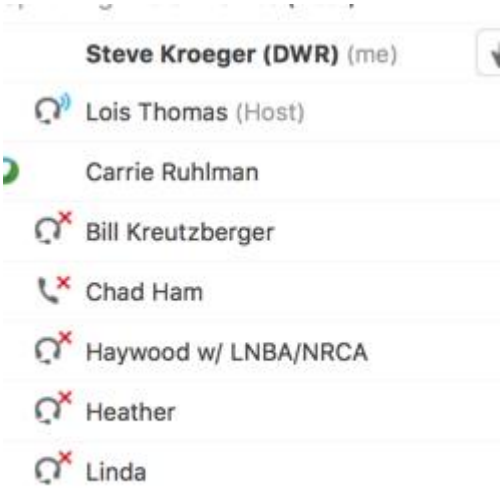
NC Nutrient Criteria Development Plan – Scientific Advisory Council (meeting #8)
4/20/2016

Attendees

SAC members in attendance:	NCDEQ NCDP Team members in attendance:
Bill Hall	Steve Kroeger
Lauren Petter	Carrie Ruhlman
Martin Lebo	Tammy Hill
Linda Ehrlich	Mike Templeton
Clifton Bell	Connie Brower
Deanna Osmond	Pam Behm
Michael O'Driscoll	Jing Lin
Nathan Hall (for Hans Paerl)	Christopher Ventaloro
James Bowen	Jucilene Hoffman
Astrid Schnetzer	Jim Hawhee
Marcelo Ardon	Nora Deamer
	Jeff Manning
Facilitator: Andy Sachs	

CIC members in attendance	Other NCDEQ staff in attendance:
Anne Coan	Jason Green
Andy McDaniel	Elizabeth Fensin
Bill Kreutzberger (via WebEx)	Raj Rajbhandari
	Cyndi Karoly

WebEx Attendees:



NC Nutrient Criteria Development Plan – Scientific Advisory Council (meeting #8) 4/20/2016

Meeting notes

All questions, comments and answers are paraphrased

1. **Convene** (Andy Sachs)
    a. SAC members, DWR staff and audience attendees provide names and affiliations.
    b. Facilitator provides overview of meeting agenda.
    c. Facilitators reminds SAC and audience of ground rules.

2. **High Rock Lake TAC Update** (Pam Behm)
    a. See presentation here
    b. Technical Advisory Committee convened in 2005 to assist DWR with development of mathematical tools for management of nutrients & turbidity in HRL.
        i. TAC members consist of local stakeholders that agreed to serve on the committee.
    c. TAC met on March 2, 2016. First meeting in about a year.
        i. Discussed
            1. Lake model
            2. TAC member review of the lake model
            3. Next steps
            4. Reviewed comments received on lake model.
    d. EPA model developer Tim Wool attended the meeting
        i. Reviewed comments received on lake model.
        ii. Tim had reviewed comments and agreed that there were some valid concerns.
        iii. Discussed some of the comments and the model capabilities.
    e. Discussed relevance of the NCDP with regard to the TAC.
        i. TAC has different purpose.
        ii. At this time TAC will remain on task.
        iii. Model can be revised if nutrient criteria are developed in the future.
    f. Target dates:
        i. Finalize model by end of April.
        ii. Work to finalize report and response to comments in May.
        iii. Tim committed to preparing DWR response to the comments.
        iv. TAC will then meet again.
    g. Comments/questions:
        i. James asks: The model set up primarily as an algal growth/dissolved oxygen model?
            1. Pam: DO was not a focus of the model. If DO ends up being of special concern the model will need additional work.
        ii. Lauren asks: What is the purpose of the model? What will it be able to predict?
            1. Pam: The model was set up to predict total chlorophyll-a (the existing standard) in response to nutrient loading.

3. **Candidate Indicators for HRL** (SAC members)
    a. All documents/presentations provided by SAC members are here
    b. pH (Clifton Bell)
        i. See presentation here
        ii. Potential targets to consider for HRL:
            1. Aquatic Life:
                - NC standards is 6.0-9.0, EPA criteria is 6.5-9.0.
                - Literature describes adverse effects of high pH:
                    i. Increases toxicity of other substances.
                    ii. Disrupts electrolyte balance and metabolism in fish.
                    iii. Causes physical damage to fish tissue.
                - EPA Red Book ("Quality Criteria for Water"; July 1976; EPA # 440976023):
                    i. Basis for low end of pH criteria has more supporting references.
                    ii. Basis of the 9.0 upper end of pH standard/criteria based on one reference.
                        1. Salmonids suffered negative effects of chronic exposure at pH 9.0.
                        2. Other species, such as perch, were more tolerant suffering negative effects at pH 10.0.
            2. Water Supply:
                - The 6.0-9.0 pH range is also protective for drinking water as source water is easily adjusted to attain proper pH.
                - A pH of > 9.0 may require additional treatment by water treatment plants in order to meet federal drinking water requirements.
        iii. Background for HRL
            1. HRL main stem stations commonly experiences pH > 9.0, but rarely pH > 9.5.
            2. Higher pH tends to occur in summer.
            3. pH does not seem to be clearly connected to chlorophyll-a during the summer in HRL.
            4. There is no model for pH in HRL and there does not appear to be a strong empirical relationship.
        iv. Recommended range
            1. 6.0 – 9.5. This tweaks the upper end of the current standard slightly.
        v. Frequency & duration
            1. No frequency or duration recommendations. None exist is current standards either.
            2. Underlining studies were long-term 30-day impacts.

