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## CHAPTER 6 INCIDENT MANAGEMENT PLANS (LEVEL 1)

### BACKGROUND

In many countries the national standard for drinking water quality does not require any monitoring of cyanotoxins. The consequence is that many drinking water utilities do not have skilled staff to monitor for cyanobacteria or their toxins and the monitoring of these variables is not included in the routine water quality monitoring programs. Several years ago the clear risk associated with this lack of process lead to the development and implementation of incident management plans (IMPs), based on alert level frameworks (ALFs), in several countries regularly affected by toxic cyanobacteria, in particular Australia and South Africa. These plans enable drinking water suppliers to deal proactively with potentially toxic cyanobacteria in a drinking water source, thus managing the incident and mitigating any risk to consumers. The plans identify a series of actions to be taken in response to various indicators of the progress of a potentially toxic cyanobacterial bloom. These actions include the identification and optimisation of processes that can reduce the potential of cyanotoxins reaching the consumer's tap, as well as the required communication steps (e.g. with the appropriate health authority, consumers).

The Alert Levels Framework is a monitoring and management action sequence that drinking water utilities can use to provide a graduated response to the onset and progress of a cyanobacterial bloom in source water. The alert levels are defined by the value of a parameter directly associated with cyanobacteria, e.g. cell number, cell biovolume or chlorophyll-a concentration. Each value represents a level of risk to drinking water, and will therefore result in an associated level of response, from increased monitoring, to notification of the relevant health authorities, to cessation of potable water supply.

### OVERVIEW OF THE DEVELOPMENT OF ALERT LEVELS FRAMEWORKS

There have been a number of frameworks developed over the past two decades designed to aid in the management of episodes of toxic cyanobacteria in drinking water. The principles on which the various frameworks are based include the monitoring of cyanobacteria either directly or indirectly, supported by cyanotoxin monitoring. Links to several frameworks are given below.

[\*ALF developed by Burch, 1993\*](#)

[\*ALF developed by the World Health Organisation, 1999\*](#)

[\*CIMF developed by Van Baalen and Du Preez 2001\*](#)

[\*Australian national protocol for the monitoring of cyanobacteria and cyanotoxins, DRAFT, developed by Burch et al., 2003\*](#)

### SELECTION AND APPLICATION OF THE APPROPRIATE ALERT LEVELS FRAMEWORK FOR DRINKING WATER PRODUCTION

The first step in the selection of the most appropriate framework is an assessment of the specific drinking water utility capacity (resources, infrastructure and personnel skill) to undertake the various monitoring and analysis activities. This is a desktop study whereby the requirements of each of the proposed approaches are assessed against the capacity of the drinking water utility. Once an ALF has been chosen it can then be modified to suit the capabilities and requirements of each individual water source/treatment plant combination. After the selection and modification of the ALF, the drinking water utility develops personalised

action plans, IMPs, which can be implemented to provide an appropriate and effective response to the presence of cyanobacteria in a drinking water source.

Three recently developed Alert Levels Frameworks, which were based on those listed in the previous section, are presented below for possible selection by a drinking water utility.

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ALERT LEVELS FRAMEWORK USING CYANOBACTERIA CELL COUNTS AS TRIGGER  
(NEWCOMBE *ET AL.* 2009) [1]

This framework follows the development of a potentially toxic cyanobacterial bloom through a monitoring program with associated actions in Alert Levels. The actions accompanying each level include additional sampling and testing, operational options, consultation with health authorities and other agencies, and customer and media releases. The sequence of alert levels is based upon initial detection of cyanobacteria at the Detection Level, progressing to moderate cyanobacterial numbers at Level 1, where notification, additional sampling and assessment of toxicity may occur. For the next stage, at Level 2, the higher cell numbers can indicate the potential for the occurrence of toxins above guideline concentrations. Alert Level 2 represents the point where the operators and health authorities may decide to issue a health warning or notice in relation to suitability of the water for consumption. This would follow a full health assessment and depend upon circumstances such as availability and performance of water treatment, consumption patterns, etc. The sequence can then escalate to Alert Level 3 for very high cyanobacterial biomass in raw water. This level represents the situation where the potential risk of adverse health effects is significantly increased if treatment is unavailable or ineffective. Alert Levels 1 and 2 ideally require an assessment of toxicity and toxins in raw water and assessment of both the drinking water and the performance of the treatment system for toxin removal.

The threshold definitions for this Alert Levels and the recommended associated actions are summarised in Table 6-1, and a flow chart for the implementation of the Alert Levels Framework is given in Figure 6-1.

*[For more details on the actions to be taken at each level follow this link](#)*

Table 6-1 Threshold definitions for a general Alert Levels Framework for management of toxic cyanobacteria in drinking water

Level	Derivation - Background intention	Threshold Definition These apply to a sample location in source water immediately adjacent to the water supply intake <sup>(1)</sup> .	Recommended Actions
<b>Detection Level</b>	<i>LOW ALERT</i>  Detection	$\geq 500$ & $< 2,000$ cells mL <sup>-1</sup> cyanobacteria (Individual species or combined total of any cyanobacteria)  <i>Cyanobacteria detected at low levels</i>	<i>Have another look</i> <ul style="list-style-type: none"> <li>➤ Regular monitoring where a known toxin producer is dominant in the total biomass</li> <li>➤ Weekly sampling and cell counts</li> <li>➤ Regular visual inspection of water surface for scums adjacent to offtakes</li> </ul>
<b>Alert Level 1</b>	<i>MEDIUM ALERT</i>  Potential for these cell numbers or equivalent biovolume to give rise to a toxin concentration that is 1/3 to 1/2 the potential the drinking water guideline concentration for microcystin.	$\geq 2,000$ <sup>(2)</sup> & $< 6,500$ cells mL <sup>-1</sup> <i>Microcystis aeruginosa</i> -or- the total biovolume of all cyanobacteria $\geq 0.2$ mm <sup>3</sup> L <sup>-1</sup> and $< 0.6$ mm <sup>3</sup> L <sup>-1</sup> <sup>(3)</sup> where a known toxin producer is dominant in the total biovolume.  <i>Trigger value for this level can be adjusted for local conditions (see text)</i>  <i>Cyanobacteria detected at levels that indicate that the population is established, and high to very numbers may occur in localised patches due to wind action.</i>	<i>Talk to the health regulators</i> <ul style="list-style-type: none"> <li>➤ Notify agencies as appropriate</li> <li>➤ Increase sampling frequency to 2x weekly at offtake and at representative locations in reservoir to establish population growth and spatial variability in source water</li> <li>➤ Establish the representativeness (ie variability) of the offtake sample over time</li> <li>➤ Decide on requirement for toxicity assessment or toxin monitoring</li> </ul>
<b>Alert Level 2</b>	<i>HIGH ALERT</i>  Potential for these cell numbers or equivalent biovolume to give rise to a toxin concentration that is around or greater than the drinking water guideline	$\geq 6,500$ cells mL <sup>-1</sup> <i>Microcystis aeruginosa</i> -or- the total biovolume of all cyanobacteria $\geq 0.6$ mm <sup>3</sup> /L <sup>(4)</sup> where a known toxin producer is dominant in the total biovolume.	<i>Assess the significance of the hazard in relation to the guidelines</i> <ul style="list-style-type: none"> <li>➤ Advice from health authorities on risk to public health, i.e. health risk assessment considering toxin monitoring data, sample type and variability,</li> </ul>

	<p>concentration for microcystin. Assumes microcystin toxicity is the worst case for potential toxicity in any unknown sample or population of cyanobacteria. This applies whether or not the cyanobacteria present are known toxin-producers.</p>	<p><i>Established bloom of cyanobacteria with the potential for toxin concentration to exceed guideline if the population is toxic and if the available treatment is ineffective.</i></p>	<p>effectiveness of available treatment</p> <ul style="list-style-type: none"> <li>➤ Consider requirement for advice to consumers if supply is unfiltered</li> <li>➤ Continue monitoring as per Level 1</li> <li>➤ Toxin monitoring of water supply (finished water) may be required, dependent upon advice from the relevant health authority</li> </ul>
<p><b>Alert Level 3</b></p>	<p><i>VERY HIGH ALERT</i></p> <p>Potential for these cell numbers or equivalent biovolume to give rise to a toxin concentration that is greater than 10x the drinking water guideline concentration for microcystin.</p>	<p><math>\geq 65,000 \text{ cells m}^{-1}</math>  <i>Microcystis aeruginosa</i>                      -or- the total biovolume of all cyanobacteria <math>\geq 6 \text{ mm}^3/\text{L}</math> <sup>(5)</sup>.</p> <p><i>In circumstances without water treatment, or ineffective treatment, there may be an elevated risk of adverse human health outcomes if alternative water supplies or contingency advanced water treatment is not implemented.</i></p>	<p><i>Assess potential risk immediately if you have not already done so</i></p> <ul style="list-style-type: none"> <li>➤ Immediate notification of health authorities if this has not already occurred at Level 1 or 2</li> <li>➤ Requires advice to consumers if the supply is unfiltered</li> <li>➤ Toxicity assessment or toxin measurement in source water and drinking water supply if not already carried out</li> <li>➤ Continue monitoring of cyanobacterial population in source water as per Level 1</li> <li>➤ In absence of treatment and subject to health risk assessment this level may require alternative contingency water supply</li> <li>➤ Continue toxin monitoring after cell numbers significantly decline (e.g. for 3 successive zero results)</li> </ul>

- 1) The cell numbers that define the Alert Levels are from samples that are taken from the source water location adjacent to, or as near as possible to, the water supply offtake (i.e. intake point). It must be noted that if this location is at depth, there is potential for higher cell numbers at the surface at this or other sites in the source water.
- 2) The variability around a cell count result of 2,000 cells mL<sup>-1</sup> is likely to be in the range 1,000 - 3,000 cells mL<sup>-1</sup>.
- 3) This is based upon a likely precision of +/-50% for counting colonial cyanobacteria such as *Microcystis aeruginosa* at such low cell densities.
- 4) These biovolume values are rounded up to express the value to one significant figure, e.g. 0.17 to 0.2 mm<sup>3</sup> L<sup>-1</sup>; 0.57 to 0.6 mm<sup>3</sup> L<sup>-1</sup>
- 5) This biovolume (> 0.6 mm<sup>3</sup> L<sup>-1</sup>) (rounded up from 0.57) is approximately equivalent to those numbers of *M. aeruginosa* for Level 2
- 6) This biovolume ( $\geq 6 \text{ mm}^3 \text{ L}^{-1}$ ) (rounded up from 5.7) is approximately equivalent to those numbers of *M. aeruginosa* for Level 3

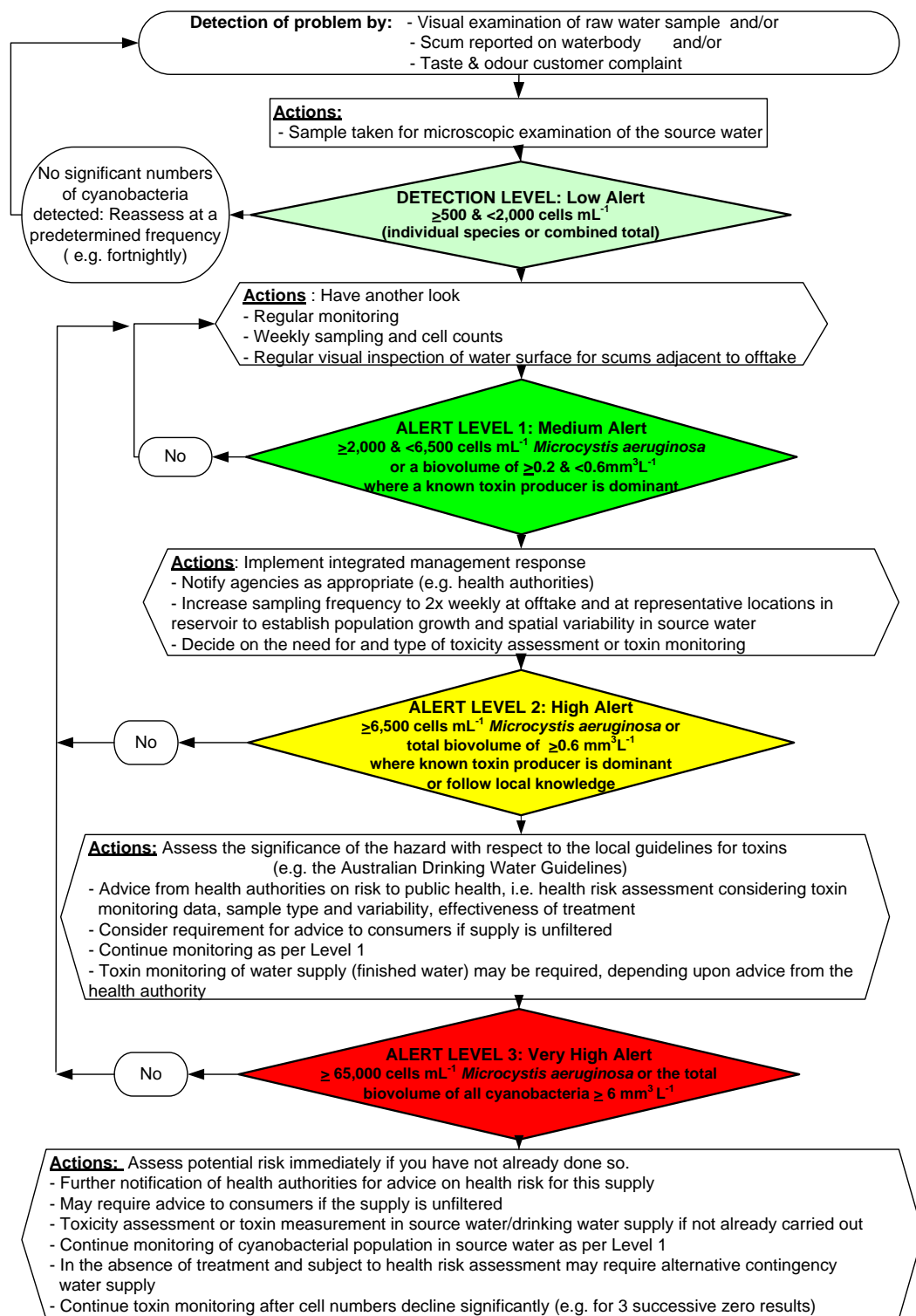


Figure 6-1 Flow chart of the Alert Levels Framework for management of cyanobacteria in drinking water

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## ALERT LEVELS FRAMEWORK USING CYANOBACTERIAL IDENTIFICATION AND ENUMERATION AS PRIMARY TRIGGER (DU PREEZ AND VAN BAALEN 2006) [2]

This Alert Levels Framework consists of various stages of action alerts, namely: Routine monitoring ↔ Vigilance Level ↔ Alert Level 1 ↔ Alert Level 2 ↔ Alert Level 3. Between the routine monitoring level and each action alert there are the primary trigger (cyanobacterial identification and enumeration), secondary trigger (cyanotoxin concentration) and tertiary trigger (mouse test bioassay), which activate the next level and which allow for “movement” (step-up or step-down) between the routine monitoring level and the action alerts.

