GETTING CONSISTENCY BETWEEN ASSET PLANNING AND ASSET OPERATION

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ABSTRACT

It is now standard practice to consider a risk-based approach to prioritising asset renewals; but are we connecting this thinking to other phases of the asset lifecycle? In particular, are we connecting this thinking to maintenance management?

If our method of prioritising renewal works uses a different approach to how we rank maintenance works a misalignment can result. The amount of misalignment between the thinking we apply to Asset Management Planning and how we think about Asset Management Operations will vary from one organisation to another.

Currently it is rare for a single prioritising tool to be used for both renewal planning and operation and maintenance management. Yet the asset data set and overall objective is the same for both activities. The common goal, whether planning for renewals or managing maintenance is to provide agreed levels of service at least cost in a sustainable way.

Applying the same thinking process and getting connection between asset planning and asset operation provides a number of benefits to the organisation and it needn't involve major change or expense.

This paper outlines a methodology that has been used to apply a risk-based approach for assets that is used for both operational and renewal planning.

KEYWORDS

Asset Operational Planning, Asset Maintenance Strategies, Weighted Risk Matrix, Decision-Making.

1 INTRODUCTION

In June 2009, the New Zealand Government announced its new strategy New Start for Fresh Water, outlining the Government's new direction for water management in New Zealand. Water management is part of Phase Two of the Government's Resource Management reforms which have as their main objective the achievement of least cost delivery of good environmental outcomes.

The use of words 'least cost' and 'good environmental outcomes' would presuppose that some form of optimisation and risk based analysis has taken place. Risk analysis is common practice for renewal planning and evaluation of new capital projects (capex) but is not common practice for operational management.

Can your organisation demonstrate to auditors that operation and maintenance decisions consider risk in the same way that you do for renewals? A consistent approach that considers risk should be applied to all lifecycle phases of an asset. Typically these lifecycle phases are reported in the Activity Management Plan (AMP) as;

- Capital New / Acquisitions (CAPEX)
- Routine Operations / Maintenance (O&M)
- Renewals / Rehabilitation (RRP) and
- Asset Disposals (ADP)

Each lifecycle phase should have a management and intervention strategy. In many AMP documents, the Routine O&M Plan refers to existing Maintenance Contracts for the relevant standards and decision framework. These contracts define actions in terms of how often an asset or site is inspected, how often cyclic tasks are done and what and when preventative maintenance is done. The specification of actions needed to provide the required service delivery has generally developed over time from asset knowledge, historical events and engineering judgment.

There is a perception that Maintenance Contracts, having been fine tuned over many iterations, present a truly optimised strategy. However if the specifications within these contracts have been heavily influenced by funding constraints they may not represent the best lifecycle decisions for the assets. An example is reducing pump station attendance to cut costs to match budget. This is commonly presented as optimisation when often there has been little or no consideration of risk or whole of life costs before implementing such decisions.

The effort and frequency of maintenance activities is often applied intuitively or based on the manufacturer's guidelines and conditions of guarantee. In many instances maintenance routines are applied equally for similar types of equipment using size or capacity as starting point. One should however question whether a 10 kilowatt sewage pump located in a remote area distant from watercourses and operating 4 hours a day poses the same maintenance need as a 10 kilowatt sewage pump located close to a school or watercourse and operating 12 hours a day. Clearly the health and environmental risk as well as utilization differ in the two cases even though both sites are equipped with the same type, size and age of pump.

Overlooking risk when designing a maintenance strategy can result in overprovision leading to wasteful expenditure or it could result in underestimating risk with potentially serious consequences. The situation is often aggravated when operational budgets are constrained and unilateral maintenance cuts are implemented - for example maintenance intervals increasing from 6 to 12 months across the board or performance monitoring being replaced by visual checks. These actions do not optimise operations but instead increase the risk profile. If a risk-based approach is followed it will identify where to increase maintenance effort in high risk situations and where maintenance effort can be scaled down in low risk situations.

The factors to be considered in a risk based approach to maintenance planning are similar to the factors used to prioritise asset renewals. These include elements influencing the probability of an asset failure such as condition, track record and age, and factors influencing the consequence of a failure such as number of people affected, monetary impact and environmental concerns. Therefore the application of a risk-based approach to maintenance should not imply a huge amount of additional effort if you can use many of the same criteria already developed for your capital and renewal programs.

The benefits of using a consistent approach for both AM Planning and AM Operation include that;

- All activity areas are working towards a common goal (alignment to service objectives)
- The relationship between AM Planning decisions and AM Operation decisions will be easier for planners, engineers and operators to understand (integration)
- Trade offs between Renewals, Capital and Maintenance activities can be identified and generate cost savings (efficiency)
- O&M effort is appropriate to the risk exposure of an asset (optimization)
- Maintenance budget (planned and reactive) justified by risk-based prioritisation and total lifecycle cost assessment (validation).

2 THE PROCESS

2.1 OVERVIEW

The process is designed to generate a link between Corporate Objectives and Operational Actions. This link is established by evaluating how important each asset is to achieving the Corporate Objectives. This importance ranking (criticality score) is then used as an input to decisions on how to manage that asset through all of its lifecycle phases.

It is important to have a link between Corporate Objectives and Operational Actions to;

- Determine whether current operational programs and strategies are consistent with the overall aim of the organisation and its service objectives.
- Identify any areas where operational effort can be optimised for a better long term outcome (i.e. where to increase or decrease operational programs to either reduce costs or improve service delivery).
- Understand how different operational decisions and actions change the risk exposure for the organisation, and be able to quantify this change in risk to compare options.
- Prioritise works on a risk basis and clearly identify the risk consequence of under funding.

