USING CRITICALITY TO MANAGE STORMWATER ASSETS

P W Utting BE(Hons), MBA, MIPENZ, CPEng, IntPE, Member WaterNZ
Director : ProjectMax

ABSTRACT

A key tool for the asset management of stormwater pipes and facilities is the concept of Criticality which is closely linked to the Consequences of Failure.

High criticality assets have high consequences of failure and the management of such assets should be largely focused on avoiding failures through a range of pro-active monitoring, condition assessment, useful remaining life prediction and renewal processes. Contingency planning and risk reduction through measures such as duplication and may also be appropriate.

Conversely, low criticality assets have low consequences of failure and can largely be managed on a 'fix when fail' basis requiring relatively minimal management input.

Stormwater assets also need to be assessed in relation to their 'Likelihood of Failure' which largely reflects their life expectancy, and the extent of deterioration that has occurred. Assets that exhibit both high consequence, and high likelihood, of failure carry the highest risk of calamitous failure and should be the primary focus of stormwater asset managers.

Understanding which assets have an elevated criticality allows the organisation to focus resources on their care, condition monitoring and eventual renewal so that overall risk is managed to an acceptable level. Typically, there is a relatively small number of these high criticality assets and the process should be manageable.

This paper explores the concept of criticality for stormwater assets and its alignment with the typical corporate Risk Management Framework. It also outlines a robust approach for identifying which assets are critical and it illustrates the wide range of asset management approaches that should vary according to the criticality of the asset.

Also included is identification of a key difference between the stormwater service and water supply and wastewater services wherein assets in perfect condition can still be involved in calamitous failures if overwhelmed, i.e. differentiating between capacity failures and asset failures.

KEYWORDS

Asset Management, Criticality, Consequence of Failure, Likelihood of Failure

PRESENTER PROFILE

Paul Utting is a Director of ProjectMax, an engineering consultancy that operates across New Zealand and Australia and specialises in helping its clients to optimise their pipeline renewals. Paul has a career in engineering spanning almost 40 years, much of which has been in the local government water sector and has undertaken a number of senior management roles

1 INTRODUCTION

For the purposes of this discussion, 'criticality', is defined as a relative measure of the Consequences of Failure of a stormwater asset.

Assets with a High Criticality have significant consequences of failure and these can include death and injury, property damage, environmental damage, severe economic impacts and damage to other lifeline utilities such as roading, power etc. Assets with a Low Criticality can also fail but the consequences of failure are largely limited to minor disruption, easily repairable damage and inconvenience which would be considered to be within the acceptable 'Level of Service' for the asset. Between these two extremes lie a range of intermediate criticalities and their associated assets.

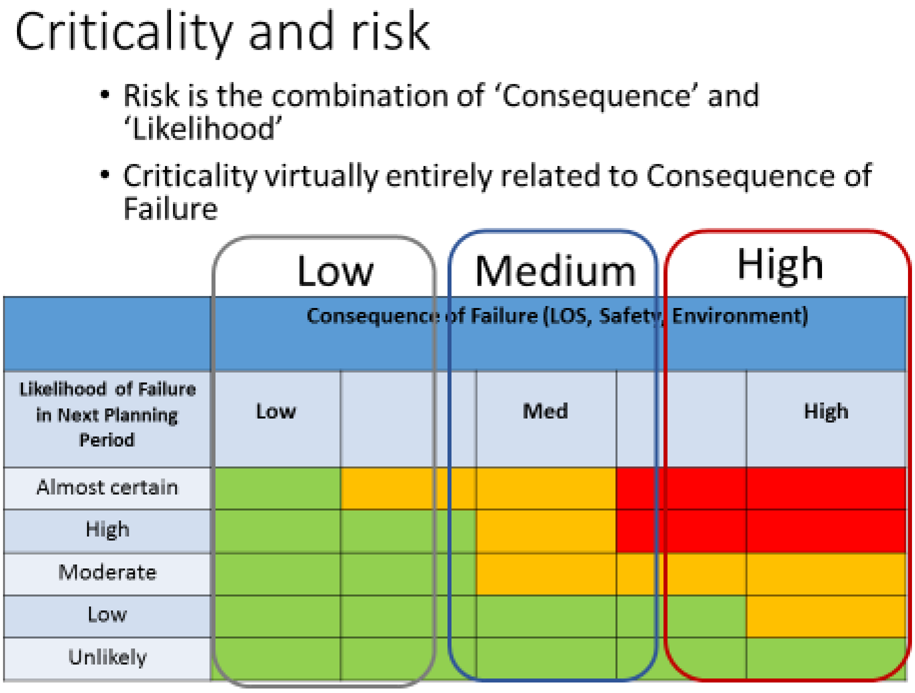
If the criticality of an asset can be defined and ranked in a consistent manner this provides the asset owner with a valuable insight into the nature of their assets and how they can be effectively managed. The ability to apply different approaches to managing assets with differing level of criticality is perhaps the greatest value to come out of understanding criticality.

