Monitoring and Treatment of Cyanobacteria & Algae by Hunter Water

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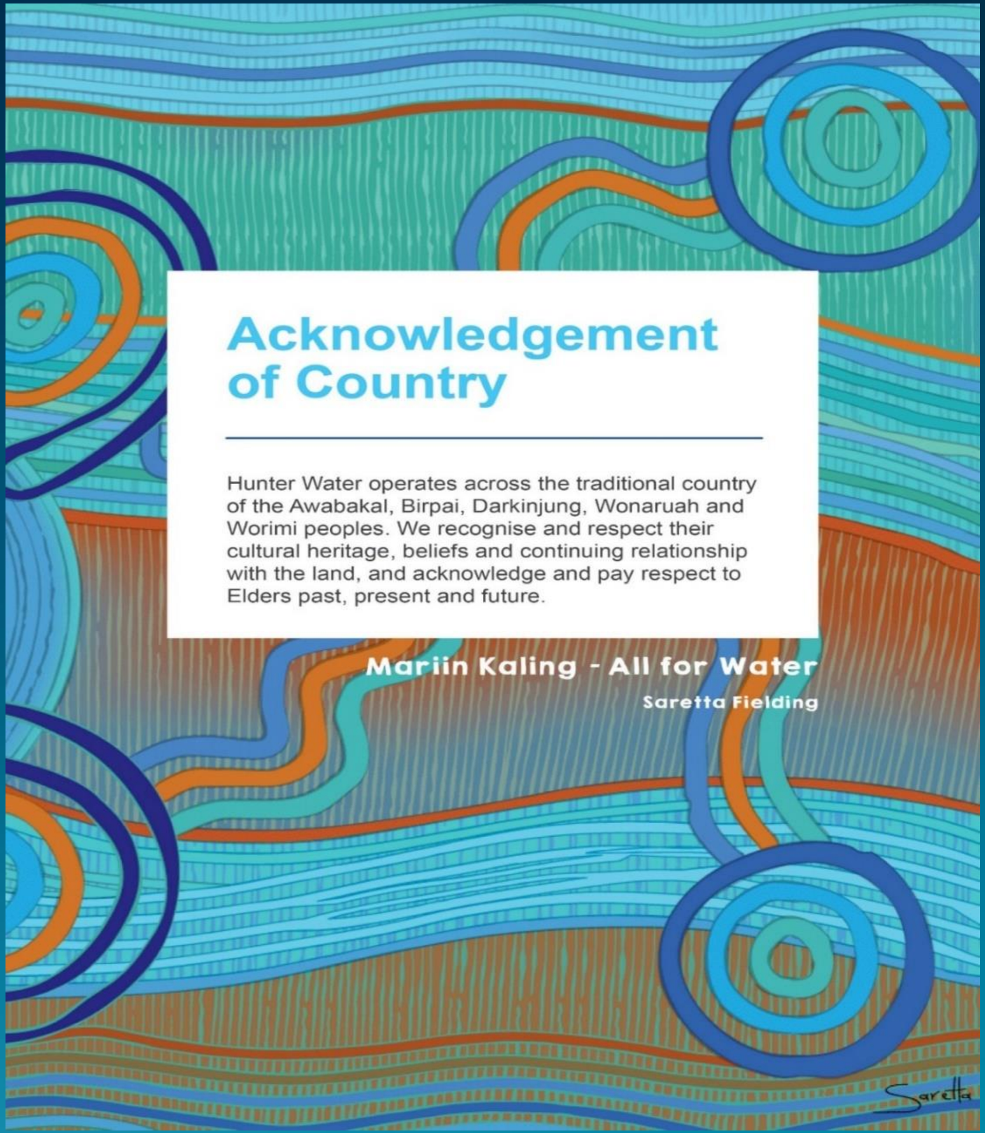
Hunter Water Corporation

Date: Wednesday 27th September 2023

Venue: 8th ANZ Cyanobacteria Workshop, Melbourne



Acknowledgement of Country

Hunter Water operates across the traditional country of the Awabakal, Birpai, Darkinjung, Wonaruah and Worimi peoples. We recognise and respect their cultural heritage, beliefs and continuing relationship with the land, and acknowledge and pay respect to Elders past, present and future.