When cyanobacteria are detected at low concentrations during the routine cyanobacterial and algal monitoring (screening) programme, an alert is raised and the alert actions are activated or “stepped-up” to the Vigilance Level. During the Vigilance Level there is an increase in the frequency of the monitoring activities, as well as an increase in the visual observation for cyanobacterial scum formation. Alert Level 1 is activated on the basis of a cyanobacterial cell concentration ( $> 2000$  cyanobacteria cells  $\text{mL}^{-1}$ ). At this alert level the actions focus on an increase in monitoring activities to include cyanotoxin analysis and the mouse bioassay, and communication and information transfer between the main role-players of the Response Committee ([follow this link for details of the Response Committee](#)). Alert Level 2 is activated when the cyanobacterial cell concentration exceeds  $100\,000$  cells  $\text{mL}^{-1}$  (primary trigger), the presence of cyanotoxins at a concentration higher than  $0.8 \mu\text{g L}^{-1}$  microcystins (secondary trigger). The main actions during this Alert Level include treatment optimisations, continuation of the monitoring program (daily monitoring of cyanobacteria and cyanotoxins), mouse test bioassays and Response Committee meetings (responsible for situation assessment, consideration of actions, communication etc.). Alert Level 3 is activated when the cyanotoxin concentration is higher than  $2.5 \mu\text{g L}^{-1}$  microcystins or when the mouse test is positive. The main actions during this Alert Level are the continued optimisation of the treatment process, daily analyses for cyanobacteria and cyanotoxins as well as performance of the mouse test. The Response Committee meets or communicates on a daily basis to ensure that any executive decisions made are implemented, while the appropriate crisis communication is carried out between governmental departments and the affected consumers. This model also stipulates that alternative drinking water should be supplied when the microcystin concentration in the drinking water is between  $2.5$  and  $5 \mu\text{g L}^{-1}$  for eight consecutive days or exceeds  $5 \mu\text{g L}^{-1}$  for two consecutive days. An important action that is incorporated in this model is the closure of an incident by the Response Committee once it has ended and the water quality has improved to Alert Level 1 or the Vigilance Level.

Figure 6-2 shows the flow diagram depicting alert levels and actions required for this framework.

[For more details on the actions to be taken at each level follow this link](#)

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## ALERT LEVELS FRAMEWORK USING CHLOROPHYLL-A CONCENTRATION AS THE PRIMARY TRIGGER (DU PREEZ AND VAN BAALEN 2006) [2]

For this ALF the primary trigger is chlorophyll-a concentration, while the secondary and tertiary triggers are the same as for 2) above. These frameworks are the same in principle, but differ in minor actions taken, especially in the lower Alert Levels. This framework is not as specific as the cyanobacterial identification and enumeration framework and acts more as a screening tool for the source water. The chlorophyll-a framework may involve the outsourcing of samples for phytoplankton analysis at specified times.

The flow diagram describing this framework is given in the figure below (Figure 6-3).

*[For more details on the actions to be taken at each level follow this link](#)*

*[For an example of a decision matrix that may be used in the application of the preferred ALF, follow this link](#)*

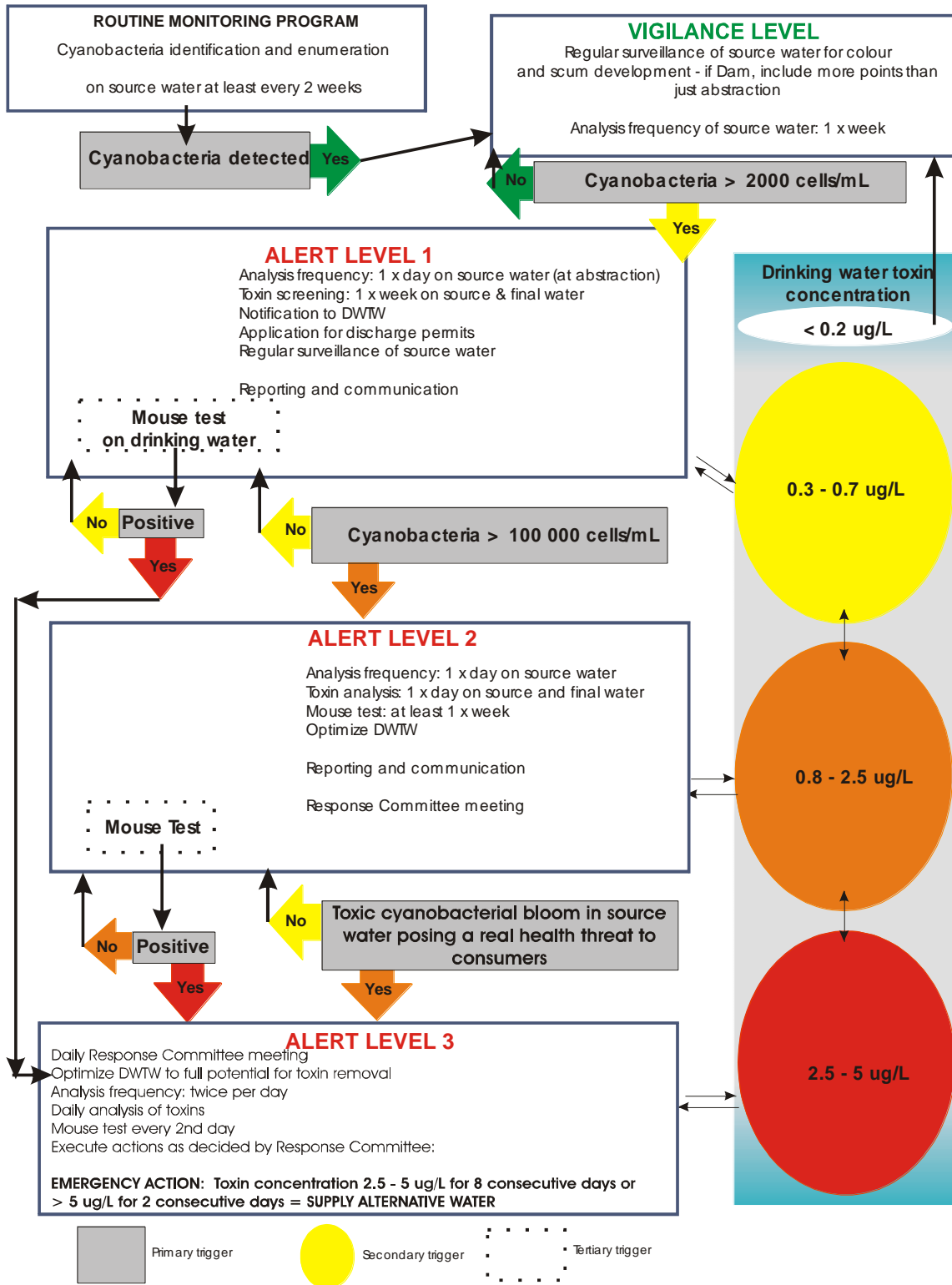


Figure 6-2 Alert Levels Framework using cyanobacterial concentration as primary trigger

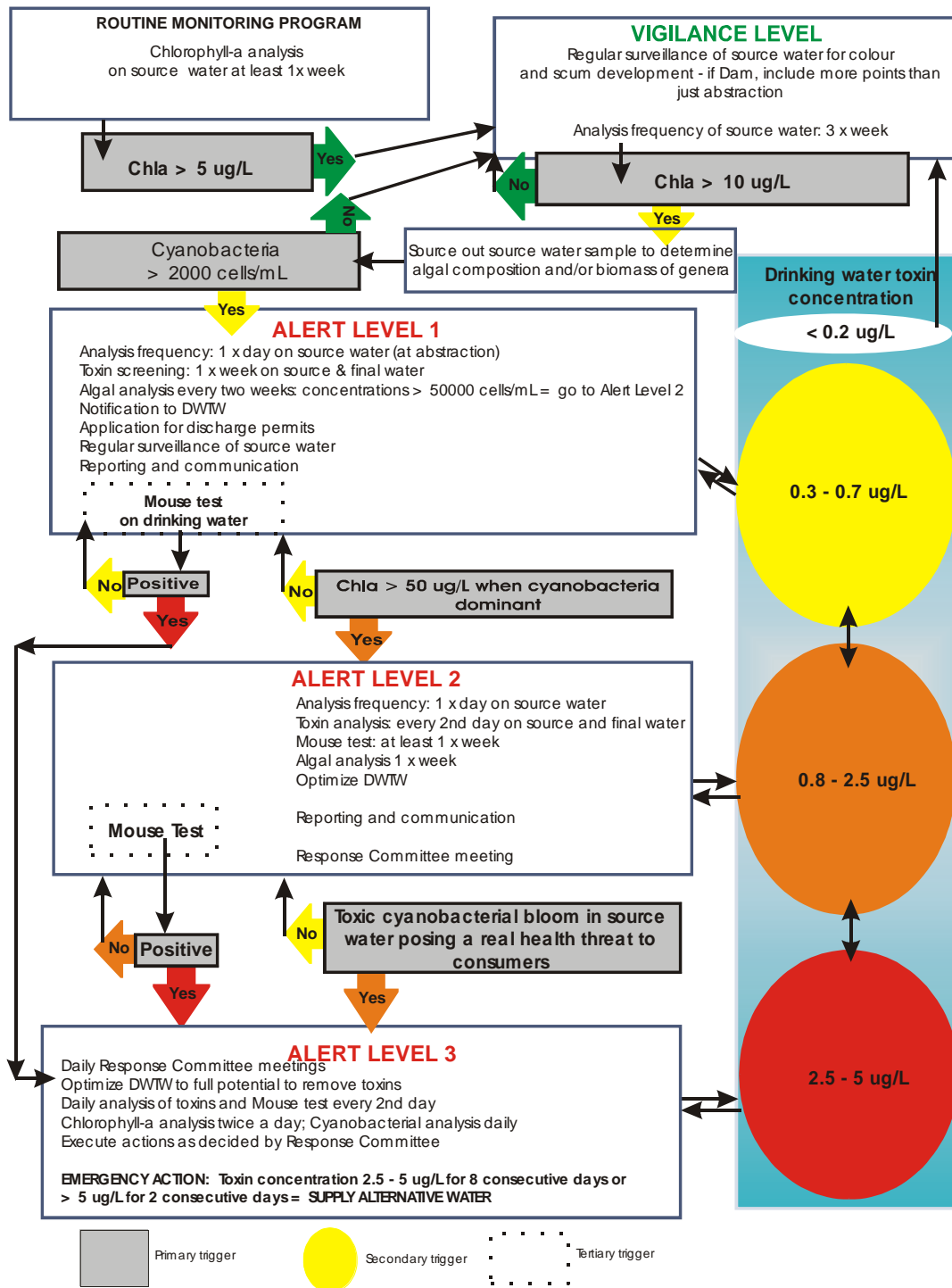


Figure 6-3 Alert Levels Framework using chlorophyll-a concentration as primary trigger

## COMMUNICATION

An essential part of the effective application of an IMP is communication. An example of a communication matrix is given in Figure 6-4.

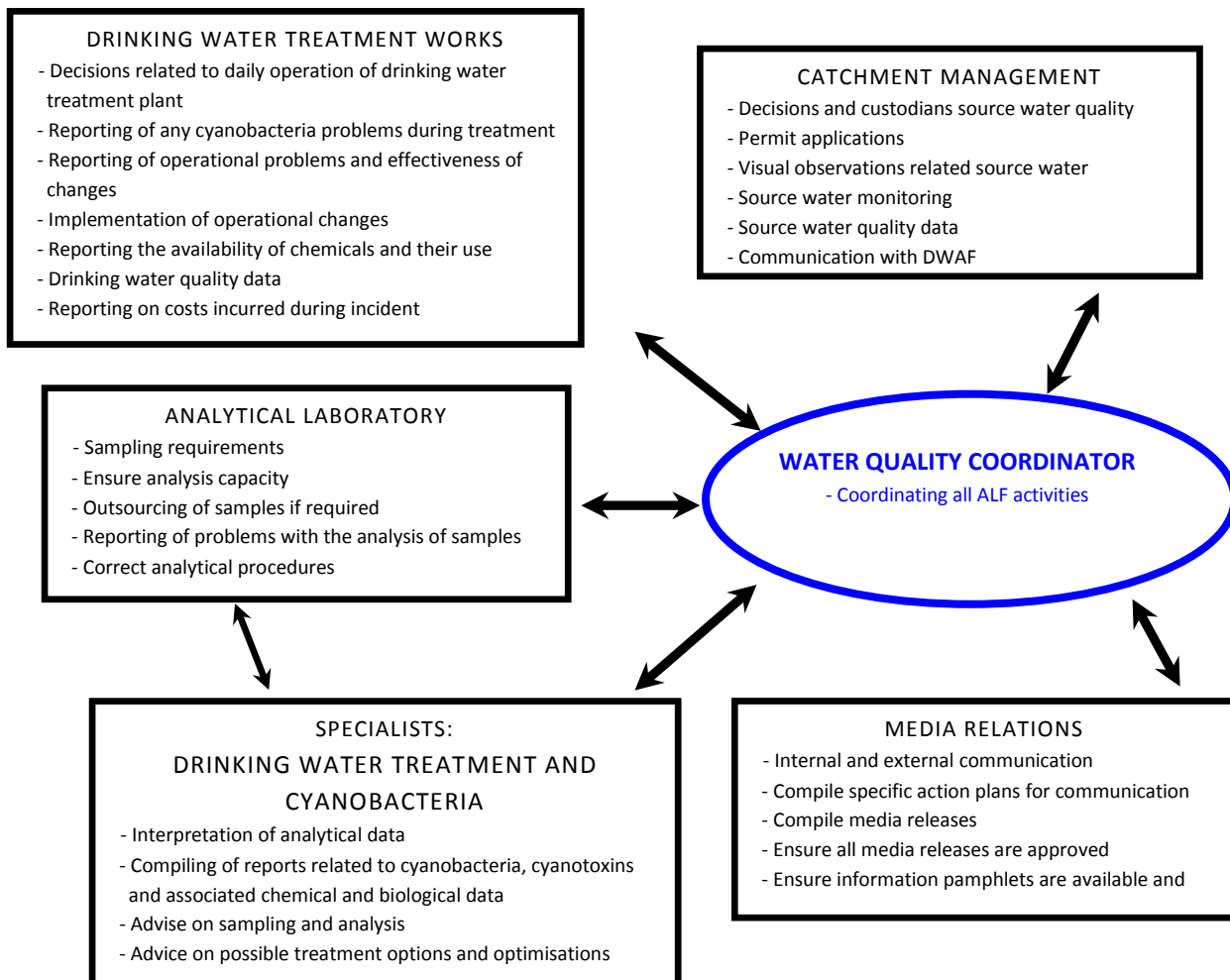


Figure 6-4 Possible communication channels for an ALF [2]

## DEVELOPMENT OF AN INCIDENT MANAGEMENT PLAN

The IMP is based on the chosen framework, and developed to apply specifically to the water utility and each water source and treatment facility. It is recommended that the development of the incident management plans for cyanobacteria be an integral aspect of the application of the overall WHO Water Safety Planning process for the combination of the water source and treatment facility [3]. In particular the treatment systems, or control measures at each facility should be assessed for the ability to reduce toxin concentrations to the required levels, and processes optimised or modified where required. This will be specific to the particular facility and may include offtake variation, powdered activated carbon dosing, increased chlorine dosing.