2.2 PROCESS OUTLINE

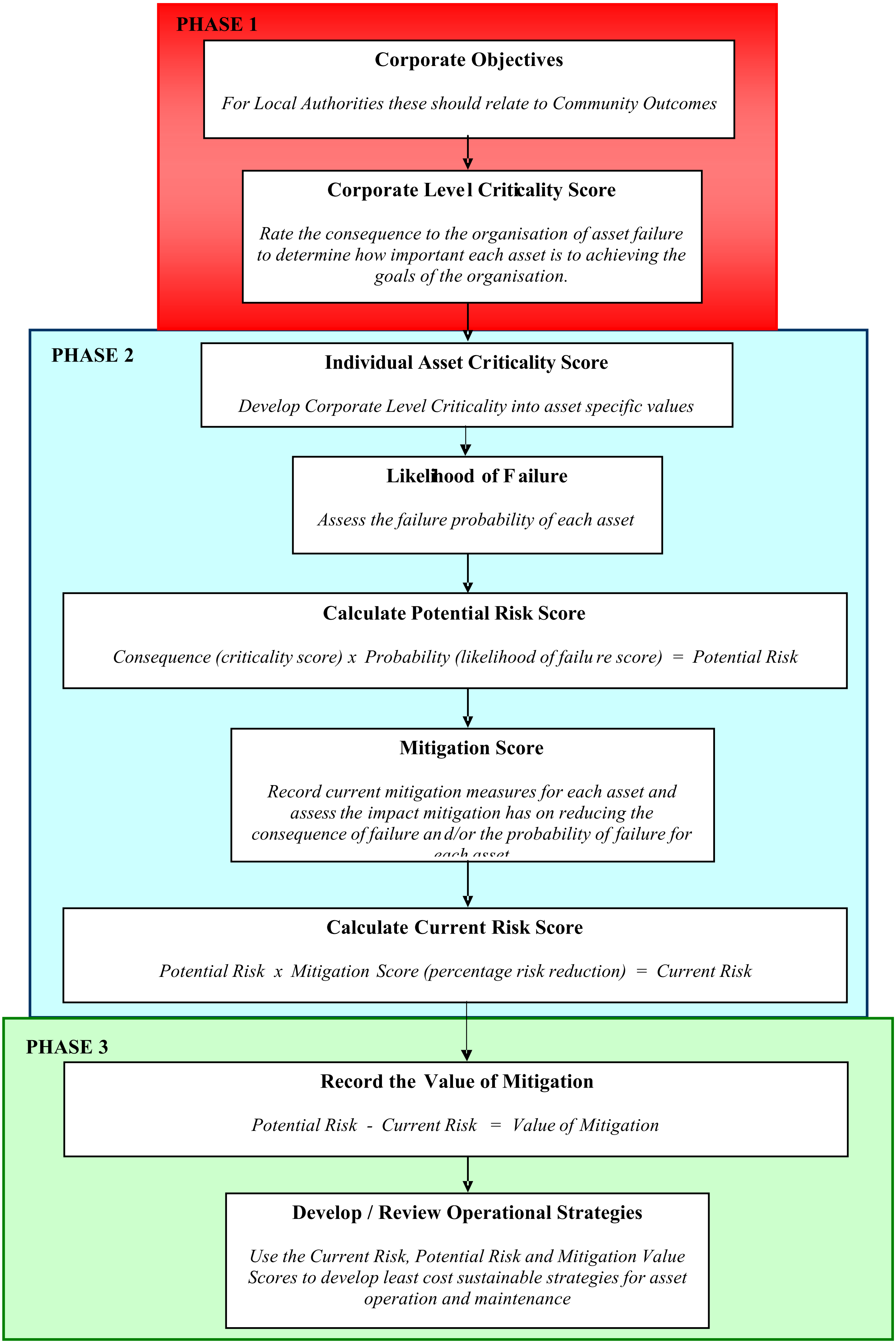
A diagram of the process outline is given in Figure 1. The process consists of a number of assessment and analysis steps that can be grouped into three primary phases.

2.2.1 KEY PHASES FOR ANALYSIS

The following Table provides an overview of the three primary phases for the assessment process;

	OBJECTIVE OF PHASE	BENEFITS
1	Corporate Level Assessment	
	Providing information to decision-makers on how critical particular assets or groups of assets are to the organisation.	This information can be used to support and validate decisions on resourcing, funding and strategic planning.
2	Asset Management Level Assessment	
	Providing information to asset managers on criticality of individual assets and likelihood of failure. Combined together, these two factors produce a risk-based score.	The risk score is used to prioritise capital and renewal programs and identify any requirements for mitigation or contingency planning. Using risk scores for Asset Management Planning establishes a link between what you plan to spend money on and what you are trying to achieve. The assessment data can also be used to develop different lifecycle strategies for high, medium and low risk assets.
3	Asset Operational Level Assessment	
	Providing information to operational managers on criticality, likelihood of failure, risk score and value of current mitigation.	This information is used to review current operation and maintenance strategies. The risk score and value of mitigation are used to identify where more effort or protection is required to manage high risks and where current effort can be reduced on low risk assets. The process will verify that the day to day operation and maintenance decisions are consistent with achieving the organisations objectives.

Figure 1: Process Outline



2.2.2 UTILISING EXISTING SYSTEMS

It is not necessary to generate an entirely new priority assessment system to achieve the desired synergy in decision-making from all levels of an organisation. What does need to happen before any process is commenced is a decision-making review. This review would identify where any gaps or misalignment exist. If would also identify if current risk-based assessment systems in parts of the organisation were suitable to expand across the whole of the organisation.

2.2.3 DECISION-MAKING REVIEW

A decision-making review would occur before any assessment process is selected. This review identifies what information is being used at different levels of an organisation to make asset management decisions. If all decision-makers are basing their decisions on the same knowledge and understanding of the assets then synergy already exists. And if that understanding includes an appreciation of risk relative to the goals of the organisation then the process will identify least cost sustainable options.

For some organisations the key impediment to top to bottom synergy is not a lack of information but one of communicating that information. It can be that the appropriate information to use for decision-making does exist within an organisation but is not available at all levels to people who could use that knowledge for making better decisions.

A decision-making review will identify if existing asset assessment and prioritisation systems are adequate or can be modified to apply organisation-wide of if a new system should be implemented.

2.2.4 PROJECT EXAMPLES

To assist with explanation of the process, this paper refers to extracts and examples from completed projects. These examples have deliberately been generalized and references to specific project detail removed or altered to respect particular projects and clients. The Appendix provides a simple worked example demonstrating the process from Phase 1 Corporate Level Assessment through to Phase 3 Operational level Assessment.

2.3 PHASE 1

2.3.1 CORPORATE LEVEL ASSESSMENT

The first phase measures the relative importance of different assets to the organisation. The measure used for this is consequence and the resultant score is called the asset criticality score.

The procedure is to identify key performance areas for the organisation and develop a 'weighted decision matrix' based on the value the organisation puts on one performance area compared to another. An example is shown in the table (Figure 2) and graph (Figure 3) below.

For this particular project the Client already had a corporate risk package listing six performance areas and five consequence levels and giving descriptions for these (refer to Figure 2). It was appropriate to use these for the asset assessment. This ensured consistency between the asset assessment and the Organisations' view of risk.

The performance areas from the corporate risk package were;

- Health and Safety
- Image / Reputation
- Environmental
- Financial Impact
- Governance
- Extent of Impact (number of people affected)