Mariin Kaling - All for Water

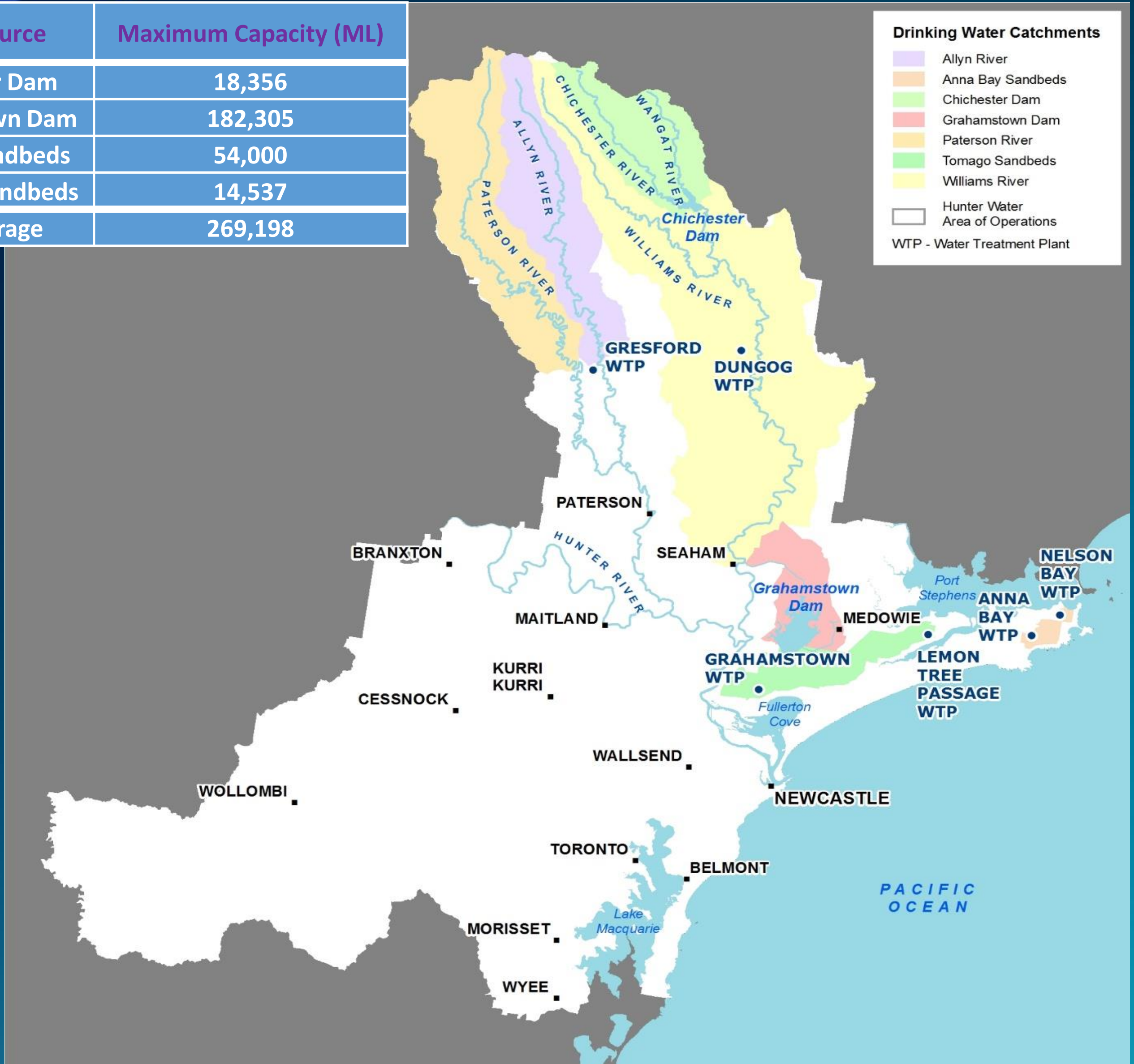
Saretta Fielding

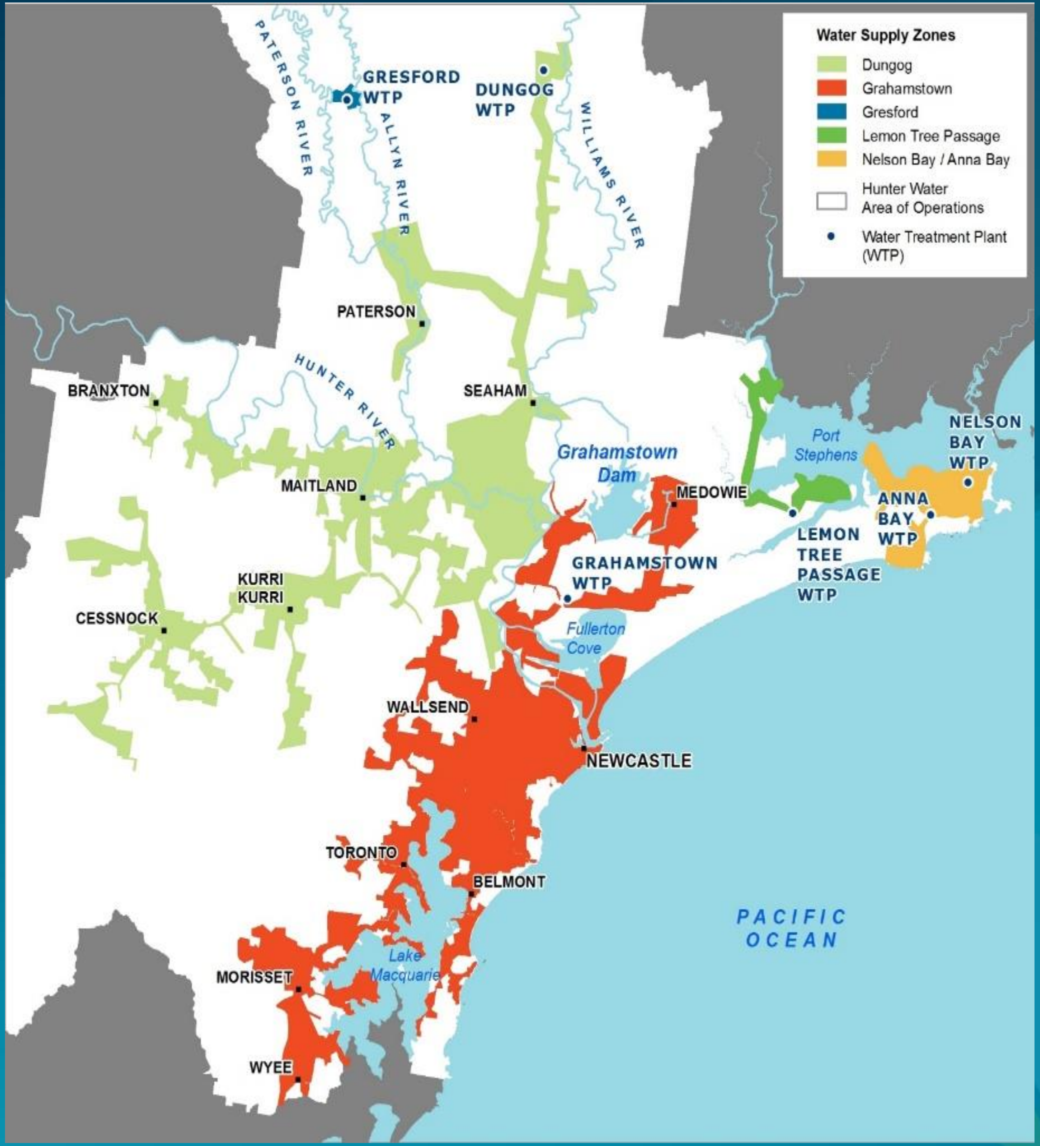
Overview of Presentation

- ✓ Overview of Hunter Water's Catchments, Storages & Water Treatment Plants
- ✓ Cyanobacteria Alert Level Framework, Contingency Plan & Routine Monitoring Sites
- ✓ Laboratory Analysis & Sampling for Cyanobacteria, Algae & Taste/Odour Compounds
- ✓ Significant Cyanobacterial, Algal & Taste/Odour Events at Hunter Water
- ✓ Treatment of Cyanobacterial, Algal & Taste/Odour Events by Hunter Water
- ✓ Review of Phytoxigene™ & Algal Toxin Results
- ✓ Future Directions (Innovations & Upgrades)

Hunter Water's Catchments, Storages & Water Treatment Plants

Water Source	Maximum Capacity (ML)
Chichester Dam	18,356
Grahamstown Dam	182,305
Tomago Sandbeds	54,000
Anna Bay Sandbeds	14,537
Total Storage	269,198