According to the WHO [3] incident response or management plans should include details such as:

- Accountabilities and contact details for key personnel, often including several organizations and individuals
- Lists of measurable indicators and limit values/conditions that would trigger incidents, along with a scale of alert levels (in the case of cyanobacteria, the appropriate ALF)
- Clear descriptions of the actions required in response to alerts, specific for each facility
- Clear guidelines and procedures for reporting and documentation of actions during an incident
- The location and identity of the standard operating procedures of required equipment (for example PAC dosing facilities)
- Location of backup equipment, if appropriate
- Relevant logistical and technical information
- Checklists and quick reference guides [3]

Ideally the IMP should include a map of the water source including sampling points and critical nutrient inputs, details of the specific treatment processes and potential risks to effective removal of cyanotoxins, and contact details for water quality experts and laboratory personnel that would be required to participate in the management of an incident. All relevant staff should be aware of their responsibilities and trained appropriately, redundancy should be built into the plan in the event that key staff are not available. Communication plans should be reviewed and updated regularly as staff members change. The entire IMP should be reviewed and practised periodically to ensure preparedness of staff to react to a water quality incident. After the application of an IMS during a cyanobacteria event, an investigation, or de-brief should occur involving all staff involved in the management of the incident to identify and correct any inadequacies in the processes.

For an example of a cyanobacteria management plan for Humbug Scrub Reservoir and treatment plant follow this link:

[\*Humbug Scrub Reservoir Algal Management Plan\*](#)

## CHAPTER 6 INCIDENT MANAGEMENT PLANS (LEVEL 2)

### OVERVIEW OF THE DEVELOPMENT OF ALERT LEVELS FRAMEWORKS

#### ALF, BURCH, 1993

In 1993 Burch [4] developed one of the first comprehensive management frameworks based on cyanobacterial cell numbers in the source water. Alert Level 1 is triggered when low numbers (500 to 2000 cells mL<sup>-1</sup>) are detected in the source water, Alert Level 2 when there are moderate numbers (2000 to 15000 cells mL<sup>-1</sup>) and Level 3 when there are persistently high numbers (> 15000 cells mL<sup>-1</sup>), which are toxic. During the Alert Level 1 and Alert Level 2 phases the water supply is considered to be of acceptable quality, but at Alert Level 3 it is considered to be unsafe. The Burch model is further useful to drinking water utilities as it also describes some operational actions (e.g. altering off-take depth, the deployment of booms, the use of PAC, etc.) that could be undertaken, as well as the analyses (e.g. cyanobacteria identification, cyanotoxins analysis) and the consultation that should be undertaken. The Burch model thus formed a generic framework, which could be or has been adapted by many drinking water utilities to include in their specific incident management plans.

#### [Return to level 1](#)

#### ALF, WHO, 1999

In 1999 the World Health Organisation [5] proposed an Alert Levels Framework for cyanobacteria which is also triggered by different cyanobacterial concentrations in the source water, which are then translated into a Vigilance Level, an Alert Level 1 and an Alert Level 2, with appropriate actions and responses. The Vigilance Level is activated when cyanobacteria are detected at low concentrations. The main actions initiated at this level are an increase in monitoring activities and inspection of the source water at the intakes. Alert Level 1 is activated when the cyanobacterial cell concentration is > 2000 cyanobacteria cells/mL, or the chlorophyll-*a* concentration of the source water exceeds 1 µg L<sup>-1</sup>. At these cell or chlorophyll-*a* concentrations it is considered possible that the WHO guideline for microcystin-LR could be exceeded in the source water. At this alert level the main interventions include the expansion of the monitoring program to include cyanotoxin analysis, the feasibility of reducing the intake of cyanotoxins from the source water, an assessment of the capacity of the drinking water treatment works to remove cyanobacteria and cyanotoxins and possible early communications with public health authorities. Alert Level 2 is activated when the cyanobacterial cell concentration exceeds 100 000 cells mL<sup>-1</sup>, the chlorophyll-*a* concentration of the source water exceeds 50 µg L<sup>-1</sup> and the cyanobacteria are toxic. The main actions during this alert level include continuing with the monitoring program and treatment optimisations, consideration of activating alternative water supply plans, increased communication with health authorities and more extensive media releases.

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#### CIMF, VAN BAALEN AND DU PREEZ, 2001

Van Baalen and Du Preez [6] developed a Cyanobacterial Incident Management Framework (CIMF) for drinking water utilities based on the principles of the Burch [4] and WHO [3] models, but adding additional criteria to make it more practical for day-to-day application by drinking water treatment managers. The Van Baalen and

Du Preez CIMF model consists of various action levels, namely: Routine monitoring ↔ Vigilance Level ↔ Alert Level 1 ↔ Alert Level 2 ↔ Alert Level 3. Between each action alert there are primary triggers (phytoplankton identification and enumeration), secondary triggers (cyanotoxin concentration) and tertiary triggers (mouse bioassay test results), which allow for “movement” (step-up or step-down) between the action alerts.

### [Return to level 1](#)

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#### DRAFT NATIONAL PROTOCOL FOR THE MONITORING OF CYANOBACTERIA AND CYANOTOXINS, BURCH *ET AL.*, 2003

In 2003 Burch *et al.* [7] developed a national protocol for the monitoring of cyanobacteria and cyanotoxins in surface fresh waters for use in Australia. This protocol includes an Alert Levels Framework for drinking water supply, information on cyanobacteria, cyanotoxins, sampling procedures and analysis procedures for cyanobacteria and cyanotoxins. The Alert Levels Framework primarily uses the cyanobacterial biomass as trigger between the alert levels, ranging from a Detection Level (cyanobacteria > 500 cells mL<sup>-1</sup>), to Alert Level 1 (cyanobacteria > 2000 cells mL<sup>-1</sup>), to Alert Level 2 (cyanobacteria > 5000 cells mL<sup>-1</sup>), and finally to Alert Level 3 (cyanobacteria > 50000 cells mL<sup>-1</sup>). Biovolumes for the cyanobacteria are also included as trigger values should cell counts not be available. Cyanotoxin analyses are also required throughout the framework and are necessary to assess the risk to the consumer.

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#### SELECTION AND APPLICATION OF THE APPROPRIATE ALERT LEVELS FRAMEWORK FOR DRINKING WATER PRODUCTION

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#### DETAILED ACTIONS OF ALF, NEWCOMBE *ET AL.*, 2009 [1]

##### LEVELS OF THE FRAMEWORK

##### DETECTION LEVEL

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This level encompasses the early stages of bloom development, where cyanobacteria are first detected at low levels in raw water samples. The cell numbers for this level are somewhat arbitrary,  $\geq 500$  cells mL<sup>-1</sup> and < 2,000 cells mL<sup>-1</sup>. Taste and odours may become detectable in the supply, although this does not necessarily indicate the presence of toxic cyanobacteria. If a routine monitoring program is not in place, this is the appropriate time to sample and dispatch the samples to a laboratory for confirmation of the presence of cyanobacteria. If there is no routine program the recommendation for monitoring is to commence weekly sampling and cell counts at a representative location(s) in the water body. The presence of low population densities of cyanobacteria could still mean there is the potential for the formation of localised surface scums, and operators should regularly inspect raw water offtakes for scums or discoloured water.

##### ALERT LEVEL 1

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Alert Level 1 represents the level at which the cyanobacterial population is established, and localised high numbers may occur.

The threshold for this level is a cell number  $\geq 2,000$  cells mL<sup>-1</sup> and  $< 6,500$  cells mL<sup>-1</sup> of *Microcystis aeruginosa* for a sample taken at the source water intake for the drinking water supply, or a total biovolume of all cyanobacteria of  $\geq 0.2$  and  $< 0.6$  mm<sup>3</sup> L<sup>-1</sup> where a known toxin producer is dominant (Table 6-1).

The variability around a cell count result of 2,000 cells mL<sup>-1</sup> is likely to be in the range of 1,000-3,000 cells mL<sup>-1</sup>. This is based upon a likely precision of  $\pm 50\%$  for counting colonial cyanobacteria such as *Microcystis aeruginosa* at such low cell densities. For counting filamentous cyanobacteria such as *Anabaena circinalis* the precision is likely to be much better at these cell densities ( $\sim \pm 20\%$ ), giving an actual likely cell density in the range of 1,600-2,400 cells mL<sup>-1</sup> for a reported result of 2,000 cells mL<sup>-1</sup> (see Chapter 3).

The definition for Level 1 is relatively conservative and has been chosen to indicate a point that represents a cell density providing a buffer, or time margin, of 4-6 days before the guideline for toxin in raw water could be exceeded (i.e. Level 2 conditions) if the population is toxic and is actively growing. This is based upon a population doubling rate of 4 days which is equivalent to a growth rate of  $\mu = 0.17$  d<sup>-1</sup>.

Alert Level 1 may require notification and consultation with health authorities and other agencies for ongoing assessment of the status of the bloom. Contact with health authorities may be made initially when this level is reached, but may not need to be made weekly if local conditions deem this unnecessary. For instance, if the dominant cyanobacterium present is not known to be problematic based on prior testing and experience (e.g. *Aphanocapsa* sp.), this alert level can be adjusted to suit the local situation.

The requirement for information on toxicity assessment at this level will depend upon advice and discussion with health authorities. It will also depend upon circumstances such as: whether the cyanobacteria are known toxigenic species, past history of toxicity, nature of the supply and associated water treatment, local sensitivity in relation to this supply, etc. This consultation should be initiated as early as possible and continue after the results of toxicity testing and/or toxin analysis become available.

The bloom population should be sampled to establish the extent of its spread and variability. Special samples (concentrated scums and/or grab samples representative for the raw water intake) should be collected and dispatched for toxicity testing or toxin analysis.

This level may warrant operational intervention in drinking water supply, such as the deployment of booms adjacent to offtakes, or changing the depth of drinking water abstraction. Mixing or destratification may be useful in some circumstances to reduce cyanobacterial growth. Treatment with algicides may be an emergency measure in some situations and should be restricted to reservoirs only; its applicability also depends upon local environmental regulations.

## ALERT LEVEL 2

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Alert Level 2 is the next stage at slightly higher cell numbers of potentially toxic cyanobacteria. The threshold for Level 2 (in the absence of toxin information) is cell numbers and/or biovolume that could indicate the potential for a toxin hazard at or above the guideline level if:

1. the population was highly toxic, and
2. all toxins were released and water treatment is ineffective for their removal.

This level is characterised in general terms by an established bloom with moderately high numbers showing a trend upwards over several successive samples at sampling frequencies of at least twice per week. The cyanobacterial population is likely to have developed to the extent that localised surface scums may form where scum-forming species are prevalent.

Two thresholds definitions for Level 2 (Table 6-1) are:

- Cell numbers  $\geq 6,500$  cells  $\text{mL}^{-1}$  for *Microcystis aeruginosa* or
- Total biovolume of other cyanobacteria of  $\geq 0.6$   $\text{mm}^3 \text{L}^{-1}$ , where a known toxin producer is dominant or for local conditions (Note that this is given at 1 significant figure)

The cell numbers for Level 2 ( $\geq 6,500$  cells  $\text{mL}^{-1}$ ) are the preliminary "hazard surrogates" given in the Australian Drinking Water Guidelines (ADWG) for toxic *Microcystis aeruginosa* equivalent to the microcystin guideline of  $1.3 \mu\text{g L}^{-1}$  (Fact Sheet 17a) [8]. The approximate biovolume of  $0.6 \text{mm}^3$  for other cyanobacteria (toxigenic or of unknown toxicity status) is equivalent to  $6,500$  cells  $\text{mL}^{-1}$  of *M. aeruginosa*. This biovolume of cyanobacterial cells could be equivalent to the ADWG guideline for microcystins if the cyanobacteria was found to be toxic and to produce microcystins. Furthermore, it is assumed that for blooms and populations of uncharacterised cyanobacteria, the hazard from toxicity is unlikely to exceed the worst case for an equivalent biovolume of highly toxic *Microcystis aeruginosa* containing microcystin. Therefore using this biovolume as indicator of potential toxin hazard in the first instance should allow protection from significant risk while further assessments are made.

As more information about toxicity of different cyanobacteria becomes available it is also possible to develop more specific definitions of Alert Levels for different species of toxic cyanobacteria.

Alert Level 2 represents the point where the operators and health authorities may decide to issue a health warning or notice in relation to suitability of the water for consumption. This would follow a health assessment and depend upon circumstances such as availability and performance of water treatment, consumption patterns, etc. It is also possible that an operator may decide to issue advice or a notice at cell numbers lower than these thresholds.

It may be acceptable to continue to supply drinking water from source water even with a positive toxicity result, dependent upon a risk assessment by the health authorities that may recommend specific action to protect more susceptible population groups. The operational interventions at this level are the same as those for Alert Level 1.

