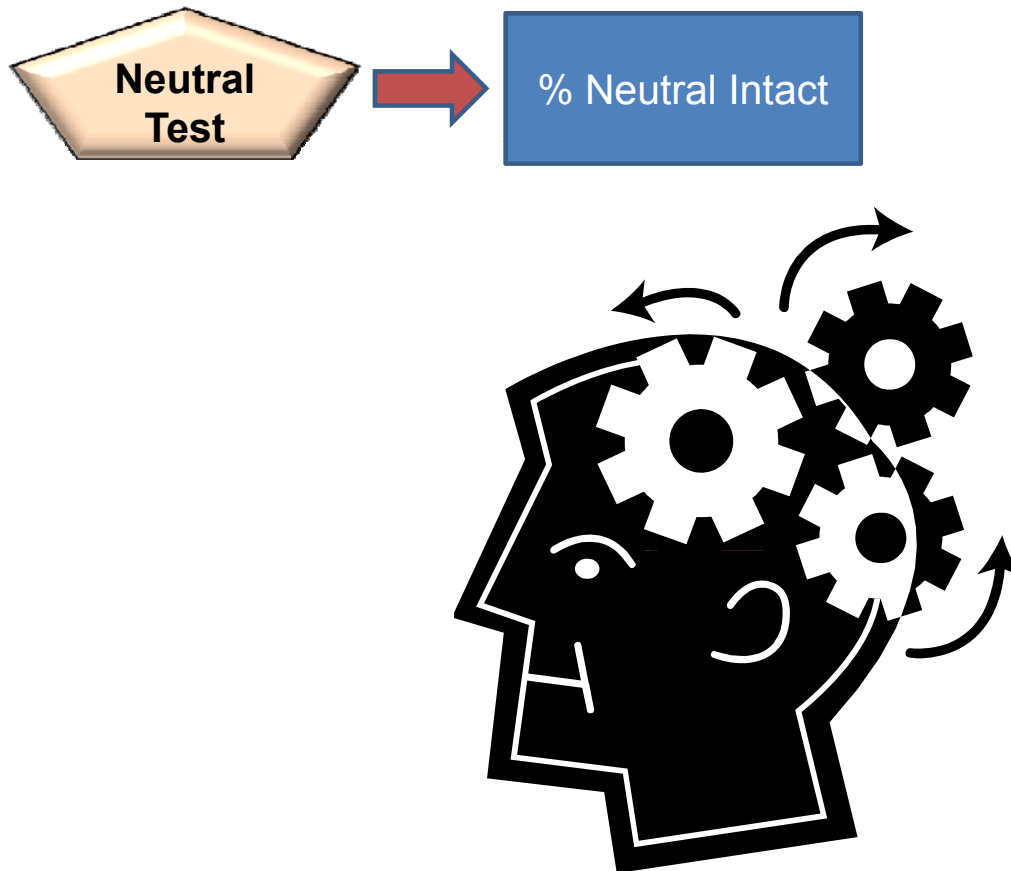
Why is a “Health Index” of interest?

- Diagnostics measure symptoms of cable system degradation.
- Measurements are not immediately actionable – a decision needs to be made about the circuit
- There are a variety of diagnostic measurements & other inputs.
- Prioritization is necessary when resources are scarce

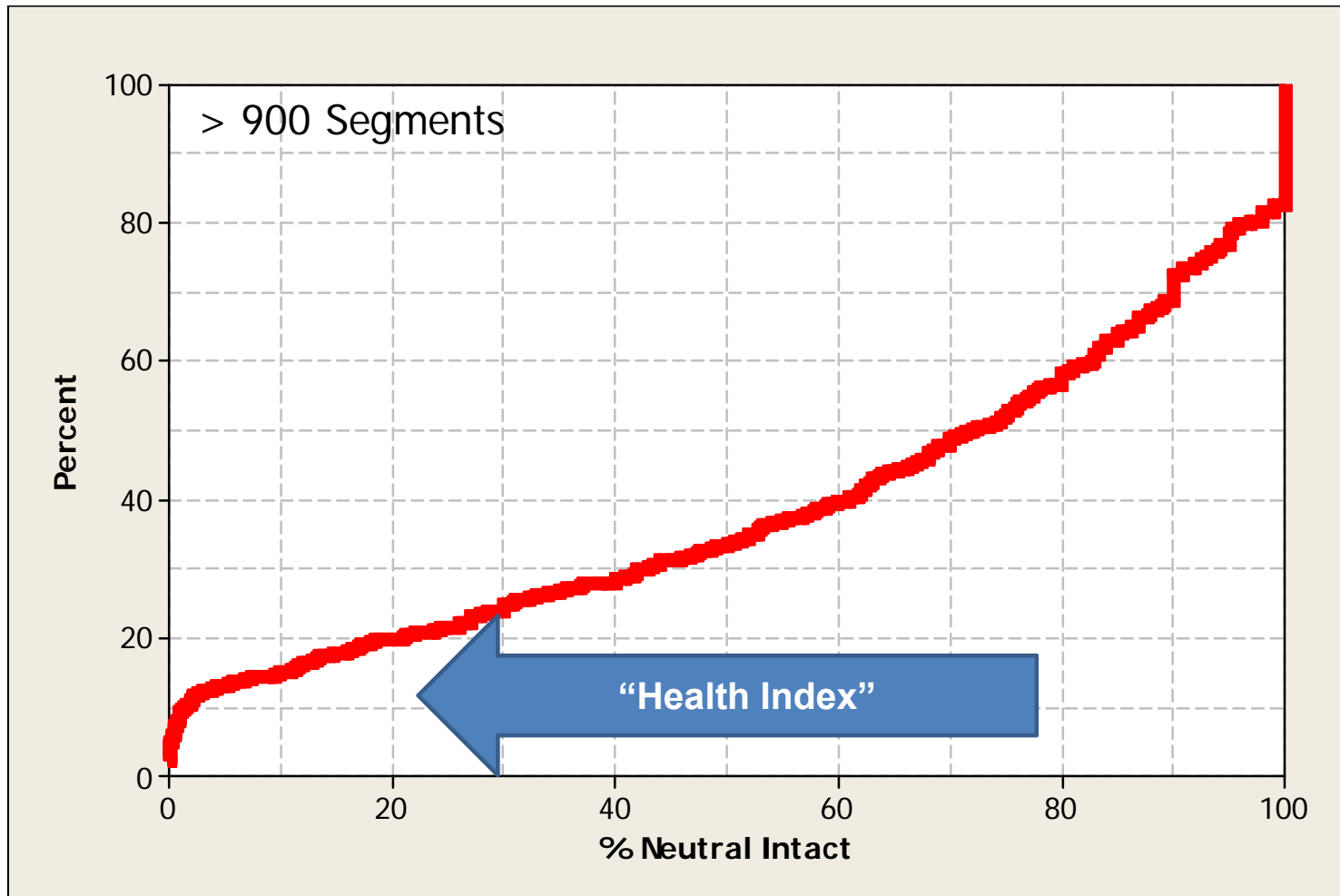
What does a “Health Index” do?

