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hydroAMP:

an equipment condition assessment framework

2012 Capital Investment Review Workshop

April 19, 2012

Portland, OR

Hydro Québec

U.S. DEPARTMENT OF THE INTERIOR
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US Army Corps of Engineers

Bonneville Power Administration

The Need

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- Equipment reliability significantly affects system generation availability and financial performance.
  - A significant amount of critical equipment in hydro facilities in North America is near or beyond its design life.
  - Substantial investment to repair, refurbish, or replace unreliable equipment is anticipated.
- The process for identifying and prioritizing investments needs strengthening – capital is a limited resource.
  - Equipment condition assessment tools used in the past have been complex and costly to administer.
  - Establishing an objective, consistent and efficient assessment process is critical for informed decision making.

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- In 2001, the Bureau of Reclamation (BOR), Hydro-Québec (HQ), the Army Corps of Engineers' Hydroelectric Design Center (HDC), and Bonneville Power Administration (BPA) began collaborating on a hydroelectric equipment condition assessment technique that was later named "hydroAMP", or hydro Asset Management Partnership.

- The hydroAMP Partners worked on the program for 5 years and in 2006, with the publication of a report describing the condition assessment technique, its development and its potential applications, officially rolled out hydroAMP during HydroVision.

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Condition Assessment Principles

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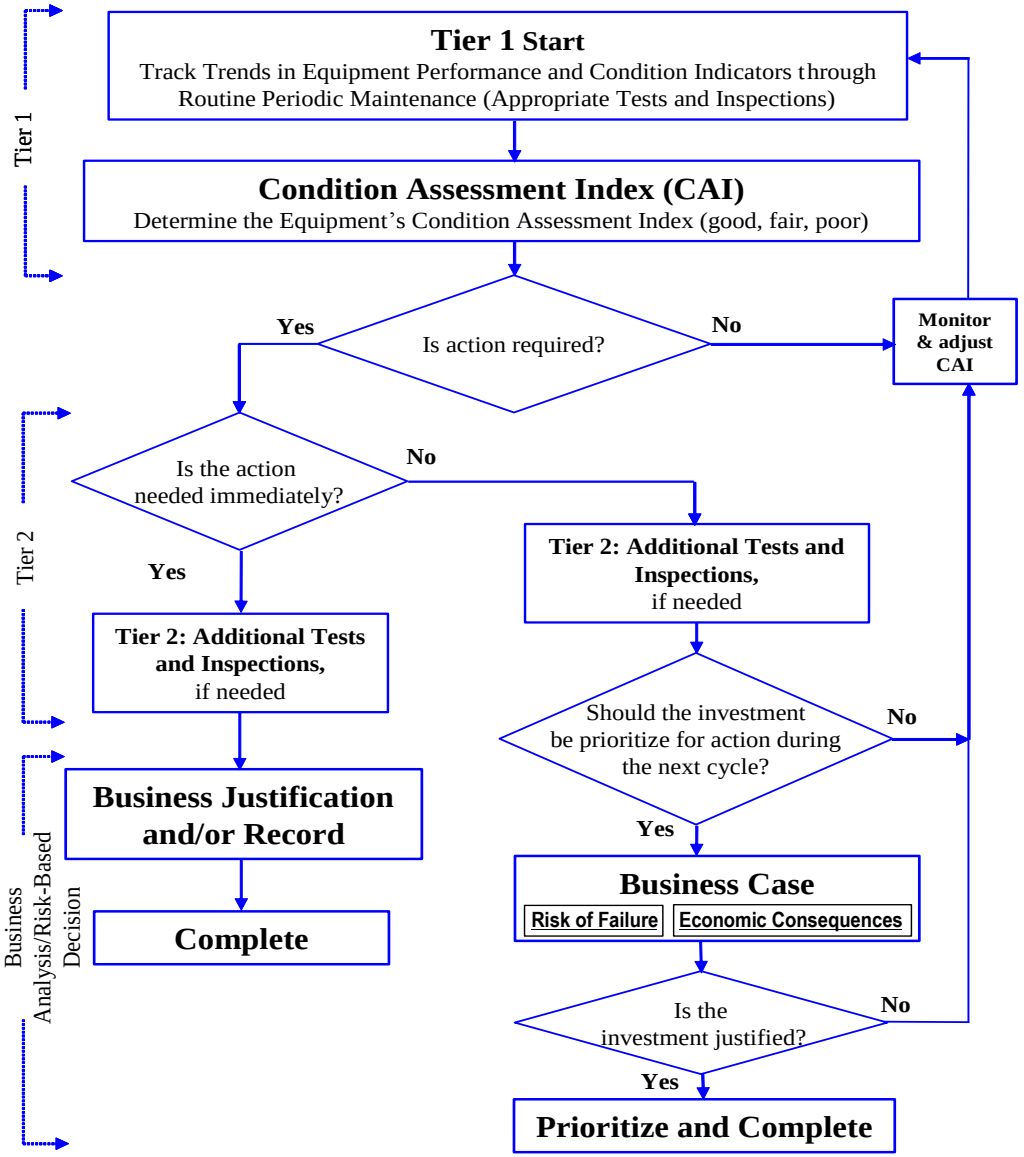
- Objective results
- Developed from routine tests and inspections
- Simplified process
- Easy interpretation
- Technically sufficient (valid though not necessarily perfect)
- Consistent and repeatable results
- Start small, expand with time
- Open to improvement

Framework

- A guidebook currently outlines condition ratings for 11 equipment types.
- The guidebook was developed to facilitate asset management decisions using equipment condition assessments.
- The guidance is open and flexible to fit into the existing structure of each utility's maintenance, planning, budgeting and decision-making processes.



Equipment Guides

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- Surge Arrestors
- Transformers
- Turbines
- Generators – in revision - 2011
- Governors
- Exciters – revised 2011
- Cranes
- Batteries
- Compressed Air System
- Emergency Closure Gate and Valve

Condition Assessment: Two-Tier Approach

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Tier 1

- The rating is based on condition indicators derived from tests, measurements, and inspections that are normally performed during routine O&M activities.
- The assessment results in a “Condition Index” with a rating scale of zero to 10; higher CI means better condition.
- Mid- to low-range values may trigger a Tier 2 evaluation.
- Assessment results are easily entered into CMMS or other databases for tracking and reporting.

Condition Assessment: Two-Tier Approach (cont.)

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Tier 2

- Includes in-depth, non-routine tests or inspections that may be invasive and/or require specialized equipment and expertise not normally found at the hydro plant.
- Results are used to adjust the Condition Index score (either up or down).
- Adds confidence to the assessment results and conclusions.

Condition Assessment: Data Quality

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Data Quality Indicator

- Is a stand-alone indicator used to reflect the quality of information available for performing the condition assessment.
- Recognizes that data may be missing, out of date, or of questionable integrity.
- Is important because poor data could affect the accuracy of individual condition indicator scores as well as the validity of the overall Condition Index.

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Turbine Example

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Tier 1 Condition Index and Data Quality Indicator

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Tier 1 condition indicators:

- Age
- Physical Condition
- Operational Limitations
- Maintenance

Condition indicators are scored and weighted, then summed to calculate the Condition Index.

The Data Quality Indicator is scored separately.

Tier 1 Condition Indicator Scoring

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Table 1 – Turbine Age Scoring

Age New / Full Rehabilitation	Age Partial Rehabilitation	Condition Indicator Score
0 – 25 years	0 – 15 years	3
26 – 35 years	16 – 25 years	2
36 – 45 years	26 – 35 years	1
> 45 years	> 35 years	0

Summary of Tier 1 Turbine Assessment

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Tier 1 Turbine Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score	X	Weighting Factor	=	Total
1	**Age** *(Score must be 0, 1, 2, or 3)*	2		1.000		2
2	**Physical Condition** *(Score must be 0, 1, 2, 3, or 4)*	3		1.000		3
3	**Operations** *(Score must be 0, 0.5, 1, or 1.5)*	1.5		1.000		1.5
4	**Maintenance** *(Score must be 0, 0.5, 1, or 1.5)*	1.5		1.000		1.5
	Tier 1 Turbine Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*					8

Turbine Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	4

Tier 2 Tests

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Tier 2 Toolbox:

- Efficiency
- Capacity
- Off-Design
- Paint Film Quality
- Surface Roughness
- Cracking
- Other Specialized Tests
- Cavitation
- Condition of Remaining Parts
- Environmental
- Operating Conditions
- Maintenance

Tier 2 results are used to refine the Tier 1 score.

