Best Practice Maintenance in New Zealand Industry

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For:
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This report is submitted as partial fulfilment of the requirements for the degree of Master of Engineering Management at the University of Canterbury. It is intended for use by Mighty River Power.

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ABSTRACT

Mighty River Power have recognised Geothermal generation as a major strength and growth area for development in the medium term. The company has identified a need to improve maintenance effectiveness and reduce costs. This report investigates current New Zealand maintenance strategies in order to benchmark the effectiveness of Mighty River Power's current maintenance scheme. The report identifies gaps in Mighty River Power's current maintenance approach and provides recommendations to improve and optimise maintenance strategy based on case studies in both power generation and related asset-intensive industries.

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James Feary – Christchurch City Council Waste Water Treatment Plant

Alan Mudie – Contact Energy

Neil Gregory – Meridian Energy

Executive Summary

Best Practice Maintenance

Mighty River Power have recognised geothermal capacity as a major strength and growth area for the company and has in turn identified a need to improve maintenance effectiveness and reduce costs. With maintenance costs estimated to be between $0.01 and $0.03 per kWh (1), this represents a significant expense to MRP over the currently installed 387MW capacity.

The objective of this project is to investigate current best practice maintenance strategies in order to benchmark the effectiveness of Mighty River Power's current maintenance scheme. The project aims to identify gaps in MRP's current maintenance approach and to provide practical insights and recommendations to improve and optimise maintenance strategy based on case studies in both power generation and related industries.

No best practice maintenance organisation was identified across all maintenance elements, however, Meridian Energy were found to be operating advanced reliability driven maintenance strategies in most areas and a best practice predictive asset management system.

Case Studies

Four maintenance surveys were undertaken with organisations in asset intensive New Zealand industries. These surveys were planned to assist in benchmarking Mighty River Power's current geothermal maintenance strategy through questions designed to determine:

- Current maintenance strategy and how it is executed
- Reasons for adoption of specified strategy
- Route taken to develop strategy
- Problems encountered and required improvements
- Level of maturity

Recommendations

A wide range of insights was found across twelve maintenance elements and feedback was analysed to quantify the maintenance maturity level of the surveyed organisations. From this information, four major recommendations were formed:

1. Form a strategic benchmarking partnership with an international geothermal facility.
2. Investigate and implement a Predictive Asset Management System to complement Maximo.
3. Introduce dedicated planners to improve long term planning efficiency and resource allocation.
4.
    a. Improve maintenance culture through transparency, empowerment and accountability.
    b. Assign measureable reliability responsibilities to maintenance staff rather than ad hoc tasks.

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Table of Terms and Acronyms

CE	Contact Energy
CMMS	Computerised Maintenance Management System
CWTP	Christchurch Wastewater Treatment Plant
FMEA	Failure Mode and Effects Analysis
GADS	Generating Availability Data System (tracking software)
GMP	Geothermal Maintenance Plan
KPI	Key Performance Indicator
ME	Meridian Energy
MEM	Master of Engineering Management
MRP	Mighty River Power
NPV	Net Present Value
O&G	A New Zealand Oil and Gas Operator
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
PAMS	Predictive Asset Management System
PdM	Predictive Maintenance
PM	Preventative Maintenance
RCA	Root Cause Analysis
RCM	Reliability Centered Maintenance

1. Introduction

In the current energy generation market, many organisations are looking to improve their maintenance strategies to reduce operation and maintenance costs and increase competitive advantage. Comparing maintenance performance across energy generation organisations and related large scale industries is difficult, as each site operates within a unique context of resources, physical plant assets and organisational goals. Similar industry/competitive and best practices benchmarking allows the organisation to analyse individual circumstances and performances within a group of organisations with a similar asset base (2). Benchmarking gives an indication of industry "best practice" which allows the organisation to identify gaps in the current maintenance strategy, and addresses and bridges these gaps through improvement of critical processes and operations.

It is important that the culture of the organisation recognises maintenance as a key contributing driver of competitive advantage as opposed to the historical view which regarded maintenance as a necessary expense. The maintenance strategy should be developed to ensure physical assets continue to fulfil their intended functions at a minimum expenditure of resources.

As geothermal generation provides base-load energy, maintenance management, reliability and plant availability are critical considerations.

There is currently over 750MW of installed geothermal generation capacity in New Zealand, this figure corresponds to approximately 13 per cent of the country's total power generation. New Zealand has significant potential for future capacity. There is currently 270MW of new capacity under construction and a further 300MW consented, with construction likely to start before 2015 (3). In 2011, total worldwide geothermal investment was approximately 2 billion NZD with a 12 per cent growth rate per annum since 2004 (4).

Mighty River Power have recognised this potential capacity as a major strength and growth area for the company. Geothermal is the fuel of choice for development in the medium term. When considering MRP's portfolio; geothermal generation accounts for 31% of production and is regarded as a "premium" base-load renewable with high availability and low fuel cost (5). Over a quarter of global geothermal power engineered uses expertise from New Zealand (6), and thus, it is clear that New Zealand is a world leader in this industry and as such should be confident in operating industry leading maintenance practices.

MRP have identified a need to improve maintenance effectiveness and reduce costs. With maintenance costs estimated to be between $0.01 and $0.03 per kWh (1), this represents a significant expense to MRP over the currently installed 387MW capacity. At 90% of generation capacity, estimated maintenance costs amount to over $60 million per annum. Even a small improvement to maintenance processes which reduced costs by 5% would result in an annual saving of $3 million.

There is significant capital invested in fixed assets and the operational maintenance cost must be balanced with the much higher cost of equipment failure, which can cause direct damage to people and facilities as well as indirect damage through outages. Whilst geothermal operations are much less complex than their fossil fuel equivalent, they incur approximately double the maintenance costs which can be attributed to the extreme operating environment, high temperatures and impurities which cause corrosion, deposition and erosion.

Maintenance serves to protect Mighty River Power's economic interests, ensure the safety of their equipment, staff, and public and maintain the availability of their plant. The majority of the actual maintenance work is undertaken by contractors and is overseen by a dedicated team within the organisation.

The objective of this project is to investigate current best practice maintenance strategies in order to benchmark the effectiveness of Mighty River Power's current maintenance scheme. The project aims to identify gaps in MRP's current maintenance approach and to provide practical insights and recommendations to improve and optimise maintenance strategy based on case studies in both power generation and related industries.

1.1. Research Objectives

The project will help identify current maintenance best practices and help align Mighty River Power Geothermal with the rest of New Zealand industry.

Two key project objectives have been identified:

- **Determine current New Zealand maintenance practices**, including reasons why organisations adopt a chosen maintenance policy, route taken, problems encountered, and current level of maturity. Research will focus on both the international and New Zealand electricity industry and will include information on the differences in how maintenance is performed between fuel types (hydro, geothermal, thermal and wind).
- **Identify a recommended maintenance strategy**(ies), specifically, strategies appropriate to the geothermal industry.

Further to these two key objectives, Mighty River Power have identified a number of additional outcomes and criteria for the project report as outlined below:

- Provides practical insight and demonstrates understanding of the industry and project topic.
- Is clear, understandable and highly communicable to MRP, respective departments and relevant people.
- Gaps in MRP's current maintenance approach are clearly identified and steps to bridge these gaps are highlighted; specifically relating to the organisation's current operating environment.
- Future work streams are identified that will allow MRP to exploit competitive advantage in the NZ market.
- Key findings, discussion areas, conclusions and recommendations are clearly outlined.

1.2. Scope

The project will primarily focus on similar industry or competitive benchmarking. The project will deliver provide feedback and recommendations to improve the MRP Geothermal Maintenance approach.

Similar industry benchmarking uses external partners and even competitors in similarly asset intensive industries. The project will focus on organisational measures and examine the long term approach and overall performance of Geothermal Maintenance, addressing subsequent gaps.

2. Research Methodology

2.1. Benchmarking

Benchmarking essentially involves learning through sharing of information and adoption of "best practices" to bring about improvements in performance. More specifically, benchmarking is defined as a continuous and systematic process of identifying, analysing and adapting industries best practices that will lead an organisation to superior performance (7). In the context of this project, a more appropriate definition is offered by Harrington who describes benchmarking as "a systematic way to identify, understand and creatively evolve superior… processes, and practices to improve your organisation's real performance" (8). Mighty River Power aims to systematically improve their current Geothermal Maintenance Strategy in order to increase performance and achieve a competitive advantage.

The use of benchmarking will continue to help Mighty River Power to:

- Improve performance
- Learn about industry leaders and competitors
- Determine what world class or best practice performance is
- Accelerate and manage change
- Identify gaps in performance
- Strive towards organisational excellence

For the purposes of this project, benchmarking will serve as an indicator to:

- Understand maintenance processes and approach effectiveness through the comparison of maintenance strategy
- Pinpoint areas for effective change. Comparing maintenance strategies across a number of organisations and similar industries will indicate areas for improvement.

Benchmarking is an evolving, improvement methodology that offers the opportunity to improve and increase performance through objective analysis. The process is a way to gain knowledge as well as generate ideas for creative imitation and innovation.

2.1.1. Types of benchmarking

2.1.1.1. Competitor

Competitive or similar industry benchmarking utilises external partners operating in geothermal or similar industries. While this process could be difficult, it is understood that most companies will be open to sharing information that is not proprietary. Competitor benchmarking usually focuses on meeting and comparing numerical standards (benchmarks), however the case studies for this project will aim to compare maintenance strategy and processes rather than maintenance performance.

2.1.1.2. Best Practice

This method focusses on finding the undisputed "leader" in maintenance strategy. This method can be costly and time consuming to undertake effectively as an in depth best practice search must consider a wide range of industry sectors and geographical locations, comparing maintenance strategy in each organisation or relying on an external authority to identify a "best practice" organisation.

The "ideal" best practice organisation will study maintenance processes both within and outside the geothermal industry, adapt and adopt superior processes and achieve a substantial leap in performance (such as lower cost or greater market share) when compared to its competitors. While no single best practice organisation will be found that is directly comparable to Mighty River Power, strengths and potential improvements in comparable processes should be identified.

Another issue when considering this method is defining how best practice is measured. For example, is "best" measured by cost effectiveness, profitability, customer satisfaction, efficiency or another metric?

Despite this, best practice benchmarking is considered to be the most effective method of benchmarking (2). It provides the greatest potential for achieving breakthrough strategies to improve competitive position and increase return on investment.

2.2. Process

Benchmarking Best Practices in Maintenance Management author Terry Wireman identifies seven necessary steps for a successful benchmarking process (2):

1. Conduct internal analysis
2. Identify areas for improvement
3. Find partners
4. Make contact, develop questionnaire, perform site visits
5. Compile results
6. Develop and implement improvements
7. Do it again

These benchmarking process steps have been adopted and adapted to give the following project methodology:

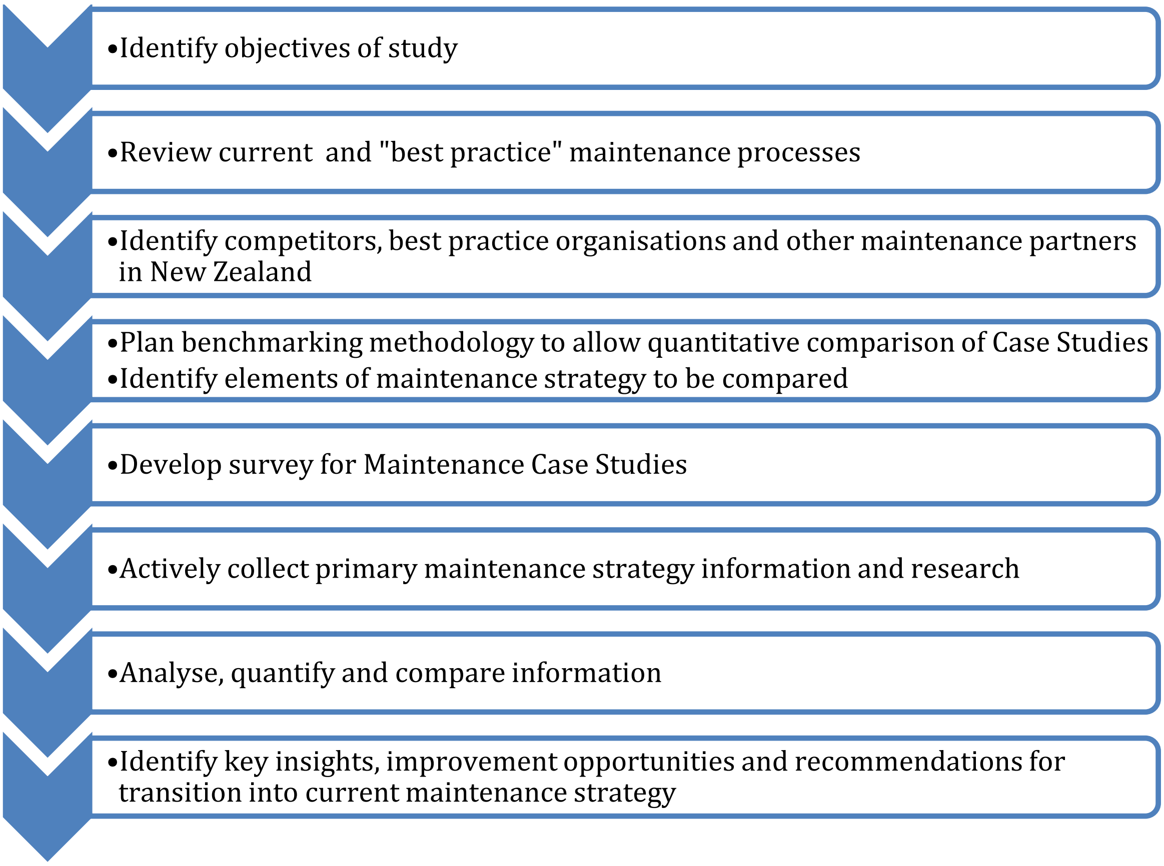

Figure 1: Project process methodology

Future work will include the development of action plans and implementation projects to improve specific maintenance processes.

The methodology has been developed to benchmark general maintenance strategy using an objective standard of comparison. There will be less focus on calculating a quantitative performance gap but rather on identifying best practices that may be adapted to improve organisational performance.

3. Maintenance Practices and Literature Review

Best practices represent benchmarking standards in that nothing exceeds the defined best practice. There is however a broad range of opinions regarding what constitutes best practice and it is sometimes regarded as an unachievable goal.

Best maintenance practices are defined in two categories: standards and methods. Standards are the measurable performance levels of maintenance execution and methods or strategies are practiced in order to meet the standards.

"Methods, strategies, and actions that can make maintenance operations more efficient, reduce maintenance and operating costs, improve reliability, and increase morale." (30)

To change the organisation's basic beliefs and maintenance culture, the current maintenance strategy must first be benchmarked and then reasons why it does not follow best practices in maintaining management determined before an action plan looking is defined.

3.1. Literature Review

Literature	Theory	Application
Allied Reliability. ***Criticality Assessment White Paper.***	Defining criticality and its importance in the maintenance function of the organisation.	The paper defines how to design and conduct a criticality assessment and analyse the results.
Bresko, Mike. ***5S: A Method to Improve Safety, Productivity and Culture.*** **s.l. : GP Allied, 2009.**	A summary of the benefits and implementation of the 5S system of sorting, simplifying, systematic cleaning, standardising and sustaining.	Potentially applicable model for a visually oriented system of cleanliness, organisation and arrangement designed to facilitate greater productivity, safety and quality.
Florida Department of Education. **Organizational Structures of Maintenance and Operations Departments.** ***Maintenance and Operations Administrative Guidelines for School Districts and Community Colleges.***	A discussion on the organisational formation of maintenance and operations departments in a school/community college context.	Defining and contrasting structure and formation of the maintenance organisation in an alternative context.
Franklin, Scott. **Redefining Maintenance - Delivering Reliability.** ***Organization and Management of the Maintenance Function.***	Metrics for measuring asset performance in reliability and utilising these for competitive advantage.	Discussion of performance elements: business drivers, process and development and business results.

GP Allied. ***What Every Senior Manager Must Know About Reliability.* 2009.**	Lessons learned from the BP Prudhoe Bay Oil Spill in 2006 which resulted from a quarter inch hole in a pipeline due to poor maintenance procedures. Highlights high cost/risks associated with reactive maintenance.	Good case study with relevant real-world lessons for the maintenance function.
Hamilton, C.O. ***Maintenance Planning in Underground Mining Operations.* Tucson, Arizona : s.n.**	A proven approach for the successful implementation of an effective maintenance planning system in the context of underground mining operations.	Focus on planning and logical distribution of personnel with defined functional relationships.
Kevin Duffy, Kepner Tregoe. **Strategies to optimize shutdowns, turnarounds and outages. *Reliable Plant.***	Article on shutdowns, turnarounds and outages (STOs) and relevant strategies to properly manage these to minimise business disruption.	A useable and stepped approach to analysing and optimising STOs.
Lanthier, Christopher Nunes and Paul. **Impact the Bottom Line: A Business Case for Reliability-Driven Maintenance. *Master Brewers Association of the Americas: Technical Quarterly.* 2005, 4.**	A case study that outlines reasons for reliability-driven maintenance and how it can be used effectively to improve cost efficiencies, impact the bottom line and gain competitive advantage.	Identification of the financial benefits and costs in a business case to justify reliability-driven maintenance.
Levery, Mike. ***Maintenance - Organisation Misfit?* 1997.**	A critical discussion on the position of maintenance within the organisation and associated observations.	Useful in defining the traditional view and role of maintenance and its position in the organisational structure.
Mather, Daryl. ***The Maintenance Scorecard: Creating Strategic Advantage.* New York : Industrial Press, 2005.**	Chapter on fundamentals and myths around asset management.	Establishing that asset management is never a one-size-fits-all generic discipline and that there is a general lack of understanding in the area as demonstrated by a number of myths that are dispelled in the chapter.
Moubray, John. ***Reliability-centered Maintenance II.* New York : Industrial Press Inc, 1997.**	Guide to RCM; a process used to determine systematically and scientifically what must be done to ensure that physical assets continue to do what their users want them to do.	A valuable and cost effective process that leads to rapid, sustained and substantial improvements in plant availability, product quality, safety and environmental integrity.

Peters, Ralph W. ***Maximizing Maintenance Operations for Profit Optimisation.*** **s.l. : The Maintenance Excellence Institute, 2002.**	Use of the scoreboard for maintenance excellence to determine current status or maturity with regard to best practice maintenance.	Potentially useful benchmarking tool however requires 300 inputs.
R. Keith Mobley, Lindley R. Higgins and Darrin J. Wikoff. ***Maintenance Engineering Handbook (Seventh Edition).*** **USA : McGraw-Hill, 2008.**	The Maintenance Engineering Handbook is regarded as the premier source for expertise on maintenance theory and practices for any industry. The handbook provides a solid knowledge foundation from the organisational level through maintenance management, analysis and reliability tools as well as applications in different industries.	Excellent foundation knowledge focussing on recognised and proven best practices in maintenance, repair, root-cause analysis, and performance management for reliability.
Smith, Ricky. ***Guiding Principles for Maintenance Planning and Scheduling.***	A brief breakdown of planning and guiding principles and the differences in the context of maintenance planning and scheduling.	Used in survey and question development.
Solomon Associates. ***Optimum Maintenance Spending.***	A methodology to determine a target optimum point where availability meets maintenance spending in the context of a coal-fired generation facility. An algorithm was developed that predicts the relationship between maintenance spending and reliability which when coupled with a market-loss curve determines optimum maintenance spend.	An interesting, scientific approach however it relies on large amounts of plant data and a number of best guess estimates.
The Maintenance Excellence Institute. ***Measuring the True Value of Maintenance Activities.***	Measuring effectiveness and bottom line results for the maintenance function of the organisation.	Continuous Reliability Improvement and plan of action. Alternative levels of maintenance benchmarking – not used. Wrench time/craft utilisation.
Wireman, Terry. ***Benchmarking Best Practices in Maintenance Management.*** **New York : Industrial Press, 2010.**	Maintenance best practice benchmarking and benchmarking fundamentals including types of benchmarking and the benchmarking process.	Valuable in defining processes and forming project methodology.
Wireman, Terry. ***Developing Performance Indicators for Managing Maintenance.*** **New York : Industrial Press, Inc., 2005.**	Good chapter on Developing Maintenance and Asset Strategies.	Maintenance philosophies, objectives and a general Maintenance Strategy structure used in the report.

3.2. Maintenance Management

In recent years, maintenance engineering has put an increasing emphasis on reliability. A business which is asset-intensive, such as energy generation, relies on a reliability-centered approach to be successful. Reliability engineering itself has become a technology used for the purpose of improving capacity or output, without capital investment. (9)

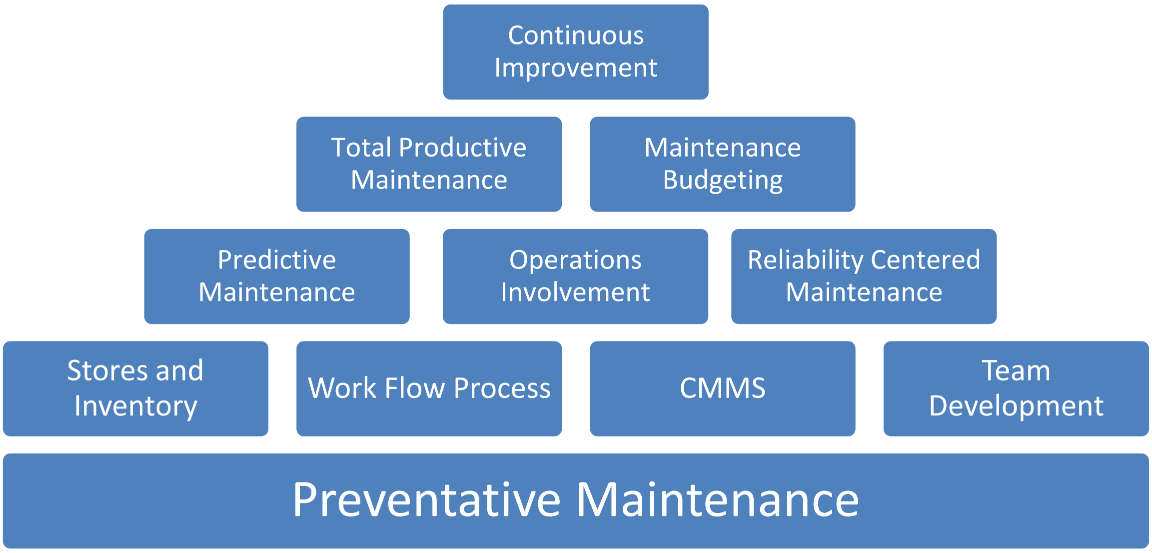

Figure 2: A comprehensive Maintenance Management Strategy (2)

The function of maintenance management has a number of (sometimes conflicting) objectives which include:

1. Maximising generation output at the lowest cost, the highest quality and within optimum safety standards.
2. Identifying and implementing cost reductions
3. Providing accurate equipment maintenance records
4. Collecting necessary maintenance expenditure information
5. Optimising maintenance resources
6. Optimising asset life-cycle.
7. Minimising resource usage (energy and spares)

3.3. Maintenance Philosophies

Knowledge of a number of maintenance techniques are required in order to benchmark the effectiveness of Mighty River Power's maintenance strategy. Below is a comparison of key techniques used in the analysis of MRP's geothermal maintenance plan.

3.3.1. Reactive Maintenance

Reactive or run to failure maintenance is the most expensive way to coordinate maintenance. This philosophy implements no preventative measures, instead maintenance staff react to break downs and only work on equipment that has malfunctioned. Availability and reliability are generally below acceptable levels and output is therefore impacted.

3.3.2. Preventative/Corrective Maintenance

Corrective maintenance refers to maintenance tasks generated from preventative maintenance (PM) inspections and is also referred to as planned or scheduled maintenance. This is often seen as the most cost effective approach to maintenance, reducing costs by between 2 and 5 times when compared to a reactive approach. Preventative maintenance tasks include lubrication programmes and routine inspections with an aim to prevent potential break downs before they occur.