- Combines all available data (performance, diagnostic, and/or experience)
 - Numerical (e.g. 4.3, 1.3, etc)
 - Condition level (e.g. “Good/Poor”, Level 3, etc)
 - Different diagnostic techniques
- Health Index should be:
 - Transparent
 - Updateable
 - Meaningful
 - Easy to verbalize / understand

Straightforward Example: Neutral Wires



Neutral Testing - OhmCheck



Cable System - Tan δ

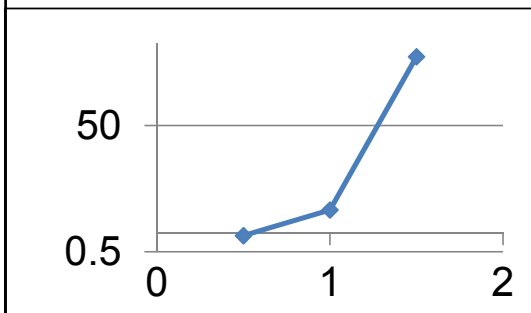
Criteria in Standards Help Interpretation

Condition Assessment	VLF-TD Stability (standard deviation) at U_0 [10-3]		Differential TD $TD_{1.5 U_0} - TD_{0.5 U_0}$ [10-3]		Mean VLF-TD at U_0 [10-3]
No Action Required	<0.05	&	<5	&	<4
Further Study	0.05 to 0.5	Or	5 to 80	Or	4 to 50
Action Required	>0.5		>80		>50

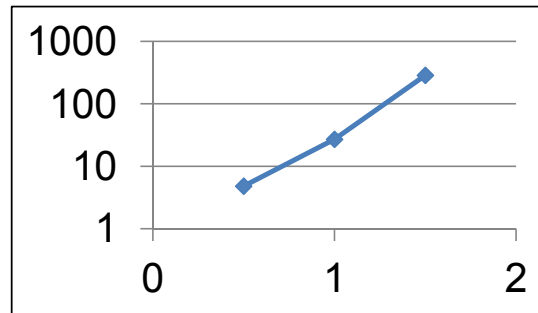
Which one is the poorest?