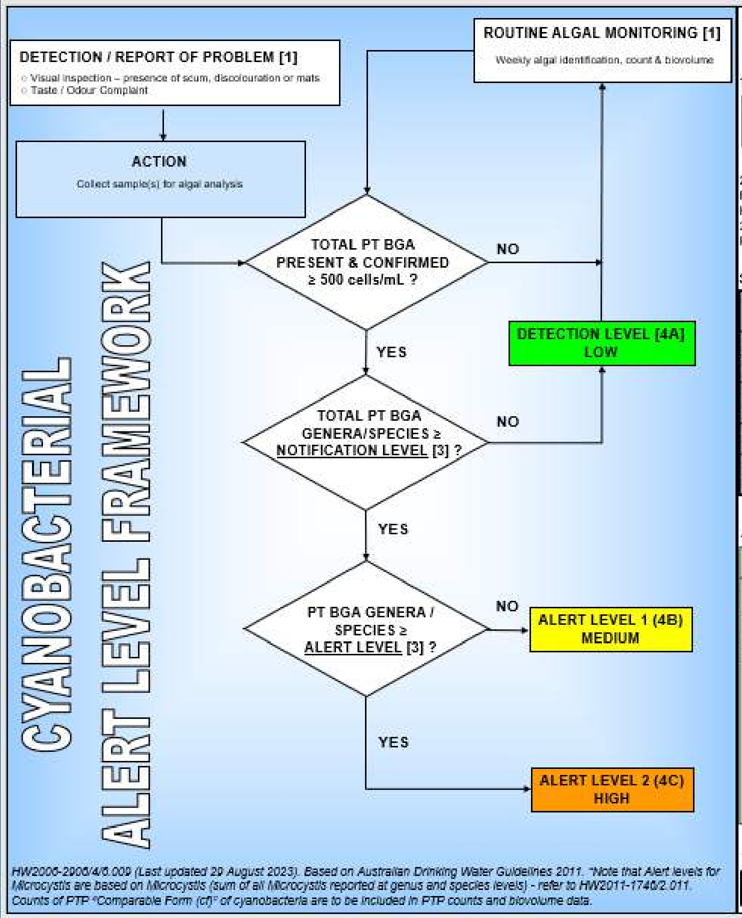
Routine Algae Sampling Sites

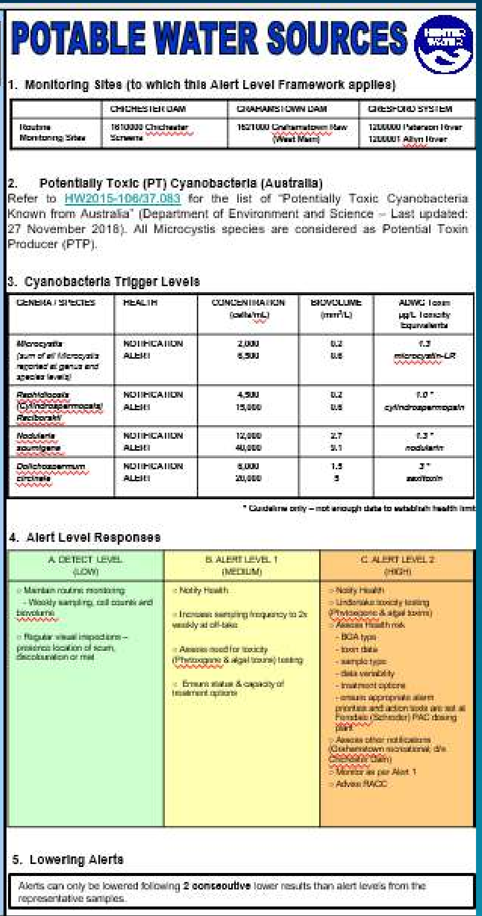
Routine Algae Sampling Points	Routine Algae Sampling Frequency
Raw Waters	
Chichester Screens (1610000)	Weekly
Grahamstown Raw (West Main) (1621000)	Weekly
Grahamstown Raw Water Tank (East Dip) (1621010)	Weekly
Allyn River (1200001)	Weekly
Paterson River (1200000)	Weekly
Treated Water	
Grahamstown Clear Water Tank (CWT)	Weekly
Source / Catchments Waters	
Chichester Middle of Dam (2m) (35C0001)	Weekly
Chichester Dam Wall (samples collected by Veolia):	Weekly
• Chichester Dam Surface Valve House (15B0000)	Weekly
• Chichester Dam 2m (16D0005)	Weekly
• Chichester Dam 4m (16D0006)	Weekly
• Chichester Dam 6m (16D0007)	Weekly
• Chichester Dam 12m (16D0010)	Weekly
• Chichester Dam 1m from bottom (16D0020)	Weekly
Williams River Clarence Town Caravan Park (15R0006)	Weekly
Williams River Boags Hill (15C1000)	Weekly
Grahamstown Dam – Northern Site R2 (5 Bridges Rd) (25D3040)	Weekly
Grahamstown Dam – Middle of Dam R12 (25D3050)	Weekly
Grahamstown Dam – Southern Site R6 (Schroder PS) (25D3010)	Weekly
Campvale Canal PS Inlet – R9 (15C9000)	Fortnightly

19 Sites

- ✓ **Chichester Dam Catchment – 8 Sites**
- ✓ **Grahamstown Dam Catchment – 7 Sites**
- ✓ **Williams River Catchment – 2 Sites**
- ✓ **Allyn River Catchment – 1 Site**
- ✓ **Paterson River Catchment – 1 Site**

Cyanobacteria Alert Level Framework & Contingency Plan for Potable Water Sources





POTABLE WATER SOURCES

1. Monitoring Sites (to which this Alert Level Framework applies)

	CHICHESTER DAM	GRAHAMSTOWN DAM	GRESFORD SYSTEM
Routine Monitoring Sites	1610000 Chichester Screens	1621000 Grahamstown Raw (West Main)	1200000 Paterson River 1200001 Allyn River

2. Potentially Toxic (PT) Cyanobacteria (Australia)

Refer to HW2015-106/37.083 for the list of "Potentially Toxic Cyanobacteria Known from Australia" (Department of Environment and Science – Last updated: 27 November 2018). All Microcystis species are considered as Potential Toxin Producer (PTP).

3. Cyanobacteria Trigger Levels

GENERA / SPECIES	HEALTH	CONCENTRATION (cells/mL)	BIOVOLUME (mm³/L)	ADWG Toxin µg/L Toxicity Equivalents
Microcystis (sum of all Microcystis reported at genus and species levels)	NOTIFICATION ALERT	2,000 6,500	0.2 0.6	1.3 microcystin-LR
Raphidiopsis (Cylindrospermopsis) Raciborskii	NOTIFICATION ALERT	4,500 15,000	0.2 0.6	1.0 * cylindrospermopsin
Nodularia spumigena	NOTIFICATION ALERT	12,000 40,000	2.7 9.1	1.3 * nodularin
Dolichospermum circinale	NOTIFICATION ALERT	6,000 20,000	1.5 5	3 * saxitoxin

* Guideline only – not enough data to establish health limit

4. Alert Level Responses

A. DETECT LEVEL (LOW)	B. ALERT LEVEL 1 (MEDIUM)	C. ALERT LEVEL 2 (HIGH)
○ Maintain routine monitoring – Weekly sampling, cell counts and biovolume ○ Regular visual inspections – presence location of scum, discolouration or mat	○ Notify Health ○ Increase sampling frequency to 2x weekly at off-take ○ Assess need for toxicity (Phytoxigene & algal toxins) testing ○ Ensure status & capacity of treatment options	○ Notify Health ○ Undertake toxicity testing (Phytoxigene & algal toxins) ○ Assess Health risk - BGA type - toxin data - sample type - data variability - treatment options - ensure appropriate alert priorities and action tools are set at Ferndale (Schroder) PAC dosing plant ○ Assess other notifications (Grahamstown recreational; d/s Chichester Dam) ○ Monitor as per Alert 1 ○ Advise RACC

5. Lowering Alerts

Alerts can only be lowered following **2 consecutive** lower results than alert levels from the representative samples.

