

Monitoring Plan for *Cylindrospermopsis raciborskii* in the Colorado River System

Background

Cylindrospermopsis raciborskii is blue-green algae capable of producing toxins that was first identified in India in the early 1900s. Since that time it has spread throughout the world and most recently has invaded lakes in Florida, North Carolina, Indiana, and Wisconsin. It is difficult to distinguish from other non-harmful algae species because it has very few distinctive characteristics. It is a filament 2 to 3 microns wide and 10 to 90 microns long (Figure 1). It has become such a successful worldwide invader because it is very efficient at utilizing phosphorus. *Cylindrospermopsis* is able to out compete the normal algae for nutrients. The nutrients are bound up by *Cylindrospermopsis* and unavailable for other algae.

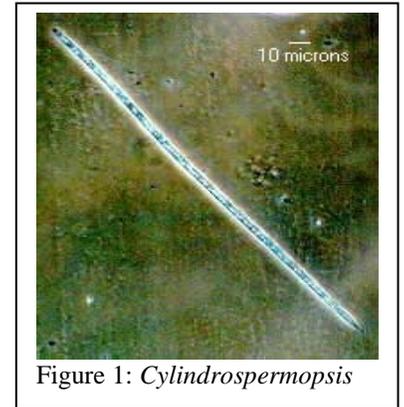


Figure 1: *Cylindrospermopsis*

There are two different morph types of *Cylindrospermopsis raciborskii*, the curly morph type and the straight morph type (Figure 2). The straight morph type is known to produce more toxins. *Cylindrospermopsis* is able to produce three toxins, cylindrospermopsin, anatoxin-a, and saxitoxin. *Cylindrospermopsis* does not always produce toxins. Cylindrospermopsin is a liver toxin. It can affect the kidneys, heart and other organs. It can also be carcinogenic and genotoxic. Anatoxin-a is a neuromuscular agent and ingestion can result in paralysis, respiratory distress, convulsions, asphyxiation, and death. Saxitoxin is a neurotoxin that causes paralysis and respiratory distress. It is the toxin commonly associated with contaminated shellfish. Toxin production must be confirmed by laboratory analysis.