Segment	Stability [E-3]	Tip Up [E-3]	Mean TD [E-3]
1	★	★	★
2	★	★	★
3	★	★	★

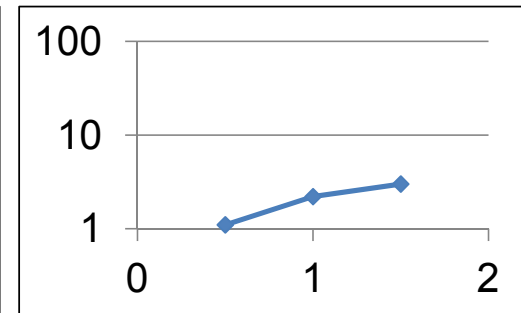
Segment 1



Segment 2



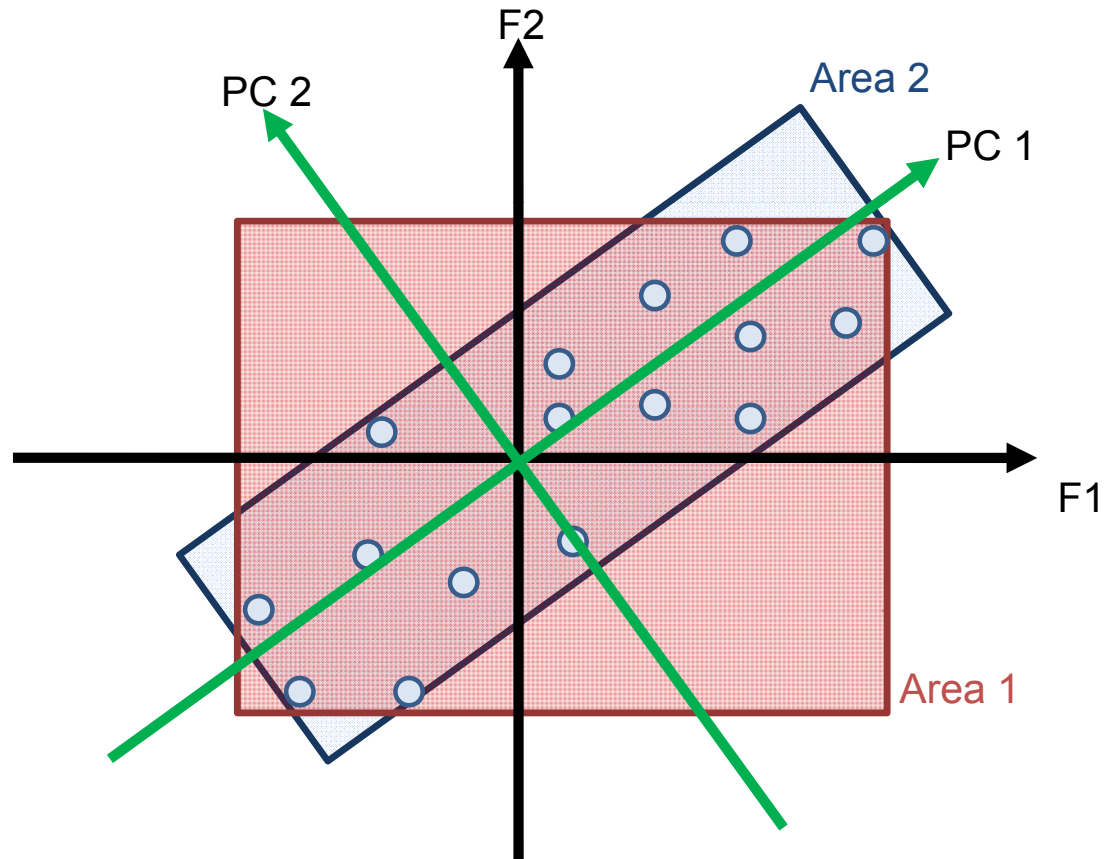
Segment 3



Multivariate Approach

- Interpretation is challenging with just four features
 - TD Stability,
 - Differential TD
 - Tip Up of Tip Up (TuTu)
 - Mean TD
- Principal Component Analysis provides a convenient route
 - Identifies sources of variability
 - Mathematical transformation of available features
 - Provides a transparent “recipe”
 - Works for any diagnostic technique
 - Incorporates other “inputs”

Principal Component Analysis (PCA)