HUNTER WATER

BLUE-GREEN ALGAE CONTINGENCY PLAN

FOR POTABLE WATER SOURCES

AUGUST 2023

Laboratory Analysis & Sampling for Algae / Cyanobacteria

HUNTER WATER

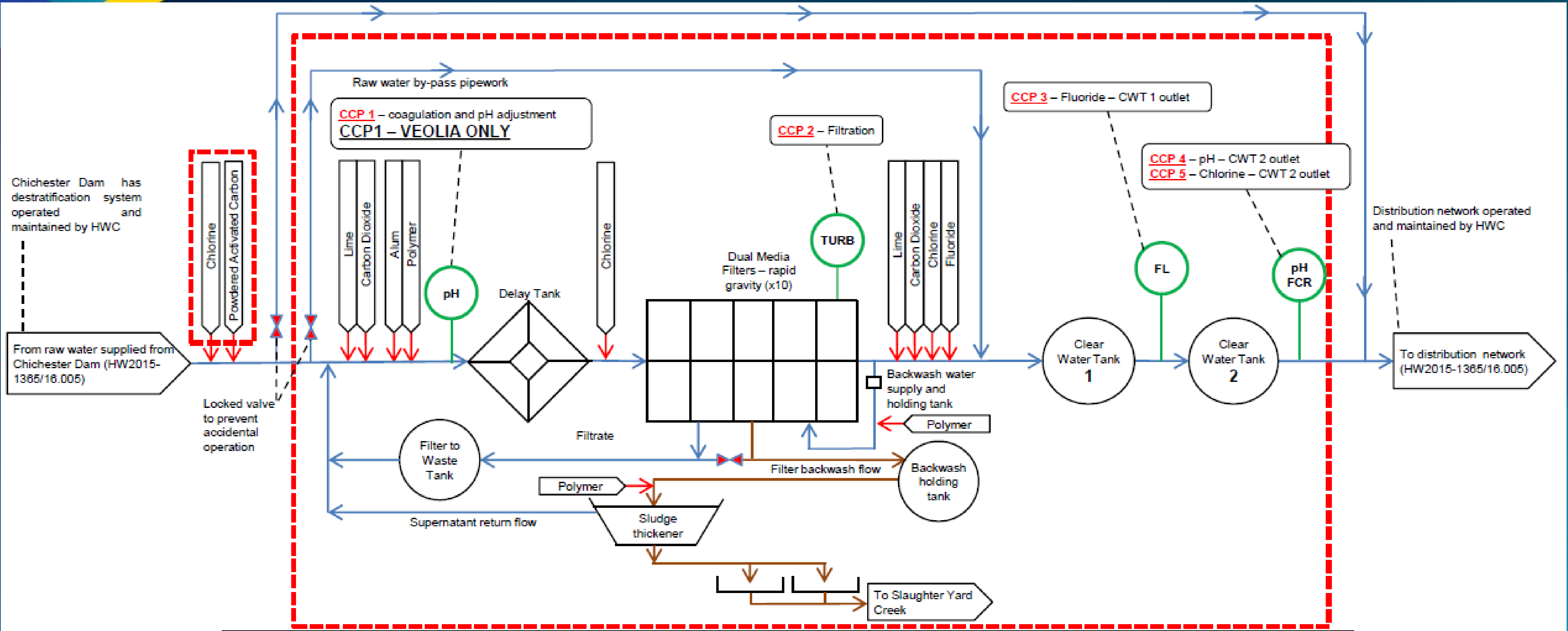
Australian Laboratory Services (ALS) – Hunter Water's Services Provider for Sampling & Analysis

- ✓ ALS' Newcastle Lab Provides:
  - Algae / Cyanobacteria Cell Count & Biovolume Analysis – Microscopic Analysis
  - Phytoxigene™ Analysis – PCR Test
  - Geosmin & MIB Analysis
- ✓ ALS' Sydney Lab Provides:
  - Algal Toxins (Intracellular, Extracellular & Total) – refer to below list
- ✓ Phytoxigene™ & Algal Toxins Analysis Prior to December 2022 Completed by Subcontracted Labs

Compound	CAS Number	LOR	Unit
			Sampling date / time
EP248-E: Extracellular Cyanotoxins in Water			
Cylindrospermopsin (CYN)	143545-90-8	0.1	µg/L
Deoxycylindrospermopsin (doCYN)	344941-42-0	0.2	µg/L
Anatoxin-a (ATX)	64285-06-9	0.1	µg/L
Nodularin-R (NOD)	118399-22-7	0.2	µg/L
Microcystin-LR (MCLR)	101043-37-2	0.2	µg/L
Microcystin-RR (MCRR)	111755-37-4	0.2	µg/L
Microcystin-YR (MCYR)	101064-48-6	0.2	µg/L
Microcystin-LA (MCLA)	96180-79-9	0.2	µg/L
Total Microcystins	----	0.2	µg/L
EP248-E: Extracellular Cyanotoxins in Water - Microcystin Toxicity Equivalents			
Microcystin-RR (MCRR) MCLReq	----	0.2	µg/L
Microcystin-YR (MCYR) MCLReq	----	0.2	µg/L
Microcystin-LA (MCLA) MCLReq	----	0.2	µg/L
Total Microcystins MCLReq	----	0.2	µg/L

EP263-I: Intracellular Saxitoxins in Water - Toxicity Equivalents to STX			
Neosaxitoxin (NEO) STXeq	----	0.5	µg/L
Gonyautoxin-1 (GTX1) STXeq	----	0.5	µg/L
Gonyautoxin-2 (GTX2) STXeq	----	0.5	µg/L
Gonyautoxin-3 (GTX3) STXeq	----	0.5	µg/L
Gonyautoxin-4 (GTX4) STXeq	----	0.5	µg/L
Gonyautoxin-5 (GTX5) STXeq	----	0.5	µg/L
Decarbamoylgonyautoxin-2 (dcGTX2) STXeq	----	0.5	µg/L
Decarbamoylgonyautoxin-3 (dcGTX3) STXeq	----	0.5	µg/L
N-sulfocarbamoyl-gonyautoxin-2 (C1) STXeq	----	0.5	µg/L
N-sulfocarbamoyl-gonyautoxin-3 (C2) STXeq	----	0.5	µg/L
N-sulfocarbamoyl-gonyautoxin-1 (C3) STXeq	----	0.5	µg/L
N-sulfocarbamoyl-gonyautoxin-4 (C4) STXeq	----	0.5	µg/L
Total Saxitoxins STXeq	----	0.5	µg/L