3.3.3. Predictive Maintenance

Predictive maintenance utilises condition monitoring to predict or forecast failure through monitoring condition data over time. Condition monitoring programmes generally measure and track a parameter such as pressure, temperature or flow rate. Sometimes complicated modelling is used to analyse asset condition using several parameters.

Predictive maintenance allows equipment maintenance or repair to be scheduled at times that will minimise disruption and unnecessary downtime. Some condition monitoring programmes enable real time monitoring of equipment with alarms generated when operation is outside the expected range.

Condition based maintenance provides an optimal maintenance cost versus equipment service level method however the initial implementation and installation cost is often a barrier.

3.3.4. Reliability Centered Maintenance

Reliability centered maintenance is a process used to systematically and scientifically determine what must be maintenance work must be done to ensure that physical assets continue to do what their users want them to do. The process aims for rapid, sustained and substantial improvements in plant availability, product quality, safety and environmental integrity.

3.3.5. Total Productive Maintenance

Total productive maintenance is a management process that views all levels of the organisation as responsible for equipment health. TPM aims to improve productivity by making processes more reliable and less wasteful through maintenance that will minimise unexpected failure (10). This is achieved by having the Operations team directly involved in the process of maintaining equipment (11). TPM also utilise preventative and predictive maintenance techniques to achieve this objective. TPM focusses primarily on manufacturing however its benefits (such as improvement of employee maintenance awareness) can be applicable to the geothermal generation process.

3.3.6. Comparison

Level	Description	Benefits	Shortcomings
Reactive	Fix or replace a device, only after failure. Suitable for non-critical and low cost equipment.	Low cost/resources required. Little time, effort or expense for maintenance until absolutely necessary.	Potential safety hazards and increased costs due to unplanned maintenance and associated downtime, overtime, spare parts and secondary damage. (12)
Preventative	Scheduling maintenance activities based on defined time intervals. It is assumed that equipment condition is directly related to time or use.	Reduces reactive maintenance and provides a structure to maintenance actions. Flexible, energy savings, cost savings over reactive.	Does not eliminate unexpected equipment problems. Unneeded maintenance performed regardless of condition. Wastes resources/labour and results in large inventories.
Predictive	Assesses the equipment health through diagnostics testing and/or on-line monitoring to find and isolate the source of equipment problems.	Predicts when a device is likely to fail, minimising the risk of random failure. Directs actions aimed at failure root causes as opposed to faults or machine wear conditions. Increased availability, quality, and safety.	High investment in diagnostic equipment and training. (12) Results in being proactive in areas which have little effect on the plants operation.
Reliability Centred Maintenance	A framework that defines a complete maintenance regime aimed at ensuring assets continue to perform their required function in the current operating context.	Increases the overall reliability of a plant by only undertaking maintenance on those components which actually affect the operation. Greater efficiencies and lower costs with fewer overhauls. Greater understanding of current risk levels.	The analysis can be time consuming, inflexible and difficult to initiate with significant start-up cost and training required.
Total Productive Maintenance	A proactive method for improving availability through better utilisation of maintenance and production resources. Critical adjunct to "lean".	Improves employee maintenance awareness and responsibility to improve equipment availability.	Primarily designed for a manufacturing environment to achieve: zero product defects, zero equipment unplanned failures and zero accidents.

3.4. Maintenance Effectiveness Benchmarking

Benchmarking defines the need to compare the effectiveness of the maintenance function. There are two reasons for measuring maintenance effectiveness: to control costs and to effect continuous improvement (13).

Benchmarking involves collecting information that can be used for comparison purposes. Comparisons can be made both internally (other sites) or externally (competitors, similar industries) in order to find centres of excellence or best practices that may be used as models for improvement. *Geber's* (14) definition of benchmarking is "finding the best way to perform a process by measuring how well you do it and comparing your performance against the best practitioners you can find" which supports a continuous improvement motive.

Idhammar (15) states "... that people are looking for the silver bullet in maintenance cost analysis; in most cases they are driven by corporate initiative. That silver bullet does not exist, not even within one company, and certainly not in comparisons between". He suggests that it is more valuable to benchmark your own operation with the objective of lowering the overall cost of providing the service and by continuously becoming more competitive.

For the purposes of this study, inter-organisational comparison is only possible where the same comparable data is available across all organisations. As such qualitative case study analysis has been employed to benchmark maintenance effectiveness of the organisations.

3.5. Best Practice Maintenance

Many organisations respond to the pressure to improve processes by adopting prescribed "best practices". There is often an underlying assumption of these efforts that if other organisations or industries can achieve success form a practice then that success can be replicated. Unfortunately this assumption is often flawed. It is possible that a specific practice with a proven record in one context may do more harm than good when applied to another. This detrimental outcome may be due to a number of factors including key drivers in the adopting organisation not being addressed or a lack of required complementary skills and processes necessary to make the practice successful.

"Best practice" encourages a one-size-fits-all approach and suppresses innovative approaches which enable competitive advantage and are critical to an organisations survival. It has been seen that when processes are developed into rigid frameworks or delivered as "best practice" products, objectivity is forgotten. The reality is that best practices are nothing more than disparate groups of methodologies, frameworks, processes and rules that attained a level of success in a specific context, and because of that success, have been deemed as universal truths for the purpose of providing a "standard" that can be applied anywhere within the industry.

For the purpose of this project it is important to consider that just because "Organisation X" had success with a particular Geothermal Maintenance Strategy, it doesn't mean that Mighty River Power can simply plug-and-play the same process and expect the same outcome. By the same token, it is not recommended to completely disregard existing methodologies, but rather critically evaluate each practice as to whether it is appropriate beyond the fact that it is already in use. These are important considerations when developing a maintenance strategy that meets the specific needs of the organisation, encourages operational excellence and promotes a long-term change in culture across all maintenance elements within the organisation.

4. Benchmarking Case Studies

Case studies were chosen as an effective method to analyse and gain insight into the maintenance strategies used by asset-intensive organisations in New Zealand industry.

A comprehensive Maintenance Strategy survey (Appendix A) was designed to gather information on the development of maintenance strategy, execution, reasons for adoption, maturity and problems or improvements required.

Four qualified respondents (maintenance, reliability and management staff) completed the hour long, face to face or phone survey about the current maintenance strategy in their respective asset intensive organisation.

4.1. Case Study Partners

- Christchurch City Council Waste Water Treatment Plant
- Contact Energy
- Meridian Energy
- A New Zealand Oil and Gas Operator

4.2. Maintenance Elements

Mighty River Power have provided a Maturity Framework (Appendix G) that identifies 35 maintenance sub-elements.

Each heading has between 1 and 6 sub-elements that present a maintenance maturity question, an expanded description and 5 levels of maturity as defined below:

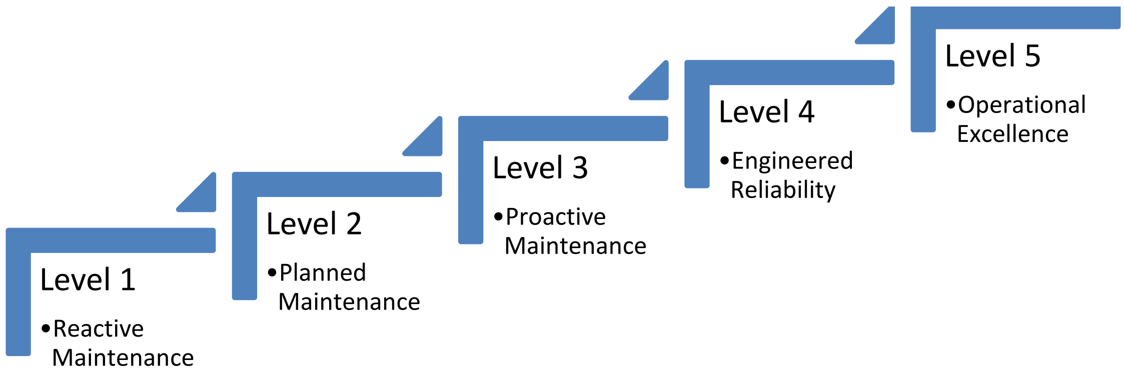

Figure 3: Maintenance maturity levels

Each level represents a level of maturity related to each of 35 maintenance elements and forms the basis of a benchmark for comparison purposes. In order to develop a survey for benchmarking purposes, 12 high-level maintenance elements were selected to be explored and 23 questions were developed to gain insight and benchmark maintenance strategy in New Zealand organisations. For full details of the Level definitions for each element see the Maintenance Survey in 0.

4.3. Maintenance Element Classification

1. **CULTURE**
    - Sponsorship and Organisational Culture
2. **COMMUNICATION**
    - Operations and Maintenance Partnership
3. **TEAM**
    - Team Development
4. **STRATEGY**
    - Geothermal Maintenance Strategy
    - Maintenance Plan Reviews
    - Maintenance Effectiveness
    - Reliability Centred Maintenance
5. **TARGETS**
    - Key Performance Indicators
6. **PROCESS**
    - Management of Maintenance Work
    - Procedures, job plans and specifications
7. **PLANNING**
    - Maintenance Initiation
    - Maintenance Execution
    - Maintenance History and Backlog Management
    - Routine Maintenance Planning
    - Work Scheduling
    - Equipment Criticality (priority)
    - Equipment Maintenance Plans (planned)
8. **REACTIVE**
    - Emergent Maintenance Work
9. **PREDICTIVE**
10. **OUTAGES**
    - Shut Initiation
    - Scope Management
    - Shut Preparation
    - Shut Execution
    - Shut Termination
11. **CONTINUOUS IMPROVEMENT**
    - Continuous Improvement Process
    - Equipment Failure Analysis
    - Plant Performance Improvement
    - Design for Maintainability
    - Reliability Centred Design
12. **MANAGEMENT**
    - Maintenance Budgeting
    - Contractor Selection
    - Stores and Inventory
    - Operational Data and Information

ELEMENTS NOT CLASSIFIED

- Equipment Hierarchy
- Reliability Centred Lubrication
- Operational maintenance and basic care

5. Case Study Results

The full case studies are available in the Appendices:

- Appendix B: Christchurch Wastewater Treatment Plant Case Study
- Appendix C: Contact Energy Case Study
- Appendix D: Meridian Energy Case Study
- Appendix E: A New Zealand Oil & Gas Operator

With full maintenance element analysis shown in Appendix F: Summary of Case Study Findings.

This section highlights insights gained from responses to the case study surveys in the Appendix.

1. Culture

Reliability Driven Culture considers the organisations culture towards maintenance and whether reliability driven culture is sponsored by senior managers in the organisation.

Common themes

Reliability driven culture is not generally a strong focus in the surveyed organisations with little in the way of strategy or improvement plans. Reliability requires a "paradigm shift" in the way the organisation operates.

Organisational sponsorship and culture provide the foundation for any successful maintenance strategy. A reliability driven culture requires buy in from all players. Sponsorship, culture and communication can be seen as the one of the biggest barriers or enablers to improving maintenance strategy outcomes. Cultural transformation is made more difficult in large organisations or organisations that contract out the maintenance function.

Key outcomes

There is a need for active and visible participation in order to gain support from all levels of the organisation. There is a need to educate employees at all levels of the organisation on the benefits of reliability driven culture, and to implement tools and technologies that clearly communicate successes and highlight the maintenance function of the organisation. While cultural changes do not happen overnight, attributing a level of responsibility and empowerment to improve maintenance outcomes to employees across the organisation can encourage a sense of ownership in maintenance outcomes. Further development of the MRP Team building program will enable improvement in organisational culture.

There is a need for greater communication, accountability and high-level, visible organisational goals that tie into maintenance KPIs.

2. Communication

Communication considers the regularity and level of communication between Maintenance, Operations and Senior Management. Partnerships, common targets and aligned frameworks are desired.

Common themes

There is generally an established meeting schedule to enable regular communication between Maintenance and Operations with some basic targets agreed upon. The disconnect between top-down and bottom-up communication is highlighted.

Key outcomes

There is a need for stronger partnerships and a better meeting structure to allow common goals and targets to be developed, shared and reviewed. There is a need for a common maintenance framework across Maintenance and Operations that defines structured reference groups or improvement teams that are accountable for goals and initiatives set at a strategic level.

It is also advised to review communication channels to ensure that there is no disconnect between top-down and bottom-up communication.

3. Team

This element considers the team development process in terms of skill matrices, competencies, career progression and future requirements of the organisation.

Common themes

Team development processes were varying in maturity and were currently being updated in two of the organisations surveyed. Generally, some level of competencies or skills is recorded, with little forward planning.

Key outcomes

There is a need to develop and implement a more structured team development process that includes development plans that align with current and future organisational requirements. Competencies should link back to initiatives in the maintenance strategy. A regular and accountable development plan review process would be valuable with incentives and deadlines for competency and skill growth.

4. Strategy

Strategy considers the overall current maintenance strategy and what maintenance philosophies this is based on as outlined in Section 3.3. This element also looks at how strategy is developed, reviewed and updated and its effectiveness.

Common themes

Asset-intensive industry maintenance strategies generally consist of some combination of reactive, preventative and predictive with the majority being preventative and a current focus on improving predictive.

Key outcomes

The strategy must continue to be a "living document" that is regularly reviewed and updated with all stakeholders involved. There is potential to explore other industry standards, frameworks and tools and to use similar industry benchmarking at a quantitative level to share process improvement initiatives. Alternative tools highlighted include the NAMS framework and Apollo RCA.

5. Targets

This considers whether the maintenance strategy includes clear quantitative targets and KPIs that are measured and tracked to drive strategy.

Common themes

High-level, strategic targets are generally well defined but do not necessarily translate into operational or tactical KPIs.

Key outcomes

It is important to ensure that high level goals are communicated and developed into action plans at an operational level. The opposite can also apply in that low level maintenance processes may not be tailored to achieve high level goals. Again, this highlights the importance of solid communication channels especially in the development of organisational strategy and targets.

Again, accountability and ownership of maintenance targets may yield improved results over assigning maintenance tasks ad hoc. The CCC initiative to have maintenance teams responsible for the reliability of assigned areas and equipment as measured by KPIs could be a valuable strategy for the MRP Geothermal environment.

Targets should be agreed and understood by all stakeholders (strategic through to tactical), widely communicated, reviewed and updated regularly and easily monitored. NZ Oil & Gas Operator also highlighted the importance of measuring safety performance above resource efficiency.

6. Process

This element considers the work flow process and how it is managed including procedures, job plans and specifications.

Common themes

A fairly common work order process is followed with varying levels of process information, verification and work order review.

Key outcomes

There is a recommendation for an improved coverage of standard operating procedures/work orders to improve the efficiency and outcomes of common tasks. A dedicated operations team to generate work packs (standard operating procedures, checks, permits and safety reviews) is also advised. There is also scope to improve the efficiency of the scheduling function. Resource allocation should be completed weekly. Formal post maintenance reviews or audits are recommended to verify data integrity, especially for critical assets. All work requests should be recorded in Maximo.

7. Planning

This element considers work planning, scheduling and prioritisation for the planned maintenance function of the organisation. This element also considers maintenance history and backlog management.

Common themes

Routine planning is generally handled by the CMMS with prioritisation by criticality, risk and safety considerations. There are varying degrees of planning or scheduling functions within the surveyed organisations.

Key outcomes

It is recommended that longer term scheduling is considered to take advantage of resource availability. Improved weekly work schedules should allocate resources and appropriate instructions (work orders) for safe execution. Dedicated schedulers could improve efficiency of the planning cycle.

8. Reactive

This element considers how reactive maintenance is managed in the organisation.

Common themes

Reactive maintenance generally managed by a formal or informal re-prioritisation of the maintenance schedule. Often an ad hoc process based on priority of the notification.

Key outcomes

MRP have a well-defined and formal process for managing reactive or emergent geothermal plant work. This takes into account risks and consequences of deferring maintenance.

There is scope for improved equipment failure analysis and more thorough event reporting.

9. Predictive

This element considers condition monitoring processes and predictive maintenance techniques.

Common themes

This is a focus area across many organisations looking to effectively manage large volume of data from the CMMS. Value of condition monitoring understood, but implementation sometimes lacking.

Key outcomes

There is scope to form a strategic partnership with Meridian Energy in order to learn from their "best practice" condition monitoring programme. Meridian's Plant Asset Management system provides many benefits including (16):

- Combines data collection and analysis and integrity checks from multiple sources
- Forces pro-active decision-making through decision support and early detection of impending faults using predictive analysis
- Aids in maintenance scheduling based on current and historical analysis
- Provides access to asset information through one easy-to-use interface
- Allows viewing of summarised data at the corporate level and the ability to drill down to the condition monitoring points at the analysis level

- Captures the intellectual property of an organisation's most experienced and skilled staff.

10. Outages

This element considers the process for managing outages or plant shuts.

Common themes

Outages generally carefully managed in asset intensive industries due to high cost of business interruption. Long term forward planning instrumental in effective management.

Key outcomes

Outage management should include resource availability. Improved and extended forward planning of outages is recommended. Full outage work order information should be recorded in Maximo.

11. Continuous Improvement

This element considers the processes that are in place for continuous improvement and implementing reliability based principles into capital projects, major modifications or new plant equipment.

Common themes

Continuous improvement sometimes claimed as a result of other maintenance initiatives but not measured or monitored. There is a general focus on greater maintenance function input in the selection of new equipment for capital projects. Varying levels of fault analysis and benchmarking undertaken by the organisations surveyed.

Key outcomes

Scope for improved benchmarking processes, feedback and improvement through GKS Hydro and entry into Asset Management awards. Further analysis of appropriate defect elimination tools or frameworks for geothermal recommended.

12. Management

This element considers maintenance management and administration including spares and inventory, contractor management, information management and maintenance budgeting.

Common themes

Spares and inventory managed poorly. Generally formal processes in place for contractor management. Data and information recorded in CMMS. Common maintenance budgeting process.

Key outcomes

Inventory management should be improved through improved understanding of stock levels, cost and lead time. Inventory should be standardised, recorded and tracked in Maximo.

There is scope for an improved contractor evaluation process based on cost and lead time with on-going contractor agreements. Contractors should be involved in reliability culture and continuous improvement for the organisation. Some Scope to improve budget calculation and allocation, especially around equipment level allocation.

6. Organisation Comparison

The maintenance maturity elements described in Section 4 and further defined by level in Appendices A and F allow for direct comparison of the participating organisations. A radar plot provides a good visual comparison of the maintenance maturity level of the five asset intensive organisations over 12 maintenance elements.

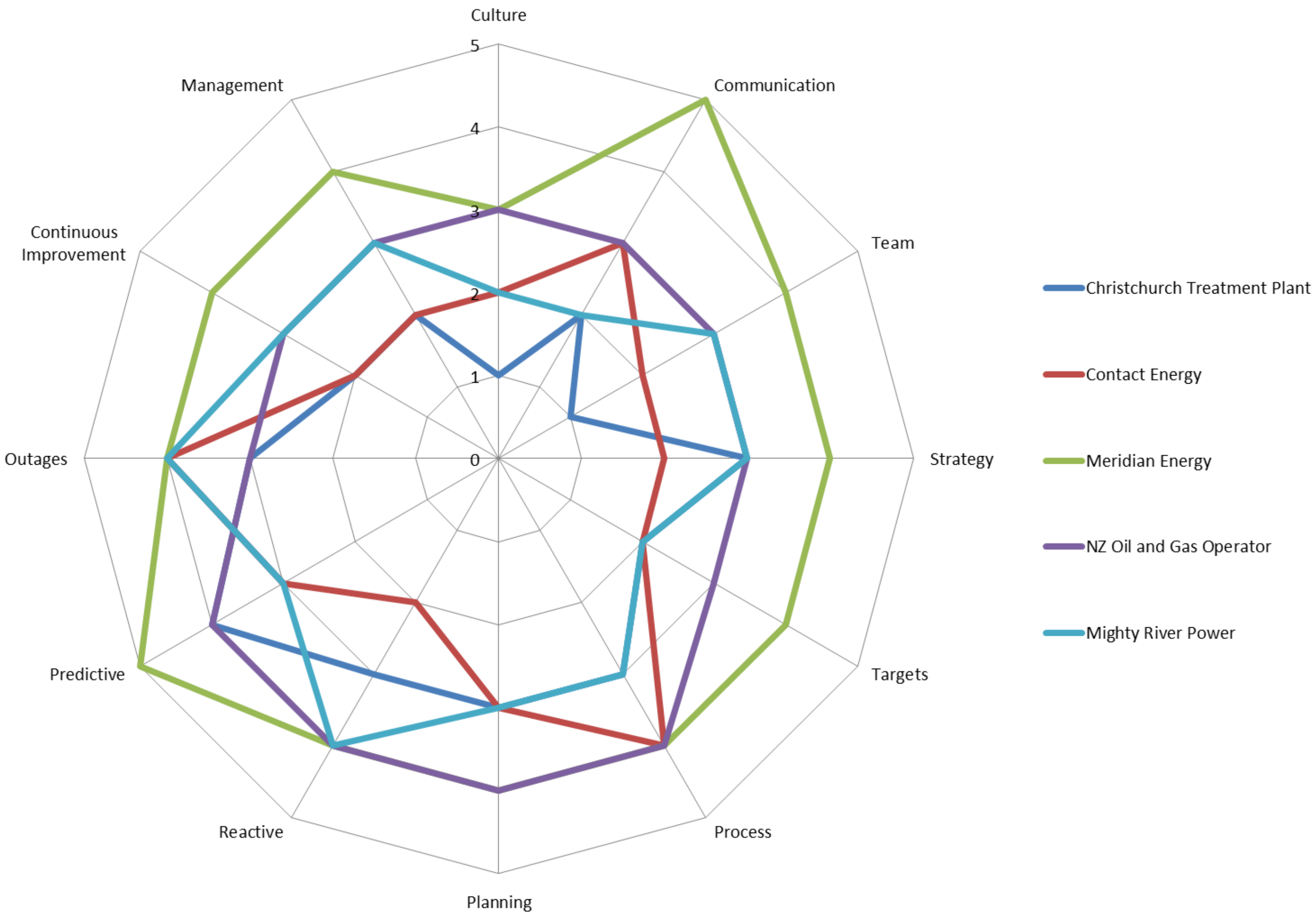

Figure 4: Comparison of maintenance maturity for five asset intensive organisations.

The radar plot clearly shows that Meridian are currently the leader in maintenance strategy of the five organisations compared. It also shows areas in which MRP need to improve their maintenance strategy in order to achieve best practice in New Zealand industry. The radar comparison is a valuable tool to compare changes over time as MRPs maintenance maturity improves relative to other organisations and the current "best practice".

Data used for the generation of the radar plot is shown in Table 1.

Table 1: Maintenance element comparison data

	Christchurch Treatment Plant	Contact Energy	Meridian Energy	NZ Oil and Gas Operator	Mighty River Power
Culture	1	2	3	3	2
Communication	2	3	5	3	2
Team	1	2	4	3	3
Strategy	3	2	4	3	3
Targets	2	2	4	3	2
Process	3	4	4	4	3
Planning	3	3	4	4	3
Reactive	3	2	4	4	4
Predictive	4	3	5	4	3
Outages	3	4	4	3	4
Continuous Improvement	2	2	4	3	3
Management	2	2	4	3	3
AVERAGE	2.42	2.58	4.08	3.33	2.92

These maturity scores were qualitatively assigned using information from the case studies and the maturity level tables shown in Appendix F (even numbered tables 2-24).

7. Conclusion

Mighty River Power have a competitive maintenance strategy when compared to four other asset intensive organisations in New Zealand industry. Their average maturity level of 2.92 puts them in the middle of the five organisations surveyed however it must be considered that the process of quantifying maturity level from survey feedback was somewhat subjective.

Regardless, the organisation comparison provides a good indication of the relative strengths in the maintenance function of the Mighty River Power Geothermal organisation. Additionally, case study results have provided valuable insight into various aspects of maintenance strategy adopted by other organisations in New Zealand industry.

A maintenance framework was developed to evaluate each organisation's maintenance strategy. Each element was evaluated as being from level 1-5 with MRP's maturity level determined through communication with Jeremy Wilson, Project Manager at Mighty River Power, and internal documentation provided by the organisation.

