Slide	Comment
1	Thank you for inviting the Three Lakes Association to share information about our ongoing study on the proliferation of golden brown algae in Torch Lake. This is a study in progress and we know that we do not as yet have definitive answers.
2	I would like right at the start to acknowledge the many people who are helping us look into what appears to be cultural acceleration of the eutrophication of our pristine lakes in this region. Our consultants, experts in the field of algae, Drs. Lowe, Stevenson, and Kociolek have guided us, gotten wet with us, brought students and colleagues, and given an excellent presentation to the public of our 2015 study. I have even borrowed some of their slides for today.
3	Here is an aerial photograph from the south end of Torch Lake illustrating the golden brown algae coating the lake floor. Notice that in this area, with a smooth sandy bottom, the algae can be readily scuffed, leaving streaks where the clean lake floor we are used to shows through.
4	But I want you to know that we are not alone. Here are a few pictures of other lakes in this region showing similar benthic algae deposits. Here are examples from the west side of the Leelanau Peninsula, Lake Charlevoix, Walloon Lake, Birch Lake
5	Here is a handful of the algae and a typical underwater view of the material.
6	And here's a representative view of what the GBA looks like under the microscope. There are many, many different types of diatoms, the form of algae most likely to be found on the lake floor.
7	Here are some of the ideas that have been suggested to explain the observed increase in benthic algae. The GBA is widespread and the zebra mussel population is modest. While we cannot exclude zebra mussel influence, we believe this cannot be the predominant factor. Our examination of the lake floor does not appear to show a loss of snails, crayfish, and other grazers. Again, we cannot discount a subtle reduction as a possible contributing factor but think this cannot be a substantial explanation. Surface runoff from storms or from excess fertilizer could readily increase nutrients in the water column. But we would expect that to more likely cause surface algae blooms rather than lake floor blooms.
8	Landsat satellite data are all we have at this time to address the question of climate change that might affect the growing season and the lake temperature. This graph, hunted up for us by one of Dr. Stevenson's grad students, shows a scatter gram of temperatures in Torch Lake, essentially unchanged over at least 15 years. Based on what temperature data we have, climate change does not appear to be a substantial factor to explain the algae proliferation.

9	Having satisfied ourselves that the other most likely candidates to explain the GBA outbreak are most likely not major factors driving the proliferation, we have focused our attention on groundwater. Study Design • Nutrient Diffusing Substrate to assess the most likely growth rate limiting nutrients • Benthic Algae Identification to learn what the orange crud is made of • Comparison of nutrient levels (principally nitrogen and phosphorus) in groundwater and lake water
10	Here is a map showing the locations where we conducted our studies in 2015 and 2016. In 2015 we collected samples from HWH, the Petty property and the Gourley property. This summer we did a small temperature experiment at the spencer property, which I'll show in a moment, revisited the 2015 properties, and added Deepwater Point (Penoza), a site in Clam Lake and two sites in Lake Bellaire.
11	This shows our HOBO temperature logger experiment in early spring this year. We wanted to see if there was a subsurface temperature difference between sites with and without visible GBA. We did find that as the lake water warmed over the course of about three weeks, a difference began to emerge, showing a slightly colder subsurface temperature where the GBA was more prominent, and we interpreted this as consistent with the groundwater being an important source of the phosphorus stimulating the GBA growth.
12	Shown on the left are containers of growth medium enriched with nitrogen, phosphorus, or both, or unenriched as control and on the right the algal growth as represented by chlorophyll a content of the algae on the surface. This experiment was severely damaged by the big August 2nd storm in this area which, we believe, explains why there was such a discrepancy between results at the two sites studied and calls into question the over-all results.
13	The 2016 NDS experiment was done with better nutrient-diffusing equipment and placed at greater depth to protect it from damage from storm and wave action. Here you see Dr. Lowe and his colleague Dr. Pillsbury with the experimental materials. On the right are the results of the stimulated growth, this time expressed as cell counts. As one would expect, there is a growth response to added nutrients and, also pretty much as one would expect, greater response to phosphorus than to nitrogen. We think that these results more accurately capture the growth-stimulating effects of added nutrients than the storm-damaged experiment from 2015.
14	From Dr. Lowe's report we have: "The genus *Nitzschia* responded strongly to phosphorus addition. This diatom genus is a strong indicator of point-source phosphorus loading and can be used as a strong indicator of areas of phosphorus loading in Torch Lake." When the algae data are available, it will be of interest to see where and how much Nitzschia is present.