Dungog WTP – Existing Treatment Processes



CCP No.	Description	Monitoring Location
CCP 1 VEOLIA ONLY	Coagulation and pH adjustment	Dosed water online pH
CCP 2	Filtration	Individual filtered water on-line turbidity (NTU); daily combined filtrate grab sample collected
CCP 3	Fluoride – CWT 1 outlet	Fluoride residual online (mg/L) CWT 1 outlet; daily grab sample collected
CCP 4	pH – CWT 2 outlet	pH online CWT 2 outlet; daily grab sample collected
CCP 5	Chlorine – CWT 2 outlet	Free chlorine residual online (mg/L) CWT 2 outlet; daily grab sample collected

Dungog WTP – Filter Clogging Algae Events

Peak Event Date	Peak Diatom (cells/mL)	Dominant Diatom
April/May 2019	1440 (Synedra)	Synedra
June 1994	480 (Synedra)	Synedra (TBC)
September 2009	260 (Synedra)	Synedra
August 2001	260 (Synedra)	Synedra
May 1998	243 (Synedra)	Synedra
June 2006	200	Synedra (TBC)
June 1999	135 – 890 (Asterionella) 70 – 135 (Synedra)	Asterionella
August 2014	19,600 (Aulacoseira) <50 (Synedra)	Aulacoseira

Dungog WTP – Cyanobacteria Events

Peak Event Date	Peak algae (cells/mL)	Potentially toxic or non-toxic
June 2020	42,000	100% Potentially toxic BGA
January 2020	36,432	BGA – 31,960 cells/mL with 99% Non-toxic
January 2014	35,335	BGA – 33,125 cells/mL with 98% Non-toxic
January 2005	35,242	BGA – 35,036 cells/mL with 98% Potentially toxic
November 2009	33,655	BGA – 23,400 cells/mL with 100% Non-toxic
August 2014	32,840	BGA – 8,000 cells/mL with 100% Non-toxic
March 2015	32,002	BGA – 27,090 cells/mL with 100% Non-toxic

It should be noted however that during the 2020 bloom, Microcystis cell counts reached significantly higher concentrations in samples collected from the dam surface (337,000 cells/mL), Chichester River (>2,000,000 cells/mL) and Wangat River (>1,750,000 cells/mL) than those reported at the screens.

Dungog WTP – Algal Toxins

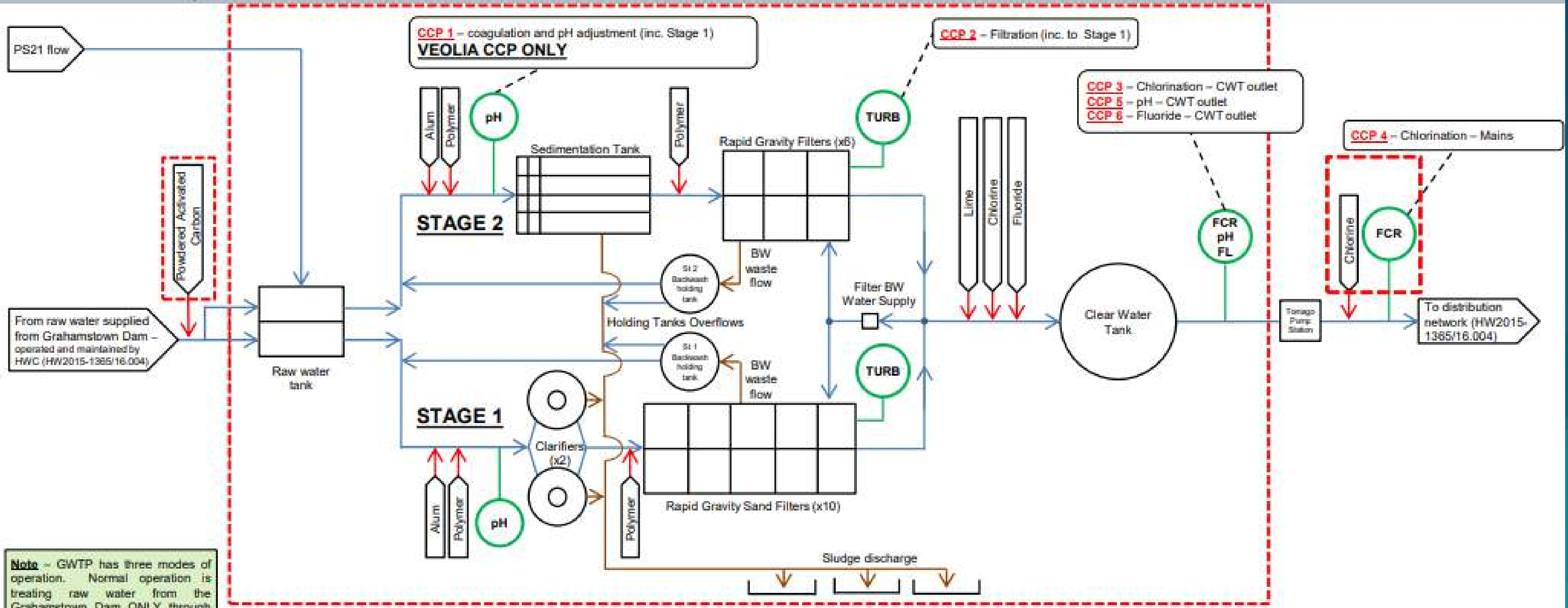
Low concentrations of the algal toxin microcystin-LR (MC-LR) has been reported in Chichester Dam in 1998, 2003 and 2006. A scum sample collected from the Chichester Dam boat ramp during the 2020 Microcystis bloom contained 5 µg/L MC-LR, while MC-LR was also detected in a number of samples collected from the Chichester and Wangat Rivers during the 2020 bloom.

Dungog WTP – Taste & Odour Events

Peak Event Date	Peak Geosmin (ng/L)	Peak MIB (ng/L)	Total T&O (ng/L)
July 2019	150	<2.0	150
August 2019	87	<1.0	87
April 2020	76	<1.0	76
November 2019	72.0	<1.0	72.0
October 2018	60.0	<2.0	60.0
November 2018	40.0	<1.0	40.0
October/November 2014	23.0	1.2	24.2

Temporary PAC Dosing Facility Upstream of Dungog WTP

Grahamstown WTP – Existing Treatment Processes



Note – GWTP has three modes of operation. Normal operation is treating raw water from the Grahamstown Dam ONLY through both stage 1 & 2 of the treatment plant.
This process flow diagram shows the basic flow/treatment path when Only Grahamstown Dam water is being treated. In this scenario both stage 1 and 2 raw water is from Grahamstown town, treated independently before the Stage 1 and 2 filtered water converge again prior to post treatment chemical dosing.