Twelve key maintenance elements were identified and provided the basis of the evaluation for each organisation

The key elements and their current level of maturity for Mighty River Power are:

1. **Culture** – Level 2
2. **Communication** – Level 2
3. **Team** – Level 3
4. **Strategy** – Level 3
5. **Targets** – Level 2
6. **Process** – Level 3
7. **Planning** – Level 3
8. **Reactive –** Level 4
9. **Predictive –** Level 3
10. **Outages –** Level 4
11. **Continuous Improvement** – Level 3
12. **Management** – Level 3

Mighty River Power have a comprehensive understanding of the various maintenance processes and elements within their maintenance operation. The company has made the first steps in improving their Geothermal Maintenance operation, but are some way from achieving the ideal of best practice or operational excellence. There is however an awareness of the steps required to achieve this.

It is important to highlight that Mighty River Power are heading in a positive direction. They have not tried to adopt a prescribed best practice strategy, instead choosing to design a maintenance plan better suited to their needs and context.

Positive Direction

The most positive aspect of Mighty River Power's maintenance programme is that there are no reactive or level 1 elements in their maintenance programme, which is vital for a generating plant. Mighty River Power have an understanding on how to prevent outages and potential equipment failures in their operating context.

In a report on best practice for Geothermal Plant Maintenance released in 2009, it was recommended that 10% be reactive, 30% be preventive, 50% predictive and 10% proactive (17). This approach is believed to be outdated and setting an arbitrary target for reactive maintenance as a percentage of total is only useful for benchmarking within the geothermal operating context.

As discussed, there is no general best practice for maintenance in geothermal industry – the best practice must be based on the operating context of specific equipment and assets. Having an aim for reactive and planned maintenance without an analysis of the causes, failures and consequences is not recommended.

Summary

Mighty River Power currently predominately rely on planned and proactive maintenance. The result is that some maintenance is being conducted unnecessarily. For example, the store does not plan for their needs based on the critically of components and their consequences, but rather when they have been scheduled to be replaced or repaired. The same is true for the assessment of the maintenance work backlogs. The size is assessed based on how long a task has been waiting to be undertaken, rather than on how critical it is that those tasks are done to avoid serious consequences.

Based on the benchmarking case studies, a number of recommendations have been made to improve Mighty River Power's geothermal maintenance strategy with an aim to move towards engineered reliability and "best practice" maintenance operation within the geothermal operating context.

However, given the scope and responsibility of maintaining four large geothermal plants, this is not a change that can be undertaken overnight and it must be acknowledge that MRP are making progress in the right direction through the on-going development and implementation of the GMP.

7. Recommendations

There are a number of low level maintenance element insights and brief recommendations highlighted in Section 5: Case Study Results. In this section, major recommendations and the reasoning will be discussed.

It was found to be difficult to get industry professionals to agree to a one hour benchmarking survey for several reasons including no net benefit to the surveyed organisation, competitor sensitivity and confidentiality. A strategic partnership with an international best practice Geothermal Generation facility will allow for on-going information sharing, strategic and process benchmarking for mutual benefit. A generation facility located in the United States or Iceland would make an ideal candidate and would eliminate the need to withhold information for competitive advantage.

1. **Form a strategic benchmarking partnership with an industry leading Geothermal facility.**

Meridian Energy operate a world leading Predictive Asset Management System (PAMS) to assess the health of generating equipment in their hydro plants. The system analyses equipment condition data and provides information for decisions related to maintenance, refurbishment and replacement. The system integrates with Meridian's existing CMMS (also Maximo) and utilises international standards and limits, factory test data, models rules and historical data to provide a "percentage health classification" for each asset. Meridian's condition monitoring practices are deemed "best practice" and are enabled through PAMS. Whilst this is currently used in a hydroelectric context, there is scope for a geothermal application.

2. **Investigate and implement a Predictive Asset Management System to complement Maximo.**

Some maintenance approaches and processes can be improved based on similar industry benchmarking. Key improvements could be made through the introduction of (a) dedicated planner(s) to improve long term planning and resourcing, update and increase the number of standard operating procedures and make general improvements in the efficiency of the planning cycle.

3. **Introduce dedicated planners to improve long term planning efficiency and resource allocation.**

Organisational sponsorship and culture provide the foundation for any successful maintenance strategy. The CCC initiative to have maintenance teams responsible for the reliability of assigned areas and equipment as measured by KPIs could be a valuable strategy for the MRP Geothermal environment. Accountability and ownership of maintenance targets may yield improved results over assigning maintenance tasks as hoc.

4.
    a. **Improve maintenance culture through transparency, empowerment and accountability.**
    b. **Assign measureable reliability responsibilities to maintenance staff rather than ad hoc tasks.**

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Personal Evaluation

Over the course of the project, a number of lessons have been learned and several opportunities for improvement have been identified. As the culture of the MEM lends itself to recording and passing on knowledge for continuous improvement, a personal evaluation including lessons learnt will endeavour to assist future MEM students (as well as others taking on industry projects) to identify and resolve issues early and hopefully improve the outcomes and experience of future MEM projects.

This initial scope of the project was to identify current maintenance best practices in New Zealand industry to help align MRP with the rest of New Zealand industry. Maintenance strategy literature is vast, varying and often contradictory and there is not a great deal of literature tailored to a geothermal operating environment. Some literature claims that maintenance theory hasn't changed for 40 years however it is surprisingly dynamic and new CMMS and predictive processes are enabling significant improvements.

The opportunity to increase the value of the project by exploring the possibility of benchmarking with international industry was taken early however this was ultimately a dead end that led to significant lost time. Organisations were reluctant to undertake case study interviews for two reasons: confidentiality and no perceived benefit for time taken. This meant that only organisations through which I had a "lead" or introduction were willing to participate. Ultimately this restricted the study to mostly New Zealand organisations as originally scoped. This was a lesson in effective use of professional networks and also fed into a recommendation for a benchmarking partnership where mutual benefit can be gained through open sharing of information.

Key lessons learnt:

- Effective time management and communication are key to a successful project: given the short timeframe, time needs to be allowed for research and planning; meetings with busy professionals; reviews and revisions. The project is undertaken during a busy period and there are numerous public holidays and times where the sponsor or other stakeholders will be on leave. Planning around this is essential. Had my planning been more robust and communication more regular I would have avoided some of the issues encountered. Communicate early, and make your requirements and intensions clear.

- Organisation and undertaking interviews with industry professionals can be a daunting task however so long as you have done the necessary background research and ask the right questions most people are willing to offer some time to help out. The answer you receive is only as good as the question. I generally found that a half hour time commitment was acceptable, however often the interviews continued up to an hour and this wasn't an issue.

- If you want to get things done pick up the phone. It may sound obvious, but don't expect people to reply to emails. I sent all of my case studies to the original interviewee for review and to ensure that they were comfortable with the information presented about their organisation. Only one person got back to me without a follow up phone call. I also sent several "cold call" emails to professionals in the United States with no response. The one person I could find a phone number for took one Skype call and they emailed through the research information within two hours.

- Do research and collect data early (read: before Christmas/New Years). This means reading and research needs to be done throughout the year or in the first month of the project. Again this requires effective time management.

- Understand the scope. Check again. The scope of my project was high-level but also very wide. I became frustrated when I spent time exploring areas of the maintenance strategy and found that they were not considered a priority. In another instance, I felt that I could use a framework outlined in a document provided but was told this was only a suggestion and not necessarily the correct way to approach the problem. Understand what your sponsor's key objectives are and keep these at the front of your mind. It is too easy to go off on a tangent and lose a week. Scope creep is another risk that needs to be managed through a clear understanding of the objectives.

Personal growth

It was an interesting experience and somewhat of a crash course in real-world project management. There was a great deal of responsibility in meeting both sponsor expectations and academic requirements and providing real world recommendations out of the research. Reading past MEM projects before commencing, I was impressed how much they had managed to achieve over such a short period but now feel proud to have completed what seemed like such a daunting task.

Areas in which I feel have grown:

- Implementing project management techniques and strategies learnt from MEM coursework.
- Gained a broad knowledge in maintenance strategy and the current state of maintenance in asset intensive industries in New Zealand.
- The ability to provide recommendations in a consulting capacity.
- How to (or not to) manage time with large feedback loops.

Overall I feel that I have learnt a lot from this project and feel that both project and learning objectives have been attained.

After Action Review (18)

1. Planned	2. Reality
To undertake research in order to understand best practice maintenance strategy in New Zealand and to provide a gap analysis and recommendations to MRP's Geothermal business.	Wide reading and literature review valuable for foundation knowledge but lacking in application specific insight. Four comprehensive real-world case studies were undertaken to qualitatively benchmark asset intensive industries in New Zealand and allow recommendations.
3. Learnings	**4. Improvements**
"Ideal" maintenance strategy in literature rarely translates to a cost effective and context appropriate strategy for implementation. Best practices are context specific and must be carefully adapted for the purpose and system in which they are being used.	Ideally a larger number of case studies would have been undertaken international "best practice" for benchmarking purposes. Unfortunately, I did not have the contacts to pursue this further and my attempts to "cold call" were not successful which may be due to the time of year or other uncontrollable factors including confidentiality and time constraints. Future work will include action plans for implementation of approved recommendations.

Appendix A: Maintenance Survey

Objectives:

To determine:

- Current maintenance strategy and how it is executed
- Reasons for adoption of specified strategy
- Route taken to develop strategy
- Problems encountered and required improvements
- Level of maturity

Profile Questions:

Name:
Job title:
Company:
Industry:

Survey Questions:

Is reliability driven culture sponsored by senior managers and the organisation?

Little awareness	Some training High level mandate to change from reactive -> proactive	Communication plan developed to articulate reasons for improvement	Need for change and objectives understood throughout organisation	Empowerment to drive change at every level

Comments:

Is there regular communication and interaction between Maintenance, Operations and SM?

None	Informal/infrequent meetings to communicate goals	Regular meetings to communicate relevant information	Common targets developed between maintenance and ops	Strong partnership, regular strategic meetings and aligned maintenance framework

Comments:

How would you describe your team development process?

No clear definitions, alignment or objectives. Informal system.	Key competencies and org. requirements documented. Basic Development plan.	Training budget is mapped to positions. Group meetings and team objectives established.	Skill matrices used to identify future skill reqs. Competence/ development plans in place based on needs of organisation	Formal systems. Existing/future skills identified and recorded. Detailed training/career plans developed, measured and updated. Incentives.

Comments:

What is your current maintenance strategy?

Run to failure/reactive	Planned/ scheduled/ preventative	Predictive/ proactive	Reliability Centred Maintenance	Strategic combination

Based on failure mode and effects analysis? Condition assessment? What % predictive/preventative/reactive?

Comments:

Is the strategy documented with clear quantitative targets?

No plan developed	Some milestones and approximate deadlines developed	Aligned with organisation's strategic direction. Defined business case for elements.	Strategy developed with SM and relevant stakeholders. Linked to long term organisational strategy.	All internal/external stakeholders involved in strategy. Best practice gained from NZ and abroad.

Comments:

How are KPI's used to drive strategy?

No KPI's used	High level KPIs defined but not reported. No value assessment.	KPIs defined with Maintenance, Ops and SM. Used to report performance and drive effectiveness.	Communicated to employees, used in daily operations. Balanced Score Card used to drive improvement.	Targeted KPIs (safety, reliability, availability, cost etc) used in daily operations as a management tool for all employees.

Comments:

How was your maintenance strategy developed, reviewed and updated?

No annual maintenance plan	Ad hoc tasks from Strategy prioritised/scheduled. Plan updated periodically.	Maintenance incorporated into Business Plan. Updated regularly and communicated to team	Detailed action plans with milestones. Costs estimated. Annual strategic meetings to update.	Cost/ROI vs benefit demonstrated. Changes in business environment monitored for plan review.

Comments:

How is maintenance effectiveness measured and tracked?

No performance measures	Maintenance expenditure measured/tracked	Loss of production measured. Weekly/ monthly/ quarterly reporting	Operational impact measured (availability, business risk/interruption)	All aspects of maintenance performance measured (including savings). Commented reports with trends and targets

Comments:

Is there a formal maintenance work flow process?

No formal system or documentation.	Formally documented and assigned (RACI). Used only by maintenance org. Not all recorded in CMMS.	Process flows with KPIs established. No ticket, no work enforced. Basic standards documented.	Work requests screened for planning/scheduling. Work control efficiency monitored. Requests prioritised and recorded.	Post maintenance reviews and correction of documentation

Work flow process: verified, approved, planned, scheduled, executed, closed out.

Comments:

What is the approach to prepare and plan for maintenance tasks?

No work order system used	Work orders used for preventative maintenance, reactive undocumented	All work performed against a WO and all labour and material costs recorded. Critical tasks linked with referenced job methods/instructions.	Method and safety/ environmental instructions issued via job plans attached to WOs.	Job performance criteria set (duration, resources, costs) with resources specified and availability confirmed.

Comments:

How is maintenance work prioritised?

Work orders undertaken without proper planning or allocation of resources	Agreed planning and scheduling process but poor prioritisation.	Collaborative prioritisation between Maintenance, Ops and Contractors. Priorities driven by asset criticality or other metric. Formal process not consistently executed.	Weekly work schedule with resource allocation and instructions. Formal process consistently executed with priorities also driven by defect severity.	Work allocated to Contractors with all information for safe/efficient execution. Opportunity maintenance. Outstanding work list communicated.

Comments:

How is routine maintenance planning and scheduling undertaken?

No planning or scheduling process exists	Planning only for major activities/outages. Poor estimating. Basic scheduling for preventative work only. High level procedures only	Training in planning function. Job plans and work packages established with basic info. Basic BOMs and job estimates. Weekly schedules developed	Well defined processes. Job plans, specific procedures, acceptance criteria. BOM developed and utilised. Minimal delays. Long term and weekly scheduling.	Continuous improvement. Planning focussed on future work only. Estimates for all resources based on feedback. Planning accuracy measured. BOMs and job history utilised. Scheduling tool used, weekly reporting and reviews.

Comments:

How is emergent/reactive maintenance actioned?

No clear process	Formal notification process used to alert Maintenance.	Responsive communication and WO created. Minimal reporting or analysis.	Emergency situation determined by O&M. Risks and consequences taken into account.	Decision process agreed, communicated and regularly reviewed. Equipment failure analysis performed and all data logged.

Comments:

How is your predictive/condition monitoring practices developed and deployed?

Comments:

What is your stores and inventory management process like?

No clear process or system.	Auxiliary spares recorded and stored based on experience or request. Stock levels controlled manually.	Basic principles used to determine stock. Frequently used parts standardised. Preferred suppliers defined but no regular price checks.	Clear process to determine spare stock. Computerised systems and stock analyses. Coding system used, parts checked against spec. Long term purchase agreements. Purchasing procedure.	Process to determine in stock, vendor or supplied spares. Based on lead time, cost, reliability, risk. Complete BoM available. Maximo used for analysis. Suppliers routinely monitored.

Comments:

How are maintenance history and backlog management utilised?

No maintenance history recorded. WO backlog not measured.	Minimal maintenance history recorded (Maximo). Completed WOs closed after approval. Backlog measured by no. of WOs/lead time.	Maintenance data about WO (duration, dates, parts) recorded before WO closed. Backlog measured by no. of WOs due in weeks.	WOs closed by Team Leader. "Ready to Schedule" backlog identified and backlog calculation used to balance work load.	Technicians record and enter ALL task data. Completed WOs closed after consultation. SM monitors backlog trends to determine resource requirements.

Comments:

What is your strategy for managing plant outages?

No formal process	Informal or manual process to determine period, plan critical tasks, follow up meetings, improvements.	Formal process to review and approve critical tasks. Maximo used to plan and report WOs. Detailed planning optimised to critical path. Risk mitigation. Daily follow up meetings. Informal suggestion/ improvement process.	Central approval process to assess requests. In/ex resources integrated into plan. Test plans, standards, work packages developed. Basic info recorded in CMMS. Risk KPIs and analysis used to reduce cost/duration of outage. Post shut reviews.	Asset management plans drive scope and critical tasks. Monthly asset health assessment. Resourcing plans. Scope/schedule revised at follow up meetings. Detailed info recorded. Continuous improvement through recommendations, audits, analysis of outages.

Initiation, scope, preparation, execution, recording. Optimisation/reduction of outages.

Comments:

What processes are in place to ensure continuous improvement?

Comments:

How are equipment failures or losses determined, mitigated and resolved? RCA? FMECA?

No root cause analysis or defect elimination. No improvement system.	Basic RCA. Failure data analysed on 25% of equipment. Informal improvement system.	5 Whys or other. Failures tracked with basic analysis. Formal improvement system. Monthly follow-up. Basic cost benefit. Losses calculated.	Formal RCA on all critical breakdowns. Thresholds established. Training in equipment failure methodologies. Systems to monitor, track and report losses. Improvement studies.	Weibull analysis for losses. All personnel trained in analysis. Results quantified and shared. Fault tree, Ishikawa, 5 Whys, RCFA, FMECA. Detailed cost benefit. Implementation plan. Well communicated.

Comments:

How are reliability based principles incorporated into capital projects, major modifications to existing equipment or new plant equipment?

Maintenance not involved in design and selection. Reliability and maintainability not taken into account	Basic maintainability assessment. Limited to review of OEM recommendations and failure prevention strategies.	Moderate involvement of Maintenance in equipment selection. Comprehensive design completed to ensure O&M can safely work.	RCM study conducted on critical equipment. Failure modes identified. Employee input to ensure future asset reliability.	Simulation modelling and failure data analysed. O&M involved in design to commissioning. RCM analysis for life cycle cost. Designed for condition monitoring.

Comments:

How are contractors selected, managed and utilised?

No selection process or follow up.	Informal process. Contractor list. Work scheduled but not planned.	Some contractor agreements. Selection on past performance. All work scheduled, major work planned. Supervision and basic evaluation.	All work scheduled and planned. Evaluation process based on cost and lead time. Performance and improvement meetings. Active continuous improvement.	Contracting guidelines. Work is recorded in CMMS. Comprehensive evaluations. Formal quarterly meetings. Contractors act as partners to continuously improve plant performance.

Comments:

How is maintenance data and information managed?

Data and information not collected	Data collected and stored. Some manuals and equipment drawings exist. Basic initiatives to update info for plant changes. Very limited reporting.	Data and information stored in Maximo (used by Team Leaders). Robust process to update, protect and control modifications. Revision numbering system. Operational loss info collected.	All documentation for critical equipment is managed. High level process maps. Classification process/systems. Links with MS Project, analysers but not fully integrated. Greater Maximo use by personnel. Basic failure info reported.	Structured approach to manage all technical info and documents (indexed, tracked). Maximo and maintenance systems integrated in CMMS. Maximo widely utilised for full functionality by all personnel. All users appropriately trained.

Comments:

How is the maintenance budget developed and controlled?

No maintenance budget defined.	Annual maintenance budget prepared based on last year's expenditure.	Annual budget prepared for each department. Uptime/downtime tracked. Costs controlled and reported monthly to SM. Monthly/quarterly statements.	Annual budget based on labour, material and sub-contracting cost. Direct costs allocated to location or group in Maximo. Financial impacts of availability calculated.	Annual zero-based budgeting process used. Distinction made between operation, outage, non-routine, capex. Direct costs allocated at equipment level. Monthly cost reports. Action to reduce operational cost at equipment level.

Comments:

Appendix B: Christchurch Wastewater Treatment Plant Case Study

Introduction:

The purpose of this case study is to gain insight through a thorough analysis of the current Maintenance Strategy utilised at the Christchurch City Council Wastewater Treatment Plant in Bromley, Christchurch. The case study aims to answer questions pertaining to development of maintenance strategy, execution, reasons for adoption, maturity and problems or improvements required. The case study will be used to qualitatively assign CWTP a maturity level for 12 maintenance elements that will allow the organisation to be benchmarked against Mighty River Power and other case study participants.

Christchurch's wastewater treatment system is highly asset intensive with sufficient parallels to the geothermal industry (comparable assets, long asset life, corrosive environment etc.) to make the plant a valuable case study for this project. The current post-earthquake environment in Christchurch also poses interesting challenges for the maintenance function of the organisation.

The Christchurch Wastewater Treatment system services approximately 350,000 Christchurch residents and manages the 170 million litres of wastewater that is removed from Christchurch homes and businesses every day. The system is operated by the Christchurch City Council and includes 120 pumping stations, 239 pumps, 13 backup generators and over 1600km of pipes. Additionally the Wastewater Treatment Plant at Bromley utilises a by-product of the treatment process, methane gas, to generate over 10,000 MWh of electricity per year in a self-sustaining process. The asset profile of the treatment plant includes pipes and reservoirs with long asset life cycles (50-100 years). The wastewater assets are valued at more than $1.2 billion and are managed through the Wastewater Management Plan 2004. (19)

Because the Christchurch Wastewater Treatment Plant is so critical to the Council, it is operated and maintained internally, unlike most Council departments which employ external consultants and contractors.

James Feary is the Water and Wastewater Treatment Manager at the Bromley plant. He is an accredited RCM facilitator and has previously worked for United Water International managing Wellington's sewage treatment plants. Mr Feary responded to the Maintenance Survey (Appendix A) and his responses have been used for the generation of this case study.

1. Organisational Culture

Reliability is not currently a strong focus within the Council as most maintenance staff do not come from a reliability-focussed background. There has been a drive towards a maintenance focus within the organisation; reliability is the next step and it is easy to demonstrate the financial value of this. The Council have only moved into a CMMS in the last 6 months which is a good start in developing a reliability driven culture, however it still requires a "paradigm shift".

There is some communication between the maintenance, operations and management functions however there is sometimes a disconnect between the top-down and bottom-up communication channels.

There is currently a change proposal to better differentiate the maintenance and operations functions within the organisation however there has been little work to identify key competencies, skill levels and future requirements due mainly to the current business environment. Two new maintenance apprentice staff have been employed and it is hoped that they will grow skills within the organisation to support the maintenance function for the next four years.

Performance incentives rarely exist within Council other than service awards.

Mr Feary's previous organisation utilised reward incentives to encourage performance improvements. It was easy to demonstrate the value of this system to senior management through measured reductions in contractor call-ins, total spares turnover, alarms, call-outs and overtime hours.

2. Maintenance Strategy

This focus for 2013 is on bringing the organisation up to a certain level within the New Zealand Asset Management Support (NAMS) framework. This target has been delayed by the immediate need to repair earthquake damaged assets.

The post-earthquake environment has prompted a need for more reactive maintenance. As such approximately 60% of current maintenance work is reactive and 40% planned (mainly lubrication, checks and inspections). Some earthquake maintenance tasks become planned work (such as equipment that is currently operating at reduced performance, but will need to eventually be repaired or replaced to avoid further consequences).

The renewals programme is based on condition based assessment, where condition data is fed into a model that determines when replacement will need to occur. This is based on expected asset life, condition grade, and asset history. Net Present Value and whole life cost are used to determine the most effective replacement.

Pump stations operate on a predictive, condition based assessment system where current loadings, flow rates, temperatures and oil pressure are measured and trends monitored to indicate any developing faults. When a decrease in performance is noticed, there is scope to plan for an appropriate time to take the pump offline for repair. The condition monitoring system has proven effective in increasing reliability and significantly reducing breakdowns or overflows from some pump stations. Electricity generating engines also run on a predictive maintenance system. The Council also performs some thermal imaging, vibration analysis and oil analysis on their engine assets where information is readily available.

The maintenance strategy follows a top-down approach and is well documented at a high level as it forms part of the overall Asset Management Plan. This includes high level targets however these targets are not always communicated or actioned at an operational level and low-level processes sometimes need to be tailored to meet the overall strategy. It is recognised that there is not enough input from the maintenance function in strategy development; instead asset management engineers develop strategy from an asset life viewpoint. The strategy is currently being reviewed and refined especially in the benchmarking and strategic direction areas. Due to the Council's wide asset base, high level strategies must consider all assets (including civil assets, parks, gardens etc.) and operating approaches (owner/operator/maintainer vs consultant/contractor) and design a strategy that fits across all areas.

The Council are relatively reactive to changes in the business environment as demonstrated by the recent earthquakes which caused an increase in the maintenance spend. A lot of earthquake related maintenance expenditure has been tied into capital projects and rebuilds.