Figure 2: Corporate Risk Matrix

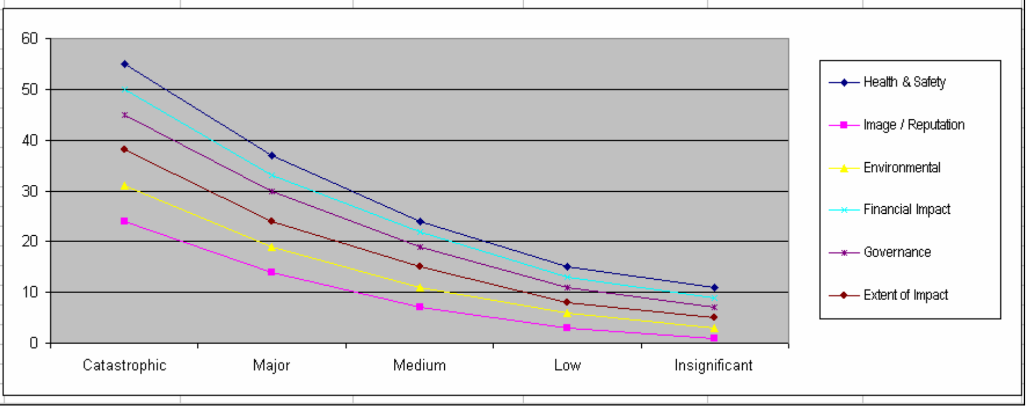
Asset Group	Asset Group Name			CRITICALITY		
Level	**Descriptor**	**Consequence Types**				
		Health & Safety	**Image / Reputation**	**Environmental**	**Financial Impact**	**Governance**	**Extent of Impact**
V	Catastrophic	Mutiple fatalities. Serious injury/illness requiring hospitalisation and ongoing treatment.	CMC, State Government and EPA involvement (State Govt Inquiry).	Significant environmental impact with long term effects.	>$150k. Significant long term impact. Organisation operation change required.	Significant number of public queries. Planned media releases and other media coverage. Initiate part BCP recovery plan	Prolonged disruption (>48hrs) to major facility or large area
IV	Major	Single fatality. Serious injury/illness requiring hospitalisation and some ongoing treatment.	CMC, State Government and EPA involvement (EPA prosecution, Qnsland Health Action).	Medium to long term environmental damage requiring immediate intervention.	$100k to $150k. Long term financial impact.	Planned response to public. ELG and Council updated. Management intervention required. Full report to Council.	Temporary disruption to large area (30% of network) OR prolonged (>48hrs) disruption to smaller area.
III	Medium	Moderate injury or outbreak of illness. No hospitalisation and no long term effects.	State Government and EPA advised (Breach of License, EMO, QLD Health involvement).	Minor environmental damage, short term effect.	$50k. Some financial redirection required, medium impact.	Public concern dealt with as queries arrive. Report required to Council although matter handled during normal business operation.	Extended loss of service (>24hrs)
II	Low	Minor injury or a few isolated cases of illness. Medical attention required but no long term effects.	EPA advised, matter handled internally (no EMO issued)	Matter handled as part of normal business operation. Minor recoverable, ecological impact.	$10k. Low financial impact. Absorbed in normal business operation.	Required to address minor public concern. Incident can be handled within normal business.	Loss of service for a period of 8 to 24 hrs
I	Insignificant	Potential injury or illness. No medical attention required.	EPA advised, matter handled internally.	Matter handled as part of normal business operation. Negligible ecological impact	< $5k. Insignificant financial impact. Absorbed in normal business operation.	Incident can be handled within normal business.	Loss of service <8hrs
CRITICALITY SCORE							
Comments							

Having established the types of consequence and described the levels of consequence, a weighted score was assigned to each option on the matrix (refer to Figure 3).

The client chose to consider relative importance at a category level i.e. they determined that overall health and safety had priority over financial impacts and that for their organisation, damage to image and reputation was considered least important. The graph below illustrates the resultant scores for this approach.

Figure 3: Weighted Scores for Corporate Risk Matrix 1

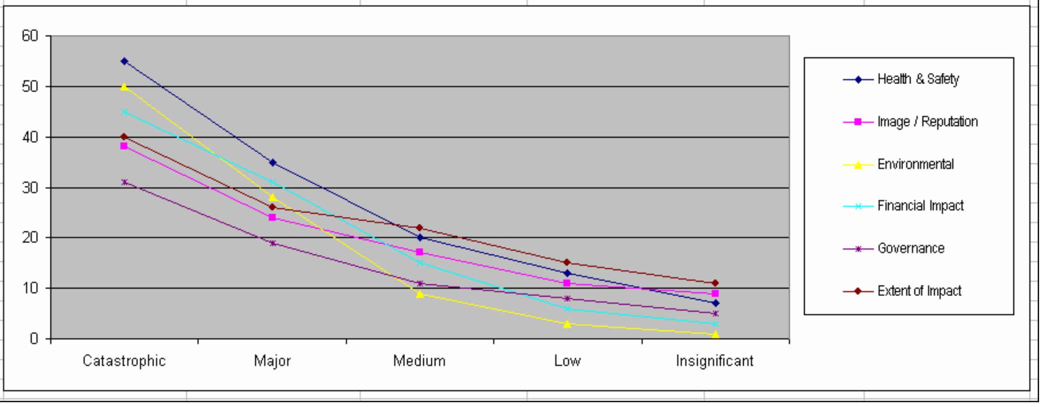
		Scores Allocation for Criticality Assessment					
Level	**Descriptor**	**Health & Safety**	**Image / Reputation**	**Environmental**	**Financial Impact**	**Governance**	**Extent of Impact**
		('Loss of Life' and 'Injury/Illness')			(Recovery Costs not renewal cost)		
V	Catastrophic	55	24	31	50	45	38
IV	Major	37	14	19	33	30	24
III	Medium	24	7	11	22	19	15
II	Low	15	3	6	13	11	8
I	Insignificant	11	1	3	9	7	5
Order of Importance Set		A	F	E	B	C	D



Different organisations may have other values, performance areas and criteria. They may score their matrix differently. For example, using the same consequence types as the example above (Figure 2 & 3), another organisation may consider the order of importance for these separately at each level. This may result in health and safety being the most important consequence at a catastrophic level while at medium level the extent of impact or number of people affected, may be the most important issue for the organisation. The graph below (Figure 4) illustrates this approach with lines of importance crossing one another.

Figure 4: Weighted Scores for Corporate Risk Matrix 2

		Scores Allocation for Criticality Assessment					
Level	Descriptor	Health & Safety	Image / Reputation	Environmental	Financial Impact	Governance	Extent of Impact
		('Loss of Life' and 'Injury/Illness')			(Recovery Costs not renewal cost)		
V	Catastrophic	55	38	50	45	31	40
IV	Major	35	24	28	31	19	26
III	Medium	20	17	9	15	11	22
II	Low	13	11	3	6	8	15
I	Insignificant	7	9	1	3	5	11
Order of Importance varies							



The second approach is more detailed than the Client's choice for the project in example 1. However, as the outcome for asset assessment is focused on comparison of scores and not the actual score values, both of these approaches are equally valid.

It is largely a matter of preference for an organisation as to the detail of the weighted decision matrix they use.

Similarly, the consequence types used for asset assessment should be relevant and particular to each organisation. For a Local Authority for example, these should to be linked to their Community Outcomes. This link is achieved through the Community Outcomes being the basis for the Corporate Objectives which are in turn the basis for the Corporate Risk Matrix (Figure 2). The Corporate Risk Matrix is the starting point for the process and a key input to the risk based assessments scores that will be used to prioritise assets and decide on appropriate management strategies.

2.3.2 GROUPING ASSETS

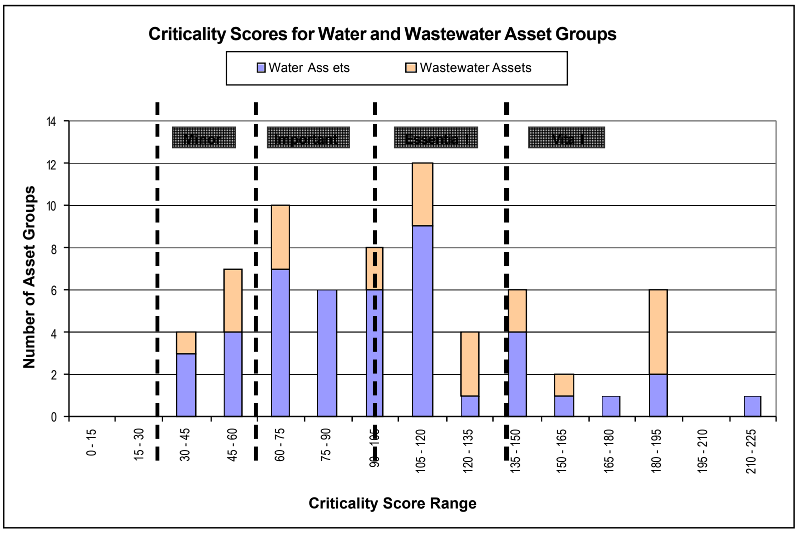
When undertaking asset assessments using a Corporate Risk Matrix (Figure 2), it is common to group similar assets together depending on how big the asset data set is and what requirements the decision-makers may have.