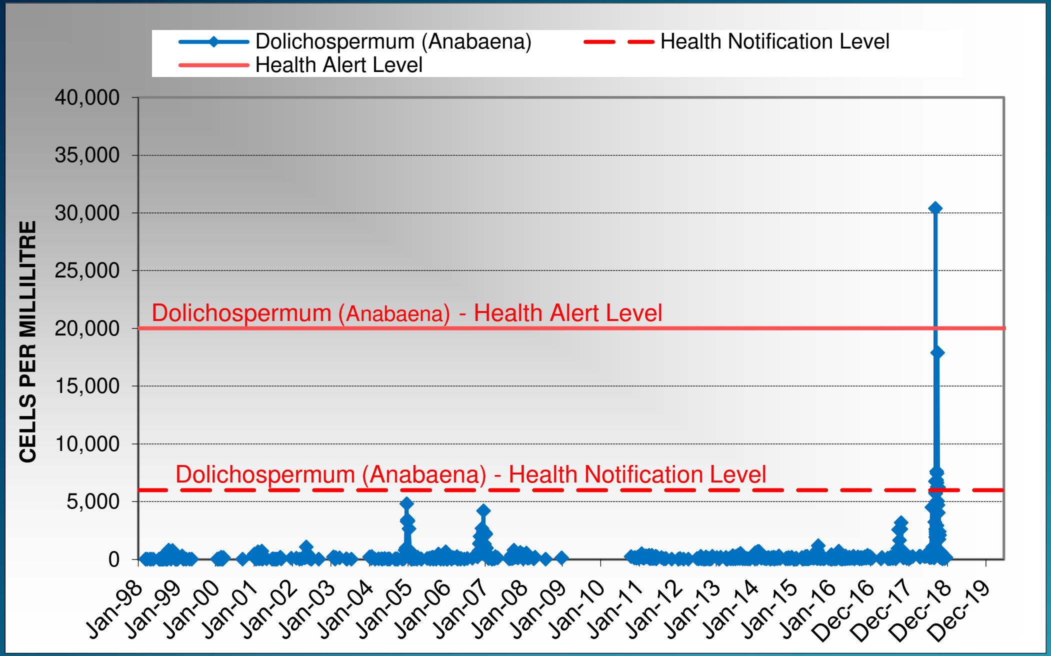
CCP No.	Description	Monitoring Location
CCP 1 VEOLIA ONLY	Coagulation and pH adjustment	Dosed water online pH (prior to entering sedimentation tank or clarifiers)
CCP 2	Filtration	Individual filtered water on-line turbidity (NTU);
CCP 3	Chlorination – CWT outlet	Free chlorine residual online CWT outlet; CT chlorine concentration contact time (min.mg/L)
CCP 4	Chlorination - Mains	Free chlorine residual (mg/L) online mains; daily grab sample collected mains (mg/L)
CCP 5	pH – CWT Outlet	pH online CWT outlet; daily grab sample CWT outlet; daily grab sample CWT outlet
CCP 6	Fluoridation – CWT outlet	Fluoride residual online (mg/L) CWT outlet; daily grab sample CWT outlet

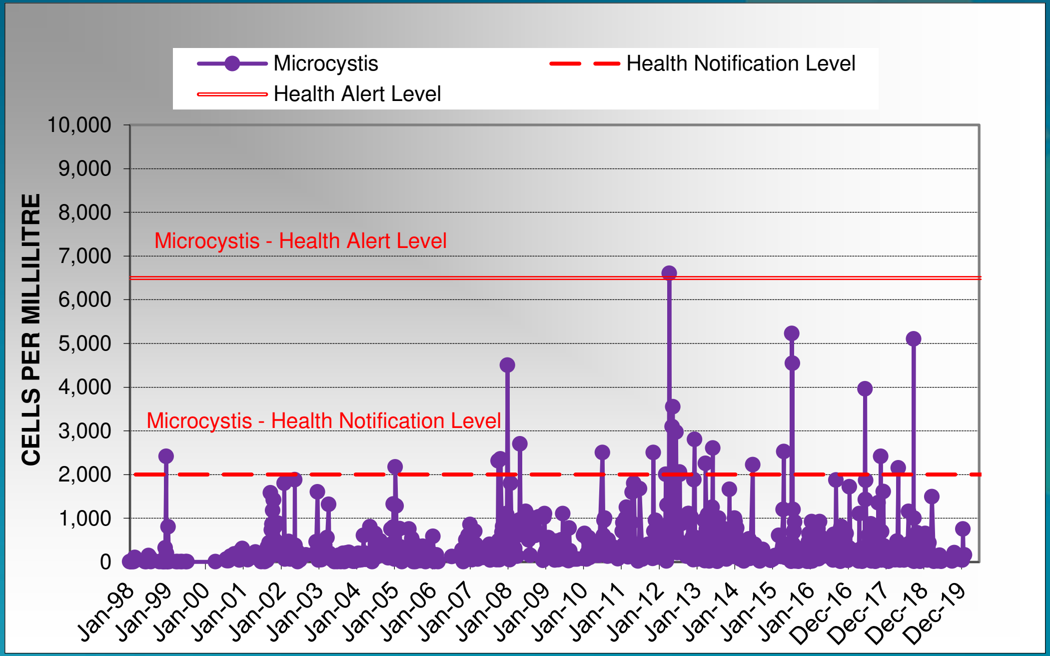
Grahamstown WTP – Cyanobacteria Events

Peak Event Date	Peak algae (cells/mL)	Potentially toxic or non-toxic
April 2010	2,069,340	BGA – 2,066,670 cells/mL with 100% Non-toxic
April 2006	483,012	BGA – 480,201 cells/mL with 100% Non-toxic
April 2007	417,462	BGA – 416,286 cells/mL with 98.7% Non-toxic
November 2019	374,005	BGA – 371,650 cells/mL with 99.8% Non-toxic
January/February 2013	347,340	BGA – 341,715 cells/mL with 99.9% Non-toxic
January 2012	341,715	BGA – 316,700 cells/mL with 100% Non-toxic
March 2007	206,371	BGA – 205,095 cells/mL with 73.6% Non-toxic

It should be noted that historical maximum total algae cell counts can be significantly higher at routine sampling points in Grahamstown Dam than at the raw water tank.

Presence of Algae in Grahamstown Dam at Raw Water Offtake





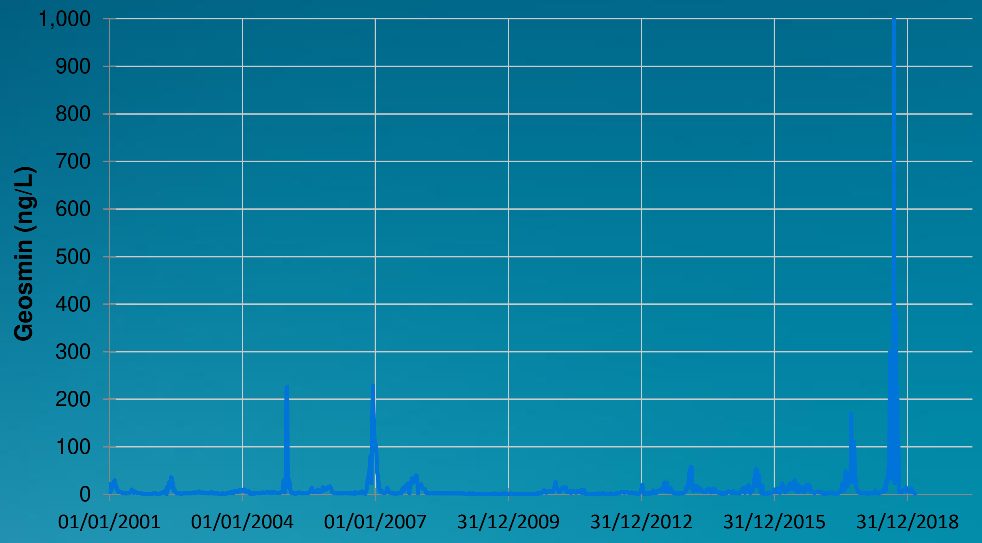
Grahamstown WTP – Algal Toxins & Toxin Producing Genes