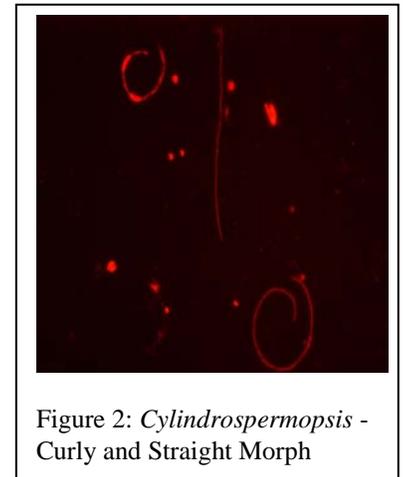


Figure 2: *Cylindrospermopsis* - Curly and Straight Morph

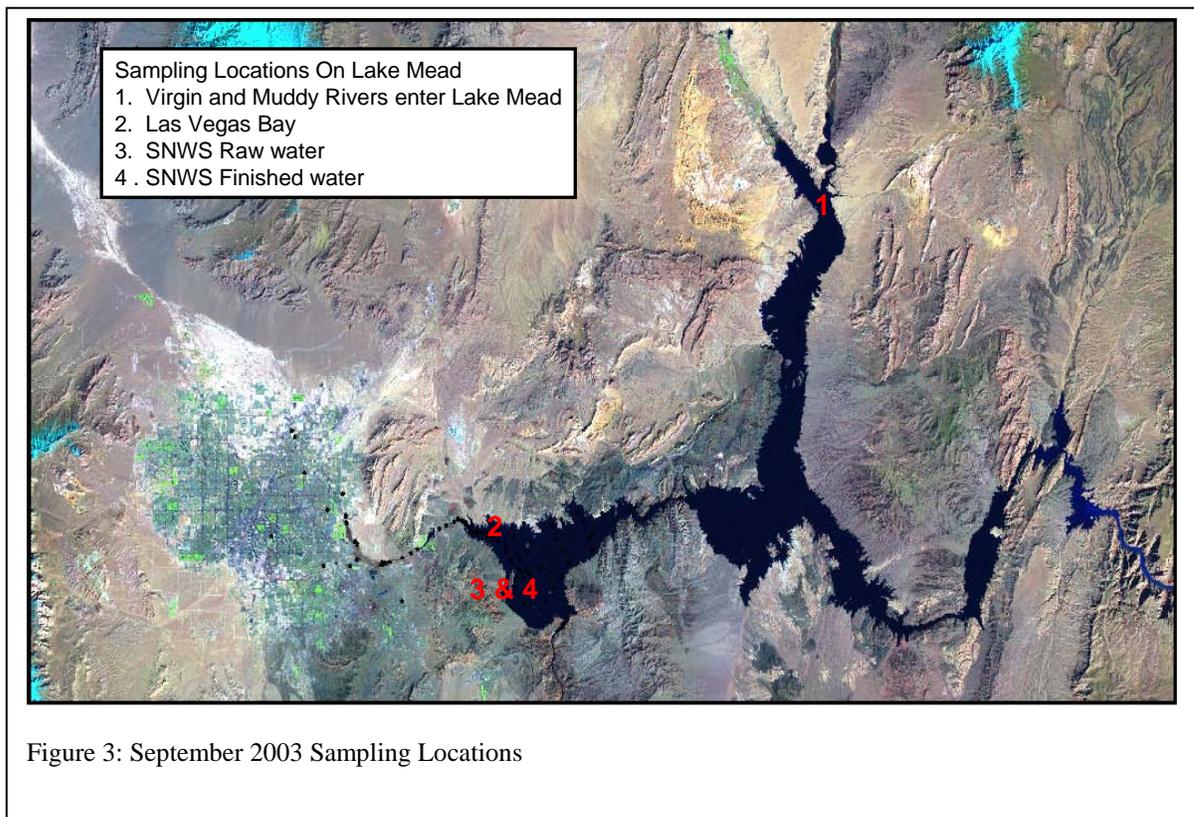
While there are no drinking water standards in the United States for this algae or the associated toxins, the World Health Organization has guidelines for the presence of different concentrations of blue-green algae. Water bodies with blue-green algae cells present in a concentration of 5,000 to 20,000 are at mild risk of adverse health affects if the water is ingested. Blue-green algae counts in the range of 20,000 to 100,000 cells/mL indicate a moderate risk of adverse health affects if the water is ingested and greater than 100,000 cells/mL signify a high risk of potentially severe, long-term health affects if the water is ingested. Australia has set health risk guidelines of 1 to 15 ug/L for cylindrospermopsin and 3 ug/L for anatoxin-a.

The presence of *Cylindrospermopsis* has been identified in increasing concentrations in the Overton Arm and Boulder Basin of Lake Mead. This monitoring plan was developed under the direction of the Lake Mead Water Quality Forum Algae Subcommittee to track

Cylindrospermopsis population trends and to address immediate, as well as long-term concerns about the presence of these toxic blue-green algae in the Colorado River system. Sampling sites were selected for one or more of the following reasons: 1) *Cylindrospermopsis* was previously reported at the location, 2) the location is in a productive region of the lake, or 3) the site's proximity to the drinking water intake. Microscopic identification of the algae will be done on each sample collected. Toxin analysis will be done as warranted based on algal counts, physical evidence of toxicity in the area, or the presence of yet undetermined stressors.