When grouping assets, consider the type of decisions that the assessment data will be used for. This will provide guidance on how broad or how specific the asset groupings should be.

An example of groupings used in one project, for comparing sewer and water assets, is given in the Table and Graph in Figure 5 below. The table also includes the weighted assessment score for each asset group and a descriptive term for the criticality (level of importance) of that group to the success of the organisation.

In this project the Client specifically wanted to know if bulk water pump stations were more or less critical than subsidiary wastewater treatment plants; whether money should first go to work on protecting or replacing trunk water mains or trunk sewers and similar questions.

Figure 5: Asset Group Lists and Criticality Scores



Asset Group Name	Score	Criticality
Main Dams	223	VITAL
Primary WWTPs	192	VITAL
Major WTPs	186	VITAL
Bulk Submarine Water Main	168	VITAL
Sensitive - Large Pump Stations	154	ESSENTIAL
Trunk Submarine Water Mains	145	ESSENTIAL
Trunk Gravity Sewer Mains	145	ESSENTIAL
Trunk Pressure Sewer Mains	145	ESSENTIAL
Bulk Ground Water Production Bores	141	ESSENTIAL
Bulk Reservoirs	135	ESSENTIAL
Bulk Transfer Mains	135	ESSENTIAL
Sensitive - Medium Pump Stations	134	ESSENTIAL
Submarine Trunk Pressure Sewer Mains	134	ESSENTIAL
Subsidary WWTPs	118	ESSENTIAL
Trunk Water Mains	117	ESSENTIAL
Subsidary WTPs	114	IMPORTANT
Bulk Water Pump Stations	114	IMPORTANT
PRVs on Bulk Water Mains	109	IMPORTANT
Valves on Bulk Water Mains	109	IMPORTANT
Valves on Water Reticulation	109	IMPORTANT
PRVs on Trunk Water Mains	109	IMPORTANT
Valves on Trunk Water Mains	109	IMPORTANT
Non-sensitive - Large Pump Stations	109	IMPORTANT
Trunk Reservoirs	103	IMPORTANT
Sensitive - Small Pump Stations	93	IMPORTANT
Non-sensitive - Medium Pump Stations	93	IMPORTANT
Trunk Booster Pump Stations	90	IMPORTANT
Hydrant on Water Reticulation	84	IMPORTANT
Hydrant on Trunk Water Mains	84	IMPORTANT
Reticulation Reservoirs	70	MINOR
MHs on Trunk Transfer Sewer Mains	69	MINOR
Effluent Main	69	MINOR
Reticulation Pump Stations	67	MINOR
Reticulation GW Production Bores	63	MINOR
Connectors on Bulk Water Mains	63	MINOR
Non-sensitive - Small Pump Stations	63	MINOR
Reticulation Water Mains	53	MINOR
Retic Pressure Sewer Mains	50	MINOR
Water House Connections	46	MINOR
Retic Gravity Sewer Mains	46	MINOR
MHs on Retic Sewer Mains	45	MINOR
Connectors on Trunk Water Mains	44	MINOR
Sewer House Connections	40	MINOR
Connectors on Water Reticulation	36	MINOR

All of the asset groups in this project were evaluated against the same Corporate Risk Matrix (Figure 2), so the scores are comparable regardless of whether they are water assets or sewer assets.

2.3.3 CROSS ASSET COMPARISON

The relative importance to the organisation of one asset group versus another is an important input for decision-making. It is not the only input and it does not account for risk at this stage, but it is none-the-less a useful comparative measure particularly at political and corporate level.

Although the Phase 1 Criticality Assessments shown in Figure 5 above were for a project comparing sewer and water assets, the same assessment process could equally have included roading, parks, property, stormwater and any of a number of other asset types.

2.3.4 PHASE 1 OUTCOME

In completing Phase 1, the organisation has a list of comparable scores that define how important various groups of assets are to achieving their corporate objectives.

2.4 PHASE 2

2.4.1 ASSET MANAGEMENT LEVEL ASSESSMENT

The second phase assesses the likelihood of failure and combines this with the criticality score (refer phase 1), to derive a risk-based priority score for each asset. In addition, any current mitigation measures that reduce the likelihood of failure or the consequence of failure are identified. The risk-based priority score for the assets is then adjusted according to the impact of these mitigation measures.

The output of phase 2 is a score representing the current risk level of each asset. This is used by the Asset Manager to;

- evaluate mitigation measures

- prioritise asset renewal programs

2.4.2 LIKELIHOOD OF FAILURE

There are many options for assessing likelihood of failure. It is expected that most organisations will already have some form of process for determining the expected fail year of every asset. This may be a simple assessment based on current age versus design life, or it may be a more advanced assessment. An advanced assessment would include;

- service conditions,
- utilization,
- performance,
- physical condition and
- ground conditions for buried assets or
- environmental exposure for above ground assets, as well as
- current age versus design life.

What ever the process, a relationship can be built between expected fail year and a score representing probability of failure. Mathematical models are available for this or a customized graph or model can be produced from analysis of actual failure rate data.

2.4.3 CRITICALITY SCORES FOR INDIVIDUAL ASSETS

At Asset Management level it is necessary to know the appropriate criticality score for each individual asset so that values can be recorded in the asset inventory against each component and used in management decisions about that component.

If at the corporate level assessment, assets were grouped and a single criticality score calculated to apply to the whole group, then individual criticality scores will need to be determined.

The process for generating individual criticality scores can be simplistic or advanced. In a simple process, all assets in a group will be assigned the group score as their individual score. In an advanced assessment, factors relevant to the asset type will be used to modify the group criticality score for an individual score.

Two examples of an advanced process are given below;

Example A: Assets at a Facility.

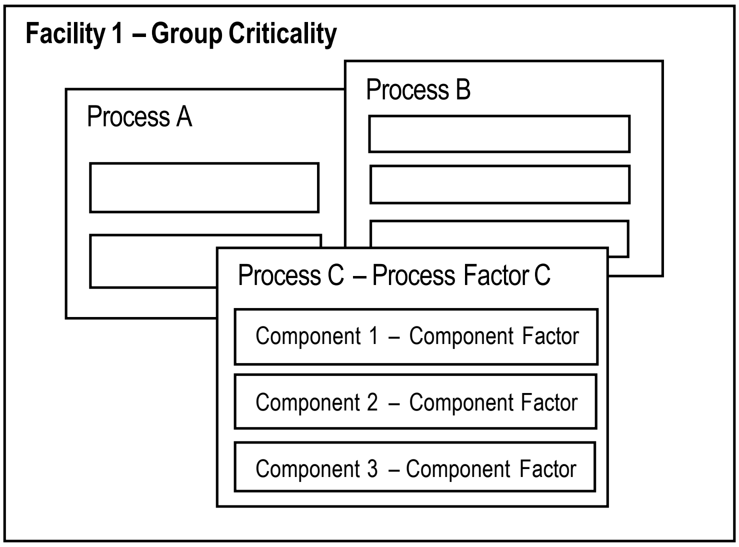
A group criticality score was determined for the entire facility (using the Corporate Risk Matrix in Figure 2). However some assets within the site are more or less critical than others. A failed intake line in a bank of four will not cause the entire plant to fail but is more critical than a failed wash hand basin in the plant rest rooms.