The Data Quality Indicator also may be adjusted.

Tier 2 Tests and Condition Index Adjustments

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Condition assessment guides also provide criteria for using Tier 2 test results.

Table 12 – Cavitation Damage of Runner and Discharge Ring Test Scoring **Cavitation Damage**	**Adjustment to Condition Index Score**
Minimal: Stainless – frosting only Carbon – frosting only	Add 0.5
Moderate: Depth Area Stainless < 1/8” < 5% Carbon < 3/8” < 5%	No Change
Severe: Depth Area Stainless > 1/8” > 5% Carbon > 3/8” > 5%	Subtract 0.5

Using hydroAMP

hydroAMP was intended to be used in conjunction with performing annual maintenance.

- Turbines: As your filling out your performing your cavitation mapping, the hydroAMP turbine assessment should be filled in.

- If you have Tier 2 data, use it: Cavitation, Reliable On-line Efficiency Monitoring, etc.

hydroAMP Simplicity

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The idea was to “KEEP IT SIMPLE.”

- Minimal time to perform, if you’re doing it while you are performing maintenance.
- You’re already thinking about the equipment and how it’s performing.

How not to use it:

- Not a paperwork exercise.
- Last minute reporting of condition because of performance measures.

Make it meaningful.

hydroAMP Data Management

Equipment guides and assessment data and are stored in a secure web-accessible database.

- The database stores and reports Tier 1 condition assessments.
- Adjustments for Tier 2 assessments have recently been added.
- It is expandable to include new plants and equipment.

www.bpa.gov/secure/hydroAMP

hydroAMP Database: Main Page

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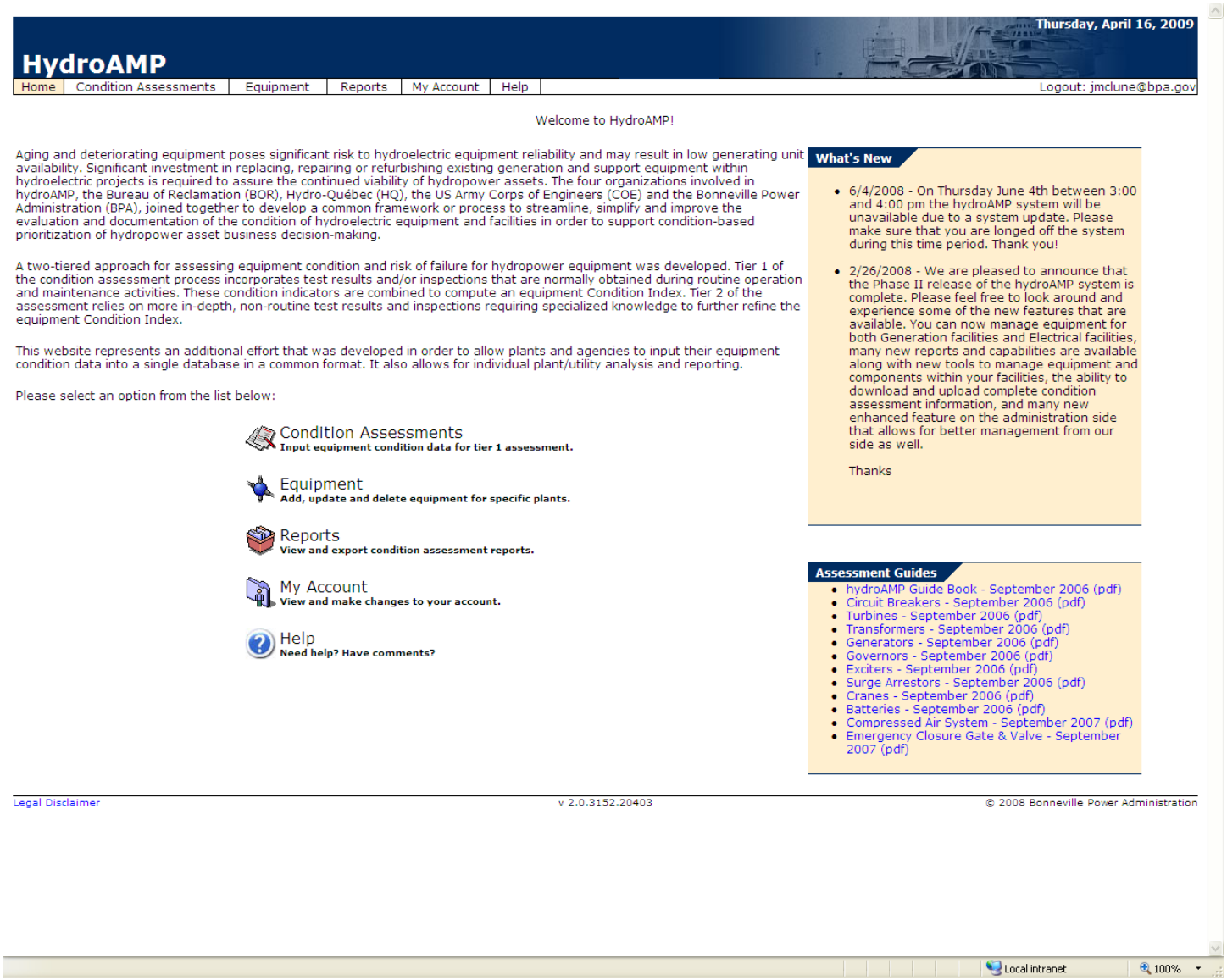

hydroAMP Database: Tier 1 Turbine Assessment

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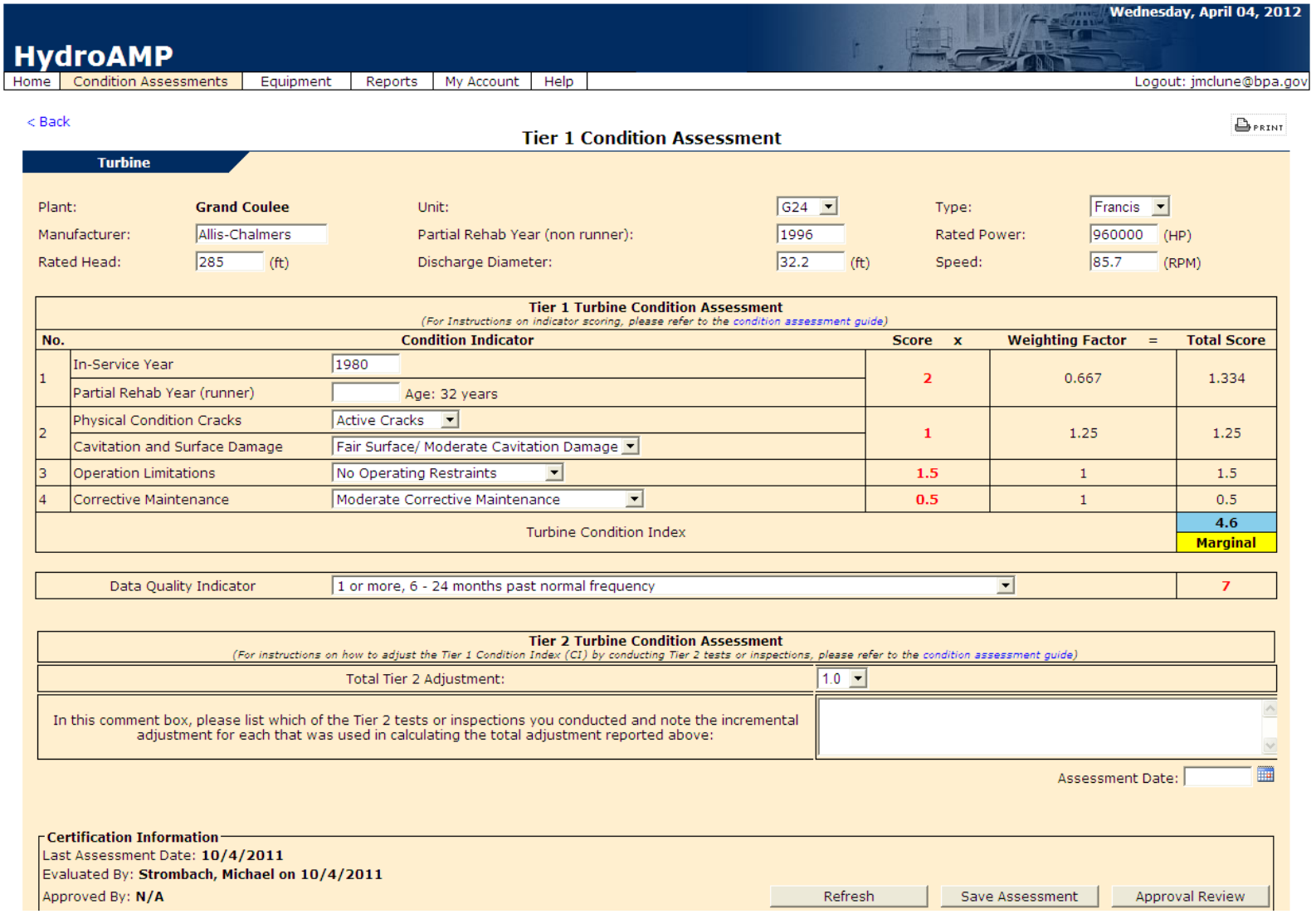