Short-term Monitoring Plan

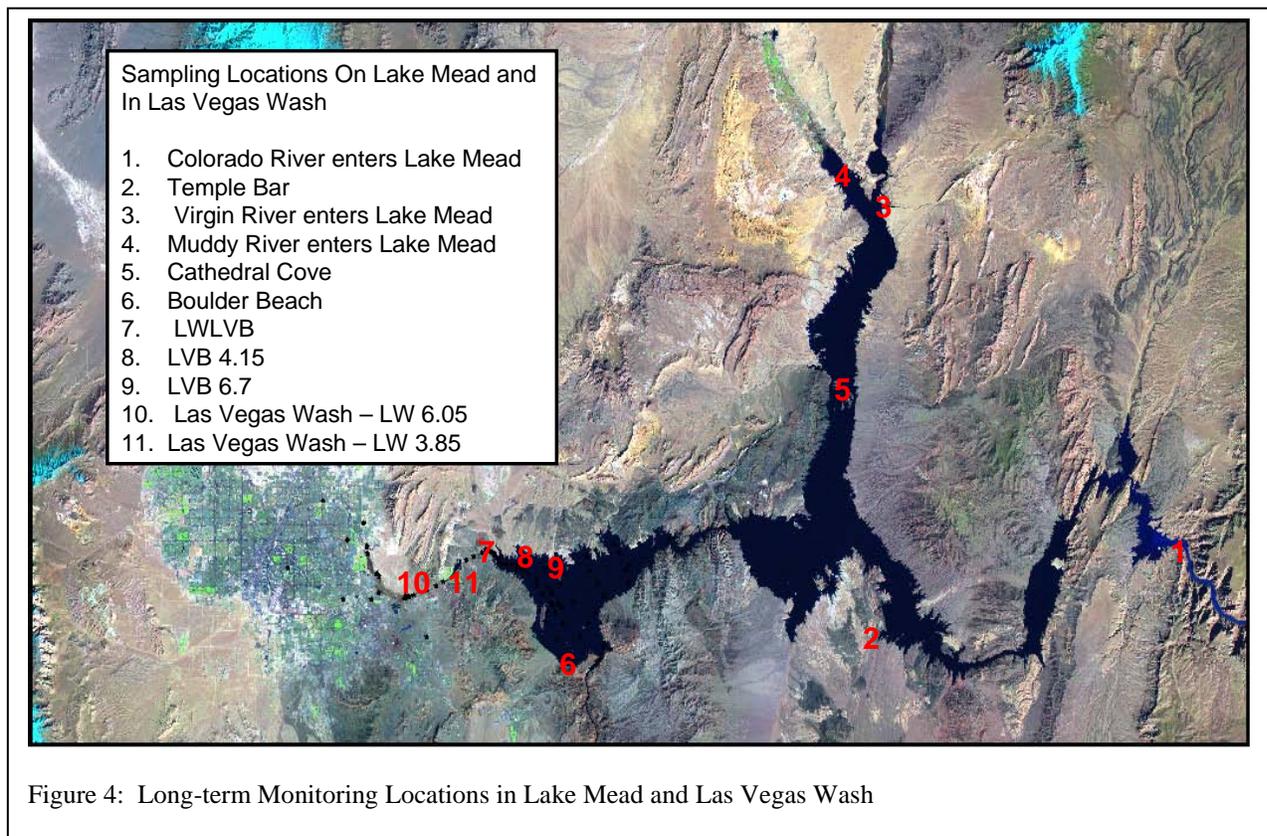
Samples will be collected the week of September 15, 2003 at two sites, one in the Boulder Basin and one in the Overton Arm. Two samples will also be collected at the Alfred Merrit Smith Water Treatment Facility (AMSWTF) in the raw and finished water (Figure 3). The samples will be sent out for *Cylindrospermopsis* counts, chlorophyll a, b, and c analysis, and algal toxin analysis. Hydrolab profiles will be taken at the Lake Mead sites to provide general water quality data. All samples will be taken to the AMSWTF laboratory to be distributed for analysis.



Long-term Monitoring Plan

Beginning in July 2004, samples will be collected at 11 sites on Lake Mead and in the Las Vegas Wash from July through October during the following weeks: July 12 to July 16, 2004, July 26 to July 30, 2004, August 9 to August 13, 2004, August 30 to September 3, 2004, September 13 to September 17, 2004, and October 4 to October 8, 2004 (Figure 4). Samples will be collected for nutrients, *Cylindrospermopsis* counts, chlorophyll a, b, and c, and algal toxin analysis. Hydrolab profiles will be taken on the sites to provide general water quality data including turbidity. Field measurements of Secchi depth, wind speed, temperature, and light transmittance will be noted.