The assets at the site are therefore sorted into sub-groups relating to process areas. A factor is applied to represent how important each process area is to the successful functioning of the facility (process factor). Then each individual asset is rated for how important it is to that process area (component factor). These two factors are combined to generate the individual asset criticality score (component criticality).

Group Criticality Score x Process Factor x Component Factor = Component Criticality

A diagram illustrating the grouping and sub grouping of assets at facility sites is shown in Figure 6 below.

Figure 6: Component Grouping – Facility Sites



The following Tables (Figure 7 & 8) are an extract from a project that included assessment of components in a Wastewater Treatment Plant facility. The process areas at the facility included Inlet works Anaerobic/Aerobic Primary Treatment Tanks, Secondary Clarifiers as well as Disinfection, Pumping, Sludge Handling, Control and Civil and Site Works. These process areas were ranked on a 1 to 5 scale for how important they were to the facility delivering the required service. This rank determined the Process Factor to use in the above equation. Similarly, the components within each process area were also ranked on a 1 to 5 scale for how important they were to the process area. That rank determined the Component Factor for use in the above equation.

Figure 8 shows the factor tables used. The values in these tables are specific to this project and dataset. The exact same values will not necessarily be applicable to a different dataset. This is because the parameters will vary i.e. range of process and component types and how they relate to the overall system.

Figure 7: Component Criticality – Facility Sites

Process Area	Process Component	Process Factor	Process Score	Component Factor	Component Score
WWTP	WWTP				132.00
Inlet Works	Inlet Works	4	135.96		
Inlet Works	INLET WORKS - INLET FLOW METER	4	135.96	2	135.82
Inlet Works	INLET WORKS - STRUCTURE	4	135.96	5	136.64
Inlet Works	INLET FLOW SPLITTER BOX	4	135.96	3	135.96
Inlet Works	INLET STEP SCREEN UNIT (SC001)	4	135.96	4	136.37
Inlet Works	INLET WORKS - KNIFE EDGE VALVE	4	135.96	3	135.96
Anoxic/Aerobic Tanks	Anoxic/Aerobic Tanks	5	138.60		
Anoxic/Aerobic Tanks	ANOXIC TANKS	5	138.60	5	139.29
Anoxic/Aerobic Tanks	AEROBIC TANKS	5	138.60	5	139.29
Anoxic/Aerobic Tanks	AERATION BLOWER *2	5	138.60	4	139.02
Anoxic/Aerobic Tanks	DIFFUSED AIR AERATION SYSTEM	5	138.60	4	139.02
Anoxic/Aerobic Tanks	AERATION BLOWER - CONTROL BOX *2	5	138.60	3	138.60
Anoxic/Aerobic Tanks	ANAEROBIC MIXER *2	5	138.60	3	138.60
Anoxic/Aerobic Tanks	ANOXIC MIXER *4	5	138.60	3	138.60
Anoxic/Aerobic Tanks	PRE-ANOXIC MIXER *2	5	138.60	3	138.60
Secondary Clarification	Secondary Clarification	4	135.96		
Secondary Clarificaton	SECONDARY CLARIFIER - Structure*2	4	135.96	5	136.64
Secondary Clarificaton	SECONDARY CLARIFIER 1 BRIDGE - STRUCTURE	4	135.96	3	135.96
Secondary Clarificaton	SCUM SCRAPER ASSEMBLY	4	135.96	2	135.82

Figure 8: Ranking Table for Facility Components

Rank	ProcessFactor	Component Factor	Significance
5	1.05	1.005	Crucial
4	1.03	1.003	Important
3	1.00	1.000	Required
2	0.90	0.999	Value Adding
1	0.50	0.995	Unnecessary
Rank is a measure indicating importance to service/delivery			

Example B: Buried Pipeline Assets.

The individual pipeline sections within a group of pipes such as Reticulation Pipes or Trunk Mains may vary in size and location. The size of a pipeline is an indicator of the number of people who would be affected if it failed. The location of a pipeline with respect to such things as land use type, proximity to schools, hospitals or parks, proximity to waterways (relevant to sewage spills), is an indicator of how much disruption and damage might be caused by a failure. These considerations determine the factors for service impact and location sensitivity and are used to generate an individual criticality score (component criticality) from the group criticality score as follows;

Group Criticality Score x Service Impact x Location Sensitivity = Component Criticality

The following Tables (Figure 9 & 10) are an extract from a project showing the assessment for a group of Sewer Trunk Pressure Mains. The factor for service impact is derived from the pipe diameter and the factor for location sensitivity is determined by both the proximity of the pipeline to waterways and the land use category for the pipeline site.

Figure 9: Component Criticality – Pipeline Assets

ID	Length	Diameter	Material	Service Impact	Landuse	Distnce to Waterways	Location Sensitivity	Component Criticality	Status
Trunk Pressure Mains (Waste)								145	Medium
56657	7.5	450	DICL	1.03	Rural	2.07	0.05	156.96	High
56658	9.05	450	DICL	1.03	Rural	0.00	0.03	152.98	High
56663	0.52	450	DICL	1.03	Rural	3.92	0.05	156.96	High
56651	2.17	450	DICL	1.03	Rural	26.40	0.05	156.82	High
56652	280.1	450	DICL	1.03	Rural	26.40	0.05	156.82	High
56653	252.75	450	DICL	1.03	Urban	0.00	0.05	156.60	High
56654	187.84	450	DICL	1.03	Rural	3.92	0.05	156.96	High
56660	230.25	375	DICL	1.01	Rural	17.85	0.05	154.06	High
56661	0.34	375	DICL	1.01	Urban	239.98	0.09	159.50	High
56662	486.2	375	DICL	1.01	Rural	163.89	0.05	152.98	High
56645	246.5	375	uPVC	1.01	Rural	122.93	0.05	152.98	High
56646	496.3	300	uPVC	1.00	HDU	1.19	0.11	160.68	Critical
56664	457.5	375	uPVC	1.01	HDU	148.08	0.09	159.89	High
56665	34.5	525	DICL	1.06	CBD	483.21	0.05	161.31	Critical
52206	230.9	100	uPVC	0.85	Rural	65.00	0.05	130.50	Low
52207	161.61	100	uPVC	0.85	HDU	104.52	0.09	136.69	Low
52209	34.86	100	uPVC	0.85	HDU	172.38	0.09	136.69	Low
52214	13.3	150	uPVC	0.90	Urban	49.04	0.10	145.44	Medium
52215	4.1	150	uPVC	0.90	Urban	47.76	0.10	145.44	Medium
52216	2.25	375	AC	1.01	Rural	47.76	0.05	153.92	High
52217	12.48	300	AC	1.00	Rural	40.77	0.05	152.47	High
52224	554.11	600	AC	1.08	Urban	19.50	0.11	171.83	Critical

52225	11.92	150	AC	0.90	Rural	19.50	0.05	138.11	Low

Figure 10: Lookup Tables for Factors for Pipeline Asset Criticality

Pipe Size	Factor
750	1.10
691	1.09
600	1.08
525	1.06
500	1.05
450	1.03
375	1.01
300	1.00
250	0.98
225	0.95
200	0.94
150	0.90
100	0.85

Landuse	Factor
CBD	1.05
HDU	1.03
Urban	1.00
Islands	0.90
Rural	0.50

Waterway	Factor
Within 25m	1.05
Within 50m	1.03
Within 100m	1.00
Within 250m	0.90
> 250m	0.50

Figure 10 shows the factor tables used for this project. The values in these tables are specific to that project and relevant to that dataset. The exact same values will not necessarily be applicable to a different dataset. This is because the parameters will vary i.e. range of pipe diameters and land use categories may be different and there may be other considerations for sensitivity besides proximity to waterways.