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Tier 1 Condition Assessment

Turbine

Plant:	**Grand Coulee**	Unit:	G24	Type:	Francis
Manufacturer:	Allis-Chalmers	Partial Rehab Year (non runner):	1996	Rated Power:	960000 (HP)
Rated Head:	285 (ft)	Discharge Diameter:	32.2 (ft)	Speed:	85.7 (RPM)

Tier 1 Turbine Condition Assessment

(For Instructions on indicator scoring, please refer to the condition assessment guide)

No.	Condition Indicator		Score	x	Weighting Factor	=	Total Score
1	In-Service Year	1980	2		0.667		1.334
	Partial Rehab Year (runner)	Age: 32 years					
2	Physical Condition Cracks	Active Cracks	1		1.25		1.25
	Cavitation and Surface Damage	Fair Surface/ Moderate Cavitation Damage					
3	Operation Limitations	No Operating Restraints	1.5		1		1.5
4	Corrective Maintenance	Moderate Corrective Maintenance	0.5		1		0.5
	Turbine Condition Index						4.6 Marginal

Data Quality Indicator	1 or more, 6 - 24 months past normal frequency	7

Tier 2 Turbine Condition Assessment

(For instructions on how to adjust the Tier 1 Condition Index (CI) by conducting Tier 2 tests or inspections, please refer to the condition assessment guide)

Total Tier 2 Adjustment:	1.0
In this comment box, please list which of the Tier 2 tests or inspections you conducted and note the incremental adjustment for each that was used in calculating the total adjustment reported above:	

Assessment Date:

Certification Information

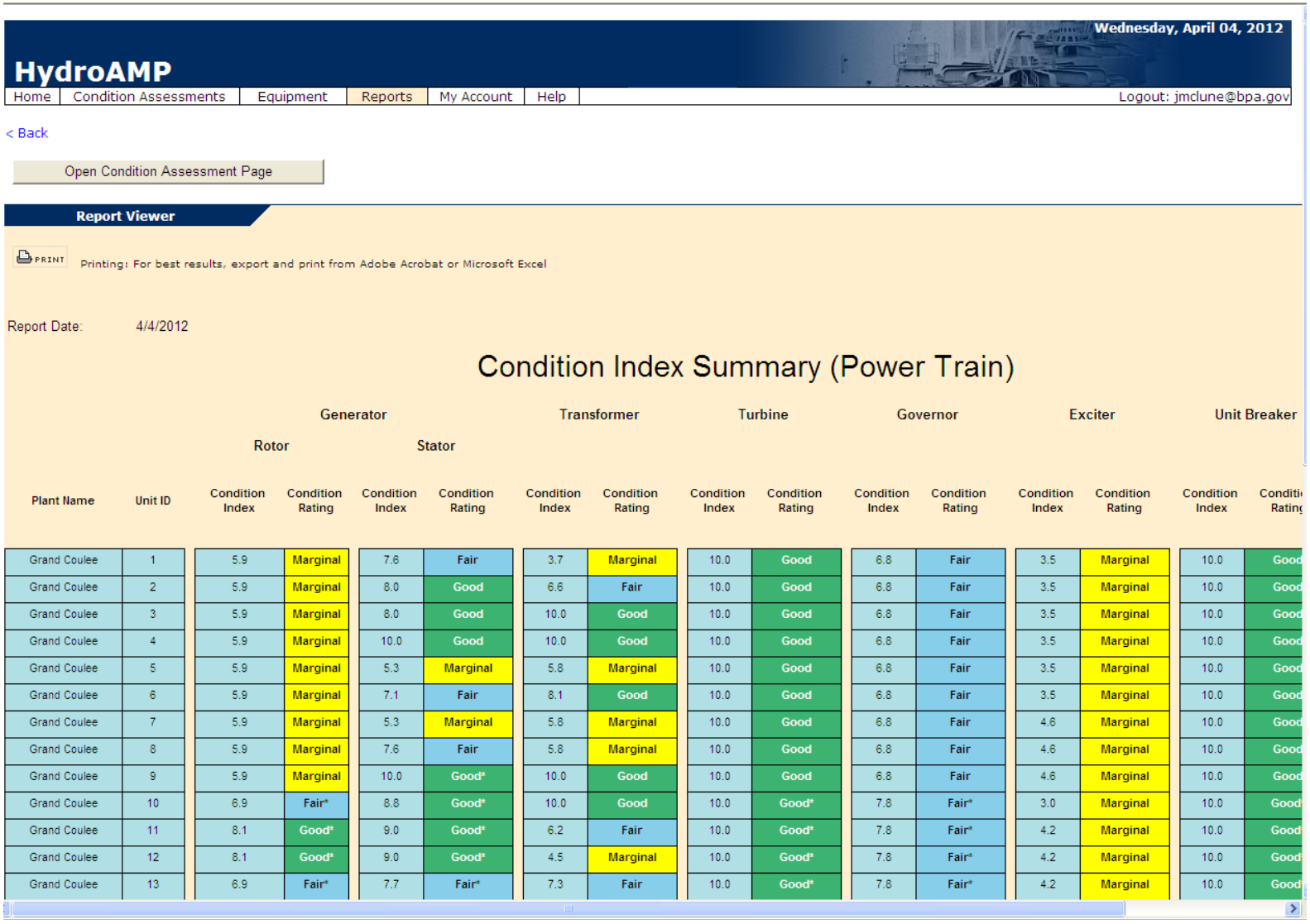
Last Assessment Date: **10/4/2011**

Evaluated By: **Strombach, Michael on 10/4/2011**

Approved By: **N/A**

Refresh | Save Assessment | Approval Review

hydroAMP Database: Powertrain Summary Report



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< Back

Open Condition Assessment Page

Report Viewer

PRINT Printing: For best results, export and print from Adobe Acrobat or Microsoft Excel

Report Date: 4/4/2012

Condition Index Summary (Power Train)