2 CRITICALITY AND RISK

Criticality is a key component of the management of risk. Most councils in New Zealand have adopted the type of risk matrix illustrated in Figure 1. The horizontal axis reflects the Consequences of Failure ranging from Low/Insignificant to High/Catastrophic. For this paper this is considered to be synonymous with Criticality. The vertical axis reflects the likelihood of failure ranging from Unlikely/Extremely Rare to Almost Certain. Relative risk is the combination of the consequences of failure and the likelihood of failure. Every stormwater asset, at any given time, lies somewhere between '*Insignificant consequence that is very unlikely to occur in the foreseeable future*' to '*Catastrophic consequence that is almost certain to occur in the foreseeable future*'. The purpose of a Criticality Framework is to provide a consistent approach to identifying where each asset falls on this continuum.

The various combinations of consequence and likelihood are typically ranked from 'Acceptable' (Green) to 'Not Acceptable' (Red) and will have a range of asset management expectations associated with them. Typically, this will range from normal (day to day) operational management at the lower (green) end to specific high level management overview, and fast-tracking of remedial actions, at the top (red) end.

Figure 1 : Alignment of Criticality Groups with Risk Matrix

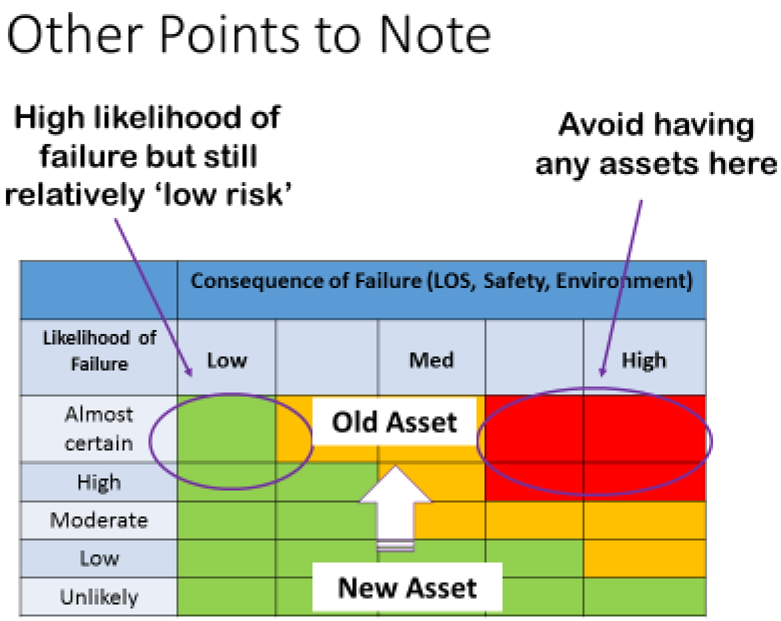


By definition assets with high consequences of failure, and hence high criticality lie at the right hand end of the matrix and can creep into the 'Not Acceptable' red zone if the Likelihood of Occurrence is too high.

A newly constructed stormwater asset will typically start life with a low likelihood of failure reflecting its 'as new' condition and this will apply irrespective of its Criticality. As it ages and deteriorates the likelihood of failure will gradually increase and the asset will gradually move up the matrix. This is illustrated in Figure 2. This is an important point as it illustrates that the risk associated with an asset is not static, but will vary over time to reflect its gradually deteriorating condition.

Other points to note in Figure 2 are that low criticality assets can still be low risk (and associated low profile management approach) even if the likelihood of failure is high i.e. the top left corner of the matrix. They fail and they are repaired. They fail too often and they are renewed – this should be a routine response maintenance and renewal capability for the asset owner. Figure 2 also illustrates that assets could end up in the top right of the matrix i.e high criticality and high likelihood of failure. Apart from illustrating that the asset management system has failed by allowing this situation to arise it should cause the asset owner to question why they would even have assets that could get to that situation. Consideration should be given to finding an alternative, lower risk, means of delivering the service, duplicating the asset, etc.