### ALERT LEVEL 3

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The threshold definition for Alert Level 3 is cell numbers of  $\geq 65,000$  cells  $\text{mL}^{-1}$  of the toxic species *M. aeruginosa* (i.e. toxins confirmed by analytical or bioassay techniques) in the raw water adjacent to the offtake. Alert Level 3 is alternatively defined by the total biovolume of other toxic cyanobacteria  $\geq 6$   $\text{mm}^3 \text{L}^{-1}$  (see Table 6-1). The cell number for Level 3 represents ten times the Australian Drinking Water Guidelines for toxic *Microcystis aeruginosa* (Fact Sheet 17a) [8] of  $6,500$  cells  $\text{mL}^{-1}$ , and is also equivalent to approximately  $13 \mu\text{g L}^{-1}$  microcystin-LR. This describes an established toxic bloom with high cell numbers and possibly localised scums. The sampling program will have indicated that the bloom is widespread with no indication of a cyanobacterial population in decline in the short term. Conditions in Level 3 are indicative of a significant increase in the risk of adverse human health effects from the water if it were untreated, or treated by an ineffective system, even for short-term exposure.

The cell count in Level 3 can be a trigger for the immediate notification to health authorities, but this would only be in a situation where this has not occurred earlier (at Level 1 or 2). This would occur where there was no prior information from an ongoing monitoring program, and treatment is limited or its performance for toxin removal is untested. This could be a scenario where a one-off sample or result is the initial discovery of a major bloom in the source water. By definition the circumstances for Level 3 are that there is some potential for adverse public health outcomes if these high numbers are present in the source water or supply combined

with the nature of the water treatment, the population sensitivity, and their consumption patterns. High cell numbers also mean there is potential for much higher localised concentrations, i.e. surface scums and, depending upon the position of the offtake, this could then mean that very high cell numbers could be entering the supply for short periods and this may not be captured by the monitoring program.

If activated carbon (powdered or granular) or an advanced oxidation process such as ozone is available in the treatment process, it is likely it will be needed at this level. The treated water should be monitored for the specific cyanotoxins occurring in the source water to confirm their removal.

The application of algicides in this phase can potentially enhance problems for treatment by releasing high concentrations of dissolved toxins as a result of cell rupture. Where coagulation and filtration systems generally remove cell-bound toxins, dissolved toxin is more likely to break through the treatment system (Chapter 5).

If water treatment is unsatisfactory for toxin removal, and toxins are present in supply at concentrations significantly above the guideline then Level 3 may result in the activation of a contingency water supply plan that is appropriate for the operator and the system. This may involve switching to an alternative supply for human consumption, or in some circumstances the delivery of safe drinking water to consumers by tanker or in bottles. More extensive media releases and even direct contact with appropriate advice to customers may be necessary. Where advice is provided to the public because of a cyanobacterial hazard to human health it may be appropriate to indicate that the water would be suitable for purposes such as washing, laundry, toilet flushing etc. Closure of a public drinking water supply because of a cyanobacterial hazard in source water is not likely to be justified since potential hazards from disruption of supply (public hygiene and fire-fighting, etc.) are likely to be worse than the cyanobacterial hazard.

Monitoring of the bloom should continue, to determine when it is in decline, so that normal supply can be resumed. Monitoring is usually only warranted at 3-7 day intervals. Experience suggests that the toxicity of a cyanobacterial population can change, but it is unlikely to become completely non-toxic or to decline in a period of a few days.

The sequence of actions at Level 3 should follow through to deactivation of an emergency with advice and media releases to confirm this. It is possible that the collapse of a bloom, or management action such as flushing and control of scum, could lead to a rapid decline from Level 3 back to Level 1 or beyond. Likewise the sequence might escalate rapidly, bypassing Level 1 & 2, if adequate monitoring and early warning information is not available.

## CUSTOMER AND MEDIA INFORMATION

Providing information to consumers and media liaison are important aspects of managing water quality problems associated with cyanobacterial blooms. Information should be prompt and concise with detail about reasons for changes to supply and explanation for any differences in water quality. It is important for all of the agencies involved to provide coordinated and consistent advice.

The Alert Levels Framework suggests a number of points where media releases could be issued. These are in situations where consumers may experience changes in water quality, e.g. due to changes in source water quality, switching to another source water, changes in treatment, implementation of a contingency plan, or warning notices for recreational use of the source water.

The approach to releasing information will depend on the nature of the supply and the problem. For example, in major urban water supplies with sophisticated treatment infrastructure, it may not be necessary to advise

consumers, as water quality changes will not be evident. In circumstances with limited treatment, as is often the case in rural or remote areas, or if the bloom occurs in a multiple use water resource (for instance, those also used for recreation) it is important to inform consumers of the extent of the problem as part of the management strategy.

[\*Return to level 1\*](#)

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## DETAILED ACTIONS FOR THE ALERT LEVELS FRAMEWORK USING CYANOBACTERIAL IDENTIFICATION AND ENUMERATION AS PRIMARY TRIGGER (DU PREEZ AND VAN BAALEN 2006) [9]

### ROUTINE MONITORING LEVEL

Routine monitoring refers to monitoring of the primary trigger namely cyanobacterial identification and enumeration, which is performed on the source water sample from the abstraction point at least once every two weeks. If the analysis can be performed more frequently, that would be an advantage. When a drinking water treatment works is prone to experiencing cyanobacterial/algal-related problems, or has a history of problems in their source water during summer and autumn months, it is recommended that cyanobacterial identification and enumeration analysis is included in the routine source water monitoring program.

### ANALYSIS

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Cyanobacterial identification and enumeration should be performed on the source water at least once every two weeks. It would be an advantage if this was performed more frequently.

### STEPPING-UP ACTIVATION

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When cyanobacteria are detected during the routine cyanobacterial analysis then the alert is stepped-up to the Vigilance Level

### VIGILANCE LEVEL

#### REGULAR SURVEILLANCE OF SOURCE WATER

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The reservoir, lake or river from which the source water is abstracted should be surveyed for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacterial growth). The first site that should be examined is the area around the abstraction point. However, areas close to the shore are usually good places to detect increased algal growth because of the concentration effect in shallow waters. The reason for “looking” for scum development in other areas of a reservoir is that many cyanobacterial species can concentrate in the top layers of the water because of the presence of gas vacuoles and can quite easily be transported by the wind from one location in a dam to another. Therefore, even though cyanobacteria may not be spotted at the abstraction point, this situation can easily change over a short period of time (within hours) by a change in the wind direction whereby a bloom present in another area of the dam will concentrate in the abstraction area.

In a river, the bloom develops as the water moves downstream and then appears at an abstraction point for a short period (pulse or plug flow). In some slow-flowing rivers frequent monitoring supports the detection of increases in cyanobacterial concentration over time. When a river has weirs or naturally-impounded areas it is more likely that cyanobacteria- and algal-related problems will occur there, if they are going to occur at all. People abstracting water along the rivers can also establish a network between companies, and the local community (then it is important to select a central coordinator), whereby the upstream users can notify the downstream users if a “pocket” of high cyanobacterial or algal biomass is seen moving downstream.

## ANALYSIS

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Cyanobacterial identification and enumeration should be performed at least once per week on the source water.

## STEPPING–UP ACTIVATION

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When the cyanobacterial concentration of the source water exceeds 2000 cells mL<sup>-1</sup>, the alert must be stepped-up to Alert Level 1.

## STEPPING–DOWN ACTIVATION

---

When cyanobacteria are not detected for 14 consecutive days during the routine cyanobacterial analysis of the source water then the alert is stepped-down to the routine monitoring level.

## ALERT LEVEL 1

## REGULAR SURVEILLANCE OF SOURCE WATER

---

Increase the surveillance of the reservoir (as described under Vigilance Level), from which the source water is abstracted to at least once a week for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacterial growth).

## ANALYSIS

---

Cyanobacterial identification and enumeration analysis must be performed daily on the source water at the abstraction point.

## CYANOTOXIN SCREENING/ANALYSIS

Cyanotoxin screening refers to the determination of cyanotoxin concentration. It is important to perform a cyanotoxin analysis on the source and the final water. The more comprehensive the better, as appropriate management is more effective when the data are more representative. Results from the source water will indicate if there are any cyanotoxins present and results from the final water will indicate how well the process is performing in removing these toxins (if at all) as well as the potential risk to the consumer.

The frequency of analysis should be at least once per week. If the drinking water utility does not have the capacity to perform cyanotoxin analysis it is important to outsource the samples to laboratories that have that capacity.

## MOUSE TEST BIOASSAY

If feasible, a mouse test bioassay is performed to establish whether a water sample has a toxic effect on a mouse. A mouse test bioassay is performed at least on the drinking water during cyanobacterial dominance in the source water. The main objective with the mouse test bioassay is to confirm that no other cyanotoxins are present.

## NOTIFICATION TO DRINKING WATER TREATMENT WORKS (DWTW)

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The manner in which the “Notification to DWTW” will be executed will proactively be defined by the Response Committee, which would in turn be determined by the size and communication structures of the drinking water utility. The responsibilities of the various role-players must be defined as in the decision matrix, which forms part of the Incident Management Plan of the drinking water treatment works. The notification should be documented and traceable and ideally should include the following:

- Background information including historical data related to previous incidents
- Current trends in the relevant water quality data related to the specific DWTWs
- Prediction in terms of immediate and short-term possibilities of cyanobacterial bloom formation
- Recommendations for possible actions (e.g. ensure sufficient coagulant is available, ensure staff are aware and ready to react at short notice, ensure all steps in process are optimised and are in working condition, etc.) that can be taken into consideration in order to prepare for a cyanobacterial incident
- Reference to the ALF that has been developed for the specific DWTW.

## DISCHARGE PERMITS

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Should a cyanotoxin incident occur, it is likely that a decision will be taken not to recycle filter backwash water or sludge supernatant back to the head of the DWTW but to store the water on-site in holding dams or to discharge the waste water into the river or reservoir/dam below the point of abstraction. No discharges are permitted without a valid permit. It is also recommended that the process of obtaining a discharge permit be initiated in a proactive manner as this can be a very lengthy process.

## REPORTING AND COMMUNICATION

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The communication and reporting that must be initiated will have been defined proactively by the Response Committee, which would in turn be determined by the size and the communication structures of the water utility. At this Alert Level there should already be some communication between the water quality coordinator, the specialist on cyanobacteria and drinking water treatment, the analytical laboratory staff and the DWTW Manager.

## STEPPING-UP ACTIVATION

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When the cyanobacterial concentration in the source water exceeds  $100\,000\text{ cells mL}^{-1}$  then actions should be stepped-up to Alert Level 2.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water exceeds  $0.7\ \mu\text{g L}^{-1}$  then actions should be stepped-up to Alert Level 2.

OR

When the mouse test bioassay is positive for cyanotoxins in the drinking water then actions should be stepped-up to Alert Level 3.

## STEPPING-DOWN ACTIVATION

---

When the cyanobacterial concentration in the source water decreases to below 2000 cells mL<sup>-1</sup> for at least 14 consecutive days, the cyanotoxins (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is < 0.2 µg L<sup>-1</sup> for 14 consecutive days and the mouse test bioassay is repeatedly negative for the drinking water, then actions should be stepped-down to the Vigilance Level.

Note: When stepping-up or -down from one Alert Level to the next it is important always to use the primary trigger (in this ALF: cyanobacterial concentration in the source water) as default analysis to determine which actions to take. However, should the cyanotoxin concentration exceed the concentration limits of the Alert Level in which it is operating based on the primary trigger then the secondary trigger (cyanotoxin concentration) overrides the primary trigger and the actions should be performed at the Alert Level specified by the secondary trigger. Similarly, should the mouse test bioassay be positive, then the tertiary trigger (mouse test bioassay) overrides the primary trigger and the actions should be performed at the Alert Level specified by the tertiary trigger. Should the concentration of the secondary trigger decrease to lower Alert Levels (or should the tertiary trigger be repeatedly negative) then actions should revert back to the appropriate Alert Level as dictated by the results of the primary trigger.

## ALERT LEVEL 2

### REGULAR SURVEILLANCE OF SOURCE WATER

---

Increase the surveillance of the reservoir, lake or river from which the source water is abstracted. This should be surveyed at least weekly at the abstraction point and surrounding area for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacterial growth).

### ANALYSIS

---

Cyanobacterial identification and enumeration analysis must be performed daily on the source water at the abstraction point.

### CYANOTOXIN SCREENING/ANALYSIS

Cyanotoxin analysis is performed daily on the source water and the drinking water (also see Section under Alert Level 1). If the drinking water utility does not have the capacity to perform cyanotoxin analysis it is important to outsource the samples to laboratories that have the required capacity

### MOUSE TEST BIOASSAY

Mouse test bioassay is performed at least once a week on the drinking water (also see Section under Alert Level 1).

## OPTIMISATION OF THE DRINKING WATER TREATMENT PROCESS

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The optimisations that should be considered fall into the following broad categories: 1) actions on the abstraction of the source water (e.g. manipulation of the abstraction depth), 2) optimisation of the conventional treatment process (e.g. stop pre-treatment with oxidants, optimisation of coagulation, flocculation, sedimentation, filtration and flotation processes, optimisation of disinfection) and 3) the use of advanced treatment processes (e.g. ozone, powdered activated carbon etc.). If the possible optimisation process that could be implemented has already been done during the development of the ALF, then the main

focus would be to ensure that the actions are implemented and are functioning optimally to ensure that the drinking water utility can effectively remove cyanobacteria and cyanotoxins from the source water as soon as the cyanobacteria numbers increase.

## RESPONSE COMMITTEE MEETING

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A meeting of the Response Committee is convened at Alert Level 2. At their first meeting it is important 1) to familiarise each member with the Incident Management Plan, 2) to clarify their roles and responsibilities and 3) to update contact information. The Response Committee discusses the current situation based on the available data, determines the appropriate actions that must be taken and identifies any problems that may hinder the implementation of those actions. Dates for feedback and follow-up meetings are set. Formal minutes of the meeting are kept.

## DISCHARGE PERMITS

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If the discharge permit has not been received from the relevant governmental authority, the Response Committee decides on the course of action to obtain it (see comments under Alert Level 1).

## REPORTING AND COMMUNICATION

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The reporting and communication focus on internal reporting and communication to ensure that information is shared and any actions are speedily taken and implemented.

## STEPPING-UP ACTIVATION

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When the cyanobacterial concentration in the source water consistently exceeds 100 000 cells mL<sup>-1</sup>, and scum forms in the source water and the cyanobacteria have been shown to be toxic then actions should be stepped-up to Alert Level 3.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is between 0.8 and 2.5 µg L<sup>-1</sup> for more than 14 days, then actions should be stepped-up to Alert Level 3.