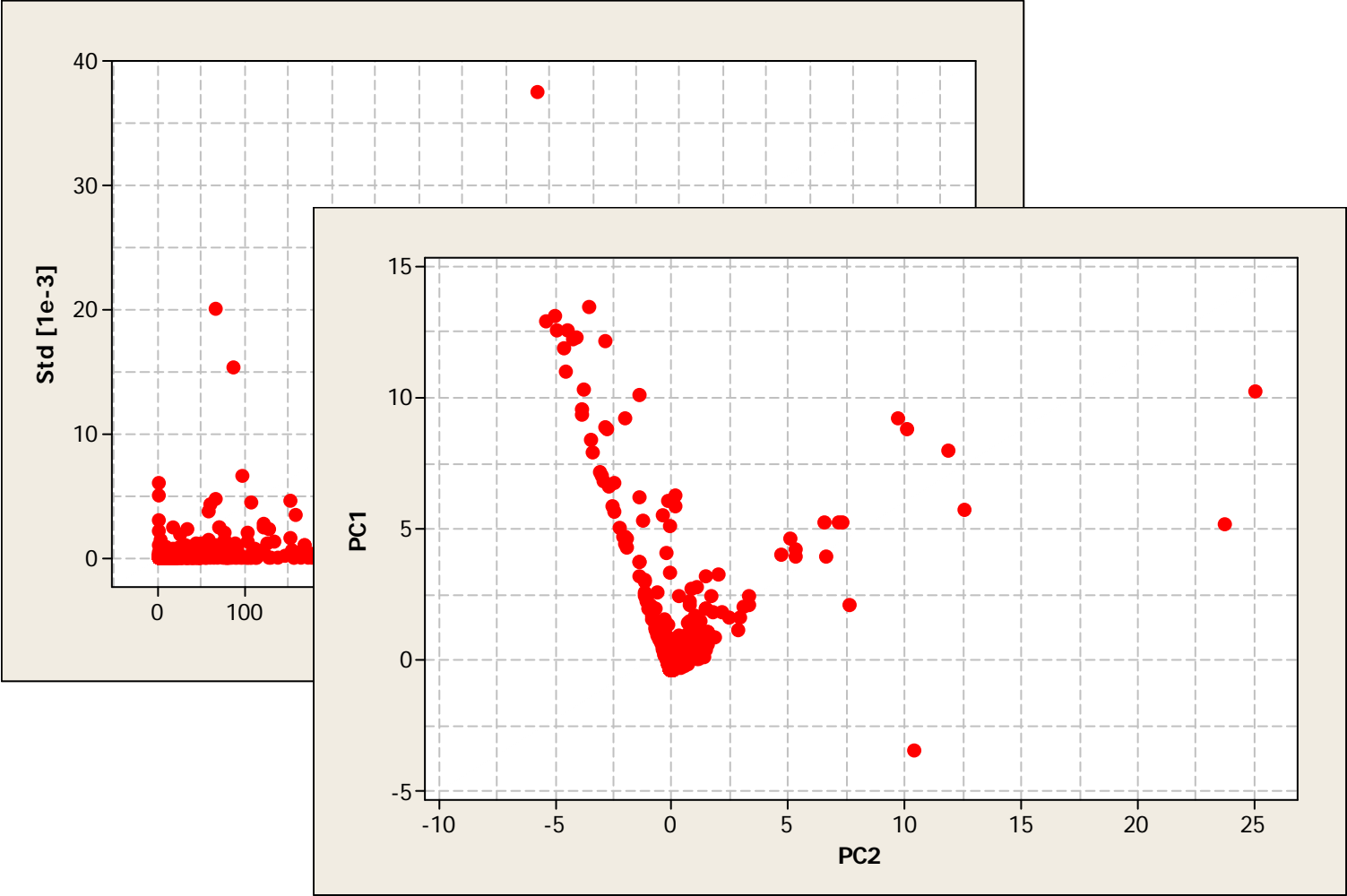


Variance in Area 2 is reduced compared to Area 1

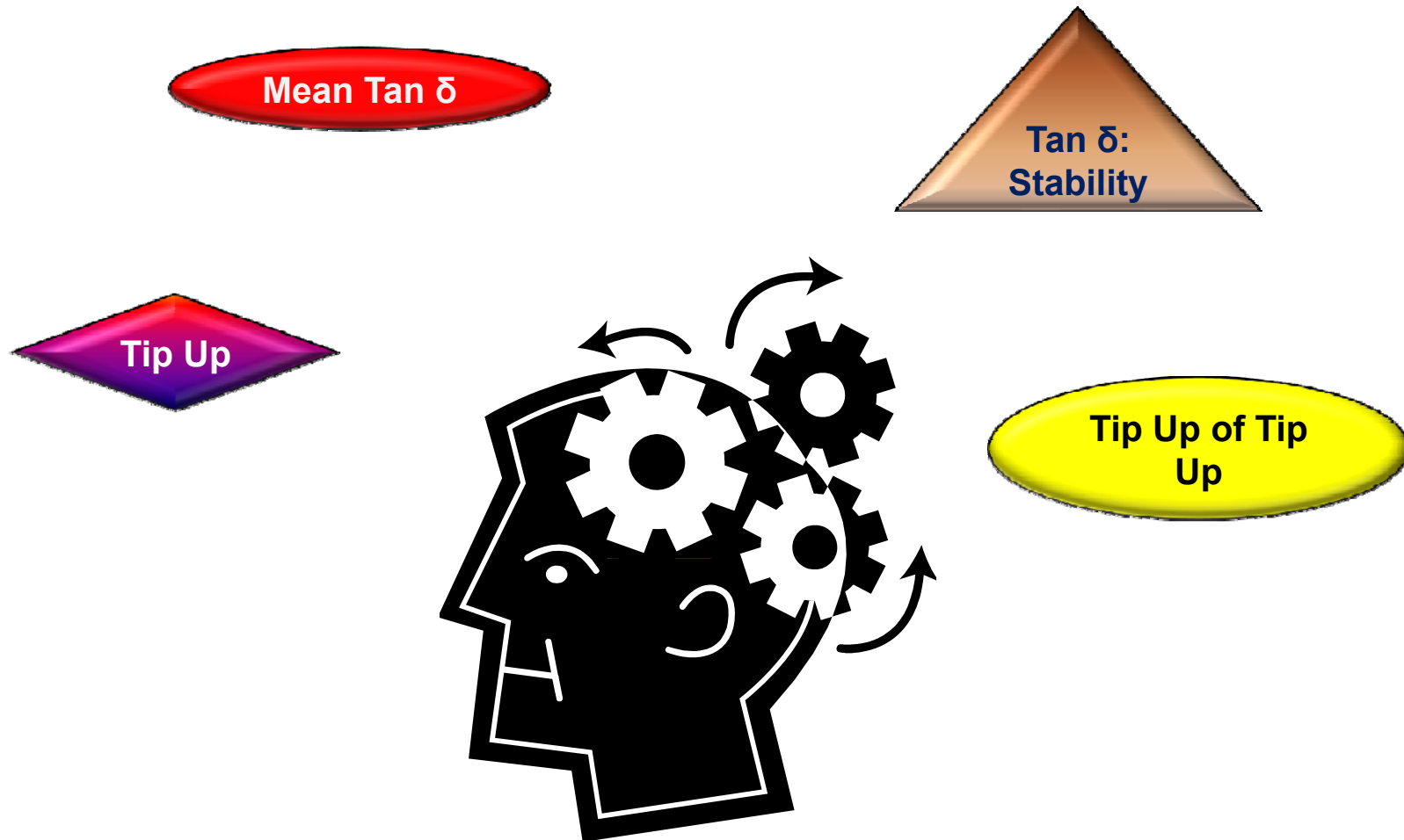
Key Elements for PCA to Work

- Organized database available
 - All segments must have data for ALL features available to be included in the PCA
- Need to know what “Good” or “New” look like in PCA domain – use as reference
- Test for non-linear effects and interactions between features
 - Identifies features / transforms that work better than others