Figure 2 : Illustration of Movement of Assets Over Time



3 WHY STORMWATER IS DIFFERENT

Stormwater assets are somewhat different to water supply and wastewater assets. Water and wastewater are very linear systems and their ability to deliver the desired level of service to customers is largely dependent on an unbroken string of various types of assets from source to customer, or customer to discharge. When an asset fails it can cause service disruption and/or property and environmental damage but this tends to be somewhat contained to a localised service area and the effects can usually be limited by shutting off the discharge.

Stormwater assets are typically arranged in a 2 tier structure. First tier pipe assets provide for up to 5 year events (20% Annual Exceedance Probability – AEP) and a combination of streets, overland flow paths, detention ponds and natural rivers and streams form the 2nd tier, with typically a 100 year capacity (1% AEP).

In a storm event the first tier pipe assets quickly reach capacity and then the second tier assets take over as the primary flow-paths. The assets in each tier should perform without structural or functionality failure throughout the event even if the storm delivers flows that exceed the design capacity of the system and damage subsequently occurs to properties.

Within this concept it is apparent an asset designed to convey only the 5 year flow should have a relatively low criticality as the 2nd tier system should be able to easily accommodate the flow if that asset fails.

Obviously, pipes are engineered structures that have defined lives and measurable condition and deterioration. Constructed detention ponds and pump stations would also fall into this category. Any other drainage features that require engineering input to maintain the desired level of service can also usefully be included in the criticality analysis. This could include rivers and estuaries that require dredging, or willow clearance, on a periodic basis.

There may also be features that are an intrinsic part of the stormwater management system but are too large to contemplate undertaking periodic maintenance on and do not readily fit into a criticality framework. This might include major rivers, wetland systems, harbours, etc. However, it remains important to understand how changes in these features arising from gradual siltation, sea level rise, etc, might impact on the behavior of the constructed stormwater system, particularly in relation to discharge capacity. These changes might have more impact on the likelihood of failure than the criticality but would still increase the risk level over time.

Another difference of the stormwater system is the possibility of flows that significantly exceed the design capacity of the stormwater system. This could result in the overwhelming of the engineered primary and secondary systems, overtopping of floodbanks and dams, etc. This might create a failure mechanism for the constructed assets that should be considered. Alternatively, the asset may survive the flood event undamaged but significant damage could still arise from the overtopping and/or flooding. To my knowledge the Brisbane floods of 2011 was not caused by the failure of any critical engineered assets, including the Wivenhoe Dam, but the flood damage within Brisbane was considered to be relatively extreme. In this case it was the capacity of the system that was critical, not the condition of the assets.

This paper is focused on constructed / engineered stormwater assets and their criticality as determined by the consequences of their failure. The assessment of the potential impact of a flood event that exceeds the design standard is not addressed in this paper but should be considered by stormwater engineers.

4 BENEFITS OF A CRITICALITY FRAMEWORK

All assets are not created equal and the primary intent of the Criticality Framework is to define how they differ, with a particular emphasis on the consequences of failure, and then to identify the assets that fall into particular levels of criticality.

While a primary outcome of the process is to identify the assets that have an elevated criticality the process will also identify the vast majority of assets that are not considered to be critical.

The non-critical assets will still have failures, and minor disruption and/or damage might arise. These failures will be responded to with standard maintenance procedures and within the Levels of Service expectations that have been identified by the asset owner. Any damage occurring will similarly be responded to within standard policies and procedures. This standardisation, and minimisation, of input requirements from the asset owner is a desirable state and the ongoing opportunity to minimise the criticality of any asset should always be considered.

The framework will create a consistent mechanism for assessing criticality that reflects the values and aspirations of the asset owner and the community. While there will be common themes evident across the country, there will also be differences, and it is important that the framework is consistent with corporate values.

The framework will also provide a consistent basis for assessing risk across the stormwater activity and using this to manage the assets.

A particularly important benefit of developing the framework is identifying all the management practices that should include consideration of criticality. This will also identify that a range of staff, and contractors, have an interest in this matter and the discussions required to create and utilise the framework provide a fertile ground for the building of understandings, and the identification of improvements, that can be made to either reduce the criticality or to better manage it.