The effectiveness of new maintenance strategies is now measured using CMMS. Information from predictive maintenance processes assist in this area, however a lot of information is "in people's heads". Spreadsheets are still used to record some maintenance tasks, intervals and durations and have in one case been used to improve asset life from 1 to 10 years. A large number of true age relationships exist between failure and wear mechanisms for equipment on site. As expected, the majority of breakdowns are linked to installation, or post-repair/testing faults.

Loss of production is not measured as the treatment process is a continuous operation. Instead, loss of redundancy is considered although it is often difficult to quantify, which can result in total loss of redundancy requiring reactive maintenance. In the case of plant outage, procedures are sometimes ad hoc especially for rare events. Documentation and procedures are recorded post-event; however it is not viable to constantly update rare outage procedures.

High-level Key Performance Indicators (KPIs) measure plant performance, whereas the low-level focus is on mechanical availability and responsiveness. Mechanical availability on all elements of plant is currently at approximately 70% (mainly due to earthquakes and including 50% redundancy on all plant) - the goal is to get availability up to 90%.

Plans are in place this year for each maintenance team to take responsibility for the reliability of assigned areas and equipment as measured by KPIs, rather than performing ad hoc maintenance tasks.

3. Maintenance Process

A formal work order system is used for all maintenance tasks and recorded in the CMMS. This process is initiated with a fault notification being made to the maintenance coordinator, the fault is then verified, a work order is created, resources allocated, work completed, equipment put back into operation and tested, hours, spares and materials are booked and finally the coordinator closes the work order. All maintenance staff hours must be booked to a work order and there are standard work orders for tasks such as cleaning and lubrication which get apportioned across all assets. Standard operating procedures (SOPs) exist for planned maintenance tasks.

Post maintenance reviews are informal and some administrative checks are undertaken to determine how many work orders are still open and what information is missing. It is important that all information (including damage and cause codes) is complete for the purpose of performance monitoring.

Prioritisation is based on plant asset criticality and functionality and is recorded in the work order by the shift engineer or operator. Scheduling is undertaken on a day to day basis by the maintenance coordinator based on experience and urgency. This is sometimes an informal process and work orders often get shuffled for various reasons.

Maintenance schedules are created and inputted into the CMMS as soon as new assets come online. All weekly tasks such as bearings and filters are completed at the same time. For capital projects, design consultants are required to deliver an asset list and a maintenance list in a format that can be inputted into SAP.

SAP is currently used and is preferred over Maximo due to easier reporting (and not requiring an expensive reporting module add-on).

The Council excel at planned maintenance. In the past, a card work order system was used but this has adapted over time and is now replaced by the CMMS. The new system is producing reports that highlight areas that are costing a lot of maintenance time, especially a couple of new projects that have been found to be maintenance intensive. These projects have somewhat limited the maintenance department's ability to successfully execute all planned tasks, and the reports produced through CMMS can be used to demonstrate the need for more staff.

4. Other aspects

There is currently no developed inventory management or spares system, only a stores room that has not yet been incorporated into the CMMS. There is a desire to bring in a warehouse system that is managed through SAP, where goods are booked out, requisitioned to work orders and minimum reorder quantities exist. This approach can be expensive but will contribute to a significant improvement in reliability.

There is a formal process for procurement of items including preferred supplier agreements and Council terms and conditions with an aim for all procurement to move to preferred suppliers.

Selection of new plant equipment is often done by third party consultants based on NPV and life cycle cost criteria with some focus on reliability. There is somewhat of a cultural shift from a maintenance focus to an operations focus in capital project planning and there is input from most stakeholders during this project planning.

Maintenance history and backlog have historically been managed informally however the CMMS now produces reports that record asset life maintenance costs and analyse common faults, breakdown frequency, top 10 maintenance cost assets and more. This allows for informal Root cause analysis (RCA), Failure modes and effects analysis (FMEA), predictive measures or a business case for new asset selection to ensure continuous improvement.

There is a well-developed formal process for contractor management that includes tendering, consideration of past performance, various KPIs and standard contracts.

The maintenance budget is generally calculated using zero based budgeting however previous year spend profiles are often considered and it can be a process of negotiation to determine appropriate figures. The budget is generally not directly allocated to locations or groups of equipment.

Conclusions

The Christchurch City Council have a well-developed Maintenance Strategy that has been limited in progress due to the significant damage to infrastructure caused by the Canterbury earthquakes. This event has however demonstrated the organisations ability to quickly react to major changes in the business environment and has vigorously tested their reactive and emergency maintenance procedures.

The Council's policy to undertake nearly all maintenance activities in-house reduces contractor reliance and external liability as well as giving them greater control over their critical asset base. The maintenance function have only introduced Maximo in the past 6 months and there is evidence that their CMMS programme and integration may not be fully mature and this process can take a number of years to effectively implement.

The Council's is weakest in the areas of culture, communication and team development. It is not apparent what the reason for this is; however there appear to be plans or processes in place to address the needs of the organisation in these areas. There is also a difficulty in monitoring available redundancy that should be addressed. An insight was gained into the effectiveness of reward incentives in a non-Council working environment.

The Council's use of the NAMS framework could be relevant to Mighty River Power and may warrant further investigation, however a surface look revealed that the framework and resources appear to be tailored for local government authorities.

The Council aim to operate an industry standard maintenance strategy with some condition assessment, however do not appear to warrant the title "best practice" in any areas. The high-level Asset Management is adapted to meet the needs of a very broad range of assets which may limit the relevance of strategy to wastewater assets.

The Council's plan to assign responsibility for the reliability of specific assets and areas (instead of ad hoc tasks) could be implemented with in-house maintenance employees within Mighty River Power with an aim to encourage ownership and empowerment and to improve reliability.

The Council prides itself on its planned maintenance processes however given their limited experience with CMMS, it may be some time before a fully optimised planned maintenance system is in operation. A proper warehouse system is seen as a priority to improve reliability in the organisation. The Council were the only organisation that used a form of zero-based budgeting and there may be further insight to be gained in this area.

Appendix C: Contact Energy Case Study

Introduction

The purpose of this case study is to gain insight through a thorough analysis of the current Maintenance Strategy utilised by Contact Energy. The case study aims to answer questions pertaining to development of maintenance strategy, execution, reasons for adoption, maturity and problems or improvements required. The case study will be used to qualitatively assign Contact Energy a maturity level for 12 maintenance elements that will allow the organisation to be benchmarked against Mighty River Power and other case study participants.

Contact Energy is a New Zealand electricity generator, natural gas wholesaler and electricity, natural gas, and LPG retailer with around 560,000 customers nationwide. Contact owns and operates eleven powers stations in New Zealand with a portfolio consisting of geothermal, hydro and natural gas assets. The company is New Zealand's second largest electricity generator, generating around a quarter of New Zealand's electricity. (20)

Contact Energy are the only other major geothermal operator in New Zealand with 309MW of installed capacity compared to Mighty River Power's 387MW. Geothermal development is a priority for the organisation with 4 developed sites near Taupo, 2 proposed sites and an exploration project in the Rotorua region. Sustainability management of the geothermal resource and any cultural impacts is a priority of the company (21).

As the only other major New Zealand geothermal operator, Contact Energy is a valuable case study for this project. It is clear that there is an existing partnership between Contact Energy and Mighty River Power in some areas (22) and this should be pursued for further mutual benefit to the respective geothermal businesses.

Alan Mudie has been a Reliability Engineer at Contact Energy for three years. Mr Mudie responded to the Maintenance Survey (Appendix A) and his responses have been used for the generation of this case study.

1. Organisational Culture

A reliability culture is sponsored within Contact Energy through a 'Reliability Steering Committee' reporting to the Generation leadership team. This top down process directs the reliability team and investment in various reliability systems and techniques to instil a reliability culture in the organisation. There are daily meetings between the operations and asset teams and high to low level performance indicators and metrics have been developed.

Contact Energy is currently in the process of updating the team development process through a structured development matrix and development plan. The reliability team is generally good in this area and the operations team already have strict processes in place due to certification requirements and the need to maintain these. Other functions of the business require improvement in team development which will be offered by the new team development process which tracks key competencies and defines skill requirements and deadlines to fulfil these.

2. Maintenance Strategy

The majority of maintenance work is structured, planned work much of which is completed during unit surveys and allows units to run smoothly between outages. Work is carried out in accordance with Quality Management System requirements and is ISO 9001 certified (23)

Reliability Centred Maintenance (RCM), failure mode and effects analysis, condition monitoring, Root Cause Analysis, precision maintenance, OEM and statutory requirements, Risk Based Inspection and "back to basics" are used to develop planned maintenance strategy. In terms of total maintenance budget, approximately 50% is spent on planned unit overhauls, 25% on general planned maintenance and 25% on reactive (total: 75% planned, 25% reactive). This will vary through the fleet depending on the type of generation and the age of the plant (e.g. hydro plant is well established and has far less reactive maintenance than the newer geothermal plant).

The maintenance strategy is defined in a 5 year plan laying out key maintenance and availability targets. A high level target was developed 3-4 years ago and aims for an increase of 1.75% in reliability over 9 years, through the introduction of new processes and reliability. Reliability is both difficult to monitor and a somewhat unreliable measure of improvement as new generation is coming online all the time which provides nominal increases in MW generation but at the same time decreases reliability as the new equipment is commissioned unreliable. Reliability is measured by availability and number of forced outages.

The reliability target was based on the existing asset base, current operating environment and improvement opportunities however it has not been updated to reflect changes in the business environment. A reliability approach is being used to update the asset management philosophy of the organisation through better planning and use of RCM.

Maintenance budget/expenditure is measured and tracked alongside a dashboard of multi level KPIs recorded in SAP and GADS which include planned vs. unplanned, compliance to schedule, availability and more. These KPIs are beginning to be communicated to employees however there is currently little training or uptake.

3. Maintenance Process

Contact use SAP to manage their work order system which provides a complex work flow for each job with numerous checks and balances. Post maintenance reviews are performed on a (criticality based) sample of work orders to check data integrity.

Work order priority is initially determined by the work requestor, it is then reviewed by the supervisor team who use equipment criticality and process safety flags during daily scheduling. Labour and material cost is recorded against each work order. Every job has an associated work instruction for safety reasons.

All routine maintenance is formally planned and is supposed to follow a 12 week planning cycle however in reality the work follows a 3 week planning cycle. There is also a team dedicated to planning and executing major surveys and shuts that occur 3-4 times per year (for geothermal plant).

Reactive maintenance is usually managed by re-prioritisation of the existing schedule. In some cases external contractors are bought in to perform the task. Operational losses are recorded in GADS and common faults are analysed using RCA and RCM approaches. Condition monitoring is performed through on-board vibration analysis, vibration tours, extensive electrical condition monitoring, thermography, transformer oil analysis and other tools used to manage high voltage assets.

Maintenance history and backlog are recorded in SAP and managed by maintenance planners with a backlog metric used to maintain backlog at a certain level.

4. Other aspects

SAP is used to manage stores and inventory alongside material requirements planning. There is limited inventory on hand however some key turbine components that have long lead times are held in stock. Alternatively, there are long term maintenance agreements in place with OEMs for gas turbines that guarantee critical life limited parts supply requirements and cost. The remainder of parts are generally common spares.

Due to the high level of redundancy, the organisation has the luxury of being able to shut equipment down if required. Standard purchasing procedures exist. Outages are managed through SAP with strict processes, checks and approvals at all levels. There is a formal production incident review process and a number of techniques such as RCA and FMEA are used for defect elimination.

Currently, maintenance strategies for new capital projects and generation development are undertaken on an ad hoc basis and do not utilise reliability based principles however Contact are starting to improve processes in this area.

Contractor management follows a formal process with demanding contracts to ensure performance targets are met. Long term budgeting is based on previous years fixed costs plus all planned outage work and is recorded in SAP. Contact currently do not use zero-based budgeting due to the large resource requirements to do so properly. Short term forecasting in SAP allocates the budget to projects/assets.

There is a functional partnership between operations and maintenance, with both teams reporting to the same manager at site level; however the team structure differs between different plants and depends on the size and nature of work. There is a centralised Engineering and Technical Services team which support Asset and Ops teams at local site level.

Conclusions

The recent implementation of the Reliability Steering Committee has introduced a number of worthwhile reliability initiatives and Mr Mudie was bought in to the organisation to drive this change.

The organisation has weaknesses in the areas of overall strategy, targets and continuous improvement. This is fundamentally due to a poorly defined maintenance strategy and the use of an availability target that is inherently difficult and unreliable to monitor. This highlights the value of comprehensive planning and careful selection of targets and indicators when developing strategy. The organisation is implementing a new team development process to manage competencies and skillsets.

Like Mighty River Power, Contact use SAP for maintenance management, however the level of employee training and uptake does not appear to be optimal.

Routine maintenance should follow a 12 week planning cycle, however this is not adhered to and instead, planning is completed only 3 weeks in advance. Contact have a dedicated team for planning and executing shuts which is advantageous. Reactive maintenance appears to be managed in an ad hoc fashion.

The high level of redundancy is a luxury that gives Contact the ability to shut plant down when required but may also be seen to hinder efficient management of the asset base.

Overall the maintenance strategy meets an acceptable standard, although there is significant room for improvement and few “best practice” processes that would assist Mighty River Power going forward.

Appendix D: Meridian Energy Case Study

Introduction

The purpose of this case study is to gain insight through a thorough analysis of the current Maintenance Strategy utilised by Meridian Energy. The case study aims to answer questions pertaining to development of maintenance strategy, execution, reasons for adoption, maturity and problems or improvements required. The case study will be used to qualitatively assign Meridian Energy a maturity level for 12 maintenance elements that will allow the organisation to be benchmarked against Mighty River Power and other case study participants.

Meridian Energy is a New Zealand state-owned electricity generator and retailer that owns and operates seven hydroelectric power stations and seven wind farms. The company generates 32% of New Zealand's electricity and is the only generator committed to generating from renewable sources. (24)

As New Zealand's largest electricity generator, with the greatest generation capacity, Meridian have an extensive renewable generation asset base that makes the company a valuable case study for this project. Meridian generate approximately twice as much electricity as Mighty River Power, making them a valuable large-scale generation case study for this project.

Neil Gregory is a Reliability Engineering Manager at Meridian Energy in Christchurch. Mr Gregory responded to the Maintenance Survey (Appendix A) and his responses have been used for the generation of this case study.

1. Organisational Culture

Reliability driven culture is a priority in maintenance and refurbishment. Meridian's Statement of Corporate Intent acts as a guide to optimise value obtained from assets. An Asset Management Policy also exists in which Meridian are the custodian of assets and owe a duty of care to maximise economic life.

Meridian's high level strategy feeds in to Markets and Production which provides a clear direction for the organisation. This strategy is mature and has developed at a high-level in that Meridian's vision is no longer as a global reference company; instead a purpose statement drives the way in which Meridian operate.

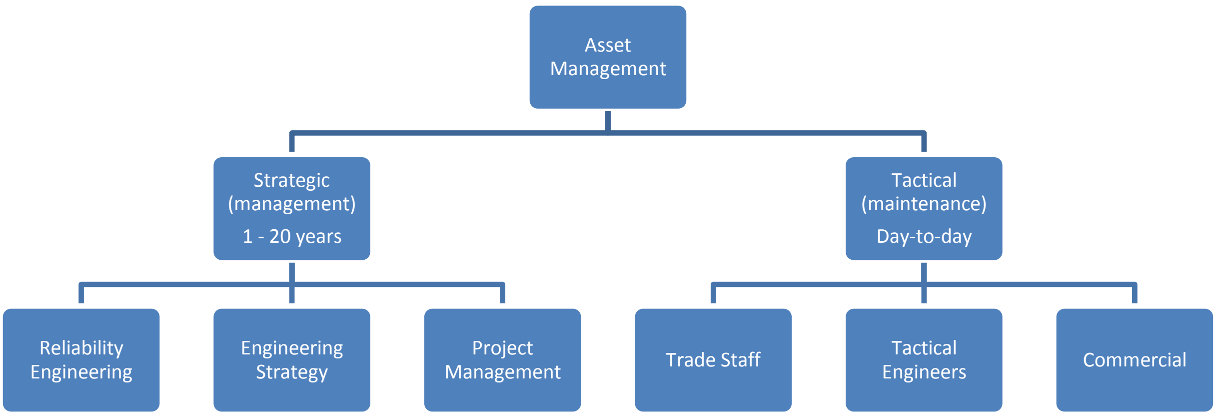

Figure 5: Meridian Asset Management Structure (25)

Asset Management is divided into Strategic and Tactical between Christchurch, Twizel and Manapouri. The Reference Group consists of approximately 8 managers from the Asset Management and Asset Maintenance teams and meets monthly to share information. The Maintenance Improvement Team is cross-functional and meets monthly to review progress and determine actions related to the Strategic Plan.

All employees have a Learning and Development Plan which is agreed on with the relevant manager at the start of every year and reviewed half yearly for progress. A company wide incentive programme exists.

2. Maintenance Strategy

The current Maintenance Strategy is estimated to be 80% proactive and 20% reactive with a comprehensive condition monitoring programme in place based on information out of Maximo. Meridian have run regular RCM workshops for the past 15 years based on criticality of the plant.

The Asset Management Plan is a 20 year plan with its own asset database. The plan is refreshed annually and is closely linked to the Reliability and Maintenance Plan. Replacement requests go into AMP database and are then reviewed in November during workshops with the Asset Management team. Initial job priority is a rough estimate based on risk, followed by a proper business case analysis.

The Reliability and Maintenance Strategic Plan is a 3 year rolling plan that is refreshed annually and is based on 3 core principles.

1. Maintenance is an investment in the plant. It delivers value in today's market whilst ensuring future capability is protected.
2. Planned maintenance of generating plant is invariably more cost effective than unplanned (depending on which literature you read it is between two and five times less expensive to perform planned than unplanned.) Prediction and prevention of equipment failure is important – understanding the condition of the asset.
3. Improvements in plant performance are achieved through better understanding of plant condition which in turn is directly dependent on the capability of the people and application of best practices.

Generally the vision, purpose and core principles remain the same however key challenges are identified and reviewed regularly. Once challenges are identified, maintenance strategies from run to fail through to sophisticated condition monitoring are developed.

High level strategic goals and initiatives are identified from challenges (usually 5) and this year fall under the following categories:

Reliability, Maintenance Delivery, Maintenance Processes, Data Integrity and Performance Metrics.

These are then described further and several initiatives are defined:

Reliability: maintain assets such that they perform as required to achieve the business purpose.

Reliability initiatives: Carry out RCM work on Ohau chain. Develop some specific strategies around Transformers.

Each initiative is accountable to someone and the goals link back into the Markets and Production strategic objectives.

The Strategy was originally written by the Reliability Engineering Manager with input from representatives from all stakeholders (managers down to trade staff). Subsequent reviews received input from a smaller sample of stakeholders. The year's review will include team leaders from each location, maintenance improvement coordinators, a representative from reliability and a representative from commercial. Once refreshed the final draft is circulated widely for feedback and peer review.

Maintenance effectiveness is measured by:

- Plant Performance Index (PPI): availability (94%), reliability (99%), forced outages, forced outage factor.
- Asset Performance Index (API): schedule accuracy, data integrity.
- Revenue Opportunity Cost (ROC): cost of timing, deferral of jobs due to market conditions.

Maintenance savings are analysed during asset RCM analysis where strategy is decided. Maximo reports on numerous KPI's and a Balanced Scorecard is completed every month.

3. Maintenance Process

The Maintenance Process is managed using Maximo. Planned maintenance jobs are generated and linked to work orders with step-by-step job plans. A Maximo audit is completed monthly to review data integrity, work order closure etc. Hours/resources are estimated for each work order then recorded as variance.

Meridian have recently changed the planning and scheduling process. A high level Planner works with Transpower to determine outages a year out. Dedicated Schedulers have been introduced to review PMs for priority on a weekly basis.

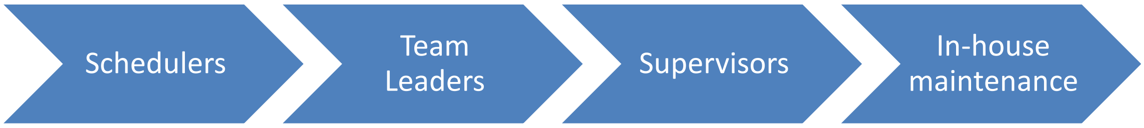

Figure 6: Meridian scheduling workflow (25)

The maintenance team have a daily toolbox meeting to discuss safety and site issues.

Maintenance history and backlog are managed through the monthly Reference Group meeting. The number of work orders scheduled vs. completed is completed and tracked. A monthly Reliability Engineering Report presents the top 5 reliability issues, number of forced outages, top 5 failed plant items and event analysis backlog.

All forced outages have an event analysis report and root cause failure analysis which is tracked on a monthly basis and reviewed (for quality, root causes, lessons learnt) by the reliability team each quarter.

Need for reactive maintenance identified by trade staff or through routine walk-rounds to monitor noise, equipment running "rough", high temperatures etc. Issue is reported and a work order is created immediately or deferred.

Meridian operate a best practice condition monitoring programme that gets looked at by other organisations from New Zealand and abroad. The condition monitoring framework was established in 1997 and has developed into a comprehensive plan that focusses mainly on key generation plant such as governors, turbines, generators, transformers, circuit breakers and batteries. Basic tests include partial discharge analysis (generators), dissolved gas analysis and oil particle analysis.

Figure 7: Meridian condition monitoring process (25)

Inventory is managed by a Storeman through Maximo although Meridian generally hold minimal stock and consumables. A Criticality Spares review was recently undertaken to determine critical spares based on risk and lead times. Some aspects are managed through the Asset Management Plan such as long term supply agreements. One member of the Projects team works solely on procurement and contracts.

Post outage/shutdown review meetings have recently been implemented to follow up on issues, job plans, scheduling and improvements.

4. Other aspects

Continuous improvement is achieved progressively through:

The Maintenance Improvement Programme

- RCM
- Condition Monitoring
- Defect Management
    - event analysis reports
    - root cause failure analysis

Benchmarking

- GKS Hydro through Navigant
    - every 2 years
    - quantitative, fiscal
- Asset Management Council of Australia awards
    - process driven

Availability Workbench is used to implement RCM and identify failure modes against criticality.

90% of maintenance is performed in-house. Contract out for water level site maintenance, UPS, thermography, compressors (Atlas Copco) and facilities management. A standard contractor management process exists.

All maintenance information is managed in Maximo and the Plant Asset Management system.

Maximo:

- Plant and maintenance history
- Job plans
- Work orders
- PMs

Plant Asset Management system:

- Inspections/measurement/testing
- Plant condition modelling
- Current state

Maximo is used regularly at trade staff and Tactical/Reliability engineering level.

The maintenance budget is developed based on previous years and plans for the upcoming year with costs allocated to a station, class of equipment and scheduled/unscheduled maintenance.

Conclusion

Meridian operate a comprehensive and well-developed Maintenance Strategy that is considered “best practice” in some areas. The organisation sponsors reliability driven culture and has robust Asset Management structures, systems and review processes. There is a good level of information sharing, stakeholder input and progress is reviewed regularly. Team development is closely tracked.

Meridian use Maximo alongside a Predictive Asset Management System which is considered “best practice” and reviewed by other asset intensive organisations. The PAMS integrates with CMMS and analyses equipment data to assess the health of generating equipment. A similar system could be extremely valuable to MRP in providing early warning of equipment condition issues.

The organisation has recently introduced dedicated schedulers that review and prioritise PMs which may be a valuable consideration for Mighty River Power’s geothermal maintenance planning function.

Meridian use a number of benchmarking tools to achieve continuous improvement such as GKS Hydro and Asset Management awards. These provide valuable feedback on the current status of Meridian’s maintenance strategy and measure performance compared to its peers. Improved benchmarking tools and frameworks would be valuable to the improvement of the MRP geothermal maintenance function.

Appendix E: A New Zealand Oil & Gas Operator Case Study

Introduction

The purpose of this case study is to gain insight through a thorough analysis of the current Maintenance Strategy utilised by a New Zealand Oil & Gas Operator. The case study aims to answer questions pertaining to development of maintenance strategy, execution, reasons for adoption, maturity and problems or improvements required. The case study will be used to qualitatively assign a maturity level for 12 maintenance elements that will allow the organisation to be benchmarked against Mighty River Power and other case study participants.