PCA Map



Tan δ Example



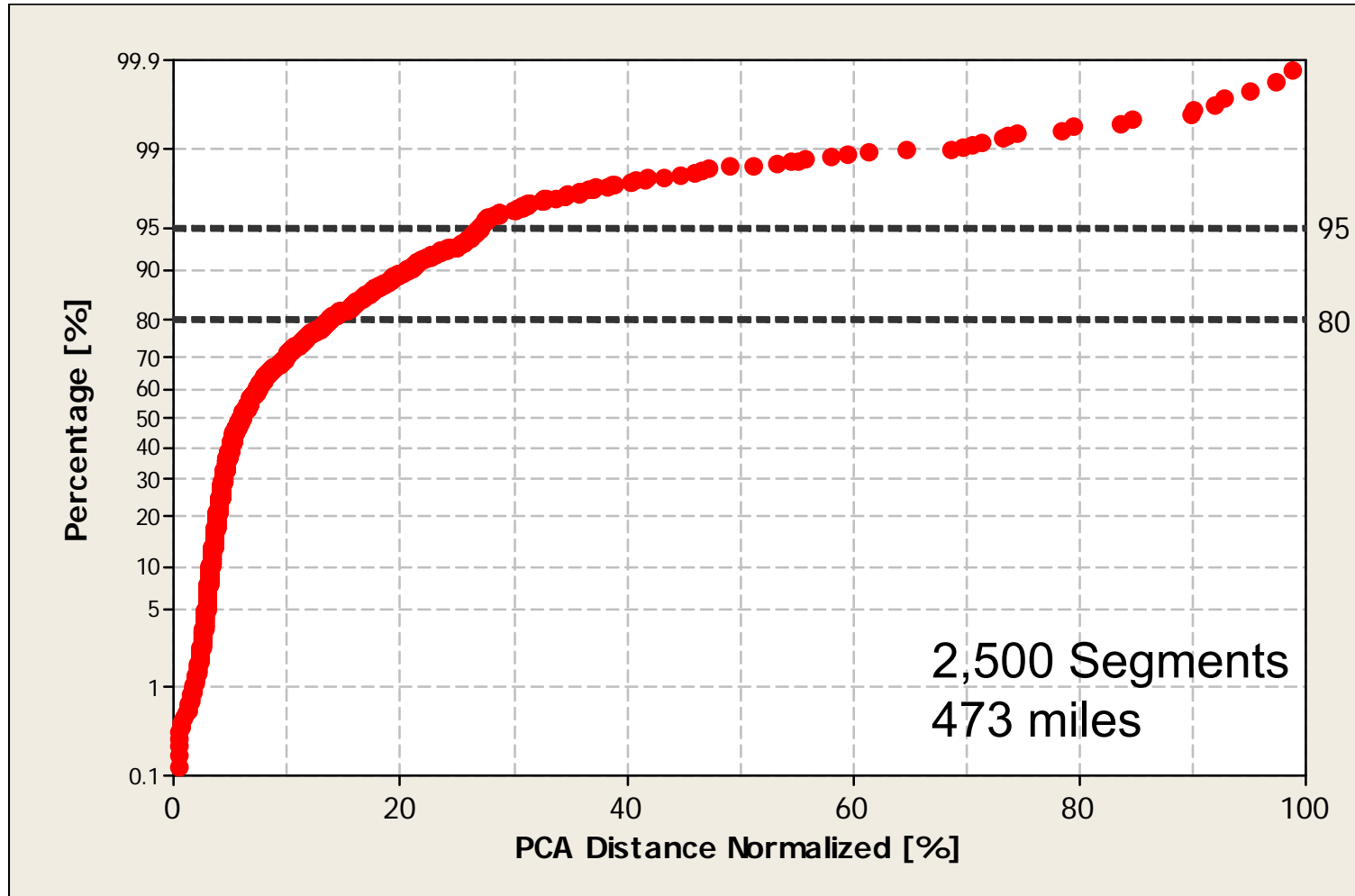
Tan δ PCA Recipe

Principal Component	Variance Described by Component [%]	Tan δ Diagnostic Features	Weights
PC1	50	Tip Up Tip Up of Tip Up	0.68 0.64
PC2	25	Std Deviation ²	0.99
PC3	22	Log Mean Tan δ	0.91

Distance from any chosen PCA positions can be calculated

Tests general “Rule of Thumb”, a good way to generate “Knowledge Rules”

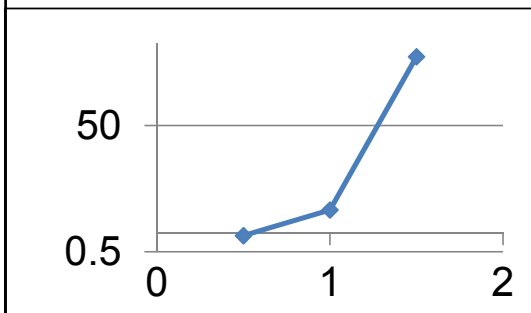
PCA Transformation – PE Insulations



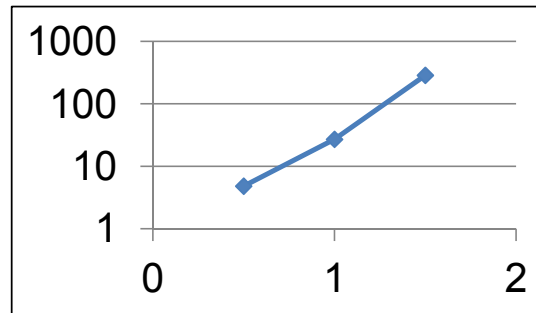
Which one has the greatest risk?

