

# HEALTH AND SAFETY CRITICAL CONTROL MANAGEMENT

## GOOD PRACTICE GUIDE



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# FOREWORD

**The global mining and metals industry has made great progress in improving health and safety performance. One of the sustainable development principles of the International Council on Mining and Metals (ICMM) is to seek continual improvement in health and safety performance.**

This document, one of a range of documents on good practice in health and safety management, is designed to support the principle of continual improvement. It provides practical guidance on preventing the most serious types of health and safety incidents, referred to here as material unwanted events (MUEs).

This guidance document provides advice on how to identify and manage critical controls that can either prevent a serious incident occurring in the first place or minimize the consequences if a serious incident were to occur. Both types of control are needed. Evidence from major incidents in mining and metals, and in other industries, indicates that although the risks were known, the controls were not always effectively implemented. Therefore, this document provides specific guidance on:

- identifying the critical controls
- assessing their adequacy
- assigning accountability for their implementation
- verifying their effectiveness in practice.

The approach described in this document is called critical control management (CCM).

CCM is well established and in use in many high-hazard industries. However, this is the first time this approach has been captured in a single document designed specifically for the mining and metals industry. This would not have been possible without the guidance and support of ICMM member companies.

As with most new organizational initiatives, the successful implementation of CCM requires senior executive support. This support is required in terms of not only establishing CCM within companies, but in its ongoing implementation. The approach enables senior leaders to more effectively exercise their leadership role in safety as a result of the transparency brought to bear by applying CCM. Under CCM, critical controls should be clearly described, and their required performance and the accountability for implementing the controls should be made explicit. This should permit senior leaders to participate even more effectively in managing the risks of major incidents. Committed leadership through the active monitoring of CCM across the mining and metals industry is essential for the long-term success of the approach.



**R. Anthony Hodge**  
President, ICMM

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# INTRODUCTION

**This document provides advice on MUEs – guidance on managing critical controls that aligns risk management and good management practice. CCM is an integral part of risk management and aids in identifying the priority risks in a company and implementing critical controls to prevent an incident or mitigate its impact.**

## Aim

The document provides advice on how to identify and manage critical controls that can either prevent a serious incident occurring in the first place or minimize the consequences if a serious incident were to occur. This document provides specific guidance on:

- identifying the critical controls
- assessing their adequacy
- assigning accountability for their implementation
- verifying their effectiveness in practice.

## Structure

This guidance document utilizes a number of steps that an organization can use to structure their approach to CCM. This document describes:

- the background and aim of the CCM process
- guidance to prepare an organization for the CCM process
- nine steps to develop the CCM process
- annexes providing additional guidance on:
  - a CCM journey model and mapping tool to help organizations assess status and progress
  - critical controls
  - lead and lag indicators.

## Preparation for the CCM process

The CCM process outlined here is a step-by-step approach where the process is divided between planning and implementation. It is important for an organization undertaking CCM to have the right skills, experience and resources to implement it to a high standard. The organization should also have buy-in from senior executives. Such support is a fundamental characteristic of the organizational maturity required to succeed with CCM.

If an organization is unsure whether it is mature enough to begin, it is recommended that the organization undertake a review of its readiness to adopt CCM. This guidance document includes an analysis tool that might help identify that readiness: the CCM journey model and mapping tool. The tool is structured as a journey chart, with each step of the journey describing an increased level of control management culture and practices. The tool can help map the organization's current status, as well as provide ideas for moving towards CCM by establishing the required foundation (see Annex A).

Once an organization has assessed its maturity and established the appropriate foundation, it is ready to proceed with the process.

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# DEFINITIONS AND ACRONYMS

This is not a definitive list of risk management terminology. The focus is on some of the key definitions and acronyms associated with critical control management used in this document.

## **Bowtie analysis (BTA)**

An analytical method for identifying and reviewing controls intended to prevent or mitigate a specific unwanted event.

## **Cause**

A brief statement of the reason for an unwanted event (other than the failure of a control).

## **Consequence**

A statement describing the final impact that could occur from the material unwanted event (MUE). It is usual to consider this in terms of the maximum foreseeable loss.

## **Control**

An act, object (engineered) or system (combination of act and object) intended to prevent or mitigate an unwanted event.

## **Critical control**

A control that is crucial to preventing the event or mitigating the consequences of the event. The absence or failure of a critical control would significantly increase the risk despite the existence of the other controls. In addition, a control that prevents more than one unwanted event or mitigates more than one consequence is normally classified as critical.

## **Critical control management (CCM)**

A process of managing the risk of MUEs that involves a systematic approach to ensure critical controls are in place and effective.

## **Hazard**

Something with the potential for harm. In the context of people, assets or the environment, a hazard is typically any energy source that, if released in an unplanned way, can cause damage.

## **Material unwanted event (MUE)**

An unwanted event where the potential or real consequence exceeds a threshold defined by the company as warranting the highest level of attention (eg a high-level health or safety impact).

## **Mitigating control**

A control that eliminates or reduces the consequences of the unwanted event.

## **Preventing control**

A control that reduces the likelihood of an unwanted event occurring.

## **Risk**

The chance of something happening that will have an impact on objectives. It is usually measured in terms of event likelihood and consequences.

## **Unwanted event**

A description of a situation where the hazard has or could possibly be released in an unplanned way, including a description of the consequences.

## **Verification activities**

The process of checking the extent to which the performance requirements set for a critical control are being met in practice. Company health and safety management systems might use a variety of terms for “verification” activities. Common terms include audit, review, monitoring and active monitoring.



Committed leadership through the active monitoring of CCM performance is essential for the long-term success of the process.

Image courtesy of Anglo American

# CRITICAL CONTROL MANAGEMENT

## Summary

CCM consists of nine steps, six of which are required to plan the CCM program before implementing them in the last three steps, as seen in Figure 1.

This document provides guidance for each step in the process, as well as key actions and selected health and safety examples.

Each step might require revisiting the previous step to achieve the desired outcome. For example, the loop from Step 7 to Step 6 indicates the potential need to revisit information from the planning steps when site implementation is defined. This might occur because the site control performance varies from assumptions made at the planning stage.

Each step in the process has a target outcome that should be achieved before moving to the next step. Table 1 summarizes all steps and outcomes.

The following pages provide a step-by-step outline of the CCM process.