Low concentrations of the algal toxin MC-LR were detected in Grahamstown Dam during a bloom event spanning the summer of 2004-05. A maximum of 0.9 µg/L was detected in raw water prior to PAC dosing, consisting 0.6 µg/L intra-cellular and 0.3 µg/L extra-cellular. The dominant species at the time was *Anabaena Circinalis*.

Toxin gene testing undertaken on a scum sample during the 2021 bloom indicated the presence of the Microcystin / Nodularin gene mcyE. The Microcystin / Nodularin gene mcyE was also detected during the 2018 Dolichospermum bloom, although all toxin samples were below the limit of reporting throughout the 2018 bloom. Toxin gene testing did not detect the presence of the Cylindrospermopsin gene cyrA or Saxitoxin gene STXA during either the 2018 or 2021 bloom events.

Grahamstown WTP – Taste & Odour Events

Peak Event Date	Peak Geosmin (ng/L)	Peak MIB (ng/L)	Total T&O (ng/L)
September 2018	1,000	<10	1000
December 2020*	250	<1	250
May 2021*	210	1.4	211.4
March 2015	180	1.2	181.2
September 2017*	170	<1	170
September 2015	72	2.4	74.4
March 2020	53	<1	53



Algal Toxin vs Toxin Gene (Phytoxigene™) Results

Sampling Location	Algal Toxin Results	Phytoxigene™ Testing	Microcystis (cells/mL)	Dolichospermum (cells/mL)
Wangat River	Microcystin-LR (0.5 µg/L)	< LOR for all 3 genes	1,810,000	< LOR
Chichester River	< LOR	66 copies of Microcystin/Nodularin gene (mcyE/ndaF) (< LOR for other genes)	714,000	< LOR
Wangat River	Microcystin-LR (0.5 µg/L)	66 copies of Microcystin/Nodularin gene (mcyE/ndaF) (< LOR for other genes)	250,000	< LOR
Southern Shoreline (Grahamstown Dam) – Scum Sample	< LOR	2,200 copies of Microcystin/Nodularin gene (mcyE/ndaF) (< LOR for other genes)	6,500	2,903,700
Grahamstown Raw Offtake (R6) – Scum Sample	0.4 Microcystin-RR (0.04 Microcystin-LR TE)	2,000 copies of Microcystin/Nodularin gene (mcyE/ndaF) (< LOR for other genes)	22,600	-

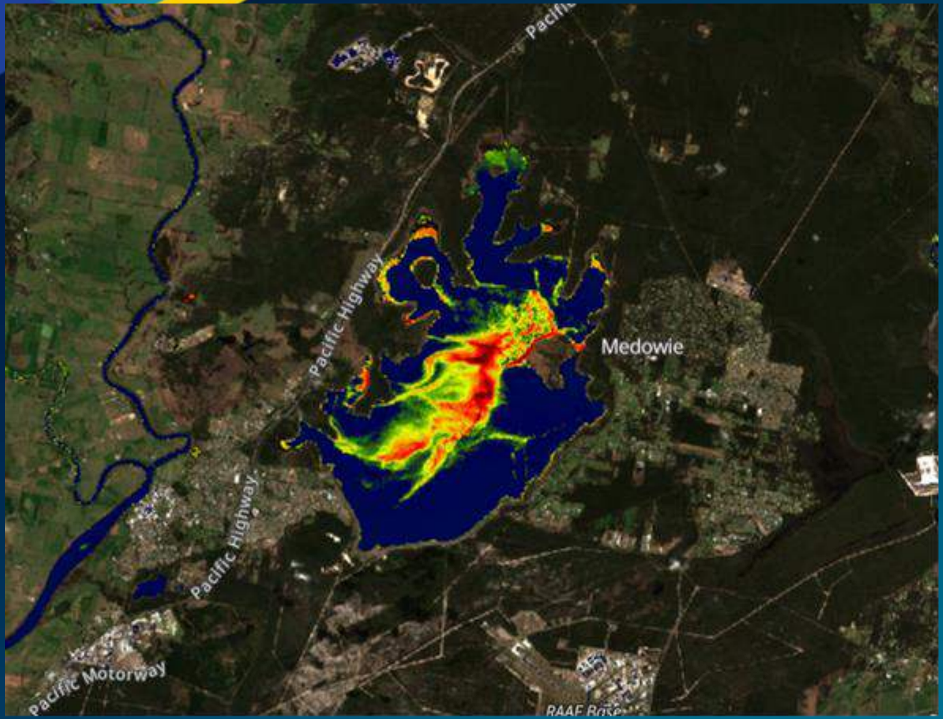
Algal toxins detected in presence and absence of toxin gene copies detected by Phyoxigene™

Questions for Future Learning & Investigations

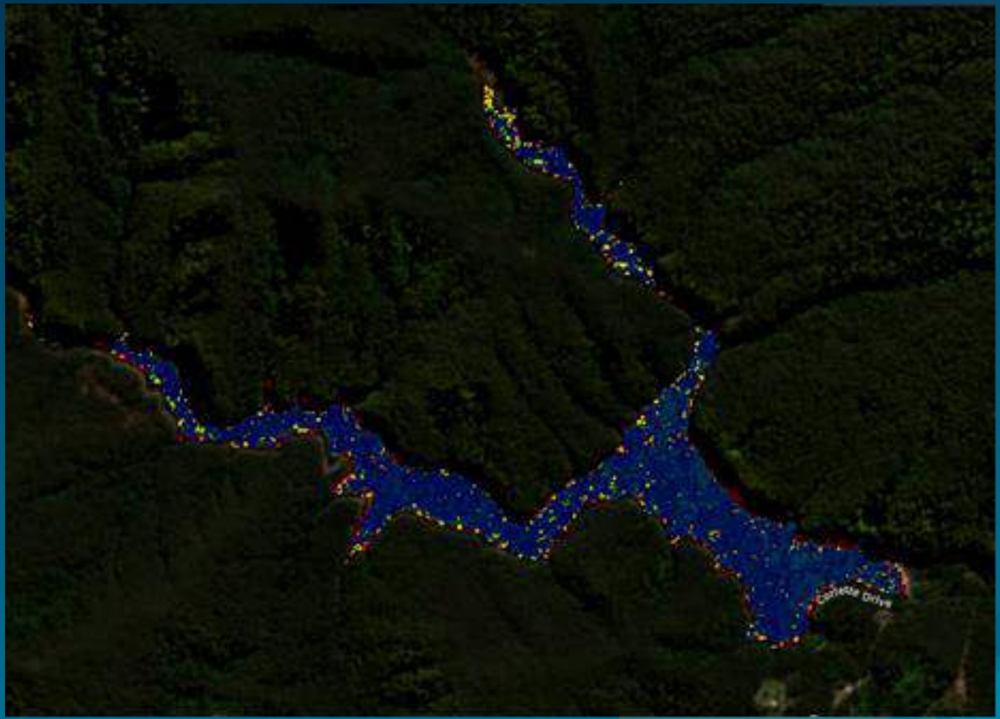
- ✓ Does Phytoxigene™ analyse ALL gene(s) that are responsible for expressing toxicity for given toxins?
- ✓ Are there any other test methods available similar to Phytoxigene™?
- ✓ Would different methods produce different results for the same toxin producing gene(s)?
- ✓ Are there any quantifiable triggers to ascertain any changes to expressiveness of toxin genes to start or cease toxin production?
- ✓ Is there any correlation between gene copies detected by Phytoxigene™ and the actual toxin production (µg/L)?