For this project and dataset, the combined landuse and waterway factors were divided by 10 to moderate the Location Sensitivity value as the product of two factors from dominating the Impact value as a product of only one factor.

Landuse Factor x Waterway Factor x 0.10 = Location Sensitivity

2.4.4 RISK-BASED PRIORITY

The first risk-based priority score in phase 2 is an assessment of potential risk and it is calculated from the consequence (component criticality score refer 2.4.3) multiplied by the probability (likelihood of failure refer 2.4.2) for each asset.

Consequence (criticality score) x Probability (likelihood of failure score) = Potential Risk

It is called potential risk at this point because many assets will have mitigation measures like standby pumps or preventative maintenance programs that will moderate either the consequence of failure or the likelihood of failure. After mitigation measures are assessed (refer 2.4.5) it is possible to determine the current risk score from the following calculation;

Potential Risk x Mitigation Score (percentage risk reduction) = Current Risk

2.4.5 POTENTIAL RISK

The potential risk score provides guidance for the organisation to focus on potential high risk areas to;

- ensure that adequate mitigation measures are in place or
- identify where additional measures are required
- prioritise capital works for mitigation measures.

Figure 11 is an extract from a particular project. It provides an example of output scores for potential risk of a number of asset components. Note the component types in the table include both pipelines and facility equipment and both sewer and water assets. This illustrates that the asset component scores for potential risk using this process are comparable across different asset groups and asset types.

Figure 11: Potential Risk Scores for Asset Components

ID	Component Name	Ph 1 Asset Group Name	Group Criticality Score	Asset Criticality Score	Failure Factor	Potential Risk Score	Potential Risk Status
15752	Trunk GRAVITY	Trunk Gravity Sewer Mains	145	165.61	0.87	144.17	Medium-Low
15753	Trunk GRAVITY	Trunk Gravity Sewer Mains	145	165.61	0.87	144.17	Medium-Low
29399	Trunk GRAVITY	Trunk Gravity Sewer Mains	145	166.28	0.93	154.80	Medium
29401	Trunk GRAVITY	Trunk Gravity Sewer Mains	145	166.28	0.93	154.80	Medium
222783	Trunk GRAVITY	Trunk Gravity Sewer Mains	145	166.78	0.90	149.85	Medium-Low
56653	Trunk Sewer Pressure	Trunk Pressure Sewer Mains	145	167.36	0.87	144.93	Medium-Low
56646	Trunk Sewer Pressure	Trunk Pressure Sewer Mains	145	166.61	0.91	151.03	Medium
56664	Trunk Sewer Pressure	Trunk Pressure Sewer Mains	145	168.60	0.91	153.42	Medium
4126	Bulk Mains (Water)	Bulk Transfer Water Mains	135	165.47	0.94	155.62	Medium
4235	Bulk Mains (Water)	Bulk Transfer Water Mains	135	165.47	0.94	155.62	Medium
12208	Bulk Mains (Water)	Bulk Transfer Water Mains	135	165.47	0.87	143.30	Medium-Low
216507	Bulk Mains (Water)	Bulk Transfer Water Mains	135	170.10	0.81	137.02	Medium-Low
216508	Bulk Mains (Water)	Bulk Transfer Water Mains	135	170.10	0.89	151.47	Medium
213716	PS 33 - PUMP 1	Sensitive - Large Pump Stns	154	165.67	1.15	190.53	Medium-High
213953	PS 29 - GENERATOR	Sensitive - Large Pump Stns	154	165.34	1.00	165.43	Medium
213713	PS 67 - PUMP 2	Sensitive - Large Pump Stns	154	177.28	1.15	203.87	High
53827	PS 67 - AIR COMPRESSOR	Sensitive - Large Pump Stns	154	176.40	1.09	192.28	Medium-High
53826	PS 67 - ODOUR CONTROL	Sensitive - Large Pump Stns	154	176.40	1.15	202.86	High
53184	PS 67 - SCADA SWITCHBOARD	Sensitive - Large Pump Stns	154	173.04	1.15	199.00	Medium-High
12924	CONTROL WELL	Main Dam	223	234.85	0.96	225.58	Very High
12979	CONTROL BLDG STRUCTURE	Main Dam	223	234.15	0.96	224.90	High
12772	INTAKE TOWER STRUCTURE	Main Dam	223	230.38	1.00	230.03	Very High
13075	INTAKE FILTER - SCREEN 1	Main Dam	223	229.46	1.00	228.43	Very High
12874	CONTROL FACILITY	Large WTP	186	191.81	1.06	203.32	High

2.4.6 MITIGATION MEASURES

The next step is the assessment of the impact of any current mitigation measures.

Depending on the size and structure of the organisation, this assessment could be included in either Phase 2 Asset Management Level Assessments or Phase 3 Asset Operation Level. The process determines a rate (expressed as a percent risk reduction) for each mitigation measure changes the organisational risk of each asset.

Mitigation measures change organisational risk by reducing the likelihood of failure or moderating the consequence of failure.

The assessment process includes the following key steps;

- List each type of mitigation factor used or intended to be used
- Consider in percentage terms how much each mitigation factor reduces the organisational risk

- Record in the asset inventory the mitigation factors that are currently in use for each asset
- Calculate the current risk

Potential Risk x Mitigation Score (percentage risk reduction) = Current Risk

The current risk value of an asset is vitally important to Asset Management. This knowledge is used to;

- Assess the adequacy of current mitigation measures
- Provide justification for Capex funding for additional mitigation measures
- Prioritise mitigation options
- Optimise existing mitigation measures
- Identify unnecessary mitigation measures already in place and support the removal or modification of these measures to optimise the risk profile
- Support a renewal program prioritised on risk rather than simply the expected fail year

Figure 12 is part of a table of mitigation factors used for a particular project;

Figure 12: Mitigation Measures

Description of Generic Mitigation Measures	% Risk Reduction
Standby equipment provision - e.g. standby pumps,	40
Standby/alternate service route - e.g. loop based water supply	35
6 Monthly Preventative Maintenance program	30
Provision of emergency storage	30
Additional operating capacity available	25
Administration measures - use of Quality control procedures to operate facilities	20
Installation of electrical power surge protection	20
Process automation	15
Use of appropriate sensor indicators that may eliminate failures	15
Self-cleaning systems in place	10
Availability of operations and maintenance manual on-site	5

2.5 PHASE 3

2.5.1 ASSET OPERATION LEVEL ASSESSMENT

The third phase measures the value of mitigation and uses this data along with the current and potential risk scores to develop and optimise maintenance strategies.

2.5.2 MITIGATION VALUE

The value of mitigation is the difference between the potential risk score and the current risk score, of any asset. It is a measure of how important the current mitigation measure(s) are in reducing the risk to the organisation of that particular asset failing.