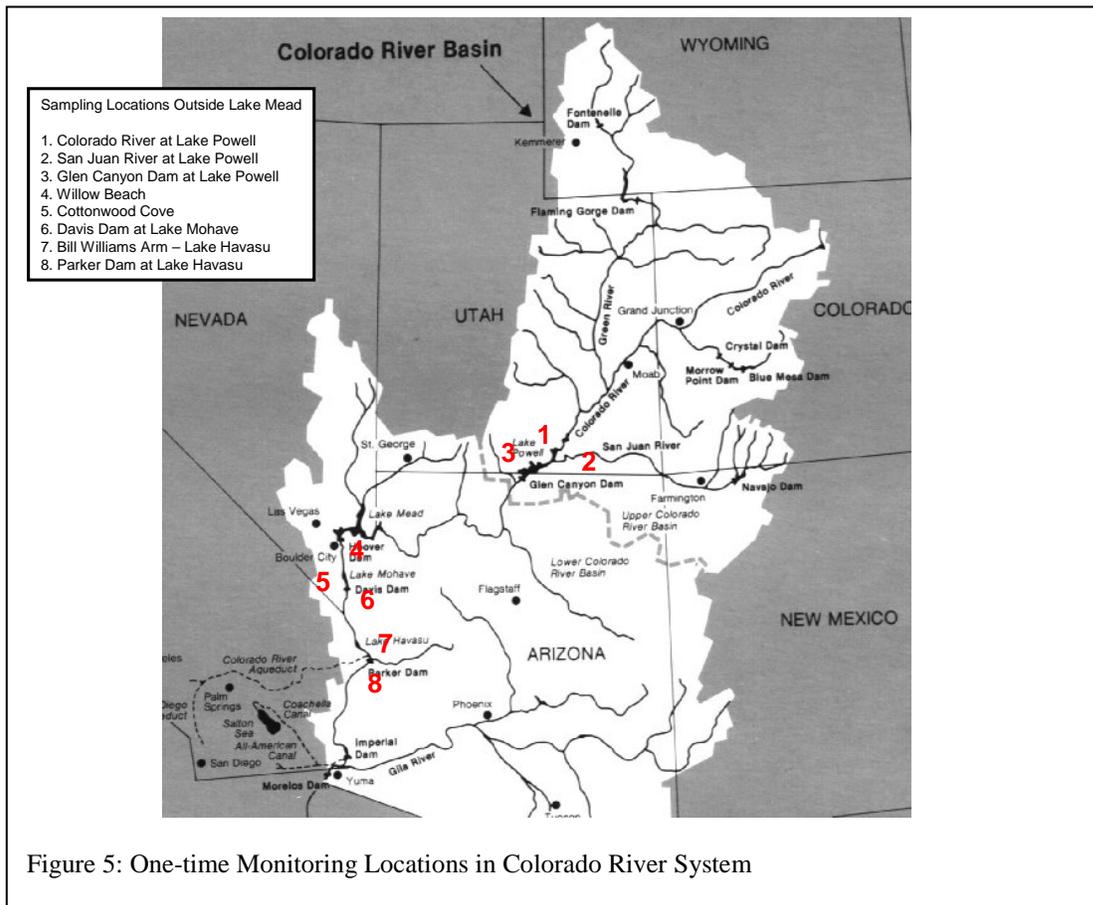
The samples will be distributed to the appropriate lab for nutrient analysis, *Cylindrospermopsis* counts and chlorophyll a, b, and c analysis. Turn around time for preliminary *Cylindrospermopsis* counts will be one day. If the preliminary counts are greater than 20,000 *Cylindrospermopsis* cells/mL at any location in Lake Mead AMSWTF raw and finished water samples will be sent out for algal toxin analysis and the National Park Service (NPS) will be notified. The NPS will be asked to identify locations where full body contact recreation is occurring in the area with elevated *Cylindrospermopsis* counts. Samples will be collected from the designated site and sent out for algal toxin analysis. A sample will also be collected at Willow Beach to determine the concentration of *Cylindrospermopsis* in Lake Mohave. Depending upon funding for this project, all sample sites collected may be sent out for algal toxin analysis or a limited subset (based on a count of greater than 20,000 cells/mL) may be sent out. All samples will be collected and taken to the AMSWTF laboratory to be distributed for analysis.