		Generator				Transformer		Turbine		Governor		Exciter		Unit Breaker	
		Rotor		Stator											
Plant Name	Unit ID	Condition Index	Condition Rating	Condition Index	Condition Rating	Condition Index	Condition Rating	Condition Index	Condition Rating	Condition Index	Condition Rating	Condition Index	Condition Rating	Condition Index	Conditi Rating
Grand Coulee	1	5.9	Marginal	7.6	Fair	3.7	Marginal	10.0	Good	6.8	Fair	3.5	Marginal	10.0	Good
Grand Coulee	2	5.9	Marginal	8.0	Good	6.6	Fair	10.0	Good	6.8	Fair	3.5	Marginal	10.0	Good
Grand Coulee	3	5.9	Marginal	8.0	Good	10.0	Good	10.0	Good	6.8	Fair	3.5	Marginal	10.0	Good
Grand Coulee	4	5.9	Marginal	10.0	Good	10.0	Good	10.0	Good	6.8	Fair	3.5	Marginal	10.0	Good
Grand Coulee	5	5.9	Marginal	5.3	Marginal	5.8	Marginal	10.0	Good	6.8	Fair	3.5	Marginal	10.0	Good
Grand Coulee	6	5.9	Marginal	7.1	Fair	8.1	Good	10.0	Good	6.8	Fair	3.5	Marginal	10.0	Good
Grand Coulee	7	5.9	Marginal	5.3	Marginal	5.8	Marginal	10.0	Good	6.8	Fair	4.6	Marginal	10.0	Good
Grand Coulee	8	5.9	Marginal	7.6	Fair	5.8	Marginal	10.0	Good	6.8	Fair	4.6	Marginal	10.0	Good
Grand Coulee	9	5.9	Marginal	10.0	Good*	10.0	Good	10.0	Good	6.8	Fair	4.6	Marginal	10.0	Good
Grand Coulee	10	6.9	Fair*	8.8	Good*	10.0	Good	10.0	Good*	7.8	Fair*	3.0	Marginal	10.0	Good
Grand Coulee	11	8.1	Good*	9.0	Good*	6.2	Fair	10.0	Good*	7.8	Fair*	4.2	Marginal	10.0	Good
Grand Coulee	12	8.1	Good*	9.0	Good*	4.5	Marginal	10.0	Good*	7.8	Fair*	4.2	Marginal	10.0	Good
Grand Coulee	13	6.9	Fair*	7.7	Fair*	7.3	Fair	10.0	Good*	7.8	Fair*	4.2	Marginal	10.0	Good

hydroAMP Database: User Accounts

- Access to the database and website is restricted and requires a user account.

- Accounts may be requested by e-mail to hydroAMP@bpa.gov, by providing the user's first and last name, company, job title, telephone number, and e-mail address. The request should also identify the hydro plants the user wishes to access.

- The hydroAMP administrator will assign a log-in and password, and send this information via e-mail to the user.

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Applying hydroAMP Results in Asset Planning

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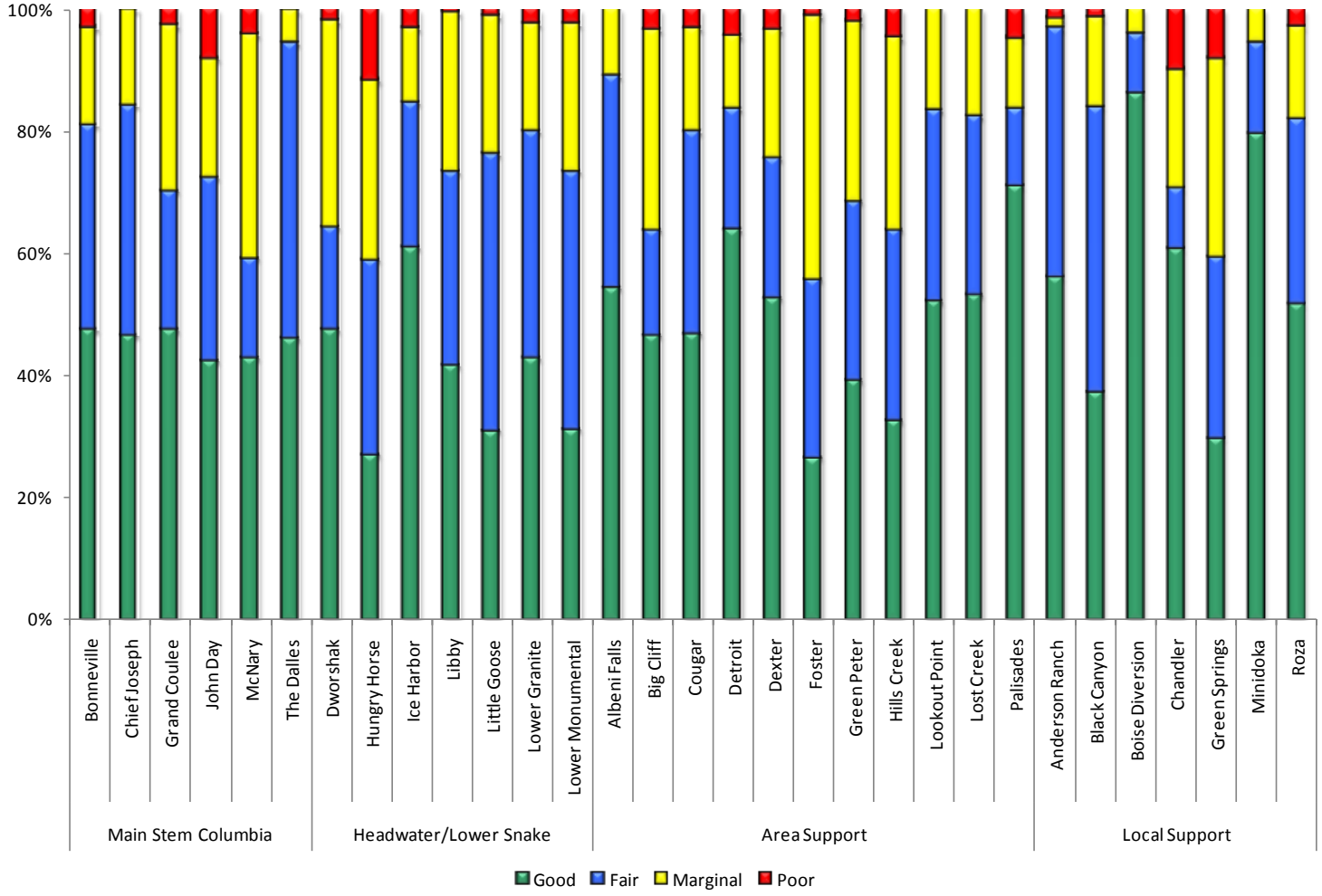
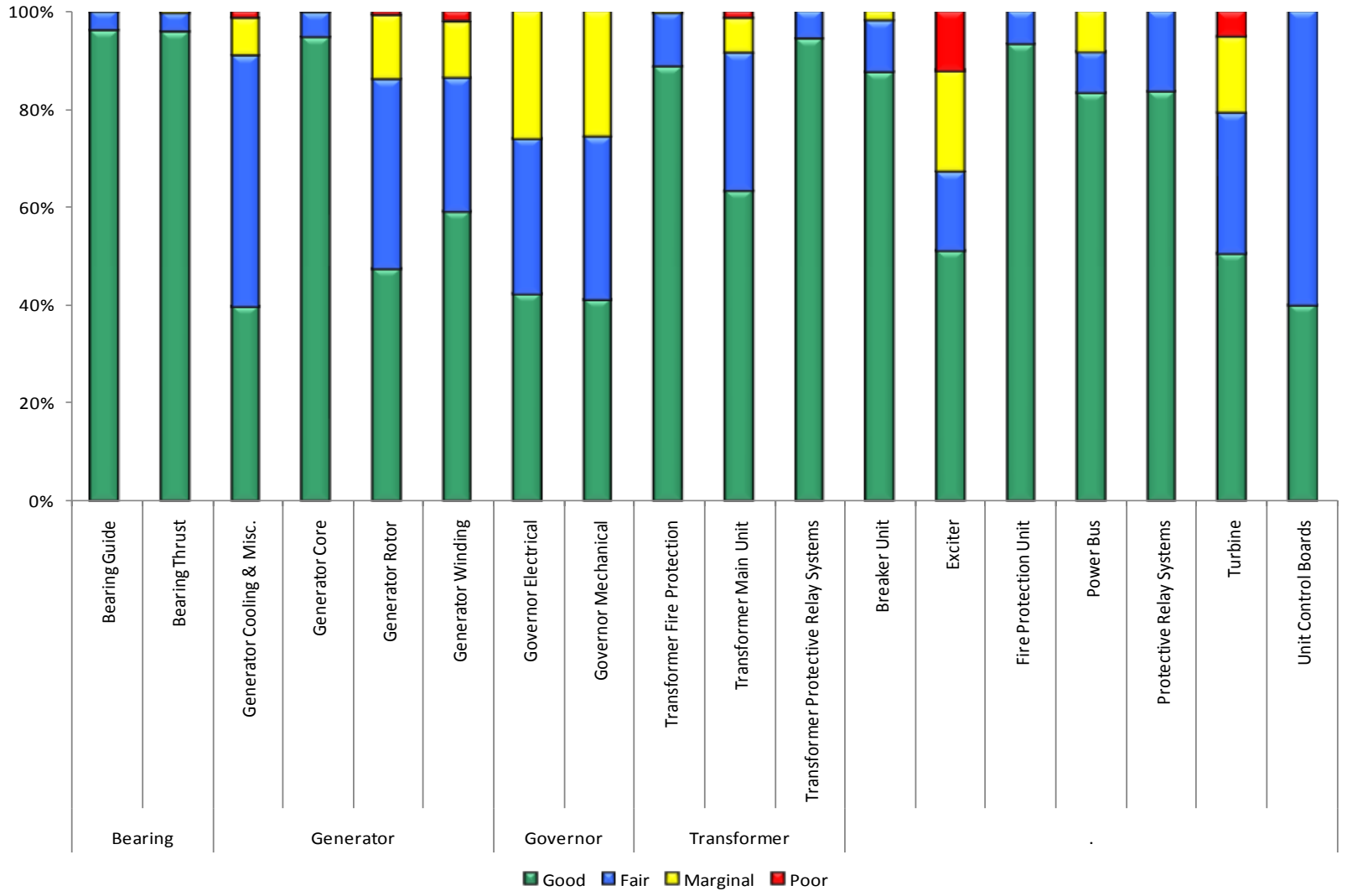
Current Condition by Plant: All Equipment