Figure 1: The critical control management process

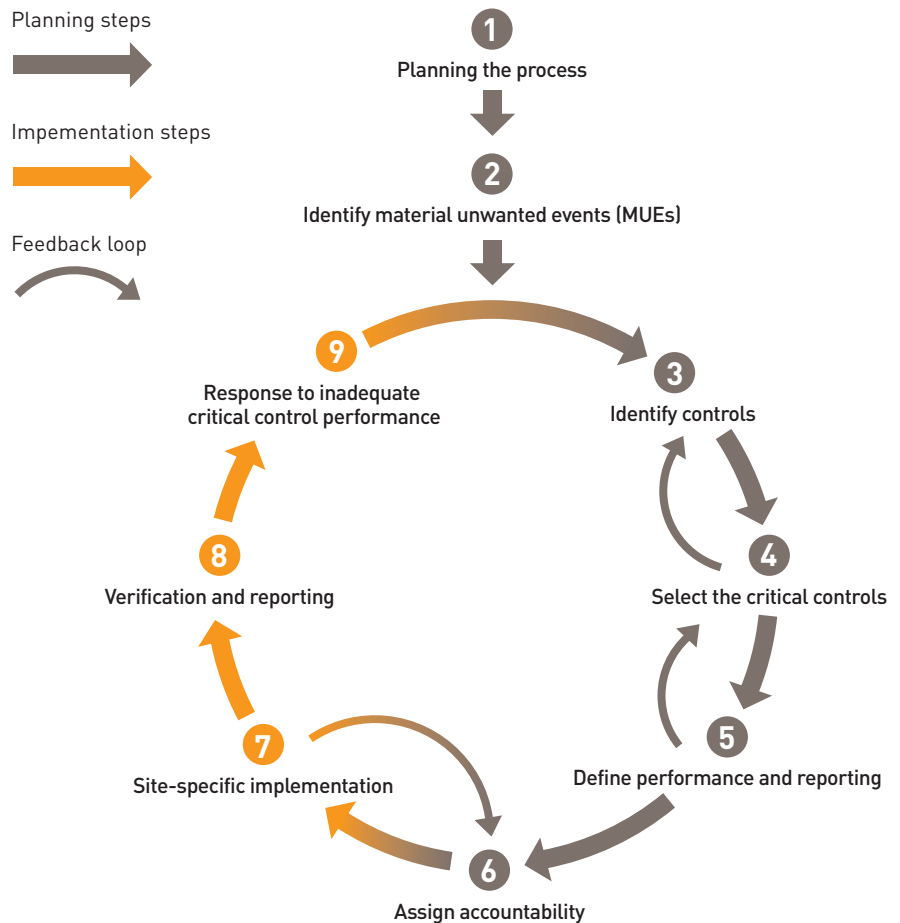


Table 1: Critical control management steps and target outcomes

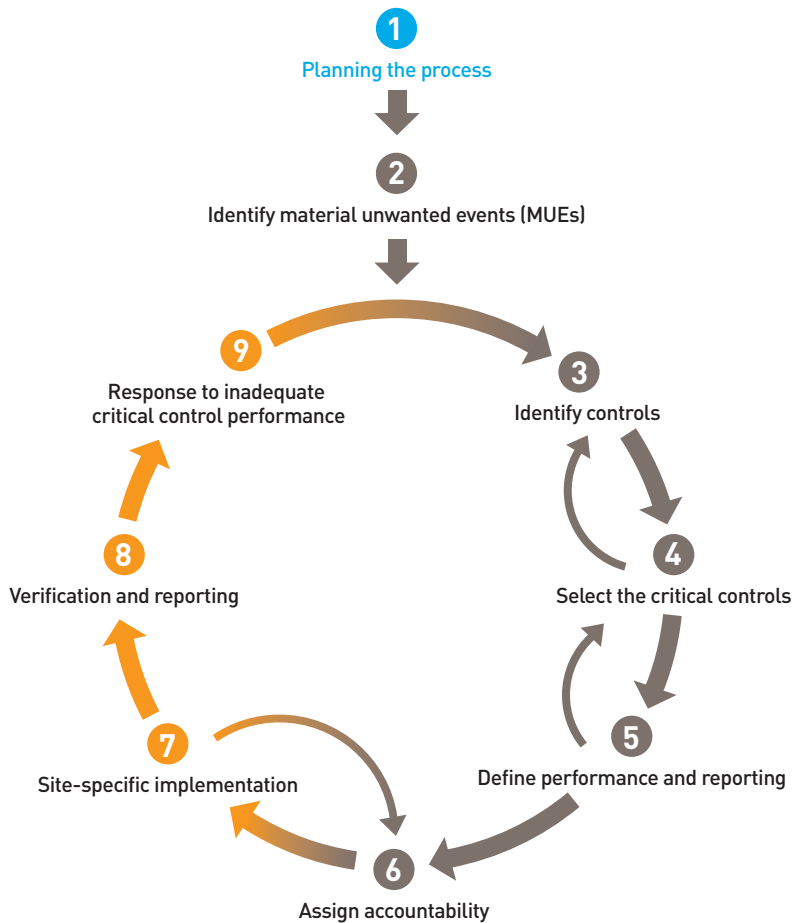
	STEP	TARGET OUTCOME
Planning steps	1	A plan that describes the scope of the project, including what needs to be done, by whom and the timescales.
	2	Identify MUEs that need to be managed.
	3	Identify controls for MUEs, both existing controls and possible new controls. Prepare a bowtie diagram.
	4	Identify the critical controls for the MUE.
	5	Define the critical controls' objectives, performance requirements and how performance is verified in practice.
	6	A list of the owners for each MUE, critical control and verification activity. A verification and reporting plan is required to verify and report on the health of each control.
Implementation	7	Defined MUE verification and reporting plans, and an implementation strategy based on site-specific requirements.
	8	Implement verification activities and report on the process. Define and report on the status of each critical control.
	9	Critical control and MUE owners are aware of critical control performance. If critical controls are underperforming or following an incident, investigate and take action to improve performance or remove critical status from controls.

# CRITICAL CONTROL MANAGEMENT

## STEP 1: Planning the process

### Target outcome

A plan that describes the scope of a project, including what needs to be done, by whom and the timescales.



### Key actions

- Develop a plan that describes the scope of the project. This includes:
  - organizational context
  - project objectives
  - responsibilities
  - business sections involved.
- Develop methods to:
  - identify potential hazards and unwanted events
  - assess risk
  - review MUEs
  - select critical controls
  - assess objectives and performance of critical controls
  - investigate critical control underperformance
  - measure impact of the project
  - identify ownership and accountability.

The first step of the CCM process is to carefully scope out and plan the work. This includes planning what definitions, criteria and actions will need to be carried out, what areas of an organization and/or specific people will be involved, and over what timeframe. The following questions should be considered (each is elaborated on in subsequent steps):

- What is the organizational context? Are there existing projects at a corporate, business unit or site level that complement or conflict with this work?
- What is the objective and what are the specific deliverables of the project?
- What sections of the business will be involved?
- What method will be used to identify potential hazards?
- What methods will be used to identify unwanted events?
- What methods will be used to assess the risk of the identified unwanted events, including the criteria for a MUE?
- What method will be used to review MUE controls?
- What will the criteria be for critical control selection?
- What will the criteria be for assessing the objectives and performance of the critical controls?
- How will the verification processes be defined?
- How will ownership and accountability be defined?
- How can critical control information be adapted to become site-specific?
- How will critical control performance be verified in practice and what actions will be taken if requirements are not met?
- What methods will be used to investigate critical control underperformance?
- How will the impact of the CCM initiative will be measured?

Scoping for a major initiative should consider additional resources such as leadership, facilitation, project team membership, timing and budget.

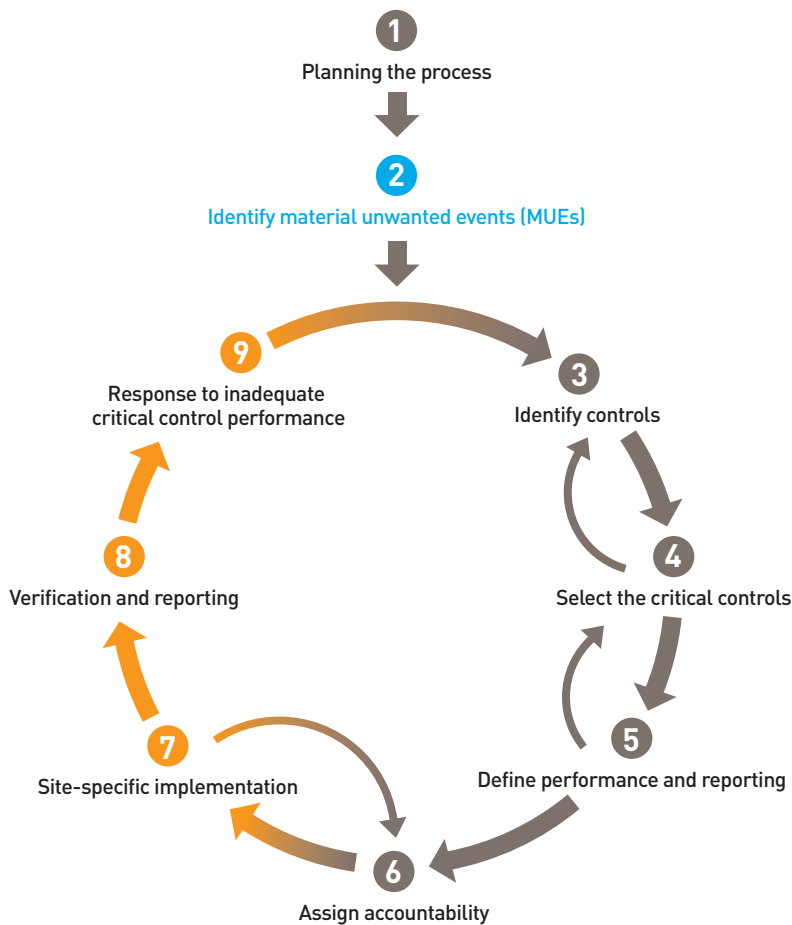


# CRITICAL CONTROL MANAGEMENT

## STEP 2: Identify material unwanted events (MUEs)

### Target outcome

Identify the MUEs that need to be managed.



### Key actions

- Understand major hazards and identify potential MUEs.
- Apply selection criteria to MUEs with a focus on the consequences.
- Identify design opportunities to address the hazard, reducing the potential consequences and eliminating the MUE from the CCM process.
- Describe the identified MUE, including the relevant hazard, mechanism of release and nature of the consequences.

### Identify material unwanted events (MUEs)

Identification of MUEs needs to consider historical as well as foreseeable events given the operations and activities at individual sites. As a result, identification of MUEs needs to include suitably experienced personnel and a review of relevant data. This will need to include the history from the site, company and the industry more widely. This is because some incidents, while rare, are potentially disastrous. For example, underground ignition of methane by lightning is rare but it is foreseeable and potentially disastrous.

### Materiality criteria

Materiality criteria define the threshold that a risk must exceed before being considered a material risk. The perceived likelihood of an event by any one individual might be inaccurate, especially for low-probability/high-consequence events. It is recommended that materiality should be defined based on consequences, such as the maximum foreseeable loss.

### Examples of MUEs

The following table is a list of typical mining- and metals-related MUEs based on historical analysis.

**Table 2: Typical mining- and metals-related MUEs based on historical analysis**

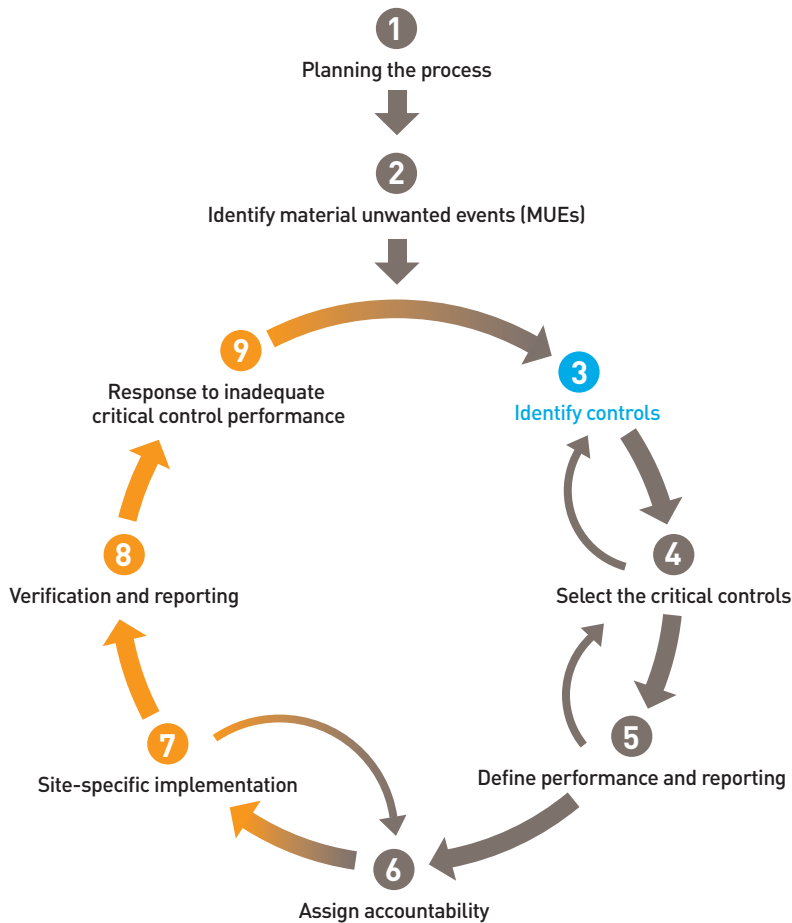
MINING AND METALS MUEs
Aviation
Underground ground control
Underground fire/explosion
Heavy mining equipment
Dropped objects
Pressurized systems
Confined spaces
Inrush/inundation
Explosives
Highwall stability
Flammable gas
Light vehicles
Work at height
Electricity
Hazardous materials

# CRITICAL CONTROL MANAGEMENT

## STEP 3: Identify controls

### Target outcome

Identify controls for MUEs, both existing controls and possible new controls. Prepare a bowtie diagram.



### Key actions

- Identify the controls.
- Prepare a bowtie diagram.
- Assess the adequacy of the bowtie and the controls.

The purpose of Step 3 is to identify all the controls – both existing ones and potential new ones – before identifying which of the controls are the critical controls in Step 4.