5 CREATING A CRITICALITY FRAMEWORK FOR STORMWATER ASSETS

A variety of approaches exist for generating a Criticality Framework and this might be done using internal resources or utilising a consultant. The following outlines the process used by ProjectMax at several council sites which have generated useful and usable outcomes for the client.

Fundamental to the approach is the engagement of council staff in the process to ensure that the outcome aligns with local values and the way that the Framework would actually be applied.

5.1 INTRODUCTION AND OVERVIEW

This is the launch of the process and provides for building an understanding with the staff who will be involved what Criticality is about, the benefits of building the framework, how the project will progress and the involvement that will be required of them.

5.2 ALIGNMENT WITH CORPORATE RISK MANAGEMENT STRATEGY AND IDENTIFICATION OF APPROPRIATE 'CONSIDERATIONS'

Most councils have adopted a Risk Management Strategy at a corporate level and this must be complied with unless specific exemption is obtained.

As this strategy applies across all council activities the level of detail provided is quite often insufficient to provide effective differentiation of stormwater assets.

Using the corporate approach as a guideline the participants will identify the 'Considerations' that will be utilised and rank their relative importance.

Typically these will include matters such as :

- Health and safety (can be split to be more specific about health risk Vs risk of injury)
- Environment
- Service disruption
- Impact on local economy and employment
- Impact on key customers (a specific sub-set of the wider economic impact)
- Property damage
- Disruption to other utilities and services such as transport, power, telecommunications

It is useful to rank the considerations and this may be used in prioritisation processes when developing capital works programmes or allocating resources.

Many corporate strategies also include elements such as legal and reputation impacts. We take the view that if you have a major asset failure that impacts dramatically on the listed considerations then it is highly likely that the Mayor will end up on television and someone will take legal action against the council. However, that would not occur if the asset failure did not occur and it should not therefore be a primary consideration. It will however inevitably occur and needs to be taken into consideration when thinking about the appropriate management responses to criticality.

Cost is also often listed at a corporate level as a consideration. While the cost of repairing an asset failure can be considerable so to can the costs associated with avoiding that failure e.g by pro-active and early renewal. These avoidance costs could include condition assessment, regular inspections and pro-active renewal prior to failure. It is the differential between these costs that might drive different levels of criticality but this is quite complicated. The potential cost of repairs might be a justification for undertaking a pre-failure renewal but it does not readily fit into the identification of 'Considerations' process.

5.3 DESCRIBING THE LEVELS OF CRITICALITY

For each of the considerations described above it is useful to describe what the different levels of criticality would look like.

These will start at 'Insignificant/Minor' which largely describe the consequences of the day to day failures that are responded to routinely by maintenance crews and have no lasting or measurable impact.

At the other end of the scale are 'Catastrophic' consequences which might include deaths, permanent damage to unique flora and fauna, significant and long lasting impacts on the local economy, etc. As noted above such events will inevitably make the national news, lead to Commissions of Inquiry and potentially lead to the disappearance of senior managers. Two key points are worthy of note regarding Catastrophic consequences of failure. The first is that there will not necessarily be a Catastrophic consequence of failure for each consideration. It needs to be comparable with mass destruction and deaths and this should be a very unusual situation. The second is that if you do identify an asset that genuinely sits at this level then urgent consideration should be given to reducing the consequences of failure if possible. Even if the likelihood of occurrence is very low the mere possibility of such an event occurring should be avoided if possible.

An example of degrees of criticality for an Environment related consideration might include :

Table 1 : Example of Criticality Levels

Minor	Moderate	Major	Catastrophic
Quick and easy clean-up. No noticeable damage	Extensive cleanup and recovery works required. Short duration impact	Harm to valued resource for extended period with significant recovery input required	Permanent harm to endangered resource. Prosecution. National news

The object of the exercise is to identify sufficient features in each category so that any relatively informed staff member could consistently allocate the appropriate level of criticality for a particular asset. The features are intended to assist with allocating a criticality level but are not an absolute requirement for occurring. They might include a gauge of how many people were impacted, for how long, would council be prosecuted, which news media would be involved, was a Civil Defence declaration considered, etc. Collectively these features would allow an assessor to qualitatively say '*it would be worse than that level but not as bad as that level – it therefore logically fits here'*. If this decision process needed to be conveyed to councillors, or senior managers, they would also understand the differentiation.