OR

When the cyanotoxins (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water exceeds 2.5 µg L<sup>-1</sup> for more than 4 days, then actions should be stepped-up to Alert Level 3.

OR

When the mouse test bioassay is positive for cyanotoxins in the drinking water then actions should be stepped-up to Alert Level 3.

## STEPPING-DOWN ACTIVATION

---

When the cyanobacterial concentration in the source water decreases to below 100 000 cells mL<sup>-1</sup> for at least 14 consecutive days, the cyanotoxins analyses (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is < 0.8 µg L<sup>-1</sup> for 14 consecutive days and the mouse test bioassays is repeatedly negative for the drinking water then actions should be stepped-down to Alert Level 1.

## ALERT LEVEL 3

### REGULAR SURVEILLANCE OF SOURCE WATER

---

Surveillance (see also Vigilance Level) of the reservoir, lake or river from which the source water is abstracted should be undertaken at least daily at the abstraction point and surrounding area for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacterial growth).

### ANALYSIS

---

Cyanobacterial identification and enumeration analysis must be performed twice a day (early morning and late afternoon) on the source water at the abstraction point. A depth profile of the cyanobacterial cell concentration in the source water column must be determined (e.g. when abstracting from a dam), and thereafter a series of profiles (at least 4) over a 24 hour period must be performed to optimise the abstraction, as the cyanobacterial cell concentrations may show diurnal depth variation.

### CYANOTOXIN SCREENING/ANALYSIS

Cyanotoxin analysis is performed daily on the source water and the drinking water (also see Section under Alert Level 1). If the drinking water utility does not have the capacity to perform cyanotoxin analysis it is important to outsource the samples to laboratories that have the required capacity.

### MOUSE TEST BIOASSAY

A mouse test bioassay can be performed on the drinking water on every alternative day (also see Section under Alert Level 1).

### OPTIMISATION OF THE DRINKING WATER TREATMENT PROCESS

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The following processes must function at their optimal capacity: 1) the abstraction of source water (e.g. manipulation of the depth of abstraction or the use of an alternative source), 2) the conventional treatment process (e.g. stop pre-treatment with oxidants, optimisation of coagulation, flocculation, sedimentation, filtration and flotation processes; optimisation of disinfection), 3) the use of advanced treatment processes (e.g. ozone and powdered activated carbon) and the discarding of filter backwash water.

### RESPONSE COMMITTEE MEETING

---

The Response Committee should meet daily during this Alert Level to evaluate the success of measures implemented and to decide if further actions should be taken. Special attention should be given to solving optimisation problems that are being experienced, alternative actions that can be implemented and to communication with external role-players (Department of Health, Department of Water Affairs, customers and the general public). Formal minutes of the meeting are kept.

## DISCHARGE PERMITS

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If the discharge permit has not been received from the relevant governmental authority, the Response Committee decides on the course of action to obtain this (see comments under Alert Level 1).

## REPORTING AND COMMUNICATION

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Reporting and communication focus on both internal and external stakeholders (Department of Health, Department of Water Affairs, customers and the general public) to ensure that information is shared and any actions are speedily taken and implemented.

## EMERGENCY ACTION

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When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is between 2.5 and 5  $\mu\text{g L}^{-1}$  for more than 8 days then an alternative drinking water source must be supplied.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water exceeds 5  $\mu\text{g L}^{-1}$  for more than 2 days then an alternative drinking water source must be supplied.

## STEPPING-DOWN ACTIVATION

---

When cyanobacterial scum formation in the source water is not evident for at least 14 consecutive days, the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is less than 2.5  $\mu\text{g L}^{-1}$  for 14 consecutive days and the mouse test bioassays are repeatedly negative for the drinking water then actions should be stepped-down to Alert Level 2.

## CLOSING PROCEDURE

When the conditions as described for Alert Level 1 occur after a cyanobacterial incident, then the Response Committee should close the incident. This would include a formal report describing the incident, the actions that were taken and the recommendations for improvements to the CIMF as well as preventative actions. All role-players must receive the final communication of the closure of the incident.

[\*Return to level 1\*](#)

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## DETAILS OF ALERT LEVELS FRAMEWORK USING CHLOROPHYLL-A CONCENTRATION AS THE PRIMARY TRIGGER (DU PREEZ AND VAN BAALEN 2006) [2]

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### ROUTINE MONITORING LEVEL

Routine monitoring refers to monitoring of the primary trigger namely chlorophyll-a concentration, which is performed on the source water sample from the abstraction point at least once every week. If the analysis can be performed more frequently that would be an advantage. When a drinking water treatment works is prone to experiencing cyanobacterial/algal-related problems, or has a history of problems during summer and autumn months in the source water it is recommended that chlorophyll-a is included in their routine source water monitoring program.

### ANALYSIS

---

Chlorophyll-a analyses should be performed at least once per week on the source water. It would be an advantage if this were done more frequently.

### STEPPING-UP ACTIVATION

---

When the chlorophyll-a concentration detected during routine monitoring exceeds  $5 \mu\text{g L}^{-1}$  then the alert is stepped-up to the Vigilance Level.

### VIGILANCE LEVEL

#### REGULAR SURVEILLANCE OF SOURCE WATER

---

The reservoir, lake or river from which the source water is abstracted should be surveyed for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacterial growth). The first site that should be examined is the area around the abstraction point. However, areas close to the shore are usually good places to detect increased algal growth because of the concentration effect in shallow waters. The reason for “looking” for scum development in other areas of a reservoir is that many cyanobacterial species can concentrate in the top layers of water (because of the presence of gas vacuoles) and can quite easily be transported by the wind from one location in a dam to another. Therefore, even though cyanobacteria may not be spotted at the abstraction point, this situation can easily change over a short period of time (within hours) by a change in the wind direction whereby a bloom present in another area of the dam will concentrate in the abstraction area.

In a river, the bloom develops as the water moves downstream and then appears at an abstraction point for a short period (pulse or plug flow). In some slow-flowing rivers frequent monitoring supports the detection of increases in cyanobacterial concentration over time. When a river has weirs or naturally-impounded areas it is more likely that cyanobacteria- and algal-related problems will occur there, if they are going to occur at all. People abstracting water along the rivers can also establish a network between companies, and the local community (then it is important to select a central coordinator), whereby the upstream users can notify the downstream users if a “pocket” of high cyanobacterial or algal biomass is seen moving downstream.

## ANALYSIS

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Chlorophyll-a analysis must be performed on the source water at least three times a week. If the analysis can be performed more frequently that would be an advantage. Cyanobacterial identification and enumeration analysis should be performed on the source water sample if the chlorophyll-a concentration exceeds  $10 \mu\text{g L}^{-1}$ . If the drinking water utility does not have the capacity to perform the cyanobacterial identification and enumeration analysis, it is important that the sample be outsourced to a laboratory that does have the required capacity.

## STEPPING-UP ACTIVATION

---

When the chlorophyll-a exceeds  $10 \mu\text{g L}^{-1}$  and the cyanobacterial concentration of the source water exceeds  $2000 \text{ cells mL}^{-1}$  then the alert must be stepped-up to Alert Level 1.

## STEPPING-DOWN ACTIVATION

---

When the chlorophyll-a concentration detected in the source water is less than  $5 \mu\text{g L}^{-1}$  for 14 consecutive days then the alert is stepped-down to the Routine Monitoring Level.

OR

When no cyanobacterial concentration is detected in the source water sample then the alert is stepped-down to the Routine Monitoring Level.

## ALERT LEVEL 1

### REGULAR SURVEILLANCE OF SOURCE WATER

---

Surveillance (as described under Vigilance level) of the reservoir, lake or river from which the source water is abstracted, should be conducted at least twice a week for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacterial growth).

## ANALYSIS

---

Chlorophyll-a analysis must be performed daily on the source water at the abstraction point. Cyanobacterial identification and enumeration analysis should be performed at least every two weeks on a source water sample. If the drinking water utility does not have the capacity to perform the cyanobacterial identification and enumeration analysis, it is important to outsource the sample to a laboratory that does have the required capacity.

### CYANOTOXIN SCREENING/ANALYSIS

Cyanotoxin screening refers to the determination of cyanotoxin concentrations. It is important to perform a cyanotoxin analysis on the source and the final water. The more comprehensive the better, as appropriate management is more effective when the data are more representative. Results from the source water will indicate if there are any cyanotoxins present and the final water will indicate how well the process is performing in removing these toxins (if at all) and also indicate the potential risk to the consumer.

The frequency of analysis should be at least once per week. If the drinking water utility does not have the capacity to perform cyanotoxins analysis it is important to outsource the samples to laboratories that have the required capacity.

## MOUSE TEST BIOASSAY

If feasible a mouse test bioassay is performed to establish whether a water sample has a toxic effect on a mouse. A mouse test bioassay is performed at least on the drinking water during cyanobacterial dominance in the source water. The main objective with the mouse test bioassay is to confirm that no other cyanotoxins are present.

## NOTIFICATION TO DRINKING WATER TREATMENT WORKS (DWTW)

---

The manner in which the “Notification to DWTW” will be executed will be proactively defined by the Response Committee, which would in turn be determined by the size and communication structures of the drinking water utility. The notification should be documented and traceable and ideally should include the following:

- Background information including historical data related to previous incidents
- Current trends in the relevant water quality data related to the specific drinking water treatment works
- Prediction in terms of immediate and short-term possibilities of cyanobacterial bloom formation
- Recommendations for possible actions (e.g. ensure sufficient coagulants are available, ensure staff are aware and ready to react at short notice, ensure all steps in process are able to be optimised and are in working condition, etc.) that can be taken into consideration in order to prepare for a cyanobacterial incident
- Reference to the ALF that has been developed for the specific drinking water treatment works.

## DISCHARGE PERMITS

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Should a cyanotoxin incident occur, it is likely that a decision will be taken not to recycle filter backwash water back to the head of the drinking water treatment works but to store the water on-site in holding dams or to discharge the filter backwash water into the river or reservoir/dam below the point of abstraction. No discharges are permitted without a valid permit. It is also recommended that the process of obtaining a discharge permit be initiated in a proactive manner as this can be a very lengthy process.

## REPORTING AND COMMUNICATION

---

At this Alert Level there should already be some communication between the water quality coordinator, the specialist on cyanobacteria and drinking water treatment the analytical laboratory staff and the drinking water treatment works manager.

## STEPPING-UP ACTIVATION

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When chlorophyll-a exceeds  $50 \mu\text{g L}^{-1}$  and cyanobacteria are dominant in the source water and their concentration exceeds  $50\,000 \text{ cells mL}^{-1}$  then the alert must be stepped-up to Alert Level 2.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water exceeds  $0.7 \mu\text{g L}^{-1}$  then actions should be stepped-up to Alert Level 2.

OR

When the mouse test bioassay is positive for cyanotoxins in the drinking water, then actions should be stepped-up to Alert Level 3.

## STEPPING-DOWN ACTIVATION

---

When the chlorophyll-a concentration detected in the source water is less than  $10 \mu\text{g L}^{-1}$  and the cyanobacterial concentration in the source water decreases to below  $2000 \text{ cells mL}^{-1}$  for at least 14 consecutive days, the cyanotoxin analysis (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is  $< 0.2 \mu\text{g L}^{-1}$  and the mouse test bioassays is negative for the drinking water, then actions should be stepped-down to the Vigilance Level.

Note: When stepping-up or -down from one Alert Level to the next it is important always to use the primary trigger (in this ALF: chlorophyll-a concentration in the source water) as the default analysis to determine which actions to take. However, should the cyanotoxin concentration exceed the concentration limits of the Alert Level in which it is operating (based on the primary trigger) then the secondary trigger (cyanotoxin concentration) overrides the primary trigger and the actions should be performed at the Alert Level specified by the secondary trigger. Similarly, should the mouse test bioassay be positive, then the tertiary trigger (mouse test bioassay) overrides the primary trigger and the actions should be performed at the Alert Level specified by the tertiary trigger. Should the concentration of the secondary trigger decrease to lower Alert Levels (or the tertiary trigger be negative repeatedly) then actions should revert back to the appropriate Alert Level as dictated by the results of the primary trigger.

## ALERT LEVEL 2

### REGULAR SURVEILLANCE OF SOURCE WATER

---

Surveillance (see also Vigilance Level) of the reservoir (dam), lake or river from which the source water is abstracted, should be conducted daily at the abstraction point and surrounding area for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacteria growth).

### ANALYSIS

---

Chlorophyll-a analysis must be performed daily on the source water at the abstraction point. Cyanobacterial identification and enumeration analysis should be performed once a week on a source water sample. If the drinking water utility does not have the capacity to perform the cyanobacterial identification and enumeration analysis, it is important to outsource the sample to a laboratory that does have the required capacity.

### CYANOTOXIN SCREENING/ANALYSIS

Cyanotoxin analysis is performed every second day on the source water and the drinking water (see also Section under Alert Level 1). If the drinking water utility does not have the capacity to perform cyanotoxin analysis, it is important to outsource the samples to laboratories that have the required capacity.

### MOUSE TEST BIOASSAY

If feasible the mouse test bioassay is performed at least once a week on the drinking water (see also Section under Alert Level 1).

## OPTIMISATION OF THE DRINKING WATER TREATMENT PROCESS

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The optimisations that should be considered fall into the following broad categories: 1) actions on the abstraction of source water (e.g. manipulation of the depth of abstraction), 2) optimisation of the conventional treatment process (e.g. stop pre-treatment with oxidants, optimisation of coagulation, flocculation, sedimentation, filtration and flotation processes, optimisation of disinfection) and 3) the use of advanced treatment processes (e.g. ozone and powdered activated carbon).

It is recommended that the possible optimisation process be identified and tested in a proactive manner during the development of the IMP for the specific drinking water utility. If this has been done, the main focus would then be to ensure that the actions are implemented and are functioning optimally so that the drinking water utility can effectively remove cyanobacteria and cyanotoxins from the source water whenever the cyanobacterial concentrations increase. This will also reduce the risk of reaching Alert Level 3.

## RESPONSE COMMITTEE MEETING

A meeting of the Response Committee is convened at Alert Level 2. The structure, roles and responsibilities of each member of the Response Committee would have been defined proactively during the development of the CIMF for the specific drinking water treatment works. However, this would be dependent on the size and the communication structures of the drinking water utility.