### Identify controls

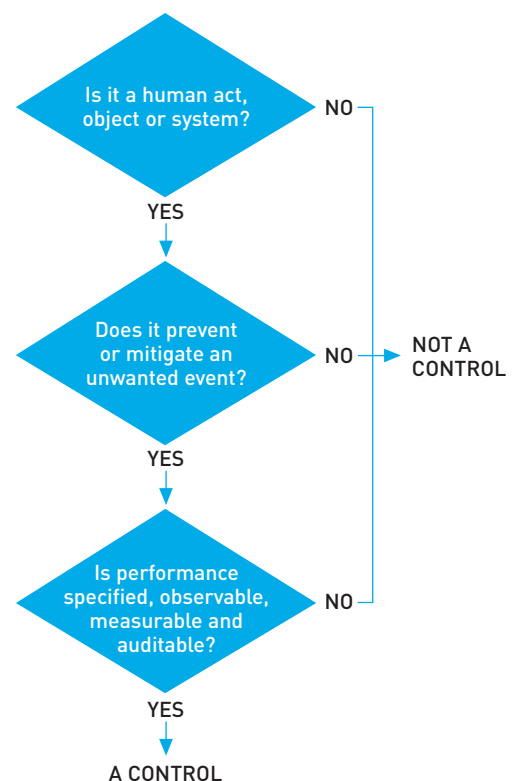
In most cases, controls will already exist as a result of previous risk-assessment work, experience within the company or industry from incidents, or as a result of legislation and associated guidance. This stage recommends that each identified MUE should be reviewed to check that the appropriate controls have been identified.

### What is a control?

Deciding on what is or is not a control is a key step. The following guidance is available:

- the definitions at the start of this document
- the control identification decision tree (see Figure 2)
- example of a critical control system given in Step 5 (see Table 3).

Figure 2: Control identification decision tree



Source: Adapted from Hassall, M, Joy, J, Doran, C and Punch, M (2015).

# CRITICAL CONTROL MANAGEMENT

## STEP 3: Identify controls *continued*

### Too many controls

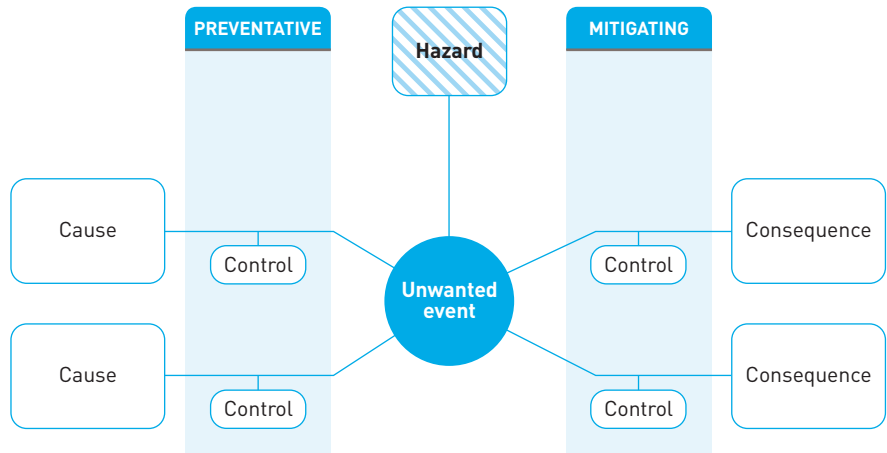
Experience from other industries suggests that it is possible to identify a large number of plans, processes and tools that can be inappropriately classified as controls. This leads to unnecessarily complex bowties that dilute the attention needed to effectively implement those controls that can have a direct impact on preventing and/or mitigating an MUE. Some examples of inappropriate controls are:

- management plans
- risk-assessment techniques such as *Step Back 5 x 5*
- behaviour-based safety tools.

All of the above are important parts of health and safety management systems but are not specific to preventing or mitigating an MUE. Management plans might describe controls, risk-assessment techniques might lead to controls being identified and behaviour-based safety tools might tell us something about how controls are working or not working. However, they are not controls themselves as defined by this guidance document.

This guidance document might demonstrate that many activities, previously thought to be controls, do not fit the definition or the purpose. For example, previously mentioned procedures, rules and expected practices are not controls. Similarly, training, supervision, maintenance and other plans are not controls.

Figure 3: Bowtie diagram indicating preventative and mitigating controls



### What is a good control?

Good controls meet the definitions given in this document and meet the criteria in the control identification decision tree in Figure 2. In addition, they have the following characteristics:

- they are specific to preventing an MUE or minimizing its consequences
- the performance required of the control can be specified
- their performance can be verified.

### Further guidance on controls

Additional information and guidance on controls can be found in Annex B.

### Prepare a bowtie

Proprietary tools are available, but bowties can also be drawn by hand (eg on a whiteboard) or developed with standard office productivity software.

There is no one right way to develop a bowtie (see as an example in Figure 3). However, this is a critical stage and the bowtie should be prepared by careful reference to the definitions at the start of this document and the additional guidance given on controls in Annex B.

It is usual to start with the MUE by asking:

- What are the possible causes that could lead to the MUE?
- What controls are in place (or could be put in place) to prevent the cause leading to the MUE?
- What are the maximum foreseeable consequences of the MUE? (It is usual at this stage to assume there are no controls in place, which is sometimes referred to as low-risk.)
- What controls are in place or could be introduced to reduce the possibility of the consequences occurring?

### Assess the adequacy of the bowtie and the controls

Once the bowtie is developed, it should be reviewed:

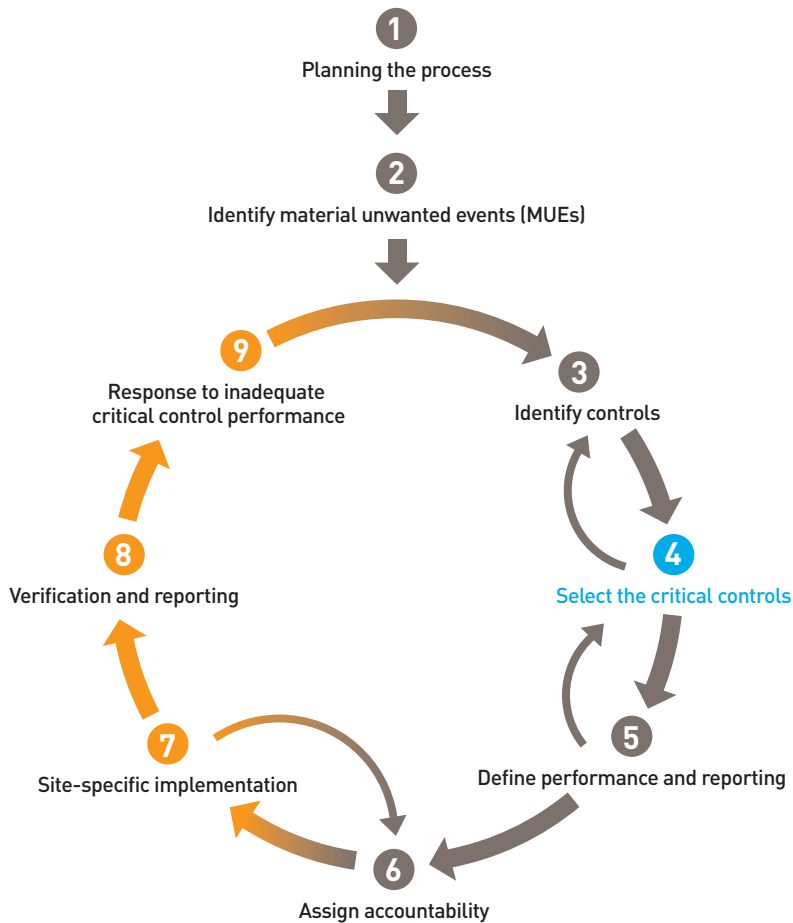
- to confirm that the controls are appropriate and relevant for each cause and/or consequence
- against the hierarchy of control – is there overdependence on people-type controls compared with engineering controls, which are higher up the hierarchy of control?

# CRITICAL CONTROL MANAGEMENT

## STEP 4: Select the critical controls

### Target outcome

Identify the critical controls for the MUE.



### Key actions

- When identifying critical controls, apply the critical control definition and guidance in this section.
- Consider the performance requirements of the potential critical controls and how they could be verified.
- The final set of critical controls for an MUE should represent the critical few that, when managed using CCM, can effectively manage the MUE risk.

### What is a critical control?

The starting point for this step is the bowties developed in Step 3. The controls identified on the bowtie should be assessed to determine if they are critical controls.

The following questions can help to determine if a control is critical:

- Is the control crucial to preventing the event or minimizing the consequences of the event?
- Is it the only control, or is it backed up by another control in the event the first fails?
- Would its absence or failure significantly increase the risk despite the existence of the other controls?
- Does it address multiple causes or of mitigate multiple consequences the MUE? (In other words, if it appears in a number of places on the bowtie or on a number of bowties, this may indicate that it is critical.)