There is no rule about how many levels of criticality are required. Most assets should sit in the 'Minor' category. It is useful to have a 'Catastrophic' category but this needs to used very sparingly for situations that would truly align with that description and a useful target is to actually have nothing in that category. Between these extremes it is practical and useful to have at least 2 or 3 categories that will tend to naturally align with the way that assets will be managed. In the above table 'Major' would include assets that could cause some serious damage and you would wish to avoid that situation happening. 'Moderate' might be allocated to assets that would cause less damage than major, would receive more ongoing monitoring than Minor assets and you could live with occasional failures.

Allied with each level are a range of management actions associated with that level, which are different to the level above and the level below. This is further described below.

5.4 ALLOCATION OF ASSETS TO THE LEVELS OF CRITICALITY

All the above steps are somewhat conceptual. The heavy lifting in developing the Criticality Framework is allocating the various assets to the levels of criticality by identifying a Consideration that could be impacted and then the criticality level of that impact.

There are a range of approaches that can be utilised for this process.

A workshop process with asset managers and operational staff to logically work through the various systems can be very useful and typically quickly focusses in on the assets that are likely to be critical e.g. the major rising main under the railway line, the reservoir with no bypass, the single raw water main across the unstable gully. Useful questions to ask in these situations are '*How much damage would it do ?*' and '*How long would it take to fix ?*' The time to fix should take into account ease of access, availability of spares, how long supply could be maintained from the reservoir, etc. If the pipe is small and easily repairable within the 3 hour Level of Service window for unplanned shut-downs then the pipe will have a low level of criticality. These discussions should quickly reveal that the number of critical assets is quite small and everything else can be managed with the normal day to day processes. If this is not the case then the process is perhaps too conservative or there is something seriously unusual about the system.

An alternative approach, that can run instead of, or alongside, the above, is to utilise the GIS to identify pipes and assets with certain characteristics e.g. pipes over 375mm diameter, pipes deeper than 3m to invert, pipes under major utilities etc. This will likely generate a very similar list of assets to the workshop process. It does however have some severe limitations in relation to building a group wide understanding of criticality, it will probably not identify areas where the pipe is actually the 2nd tier flow path and the GIS will have difficultly identifying sensitive environmental areas or key customers.

Some Criticality Frameworks may also utilise a scoring system to rank assets. The Considerations are identified and ranked and then the different levels of criticality are also allocated scores. The number of residents impacted by an asset failure might be reflected with a multiplier and there may be a process for combining the considerations where several occur for a single event e.g. killing someone as well as destroying their house. In our experience this process tends to be complicated and diminishes the benefits of discussions identifying the impacts of various asset failures. As noted the number of high criticality assets should be quite small and it would be unusual for several to be competing for funding at the same time. Even if this was to occur the 'Criticality Scores' from the framework would be subservient to a detailed discussion of the circumstances and relative risks.

In the above processes it will become evident that the circumstances of an asset can dramatically change its relative criticality. Consider 2 pipes the same size and installation depth. When one fails, the flow runs across a local park and no-one particularly cares. When the other pipe fails, it floods the CBD, business is severely disrupted for a week, the Mayor is on television and there are huge remediation costs involved. The criticality levels of these pipes should be significantly different and a GIS search may not pick up this difference.

5.5 MANAGING THE DIFFERENT LEVELS OF CRITICALITY

One of the key benefits of identifying the different levels of criticality that may exist is the identification of different asset management approaches to be utilised for each level.