At the first meeting it is important 1) to familiarise each member with the IMP, 2) to clarify the roles and responsibilities and 3) to update contact information. The Response Committee discusses the current situation based on the available data, the appropriate actions that must be taken and identifies any problems that may hinder the implementation of the actions. Dates for feedback and follow-up meetings are set. Formal minutes of the meeting are kept.

## DISCHARGE PERMITS

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If the discharge permit has not been received from the relevant governmental authority, the Response Committee decides on the course of action to obtain this (see comments under Alert Level 1).

## REPORTING AND COMMUNICATION

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Reporting and communication focus on internal reporting and communication to ensure that information is shared and actions are speedily taken and implemented.

## STEPPING-UP ACTIVATION

---

When the cyanobacterial concentration in the source water consistently exceeds  $100\,000\text{ cells mL}^{-1}$ , are toxic and with scum forming in the source water, then actions should be stepped-up to Alert Level 3.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is between  $0.8$  and  $2.5\ \mu\text{g L}^{-1}$  for more than 14 days then actions should be stepped-up to Alert Level 3.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water exceeds  $2.5\ \mu\text{g L}^{-1}$  for more than 4 days then actions should be stepped-up to Alert Level 3.

OR

When the mouse test bioassay is positive for cyanotoxins in the drinking water then actions should be stepped-up to Alert Level 3.

## STEPPING-DOWN ACTIVATION

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When the chlorophyll-a concentration detected in the source water is less than  $50 \mu\text{g L}^{-1}$  and the cyanobacterial concentration in the source water decreases to below  $50\,000 \text{ cells mL}^{-1}$  for at least 14 consecutive days, the cyanotoxin analysis (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is less than  $0.8 \mu\text{g L}^{-1}$  and the mouse test bioassays are negative for the drinking water, then actions should be stepped-down to the Alert Level 1.

## ALERT LEVEL 3

### REGULAR SURVEILLANCE OF SOURCE WATER

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Surveillance (see also Vigilance Level) of the reservoir, lake or river from which the source water is abstracted, should be conducted at least daily at the abstraction point and surrounding area for the development of colour and scum associated with a cyanobacterial bloom (excessive cyanobacteria growth).

### ANALYSIS

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Chlorophyll-a analysis must be performed twice a day (early morning and late afternoon) on the source water at the abstraction point. Cyanobacterial identification and enumeration analysis must be performed daily on the source water at the abstraction point. A depth profile of the cyanobacterial cell concentration in the source water column must be determined if applicable (e.g. if water is abstracted from a dam), thereafter a series of at least 4 profiles over a 24 hour period must be performed to optimise the abstraction as the cyanobacterial cell concentrations may show diurnal depth variation.

### CYANOTOXIN SCREENING/ANALYSIS

Cyanotoxin analysis is performed daily on the source water and the drinking water (also see Section under Alert Level 1). If the drinking water utility does not have the capacity to perform cyanotoxin analysis it is important to outsource the samples to laboratories that have the required capacity.

### MOUSE TEST BIOASSAY

A mouse test bioassay can be performed on the drinking water at every alternative day (also see Section under Alert Level 1).

### OPTIMISATION OF THE DRINKING WATER TREATMENT PROCESS

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The following processes must function at their optimal capacity: 1) the abstraction of source water (e.g. manipulation of the depth of abstraction or the use of an alternative source), 2) the conventional treatment process (e.g. stop pre-treatment with oxidants, optimisation of coagulation, flocculation, sedimentation, filtration and flotation processes, optimisation of disinfection), 3) the use of advanced treatment processes (e.g. ozone and powdered activated carbon) and the discarding of filter backwash water.

## RESPONSE COMMITTEE MEETING

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The Response Committee should meet daily during this Alert Level to evaluate the success of measures implemented and to decide if further actions must be implemented. Special attention should be given to solving optimisation problems that are being experienced, alternative actions that can be implemented and to communication with external role-players (Department of Health, Department of Water Affairs, customers and the general public). Formal minutes of the meeting are kept.

## DISCHARGE PERMITS

---

If the discharge permit has not been received from the relevant governmental authority, the Response Committee decides on the course of action to obtain this (see comments under Alert Level 1).

## REPORTING AND COMMUNICATION

---

Reporting and communication focus on both internal (relevant role-players) and external role-players (Department of Health, Department of Water Affairs, customers and the general public) to ensure that information is shared and any actions are speedily taken and implemented.

## EMERGENCY ACTION

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When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is between 2.5 and 5  $\mu\text{g L}^{-1}$  for more than 8 days then an alternative drinking water source must be supplied.

OR

When the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water exceeds 5  $\mu\text{g L}^{-1}$  for more than 2 days then an alternative drinking water source must be supplied.

## STEPPING-DOWN ACTIVATION

---

When cyanobacterial scum formation in the source water is not evident for at least 14 consecutive days, the cyanotoxin (microcystins or nodularin or cylindrospermopsin) concentration in the drinking water is less than 2.5  $\mu\text{g L}^{-1}$  for 14 consecutive days and the mouse test bioassays are repeatedly negative for the drinking water then actions should be stepped-down to Alert Level 2.

## CLOSING PROCEDURE

When the conditions as described for Alert Level 1 occur after a cyanobacterial incident, then the Response Committee should close the incident. This would include a formal report describing the incident, the actions that were taken and the recommendations for improvements to the ALF, as well as preventative actions. All role-players must receive the final communication of the closure of the incident.

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## RESPONSE COMMITTEE FOR THE ALF

The application of an ALF requires a co-ordinated effort from all stakeholders. It is recommended that a Response Committee is formed to ensure the ALF is applied effectively and in a timely manner.

A typical Response Committee can comprise members with the following ability/authorisation:

- Water Quality Coordinator (Coordinator of the ALF)
- Management Representative from the drinking water utility (authority to make highest level decisions)
- Person responsible for the day-to-day management of the drinking water utility and who has authority to make decisions
- Person responsible for the sludge disposal plant and has who authority to make decisions
- The drinking water utility chemist (to advise on water quality optimisation)
- Analytical laboratory representative (responsible for analysis of samples)
- Catchment management representative (responsible for discharge permits and catchment monitoring)
- Communication representative (responsible for external communication - media, other companies, Department of Health, newspapers, etc.)
- Specialist on drinking water treatment
- Specialist on cyanobacteria and cyanotoxins

It must be stressed that there is no fixed composition of representation on the Response Committee as it will depend on the size, reporting structure and the communication lines of the specific structures of the drinking water utility. One representative can also fulfill more than one of the functions listed above.

## AGENDA FOR THE RESPONSE COMMITTEE MEETING

An example of a basic agenda for a Response Committee meeting is as follows:

- Welcome
- Brief situation summary by the Water Quality Coordinator.
- Brief overview of the Alert Levels Framework
- Clarification of roles and responsibilities as required by ALF
- Feedback by the specialist on Cyanobacteria:
  - Graphs with cyanobacterial concentrations during the current season and graphs with concentrations of previous seasons (if available)
  - Prediction on cyanobacterial biomass/growth for the remainder of the season and the risk of the occurrence of cyanotoxins. Input from Catchment Management Representative
  - Indication of the company's standing on the Alert Levels Framework
- Water Quality Coordinator feedback:
  - The company's standing on the Alert Levels Framework

- Feedback on measures that have been implemented to date. (Make sure that these are in line with recommendations provided in the Alert Levels framework)
- Highlight problem areas
- Feedback by the drinking water treatment works representatives:
  - Identification of envisaged optimisation problems
  - Recommendations on what should be done operationally to reduce the risk of going to a higher Alert Level
- Open-floor discussion on:
  - The optimisation actions that should be applied, which must be in line with the ALF
  - Alternative measures that are available but which are not included in the ALF
- Feedback from the media relations representative:
  - Clarification of communication channels as documented in the ALF
  - Presentation of available communications documentation
  - Identification of information needs (with sources and timing)
  - Confirm communication channels for the benefit of all
- Summary by water quality coordinator the main actions to be taken, and their links to the ALF
- Date of the next meeting
- Meeting Close

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DECISION MATRIX FOR THE ALF

Table 6-1(L2) Example of a decision matrix for an Alert Levels Framework

ACTIVITY	RESPONSIBILITY	ALERT LEVEL 1							ALERT LEVEL 2						
		M1	C1	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	M2.1	M2.2	C2.1	C2.2	C2.3
<b>ACTIVITY NUMBER</b>	<b>Responsibility</b>														
<b>SCIENTIFIC SERVICES</b>															
Stop-up Routine sampling Cyanobacteria > 2000 cells/mL from Task M1 or Task > (0.2µg/L)															
Inform staff B and Care group of Stop-up Routine sample data															
Arrange for stop up of monitoring programme and submission of specified sample if required															
Arrange with DWRF for optimal abstraction points to be used															
Confirm appropriate site meeting and if necessary search care group members															
Check purification process systems (ensure maximum adherence to)															
Check functioning of backwash treatment and plants															
Check backwash water storage capacity at															
Check status of discharge permit from Pollution Control to apply from DWRF															
Stop-up Routine sampling Cyanobacteria > 2000 cells/mL from Task M1 and/or Task > 0.2µg/L in the drinking water															
Special investigations monitoring (non routine)															
Stop-down Routine sampling Cyanobacteria > 500 000 cells/mL from Task R1.3 and/or Task > 0.2µg/L in the drinking water for 14 days															
Inform staff B and Care group of Stop-up Routine sample data															
Inform staff B and Care group of Stop-up of Alert Level															
Notify DWRF of work cyanobacteria blooms in the Vauld Farm catch															

- 1: Indicates the list of activities that needs to be performed
- 2: Indicates responsible persons and the respective departments and sites
- 3: Indicates specific activities in respect of monitoring, communication and remedial action.

**M (Green)** = Monitoring activities  
**C (Yellow)** = Communication activities  
**R (Light brown)** = Remedial activities

**As an example activity R1.1:**

- R = Indicates that the activity falls under remedial actions.
- R1 = Indicates that this activity is included under Alert Level 1 of the remedial action.
- R1.1 = Indicates the first activity under Alert Level 1 of the remedial actions.

Increasing numbers i.e. R2.1, R2.2 to R2.6 indicates the sequence in which activities should be performed.

- 4: Indicates the Alert Levels 1, 2 or 3.
- 5: Indicates who is responsible for what. This requires that the specific activity is read from the horizontal axis '1' and the responsibility of the respective persons indicated on the vertical axis '2' is found where the two lines intersect '5'.

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## HUMBUG SCRUB RESERVOIR ALGAL MANAGEMENT PLAN

### Management of *Anabaena circinalis* blooms using natural limitation

#### Table of contents

- 1 Humbug Scrub reservoir statistics
- 2 Incident criteria for *Anabaena circinalis*, saxitoxin and geosmin
- 3 Preventive measures in place for algae, toxins and taste & odour compounds
- 4 Variable offtake
- 5 Aerator operation
- 6 Reservoir and WTP inlet monitoring program
- 7 Humbug Scrub water treatment plant
- 8 Possible equipment failure
- 9 Management of geosmin
- 10 Management for saxitoxin
- 11 Communications
- 12 Recommended actions based on cell numbers at reservoir offtake
- 13 Benthic cyanobacteria
- 14 Map of Humbug Scrub reservoir showing sampling locations

**1 Humbug Scrub reservoir statistics**

- Supplied solely by a local catchment, does not receive any pumped water from the River Paradise
- Total catchment area: 12,294 hectares
- Reservoir capacity: 26,800 megalitres
- Maximum depth: 36 m
- Area of waterspread: 280 hectares

**2 Incident criteria for *Anabaena circinalis*, saxitoxin and geosmin**

Direct Supply Reservoir		
<b><i>Anabaena circinalis</i></b> in reservoir (cells/mL)	≤ 1,999	N/A
	2,000 – 19,999	TYPE 2 (DH)
	≥ 20,000	TYPE 1 (DH)
<b>Saxitoxin</b> in reservoir (µg/L)	≥ 1	TYPE 2 (DH)
	≥ 3	TYPE 1 (DH)
Water Treatment Plant Inlet		
<b><i>Anabaena circinalis</i></b> WTP inlet (cells/mL)	≤ 499	N/A
	500 – 999	TYPE 3 (HUMBUG SCRUB)
	1,000 – 1,999	TYPE 2 (DH)
	2,000 – 19,999	TYPE 1 (DH)
	≥ 20,000	PRIORITY TYPE 1 (DH)
<b>Total geosmin</b> WTP inlet (ng/L)	≤ 9	N/A
	10 - 79	TYPE 3 (HUMBUG SCRUB)
	≥ 80	TYPE 2 (HUMBUG SCRUB)
<b>Saxitoxin</b> WTP inlet (µg/L)	≥ 1	TYPE 1 (DH)
	≥ 3	PRIORITY TYPE 1 (DH)
Water Treatment Plant Outlet and Distribution System		
<b>Total geosmin</b> WTP outlet /	≤ 9	N/A

distribution (ng/L)	10-29	TYPE 3 (HUMBUG SCRUB)
	≥ 30	TYPE 1 (HUMBUG SCRUB)
Saxitoxin WTP outlet / distribution (µg/L)	≥ 1	PRIORITY TYPE 1 (DH)

### 3 Preventive measures in place for algae, toxins and taste & odour compounds

System component	Current preventive, management and contingency measures for algae, toxins and taste & odour compounds in the Humbug Scrub system
Catchment	<ul style="list-style-type: none"> <li>Control of nutrient inputs from catchment</li> </ul>
Reservoir	<ul style="list-style-type: none"> <li>Variation of offtake level</li> <li>Use of aerator when required</li> </ul>
Water Treatment Plant	<ul style="list-style-type: none"> <li>Filtration process</li> <li>Flocculation process / DAFF</li> <li>PAC dosing</li> <li>Disinfection (chlorine)</li> </ul>
System capacity	<ul style="list-style-type: none"> <li>Increase water storages at Pansy Hill and Mt Coke Tank to full capacity</li> </ul>

### 4 Variable offtake

#### Management recommendation:

Variable offtake to be set to the lowest level during a cyanobacterial bloom in order to minimise algal cells and associated metabolites such as geosmin from entering the WTP.

#### Humbug Scrub reservoir offtake depths:

Full Supply = EL 211.00 (33.10m on depth sight board)

- No 4 Offtake = EL 201.25 (15m)
- No 3 Offtake = EL 184.54 (21m)
- No 1 & 2 Offtake = EL 177.75 (30m)

#### Rationale:

*Anabaena circinalis* tends to form surface scums, and highest cell numbers tend to be distributed through the upper layer of water.