Current Condition: Unit Reliability Equipment



Risk: Condition Index vs. Likelihood of Failure

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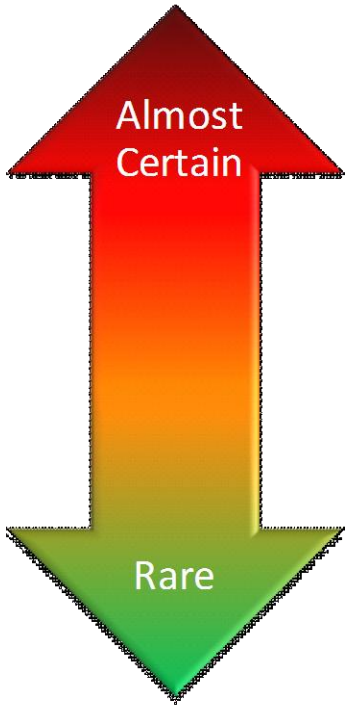
The hydro program correlates a condition rating with the likelihood of equipment failing to perform as expected. An equipment component with a low condition rating has a higher likelihood of failure than one with a higher rating. The correlation is shown below.

Likelihood	Condition Index	Description
	0 to 0.9	Poor
	1 to 1.9	
	2 to 2.9	
	3 to 3.9	Marginal
	4 to 4.9	
	5 to 5.9	
	6 to 6.9	Fair
	7 to 7.9	
	8 to 8.9	Good
	9 to 10	

Current Financial Risk Map

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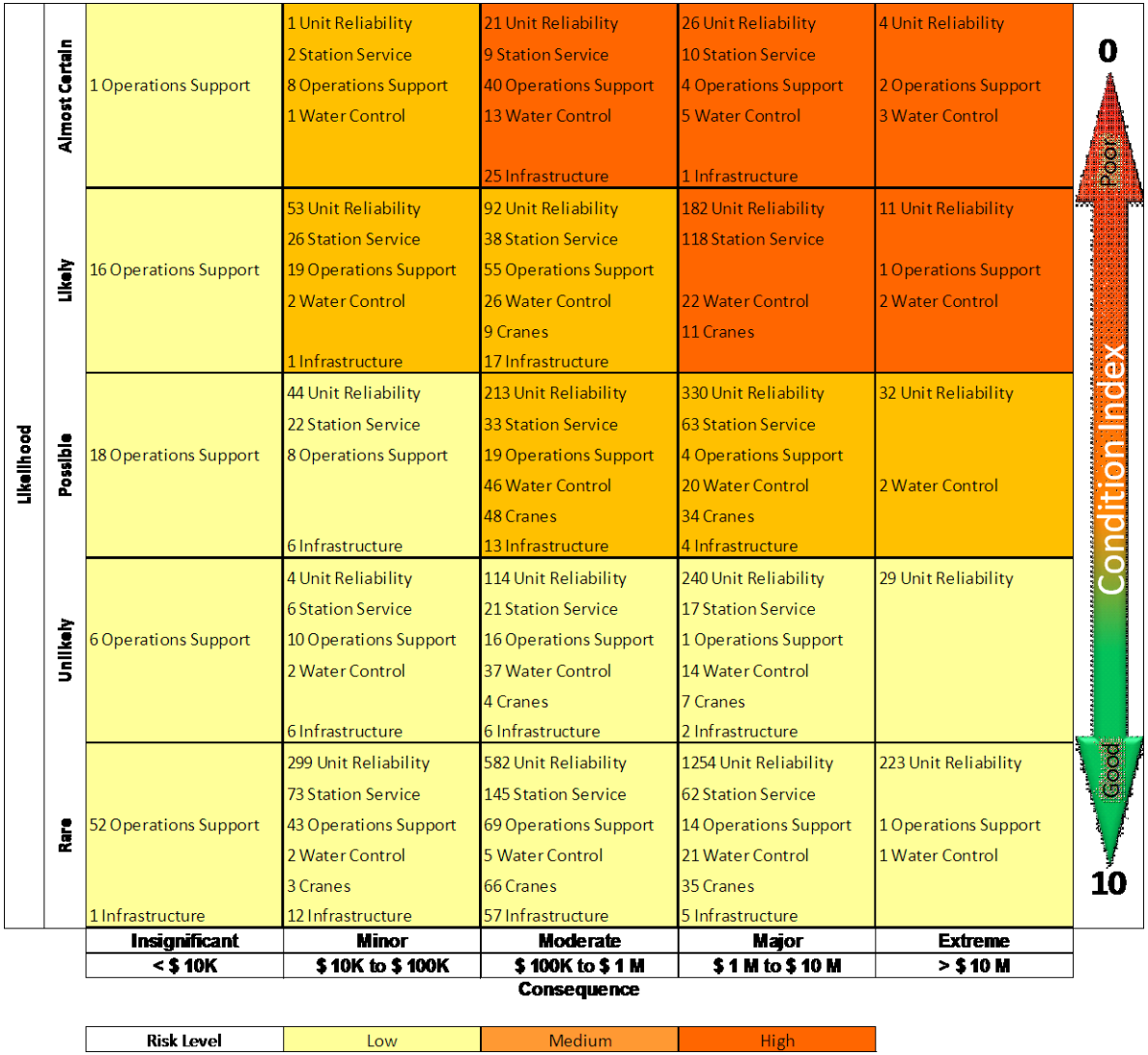