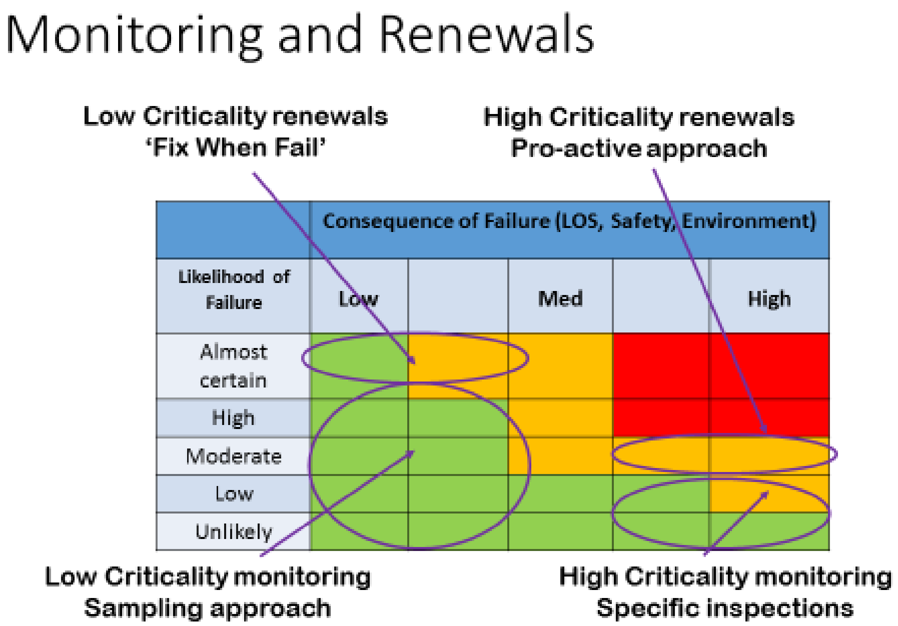
To illustrate this the following table includes various asset management approaches and an arbitrary Low and High level of criticality. As discussed above more differentiation is preferable but the table provides an indication of how they might vary.

Table 2 : Example of Asset Management Approaches

Asset Management Approach to :	Low Criticality	High Criticality
Condition Monitoring	Sampling approach across 'class' of asset	Specific monitoring plan for asset
Contingency Planning	Generic plan driven by maintenance contractor	Specific plan for asset with wide input
Renewal Planning	Fix when fail or when cost of repairs exceeds renewal cost	Pro-active renewal prior to failure occurring justified by risk management
Communications Management	Generally through Call-Centre with formal input only in exceptional cases	Immediate escalation to managed response from Comms when failure occurs
Response Escalation	Managed by maintenance contractor and included in monthly report	Immediate escalation when failure occurs to senior management and briefing of Mayor and councillors
Prioritisation	Renewal and maintenance still need to occur but have lowest priority if resources are scarce.	Highest priority for allocation of funding and resources

The following figure illustrates how the renewal planning and condition monitoring approaches indicated above fit onto the risk matrix.

Figure 3 : Illustration of Asset Management Approach in Relation to Risk and Criticality



5.6 REALITY CHECK

At the end of the above process a reality check is required to ensure that nothing of significance has been missed and the assets that have fallen into the various levels of criticality are comparable. A further check is required to ensure that the Asset Management Approaches associated with each level of criticality are able to be resourced and are sensible relative to what is currently being done.

5.7 WHO NEEDS TO BE INVOLVED

All of the above can realistically be achieved by the asset manager working in complete isolation, or assisted by a consultant.

The disadvantage of this approach is that the insight and experience of others involved in looking after the assets is not incorporated and the better understanding of what criticality means does not emerge from the conversation.

The largest drawback of developing the Framework in isolation is the outcomes do not get utilised across the organisation in actually managing the assets. The Operations Manager might not be aware of the implications for 'Critical Spares', contingency planning or escalation. The Communications Manager may be blissfully unaware of the potential for an asset failure to result in the council making the national television news and senior management may be unaware of the potential impact of budget restrictions on the organisation's ability to properly manage critical assets.

5.8 APPLICATION TO RISK MANAGEMENT

The Criticality Framework is primarily focused on the consequences of failure of an asset and this does not change over time unless the circumstances change e.g. there are now houses where there used to be paddocks.

The current risk is the combination of the criticality and the likelihood of failure. The likelihood does change over time as the assets deteriorate and the current risk requires regular review. If this indicates that the current risk has climbed into a part of the risk matrix that requires a different response then that might drive a change in monitoring or a renewal.

6 CONCLUSIONS

The development of a Criticality Framework provides a very valuable insight into the nature of the assets utilised by a utility and the consequences of failure of those assets.

It should be found that the vast majority of the assets have minor impacts if they fail and these assets can be managed with a 'light touch' and minimal management input.

A small number of assets will have elevated criticality and the framework will identify these and will also identify how asset management approaches should change as criticality increases.

It may emerge that some assets have unacceptable consequences of failure, irrespective of the likelihood of that event actually occurring, and action will be required to lower the criticality to an acceptable level.

While a range of approaches can be utilised to generate the framework they share many common elements and all benefit from a range of inputs and perspectives.