The New Zealand Oil and Gas Operator, operates a number of gas fields and production stations and is responsible for producing a portion of New Zealand's energy supply. The company wished to remain anonymous for the purposes of this case study.

The company has set operational, environmental and safety benchmarks in the New Zealand oil and gas industry. Safety is a major priority in all company operations and all staff are empowered to take action against any work they consider unsafe. All employees have been trained to eliminate or protect against situations that could lead to personal injury, occupational illness or damage to the environment. The company operates a systematic approach to health, safety and environmental management to enable continuous improvements in performance.

The company operates a large range of assets in high pressure environments, including choke and valve systems, well sites, tanks, reservoirs, drilling platforms, gas processing plants, injection tools, rotating equipment, pumps and pipelines. Operating in an asset intensive industry with a comparable asset base to Mighty River Power, the company makes a valuable case study for this project.

A Maintenance Engineer at the company responded to the Maintenance Survey (Appendix A). The responses from this survey have been used for the generation of this case study.

1. Organisational Culture

A reliability driven culture is sponsored by the Senior Management at a high level and reliability is measured as a global "goalpost" and KPI. The maintenance team are measured against and must comply with strategies rolled down from senior management.

The company operate separate Maintenance and Operations teams; however there is some overlap where some low-level maintenance tasks can be performed by the Operations team.

There are daily meetings between Operations Management and Maintenance Management for each facility. During these meetings, all jobs raised are reviewed for safety, priority and execution by both parties.

Team development skill matrices exist however, the major difficulty is in managing contract staff and there are stringent rules that define competencies, training, unit standards and registration that must be checked before any work is undertaken. Tracking training skills and competencies in a large labour pool requires careful management.

A process exists to measure and track employee competencies for progression and development. Competencies link back to the Maintenance Strategy for each discipline (for example the Instrument and Electrical Strategy defines qualifications or standards that the technicians and foremen are required to have).

Employees are recognised for safety performance against stringent KPIs.

2. Maintenance Strategy

There is a strong preventative maintenance culture that is driven by a number of factors including compliance, regulation, strategy and knowledge. A level of corrective maintenance exists and this stems from breakdowns or arises during preventative inspections. There is also a condition monitoring program (including vibration tests and oil analysis) that focusses on rotating equipment with an aim to pre-empt failure based on "real-time" data. The overall balance of maintenance work is estimated to be 60% preventative and 40% corrective.

Apollo Root Cause Analysis is used to objectively identify root cause for unexpected equipment failure, based on information available and without casting blame. This process is required due to often having large amounts of input data, many stakeholders and strong emotions that can be involved following safety breaches or accidents.

The primary measurement tool is a global dashboard that looks at integrity level for barriers across the organisation. "Barriers" are defined for each section within the organisation and include; management for process control, containment and managing sources of ignition. Each barrier is measured for integrity (planned versus completed) and communicated to Senior Management who review reasons for incomplete or late tasks and mitigate these. Outcomes are used to drive improvement.

The Maintenance Strategy is spread across a range of documents and ensuring all documents are current and aligned can be time consuming. A robust change management system is required and it is recommended to keep maintenance documentation as simplified as possible.

There are well defined targets and rules based on job plans and closeout. Additionally, there are stringent and well scrutinised guidelines and standards for safety critical assets such as relief valves and gas detectors. Each facility or asset group (electrical, instrument, materials and corrosion, tank inspection, structural inspection, relief valve inspection, pressure equipment, rotating equipment) has a separate Maintenance Strategy or Reference Plan based on asset life, safety, risk and criticality.

As a global organisation there are valuable opportunities to analyse and benchmark with overseas operations. Additionally, some comparisons are made with other multinational competitors.

There are monthly Operations, Reliability and Improvement Process meetings to review and analyse any issues that have occurred more than once in a 6 month period. Cost estimates are used to justify projects such as equipment replacement, capital projects and process improvement. Integrity or safety improvements are a major priority and are therefore not fiscally driven.

3. Maintenance Process

For Preventative Maintenance, jobs are programmed and scheduled for each asset using SAP. Corrective Maintenance tasks are reviewed daily and scheduled based on criticality. Again, safety is the number one priority.

General work order process:

Figure 8: Oil and Gas maintenance work order process (26)

A dedicated operations team generate work packs for any process work. All work packs are linked back to strategy and include isolation procedures, checks, permits and safety reviews. Permit issuers review all documentation. During close out, the manager verifies information integrity and reviews accuracy and quality of information.

There is a daily meeting at all sites to discuss plans, clashes and emergent properties of multiple jobs. SAP provides scheduled maintenance tasks however priority and timing of all tasks is finalised by operations engineers and the maintenance supervisor. Safety critical equipment will have a high priority.

A dedicated team work on long term (18 months out) turnarounds for shuts. This is separate from day-to-day planning and incorporated into SAP later when work packed.

Condition monitoring practices are taken from the Mechanical Rotating Equipment Global Strategy. Contractors are employed to measure and monitor performance of rotating equipment at a prescribed frequency with agreed trip limits. There is a great deal of logistics in organising contractors to go offshore to platforms. Contractors report back to maintenance supervisors, planners and mechanical engineers.

4. Other aspects

Ideally the overall Maintenance Strategy should operate as a “living document” that is reviewed regularly by all stakeholders in order to remain effective. Maintenance as a function requires constant buy in from stakeholders at all levels of the organisation.

There are comprehensive spare parts in the main store however it there is a balance to be had between contractors who want all spares on the shelf and the store operator who wants minimum stock. The company recognise that there is some room for improvement in inventory management. Another major consideration is spares lead time which can change over the life of an asset and requires the spares regime to be regularly reviewed.

All maintenance history and backlog information is recorded in SAP. Early/late job completion affects performance KPIs. Shuts are planned and resourced outside of SAP but recorded later.

Continuous improvement is driven from a high-level and comes naturally through analysing processes, reasons and opportunities for improvement and value adding. The Lean Team compliments this continuous improvement approach.

It is sometimes difficult to incorporate reliability based principles into new projects due to fiscal constraints and a lack of understanding of the difference between instantaneous capital cost as opposed to asset life cycle cost of ownership. Major considerations for new projects are: built in condition monitoring of large rotating equipment, bearings, and additional reliability measures.

Contractors are not monitored on time to complete, as safety is the major KPI. Long term contractor agreements exist and procurement of large equipment is completed through global purchasing agreements.

Due to penalties for non-fulfilment of production contracts, there are KPI measurements for deferment. SAP is the heart of maintenance information measurement and the "Business Warehouse" reporting tool is used.

The maintenance budget is based on a number of factors including forward plans, past cost, inflation, job market/employment cost. Maintenance budget is assigned at an asset level.

Conclusion

The company has set operational, environmental and safety benchmarks in the industry and operates a well-developed Maintenance Strategy that is strongly safety focussed due to the risk prone environment in which the company operates. There is a high level of safety training in an effort to mitigate risk of damage to people, equipment or the environment. The company follows a systematic approach to both safety and maintenance management.

The company recognises the difficulty in managing team development for a large pool of labour staff especially where the majority are contractors to the company. All employees are measured for safety performance.

Maintenance strategy focusses primarily on preventative maintenance with a condition monitoring program in place for rotating equipment. The company uses the Apollo Root Cause Analysis process for unexpected equipment failure which offers advantages over other RCA methodologies and may be beneficial to the MRP geothermal fault analysis.

Maintenance strategy is not well consolidated as it is spread across a range of documents with each facility or asset group having a separate maintenance strategy or reference plan. As such change management for maintenance strategy is time consuming and effort should be made to ensure maintenance strategy is well structured and easily adapted to meet Mighty River Power's future needs.

The company has a dedicated operations team that generate work packs for process work and there is also a dedicated team that work on long term turnarounds for shuts. These specialised positions increase efficiency in the planning function.

Appendix F: Summary of Case Study Findings

This section summarises case study findings according to the 12 maintenance elements identified in Section 4.2. The conclusions and insights from each element form the Case Study Results presented in Section 5. Each organisation is qualitatively assigned a maturity level for each element based on results from case study surveys and the maturity level tables included in this section. The maturity levels are evaluated and adapted from the MRP Maintenance Maturity Matrix in Appendix G. Where there are numerous sub-elements an average is taken to determine the approximate maturity level.

1. Culture

Reliability Driven Culture considers the organisations culture towards maintenance and whether reliability driven culture is sponsored by senior managers in the organisation.

Table 2: Culture maturity levels

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Little awareness	Some training. High level mandate to change from reactive to proactive	Communication plan developed to articulate reasons for improvement	Need for change and objectives understood throughout organisation	Empowerment to drive change at every level

Mighty River Power are developing a Team building program to improve Team culture. This aims to improve morale, thwart barriers to creativity and improve productivity. As part of the team building exercise for the Geothermal Maintenance team, several areas will be discussed including reviewing the vision, mission and values that support goals and objectives of the business, reviewing roles and responsibilities, expectations for effective work and establishment of social activities to support Team culture (27).

Mighty River Power currently operate at Level 2 for Organisational Culture.

Table 3: Culture maturity summary

Christchurch Wastewater Plant LEVEL 1	Contact Energy LEVEL 2
• Reliability not currently a strong focus within the Council as most maintenance staff are not from a reliability-focussed background. • New CMMS a good step in developing reliability driven culture. • There is a drive towards a maintenance focus within the organisation; reliability is the next step. • Still requires a “paradigm shift”.	• Reliability culture sponsored within Contact Energy through recent introduction of the Reliability Steering Committee. • Reliability team introduced • Investment in various reliability systems to instil reliability culture in the organisation.
Meridian Energy LEVEL 3	**NZ Oil & Gas Operator LEVEL 3**
• Reliability driven culture a priority in maintenance and refurbishment. • Meridian high level strategy aims to optimise value obtained from assets. • Asset Management Policy aims to maximise economic life.	• Reliability driven culture sponsored by Senior Management. • Reliability measured as a global “goalpost” and KPI.

2. Communication

Communication considers the regularity and level of communication between Maintenance, Operations and Senior Management. Partnerships, common targets and aligned frameworks are desired.

Table 4: Communication maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
None	Informal/infrequent meetings to communicate goals	Regular meetings to communicate relevant information	Common targets developed between maintenance and ops	Strong partnership, regular strategic meetings and aligned maintenance framework

MRP recognise the need for a strong partnership between Maintenance and Operations with regular meetings to communicate all aspects of the business (objectives, procedures, training etc.). They are establishing monthly plant meetings and a monthly meeting for Maintenance Team Members to share information and address issues relating to safety, performance and plant.

Mighty River Power currently operate at Level 2 for Communication

Table 5: Communication maturity summary

Christchurch Wastewater Plant LEVEL 2	Contact Energy LEVEL 3
• Some communication between maintenance, operations and management functions. • Sometimes a disconnect between top-down and bottom-up communication channels.	• Daily meetings between operations and asset teams. • High level performance indicators and metrics developed together.
Meridian Energy LEVEL 5	**NZ Oil & Gas Operator LEVEL 3**
• Reference Group consists of managers from Asset Management and Asset Maintenance teams and meets monthly. • Cross-functional Maintenance Improvement Team meets monthly to review progress and determine actions related to Strategic Plan. • The maintenance team have a daily toolbox meeting to discuss safety and site issues.	• Daily meetings between Operations Management and Maintenance Management for each facility. • Discuss plans, scheduling clashes and emergent properties of multiple jobs. • All jobs raised are reviewed for safety, priority and execution by both parties • Daily meeting at all sites to discuss plans, clashes and emergent properties of multiple jobs.

3. Team

This element considers the team development process in terms of skill matrices, competencies, career progression and future requirements of the organisation.

Table 6: Team maturity levels

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
No clear definitions, alignment or objectives. Informal system.	Key competencies and org. requirements documented. Basic Development plan.	Training budget is mapped to positions. Group meetings and team objectives established.	Skill matrices used to identify future skill reqs. Competence/ development plans in place based on needs of organisation	Formal systems. Existing/future skills identified and recorded. Detailed training/career plans developed, measured and updated. Incentives.

MRP recognise that a major key to the success of the geothermal maintenance business is the recruitment, development and retention of professional and engaged maintenance specialists. The company has developed a Maintenance Team development process that is divided into four phases: Team Development, Competence Development, Motivation Management and Career Development as described in the Geothermal Maintenance Plan (27).

Mighty River Power currently operate at Level 3 for Team Development

Table 7: Team maturity summary

Christchurch Wastewater Plant LEVEL 1	Contact Energy LEVEL 2
• Little work to identify key competencies, skill levels and future requirements • Mainly to the current business environment (earthquakes) • Two new maintenance apprentice staff have been employed to grow skills and support the maintenance function for the next four years.	• Currently in the process of updating team development process. • The reliability and operations teams are generally good in this area due to certification requirements and the need to maintain these. • Other functions of the business require improvement • New team development process will track key competencies and define skill requirements and deadlines.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 3**
• All employees have a Learning and Development Plan which is agreed on with the relevant manager at the start of every year and reviewed half yearly for progress. • A companywide incentive programme exists.	• Team development skill matrices exist. • Careful management required to track training skills and competencies for a large pool of contract staff. • Process exists to measure and track employee competencies. • Competencies link back to the Maintenance Strategy including standards that the employee is required to meet. • Competencies used to track progression and development.

4. Strategy

Strategy considers the overall current maintenance strategy and the maintenance philosophies that this is based on as outlined in Section 3.3. This element also looks at how strategy is developed, reviewed and updated and its effectiveness.

Table 8: Strategy maturity levels

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Run to failure/reactive	Planned/ scheduled/ preventative	Predictive/ proactive	Reliability Centred Maintenance	Strategic combination
No plan developed	Some milestones and approximate deadlines developed	Aligned with organisation's strategic direction. Defined business case for elements.	Strategy developed with SM and relevant stakeholders. Linked to long term organisational strategy.	All internal/external stakeholders involved in strategy. Best practice gained from NZ and abroad.
No annual maintenance plan	Ad hoc tasks from Strategy prioritised/scheduled. Plan updated periodically.	Maintenance incorporated into Business Plan. Updated regularly and communicated to team	Detailed action plans with milestones. Costs estimated. Annual strategic meetings to update.	Cost/ROI vs benefit demonstrated. Changes in business environment monitored for plan review.
No performance measures	Maintenance expenditure measured/tracked	Loss of production measured. Weekly/ monthly/ quarterly reporting	Operational impact measured (availability, business risk/interruption)	All aspects of maintenance performance measured (including savings). Commented reports with trends and targets

Mighty River Power recognise the need to develop a maintenance and reliability framework "containing best practice concepts, tactics and processes to facilitate a shift from a reactive maintenance culture to a proactive maintenance regime" (27). A key initiative is the rationalisation and optimisation of preventative maintenance and condition monitoring routines. The Geothermal Maintenance Plan (GMP) has been developed to demonstrate how the maintenance team will develop manage and execute maintenance within MRP Geothermal. All current operational geothermal plants utilise performance measurement proactively as management tools. Operationally focussed performance indicators (PI) are being developed to facilitate strategic direction and continuous improvement within Geothermal Maintenance and to align with the overall Geothermal business.

Mighty River Power currently operate at Level 3 for Strategy.

Table 9: Strategy maturity summary

Christchurch Wastewater Plant LEVEL 3	Contact Energy LEVEL 2
• Current focus on bringing the organisation up to a certain level within the New Zealand Asset Management Support (NAMS) framework. • Target delayed by the immediate need for reactive maintenance to earthquake damaged assets. • Approximately 60% reactive and 40% planned (mainly lubrication, checks and inspections). • The renewals programme, pump stations and electricity generating engines run on a condition assessment model.	• Maintenance strategy not well defined however there are availability targets. • Majority of maintenance work is planned work completed during unit surveys. • Reliability Centred Maintenance (RCM), failure mode and effects analysis and “back to basics” used to develop planned maintenance strategy. • Approximately 50% planned unit overhauls, 25% general planned maintenance and 25% reactive. • Total: 75% planned, 25% reactive.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 3**
• Current Maintenance Strategy estimated to be 80% proactive and 20% reactive. • Comprehensive condition monitoring programme in place based on information out of Maximo. • Meridian have run regular RCM workshops for the past 15 years based on criticality of plant.	• Strong preventative maintenance culture driven by compliance, regulation, strategy and knowledge. • A level of corrective maintenance exists that stems from breakdowns or preventative inspections. • Condition monitoring program focusses on rotating equipment. • Approximately 60% preventative and 40% corrective.

5. Targets

This considers whether the maintenance strategy includes clear quantitative targets and KPIs that are measured and monitored to drive strategy.

Table 10: Target maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
No KPI’s used	High level KPIs defined but not reported. No value assessment.	KPIs defined with Maintenance, Ops and SM. Used to report performance and drive effectiveness.	Communicated to employees, used in daily operations. Balanced Score Card used to drive improvement.	Targeted KPIs (safety, reliability, availability, cost etc) used in daily operations as a management tool for all employees.

Mighty River Power have defined high-level KPIs but little KPI reporting exists and there no maintenance scorecard used to assess value.

Mighty River Power currently operate at Level 2 for Maintenance Targets.

Table 11: Target maturity summary

Christchurch Wastewater Plant LEVEL 2	Contact Energy LEVEL 2
• Asset Management Plan includes high level targets however these targets are not always communicated or actioned at an operational level. • Low-level processes sometimes need to be tailored to meet high-level strategy. • High level KPIs measure plant performance. • Low-level KPIs focus on mechanical availability and responsiveness. • Mechanical availability of plant approximately 70% (due to earthquakes and 50% redundancy) • Goal to increase to 90% mechanical availability. • Plans in place for maintenance teams to take responsibility for the reliability of assigned areas and equipment as measured by KPIs, rather than performing ad hoc maintenance tasks.	• Main high level target developed 3-4 years ago aims for an increase of 1.75% in reliability over 9 years. • Difficult to monitor and a somewhat unreliable measure of improvement due to new generation coming online. • Reliability measured by availability and number of forced outages. • Reliability target based on the existing asset base, current operating environment and improvement opportunities however has not been updated to reflect changes in the business environment. • Maintenance budget/expenditure, planned vs. unplanned, compliance to schedule, availability and other KPIs measured and recorded in SAP. • KPIs beginning to be communicated to employees however currently little training or uptake.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 3**
• Defined process and hierarchy to define high level goals, challenges and initiatives. • Current challenges: Reliability, Maintenance delivery, Maintenance Processes, Data Integrity and Performance Metrics. • All initiatives accountable and goals link back into Markets and Production strategic objectives. • Balanced Scorecard completed monthly. • Plant Performance Index (PPI): availability (94%), reliability (99%), forced outages, forced outage factor. • Asset Performance Index (API): schedule accuracy, data integrity. • Revenue Opportunity Cost (ROC): cost of timing, deferral of jobs due to market conditions. • Maintenance savings analysed during asset RCM analysis where strategy is decided.	• Primary measurement tool is a global dashboard that looks at integrity level for barriers across the organisation. • "Barriers" defined for each section within the organisation and include; management for process control, containment and managing sources of ignition. • Each barrier measured for compliance (planned versus completed) and communicated to Management for review. Outcomes used to drive improvement. • Safety is the major KPI.

6. Process

This element considers the work flow process and how it is managed including procedures, job plans and specifications.

Table 12: Process maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
No formal system or documentation.	Formally documented and assigned (RACI). Used only by maintenance org. Not all recorded in CMMS.	Process flows with KPIs established. No ticket, no work enforced. Basic standards documented.	Work requests screened for planning/scheduling. Work control efficiency monitored. Requests prioritised and recorded.	Post maintenance reviews and correction of documentation
No work order system used	Work orders used for preventative maintenance, reactive undocumented	All work performed against a WO and all labour and material costs recorded. Critical tasks linked with referenced job methods/instructions.	Method and safety/ environmental instructions issued via job plans attached to WOs.	Job performance criteria set (duration, resources, costs) with resources specified and availability confirmed.

MRP recognise that the management of maintenance work is a key driver for a successful maintenance regime. The effective management of the work order process is a key driver for this and a maintenance work schematic and is being developed to facilitate the process. Communication is also a key consideration especially for remedial work.

Mighty River Power currently operate at Level 3 for Maintenance Process.

Table 13: Process maturity summary

Christchurch Wastewater Plant LEVEL 3	Contact Energy LEVEL 4
• Formal work order system used for all maintenance tasks and recorded in CMMS. • General work order process: 1. Fault notification to maintenance coordinator. 2. Fault verified. 3. Work order created. 4. Resources allocated. 5. Work completed. 6. Equipment tested. 7. Resources booked. 8. Work order closed. • All maintenance hours must be booked to a work order. • Standard work orders for tasks such as cleaning and lubrication which get apportioned across all assets. • Standard operating procedures (SOPs) exist for planned maintenance tasks. • Post maintenance reviews and data integrity checks informal.	• SAP used to manage work order system. • Complex work flow with numerous checks and balances. • Post maintenance reviews performed on a (criticality based) sample of work orders to check data integrity. • Labour and material cost recorded against each work order. • All jobs have an associated work instruction for safety reasons.

Meridian Energy LEVEL 4	NZ Oil & Gas Operator LEVEL 4
• Maintenance execution managed using Maximo. • Planned maintenance jobs generated and linked to work orders with step-by-step job plans. • Maximo audit is completed monthly to review data integrity, work order closure etc.	• SAP used to programme and schedule preventative maintenance jobs for each asset. Corrective Maintenance tasks reviewed daily and scheduled based on criticality. • Safety is the number one priority. • General work order process: 1. Notification raised 2. Work order generated 3. Work planned and packed 4. Parts ordered 5. Work executed 6. Hours and materials booked 7. Close out • Dedicated operations team generate work packs for all process work. • Work packs link back to strategy and include procedures, checks, permits and safety reviews. • Information integrity and quality of information reviewed by manager.

7. Planning

This element considers work planning, scheduling and prioritisation for the planned maintenance function of the organisation. This element also considers maintenance history and backlog management.

Table 14: Planning maturity levels

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Work orders undertaken without proper planning or allocation of resources	Agreed planning and scheduling process but poor prioritisation.	Collaborative prioritisation between Maintenance, Ops and Contractors. Priorities driven by asset criticality or other metric. Formal process not consistently executed.	Weekly work schedule with resource allocation and instructions. Formal process consistently executed with priorities also driven by defect severity.	Work allocated to Contractors with all information for safe/efficient execution. Opportunity maintenance. Outstanding work list communicated.
No planning or scheduling process exists	Planning only for major activities/outages. Poor estimating. Basic scheduling for preventative work only. High level procedures only	Training in planning function. Job plans and work packages established with basic info. Basic BOMs and job estimates. Weekly schedules developed	Well defined processes. Job plans, specific procedures, acceptance criteria. BOM developed and utilised. Minimal delays. Long term and weekly scheduling.	Continuous improvement. Planning focussed on future work only. Estimates for all resources based on feedback. Planning accuracy measured. BOMs and job history utilised. Scheduling tool used, weekly reporting and reviews.
No maintenance history recorded. WO backlog not measured.	Minimal maintenance history recorded (Maximo). Completed WOs closed after approval. Backlog measured by no. of WOs/lead time.	Maintenance data about WO (duration, dates, parts) recorded before WO closed. Backlog measured by no. of WOs due in weeks.	WOs closed by Team Leader. "Ready to Schedule" backlog identified and backlog calculation used to balance work load.	Technicians record and enter ALL task data. Completed WOs closed after consultation. SM monitors backlog trends to determine resource requirements.

MRP utilises a formal process to prioritise work and has basic training in job planning and work package creation with weekly schedules.

Mighty River Power currently operate at Level 3 for Maintenance Planning.