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
	< $ 10K	$ 10K to $ 100K	$ 100K to $ 1 M	$ 1 M to $ 10 M	> $ 10 M
Almost Certain	1 Operations Support	1 Unit Reliability 2 Station Service 8 Operations Support 1 Water Control	21 Unit Reliability 9 Station Service 40 Operations Support 13 Water Control 25 Infrastructure	26 Unit Reliability 10 Station Service 4 Operations Support 5 Water Control 1 Infrastructure	4 Unit Reliability 2 Operations Support 3 Water Control
Likely	16 Operations Support	53 Unit Reliability 26 Station Service 19 Operations Support 2 Water Control 1 Infrastructure	92 Unit Reliability 38 Station Service 55 Operations Support 26 Water Control 9 Cranes 17 Infrastructure	182 Unit Reliability 118 Station Service 22 Water Control 11 Cranes	11 Unit Reliability 1 Operations Support 2 Water Control
Possible	18 Operations Support	44 Unit Reliability 22 Station Service 8 Operations Support 6 Infrastructure	213 Unit Reliability 33 Station Service 19 Operations Support 46 Water Control 48 Cranes 13 Infrastructure	330 Unit Reliability 63 Station Service 4 Operations Support 20 Water Control 34 Cranes 4 Infrastructure	32 Unit Reliability 2 Water Control
Unlikely	6 Operations Support	4 Unit Reliability 6 Station Service 10 Operations Support 2 Water Control 6 Infrastructure	114 Unit Reliability 21 Station Service 16 Operations Support 37 Water Control 4 Cranes 6 Infrastructure	240 Unit Reliability 17 Station Service 1 Operations Support 14 Water Control 7 Cranes 2 Infrastructure	29 Unit Reliability
Rare	52 Operations Support 1 Infrastructure	299 Unit Reliability 73 Station Service 43 Operations Support 2 Water Control 3 Cranes 12 Infrastructure	582 Unit Reliability 145 Station Service 69 Operations Support 5 Water Control 66 Cranes 57 Infrastructure	1254 Unit Reliability 62 Station Service 14 Operations Support 21 Water Control 35 Cranes 5 Infrastructure	223 Unit Reliability 1 Operations Support 1 Water Control

Consequence

Risk Level	Low	Medium	High

Prioritizing Investments

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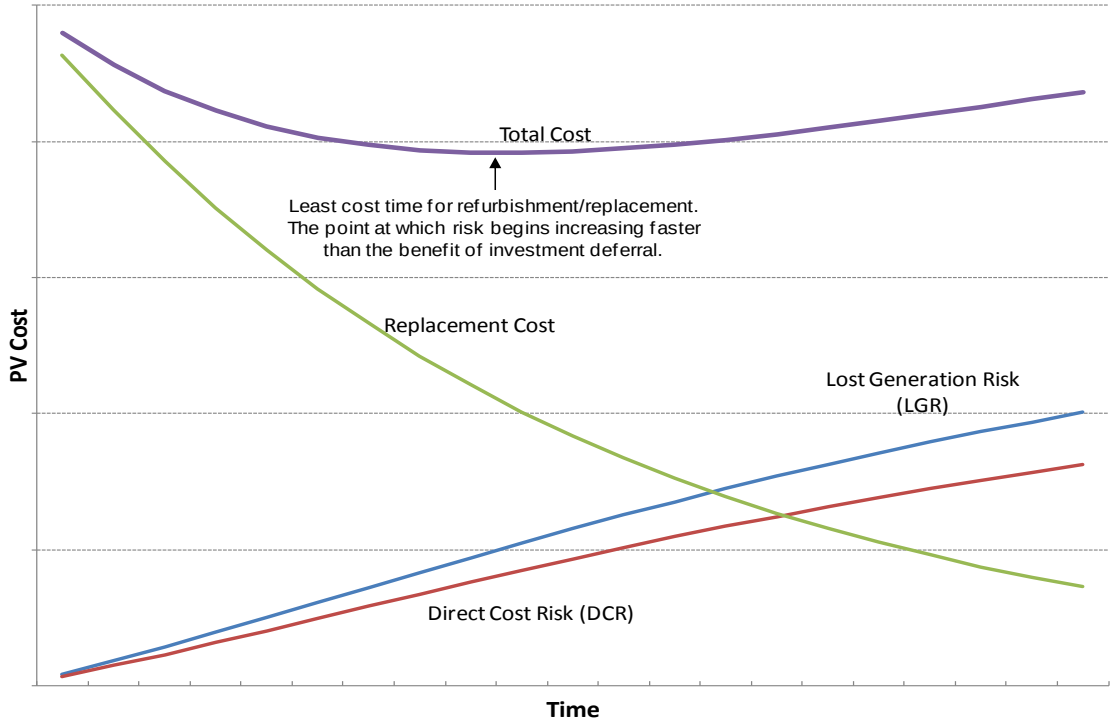
Without intervention, condition degrades over time and the risk of equipment failing to perform as expected increases. Three factors influence the prioritization of investments:

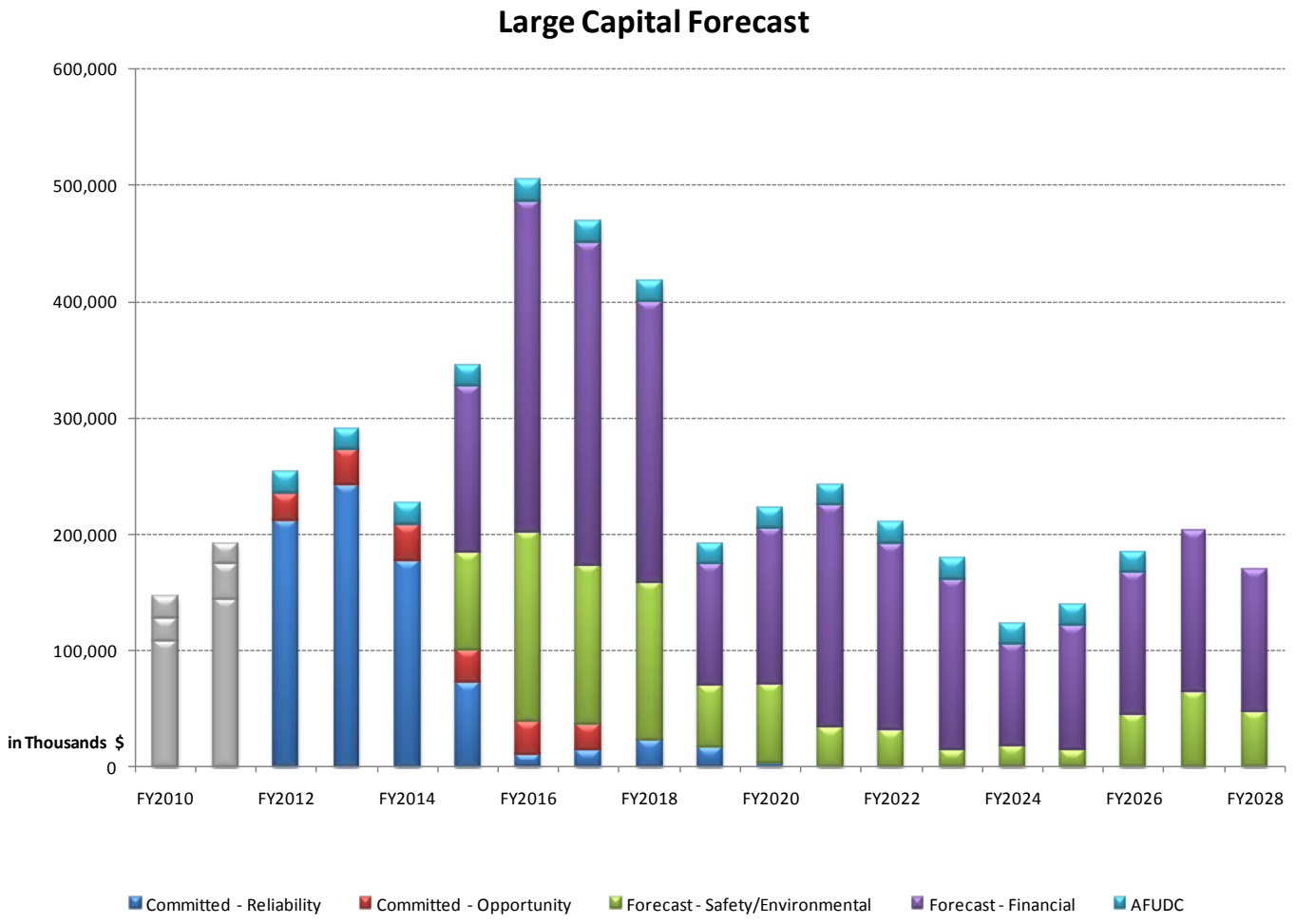
- Replacement Cost, Lost Generation Risk, and Direct Cost Risk



The **Total Cost** is the present value sum of replacement and risk costs. The cost minimum of this curve is the point at which cost risk is forecasted to begin growing faster than the benefit of investment deferral. This represents the optimum timing for equipment replacement.