15	Moving on, now, to our groundwater-related activities… On the left you see some of the TLA team constructing shallow groundwater wells (piezometers) and on the right you can see how small the business end of the device is.
16	This slide depicts the installation of a piezometer well. The point and the withdrawal tubing are housed inside steel pipe and the point is pounded about two feet into the lake floor. Where the benthos is sandy this is an easy task and where there is a lot of cobble or marl, it can be quite tough. Odd as it may seem, we had to have an MDEQ permit for these wells, at the modest cost of $500!
17	Once the piezometer well was installed we used a hand vacuum pump to retrieve the groundwater. On the left is a schematic of the connections: a two-holed stopper in the collection vessel houses tubing attached to the suction pump and to the piezometer. As the pump is operated, air is withdrawn from the collection vessel, creating the suction needed to draw groundwater up the delivery tubing from the piezometer well. On the right you can see Dean, his granddaughter and me collecting a sample.
18	So as not to have to obtain another expensive MDEQ permit to study additional sites we purchased a temporary piezometer from the Solinst Company in Canada. This device could be pounded into the lake floor, a water sample obtained, and the device immediately removed and used over and over again in different locations. As you can see, the point is much larger than the TLA home-made ones.
19	The same collection scheme was used with the Solinst piezometer which proved to be convenient and easy to use.
20	In 2005 TLA conducted an extensive study of groundwater using our home-made piezometers as part of a project funded by MDEQ grants to develop a water quality model. At that time the sample collection technique did not include filtering of the samples prior to analysis so particulate, non-bioavailable phosphorus was captured in the measured levels. The assayed phosphorus results of unfiltered groundwater samples from the 2015 GBA study were compared with the 2005 data and appear to show that there may have been some increase in groundwater phosphorus level over the ten years between studies. The high variability of the results both in 2005 and 2015 and the fact that different laboratories were used make it prudent to consider the validity of this conclusion of uncertain reliability.
21	This graph shows results from six replicate samples. We looked at the total phosphorus levels in one of our shallow groundwater wells, near-shore lake water and offshore (deep) lake water to assess the impact of filtration prior to nutrient assay. As expected, the groundwater phosphorus was substantially higher than near-shore and deep lake water. Filtration had the greatest effect on the groundwater samples with a smaller effect on near-shore lake water and an almost undiscernible effect on water from offshore in deep water. We believe these results demonstrate that filtration is an effective way to remove suspended particles containing undissolved and thus not bioavailable phosphorus.

22	Our study design included four monthly sampling events at 7 sites. Algae samples were collected both from the benthic floor and 3 – 4 inches below grade; this was our “poor man’s coring” effort to compare surface algae with what may have been present historically. Water samples from deep groundwater (household well water), shallow groundwater (piezometers), lake water, and benthic sediment moisture were collected, filtered, and assayed for nitrogen and phosphorus levels. Additionally, piezometer samples were collected for assay of human-associated elements (caffeine and boron) as our “poor man’s” effort to detect potential evidence of septic field effluent contamination of the groundwater. Aerial and ground level photography was used to document any visible change over time in the GBA appearance.
23	Here is a comparison of the appearance of the GBA at one of the sampling sites over the course of the summer. In June there was already a substantial coating of GBA which became more dense as the summer progressed and, as we can see in the next slide,
24	There was some clearing in September following wave action from a summer storm.
25	The algae samples are currently being analyzed in Dr. Stevenson’s lab at MSU and there are no results yet available to share. The boron level results from the groundwater samples appear to be pretty much what one observes in nature and do not seem to indicate a problem. The caffeine samples are in analysis at the University of Michigan and there are no results yet available to share.
26	The nitrogen and phosphorus data have been generated at the University of Michigan Biological Station up in Pelston. What we were expecting to see was nutrient levels lowest in lake water, then household drinking well water, and highest in shallow groundwater and benthic sediment. POINT OUT THE GREEN DOTTED LINE AND NUTRIENT CONCENTRATION SCALE ALONG THE X AXIS.
27	These results are close to what we expected, but we were surprised to see higher phosphorus levels in the deeper groundwater (household drinking water wells) than in the shallow piezometer samples.
28	The very high nitrogen content in the benthic sediment is made up mostly of ammonia with much more modest levels of nitrate and nitrite.

29	Phosphorus is the rate-limiting nutrient in Torch Lake Groundwater and benthic sediment have more phosphorus than lake water Benthic sediment contains much more nitrogen than the water samples and is composed largely of ammonia Results thus far have not demonstrated a definite link between GBA growth and an identified source of phosphorus
30	Cultural eutrophication (acceleration of natural eutrophication due to human influence) is highly likely to be contributing to the GBA proliferation we are observing The one thing I believe we can be sure of is that the increasing GBA proliferation is an early warning sign that, one way or another, too much nutrient is getting into the lake and this will, ultimately, reduce water quality