Segment	Stability [E-3]	Tip Up [E-3]	Mean TD [E-3]
1	★	★	★
2	★	★	★
3	★	★	★

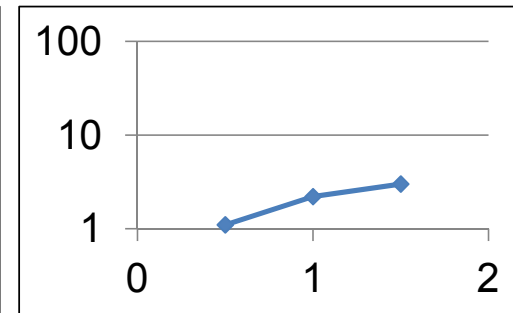
Segment 1



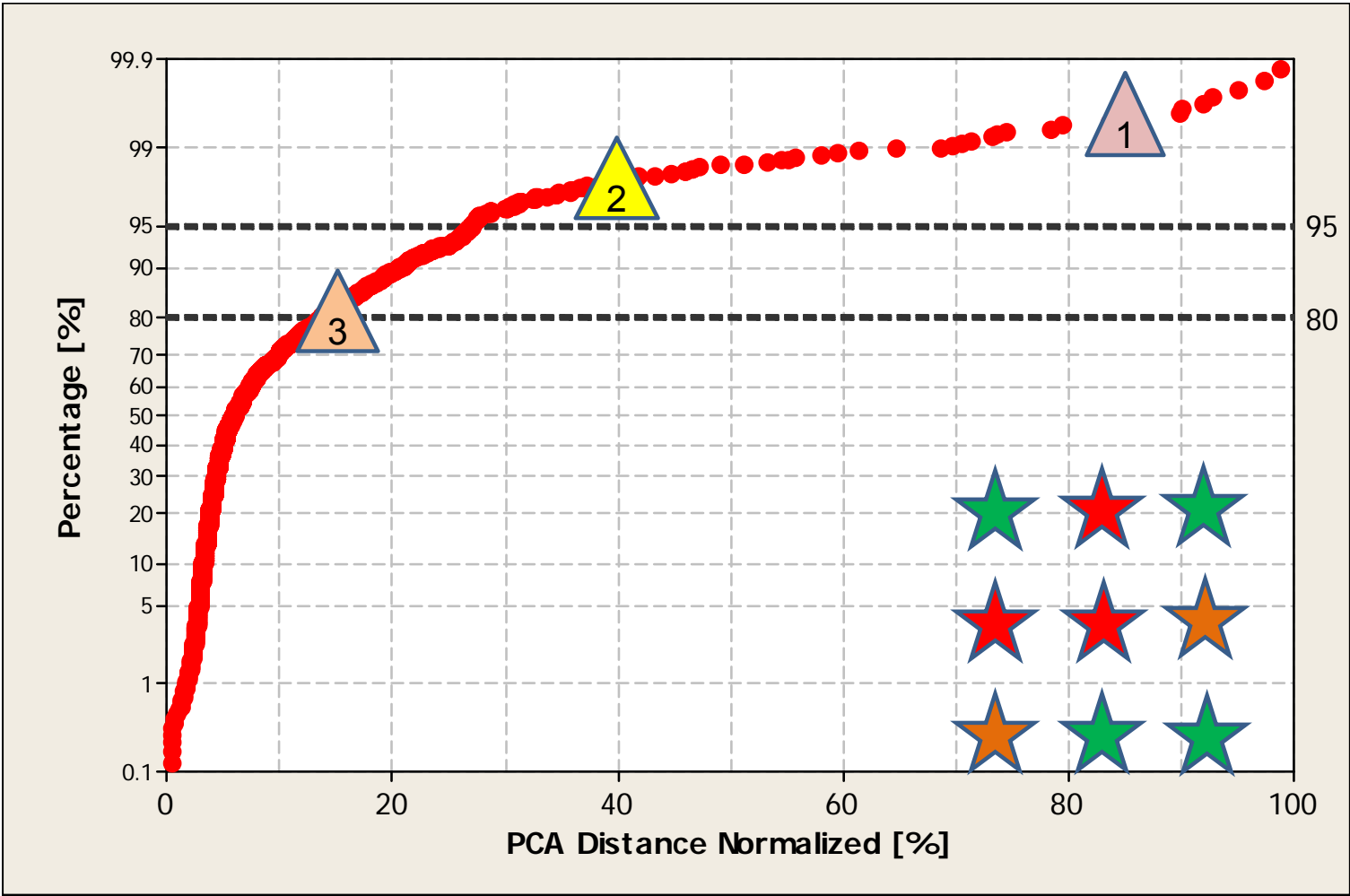
Segment 2



Segment 3



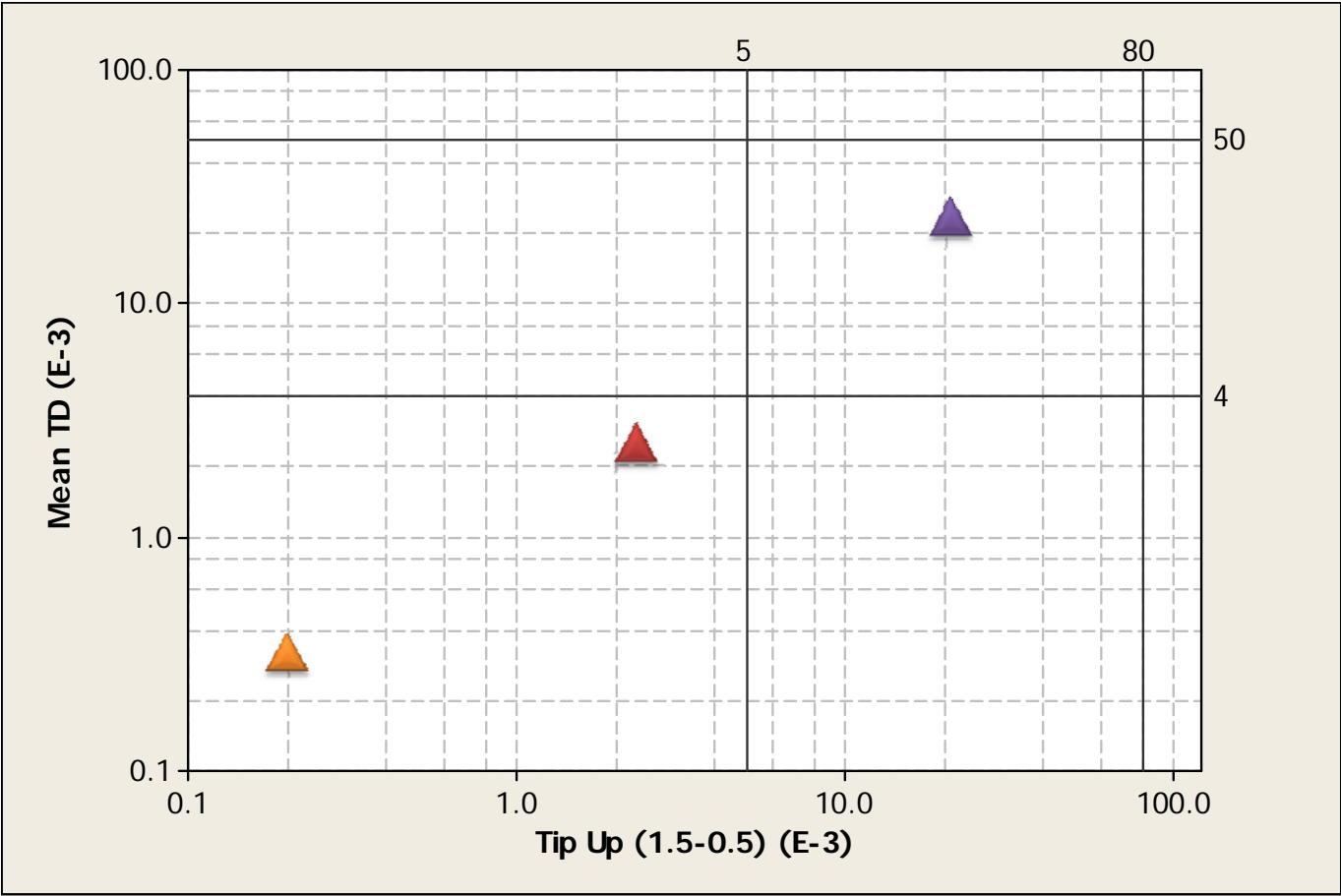