Future Direction (Innovation)

Catchment Monitoring using Sentinel Hub EO Browser and WaterNSW Custom Algae Script



Large scale cyanobacteria (Dolichospermum) bloom in Grahamstown Dam, September 2018



Filter blocking algae (Synedra and Aulacoseira) bloom in Chichester Dam, July 2023

- Sentinel Hub EO Browser displays images from the Sentinel-2 satellite. Custom script created by WaterNSW to visualise chlorophyll-a to detect algal growth. Sentinel Hub is a free service and WaterNSW has generously provided their script free of charge.
- Hunter Water uses this for monitoring any changes in the rivers and storages in our area of operations.
- Potential to provide a pre-warning and tracking of any blooms. But it also picks up floating weed and vegetation, so indications of a bloom requires further verification by field observation and sampling/analysis for algae.
- Potential to further improve with the use of CyanoLakes, which can detect the presence of phycocyanin, and therefore distinguish cyanobacteria from other types of algae but probably not suitable for small dams such as Chichester Dam.

Future Direction (Innovation)

AquaWatch Trial for Grahamstown Dam – Collaboration with CSIRO

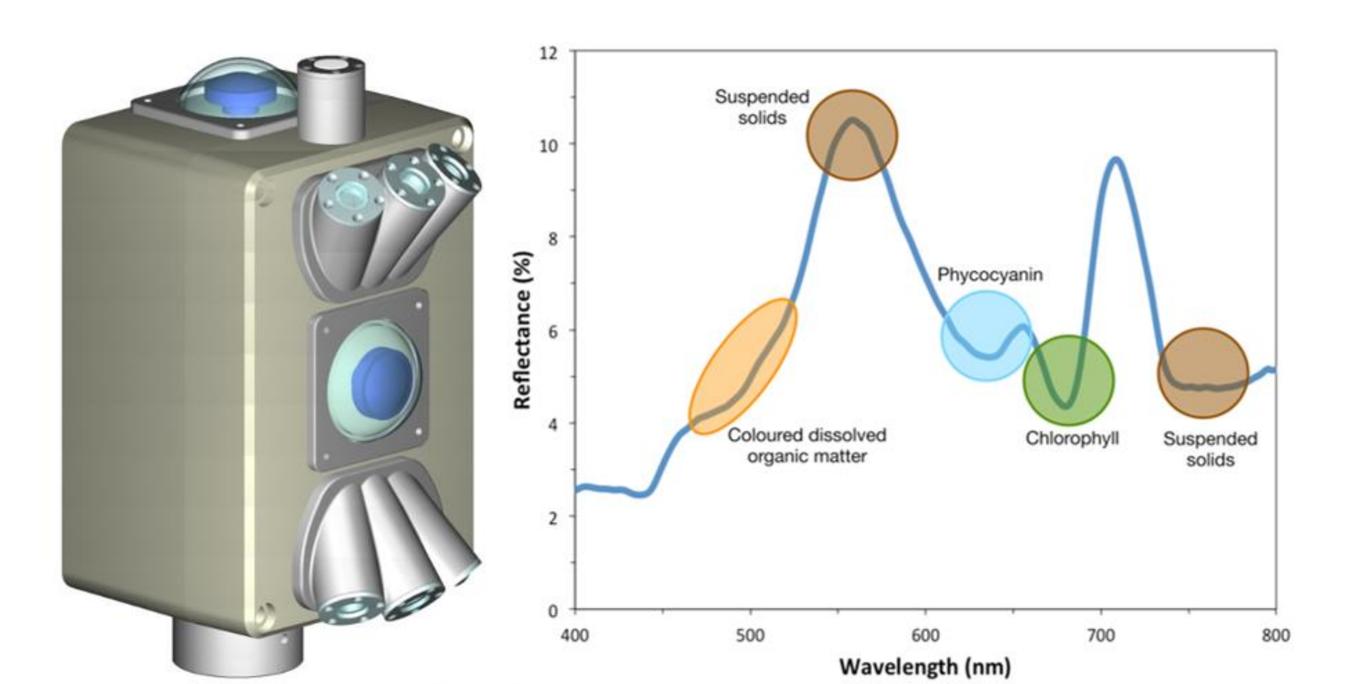


Figure B. HydraSpectra© camera to be deployed as part of this proposal. The sensor has several optical inputs for spectral measurement plus two hemispherical cameras to monitor both water and sky condition.

Figure C. The spectral reflectance signature from an algal dominated water body and the regions of the spectrum which can be used to derive information about its underlying water quality.

- ✓ HydraSpectra unit captures light from several '**orientations**' and '**fields of view**' – measures **reflectance wavelengths** between 400-800 nm.
- ✓ Green and Blue pigments (chlorophyll and phycocyanin) are released into the water by cyanobacteria. **Cyanobacteria have a reflectance wavelength signature of 620-690 nm.**
- ✓ **2 Cameras verify the sky and water conditions** at each 15 minute sample interval.
- ✓ Once the spectral '**reflectance signature**' of the local water source has been established, remote sensing for water quality, using Earth Observation Satellites (AquaSat), can then be used.
- ✓ Further Aim is to **Develop the Hydrologic Forecasting Model**

Future Direction (Innovation & Upgrades)

Use of Drones

- ✓ Catchment Surveillance
- ✓ Sampling from Remote Sites (This is being explored)

Additional Robust Treatment Options being Explored for Dungog WTP

- ✓ Add Solids Removal Step Upstream of Existing Filtration
- ✓ Set up Permanent Powdered Activated Carbon (PAC) Dosing Facility

Planned Upgrades for Grahamstown WTP to Increase Robustness of Existing Treatment Processes

- ✓ Sedimentation Tanks
- ✓ Filters

Questions?