### Critical control decision tree

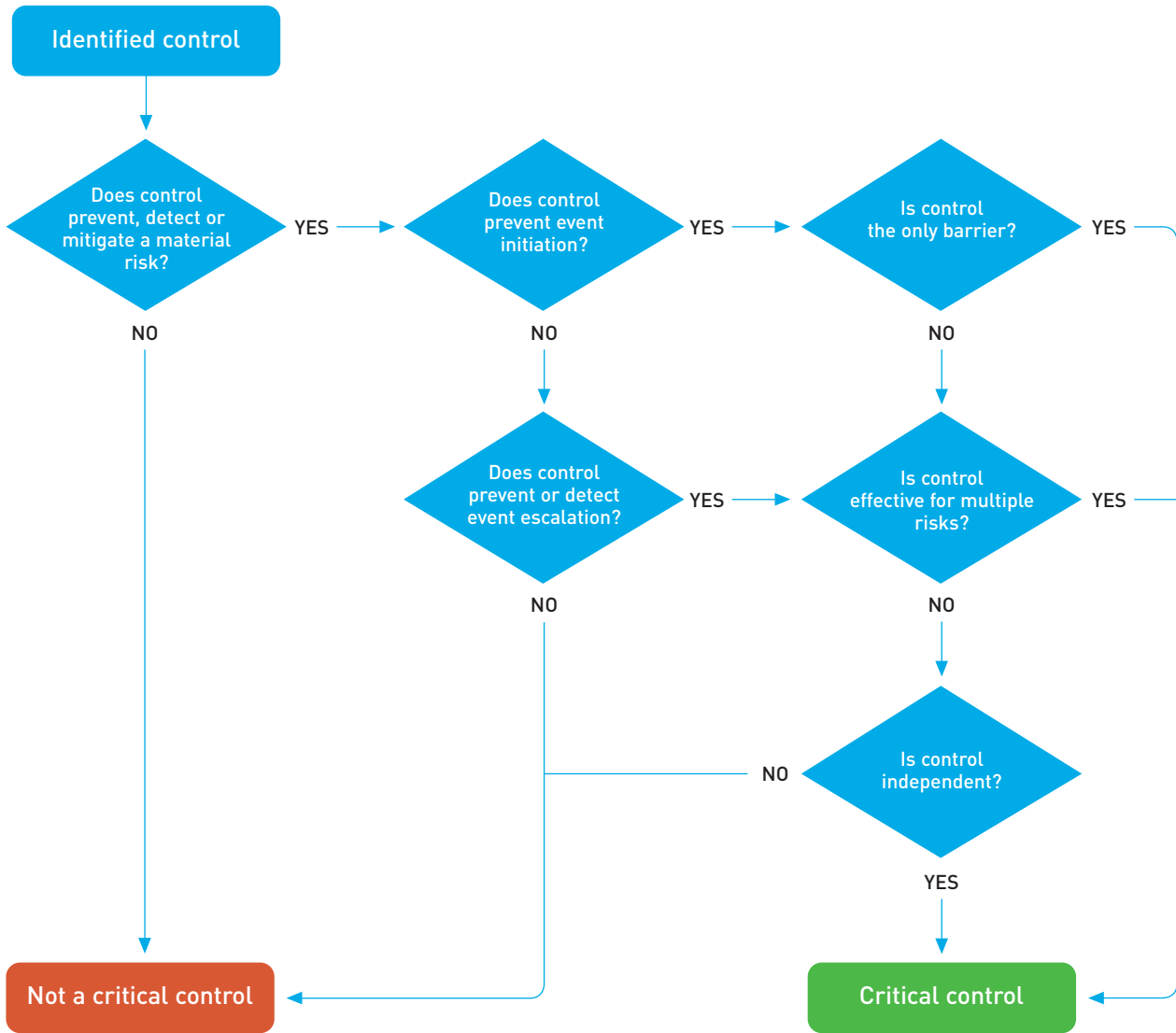
The decision tree in Figure 4 provided by an ICMM member may also help determine if a control is critical.

Note that the decision tree indicates that selecting a critical control may be an iterative process and could involve reviewing several aspects of a control before deciding whether it meets the criteria for a critical control.

# CRITICAL CONTROL MANAGEMENT

## STEP 4: Select the critical controls *continued*

Figure 4: BHP Billiton critical control decision tree



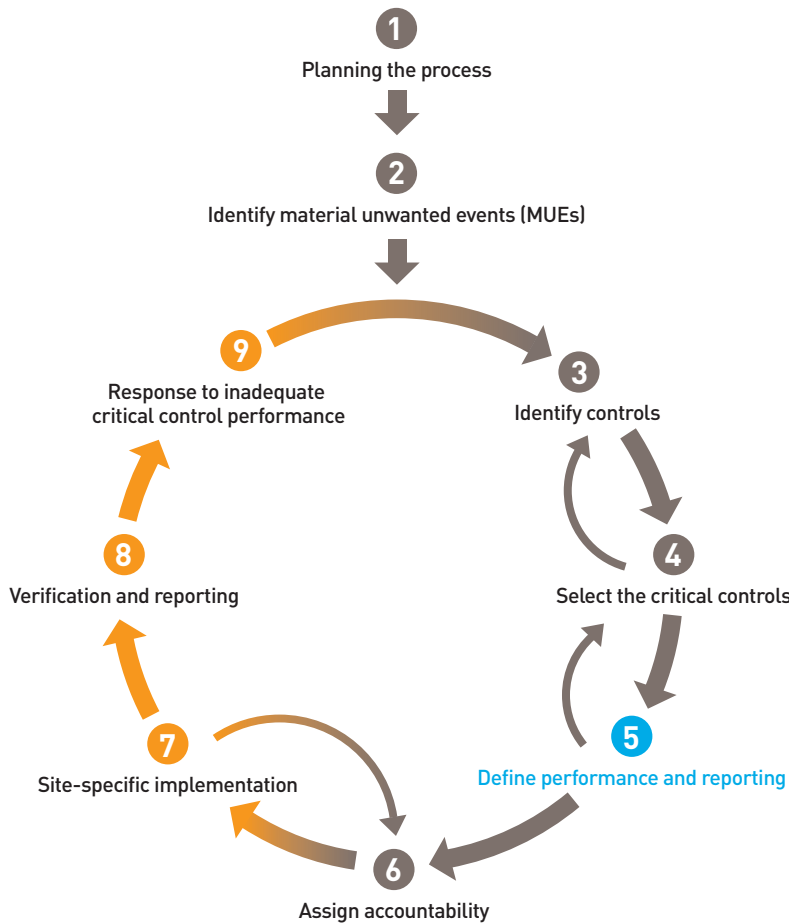
Source: Adapted from BHP Billiton.

# CRITICAL CONTROL MANAGEMENT

## STEP 5: Define performance and reporting

### Target outcome

Define the critical controls' objectives, performance requirements and how performance is verified in practice.



### Key actions

- Define objectives and performance requirements for each critical control.
- Identify current activities that affect the critical control's performance.
- Describe activities to verify performance and reporting requirements.
- Identify what would trigger immediate action to stop or change the operation and/or impose the performance of the critical control.

Step 5 involves examining the objectives, performance requirements (including current performance) and reporting mechanisms for a critical control. The following questions should be considered when defining each of these points:

- What are the specific objectives of each critical control?
- What performance is required of the critical control? (This is sometimes referred to as a performance standard.)
- What activities support or enable the critical control to perform as required and specified?
- What checking is needed to verify that the critical control is meeting its required performance? How frequent is the verification needed? What type of verification is needed?
- What would initiate immediate action to shut down or change an operation or improve the performance of a critical control?

### Control information summary

For each critical control the following information is needed:

- The name of the critical control
- What are the specific objectives of the critical control?
- What performance is needed from the critical control?
- What activities support the performance of the control to the standard?
- What verification activities are needed to ensure the critical control is meeting its required performance?

An example of a critical control system for a specific MUE is provided in Table 3.

# CRITICAL CONTROL MANAGEMENT

## STEP 5: Define performance and reporting *continued*

**Table 3:** Health example (a critical control system)

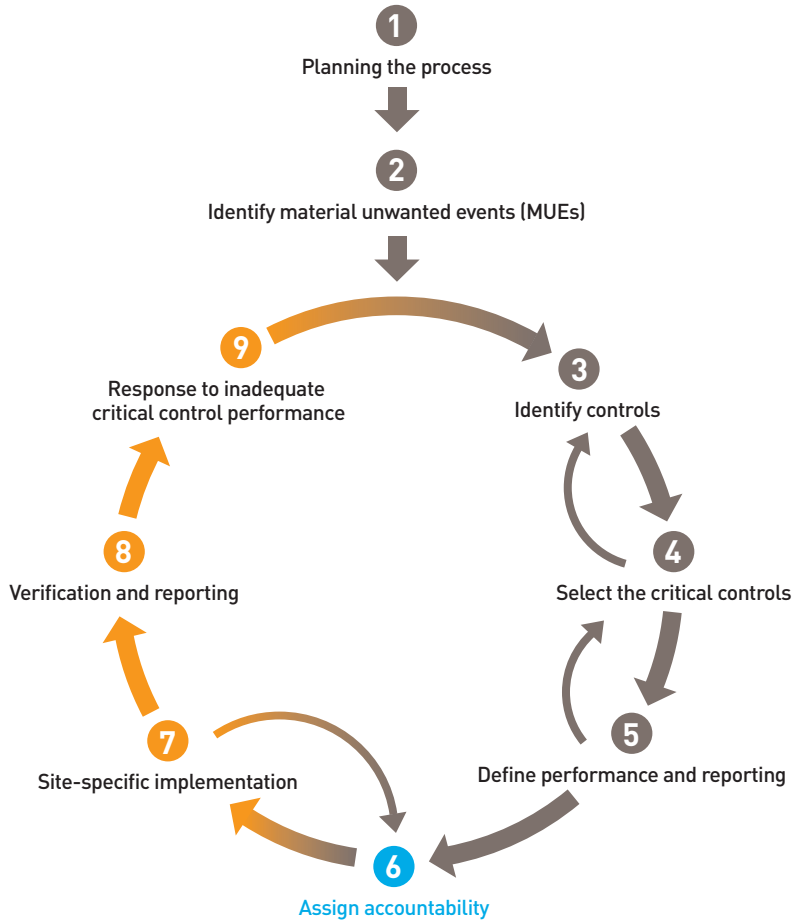
<b>1 What is the name of the critical control for diesel particulate overexposure (MUE)?</b> Enclosed cab on mining equipment		
<b>2 What are its specific objectives related to the MUE?</b> To restrict the access of diesel particulates into the operators' environment to levels well below the occupational exposure limit		
<b>3 What are the critical control performance requirements to meet the objectives?</b>	<b>4 What are the activities within the management systems that support having the critical control able to do what is required?</b>	<b>5 What can be sampled from the set of activities for verification, providing a clear image of the critical control status?</b>
Positive pressure cabin environment maintained to level that prevents ingress of diesel particulates  Pressure differentiator indicator that alarms when pressure drops below critical level	Scheduled maintenance and calibration of indicator according to manufacturer's requirements	Review maintenance and calibration records  Review alarm log and corrective action taken
Air intake filter operating at greater than 99% efficiency	Pre-shift filter housing inspection for damage  Filter inspection at planned maintenance every 500 hours  Filter change-out every 1,000 hours	Review documented pre-start inspections  Review 500-hour inspection records  Review 1,000-hour change-out records
<b>6 What is the target performance for critical control?</b> 100 per cent of inspection and tests either satisfactory or repair is done before truck is put back into operation		
<b>7 What is the critical control performance trigger for shutdown, critical control review or investigation?</b> 5 per cent of inspections and tests indicate cab ventilation issues that cannot be resolved or are not resolved before truck returned to service		

# CRITICAL CONTROL MANAGEMENT

## STEP 6: Assign accountability

### Target outcome

A list of the owners for each MUE, critical control and verification activity. A verification and reporting plan is required to verify and report on the health of each control.



To ensure the risk of an MUE is being managed, the controls must be working effectively. This requires the health of the controls to be monitored through verification activities that are assigned to specific (or multiple) owners. This can be described in a verification and reporting plan.