#### Considerations:

Should a major rainfall event occur resulting in significant catchment runoff, the offtake depth is routinely raised to reduce the risk of *Cryptosporidium* entering the WTP. These protozoa are carried with the inflowing water along the bottom of the reservoir, frequently short-circuiting towards the dam wall/WTP inlet tower. Should there be a concurrent algal bloom and rainfall event, a considered approach has to be taken, weighing up the potential risks from *Cryptosporidium* and from algal cells at the WTP inlet. In this situation, it is generally advisable to raise the offtake depth as far as practicable to reduce the *Cryptosporidium* risk at the

WTP inlet. However, as algal cell numbers have been shown to vary significantly at the offtake depending on wind strength and direction (i.e. elevated cell numbers during persistent easterly winds), the most appropriate offtake depth should be selected following thorough assessment of prevailing conditions at the time.

## **5 Aerator operation**

### **Management recommendation:**

Aerator to be left on during algal blooms to prevent stratification and anoxia in the hypolimnion (leading to release of P, Fe, Mn).

### **Rationale:**

Management of previous algal bloom incidents has shown that the aerator in Humbug Scrub reservoir should be left on during algal blooms, as a strong link between the aerator being turned off and release of soluble iron and manganese from the sediments was demonstrated during these past events. The dissolved metals subsequently enter the WTP and tend to precipitate out in the filtered water storage. Anoxic conditions are also conducive to the release of phosphorus from sediments.

### **Considerations:**

During previous bloom events it was discovered that under persistent easterly winds elevated algal cell numbers and subsequently higher geosmin concentrations were entering the WTP, even when the offtake was set at the lowest level. This situation was traced back to an interaction between aerator operation and prevailing wind direction driving algal cells down into deeper waters (offtake depth). Turning off the aerator for short periods of time (i.e. not more than three days) should be considered to mitigate this situation should it occur.

In relation to the release of soluble manganese from sediments when the aerator is turned off, investigations have shown that it is possible to dose potassium permanganate for manganese removal without compromising algal treatment in the WTP as algal cells are not damaged by this process.

The aerator should be turned off in case of a major rainfall event resulting in significant inflow from the catchment. This is to minimise the risk of *Cryptosporidium* being entrained in the aerator plume and being carried into the upper layers of the water column (WTP offtake level during rain events).

Note that the WTP needs to be informed whenever the aerator is turned on or off.

## **6 Reservoir and WTP inlet monitoring program**

Routine and non-routine monitoring is essential for the application of control measures such as changing offtake levels, use of the aerator and PAC, as well as the assessment of the efficiency of the control measures that are in place.

Please refer to the map at the end of the document for sample point locations.

- **Reservoir (routine – summer)**

Water Quality parameter	Sampling frequency
Phytoplankton (surface all locations)	Twice weekly (Monday/Thursday)
Phytoplankton (Loc 1 at 10m, 20m, 30m depth)	Weekly
Nutrients	Weekly
pH / turbidity / colour	Weekly
Temperature / DO	Weekly
Chlorophyll	Weekly
Fe / Mn	Fortnightly
Microbiological	Monthly
TDS	Monthly
Pesticides	Bi-monthly

- **WTP Inlet – (routine – summer)**

Water Quality parameter	Sampling frequency
Total MIB / geosmin	Weekly
Fe / Mn	Weekly
Odour	Fortnightly
DOC	Fortnightly
Turbidity / colour	Monthly
<i>Cryptosporidium / Giardia</i>	Monthly
Microbiological	Monthly
pH	Monthly
Physical	Monthly
Lang Index	Monthly
Nutrients	Monthly
SiO <sub>2</sub>	Monthly
Corrosive metals	Monthly
Rare inorganics	Monthly
Aluminium	Monthly
Pesticides	Monthly

- **In-reservoir temperature and water quality monitoring**

A thermistor chain (plus weather station, including wind speed and direction) is installed in the reservoir with data accessible via SCADA and automatic data downloads via GPRS emailed twice a week.

A pontoon fitted with an automated vertical water quality profiler system provides in-situ on-line data (available via a web-based interface) for temperature, turbidity, total cyanobacteria, chlorophyll, pH, conductivity and dissolved oxygen. The pontoon also carries a meteorological station including wind speed, solar radiation and temperature sensors.

- **Non-routine sampling**

To obtain as much information as possible on the status and possible trend in bloom development and to assist in management of the bloom, an increased monitoring regime will need to be initiated, consisting of both increased monitoring frequency and analyses (with fast turnaround times). In particular, increased monitoring will consist of phytoplankton sampling/algal scum enumeration (including direct counts), geosmin

analyses, nutrient sampling and additional temperature/DO profiles at key locations. Consideration should also be given to non-routine cell counts of *Anabaena circinalis* at the WTP inlet to compare with counts at the reservoir offtake. The field cyanobacterial probe can also be deployed to track total cyanobacteria numbers *in-situ*, including monitoring of cyanobacteria at the various offtake levels to determine the best offtake to use at times of very high cell counts. There will also be a need for saxitoxin testing, using the rapid Jellet field test to establish initial toxicity and then the quantitative HPLC method.

- **Field Response Team**

The Field Response Team based within Humbug Scrub Council's Water Quality and Integrated Management Group can be mobilised for additional surveillance on the reservoir if required (for example rapid saxitoxin tests, use of the YSI cyanobacteria sensor).

## **7 Humbug Scrub water treatment plant**

The WTP is a dissolved air flotation, filtration (DAFF) design, which is ideal for the removal of algal cells. It includes a powdered activated carbon (PAC) dosing facility designed to remove taste and odour compounds and algal toxins. It has a nominal capacity of 50 ML day<sup>-1</sup>, however this is not achievable for extended periods.

The treatment process consists of:

- Powdered activated carbon
- Potassium permanganate dosing for manganese oxidation
- Coagulation, using alum plus cationic polymer
- One stage flocculation
- Six flotation tanks
- Mono media filter beds situated in the flotation tanks
- Filter backwash facilities, including air scour
- Four sludge lagoons
- Clarification plant for filter backwash and lagoon supernatant, prior to recycle
- Chlorination: product water is chlorinated once between the WTP and the product water storages. Water flowing to southern metropolitan area receives trim chlorination. Water for the regional centres is drawn from the trunk main supplying the metropolitan area, with a significant storage at Pansy Hill. After Pansy Hill, the water is again chlorinated at Daydream Valley chlorination station prior to distribution. Water for the Bigville supply zone is drawn from the product water storage at the Humbug Scrub WTP. This water receives a trim dose of chlorine at the treatment plant before distribution.

Contingency in case of cyanobacterial bloom:

- Reduce flow as much as possible and dose PAC based on dissolved geosmin levels at the WTP inlet (obtained through the increased monitoring)
- Prior to receiving geosmin concentration results, a conservative estimate of the potential geosmin concentration can be made using *Anabaena circinalis* cell counts (refer to table in section 9)
- Humbug Scrub WTP can dose PAC at 50mg L<sup>-1</sup> for a very short period and at reduced flow
- Ensure all tanks are at highest possible level (e.g. Pansy Hill Storage, Mt Coke Tank) before reaching major bloom status (i.e. prior to reaching cell counts of 50,000 cells mL<sup>-1</sup>)

- During times of reduced output from Humbug Scrub WTP during PAC dosing – Tearful Valley WTP will need to supply parts of southern areas normally supplied by the Humbug Scrub WTP
- Humbug Scrub WTP output – 40ML per day at 10mg L<sup>-1</sup> PAC
- Humbug Scrub WTP cannot run below 20ML day<sup>-1</sup>
- Implement appropriate changes to supernatant return
- Storages to return to normal operating levels after a bloom to minimise water age in the system. This should be coordinated with Outer Metro Operations.

## 8 Possible equipment failure

Three key areas have been identified for possible equipment failure that can impact water quality:

- Failure of the aerator
- Failure of the PAC dosing facility
- Complete breakdown of the WTP

Contingency plans need to be in place for all potential failure scenarios, including ensuring that a replacement compressor for the aerator is available in the shortest possible time, the availability of spares for PAC dosing equipment with the aim of reducing outages to the shortest time possible. A complete WTP breakdown would result in a shutdown of the treatment plant.

## 9 Management of geosmin

GEOSMIN - MANAGEMENT / CONTROL MEASURES				
Reservoir	Multiple offtake	PAC	Flocculation/ Filtration	Cl <sub>2</sub>
<p><b>Yes</b> Half-life of geosmin loss due to biodegradation and loss to atmosphere in reservoir = 1 - 2 days. Time in reservoir with WTP shut off depends on product water storage capacity and system demand</p>	<p><b>Yes</b> Barrier under most situations for intact cells where cells unevenly distributed through water column</p>	<p><b>Yes</b> 92% at 20 mg L<sup>-1</sup></p>	<p><b>Yes</b> 70% intact cell removal</p>	<p><b>No</b></p>

Typical PAC doses required to remove geosmin to levels below 10 ng L <sup>-1</sup> *	
WTP inlet geosmin concentration (ng L <sup>-1</sup> )	PAC dose (mg L <sup>-1</sup> )
10-30	4-15
30-100	15-35

\*These doses were estimated from many laboratory experiments but the actual doses required will depend strongly on water quality. Site specific testing is recommended

*Anabaena circinalis* cell numbers and associated potential geosmin concentrations, percent removal required to reach a concentration goal of <10 ng L<sup>-1</sup>, and estimated PAC doses for 30 minute contact time. All values for PAC doses are estimates as the actual values will depend on mixing and water quality conditions

<i>Anabaena circinalis</i> (cells mL <sup>-1</sup> )	Potential geosmin concentration (ng L <sup>-1</sup> )	% removal required to achieve final concentration goal of < 10 ng L <sup>-1</sup> *	PAC dose for dissolved geosmin (mg L <sup>-1</sup> ) (30 min contact time)
200	9	0	0
400	18	50	5
500	23	60.9	7
1,000	46	80.4	10
2,000	91	90.1	17
3,000	137	93.4	20
4,000	182	95.1	25
5,000	228	96.1	30
7,500	341	97.4	>30
10,000	455	98.0	>30
15,000	683	98.7	>30
20,000	910	99.0	>30
30,000	1365	99.3	>30
40,000	1820	99.5	>30
50,000	2275	99.6	>30
60,000	2730	99.7	>30
80,000	3640	99.8	>30
100,000	4550	99.8	>30
200,000	9100	99.9	>30

\* If all geosmin is released from cells

## 10 Management of saxitoxin

Note that it is highly likely that management actions for geosmin will be necessary before actions are needed for saxitoxins.

- Different variants of the saxitoxins adsorb to different extents on PAC. In the case of saxitoxins, the most toxic are generally those in the lowest concentration and are removed more readily. In general a dose of 20 to 30 mg/L PAC and a contact time of at least 60 minutes would be recommended for an inlet concentration of 10 µg L<sup>-1</sup> STX equivalents, and a finished water goal concentration of <3 µg L<sup>-1</sup>
- Chlorination is considered an effective process in the multi-barrier approach to saxitoxin removal, with destruction of toxicity in the range of 75-90% at C.t of 20 mg min L<sup>-1</sup>.

SAXITOXIN - MANAGEMENT / CONTROL MEASURES				
Reservoir	Multiple offtake	PAC	Flocculation / Filtration	Cl <sub>2</sub>

<p><b>No</b> Saxitoxin does not biodegrade</p>	<p><b>Yes</b> Barrier under most situations for intact cells where cells unevenly distributed through water column; extracellular toxin expected to move through water column rapidly</p>	<p><b>Yes</b> 60% at 20 mg L<sup>-1</sup> 64% at 30 mg L<sup>-1</sup>  30 mg L<sup>-1</sup> PAC can be dosed at reduced flow but is limited to a few hours</p>	<p><b>Yes</b> Removal of intact cells; however intact cells removed likely to break down in supernatant return</p>	<p><b>Yes</b> 96% Assuming maximum removal contact time of 111 mins. At Humbug Scrub WTP: 13 hr contact time at &gt;1.5 mg L<sup>-1</sup> Cl<sub>2</sub></p>
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*Anabaena circinalis* cell numbers and associated potential saxitoxin concentrations, percent removal required to reach goals of < 3 µ/L and < 1 µ/L, estimated PAC doses for 30 minute contact time and chlorine contact time values to reach the target percent removal. Note that all values for PAC and chlorine doses are estimates as the actual values will depend on mixing and water quality conditions (from AWQC).