If *Cylindrospermopsis* is detected in any sample, a duplicate sample will be sent out for algal counts and identification to another qualified Phycologist (other than Phycotech) to verify the identification. A quality assurance plan will be developed detailing the procedures to be used to collect the duplicate sample, detail the number of samples to be collected, and specify the analysis method.

Extensive One Time Sampling Event

If preliminary monitoring results indicate an increasing trend in algal concentrations throughout the summer, a one time sampling event will be conducted the week of August 30 to September 3, 2004. Samples will be collected for *Cylindrospermopsis* counts throughout the Colorado River system (Figure 4 and 5), nutrients, chlorophyll a, b, and c, and algal toxin analysis. Hydrolab profiles will be taken on the sites to provide general water quality data including turbidity. Field measurements of Secchi depth, wind speed, temperature, and light transmittance will be noted. The samples will be distributed to the appropriate lab for nutrient analysis, *Cylindrospermopsis* counts and chlorophyll a, b, and c analysis. Turn around time for preliminary *Cylindrospermopsis* counts will be one day. If the preliminary counts are greater than 20,000 *Cylindrospermopsis* cells/mL AMSWTF raw and finished water samples will be sent out for algal toxin analysis. Depending upon funding for this project, all sample sites collected may be sent out for algal toxin analysis or a limited subset (based on a count of greater than 20,000 cells/mL) may be sent out. All samples will be taken to the AMSWTF laboratory to be routed for analysis.



Sample Collection Protocol and Laboratory Performing Analyses

The sample collection and preservation protocols will be developed in a separate document using recommendations from the laboratories performing the analyses. Quality assurance specifications will also be included in the manuscript. Analytical laboratory selections will be made with recommendations of the Lake Mead Water Quality Forum Algae Subcommittee.

Entity Responsible for Sample Collection

The entities responsible for sampling the different sites can be found in Table 1.

Table 1: Entities Responsible for Collecting Samples, Recording Field Data, and Performing Hydrolab Profiles

Location	7/12-7/16	7/26-7/30	8/9-8/13	8/30-9/3	9/13-9/17	10/4-10/8
1. Point where Colorado River enters Lake Mead	USBR	CLV	USBR	CLV	CLV	CLV
2. Temple Bar	USBR	CLV	USBR	CLV	CLV	CLV
3. Point where Virgin River enters Lake Mead	USBR	CLV	USBR	CLV	CLV	NDOW
4. Point where Muddy River enters Lake Mead	USBR	CLV	USBR	CLV	CLV	NDOW
5. Cathedral Cove	USBR	CLV	USBR	CLV	CLV	NDOW
6. Boulder Beach	NPS	NPS	NPS	NPS	NPS	NPS
7. LWLVB	USBR	USBR	USBR	CLV	USBR	CLV
8. LVB 4.15	USBR	USBR	USBR	CLV	USBR	CLV
9. LVB 7.3	USBR	USBR	USBR	CLV	USBR	CLV
10. LW 6.05	SNWA	SNWA	SNWA	SNWA	SNWA	SNWA
11. LW 3.85	SNWA	SNWA	SNWA	SNWA	SNWA	SNWA
12. Colorado River at Lake Powell	X	X	X	SNWA	X	X
13. San Juan River at Lake Powell	X	X	X	SNWA	X	X
14. Glen Canyon Dam at Lake Powell	X	X	X	SNWA	X	X
15. Willow Beach	X	X	X	NPS	X	X
16. Cottonwood Cove	X	X	X	NPS	X	X
17. Davis Dam at Lake Mohave	X	X	X	NPS	X	X
18. Bill Williams Arm of Lake Havasu	X	X	X	SNWA	X	X
19. Parker Dam at Lake Havasu	X	X	X	SNWA	X	X