The verification and reporting plan must include:

- an MUE owner (this should be a senior line manager responsible for the operation)
- a critical control owner, who should be a line manager responsible for operations (they are responsible for monitoring the health of the critical controls through review of verification activity reports)
- a verification activity owner, responsible for undertaking and reporting the verification activity outcome
- a communication plan among all owners (see as an example Figure 5)
- a description of verification activities
- an owner for the review of verification reports at a senior line management level.

An example of a verification and reporting plan for a health MUE is presented in Table 4.

### Key actions

- Assign owners for MUEs, critical controls and verification activities.
- Describe reporting plan for the health of critical controls.
- Assign owner for review of reports.



# CRITICAL CONTROL MANAGEMENT

## STEP 6: Assign accountability *continued*

Figure 5: A sample CCM management framework

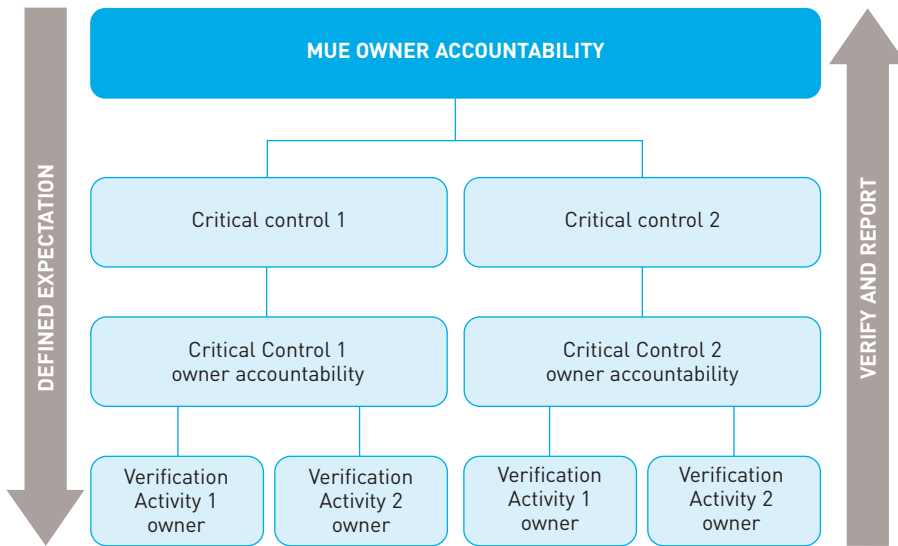


Table 4: Example of a critical control verification and reporting plan for an MUE

MATERIAL UNWANTED EVENT (MUE) Diesel particulate overexposure	CRITICAL CONTROL Positive pressure cabin environment maintained	VERIFICATION ACTIVITY Review maintenance and calibration records
<b>MUE owner</b> Underground mine manager	<b>Critical control owner</b> Underground mine maintenance superintendent	<b>Verification activity owner</b> Maintenance supervisor who oversees the relevant equipment/task
<b>Role of MUE owner:</b> <ul style="list-style-type: none"> <li>Review reports monthly* from relevant critical control owners.</li> <li>Decide on required action.</li> </ul>	<b>Role of critical control owner:</b> <ul style="list-style-type: none"> <li>Review verification activity reports weekly*.</li> <li>Report summary to the MUE owner.</li> </ul>	<b>Role of verification activity owner:</b> <ul style="list-style-type: none"> <li>Gather and review information-based verification activity requirements and compare to expectations.</li> <li>Initiate actions.</li> <li>Submit weekly* verification summary report to the critical control owner.</li> </ul>

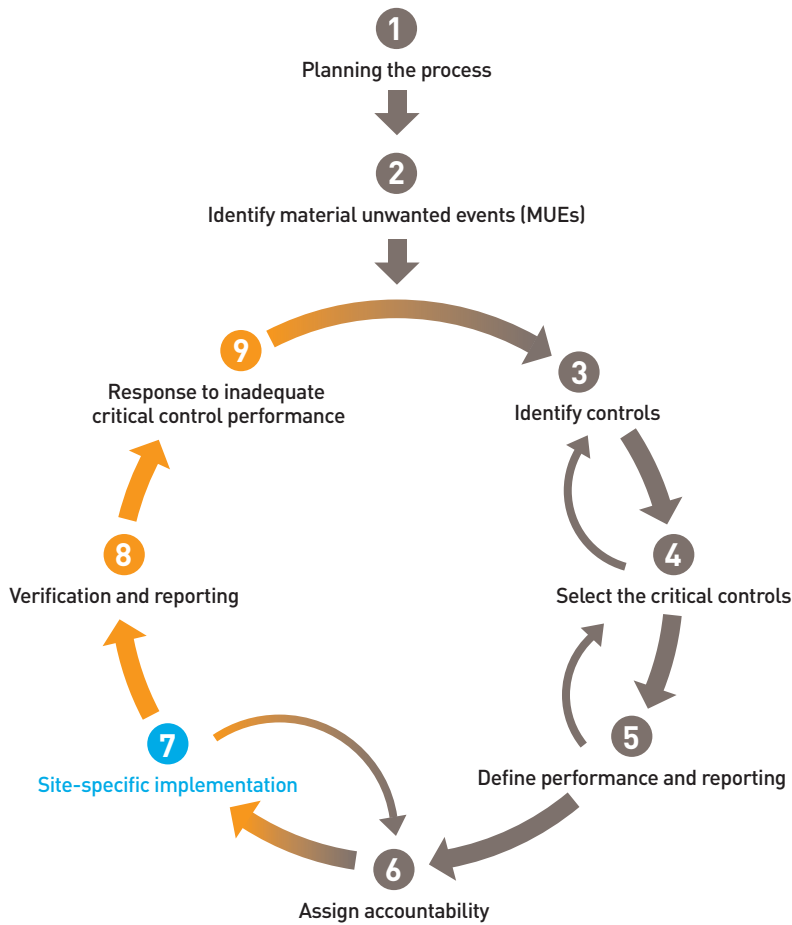
Note: \* this is an example timeline only.

# CRITICAL CONTROL MANAGEMENT

## STEP 7: Site-specific implementation

### Target outcome

Defined MUE verification and reporting plans, and an implementation strategy based on site-specific requirements.



### Key actions

- Critical control information must be specific to a site or asset.
- Adjust the critical control definition, performance information and verification requirements as necessary to suit the local context.
- Site-specific planning for implementation may involve an iterative process.
- Site-specific planning should include establishing a foundation for CCM that includes leadership, communication and appropriate development of knowledge and understanding related to the critical controls.

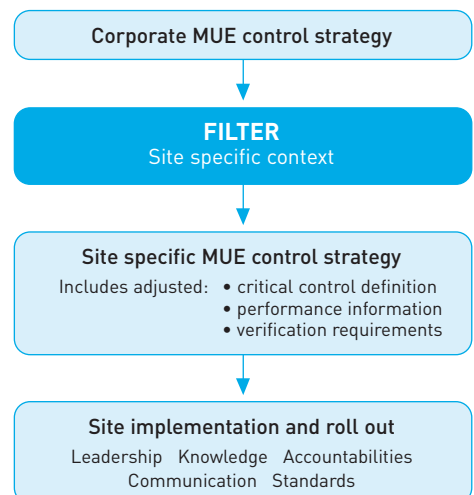
Steps 1 to 6 may have taken place at the corporate or business unit level in a company that has similar sites and therefore common MUEs. Step 7 requires that the previous steps be reviewed to ensure they are appropriate and applicable to each site.

Figure 6 describes the process required to develop a site specific MUE control strategy and subsequent implementation and roll out. It involves taking the corporate or business unit MUE control strategy developed in steps 1 to 6 and adjusting it to suit the local context.

A site-specific approach for a MUE should include an overall MUE verification and reporting plan, subsections of which define a specific critical control owner’s verification plan and the individual verification activities for a critical control. The site specific strategy may need to be tested with the corporate or business unit level before proceeding. Once agreed, a plan to implement the strategy at the site will need to be developed. The plan should include leadership, accountabilities, a communications plan, standards and developing knowledge and understanding related to the critical controls.

The feedback loop between Steps 6 and 7, as shown in the CCM process diagram above, indicates the iterative aspect of Step 7 where the site submits their CCM plans to the corporate or business unit before finalization.

**Figure 6:** Developing a site specific control strategy adjusted to suit local requirements

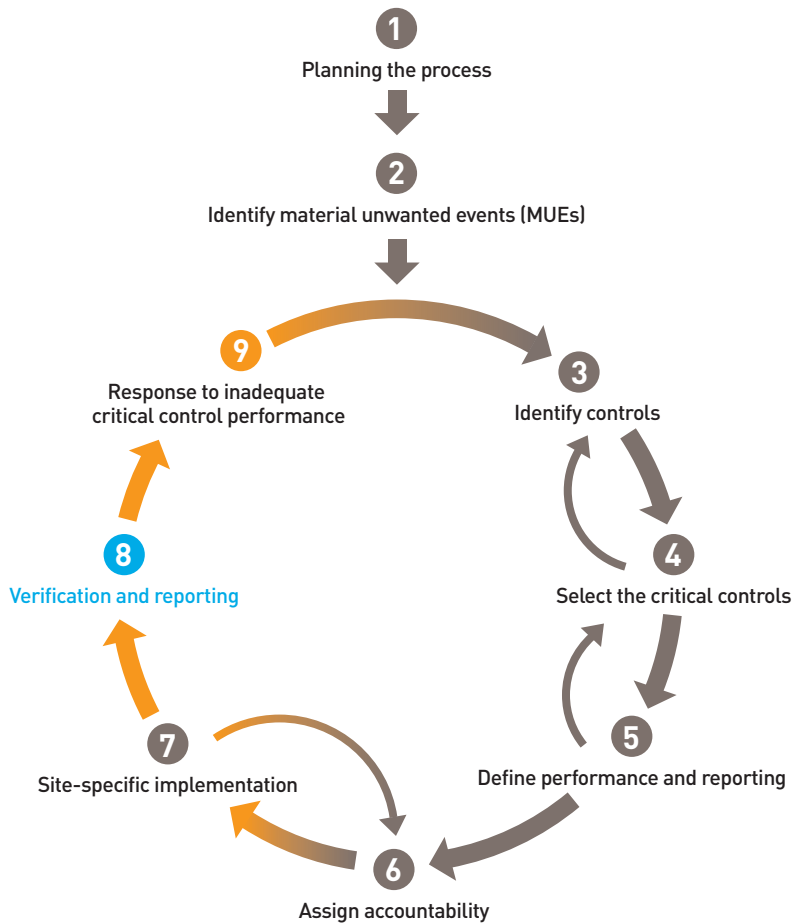


# CRITICAL CONTROL MANAGEMENT

## STEP 8: Verification and reporting

### Target outcome

Implement verification activities and report on the process. Define and report on the status of each critical control.