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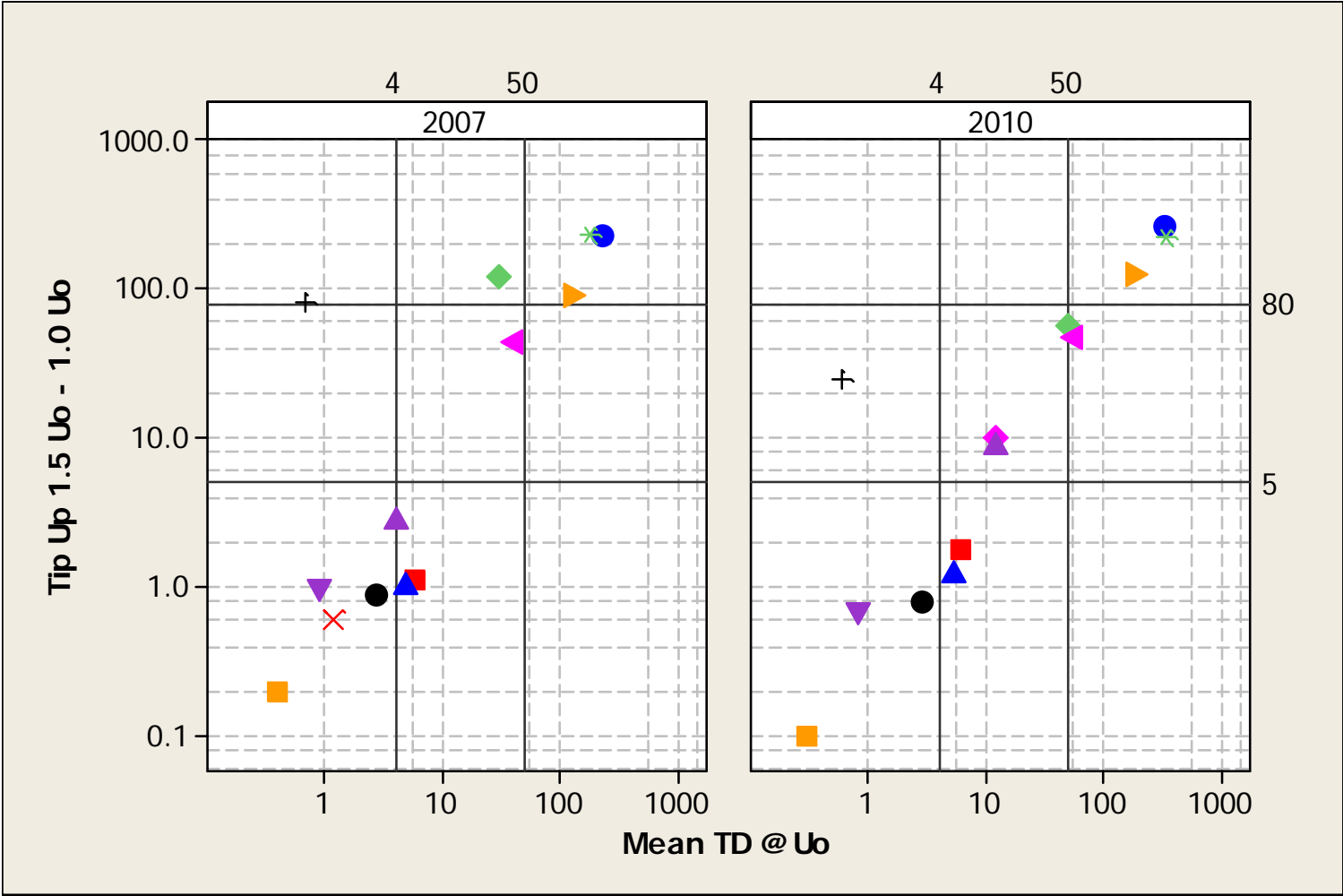
“Health Monitoring”

- Several subdivisions were tested in 2006-2007 using VLF Tan δ .
- Retests using VLF Tan δ were then conducted in 2010-2011 to determine if any changes could be measured.