Potential Risk - Current Risk = Value of Mitigation

This is important to know for Operational Strategies and Contingency Planning.

For example, consider a pump station that has a duty and standby pump. If only the current risk value of an asset is recorded, a decision may be made to remove one of the pumps for servicing without understanding the change in risk that will occur. If both current and potential risk are recorded and both assets are indicated as being a mitigation measure for the other asset, then the consequence of taking one of them out of service will be understood and can be managed appropriately.

Recording mitigation measures and value of mitigation against individual asset components ensures that the relationships and dependencies between assets are more visible. Operational Strategies can be planned and contingencies can be written up in site manuals. The performance of the organisation becomes less reliant on historical knowledge passed down from operator to operator and asset management can be more pro-active.

The higher the mitigation value of an asset, the greater the attention an operations manager must give to scheduling any work on that asset and ensuring adequate contingency in adverse events.

2.5.3 OPTIMISING MAINTENANCE STRATEGIES

In many organisations, the optimisation of maintenance strategies has been based solely on minimizing costs. The optimising rationale used to cut costs has more often been based on asset size rather than asset risk or asset criticality.

True optimization requires consideration of risk and sustainability.

As an example, one organisation undertook a review of their pump vibration test program. Every two years they had every pump tested. However when they looked at the risk data for each of their pumps, many pumps were already low risk or their risk score would not change significantly with vibration testing. They were able to justify a reduction in their testing program, save costs and be confident that this would not increase their risk.

In another scenario, the decision to reduce pump station attendance considered only the size of the pump station. The importance of the site from an organisational perspective was not assessed. No check was made on whether this action would change the risk ranking for that site. As a result one small pump station had a fault that was not picked up and resulted in a sewage spill near a school and waterway. Using risk data, this site would have been identified as needing mitigation. Such mitigation could have been more frequent attendance or it could have been more controls and alarms on site. Either option would have prevented the event.

The purpose of assessing and recording risk data for operational management and planning is not to specify what mitigation measure should be implemented, but to;

- Identify the level of risk that exists
- Assess what the change in risk will be for different mitigation options
- Provide guidance to set appropriate levels of monitoring for condition and performance
- Select maintenance strategies that are appropriate to an assets risk score
- Understand which assets and events need contingency planning

2.6 IMPLEMENTATION

2.6.1 SHARING KNOWLEDGE

For the process to be effective, the data outputs must be readily available to all decision-makers. Ideally the information should be recorded in both the asset inventory and on GIS if the organisation uses a system to graphically display assets.

Everyone who makes decisions about assets should have access to the following values;

- Criticality Score (how important is this asset to achieving the organisations goals)
- Failure probability (how likely or unlikely is it that this asset will fail in the near future)
- Potential Risk (if there were no mitigation measures how vulnerable would this asset be)
- Mitigation Measures (what protection do we have in place for this asset)
- Mitigation Score (what effect does current mitigation have on reducing risk)
- Current Risk (what is the current risk value of this asset)
- Mitigation Value (how essential is it that we maintain the current mitigation measures)

Not all values will be relevant to all decisions. Sometimes the decision-maker will only be interested in current risk and other times in failure probability. An Operations Manager would be particularly interested in current risk and mitigation value. The important point is to have access to all parameters so the most appropriate information can be considered to make decisions that will have the best result for the organisation.

2.6.2 FOLLOWING THROUGH

The process described in this paper cannot be a black box type of tool because every organisation is different. Client input to the Corporate Risk matrix (refer Phase 1) is essential to the evaluation. For Local Authorities, the risk tolerance of the Council should reflect that of its Community and this will vary with size, location and local issues. Client data regarding expected fail year and current mitigation measures is also essential to the process. If these are not known they will need to be established and recorded as part of the assessment.

Once complete the information must be maintained. As circumstances change and assets are replaced or mitigation measures altered, the assessment values and risk score must be updated.

With the information from this process readily available to both Asset Managers and Operation Managers, trigger points for when assets should be replaced rather than repaired can be agreed and implemented. Similarly, until such time as asset replacement is appropriate, the Operations Manager can use the same risk values to develop appropriate maintenance strategies. Establishing trigger points for operations, maintenance and renewals that all have a relation to asset risk and criticality is sound business practice.

2.6.3 KEY ELEMENTS

The key elements to achieve synergy in an organisation in regard to asset management decisions are;

- Connect the organisation goals (community outcomes) to asset priority
- Share information about the assets to all decision-makers
- Determine a risk value for every asset and maintain this data to keep it current
- Use the asset risk score as the primary basis for decision-making at all levels

These key elements apply regardless of whether you use the process described in this paper or develop a variation based on a prioritizing process already in use in your organisation.

3 CONCLUSIONS

This paper outlines a single risk assessment process that has been applied to an organisation to achieve consistency for decision-making in all departments and levels of that organisation.

A key benefit to implementing such a process is the widespread sharing of asset knowledge.

Asset knowledge is essential to robust and effective management, planning and decision-making.

Asset knowledge differs from asset data in that knowledge comes from understanding such things as;

- how critical an asset is to the aims and obligations of an organisation
- what an asset's potential and current risk values are
- what mitigation measures are in place for an asset
- how do these mitigation measures change an assets risk profile

Without such knowledge at an operational level, attempts to optimise costs could increase risk and attempts to minimize risk with mitigation measures could be wasting money.

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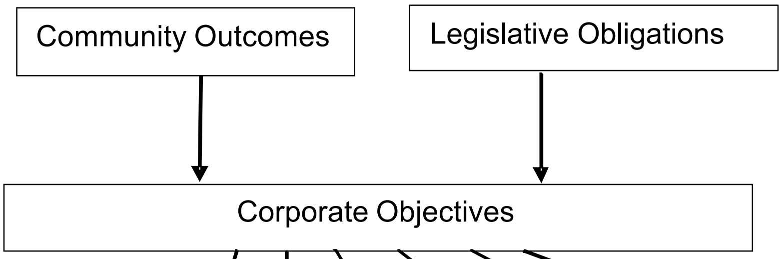
APPENDIX

PROCESS EXAMPLE

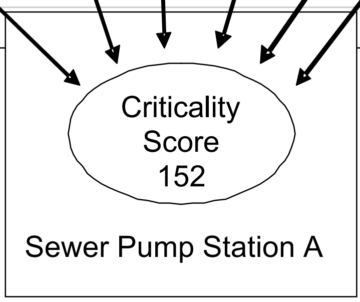
The following example illustrates the use of the process linking through from Corporate Objectives to Maintenance Strategies. In this example we consider a Sewer Pump Station A equipped with 2 pumps of which Pump No.1 has recently been renewed.

PHASE 1

Calculate Corporate level criticality score. This is done for a group of assets such as sewer pump stations.