### Key actions

- Undertake verification activities for critical controls as described in MUE/critical control verification and reporting plan (developed in Step 5).
- Report a summary of verification activity results to the critical control owner.
- Report critical control verification status to the MUE owner.
- Reports should highlight priority information succinctly using traffic light system.
- Action initiated if critical control performance drops below the defined triggers (established in Step 5).

Step 8 puts into practice the verification of critical control status that was defined in Steps 5 and 6, and specified in the MUE verification and reporting plan from Step 7. Information regarding each critical control will be gathered on behalf of the critical control owner who will report to the MUE owner at a defined frequency. This information flow should be designed to efficiently communicate variances between expected and actual critical control performance, such as with a traffic light reporting system.

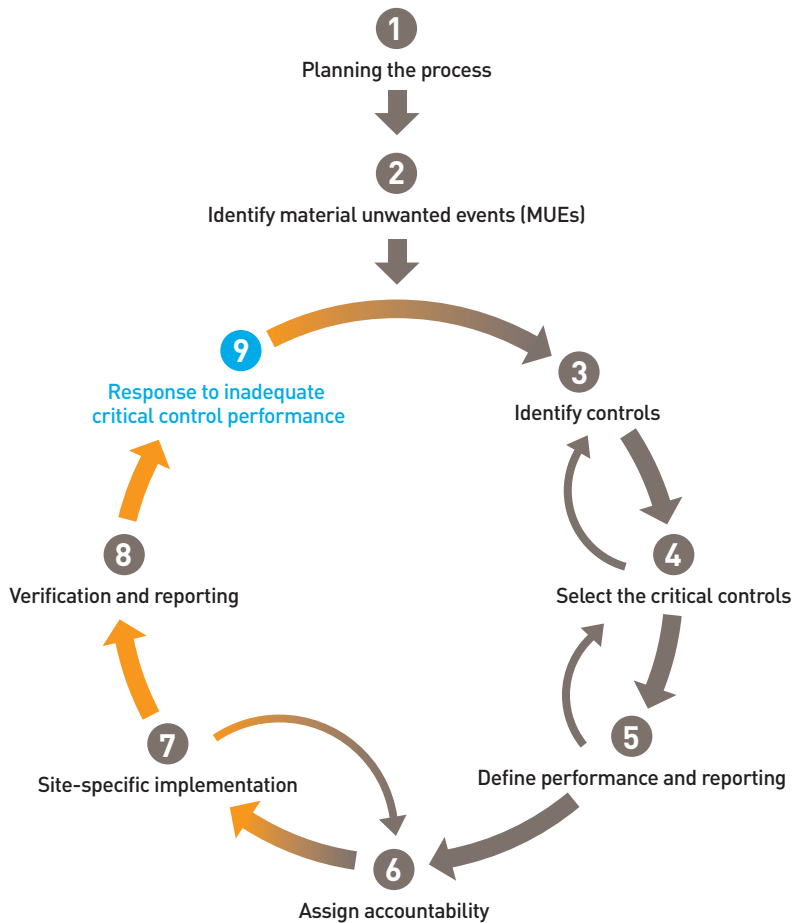
The threshold of unacceptable critical control performance was defined in Step 5 and localized in Step 7. Performance below that threshold should trigger action, which might vary from an investigation to an order to immediately stop the relevant work processes.

# CRITICAL CONTROL MANAGEMENT

## STEP 9: Response to inadequate critical control performance

### Target outcome

Critical control and MUE owners are aware of critical control performance. If critical controls are underperforming or following an incident, investigate and take action to improve performance or remove critical status from controls.



### Key actions

- Take action when critical control performance is inadequate (below the defined trigger threshold).
- Investigate the causes of unacceptable critical control performance.
- Information and data from the investigation should be used to continuously improve the CCM.

The low performance or failure of critical controls must be investigated and understood in order to continuously improve the CCM process. The absence of accidents or incidents must not be taken as evidence that controls are working adequately. Where there is more than one control, a control may fail without any incident occurring because of redundancy in the controls. As a result, the verification process is important to detect controls that are not performing according to the specified requirements.

Where the failure of a critical control is detected following an incident, this could be:

- a hazard or at-risk situation (usually associated with a human action/error)
- a failure of the critical control
- an event that resulted in serious harm or had the potential to cause serious harm.

It may be necessary to review the current site incident investigation methods to ensure that the investigation process includes identification of relevant critical controls, understanding of their status at the time of the event and the causation related to the critical control failure. Many common accident investigation methods may need to be modified for the CCM investigation.

The critical control failure may also trigger a review of the critical control design related to its previously documented objectives and performance requirements.

Following is a sample set of questions for reviewing the critical control design, selection and management after an incident, adapted from BHP Billiton information.

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# CRITICAL CONTROL MANAGEMENT

## STEP 9: Response to inadequate critical control performance *continued*

For the inadequate performance of the critical control in an incident:

- What critical controls failed?
- How did the critical control fail or perform inadequately?
- What were the causes of the failure or inadequate performance of the critical control? In order to determine the cause it can be helpful to ask the “5 Whys”.

Based on the answers to the last question, the following sample critical control questions might also be helpful:

- Was the critical control designed to operate in the incident situation?
- Was the description of the critical control performance requirements adequate?
- Did the defined critical control performance requirements include the management activities that are required to ensure its function in the circumstances of the incident?
- Did the owners and operators of the critical control understand its objective, design and operation (ie are they suitably trained and/or experienced)?
- Was the appropriate critical control documentation available to all relevant control operators?
- Did the verification activities check the status of the control in a manner that could have avoided the incident?
- Did the verification reporting system communicate critical control status prior to the incident to initiate required action and to prevent the incident?

The investigation of critical control failures and a subsequent critical control review process should establish required improvements or changes related to the critical control, including modification of performance requirements and the verification activities, or even replacement of the critical control with another control.

As such, critical control failure investigation and review provides important lessons learned for continuous improvement of the CCM – hence, its circular design.

Note that investigation might also suggest a review of the MUE or the addition of a new MUE, requiring a return to Step 2.

Buy-in from senior executives is a fundamental characteristic of the organizational maturity required to succeed with CCM.



# APPENDIX A

## The CCM journey model and mapping tool

The CCM summary journey model and mapping tool (see Figure A1) is intended to assist a company, business unit or site to benchmark their current CCM maturity.

Managers should use the summary illustration to gain a high-level understanding of the characteristics and the indicators. It can also be used to provide an indication of where the organization is positioned in regard to the CCM journey.

In implementing CCM improvements, the tool provides a useful benchmark for managers to review progress. The implementation plan should also include information on the review cycle for monitoring progress.

Figure A1: Summary illustration of the CCM journey model and mapping tool

GENERAL CHARACTERISTICS	LIMITED CONTROL FOCUS	CONTROL FOCUS	CRITICAL CONTROL FOCUS	CCM PLANNING	WORK PROCESS CCM
Leadership mindsets	Compliance	Compliance but support health and safety recommendations	Seeing value and appreciating the focus	CCM is driven by line leaders	CCM is an accepted, important part of the work process
Individual mindsets	Limited appreciation for the control focus	Limited appreciation for the critical control focus	Engaged in the process and some critical control understanding	Critical controls are an accepted focus	Work methods and CCM are the same
Finding the highest risk unwanted events	Basic historical or proactive methods for priority unwanted events	Systematic historical or proactive methods for priority unwanted events	Effective historical or proactive methods for MUEs	Proactive and lessons learned processes are combined to identify MUEs	Proactive and lessons learned processes identify MUEs
Analyzing controls and identifying the most critical	Controls noted to re-rank risk but no significant control discussion	BTA applied to discuss controls and their effectiveness	Critical controls identified using BTA and effectiveness	Critical controls are identified with objectives and performance requirements	Identified critical controls include information for work process integration
Defining required control performance	No discussion of required control performance	No performance requirements defined	Control information defined, including accountability	Critical control performance requirements defined and the verification process	Integrated critical control information is in work process requirements
Embedding and managing controls	Limited, if any, embedding and monitoring of controls	Some informal or sporadic monitoring of controls	Some monitoring is defined and done for critical controls	All critical controls are systematically embedded and verified and status is reported	Verifying the work process includes critical controls
Improving controls	Sporadic actions related to controls, close out limited	Improved action management but not well linked to controls	Deviations from critical control monitoring generate actions	Any deviations from the CCM planning expectations are investigated and actioned	Acting on deviations in work process includes critical control needs

# APPENDIX B

## Guidance on critical controls

### Method to assess control adequacy

Figure B1 shows a sample control adequacy analysis method developed by an ICMM member. This example includes three control schemes: people based, system based and engineering based.

The illustration shows seven levels of event severity where Level 7 is the highest. It also suggests that the most effective controls for the highest-severity levels are engineering based (or objects), that is Control Level 4, 5 and 6. Note that control levels equate to levels of reliability. This framework can assist with discussion on the adequacy of controls for severe consequences or an MUE.

Following is an overview of the support information for Figure B1.

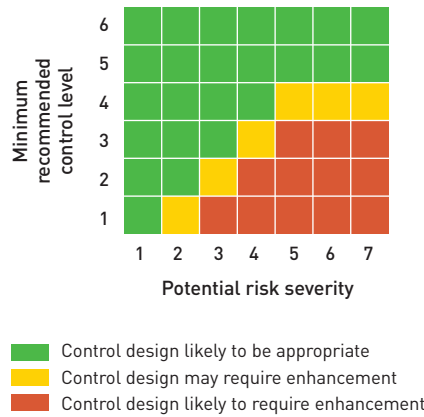
#### People-based controls

These rely on the skills, knowledge and experience of individuals or groups. Control actions (*or acts*) are initiated by individuals based on their skills, knowledge and experience and on their interpretation of the organization's values and objectives. Given the reliance on people, the reliability of people-based controls may vary over time. People-based controls (*or acts*) have three levels of adequacy based on considerations such as degree to which people understand the roles and responsibilities, how skilled and trained they are and the overall level of process discipline. Note that even the highest-level control, a Level 3, is not seen to be adequate for high-severity consequences or MUEs.