Table 15: Planning maturity summary

Christchurch Wastewater Plant LEVEL 3	Contact Energy LEVEL 3
• Council excels at planned maintenance. • SAP used and preferred over Maximo due to easier reporting. • Maintenance schedules created and input into SAP as soon as new assets come online. • For capital projects, asset and maintenance list required from consultants for input to SAP. • SAP highlights high cost or maintenance intensive areas for review and analysis. • Maintenance history and backlog now managed through SAP • Measure asset life maintenance costs, common faults, breakdown frequency, top 10 maintenance cost assets and more.	• Work order priority initially determined by criticality and process safety flags. • Priority reviewed by supervisor during daily scheduling. • All routine maintenance supposed to follow 12 week formal planning cycle however usually only a 2 week planning cycle. • Maintenance history and backlog recorded in SAP and actively managed to maintain backlog at a certain level.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 4**
• Recently updated the planning and scheduling process. • Dedicated Schedulers introduced to review PMs for priority on a weekly basis. • Maintenance history and backlog managed through monthly Reference Group meetings. • Work orders scheduled vs. completed tracked. • Monthly Reliability Engineering Report presents top 5 reliability issues, number of forced outages, top 5 failed plant items and event analysis backlog.	• SAP provides scheduled maintenance tasks Priority and timing of all tasks finalised by operations engineers and the maintenance supervisor. • High priority given to safety critical equipment. • Daily site meetings to discuss plans, clashes and emergent properties of multiple jobs. • Maintenance history and backlog information recorded in SAP. • Early or late job completion affects performance KPIs.

8. Reactive

This element considers how reactive maintenance is managed in the organisation.

Table 16: Reactive maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
No clear process	Formal notification process used to alert Maintenance.	Responsive communication and WO created. Minimal reporting or analysis.	Emergency situation determined by O&M. Risks and consequences taken into account.	Decision process agreed, communicated and regularly reviewed. Equipment failure analysis performed and all data logged.

MRP have a well-defined and formal process for managing reactive or emergent geothermal plant work. This takes into account risks and consequences of deferring maintenance.

Mighty River Power currently operate at Level 4 for Reactive Maintenance.

Table 17: Reactive maturity summary

Christchurch Wastewater Plant LEVEL 3	Contact Energy LEVEL 2
	• Reactive maintenance usually managed by shuffling of the existing schedule. • External contractors sometimes bought in to perform the task. • Operational losses recorded in GADS and common faults analysed using RCA and RCM.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 4**
• Requirement for reactive maintenance identified by trade staff or through routine walk-rounds to monitor noise, equipment running "rough", high temperatures etc. • Issues reported and a work order created immediately or deferred based on priority.	• Corrective maintenance tasks reviewed daily and scheduled based on criticality. • Safety is the number one priority.

9. Predictive

This element considers condition monitoring processes and predictive maintenance techniques.

Table 18: Predictive maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
No predictive maintenance programme	Some asset condition data collected. Not monitored consistently and no condition trends	Some assets utilise a formal condition monitoring process that is consistently executed and monitors trends.	Condition assessment includes modelling based on asset history or other information.	Best practice predictive maintenance program including competent condition monitoring regime

MRP have developed a preventative maintenance optimisation system (PMO) that operates alongside plant criticality assessment to improve the quality of current time and condition based maintenance plans. MRP also recognise the need to effectively process the data produced by a predictive maintenance program in order to create informed action plans.

Mighty River Power currently operate at Level 3.

Table 19: Predictive maturity summary

Christchurch Wastewater Plant LEVEL 4	Contact Energy LEVEL 3
• The renewals programme, pump stations and electricity generating engines run on a condition assessment model. • Condition assessment monitors current loadings, flow rates, temperatures, oil pressure, thermal imaging, vibration analysis and oil analysis. • Condition data is fed into a model that determines when replacement will need to occur based on expected asset life, condition grade, and asset history. • When a decrease in performance is noticed, there is scope to plan for an appropriate time to take asset offline for repair. • Condition monitoring proven effective in increasing reliability and significantly reducing breakdowns.	• Condition monitoring performed through flue on-board vibration analysis, vibration tours, extensive electrical condition monitoring, thermography, transformer oil analysis and other tools used to manage high voltage assets.

Meridian Energy LEVEL 5	NZ Oil & Gas Operator LEVEL 4
• Meridian operate a best practice condition monitoring programme that gets looked at by other organisations from New Zealand and abroad. • Condition monitoring framework established in 1997 and has developed into a comprehensive plan that focusses on key generation plant • Governors, turbines, generators, transformers, circuit breakers and batteries are monitored. Basic tests include partial discharge analysis (generators), dissolved gas analysis and oil particle analysis. • Process: inspection, measurement, result recorded in Maximo, result read by Plant Asset Management system, condition of asset modelled (Meridian models), analysis/feedback on asset provided.	• Condition monitoring practices taken from the Mechanical Rotating Equipment Global Strategy. • Contractors employed to measure and monitor performance of rotating equipment with agreed limits. • Complicated logistics in organising contractors to go offshore to platforms.

10. Outages

This element considers the process for managing outages or plant shuts.

Table 20: Outage maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
No formal process	Informal or manual process to determine period, plan critical tasks, follow up meetings, improvements.	Formal process to review and approve critical tasks. Maximo used to plan and report WOs. Detailed planning optimised to critical path. Risk mitigation. Daily follow up meetings. Informal suggestion/ improvement process.	Central approval process to assess requests. In/ex resources integrated into plan. Test plans, standards, work packages developed. Basic info recorded in CMMS. Risk KPIs and analysis used to reduce cost/duration of outage. Post shut reviews.	Asset management plans drive scope and critical tasks. Monthly asset health assessment. Resourcing plans. Scope/schedule revised at follow up meetings. Detailed info recorded. Continuous improvement through recommendations, audits, analysis of outages.

MRP have recognised the value in the use of technology that is capable of monitoring and maintaining plants on line therefore minimising the need for costly outages and the associated risk. Despite this, outages are still a key consideration for MRP and effective shutdown management is needed to minimise business interruption. MRP are developing a robust, logical and transparent shut management model for planned outages.

Mighty River Power currently operate at Level 4.

Table 21: Outage maturity summary

Christchurch Wastewater Plant LEVEL 3	Contact Energy LEVEL 4
	• Dedicated planning team to execute major surveys and shuts that occur 3-4 times per year. • Outages managed through SAP with strict processes, checks and approvals at all levels. • No formal post outage review system. • Basic level of RCA and FMEA used for defect elimination.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 3**
• High-level planner liaises with Transpower to determine outages one year out. • Post outage review meetings implemented to follow up on issues, job plans, scheduling and improvements. • Forced outages have an event analysis report and root cause failure analysis which is tracked on a monthly basis and reviewed (for quality, root causes, lessons learnt) by the reliability team each quarter.	• A dedicated team work on long term (18 months out) turnarounds for shuts. • Shuts are planned and resourced outside of SAP but incorporated when work packed.

11. Continuous Improvement

This element considers the processes that are in place for continuous improvement and implementing reliability based principles into capital projects, major modifications or new plant equipment.

Table 22: Continuous Improvement levels

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
No continuous improvement processes	Informal improvement programme not reliably executed	Maintenance improvement programme or maintenance benchmarking undertaken.	Maintenance improvement programme and benchmarking undertaken. Effective improvement demonstrated.	Best practice continuous improvement at all levels of the organisation. Formal programme in place and benchmarking widely used to drive improvement in the business.
Maintenance not involved in design and selection. Reliability and maintainability not taken into account	Basic maintainability assessment. Limited to review of OEM recommendations and failure prevention strategies.	Moderate involvement of Maintenance in equipment selection. Comprehensive design completed to ensure O&M can safely work.	RCM study conducted on critical equipment. Failure modes identified. Employee input to ensure future asset reliability.	Simulation modelling and failure data analysed. O&M involved in design to commissioning. RCM analysis for life cycle cost. Designed for condition monitoring.
No root cause analysis or defect elimination. No improvement system.	Basic RCA. Failure data analysed on 25% of equipment. Informal improvement system.	5 Whys or other. Failures tracked with basic analysis. Formal improvement system. Monthly follow-up. Basic cost benefit. Losses calculated.	Formal RCA on all critical breakdowns. Thresholds established. Training in equipment failure methodologies. Systems to monitor, track and report losses. Improvement studies.	Weibull analysis for losses. All personnel trained in analysis. Results quantified and shared. Fault tree, Ishikawa, 5 Whys, RCFA, FMECA. Detailed cost benefit. Implementation plan. Well communicated.
Maintenance not involved in design and selection. Reliability and maintainability not taken into account	Basic maintainability assessment. Limited to review of OEM recommendations and failure prevention strategies.	Moderate involvement of Maintenance in equipment selection. Comprehensive design completed to ensure O&M can safely work.	RCM study conducted on critical equipment. Failure modes identified. Employee input to ensure future asset reliability.	Simulation modelling and failure data analysed. O&M involved in design to commissioning. RCM analysis for life cycle cost. Designed for condition monitoring.

MRP use equipment failure analysis and performance improvement to drive continuous improvement within the geothermal plant. This includes continuous measurement and evaluation of a wide range of metrics and the use of RCA to isolate factors that result in equipment failure. Additionally, Five Why's and Pareto analysis will be used to eliminate repetitive equipment issues. MRP have recognised the value of improved maintenance technical input to new projects and greater maintenance input during equipment specification.

Mighty River Power currently operate at Level 3.

Table 23: Continuous Improvement maturity

Christchurch Wastewater Plant LEVEL 2	Contact Energy LEVEL 2
• Selection of new plant equipment often done by third party consultants based on NPV and life cycle cost criteria with only some focus on reliability. • Somewhat of a cultural shift from maintenance to operations focus in capital project planning. • Sufficient input from stakeholders during this process. • Informal RCA and FMEA used to generate business case for new asset selection and to ensure continuous improvement.	• Currently, capital projects and generation development undertaken on an ad hoc basis. • Do not utilise reliability based principles Processes improving in this area.
Meridian Energy LEVEL 4	**NZ Oil & Gas Operator LEVEL 3**

• Continuous improvement achieved progressively through:
• **Maintenance Improvement Programme**
  • RCM
  • Condition Monitoring
  • Defect Management
    ▪ event analysis reports
    ▪ root cause failure analysis
• **Benchmarking**
  • GKS Hydro through Navigant
    ▪ every 2 years
    ▪ quantitative, fiscal
  • Asset Management Council of Australia awards
    ▪ process driven
	• Continuous improvement driven from a high-level.
	• Achieved through organic analysis of processes, reasons and opportunities for improvement and value adding.
	• Lean Team compliments continuous improvement approach.
	• Difficult to incorporate reliability based principles into new projects due to fiscal constraints.
	• Lack of understanding of instantaneous capital cost versus asset life cycle cost of ownership.
	• Major considerations for new projects: built in condition monitoring of large rotating equipment, bearings, and additional reliability measures.
	• Apollo Root Cause Analysis is used to objectively identify root cause for unexpected equipment failure.

12. Management

This element considers maintenance management and administration including spares and inventory, contractor management, information management and maintenance budgeting.

Table 24: Maintenance maturity levels

Level 1	Level 2	Level 3	Level 4	Level 5
No clear process or system.	Auxiliary spares recorded and stored based on experience or request. Stock levels controlled manually.	Basic principles used to determine stock. Frequently used parts standardised. Preferred suppliers defined but no regular price checks.	Clear process to determine spare stock. Computerised systems and stock analyses. Coding system used, parts checked against spec. Long term purchase agreements. Purchasing procedure.	Process to determine in stock, vendor or supplied spares. Based on lead time, cost, reliability, risk. Complete BoM available. Maximo used for analysis. Suppliers routinely monitored.
No selection process or follow up.	Informal process. Contractor list. Work scheduled but not planned.	Some contractor agreements. Selection on past performance. All work scheduled, major work planned. Supervision and basic evaluation.	All work scheduled and planned. Evaluation process based on cost and lead time. Performance and improvement meetings. Active continuous improvement.	Contracting guidelines. Work is recorded in CMMS. Comprehensive evaluations. Formal quarterly meetings. Contractors act as partners to continuously improve plant performance.
Data and information not collected	Data collected and stored. Some manuals and equipment drawings exist. Basic initiatives to update info for plant changes. Very limited reporting.	Data and information stored in Maximo (used by Team Leaders). Robust process to update, protect and control modifications. Revision numbering system. Operational loss info collected.	All documentation for critical equipment is managed. High level process maps. Classification process/systems. Links with MS Project, analysers but not fully integrated. Greater Maximo use by personnel. Basic failure info reported.	Structured approach to manage all technical info and documents (indexed, tracked). Maximo and maintenance systems integrated in CMMS. Maximo widely utilised for full functionality by all personnel. All users appropriately trained.
No maintenance budget defined.	Annual maintenance budget prepared based on last year's expenditure.	Annual budget prepared for each department. Uptime/downtime tracked. Costs controlled and reported monthly to SM. Monthly/quarterly statements.	Annual budget based on labour, material and sub-contracting cost. Direct costs allocated to location or group in Maximo. Financial impacts of availability calculated.	Annual zero-based budgeting process used. Distinction made between operation, outage, non-routine, capex. Direct costs allocated at equipment level. Monthly cost reports. Action to reduce operational cost at equipment level.

Mighty River Power currently operate at Level 3.

Table 25: Management maturity summary

<table>
<tr><th>Christchurch Wastewater Plant LEVEL 2</th><th>Contact Energy LEVEL 2</th></tr>
<tr><td>

Well-developed formal process for contractor management includes tendering, consideration of past performance, various KPIs and standard contracts.
Maintenance budget supposed to be zero based however often considers previous year spend profiles.
Budget is generally not directly allocated to locations or groups of equipment.

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Contractor management follows a formal process with demanding contracts to ensure performance targets are met.
Long term budgeting based on previous years fixed costs plus planned outage work.
Short term budget forecasting and project/asset allocation in SAP.

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<tr><th>Meridian Energy LEVEL 4</th><th>NZ Oil & Gas Operator LEVEL 3</th></tr>
<tr><td>

90% of maintenance performed in-house. Contract out for water level site maintenance, UPS, thermography, compressors and facilities management.
Standard contractor management process exists.
Maintenance information managed in Maximo and the Plant Asset Management system.
Maximo:

Plant and maintenance history
Job plans
Work orders
PMs

Plant Asset Management system:

Inspections/measurement/testing
Plant condition modelling
Current state

Maximo used regularly at trade staff and Tactical/Reliability engineering level.
Maintenance budget developed based on previous years and plans for upcoming year.
Costs allocated to a station, class of equipment or scheduled/unscheduled maintenance.

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Contractors not monitored on time to complete but safety.
Long term contractor agreements exist and procurement of large equipment completed through global purchasing agreements.
SAP used for maintenance information recording alongside the “Business Warehouse” reporting too.
Maintenance budget based on forward plans, past cost, inflation, job market/employment cost.
Budget assigned at an asset level.

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Appendix G: Mighty River Power Maintenance Maturity Framework

	Elements	Questions (What)	Description (Why)	Level 1 Reactive Maintenance	Level 2 Planned Maintenance	Level 3 Proactive Maintenance	Level 4 Engineered Reliability	Level 5 Operational Excellence
Leadership	Sponsorship & Organisational Culture	Is a reliability driven culture sponsored by Senior Managers / Organisation?	The level of sponsorship and culture is seen as the primary pillar of a successful maintenance program. Sponsors participate actively and visibly throughout the development and implementation of the Geothermal maintenance program, build a coalition of support throughout MRP with peers and managers, and communicate effectively with their teams concerning the importance of proactive maintenance strategy. Proactive leadership will determine the speed of adoption, the % of targeted benefit realized, and the sustainability of the results - all of which have an impact on the overall ROI of any initiative.	The concept of reliability driven maintenance has not been integrated into the Organisation. Little awareness for the need to change from reactive to a proactive culture.	Team has received training in maintenance / reliability best practices. A high level mandate to change from reactive to proactive maintenance has been communicated.	Middle Managers and Team Leaders have received training / awareness in maintenance / reliability best practices. A high level mandate to change from reactive to proactive maintenance has been embraced & a communication plan been developed to articulate the compelling reasons for continued change & improvement of current maintenance regime.	Middle Managers, Team Leaders and Team Members have received training / awareness in maintenance / reliability best practices. A high level mandate to change from reactive to proactive maintenance has been embraced & a communication plan been developed to articulate compelling reasons for change & improvement of current maintenance regime. Reliability driven maintenance is more than mandating / articulating change, but ensuring strategy, goals & roles required to enable change are well understood throughout the Geothermal business. Organisational goal & objectives have been aligned to the process & RACIs for all core elements / work streams developed.	Level 4 plus... employees at every level (inclusive of Senior Managers) are empowered through active learning, access to the necessary tools, & the time to drive change at every level of the Organization.
Geothermal Maintenance Strategy	Geothermal Maintenance Strategy	Is there a documented maintenance strategy and roadmap with clear quantative goals and targets?	A comprehensive document that sets out MRPs overall maintenance strategy. The strategy is aligned with MRPs overall business objectives and business environment. The strategy is divided into tactics, and outlines all major elements of the master maintenance strategy (to be achieved within a stated timeline). The maintenance strategy provides a road map that helps both Maintenance & Operational teams focus on short term objectives, but also enables long term objectives to be visualised i.e. aides individual employees understanding of short term goals, how these goals fit into the big picture, interdependencies of individual team member goals, and what objectives will be completed long term. The Geothermal Maintenance Strategy should be developed through a process that includes the following steps: Business planning - Review and evaluation of current Geothermal business plans and respective business drivers. Leadership direction - Developing and	No Master Plan developed. No actions taken to determine current & future organisational objectives / goals	Bespoke milestones, and approximate due dates / task assignments have been developed driven by individual sites requirements and local operating environment.	The Organisation's strategic direction is used to determine current and future requirements. Each core element has its own detailed project timeline, but sub components and interdependencies are not taken into account. Each core element has a detailed business case with clearly defined ROI.	Maintenance strategy is developed with Operations and Senior Management providing direction on key aspects of performance service delivery taking into account all relevant stakeholders. The Organisation's long-term strategy is used to determine current & future requirements and expectations. The development of an overall master plan linked to organisational goals / strategy; inclusive of a clear resource plan and dedicated allocation.	Level 4 plus... the maintenance strategy forms an integral part of the Geothermal strategy, and is developed involving all internal and external stakeholders i.e. Operations, employees, suppliers, etc. The Organisation's long-term strategy and market situation is used to determine current and future requirements. Independent market reports are analysed by Maintenance to meet the company's future strategic objectives. Best practices gained from NZ and Abroad are deployed and used accordingly.
	Maintenance Strategy / Annual Maintenance Plan Reviews	How is the Maintenance Plan followed, reviewed and updated?		No annual Maintenance Plan exists or translated from the master Geothermal Maintenance Strategy	Ad hoc tasks from the Geothermal Maintenance Strategy are prioritised and scheduled, and some detailed action plans exist. The Maintenance Plan is periodically updated but the content is static. Visibility of maintenance Plan is not known by all employees or Operations.	The annual Maintenance Plan is incorporated into respective Geothermal Business Plans; strategies / tactics are implemented over a defined period. The Maintenance Plan is updated on a regular basis and is formally communicated to all Team Members.	Level 3 plus... core elements / sub tasks incorporated in an annual Maintenance Plan, and detailed action plans with timelines and milestones established. Actions are assigned to a responsible owner, and the cost of implementation estimated. The status of the Maintenance Plan is communicated to all employees, annual strategic meetings are held with all concerned parties to update plan annual basis.	Level 4 plus... elements / tasks are broken down in detailed action plans (time schedules, checkpoints, responsible person, resources, etc.). The cost of implementation is calculated and followed, and the result of the implementation is verified. ROI v benefits demonstrated. The status of the Maintenance Plan is communicated to all parties concerned, and strategic meetings are held with them at least once a year. Changes in business environment as well as the outcome of Operations satisfaction surveys, employee surveys and supplier surveys are used as an input to review and update the plan. Maintenance strategy is visible in the workplace as a common guideline.

Maintenance Performance / Effectiveness	How is maintenance performance / effectiveness tracked and measured?	aligning the Maintenance Team's vision, values and strategic focus areas. Geothermal plant – Identifying opportunities for maintenance excellence as related to the strategic focus areas through gap analysis, focus groups and key stakeholder interviews. Maintenance best practice from New Zealand and Abroad are used to substantiate derived focus areas. Geothermal capabilities – Assessing Team's capacity to meet expectations through consultation with Team Members.	No performance measures used to track effectiveness and ROI of maintenance	Maintenance expenditure is measured and tracked through SAP and Maximo	Maintenance expenditure is measured and tracked through SAP and Maximo. Maintenance expenditure and the loss of generation is measured and communicated. Weekly, monthly and quarterly reports are generated; reports are clear, and standardized.	Maintenance expenditure is tracked through SAP and Maximo. Maintenance expenditure and the loss of generation is measured and communicated. Maintenance performance and operational impact (availability, business risk, business interruption, etc.) is measured, tracked and communicated. Standardized weekly, monthly and quarterly reports are generated, including all business relevant figures and actions.	All forms of maintenance expenditure are tracked through SAP and Maximo. Maintenance expenditure and the loss of generation is measured and communicated. Maintenance performance (direct, continuous and long term) and the impact on operations as an absolute value ($), including energy savings - measured and communicated. Standardized weekly, monthly and quarterly reports are generated, including all business relevant figures and actions. All figures are commented and shown in a trend graph provided with mutually agreed targets.
Key Performance Indicators	How are Key Performance Indicators used to drive strategy?	Priority tasks and strategies – Developing and evaluating alternatives within each focus area to produce a set of high level goals and strategic objectives related to the Geothermal business. Plans and performance targets – Reconciling strategic objectives, performance measures and targets to produce plans and strategies that are effective, technically realistic and fiscally responsible. Effective master plans have milestone or gateway reviews to ensure specific initiatives or tactics are delivering the intended results. A traditional Maintenance department can and should improve the internal processes and practices used to execute maintenance activities. It is impossible to achieve and sustain world-class maintenance and reliability levels without the support and cooperation of other, non-maintenance plant functions. Equally, these non-maintenance functions are also dependent on the maintenance function to achieve stated plant availability targets and thus cannot operate effectively without proactive Maintenance cooperation. The ideal partnership between Operations and Maintenance will be derived from open and forthright communications, shared beliefs, well-defined expectations from both Operations and Maintenance, and a set of common goals that are aligned with business needs and drivers. To guarantee that an effectual partnership is fostered between Maintenance and Operations, the following factors are essential: Active involvement between	No KPIs used to manage Maintenance and Operational effectiveness.	High level KPIs defined, but no KPI reporting. Maintenance Scorecard is not applied or used to assess the value of the respetive tactic of maintenance task.	KPIs defined with Maintenance, Operations and Senior Management. KPIs used to report business performance and drive maintenance effectiveness; but not communicated to employees.	KPIs defined with Maintenance, Operations and Senior Management. KPIs used to report business performance and drive maintenance effectiveness; communicated to employees, and used in day-to-day operations. A standard Balanced Score Card is used and followed regularly. Evidence can be shown that it is used to drive decisions and improvements.	Targeted KPIs are agreed with Maintenance, Operations and Senior Management, and are used in day-to-day operations as a management tool for all employees. KPIs cover areas such as safety, reliability, availability, cost, personnel and progress of strategy implementation. A standard Balanced Score Card is used as the Business Leaders tool to drive the business in the correct direction. Many practical examples and improvement actions can be shown.