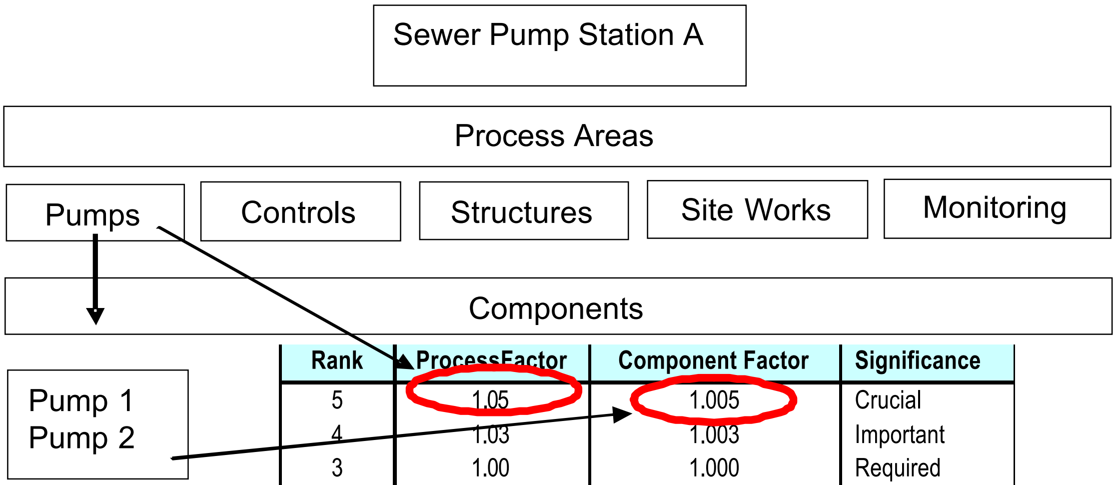
Asset Group	Asset Group Name			CRITICALITY		
Level	Descriptor	Consequence Types				
		Health & Safety	Image / Reputation	Environmental	Financial Impact	Governance	Extent of Impact
V	Catastrophic	Mutiple fatalities. Serious injury/illness requiring hospitalisation and ongoing treatment.	CMC, State Government and EPA involvement (State Govt Inquiry).	Significant environmental impact with long term effects.	>$150k. Significant long term impact. Organisation operation change required.	Significant number of public queries. Planned media releases and other media coverage. Initiate part BCP recovery plan	Prolonged disruption (>48hrs) to major facility or large area
IV	Major	Single fatality. Serious injury/illness requiring hospitalisation and some ongoing treatment.	CMC, State Government and EPA involvement (EPA prosecution, Qnsland Health Action).	Medium to long term environmental damage requiring immediate intervention.	$100k to $150k. Long term financial impact.	Planned response to public. ELG and Council updated. Management intervention required. Full report to Council.	Temporary disruption to large area (30% of network) OR prolonged (>48hrs) disruption to smaller area.
III	Medium	Moderate injury or outbreak of illness. No hospitalisation and no long term effects.	State Government and EPA advised (Breach of License, EMO, QLD Health involvement).	Minor environmental damage, short term effect.	$50k. Some financial redirection required, medium impact.	Public concern dealt with as queries arrive. Report required to Council although matter handled during normal business operation.	Extended loss of service (>24hrs)
II	Low	Minor injury or a few isolated cases of illness. Medical attention required but no long term effects.	EPA advised, matter handled internally (no EMO issued)	Matter handled as part of normal business operation. Minor recoverable, ecological impact.	$10k. Low financial impact. Absorbed in normal business operation.	Required to address minor public concern. Incident can be handled within normal business.	Loss of service for a period of 8 to 24 hrs
I	Insignificant	Potential injury or illness. No medical attention required.	EPA advised, matter handled internally.	Matter handled as part of normal business operation. Negligible ecological impact	< $5k. Insignificant financial impact. Absorbed in normal business operation.	Incident can be handled within normal business.	Loss of service <8hrs
CRITICALITY SCORE							
Comments							



The Criticality Score for Pump Station is 152

PHASE 2

The next step is to calculate the criticality scores for individual assets and the potential risk of those assets. In this example, pumps would be a process area and the individual pump sets are components.



Rank	ProcessFactor	Component Factor	Significance
5	1.05	1.005	Crucial
4	1.03	1.003	Important
3	1.00	1.000	Required
2	0.90	0.999	Value Adding
1	0.50	0.995	Unnecessary

The Group Criticality Score of the pump station is adapted using a the process factor and component factor as illustrated below.

Criticality for Pump No.2 = 152 x (Process Factor) x (Component Factor)

= 152 x 1.05 x 1.005

= 160.40

Criticality for Pump No.1 = Pump No. 2 = 160.40

The criticality score for both pumps is the same as the same consequence will happen if either pump fails.

However, Pump No.1 was recently renewed therefore has a lower Failure Score. This will give Pump No.1 lower Risk Scores because it is significantly less likely to fail than the older Pump No.2.

Assuming the following failures scores:

- Pump No.1 Failure Score = 0.20
- Pump No.2 Failure Score = 0.94

The potential risk for each pump can now be calculated.

Potential Risk = Consequence (criticality score) x Probability (likelihood of failure score)

Therefore:

Pump No.1 Potential Risk = 160.40 x 0.20 = 32.08

Pump No.2 Potential Risk = 160.40 x 0.94 = 150.77

Once the Potential Risk has been established, the Current Risk is calculated taking account of existing mitigation measures. In this example the existing mitigation is the fact that the pumps act as standby for each other.

Pump 1
Pump 2

Description of Generic Mitigation Measures	% Risk Reduction
Standby equipment provision - e.g. stand by pumps,	40
Standby/alternate service route - e.g. loop based water supply	35
6 Monthly Preventative Maintenance program	30
Additional operating capacity available	25
Installation of electrical power surge protection	20
Process automation	15
Availability of operations and maintenance manual on-site	5

Current Risk = Potential Risk x Mitigation Score (percentage risk reduction)

Therefore:

- Pump No.1 Current Risk = 32.08 x 0.40 = 12.83
- Pump No.2 Current Risk = 150.77 x 0.40 = 60.31

PHASE 3

Next step is to calculate the value of mitigation

Value of Mitigation = Potential Risk - Current Risk

Therefore:

- Pump No.1 Mitigation Value = 32.08 - 12.83 = 19.25
- Pump No.2 Mitigation Value = 150.77 - 60.31 = 90.46

Note that Pump 2 is older and more likely to fail therefore has higher risk scores resulting in a higher score for mitigation value. This will alert the Operator that Pump 2 is more reliant on the backup of Pump 1 than vice versa.

Following the assessments made for Pump No.1 and Pump No.2 at Pump Station A, the values calculated can be used to consider management strategies.

Assessment	Pump 1	Pump 2	Management comment
Criticality Score	160.40	160.40	If either pump failed the consequence would be significant
Potential Risk Score	32.08	150.77	Pump 2 has a much higher risk of failure.
Current Risk Score	12.83	60.31	Although the potential risk is significantly mitigated, Pump 2 still needs monitoring whereas pump 1 is a low risk at this stage – this will change as the asset ages and failure score is updated over time.

Mitigation Score	0.40	0.40	It would also be noted against the assets that each is a mitigation factor for the other so the dependency of these assets on each other would be visible in the asset inventory
Mitigation Value	19.25	90.46	The fact that the mitigation value of Pump 2 is high demonstrates the influence of the mitigation in place and it is therefore important that mitigation for Pump 2 is maintained.

Maintenance strategies can now be developed to reduce the levels of risk and may include the following;

- Reduce the Potential Risk by influencing the probability of failure, for example by increasing maintenance activities and overhauls.
- Reduce the Current Risk of Pump 2 failure by increasing monitoring.
- The high Mitigation Value of Pump 2 must be accommodated in contingency planning prior to removing Pump 1.