#### System-based controls

These are executed by individuals within the bounds of a management system. Execution is based on a prescribed approach either as a common practice or as a defined procedure and in some instances, input from people is governed by system-set rules and protocols. Control reliability is achieved through the system surrounding the control, including management review and follow-up. Systems-based controls potentially range in adequacy from Level 1 to Level 5, where Level 5 is

Figure B1: Example control adequacy analysis method



Sources: BHP Billiton and MMG.

suitable for an MUE. A Level 5 system-based control has a documented procedure including document control, there are system-set rules and protocols (access, authority levels, expected control range), operators are trained in the procedure including periodic assessment, control outcome performance is clearly defined and verified (similar to the suggested CCM approach) and the system design is covered by a rigorous change management process.

#### Engineering-based controls (*or objects*)

These execute automatically and do not require human intervention. Engineering-based controls may include both hardware and automated IT-based controls. Engineering controls are designed to achieve a specific repeatable level of control to a set level of availability. Reliability of engineering controls is achieved through the management system surrounding the ongoing review and improvement of the controls performance. Engineering controls can achieve the highest level of adequacy ranging from 4 to 6. Levels 5 and 6 are suitable for MUEs. These controls are designed and implemented to specific performance criteria (availability and reliability), are managed as part of a preventative maintenance system, have a system-generated alarm/notification in the event of control failure and have management follow-up of system deficiencies, and there is a rigorous management of change.

Response type CONTROL LEVEL	Response by CONTROL SCHEME		
	People based	System based	Engineering based
6	Green	Green	Green
5	Green	Green	Green
4	Green	Yellow	Yellow
3	Green	Red	Red
2	Yellow	Red	Red
1	Red	Red	Red

This method can be used to establish a control level for an individual control by assigning the relevant adequacy rating (green, yellow or red) based on consideration of the control level and potential consequence. The method can be repeated for all controls in the MUE bowtie analysis (BTA). Also, the graphic BTA can be modified to show the relevant colour for each control.

Once every control in the BTA is categorized red, yellow or green, the BTA can be evaluated to consider the overall risk-control strategy. As a guide, tolerable risks will have at least one green control per cause. As a result of applying this control adequacy analysis method to an MUE BTA, there should be an opportunity to:

- confirm that the overall MUE control strategy is adequate and the risk is tolerable, or
- identify causes for which control enhancements are required.

Successful definition of a well-derived BTA for the selected MUE, which includes agreement that the overall control strategy is adequate, will provide the basis for critical control selection in Step 4. An example of a BTA is provided in Figure B2.

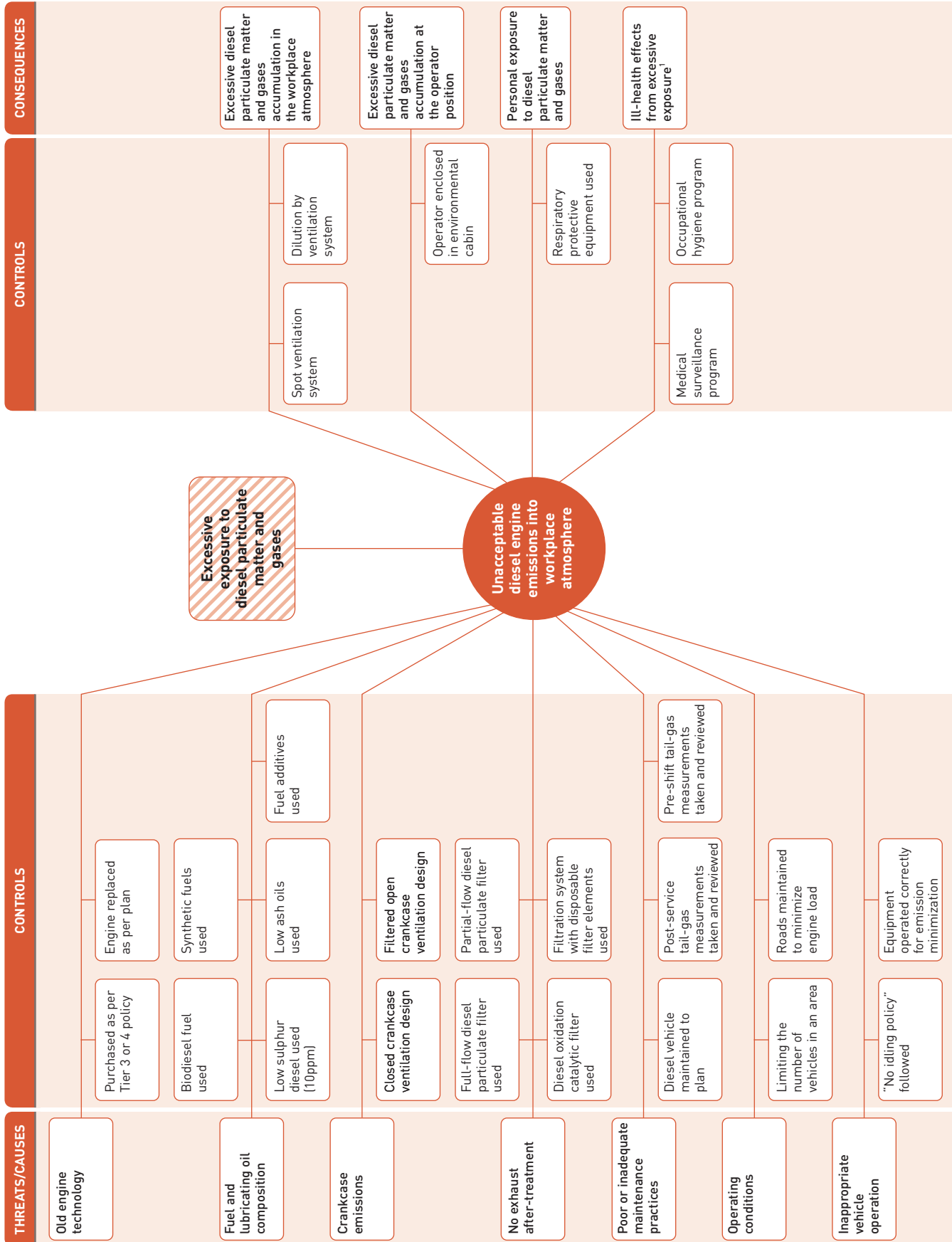
Other analysis methods for examining control design adequacy or overall control effectiveness are available in Hassall, M, Joy, J, Doran, C and Punch, M (2015).



# APPENDIX B

## Guidance on critical controls *continued*

Figure B2: Health BTA example



<sup>1</sup> Occupational hygiene monitoring and medical surveillance are used to monitor the effectiveness of controls on the "left hand" side of the unwanted event but are also regarded as controls if used to reduce the severity of the consequence on the "right hand" side.

# APPENDIX C

## CCM lead and lag indicators

Like other major initiatives, there are two measurement requirements for CCM:

- the impact of the CCM initiative on the problem it is intended to address
- the degree to which the initiative is functioning as expected.

Indicators for measuring the impact of the CCM initiative can be lead and/or lag.

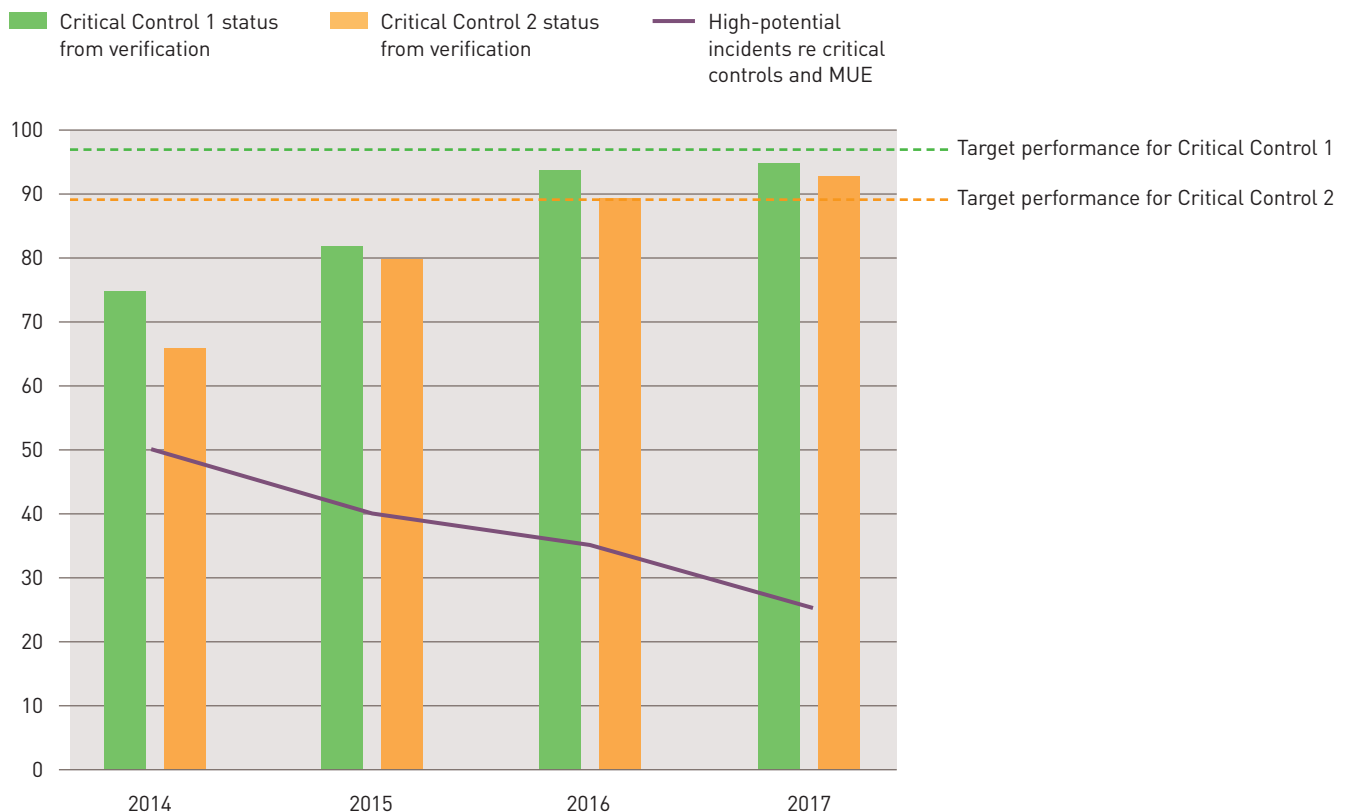
Lag indicators are a common measure of occupational health and safety, though there is recognition of their limitations as a sole measure. CCM targets MUEs. Therefore, the lag indicator could be the frequency of those major events and, possibly, the resultant consequences. Of course, MUEs are rare and, as such, weak measures.