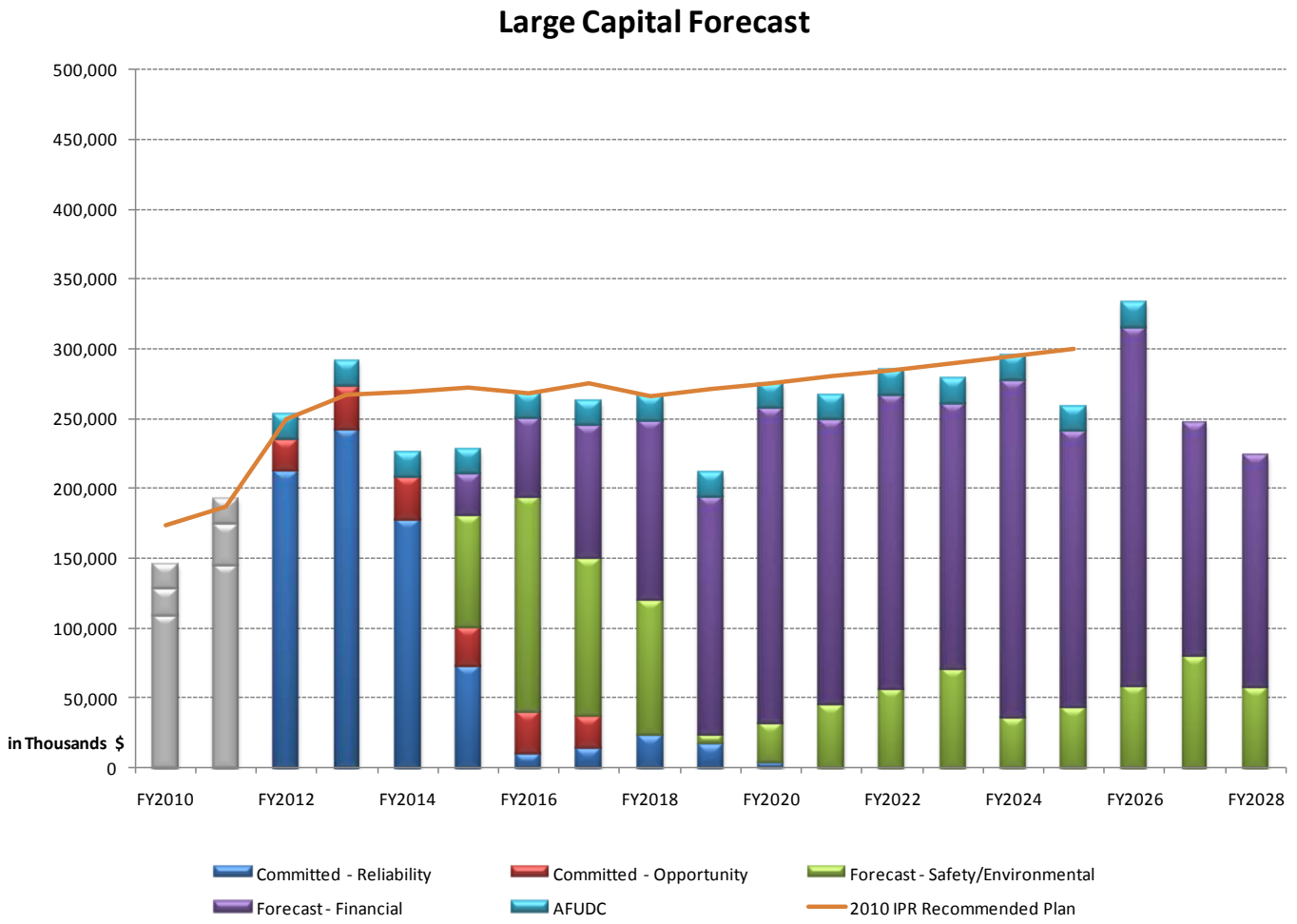
Least Cost Case

- The least cost case represents all equipment being replaced at the cost minima.



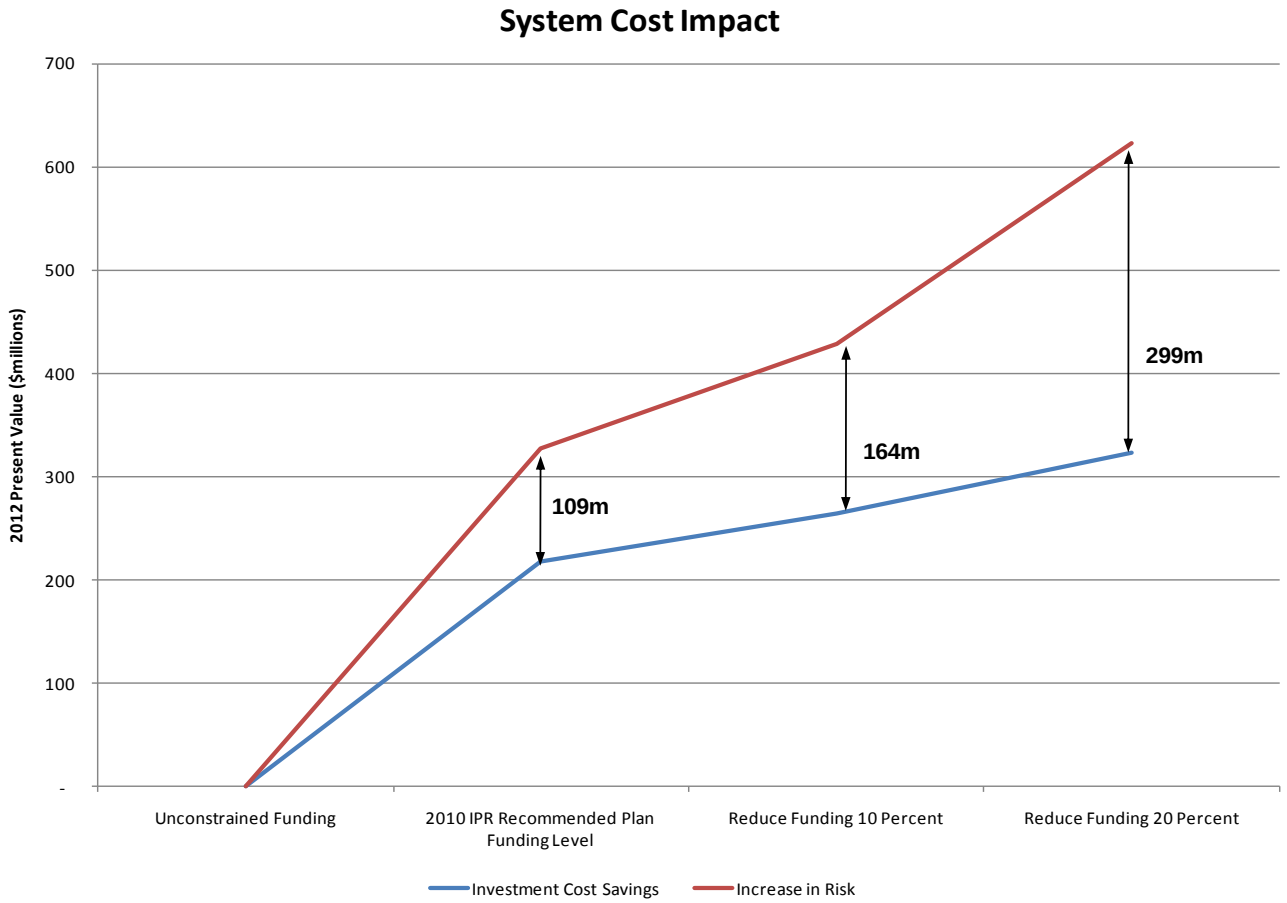
Modeling Funding Constraints

When funding constraints are applied, Total Cost for the system (system cost) increases because new investments are deferred past their cost minima.