X= Not Collected

CLV = City of Las Vegas
 SNWA = Watershed Division
 NPS = National Park Service

USBR = Bureau of Reclamation Denver Office
 NDOW = Nevada Division of Wildlife

Cost

Option A - All samples are analyzed as written in the plan (Table 2)

- Phycotech will perform algal counts for *Cylindrospermopsis* counts only.
- The Southern Nevada Water System or the United States Bureau of Reclamation will perform chlorophyll a, b and c analyses at no charge
- The City of Las Vegas and the United States Bureau of Reclamation will perform nutrient analyses at no charge
- All samples will be sent out for algal toxin analysis for cylindrospermopsin and anatoxin a.
- One sample will be sent out for outside verification of identification.
- Labor costs for collecting samples and Hydrolab profiles is not included and considered in-kind.
- SNWA will fund toxin analysis of AMSWTF raw and finished water.
- Additional QA/QC will add to cost

Table 2: Maximum Cost of Monitoring Plan

date	# of locations	Algal Counts @\$80.00	Verification ID @\$200.00	Nutrients	Chlorophyll a, b and c	Hydrolab profiles	Algal Toxins @\$1000
7/12-7/16	11	\$880		0	0	0	\$11000
7/26-7/30	11	\$880	\$200	0	0	0	\$11000
8/9-8/13	11	\$880		0	0	0	\$11000
8/30-9/3	19	\$1520		0	0	0	\$19000
9/13-9/17	11	\$880		0	0	0	\$11000
10/4-10/8	11	\$880		0	0	0	\$11000
Total	74	\$5920	\$200	0	0	0	\$74000
Grand Total							\$80120

Option B – All samples performed as written in the plan, limit number of samples sent out for algal toxins (Table 3)

- Phycotech will perform algal counts for *Cylindrospermopsis* counts only.
- The Southern Nevada Water System or the United States Bureau of Reclamation will perform chlorophyll a, b, and c analyses.
- The City of Las Vegas and the United States Bureau of Reclamation will perform nutrient analyses at no charge
- Samples will be sent out for algal toxin analysis for cylindrospermopsin and anatoxin-a only if counts are greater than 20,000 cells/mL. Numbers

of samples sent out for algal toxin analysis based on number of samples seen with counts greater than 20,000 cells/ml in 2003

- One sample will be sent out for outside verification of identification.
- Labor costs for collecting samples and Hydrolab profiles is not included and considered in-kind.
- SNWA will fund toxin analysis of AMSWTF raw and finished water.
- Additional QA/QC will add to cost

Table 3: Estimated Minimum Cost of Monitoring Plan

date	# of locations	Algal Counts @ \$80.00	Verification ID @ \$200.00	Nutrients	Chlorophyll a, b and c	Hydrolab profiles	Algal Toxins @ \$1000
7/12-7/16	11	\$880		0	0	0	0
7/26-7/30	11	\$880	\$200	0	0	0	0
8/9-8/13	11	\$880		0	0	0	\$3000
8/30-9/3	19	\$1520		0	0	0	\$5000
9/13-9/17	11	\$880		0	0	0	\$8000
10/4-10/8	11	\$880		0	0	0	
						TBD	\$5000
Total	74	\$5920	\$200	0	0	0	\$21000
Grand Total							\$27120

Public Notification and Results

A separate document will be developed by the Algae Subcommittee describing procedures for public notification, if necessary. The final results of these analyses will be compiled and a final report will be written. All members of the Lake Mead Water Quality Forum Algae Task Force will have input into the final report. The final report should be complete by March 2005.