	Operations and Maintenance Partnership	Does interaction between Maintenance, Operations (and Senior Management) occur on a regular basis?	Maintenance and Operations concerning core maintenance procedures, maintenance best practice, plant improvements, modifications etc. Development of a common set of targets / objectives that Maintenance and Operations expect to deliver over a 3 to 5 year period. Determination of Maintenance and Operations boundaries; with respect to authority concerning key maintenance decisions. Review of maintenance goals and targets to ensure appropriateness and also alignment with the overall Geothermal business objectives. The establishment of monthly plant meetings used as a conduit to address respective plant issues. An agreed level of information and data capture to enhance and optimise plant operations.	Little evidence of interaction between Maintenance and Operations.	Informal meetings designed to share and communicate information concerning common goals and targets. Meetings between Maintenance & Operations occur infrequently.	Meetings held regularly to share and communicate information; site specific and cross functional. Maintenance & Operations meet on a regular basis, but common goals not developed to determine progress.	Level 3 plus...common targets and metrics developed (Maintenance & Operations) to measure relationship effectiveness.	Well-defined partnership with common operational targets and bonus criteria. Regular bilateral strategic meetings held to define common organisational goals. A common maintenance framework is developed, and aligned with MRP's overall business objectives and business environment.
Maintenance Operation & Execution	Management of Maintenance Work	Is there a formal maintenance work flow, process or system?	A fundamental driver of a successful, proactive maintenance regime is the management of maintenance work i.e. how maintenance is performed and executed on a daily basis. Without an effective maintenance work system / process; planning and scheduling are not possible. This is the vehicle by which all maintenance work is managed and documented. An effective Work Control Process screens out the unnecessary and unimportant activities; establishes responsibility for planning and execution of work; reduces mistakes; and provides a universal understanding of what is to be done and the priority sequence that is to be followed. Wrench time or labour utilization rates without planning and scheduling are typically less than 30% - with planning and scheduling they exceed 50%. Meaning that you can double the productivity of your work force with effective planning and scheduling - work control is the foundation that enables this process.	No formal work system / process in place. Maintenance work is not documented. Work control is informal and standards of practice are undocumented.	Work flow process is formally documented and includes RACI chart. Work orders only used by the maintenance organisation, but not all work requests are recorded in the CMMS.	Process flows and RACI in place with KPIs established. "No ticket - "no work" enforced - must have a work order to perform a maintenance task. Basic maintenance standards for each step, task, or function of work control formally documented.	Level 3 plus... Operations and Maintenance enter work requests that are screened to determine appropriate levels of work planning and scheduling. Formal procedures exist for measurement and monitoring of work control efficiency. All work requests are recorded in Maximo. A priority coding allocation system is used for all work.	Level 4 plus... Post maintenance task, a comprehensive review of the documentation quality is completed and any inaccuracies are returned to the originator for correction.
	Maintenance Initiation	What is the approach to prepare and plan for maintenance tasks.		No WO preparation or requisition raised. Work orders are not used.	Work orders are used for preventive maintenance. Blanket or standing work orders are predominant. Reactive work is undocumented.	All work is performed against a work order. 100% of all labour and material expenditures are recorded against a work order. Critical tasks are linked with job methods and safety/environmental instructions - a reference number of the job method and safety / environmental instructions are on the work order.	Level 3 plus… Job method and safety / environmental instructions are issued via job plans and attached to work orders. Details about job duration, resources, job costs, parts, special tools etc. are not provided.	Job method and safety/environmental advice are prepared and issued via job plans. Job performance criteria are set e.g. job duration, resources, job costs etc. Parts, special tools as well as equipment required for the task are specified, and available before commencing maintenance task.

	Maintenance Execution	How is maintenance work prioritised and executed?		Work orders are given directly to supervisors without proper allocation of resources and planning.	Work orders following an agreed planning and scheduling process, but maintenance priorities are constantly shifting. Prioritisation process is not collaborative between Operations, Maintenance, and Contractors.	Work orders following an agreed planning and scheduling process. Work prioritisation is collaborative between Operations, Maintenance, and Contractors. Priorities are driven by either asset criticality, defect severity, or work order type. A formal process exists but is not consistently executed.	Level 3 plus… A weekly work schedule is provided to the supervisor with allocation of resources and appropriate instructions to perform the maintenance task safely. Priorities are driven by both asset criticality and defect severity; work order type is not considered. Formal process documented and consistently executed.	Level 4... Opportunity maintenance is allocated to maximize use of plant and market conditions. Work is allocated to Contractor with all necessary information (job plans, work packages, standards as well as verbal instructions) needed for safe and efficient execution of the task. An outstanding work list is easily accessible for both supervisors and Contractor. Priorities are driven by asset criticality, defect severity, and work order type simultaneously. Formal process documented and consistently executed.
	Maintenance History and Backlog Management	How are maintenance history and backlog management utilised?		No maintenance history in Maximo. Work order backlog is not measured or understood.	Minimal maintenance history in Maximo. Completed work orders are closed after approval from the technicians. Work order backlog is measured by the number of work orders due for completion / lead time.	Level 2 plus… Maintenance data about the job (duration, date completed, parts replaced or repaired) is provided to the Team Leader. The team Leader or administrative personnel records the data in Maximo, and the WO closed. Work order backlog is measured by the number of work orders due "in weeks".	Level 4 plus… All WOs are closed by the Team Leader. “Ready to Schedule” backlog is easily identifiable and decisions are made to balance Contractors' work load using backlog calculation.	Technician enters all data (basic data, failure symptom, failure type, root cause etc.) about the task in Maximo. Completed work order are closed regularly after consulting Operations & Maintenance. Senior Management closely monitors backlog trends to determine correct staffing and outsourcing requirements.
	Emergent Maintenance Work	How is emergent / remedial maintenance actioned?		No clear communication process exists to handle equipment emergencies.	A formalised system / notification process is used to alert Maintenance regarding remedial or emergent work.	Responsive communication and notification to alert Operations and Maintenance. Work order created in Maximo. No or minimal feedback exists to capture and analyse the incident.	Level 3...An emergency situation is determined by Operations and Maintenance in collaboration, taken into account risks / consequences of not performing maintenance	Level 4...There is a mutually agreed and regularly reviewed decision process to determine emergency situations. This process is known and followed by all employees (including Operations). Upon completion of the repair, an equipment failure analysis is performed. MRP's Event Reporting template is used to log all necessary data (duration, failure mode, parts replaced or repaired, etc.).

Geothermal Plant Outages	Shut Initiation	How is the shut initiated?	The effective management and execution of plant outages contributes significantly to plant availability and reliability, and is a noteworthy contributor to budget performance. The effective planning and management of planned outages are seen as a critical business process – one where competitive advantage is gained or lost. The development of a robust, logical and transparent outage model to be used as an effective tool to deliver planned outages, which can be applied to a specific operating context is imperative. The following points will form the basis of the shut management model and will be developed accordingly: • Organisational structure and integration of all Geothermal functions. • Preparation of activities and work scope incorporating a shut preparedness model. • Contractor management. • Budgetary control. • Planning and logistics. • Outage execution and handover. • Safety management plan. • Quality management and assurance. • Appraisal and audit of outage. • Management overview and support.	No formal outage planning process	Outage period is determined by Operations based on the market situation or a set period occurring annually.	Outage period is agreed upon between Operations and Maintenance considering both market situation and equipment conditions. Commercial plan is aligned to operations' capabilities /constraints, but strategic planning to remove market constraints not realised.	Outage period is agreed upon between Operations, Maintenance, Contractors based on market situation, equipment conditions and resource availability. Commercial plans developed allowing a 12-24 month horizon to be developed removing operational constraints and meeting current project market demands.	Clear strategy exists incorporating long and short term asset management plans. outage period are agreed upon between Operations, Maintenance, Contractors incorporating market conditions, equipment condition and resource availability. Communicated in advance to companies to assure timely availability of resources and equipment. Senior Managers engaged in strategic planning to help operations prepare for future market constraints; 3-5 years out. This includes full portfolio management of potential outages affecting the organisation.
	Scope Management	How is the outage scope / critical path determined?		No approval or review process exists for shut tasks and activities	An informal review process is established to assess critical tasks. A cost-based approval process is used to prioritise work scope.	A formal process of reviewing / evaluating critical tasks is established. A central approval process (i.e. Maximo) is used for all tasks / activities incorporating equipment condition, cost, safety & environmental requirements.	A central approval process is used for all work - capturing emergent work, scope changes, project work, etc. A baseline asset health assessment is facilitates scope development. All work requests are assessed / justified. Risk levels determined and mitigated for all critical tasks - remedial strategies in place.	Detailed asset management plans used to drive work scopes and critical tasks. Monthly asset health assessments facilitate scope development. Long lead projects identified and justified. Post shut reviews used to drive scope development. A central approval process used to capture emergent work, planned maintenance, condition based tasks, etc. All work requests assessed / justified. Risk levels determined and mitigated (risk plans developed) for all critical tasks. Resourcing plan developed and determined.

Shut Preparation	How is the outage prepared?		No defined criteria for the preparation of Work requests. No process to freeze the work list. No indication of tasks required to execute outage successfully. Schedule optimised to outage duration.	Manual planning is made without attention for critical path and without optimizing resource utilization. No clear process to freeze the work scope in advance. Only critical tasks are prepared (safety & environmental instructions, working method, material, labour, tools, special equipment etc.). Preparation indicator used to assess aide planning process.	Maximo is used to plan all WOs. Details of different activities and resource utilisation is only performed at a high level. Work scope frozen with sufficient time to complete safe, efficient and effective preparation. Detailed planning exists for all outage tasks. Schedule optimised to critical path. Pre outage work complete. Risk mitigation plans established. Preparation indicators used to drive the completion of high level tasks.	Level 3 plus... internal and external resources integrated into the planning process. Inspection Test Plans, Maintenance standards, Work Packages developed to support all critical path tasks.	Level 4 plus... tasks grouped or packaged as appropriate; materials kitted for planned jobs, stored and identified by work order (WO) number. Inspection Test Plans, Maintenance standards, Work Packages developed to support all tasks.
Shut Execution	How is the outage executed?		No follow-up concerning shut activity is performed during the execution of the outage.	There are informal follow-up meetings during the outage.	Daily follow-up meetings between the maintenance responsible and the technicians are held to report progress and problems which have occurred	Daily follow-up meetings with Operations, contractors, engineering etc. are held. These meetings address progress, manage adjustments and allocate / redirect resources.	Daily follow-up meetings with Operations, contractors, engineering etc. are held. These meetings address progress, manage adjustments and allocate/redirect resources. If required the schedule is revised depending on completion progress (S-curves), resource utilization and cost performance versus budget. Scope changes are evaluated prior to being added to existing outage work packages.
Shut Termination	How are the completion of tasks / activities communicated and established?		No formal method of reporting / recording completed work.	Work Orders (with no or little detail concerning current equipment condition) are reported by the end of each day to the supervisor.	Completed Work Orders are reported daily to work supervisor; communicated to the shut manager and planning coordinator. Maximo is subsequently updated.	Level 3 plus… basic information (duration, date completed, parts replaced or repaired) are also recorded in the CMMS.	Level 4 plus... completed activities are reported in real time to supervisor & planning coordinator. Detailed Information is recorded Maximo facilitating detailed analysis and future shut planning.
Continuous Improvement Process	How is the number, duration, and cost of outages reduced / optimised?		No process exists to improve / optimise duration, cost, resource, schedule tasks, safe work practices, etc.	Improvements largely based on past experiences, and are focussed on reducing duration and cost of outage. No formal meetings are held to improve status quo.	A method devised to collect suggestions during the outage. Improvements based on past experiences used to reduce duration and cost of outage. An informal outage closeout meeting held where all suggestions are analysed to make improvement recommendations for the next outage.	Level 3 plus... the inclusion of a reliability / risk-based process to reduce cost and duration of outages. KPIs developed to guide discussion. New techniques and systematic analyses of previous outages used to optimise key areas of the shut planning process. A formal post shut review is held where all suggestions are analysed to improve future outages.	Level 4 plus...the inclusion of a reliability / risk-based process used to optimise the outage in all key areas. KPIs developed - used to guide outage performance pre / post shut. Daily meetings held to review and implement recommendations. Audits performed during the shut to rectify immediate issues and also improve task execution. A systematic analyses of previous outages used to optimise all areas of the shut planning process and disseminated to all sites.

Routine Maintenance Planning	Routine Maintenance Planning	How is routine maintenance planning organised?	Routine maintenance planning is the process by which maintenance work is scoped, planned, estimated, and otherwise prepared to allow maintenance to be performed safely and efficiently with minimal interruption and delay. The following practices are essential for a robust planning process: Job plans and work packages for the majority of maintenance work. Skill requirements required to perform the maintenance task. Job plan or work package that identifies the source and location of auxiliary equipment required to perform the task. A requisition process for parts and materials which are not available to support performance of the work package. Identification of special tools or equipment. Work sequencing information to perform effective maintenance execution. Inclusion of pertinent information in the work package: safety & risk precautions, specific permits, safe work practices etc.	No formal planning process. No planning role identified.	Planning predominantly for major activities and /or outages. Planning function not clearly identified. Maintenance work overestimated (1/2 shift or full shift) and not taken seriously in the scheduling process. No formal estimating techniques used. High level work procedures developed for large jobs and outages. Heavily dependent on OEM manuals. Standard set of expectations for job plan content not established.	Planning function developed and individuals have been formally trained. Maintenance tasks include job plans with basic information (skill, duration, spare parts). Work packages developed and assembled. Dedicated planner as a full-time resource. Standardised format for job plans established; expectations on quality and content are subjective. No clear understanding which jobs should have a detailed plans developed. Several (ad hoc) BOMs developed, but only for a small portion of equipment; linked to drawings, item number, and lead time for delivery. Maintenance work sometimes delayed due to a delay in materials or parts. Job estimates are accurate; basic estimating process applied. Estimates are usually accepted as being accurate.	Level 3 plus... Processes are well defined with maintenance and operations Team Leaders given specific training regarding expectations and additional on-the-job coaching. Planning includes job plans and specific procedures with acceptance criteria and standards (moving towards quantitative vs. subjective inspection criteria). Job plan library being built. Ad hoc feedback provided from Contractors to improve job plans and work packs. Formal plan in place to address BOM shortcomings. BOM development focused at equipment level. Plan clearly being executed with results of efforts evident. BOMs and job history extensively utilised. Minimal delay in maintenance execution due to missing materials or parts.	Level 4 plus... planning strictly focused on future work. Zero involvement with reactive work. Roles and responsibilities are clearly defined and adhered to. Job plan includes estimates for coordination and other outside resources. Estimates adjusted based on history / feedback. Large majority of job plans accessed from job plan library. Reports generated to measure and improve planning accuracy. BOMs developed to component level with minor exceptions. BOMs are standard part of the CAPEX process. BOMs and past job history leveraged extensively. Delays in job execution due to missing materials rare. Evidence of continuous improvement in place. Team Member and Contractors involved in review and approval process.
Work Scheduling	Work Scheduling	How is routine maintenance scheduling organised?	Scheduling is the methodical and optimal process of reviewing work backlogs, determining when work will be performed and assigning work to the appropriate Contractor. To realise value in this approach, long range planning meetings will occur between Operations and Maintenance; with subsequent roll out to weekly / fortnightly meetings if successful. Ideally, weekly schedules are developed jointly between Operations and Maintenance.In successful organizations, the schedule is viewed as a “contract” between the two groups. Operations commits to have assets available at the agreed time while Maintenance ensures resources – labour, material, contractors, etc. are available to execute the work in a timely manner. Both groups are held accountable for compliance. Schedule compliance is often the foundation that trust can be built upon between maintenance, operations, and procurement.	No WO scheduling process exists.	Some basic scheduling is performed for preventive maintenance activities. Corrective activities not scheduled.	Weekly schedules developed - 1 week prior with Operations and Maintenance involvement. Proactive work load levelling occurring.	A long-term, as well as a weekly schedule, for preventive maintenance work based on "due date and resource availability" is prepared. Corrective work is planned in cooperation with Maintenance Supervisor. All available "craft" hours are scheduled 1 week in advance and jobs assigned to individuals. Schedule compliance measured, job kitting taking place for all scheduled jobs, proactive work load levelling process refined. Weekly schedule is integrated into the master Operations schedule on site.	A scheduling tool is used to prepare long term and weekly schedules based on "due date" and "resource availability". A weekly planning review meeting of past and future jobs is held with the parties concerned (Operations, contractors, etc.) to prioritise work and agree on a timely schedule. Reasons for unrealised, cancelled maintenance activities are documented. All available craft hours are scheduled 1 week in advance and jobs assigned to individuals. Schedule compliance measured, job kitting taking place for all scheduled jobs, proactive work load levelling process has been refined. Schedule compliance measures used to improve scheduling and planning process.Maintenance schedule is integrated into the master Operations schedule of the facility.

Maintenance & Reliability Basics	Equipment Hierarchy	Do plants have well structured (parent / child) equipment hierarchies?	The hierarchy in a plant is important because it forms the backbone of any system whereby information is stored and used as a part of running the business. These systems include but are not limited to: accounting, Operations, maintenance and stores.	No association of equipment or assets exists. No equipment hierarchy.	A well-structured equipment hierarchy in use for all installations	A well-structured equipment hierarchy in use for all installations. Assets grouped by area or process. Maximo is used to catalogue assets in a parent / child relationship that allows for logical tracking of processes and parts and conforms to ISO 14224	Complete equipment hierarchy and asset database developed including locations, relationships, spares, BOMs. Maximo used to catalogue assets in a parent / child relationship that allows for logical tracking of processes and parts conforming to ISO 14224.	Formal management of change and quality assurance processes developed to ensure overall hierarchy, configuration and catalogue information remains complete, current and accurate representation of facility and conforming to ISO 14224. All physical equipment (and locations) documented; process flow diagrams (PFD's) and reliability block diagrams maintained; 100% of redundant equipment listed and all equipment relationships defined.
	Equipment Criticality	Has a formal criticality analysis been performed for all assets?	Plant criticality assessment underpins maintenance decision-making by prioritising / classifying equipment according to the severity of equipment failure. Moreover, the identification of critical plant equipment supports the inventory management process by identifying critical spares to perform an equipment overhaul in a timely fashion	No analysis performed	Informal analysis performed and no approved tool. "Downtime" only criteria. No facilitator training or certification.	Approved criticality tool represented by the Maintenance function only. Certified facilitator used or referenced during initial exercise	Multiple professional disciplines represented through use of a non-approved criticality tool for critical assets w/o periodic review or incorporation of additional assets. Certified facilitator used or referenced during initial exercise.	Approved Criticality tool used to evaluate system level and critical assets. Process developed to include new assets/systems or major changes in operating context. Certified facilitator used or referenced during initial exercise. Each plant has site champion to periodically review criticality analysis.
	Equipment Maintenance Plans	Are current EMPs physically mapped to mechanical, electrical, stationary failure modes and to the appropriate inspection methods?	The primary benefit of targeted equipment maintenance plans is the increase of equipment reliability leading to increased plant availability and reduced business interruption. Moreover, increased equipment reliability also reduces maintenance costs with respect to reduction in expensive overhauls and consequential repairs. The intention of preventative maintenance (PM) is to decrease the occurrence of equipment failure as well as promoting equipment awareness and disciplined inspections. This is accomplished through early detection of potential failures allowing corrective actions to be scheduled in a timely and efficient manner. The optimal approach for a PM program is made up of three functions:• Daily inspection by Maintenance or Operators Team Members (Operator Care) to prevent equipment deterioration.• Periodic inspections by Maintenance Team Members to measure equipment deterioration and to perform minor repairs.• Scheduling timely equipment shutdowns to inspect or repair the equipment deterioration before failure occurs.	A majority of maintenance is performed in response to emergent and corrective work orders. Maintenance plans are static and rarely reviewed. No predictive maintenance techniques are used. No failure mode library exists.	Various equipment maintenance plans developed, but are static and rarely reviewed. Organisation is free to use whatever they view appropriate to detect equipment failure. A component level failure modes library exists. No front line maintenance performed by operators	Equipment maintenance plans developed for process critical machines, based on the technicians' experience. Frequency of preventive activities based on the breakdowns. A basic set of condition monitoring techniques, such as oil analysis and vibration analysis, used. Operators perform basic condition checks of specific equipment.	Equipment maintenance plans developed for all equipment, based on technicians and operations experience as well augmenting results from FMEA. All failure modes have been mapped to the appropriate technologies and equipment inspections, and are reviewed based on failure analysis. Condition monitoring - "Big 6" technologies (Vibration, Oil, IR, UE, UT, and MCA) have been mapped to all process critical equipment. The condition status is recorded in Maximo. Operators perform equipment condition checks in all Operational areas.	Equipment maintenance plans developed based on the RCM approach. Failure characteristics (mode, mechanism, MTBF, and probability) are used to determine the required maintenance (preventive, predictive, operate to failure, design out) for all critical equipment. The component level failure modes library has been augmented with the use of RCM analysis on the top 5-20% of systems and mapping has been expanded to include Essential Asset Care Tasks as well. Preventive activities are reviewed based on service history, result from inspections, and services. Failure analyses are the basis for changes of lubrication, preventive and predictive maintenance activities as well as frequencies. Operators perform equipment condition checks, cleaning, lubrication and some minor component changes such as filters, seals etc. in all Operational areas.

	Reliability Centred Lubrication	How are lubrication practices / standards developed and deployed?	Reliability centred lubrication focuses on designing a lubrication and oil analysis program taking into account operational conditions, best practices, OEM data and local operating conditions.	No formal process identified or used.	Practices developed and supported through lubricant supplier / OEM. Dedicated lubrication champion identified at each site.	Executing elements from a formal lubrication assessment (identify gaps between current and future state) - 50% above. Trained and certified technicians (ICML); leading, designing and executing lubrication processes. Oil sampling and submission to oil lab and results interpreted locally.	Executing elements from a formal lubrication assessment - 75% above. Physical asset modifications made for filtration, breathers, sight glasses, fill and drain. Oil samples sent to an approved lab; results interpreted through site champion or reliability function with respect to local operating context.	Multiple persons trained and single championing lubrication excellence. Executing all elements from a formal lubrication assessment. Physical asset modifications made for filtration, breathers, sight glasses, fill and drain. Oil samples sent to an approved lab; results interpreted through site champion or reliability function with respect to local operating context. Both the health of the lubricant and the asset are taken into account when delivering recommendations, and must be integrated into Asset Health.
	Maintenance Procedures / Job Plans / Specifications	How are maintenance procedures, work packages, job plans, etc. developed and used?	Each inspection method needs to have a work execution standard that covers everything from how to collect the data, the alarming criteria, reporting criteria, assignment of Asset Health Code, etc. Unless personnel are executing the work to the same standard, the output will not be consistent so the KPIs derived cannot be compared.	No work procedures / job plans exist. There are no inspection plans for basic machine conditions.	Basic job plans / work procedures exist, but not for all equipment maintenance plans deployed. Knowledge is retained by maintenance personnel.	Maintenance Procedures / Inspection Test Plans / Standards exist - 50% above, and for the application of each deployed condition monitoring routine.	Maintenance Procedures / Inspection Test Plans / Standards exist - 75% above, and for the application of each deployed condition monitoring routine. Routine annual audits are conducted to assure compliance to the standards and continuous improvements.	Maintenance Procedures / Inspection Test Plans / Standards exist for all equipment and integrated in Maximo (and provided with the appropriate work orders). Quality assurance program is put in place that guarantees compliance to all standards and practices. Labour, safety and job process are included and reviewed with input from technicians.
	Operational Maintenance & Basic Care	What is the role of Operations in the reliability improvement process?	Basic operator care involves the inspection, cleaning and adjustment of process equipment by Operating personnel on a frequent basis to ensure correct equipment operation and equipment defect is exposed before failure interruption. Operators should have assigned routes on which they collect data and make equipment observations. This process is critical to identifying potential equipment failures before they occur. Operators can take action in addition to collecting data, to include initiation of a work order and even the identification of spare parts.	Maintenance fixes mentality	"Operations" is a passive participant in driving reliability centred maintenance.	A partnership exists, and Operators actively participate in maintenance activities.	Partnership exists between all functional areas and Operations. Operations personnel are heavily involved in operator care and in quantifying and tackling losses from ideal.	Level 4 plus…Operators have assigned routes collecting data and make equipment observations pre-empting equipment failures. Operators take basic maintenance action in addition to collecting data, to include initiation of a work order and even the identification of spare parts.Operators are adequately trained to perform basic equipment maintenance and have appropriate training has been provided.
Plant Performance / Continuous Improvement	Equipment Failure Analysis	How are equipment failure / operational losses determined?	The concept and methodology of root cause analysis (RCFA) is designed to provide a cost effective means to isolate factors that directly or indirectly result in equipment failure, loss of plant availability or significant business interruption. This process is not limited to equipment or system failures, but can effectively be used to resolve problems that have a serious, negative impact on effective inherent system, organisational or human related equipment issues. The use of RCFA should feature prominently as a methodology to eliminate and resolve equipment failure.	No root cause analysis or basic defect elimination process. There is no evidence that root cause analysis is performed. Equipment failures / loss elimination not calculated.	Ad hoc root cause analysis performed by Operations or Maintenance personnel. Equipment failure data is tracked and analysed on less than 25% of the machines	5 Why and / or informal approach to identify equipment failures. All equipment failures are tracked, but limited tracking at machine level. Rudimentary analysis performed on an ad hoc basis.	Level 3 plus...Operations and Maintenance personnel perform root cause analysis on all major equipment (critical) breakdowns. Threshold limits established. Formal root cause analysis established and personnel trained in the use of appropriate equipment failure methodologies	Level 4 plus... the introduction of weibull analysis for both common and special cause losses. All personnel trained and instructed in analysis techniques. Demonstrated results quantified. Results shared among similar assets and similar users. Fault Tree Analysis, Ishikawa, 5 Whys, Root Cause Failure Analysis, FMECA (Failure Modes, Effects & Criticality Analysis, etc.) established and used.