A more effective lag indicator may be found in the frequency of high-potential incidents related to the MUEs. These specific high-potential incidents can be captured, compared to pre-CCM frequency and tracked so the numbers can be trended.

Lead indicators for CCM should be easily found in the reports from critical control verification activities. This “dashboard” information summarizes the performance status of the critical control versus defined expectations. For example, well-defined and executed verification activities could yield information such as critical control performance percentages.

As an example, Figure C1 shows basic annual lag and lead indicators for two critical controls related to a single MUE. The lead indicators for the two critical controls are tracking upward, indicating increasing performance of the critical controls. The lag indicator, high-potential incidents, is tracking downward. Assuming that the high-potential incident reporting culture has not changed, this probably indicates improvement too.

Figure C1: Lag and lead indicators for an MUE



# APPENDIX C

## CCM lead and lag indicators *continued*

The UK HSE suggests that both lag and lead indicators should be used for MUE risk management. The illustration below is from their guide, *Developing process safety indicators* (Health and Safety Executive (HSE) 2006). Their focus is the “risk control system”, which we can consider synonymous with our CCM system – the result of applying the CCM process in this document.

Like the UK HSE, this document recommends that both lag and lead indicators be established to measure the CCM system.

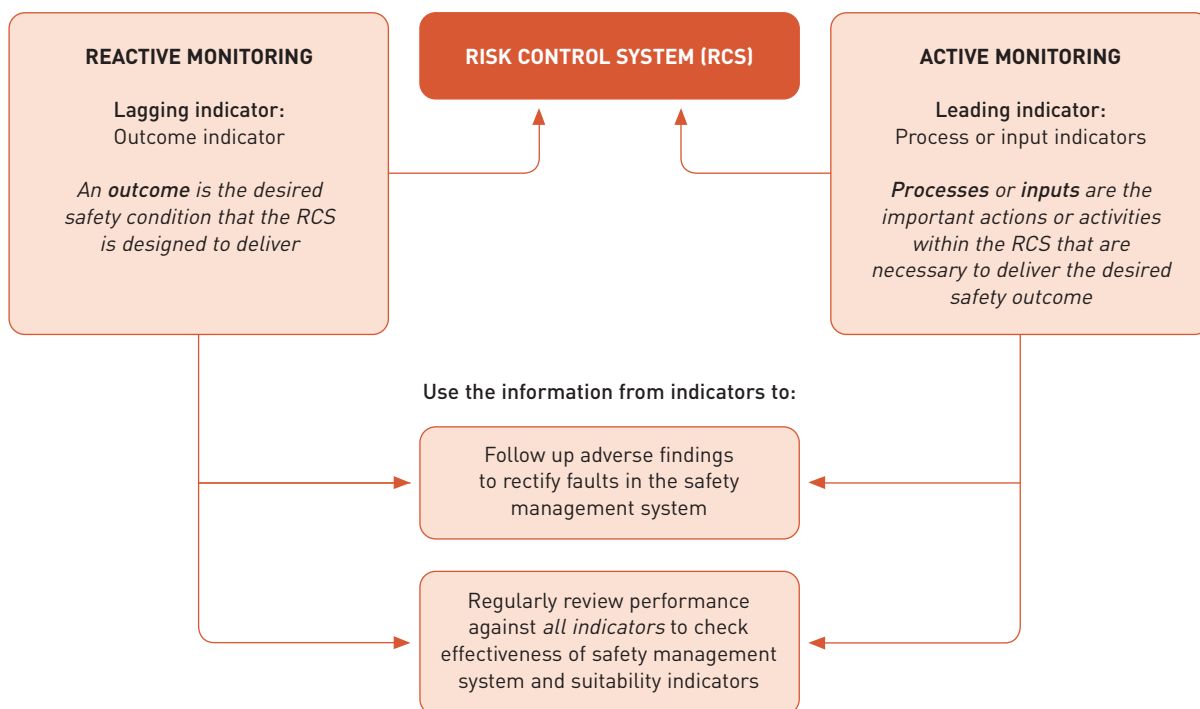
These measures can also be used to define key performance indicators at various levels of the organization. The CCM process defines verification and reporting activities. For additional information relating to the importance of developing key performance indicators, please refer to International Association of Oil & Gas Producers (2011).

This ICMM document also recommends regular review of the entire CCM process and system in order to identify the degree to which the initiative is being implemented and operated to expectations. An annual review of the CCM initiative could involve a gap analysis comparing actual status with the original scope and the detailed execution of all steps in the process, including the measurement of performance and the use of key performance indicators.

This information can also assist with the continuous improvement of the CCM process.

Additional information on leading indicators can also be found in the ICMM publication *Overview of leading indicators for occupational health and safety in mining* (ICMM 2012).

**Figure C2:** UK HSE illustration of “Dual assurance – leading and lagging indicators measuring performance of each critical risk control system”



Source: Health and Safety Executive (HSE) 2006.

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# APPENDIX D

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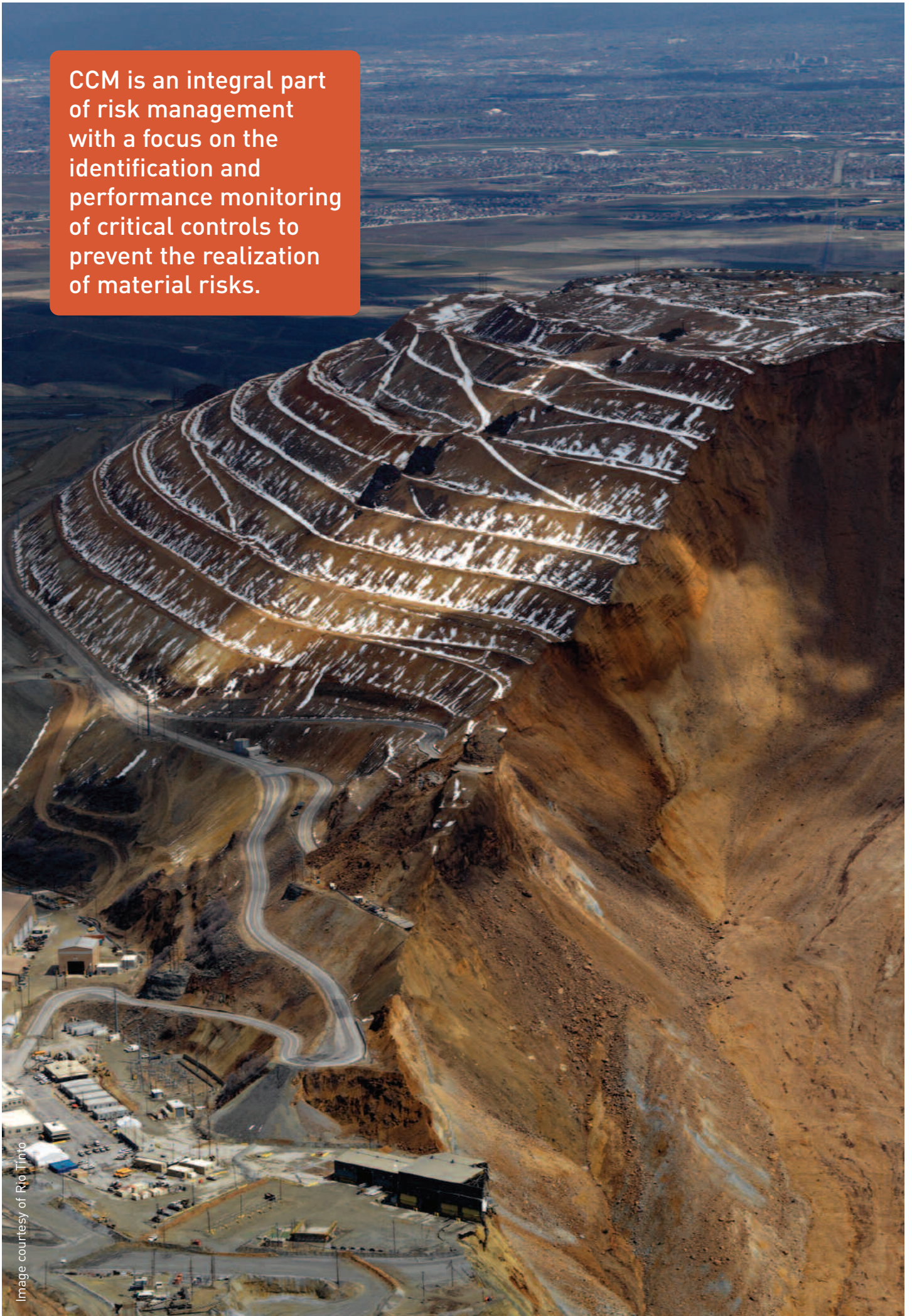
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*Control measures and performance standards*.  
Guidance note N04300-GN0271, Revision no 4.

Available at  
[www.nopsema.gov.au/assets/Guidance-notes/N-04300-GN0271-Control-Measures-and-Performance-Standards.pdf](http://www.nopsema.gov.au/assets/Guidance-notes/N-04300-GN0271-Control-Measures-and-Performance-Standards.pdf).

CCM is an integral part of risk management with a focus on the identification and performance monitoring of critical controls to prevent the realization of material risks.



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## ICMM members

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## Working group

**Chair:** Andrew Lewin (BHP Billiton)  
Nerine Botes Schoeman (African Rainbow Minerals)  
Cas Badenhorst (Anglo American)  
Frank Fox (Anglo American)  
Gareth Williams (Anglo American)  
Craig Ross (Barrick)  
André Fey (Hydro)  
Barries Barnard (Lonmin)  
Phil Stephenson (Newmont)

## Additional technical support

Ian Home (Anglo American)  
George Coetzee (AngloGold Ashanti)  
Felipe Fuentes (Barrick)  
Rob McDonald (BHP Billiton)  
Tony Egan (Glencore)  
Andrew McMahon (Minerals Council of Australia)  
Martin Webb (MMG)  
Ben Huxtable (MMG)  
Anthony Deakin (Rio Tinto)

## ICMM team

Hannes Struyweg and Mark Holmes led the process to develop this document on behalf of the ICMM secretariat. Communication support was provided by Holly Basset and Laura Pocknell.

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Teck

ICMM  
35/38 Portman Square  
London W1H 6LR  
United Kingdom  
Phone: +44 (0) 20 7467 5070  
Fax: +44 (0) 20 7467 5071  
Email: [info@icmm.com](mailto:info@icmm.com)  
[www.icmm.com](http://www.icmm.com)

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