Southern Utility Example



2010 versus 2007 Results

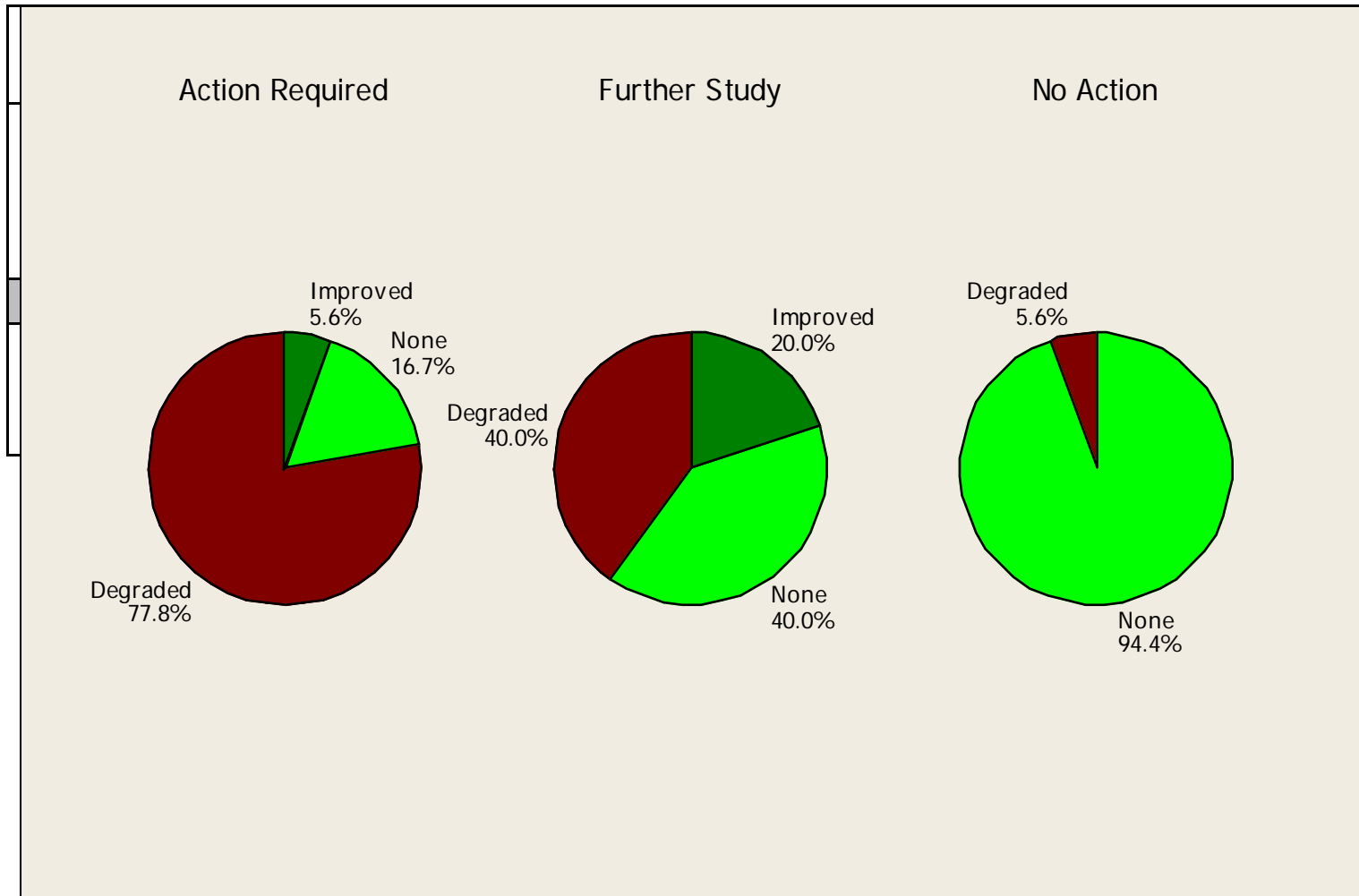


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Retest Circuits

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Retest Summary

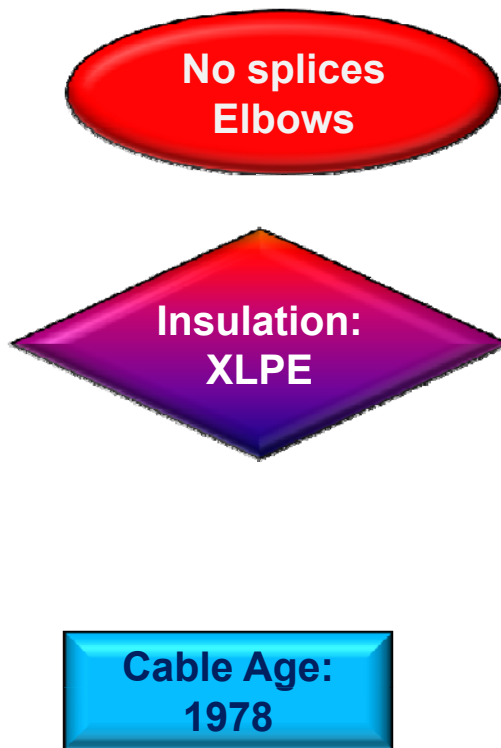


Summary

- Prioritization is important when resources are limited
- Health Index is a useful concept for combining information together to obtain a ranking
- Principal Component Analysis technique can be used to generate a “Health Index” for diagnostic data.
 - PCA tool for Tan δ
- PCA approach can be extended beyond Tan δ ...

Managing the Cable System as an Asset

Knowledge



Diagnostic Data