<i>Anabaena circinalis</i> (cells mL <sup>-1</sup> )	Potential STX equivalent concentration (µg L <sup>-1</sup> )	% removal required (to reach 3 µg L <sup>-1</sup> )	PAC dose for dissolved saxitoxin (mg L <sup>-1</sup> ) * (30 min contact time)	Chlorine contact time for dissolved saxitoxin (mg min L <sup>-1</sup> ) **	% removal required (to reach 1 µg L <sup>-1</sup> )	PAC dose for dissolved saxitoxin (mg L <sup>-1</sup> ) *** (30 min contact time)	Chlorine contact time for dissolved saxitoxin (mg min L <sup>-1</sup> ) ****
200	0	0	0	0	0	0	0
400	0	0	0	0	0	0	0
500	0.1	0	0	0	0	0	0
1,000	0.1	0	0	0	0	0	0
2,000	0.3	0	0	0	0	0	0
3,000	0.5	0	0	0	0	0	0
4,000	0.6	0	0	0	0	0	0
5,000	0.8	0	0	0	0	0	0
7,500	1.1	0	0	0	9.1	5	2
10,000	1.5	0	0	0	33.3	7	5
15,000	2.3	0	0	0	56.5	15	13
20,000	3.0	0	0	0	66.7	25	21
30,000	4.5	33.3	7	5	77.8	30	33
40,000	6.0	50.0	10	10	83.3	>30	40
50,000	7.5	60.0	20	15	86.7	>30	>45
60,000	9.0	66.7	25	20	88.9	>30	>45
80,000	12.0	75.0	30	20	91.7	>30	>45
100,000	15.0	80.0	>30	35	93.3	>30	>45
200,000	30.0	90.0	>30	45	96.7	>30	>45

\* If all saxitoxins are released from cells, estimate

\*\* Dependent on the saxitoxin variants present, applicable to a “typical” Australian toxic bloom, final concentration goal, < 3 µg L<sup>-1</sup>

\*\*\* If all saxitoxins are released from cells

\*\*\*\* Dependent on the saxitoxin variants present, applicable to a “typical” Australian toxic bloom, final concentration goal, < 1 µg L<sup>-1</sup>



<p><b>500 – 1,000</b></p>	<p><b>Monitoring:</b></p> <ul style="list-style-type: none"> <li>• Increase monitoring as per below</li> </ul> <p><b>Algae in reservoir:</b></p> <ul style="list-style-type: none"> <li>• Sample any scums and consider using YSI cyanobacteria sensor</li> </ul> <p><b>Geosmin:</b></p> <ul style="list-style-type: none"> <li>• In addition to routine total geosmin at WTP inlet also schedule dissolved geosmin sample.</li> <li>• If mostly dissolved geosmin present, geosmin removal required</li> </ul> <p><b>Variable offtake:</b></p> <ul style="list-style-type: none"> <li>• Ensure variable offtake is set to lowest level</li> </ul> <p><b>Treatment:</b></p> <ul style="list-style-type: none"> <li>• Consider PAC to remove taste &amp; odour</li> </ul>
<p><b>1,000 – 2,000</b></p>	<p><b>Monitoring:</b></p> <ul style="list-style-type: none"> <li>• Increase monitoring as per below</li> </ul> <p><b>Algae in reservoir:</b></p> <ul style="list-style-type: none"> <li>• In addition to routine twice weekly phytoplankton samples (Mondays &amp; Thursdays), consider non-routine phytoplankton samples if <i>A. circinalis</i> &gt;1000 cells mL<sup>-1</sup> at reservoir locations 1, 4 or 5, or the reservoir average exceeds 1000 cells mL<sup>-1</sup></li> <li>• Sample any scums and consider using YSI cyanobacteria sensor</li> <li>• Schedule twice weekly phytoplankton depth samples at location 1 at 10m, 20m and 30m if <i>A. circinalis</i> &gt;1000 cells mL<sup>-1</sup> at reservoir location 1</li> <li>• Schedule regular phytoplankton samples at WTP inlet</li> </ul> <p><b>Geosmin:</b></p> <ul style="list-style-type: none"> <li>• Geosmin removal required</li> <li>• Paired geosmin samples: WTP Inlet and Plant Outlet</li> <li>• PAC dosing required to remove geosmin</li> </ul> <p><b>Communication:</b></p> <ul style="list-style-type: none"> <li>• As per Notification Protocol including Incident Notification Table; all step changes must be reported to DH; if PBS geosmin result is &gt;10 ng L<sup>-1</sup> notify Council Customer Call Centre; consideration should also be given to notification of customers in consultation with Stakeholder Relations, Head of Council and DH</li> </ul>
<p><b>2,000 – 5,000</b></p>	<p><b>Monitoring:</b></p> <ul style="list-style-type: none"> <li>• Increase monitoring as per below and continue to closely monitor progress of bloom</li> <li>• Consider mobilising Field Response Team for additional surveillance (rapid saxitoxin tests, YSI cyanobacteria sensor)</li> </ul> <p><b>Algae in reservoir:</b></p> <ul style="list-style-type: none"> <li>• In addition to routine twice weekly phytoplankton samples (Mondays &amp; Thursdays), continue with non-routine phytoplankton samples, including sampling any scums and consider using YSI cyanobacteria sensor</li> </ul> <p><b>Geosmin:</b></p> <ul style="list-style-type: none"> <li>• Geosmin removal required</li> <li>• Paired geosmin samples: WTP Inlet and Plant Outlet</li> </ul> <p><b>Toxins:</b></p> <ul style="list-style-type: none"> <li>• Determine whether bloom is toxic using Jellet rapid field test. NOTE: this test requires a concentrated raw water sample (plankton net tow) as limit of detection &gt;100 µg L<sup>-1</sup> saxitoxin. If positive toxin result, run analysis by HPLC</li> </ul> <p><b>Treatment:</b></p> <ul style="list-style-type: none"> <li>• PAC dosing required to remove potential toxin and geosmin</li> </ul>

	<p><b>Communication:</b></p> <ul style="list-style-type: none"> <li>As per Notification Protocol including Incident Notification Table; all step changes must be reported to DH; if PBS geosmin result is <math>&gt;10 \text{ ng L}^{-1}</math> notify Council Customer Call Centre; consideration should also be given to notification of customers in consultation with Stakeholder Relations, Head of Council and DH</li> </ul>
<p><b>5,000 – 10,000</b></p>	<p><b>Monitoring:</b></p> <ul style="list-style-type: none"> <li>Increase monitoring as per below and continue to closely monitor progress of bloom</li> <li>Mobilise Field Response Team for additional surveillance (rapid saxitoxin tests, YSI cyanobacteria sensor)</li> </ul> <p><b>Algae in reservoir:</b></p> <ul style="list-style-type: none"> <li>In addition to routine twice weekly phytoplankton samples (Mondays &amp; Thursdays), continue with non-routine phytoplankton samples, including sampling any scums and consider using YSI cyanobacteria sensor</li> </ul> <p><b>Geosmin:</b></p> <ul style="list-style-type: none"> <li>Geosmin removal required</li> <li>Paired geosmin samples: WTP Inlet and Plant Outlet</li> </ul> <p><b>Toxins:</b></p> <ul style="list-style-type: none"> <li>Determine whether bloom is toxic, analysis by HPLC</li> <li>Take samples: Plant Inlet, Pre-disinfection and Post-disinfection</li> <li>Analyse pre-disinfection only if Plant Inlet is <math>&gt;1\mu\text{g L}^{-1}</math></li> <li>Analyse post-disinfection only if Pre-disinfection is <math>&gt;1\mu\text{g L}^{-1}</math></li> </ul> <p><b>Treatment:</b></p> <ul style="list-style-type: none"> <li>PAC dosing required to remove potential toxin and geosmin, maximise chlorine CT for saxitoxin removal</li> <li>Ensure plant is optimised for cell, geosmin and toxin removal</li> </ul> <p><b>Communication:</b></p> <ul style="list-style-type: none"> <li>As per Notification Protocol including Incident Notification Table all step changes must be reported to DH; if PBS geosmin result is <math>&gt;10 \text{ ng/L}</math> notify Council Customer Call Centre; consideration should also be given to notification of customers in consultation with Stakeholder Relations, Head of Council and DH</li> </ul>

<p><b>10,000 – 20,000</b></p>	<p><b>Monitoring:</b></p> <ul style="list-style-type: none"> <li>• Increase monitoring as per below and continue to closely monitor progress of bloom</li> <li>• Mobilise Field Response Team for additional surveillance (rapid saxitoxin tests, YSI cyanobacteria sensor)</li> </ul> <p><b>Algae in reservoir:</b></p> <ul style="list-style-type: none"> <li>• In addition to routine twice weekly phytoplankton samples (Mondays &amp; Thursdays), continue with non-routine phytoplankton samples, including sampling any scums and consider using YSI cyanobacteria sensor</li> </ul> <p><b>Geosmin:</b></p> <ul style="list-style-type: none"> <li>• Geosmin removal required</li> <li>• Paired geosmin samples: WTP Inlet and Plant Outlet PBS</li> </ul> <p><b>Toxins:</b></p> <ul style="list-style-type: none"> <li>• Determine whether bloom is toxic, analysis by HPLC</li> <li>• Take samples: Plant Inlet, Pre-disinfection and Post-disinfection</li> <li>• Analyse pre-disinfection only if Plant Inlet is <math>&gt;1\mu\text{g L}^{-1}</math></li> <li>• Analyse post-disinfection only if Pre-disinfection is <math>&gt;1\mu\text{g L}^{-1}</math></li> </ul> <p><b>Treatment:</b></p> <ul style="list-style-type: none"> <li>• PAC dosing required to remove toxin and geosmin</li> <li>• Ensure plant is optimised for cell, geosmin and toxin removal</li> <li>• Consider adjusting dose rate to increase chlorine CT to maximise saxitoxin removal; also consider impact on THMs in distribution system and notify Outer Metro Operations and DH of changes / possible impacts</li> <li>• If saxitoxin levels <math>&gt;1.0 \mu\text{g L}^{-1}</math> at outlet (prior to chlorination) then undertake further in-plant toxicity analysis of recycle streams (sedimentation, filter back wash, supernatant from lagoon or thickener) to determine source of toxins. Make adjustments to the process as required</li> <li>• If saxitoxins <math>&gt;3.0 \mu\text{g L}^{-1}</math> at WTP outlet, implement contingency plan to supply drinking water</li> </ul> <p><b>Communication:</b></p> <ul style="list-style-type: none"> <li>• As per Notification Protocol including Incident Notification Table; all step changes must be reported to DH; if PBS geosmin result is <math>&gt;10 \text{ ng L}^{-1}</math> notify Council Customer Call Centre; consideration should also be given to notification of customers in consultation with Stakeholder Relations, Head of Council and DH</li> </ul>
<p><b><math>\geq 20,000</math></b></p> <p><b>Trigger Type 1 incident</b></p>	<p><b>Monitoring:</b></p> <ul style="list-style-type: none"> <li>• Increase monitoring as per below and continue to closely monitor progress of bloom</li> <li>• Mobilise Field Response Team for additional surveillance (rapid saxitoxin tests, YSI cyanobacteria sensor)</li> </ul> <p><b>Algae in reservoir:</b></p> <ul style="list-style-type: none"> <li>• In addition to routine twice weekly phytoplankton samples (Mondays &amp; Thursdays), continue with non-routine phytoplankton samples, including sampling any scums and consider using YSI cyanobacteria sensor</li> </ul> <p><b>Geosmin:</b></p> <ul style="list-style-type: none"> <li>• Geosmin removal required</li> <li>• Paired geosmin samples: WTP Inlet and Plant Outlet PBS</li> </ul>

	<p><b>Toxins:</b></p> <ul style="list-style-type: none"> <li>• Determine whether bloom is toxic, analysis by HPLC</li> <li>• Take samples: Plant Inlet, Pre-disinfection and Post-disinfection</li> <li>• Analyse pre-disinfection only if Plant Inlet is <math>&gt;1\mu\text{g L}^{-1}</math></li> <li>• Analyse post-disinfection only if Pre-disinfection is <math>&gt;1\mu\text{g L}^{-1}</math></li> </ul> <p><b>Treatment:</b></p> <ul style="list-style-type: none"> <li>• PAC dosing required to remove toxin and geosmin</li> <li>• Ensure plant is optimised for cell, geosmin and toxin removal</li> <li>• Consider adjusting dose rate to increase chlorine CT to maximise saxitoxin removal</li> <li>• If saxitoxin levels <math>&gt;1.0\mu\text{g L}^{-1}</math> at outlet (prior to chlorination) then undertake further in-plant toxicity analysis of recycle streams (sedimentation, filter back wash, supernatant from lagoon or thickener) to determine source of toxins. Make adjustments to the process as required</li> <li>• If saxitoxins <math>&gt;3.0\mu\text{g L}^{-1}</math> at WTP outlet, implement contingency plan to supply drinking water</li> </ul> <p><b>Communication:</b></p> <ul style="list-style-type: none"> <li>• As per Notification Protocol including Incident Notification Table; all step changes must be reported to DH; if PBS geosmin result is <math>&gt;10\text{ ng L}^{-1}</math> notify Council Customer Call Centre; consideration should also be given to notification of customers in consultation with Stakeholder Relations, Head of Council and DH</li> <li>• Meeting with Stakeholders if cell counts at location 1 or reservoir average <math>&gt;50,000\text{ cells/mL}</math></li> </ul>
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### 13 Benthic cyanobacteria

**Species of concern:** The two benthic cyanobacteria of particular concern in Australia are *Phormidium* spp and *Oscillatoria* spp.

**Habit:** Benthic algae grow on bottom sediments, on rocks and also grow attached to larger aquatic plants such as water milfoil and reeds. They usually form distinct mats on these substrates and can frequently be found forming a distinct band around the shallow margin of a reservoir. In general, benthic cyanobacteria prefer shallower water bodies with low turbidity.

**Water quality issues:** The major water quality issue is the production of the taste and odour compounds geosmin and MIB (2 methyl-isoborneol), produced by both *Phormidium* and *Oscillatoria*. There is anecdotal evidence that the benthic cyanobacterium *Geitlerinema* (a relatively new genus) is a potential geosmin producer.

*Oscillatoria* is not known to be toxic in Australia. While *Phormidium* has been shown to be toxic overseas (including anatoxin-a), there is no evidence to suggest that *Phormidium* in Australia produces the same toxin(s). Tests using *Phormidium* material collected in 2000 showed that mice injected with cell extracts died, however they did not show the usual symptoms associated with cyanobacterial toxins. Cell extracts administered orally did not show any toxicity, nor could the toxin be extracted into water. Furthermore, boiling and chlorination effectively destroyed the toxin, while chloramine had no effect in reducing toxicity. Based on the above, there is evidence of *Phormidium* in Australia producing a cyanobacterial toxin, however the exact type of toxin(s) produced has not been established. It would be fair to assume that elevated geosmin levels would make a water supply undrinkable before toxin from *Phormidium* would reach a level where it would be necessary to stop supply.

**Detection:** Benthic algal mats impact on water quality when fragments are dislodged and float free in the water column. This can be caused by wind and wave action or variation in flow and water level. It can also occur during periods of high photosynthetic activity when oxygen bubbles form and may carry fragments into the water. As they grow attached to submerged substrates, benthic algal cells are likely to be under stress/ruptured when free-floating and these conditions can lead to spikes in geosmin. In the absence of significant numbers of geosmin-producing planktonic cyanobacterial species such as *Anabaena circinalis*, it is highly likely that any elevated geosmin levels are due to benthic algal activity. Furthermore, in the case of benthic cyanobacteria there is usually very little difference between total and dissolved geosmin figures as most geosmin would be in solution throughout the water column emanating from benthic mats or dislodged floating clumps.

**Management:** Benthic cyanobacteria are more difficult to manage than planktonic species. Changing the level of a reservoir to expose areas of benthic algal growth is usually of very little benefit as it will take a long time for the mats to desiccate and the likelihood of cells surviving in the body of the mats is very high.  $\text{CuSO}_4$  dosing would present little benefit, as the  $\text{CuSO}_4$  in the form it is commonly applied for the control of planktonic cyanobacteria (fine granules) is not effective at depth. A potential option could be the use of  $\text{CuSO}_4$  in the form of larger pieces which sink to the bottom of the reservoir. However, this would still lead to a very patchy result and would be a quite temporary measure (and likely lead to a spike in geosmin release).

[Return to level 1](#)

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