	Plant Performance Improvement	How are plant losses or equipment failures mitigated and resolved?	Plant performance improvement addresses the current issues limiting plant availability and business interruption. Plant performance improvement focuses on improvement, identification and establishment of maintenance excellence and the development of methods to reduce plant losses that deviate from optimum performance levels. Plant performance improvement should be achieved by: • Identifying and correcting persistent equipment issues. • Provision of technical advice to Operations and Maintenance. • Improving how issues on plant are captured, analysed and prioritised. • Implementing a detailed defect elimination program to clearly understand root causes behind repetitive equipment problems. • To identify solutions to problems with the implementation of cross functional improvement Teams and improved knowledge sharing across the Geothermal business.	No formal system to collect, evaluate and implement improvements or suggestions on site.	Informal system to collect, evaluate and implement improvements / suggestions exist. Equipment failures / loss elimination not calculated.	A formal system exists to collect, evaluate and implement improvement suggestions. Suggestions made and implemented, and are followed by Lead Team on a monthly basis. Basic cost benefit analysis used to highlight projects. Equipment failure / losses calculated, but not widely understood.	Cost Benefit Analysis performed to understand return on investment of capital employed. Systems in place to monitor, track and report on losses from plant design. Cross functional teams assigned to address major loss areas. Evidence of regular improvement studies realised. Calculation methodology not standardised and metric left open for interpretation.	Detailed Cost benefit Analysis performed (ROI) to determine the most appropriate solution. Actual benefits of the solution are calculated based on OEE improvement, energy improvement, etc. An implementation plan with milestones is developed to assure on-time implementation. Cross functional teams in place to understand and actively pursue plant losses. Achievements are communicated in the organization and published on Enernet.
	Design for Maintainability	Are reliability based principles incorporated into capital projects or major modifications to plant equipment?	Input into design, installation and operation of the plant in a manner that will provide maximum useful life and optimum life cycle cost. Examples of Maintenance / Reliability based principles include: • Develop and standardise a program that influences new construction and equipment purchase including materials, equipment and spare parts. • Participate in approval of all new installations, including those done by Contractors to ensure their maintainability and reliability as influenced by life cycle costing.	Capital projects and modifications do not take design for maintainability into account.	Basic maintainability assessment developed to ensure basics human factors' engineering have been implemented.	A comprehensive design has been completed to ensure Operators and Maintainers can safely (and successfully) perform their assigned work. It is well understood what maintenance, operations, and stores needs from the project team and a detailed check list exists.	A comprehensive design has been completed to ensure Operators and Maintainers can safely (and successfully) perform their assigned work. It is well understood what maintenance, operations, and stores needs from the project team and a detailed check list exists. Maintenance are using "Employee requirements documents' to ensure future asset reliability.	Level 4 plus... Design for condition monitoring has been installed to ensure targeted Condition Based Maintenance tasks can be efficiently and effectively executed.

	Reliability Centred Design	How are maintenance based principles incorporated into the design and selection of new equipment?		Maintenance personnel are not involved in the design and selection of new equipment. Capital projects and modifications do not take reliability centred design into account.	Reliability Centred Design limited to a review of the Original Equipment Manufacturers' recommendations and failure prevention strategies.	Moderate involvement of Maintenance personnel in the selection of new equipment. A standardised failure mode library has been developed and applied to the overall equipment Geothermal Maintenance Strategy.	A full RCM study is conducted on the most critical equipment (5-20%) to help identify all failure modes likely to occur with respect to operating context. Data is used to create equipment maintenance plans, parts lists, and operations procedures. Maintenance personnel are involved in the selection of new equipment, but no studies (except cost) are performed to justify equipment selection.	A full RCM study is conducted on critical equipment (5-20%) to help identify all failure modes likely to occur with respect to operating context. Full simulation modelling is applied, and failure data is taken from industry best practice data or sister operations. Both Operations and Maintenance are involved from design until commissioning of all new equipment. RCM study / analysis contributes to life cycle cost calculations. Life cycle cost, standardization, reliability and maintainability are performed for all new installations.

Maintenance Budgeting	Maintenance Budgeting Annual Reviews Equipment Downtime Work In Progress Budgetary Control and Reporting	How is the maintenance budget developed and controlled?	The maintenance budget should support site efforts to meet stated performance requirements. Establishing an adequate maintenance budget requires an understanding of many variables associated with maintaining assets, particularly when dealing with a portfolio that consists of a complex mix of assets ranging from age, varied geographical location / environment, intensity of use and functional / service delivery requirements). When formulating a maintenance budget, due consideration must be given to: • Existing assets to be maintained. • New assets requiring maintenance. • Existing assets to be upgraded, refurbished or have components replaced (a "minimum maintenance" approach may be appropriate for these assets in the lead up to the intended actions). • Existing assets identified for inclusion in special maintenance programs and initiatives (as applicable). • Existing surplus assets scheduled for disposal. Maintenance expenditure should be governed by the total maintenance needs of the site and Geothermal portfolio (i.e. maintenance demand), and not based on perceived limitations related to availability of funds. It is a department's responsibility to seek the required level of funding to address identified maintenance needs. The development of a maintenance budget should be part of the annual budgetary process undertaken by departments. The requirements and timeframes for budget development are administered by Queensland Treasury2. In determining the make-up of the maintenance budget, the site maintenance expenditure requirements should be split into the following cost components: • Condition assessment costs • Statutory maintenance costs • Preventative maintenance costs • Condition-based maintenance costs • Unplanned maintenance costs • Maintenance management costs	No maintenance budget is defined. No structured approach exists to control and report costs. The cost of equipment down-time is not tracked. No maintenance budget exists.	An annual maintenance budget is prepared based on last year's operating expenditure. A structured approach exists to control costs, but reporting is ad hoc The cost of equipment down-time is capture, but not analysed.	An annual maintenance budget is prepared for each department. Uptime or downtime is tracked but the financial impact is not calculated. Total costs are controlled monthly and reported to Senior Management. Monthly/quarterly financial statements are regularly communicated to the respective site managers.	An annual maintenance budget is prepared for each department based on labour, material and sub-contracting costs. Direct costs are allocated to a location or a group of equipment in the Maintenance system (Maximo). Uptime or downtime is tracked but the financial impact is calculated. Total costs are controlled monthly and reported to Senior Management. Availability losses are calculated and the financial impact on site is highlighted. Monthly/quarterly financial statements are regularly communicated to the respective site managers.	An annual zero-based budgeting process is used (to establish the budget, historical failure rate data and preventive actions are used and not only previous years' spending). Maintenance budget per equipment is clearly defined between operational budgets, outage budget, non routine maintenance and capital expenditure Direct costs are allocated at equipment level and divided into labour, material and subcontracting in the CMMS. Distinction is made between operational budgets, non routine maintenance, and capital expenditure. Availability losses are calculated and the financial impact on site is highlighted. Monthly cost reports are prepared for the different organisational levels, including labour, materials and contractors. Operational cost, at line and equipment level is outlined, and action plans are used to decrease major contributors. Action plans are developed to improve the situation and sustained improvement can be shown.

Reliability Centred Maintenance	Reliability Cantered Maintenance		RCM is a process to ensure that assets continue to perform according to their stated operating context. This process is used to achieve improvements in fields such as the establishment of safe minimum levels of maintenance, changes to operating procedures and strategies and the establishment of capital maintenance regimes and plans. RCM analysis starts with the 7 questions below, worked through in the order that they are listed: 1) What is the item supposed to do and its associated performance standards? 2) In what ways can it fail to provide the required functions? 3) What are the events that cause each failure? 4) What happens when each failure occurs? 5) In what way does each failure matter? 6) What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure? 7) What must be done if a suitable preventive task cannot be found?	No RCM analysis completed. No RCM training. No leveraged RCM analysis used from other site or fuel types.	Awareness of RCM Analysis. Partial analysis completed i.e. FMEA only. No formal training or understanding or benefits.	Formal RCM training completed. Multiple RCM's completed at all sites. No formal implementation plan of recommendations. Maintenance specific recommendations implemented.	RCM champion identified overseeing and executing process through RCM Playbook. All persons participating are formally trained. Formal implementation plan for executing recommendations in all areas i.e. operating context RCM criteria established based on a relative threshold of critical equipment.	Level 4 plus...RCM Process in place that addresses all critical plant systems including installed asset base, incorporated into design phase of all critical projects. Formal implementation strategy and process ensuring all recommendations are addressed and completed. Several persons trained within the organisation and are certified facilitators

Contractor Management	Contractor SelectionContractor ManagementContractor Evaluation Contractor Costs & ReportingContractor Continuous Improvement	How are contractors selected, managed and utilised at Geothermal sites?	The selection of Contractors should be based on a process that includes a set of objective criteria and assessed on a frequent basis. The inclusion of contracting companies as an integral part of the operation is a necessity with the establishment of expectation and performance measures targeted at best in class performance; deemed essential. These performance measures will be value added with the Contractor delivering improved equipment life, higher plant availability, reduced maintenance costs (per unit of Contractor), excellent safety performance, etc.	No selection procedure is used for contractors. Contractor maintenance is performed on ad hoc basis.There is no follow up of the contractors scope of supply, man-hours and cost.	An informal / ad hoc process used for contractor maintenance selection.Contractor evaluations are not performed.A defined contractor list exists. Contractors are selected based on price only. Contracted work is scheduled in agreement with the contractor but not planned/prepared.Contractors and Subcontractors are not involved in continuous improvement programs.	Some contractor agreements have been signed, and a defined contractor list exists. Contractor selection is based on their past performance.All contracted work is scheduled and only the major works are planned / prepared. Supervision and control by maintenance supervisors/technicians is done during the execution.Systematic approach exists for contractor evaluation. Ad hoc evaluations are performed, but no further actions are taken.There is no exact follow up of the contractors cost, but some approximate figures can be found.Contractors are participating in continuous improvement programs.	All major areas of maintenance defined with contractor agreements signed to cover these areas. A defined contractor list exists to cover other areas. Contractor selection is based on their past performance.All contracted work is scheduled and planned/prepared but not recorded in Maximo. Supervision and control by maintenance supervisors/technicians is performed during execution.An evaluation process for main contractors is used based on cost and lead-time; and not on the technical performance, safety performance, etc. There are scheduled meetings to discuss the performance and the improvement plans.Main contractors' scope of supply, man-hours and cost is followed on a regular basis.Contractors are actively participating in continuous improvement programs and evidence of the co-operation can be shown.	Level 4 plus..Contracting guidelines (safety, cost, quality, lead-time) are used. Alliances and long-term relationships exist with major contractors.All contracted work is scheduled and planned/prepared, incorporated into the plant schedules and recorded in the CMMS.Supervision and control by maintenance supervisors/technicians is done during the execution.A robust evaluation process for all contractors is used, considering safety performance, technical performance, quality of supervision etc.Formal quarterly meetings held to discuss performance and the improvement plans.Contractors' scope of supply, man-hours and cost are followed on a monthly basis and stored in the CMMS.Contractors are deemed partners, working together with MRP Technicians and Supervisors to improve plant performance continuously.

Stores & Inventory Management	Critical Spares Analysis Bill of Materials Material & Equipment Level Estimation Equipment Standardisation Stores Function Preferred Supplier Initiative Equipment / Material Procurement Equipment Standardisation	Is there a process available that describes MRPs overall strategy concerning Stores and Inventory Management?	The objective of stores & supply chain management in the context of the MRP's Maintenance function is to ensure auxiliary equipment is available in the right quantity at the right time with effective and efficient processes to manage Suppliers and Contractors. The process includes equipment requisitioning, storage, repair management, shutdown support, configuration management. To fulfil these requirements, the use of best practice for inventory management is required; including responsibility for equipment usage, work order kit creation, material delivery, order point and order quantity management. Moreover, good housekeeping and equipment security are necessary components for effective stores management in addition to the application of the 5S methodology. Therefore, good stores and supply chain management requires value adding capability of a good stores function, which ultimately leads to increased plant availability, reduced inventory costs and improved maintenance efficiency. Implementing a quality stores management function, several functions must be addressed: • Development of preferred Supplier contracts and main Contractors. • Review and development of procurement process. • Understanding of critical equipment to determine the optimum stock level / consignment stocks. • Effective management of equipment and materials to ensure expeditious delivery and ensuring unused equipment are returned efficiently (stores or Supplier).	There is no clear process to determine which parts to have on stock. Parts are stored based on what happens. Parts on stock are not linked to the equipment. There is no systematic approach to optimize the stores and inventory levels. There is no standardization of parts and no codification system. Technical specifications for the part are not available.	Auxiliary spares are stored based on the technicians' experience and based on their request. Auxiliary spares on stock are linked to the equipment in Maximo. Stock levels are controlled manually by the storeroom and/or technicians. All materials are requested by the personnel when needed.	Some basic rules and principles are used to determine which parts to have on stock, such as cost, lead-time and experience. Auxiliary spares on stock are linked to the equipment in Maximo Stock levels are controlled manually by the storeroom and/or technicians. Some frequently used parts (e.g. proximity switches, fuses, etc.) are standardized, but there is no codification system. Technical specifications are part of the requirement. Some parts are coded and most parts are placed on racks. Parts are stored per group (electrical, mechanical, hydraulics, etc.). A defined list of preferred suppliers is used, but no regular price checks are done. Major material requests are handled by authorized personnel, smaller requests are handled by technicians.	A clear process to determine auxiliary spares that should be held at individual site level and across all geothermal sites. All parts on stock are linked to specific equipment in the CMMS (Bill of Material) and can be easily accessed by appropriate people. Besides a computerized Business Leaders system to control order points, order quantity, and inventory levels, regular analyses of slow-moving stock is performed. There are routines to identify and delete obsolete stock items. Most parts are standardized and a classification codification system for most parts is used. Technical specifications are part of the requirement, and parts are checked against the specification when received (e.g. documented test results, certificates, packaging and preservation requirements, etc.). All parts are coded and placed on identified racks. Storeroom access is controlled. A defined list of preferred suppliers is used, and some long-term purchase contracts have been developed. There is no system to evaluate price, quality and lead-time. A purchasing Business Leaders procedure is used with clear authorizations and responsibilities. Duplication possibilities are analysed and determined, and equipment specifications are adapted.	A clear process is used to determine which spares to have on stock, consignment or to be held with preferred suppliers. Auxiliary Spares are stored based on lead-time of the item, cost of the item, equipment reliability, Operations cost and risk assessment. All spares are linked to specific equipment, and a complete listing of parts (stock or direct purchase) for any equipment item is readily available (Bill of Material) in the CMMS and can be easily accessed by the technicians. Maximo is used and annual analyses of slow-moving stock is performed. A defined approach like vendor stocking, consignment stocking of parts and materials, and vendor consolidation is established to reduce the amount of capital invested in inventory. Standardisation of parts and a codification system is in use. Technical specifications are part of the requirement and parts are checked against the specifications when received (e.g. documented test results, certificates, packaging and preservation requirements, etc.). All parts are coded and placed on identified racks. Parts are protected from contamination and degradation and access to the storeroom is managed and controlled. Suppliers are routinely monitored on the quality of parts, lead-time and prices. Long-term purchase contracts have been developed to minimise the number of suppliers. Maximo is utilised with clear DFA / responsibilities. Spares duplication are analysed and determined, and equipment specifications, as well as consequences of new equipment standards, are discussed with the preferred suppliers.

Team Development	Roles and Responsibilities Organisational Alignment Employee Training aligned with Organisational Goals & Objectives Employee Motivation Employee Personal Development Career Progression Team Building Reward and Recognition	The key to successful maintenance is the recruitment, development, retention of professional and engaged Maintenance specialists. Major actions to be undertaken to guarantee the success of the Geothermal Maintenance Team, include: • Understanding future recruitment and organisational requirements, and the implementation of a development program to accommodate future MRP hierarchy. • Identification of induction and communication needs for Maintenance Team Members. • Implementation of skills assessment program to ensure a comprehensive training program is established. • Routinely monitor progress and satisfaction of Maintenance Team Members. • Identify high potential / future leaders and implement succession plan to manage future requirements.	The key to successful maintenance is the recruitment, development, retention of professional and engaged Maintenance specialists. Major actions to be undertaken to guarantee the success of the Geothermal Maintenance Team, include: • Understanding future recruitment and organisational requirements, and the implementation of a development program to accommodate future MRP hierarchy. • Identification of induction and communication needs for Maintenance Team Members. • Implementation of skills assessment program to ensure a comprehensive training program is established. • Routinely monitor progress and satisfaction of Maintenance Team Members. • Identify high potential / future leaders and implement succession plan to manage future requirements.	No clear definitions exist. Key competences for roles not categorised. No organisational alignment sought or established. Training is done on an ad hoc basis. An informal system exists with no follow-up. No team or individual objectives are set or communicated. No Personal Development Plan in place. No employee career plans exist.	Position descriptions developed and matched to employee job type. Key competences identified for each employee. "Organizational requirements are determined and documented. No succession planning exists. No training budget exists - training is delivered on an ad hoc basis Basic Development Plan in place but little to no actions are being completed. No employee career plans exist. People are dedicated to certain teams, but no teamwork exists. Team and/or individuals are recognized by the Business Leaders in a non-monetary way.	Position descriptions developed and matched to employee job type. Key competences identified for each employee. Competence training matrix developed & mapped to position. Organizational requirements are determined and documented in cooperation with Operations. Personal Development Plans / Scorecards developed and aligned. Succession planning exists for some key positions and training is planned. A rough training budget exists (% of the total budget). A training program exists to address key issues. Employee career plans exist, but are never reviewed. Group meetings are held to allow the employees to express their opinion. Actions are followed up by Business Leaders. Team objectives deployed from the Organisation's overall objectives are set and communicated, but no individual objectives set. Employee career plans exist, but are never reviewed. Teams are established and team objectives are set and followed by Senior Managers as well as by the team. Team and/or employee of the month is elected and recognized.	Position descriptions developed and matched to employee job type. Key competences identified for each employee. Based on the skill matrices, gap analyses are performed for future skill requirements established for each employee. Competence plan developed (for each individual as part of appraisal & ongoing development). "Level 3 plus... skills and competencies developed to satisfy organizational requirements. Succession planning with action plans are performed for all key personnel. A fixed and adequate training budget exists, which is based on the needs coming from the annual training plan. Individual development programs are agreed on based on the skill matrices and organizational needs. Team as well as individual objectives, based on Departmental objectives are set by Senior Management. Development Plans are reviewed and updated annually. Employee career plans exist and are regularly updated based on performance appraisals. Teams are established and annual team activities are carried out to encourage team spirit. Incentive/motivation bonus (gifts, productivity bonus) is used.	Position descriptions developed and matched to employee job type. Key competences identified for each employee. Based on skill matrices; gap analyses are performed, and a plan for future skill requirements established for each employee. Actual and future skills for each employee are stored in a competence database and updated annually. Training plans developed - targeted in order of priority and value added to business. A fixed and adequate training budget exists, accompanied with an annual training plan. The effectiveness of the training is measured against the skills. A training database exists, and individual development plans are agreed on to fulfil current and future needs. A formal system is used and the result of the survey is communicated. Based on the outcome, a mutually agreed action plan is prepared for the top priorities, and the implementation of the actions is communicated to employees. Team as well as individual objectives are set and agreed on in cooperation with the team(s) and the individuals annually. Quarterly information and follow-up meetings are held to review team and individual performances and to deliver feedback. Employee career plans exist and are annually updated based on the employee's need and the performance appraisals. Individual action and training plans to meet the requirements are prepared with each employee and regularly evaluated. Organization seen as environment were talent is grown and supplied to other parts of enterprise. Employee career plans exist and are annually updated based on the employee's need and the performance appraisals. Individual action and training plans to meet the requirements are prepared with each employee and regularly evaluated. Organization seen as environment were talent is grown and supplied to other parts of enterprise. A combination of a fixed and performance-based salary, based on their objectives, is used to recognize and reward employee performance.

Information & Data Management	Operational Data & Information Technical Documentation Equipment Change Management System Integration CMMS Functionality & Utilisation	How is maintenance data & information managed?	The use of maintenance data and information to manage the Geothermal business (especially maintenance) is of the utmost importance and should be identified early in the business planning process. The maintenance management system and database will encompass the total maintenance function and provide real time information to improve Geothermal Maintenance management. In addition, information and data to support planning, scheduling, equipment history, technical data, bill of materials etc. to establish improved decision making concerning the state of the Geothermal assets. The management of information within Geothermal Maintenance and the business will include: • Effective utilisation and operation of Maximo. • Access to technical documentation and maintenance operating processes / procedures. • Centralisation and standardisation of documentation / data management. • Development and utilisation of software / infrastructure / applications. • Application of continuous improvement of current systems and those developed for the future.	Maintenance data & equipment information is not collected. No manuals and drawings are available or exist, and / or superseded by modified plant. No method, system or software exists to manage and control equipment modification. No CMMS exists. Maintenance data is not collected or analysed.	Maintenance data & equipment information is collected and stored in a central repository. Some manuals and drawings for equipment exist. There is no classification assigned to technical documentation. Ad hoc initiatives are taken to update changes in plant or system modifications. A revision numbering system exists, but not consistently applied. Maximo is a stand-alone system. Very limited reporting and information capabilities are available, and manual work must be done to get the required information.	Maintenance data & equipment information is collected and stored in Maximo. Some manuals and drawings for equipment exist, and a bespoke method of classification for technical documentation is used. Ad hoc actions are taken to request missing documentation. There is a robust and auditable process with clear lines of responsibilities to update, protect and control plant and system modifications. A revision numbering system together with an information Business Leaders system enable identification of the latest documentation. Maximo is only used by Team Leaders. Technicians are not trained and / or do not interrogate maintenance data. Maximo is used for Preventive Maintenance only. Operational losses that have an impact on plant performance are collected (e.g. shift books). Maximo has reporting and information capabilities, but much manual work (e.g.; copying to MS Excel, etc.) is required to get the information.	All documents, drawings, P&IDs, etc. for critical equipment exist, and a formalised classification system is used. High level process maps with technical documentation, end-user role definitions, and fully defined business process procedures. There is a robust and auditable process with clear lines of responsibilities to update, protect and control plant and system modifications. A classification process / system exists together with a transparent process established enabling identification of the latest documentation. Essential links with other systems like MS-projects, analysers (Power Play etc.) exist, but the CMMS is not fully integrated. Maximo is available for use by different functionalities / craft skills. Appropriate user training is provided so that users understand functionality and capability. Technicians are able to consult / interrogate Maximo, and enter work hours and activities. Maximo is used to plan all work (corrective and preventive) and to register basic information of the equipment. Operational losses that have an impact on plant performance are collected. Basic information about the failure is recorded. Reporting facilities are clearly defined and used to generate necessary routine equipment failure reports.	A technical library exists containing a master file, and a structured approach to manage technical information, drawings and documents. All documents, drawings, P&IDs etc. for each piece of equipment are numbered to enable indexing, tracking and retrieval of information. High level process maps with technical documentation, end-user role definitions, fully defined business process procedures, and role-defined training documents. Maximo is integrated with SAP, including payroll & budgeting, supply chain, warehousing and purchasing. Maintenance systems like condition monitoring, maintenance procedures, drawings and equipment registers, and safety and environmental procedures are integrated in the CMMS. Sufficient terminals are available for use by the different functionalities. Appropriate user training is undertaken so that users understand functionality and capability. Technicians and contractors are using Maximo to enter work orders and activities. All functionalities of the Maximo are used, such as failure codes, routes, preventive maintenance, job plans, safety plans, safety hazards, lock outs/tag outs, inventory control, labour, calendars etc. In addition to the above points, information about problems, causes, symptoms and consequences is collected in key word format (failure codes, etc.) in Maximo.