System Cost Impacts of Funding Constraints

- System costs increase as funding is further constrained because more investments are deferred past the cost minimum.



Condition by Plant in 2022: Unit Reliability Equipment

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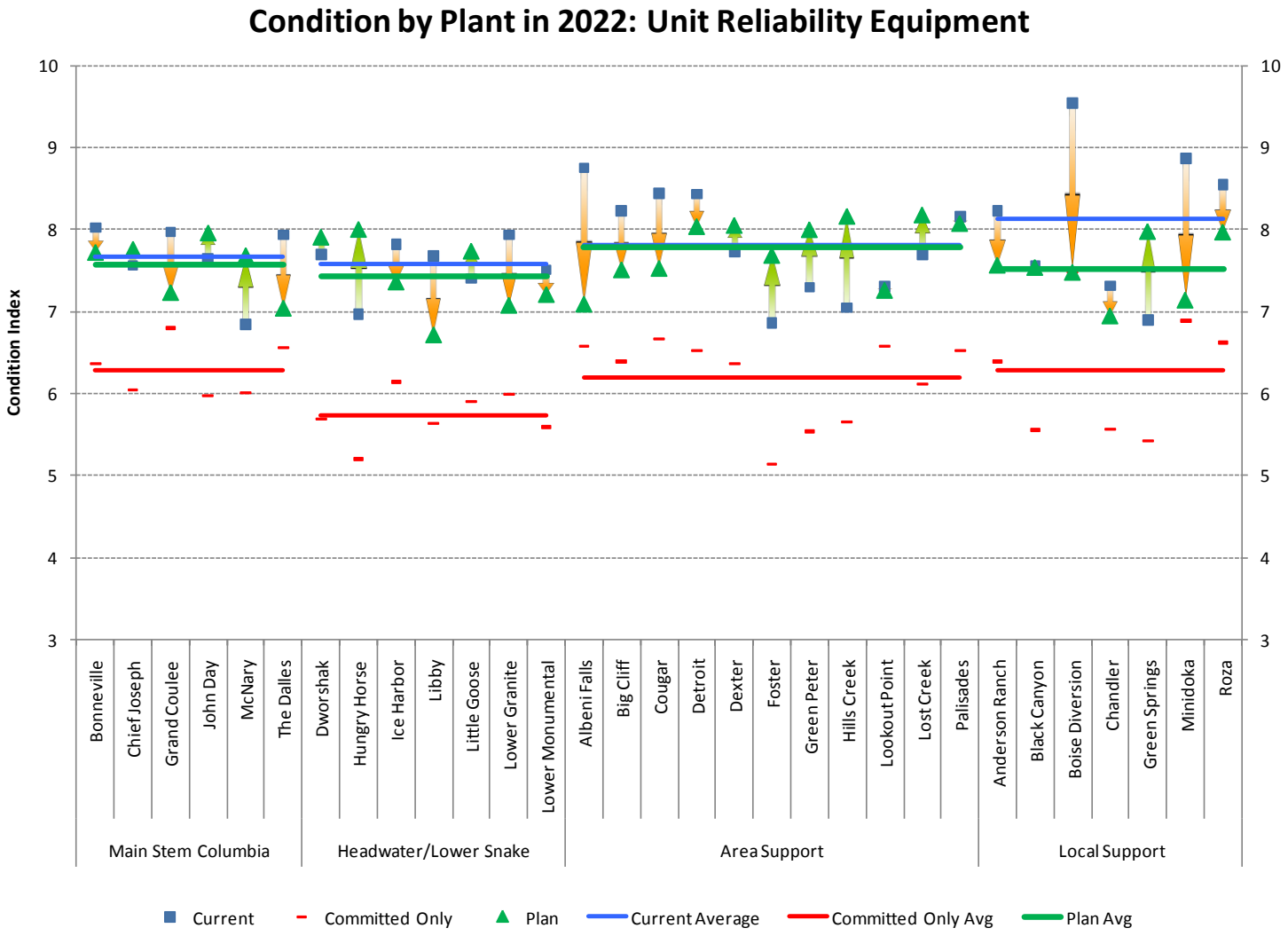

Lost Generation Risk by Plant in 2022

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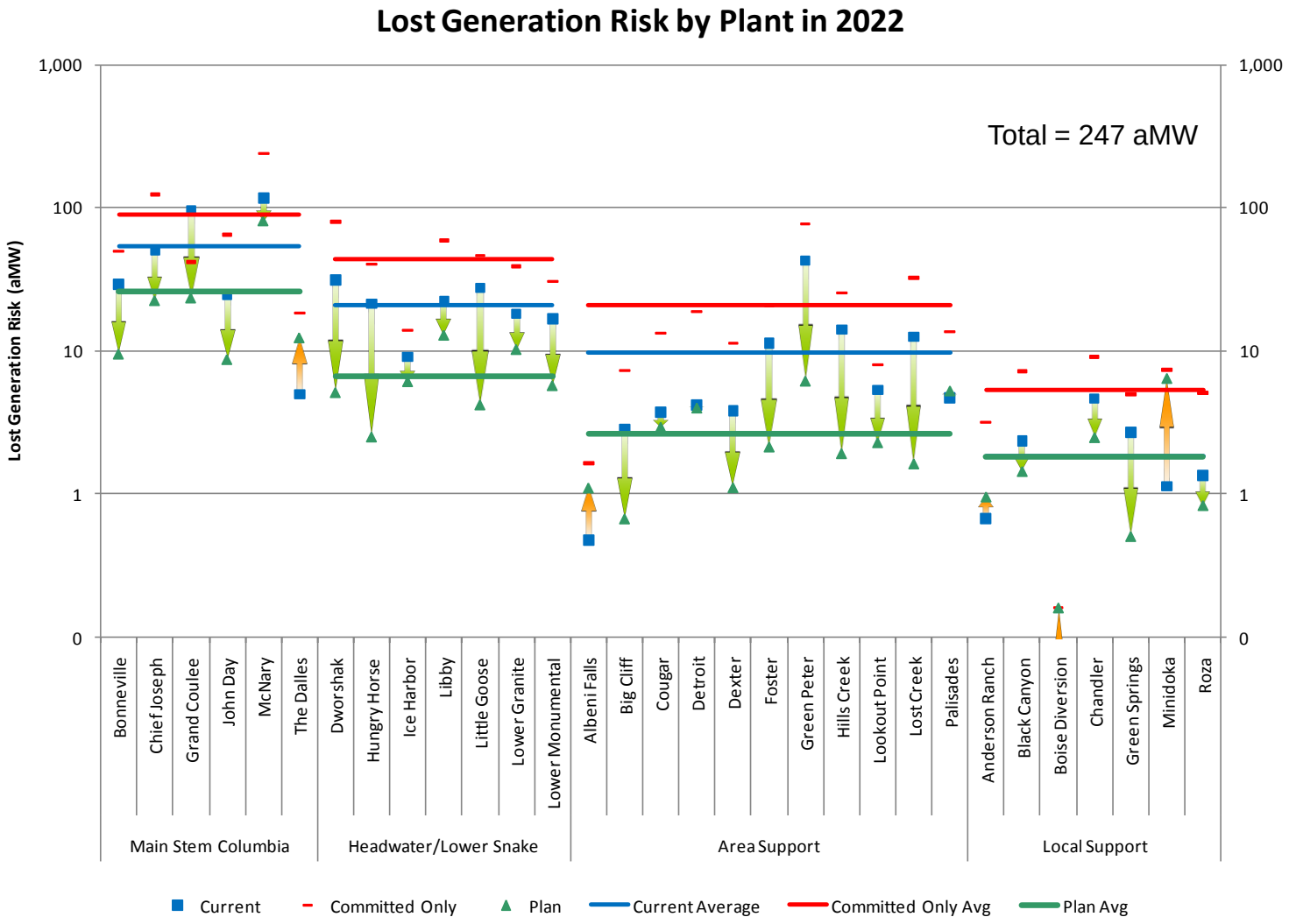

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Thank you

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