3. Currently treated as a 10% exceedence with 90% confidence for assessment purposes.
4. Option #1:
    - Keep as is (multi-year 10% exceedence with 90% confidence) without adding frequency or duration.
5. Option #2:
    - Express as an annual or seasonal 90th percentile.

vi. Spatial considerations
1. Current assessment method is to assess at surface only.
2. May want to aggregate data from mainstem when assessing for pH.

vii. Questions/comments:
1. Bill asks: Is the 6.0-9.5 pH based on instantaneous measurements?
    - Clifton: Yes. If it were expressed as the 90th percentile of seasonal or yearly data it would likely be more stringent.
2. Jing asks: Some data shows that the release of PCBs from soils may increase at higher pH. Have you seen reference to this?
    - Clifton: I did not look at PCBs and am not aware of this relationship. It may be worth it to consider this further. Will follow up on this.
    - Martin: PCBs are hydrophobic. Uptake would be more of a concern than leaching.
3. Linda asks: Do we know anything about the duration of the periods where pH > 9.0 in HRL during the summer?
    - Clifton: In the summer the pH tends to stay around 9.0. We can look at the old data to see.
4. Bill asks: This information is all related to surface pH, correct? Do we have any data for pH lower in the water column?
    - Clifton: This is just the surface water column pH data. There are depth profiles done for pH in HRL at each monitoring station. The pH at lower depths is typically much lower.

c. Algae & Toxins (Nathan Hall & Astrid Schnetzer)

i. Nathan:
1. Water Supply:
    - Many different algal toxins. The class of toxins for which the most relevant data is available is microcystin.
    - EPA's Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins (June 2015; EPA-820R15100) is focused on drinking water exposure and assumes a lifetime risk. It is a very conservative guideline.
        i. 1.6 ug/L toxin in drinking water (2 L/day) for adults
        ii. 0.3 ug/L toxin in drinking water (2 L/day) for babies

- If we consider using this for protecting a water supply it becomes an extremely conservative guideline as people are not generally consuming the water directly prior to treatment and they are not consuming it regularly over the course of a lifetime. Also most toxins in a lake will be bound in cells.

2. Recreation:
    - The World Health Organization's 2003 document "Guidelines for safe recreational water environments, Volume 1: Coastal and Fresh Waters" (ISBN 92 4 154580 1) provides guidelines for accidental consumption of 100 ml ambient water/recreational session. Based on the EPA guidelines above this comes to:
        i. 32 ug/L for a swimming adult
        ii. 6 ug/L for a swimming baby
    - Very few data regarding cyanotoxins in HRL. The few that are available were below the 0.3 ug/L EPA guideline for babies.
    - Refers to a paper published in the online journal F1000. This paper discusses the relationship between chlorophyll-a concentration and microcystin toxins.
        i. Hollister JW and Kreakie BJ. Associations between chlorophyll *a* and various microcystin-LR health advisory concentrations [version 1; referees: 1 approved, 2 approved with reservations]. *F1000Research* 2016, **5**:151 (doi: 10.12688/f1000research.7955.1)
3. Aquatic life:
    - Not a lot of studies on the direct effects of microcystins on fish.
    - Microcystin can definitely harm fish, but it is difficult to relate a set standard with toxin concentrations and effects in fish.
    - Effects in fish can be very specific with generally small amounts accumulating in muscle tissue and larger amounts accumulating in the liver. This also varies by species so it is difficult to make assumptions.
4. Questions/Comments:
    - Jim asks: There was a study done in the Chesapeake that showed some correlation between chlorophyll-a and toxin counts. Have you seen this?
        i. Nathan: I have not seen this study.

ii. Astrid:

1. Discussion of screening and detection of cyanotoxins
    - See presentation here

- Few studies being currently being conducted. This may be due to the high costs of purified toxins.
- EPA currently undergoing a study of cylindrospermopsin
- Studies are typically done based on ingestion of toxin and not general exposure of aquatic organisms to toxin.
    i. Ingestion of toxin can have a different effect that just being exposed to the toxin in the water column. Also, different isomers of the toxins can produce different responses.
        1. Ex: For marine toxins, mussels were fine just being in water that contained toxins, but showed effects when the toxin was injected.
- Brief overview of cyanobacteria genera that are present in HRL (see presentation for specifics). These species are capable of producing toxins so it is possible that toxins may be present in the lake.
- Options for detection/screening of cyanotoxins:
    i. Chromatography
        1. Golden standard for measuring cyanotoxins.
        2. This will show the exact types of toxins that are present.
        3. Requires expertise and specialized lab equipment.
    ii. Bioassay
        1. Includes ELISA, mouse bioassay, phosphate inhibition assay.
        2. Can measure for dissolved, total or cell bound toxins.
            a. Dissolved goes into drinking water.
            b. Cell bound can be flocculated out in the water treatment process.
        3. Kits are available for anatoxins, microcystin, saxitoxin, cylindrospermopsin.
    iii. Solid Phase Adsorption Toxin Tracking (SPATT)
        1. Resin adsorbs dissolved toxins directly from water over time.
        2. Provides a spatial and temporal cumulative profile of toxins in the water.
        3. Not really useful for determining acute impacts.
        4. Timespan of exposure is flexible (2-weeks, 4-weeks, etc…).
        5. Actual analysis is done via ELISA.
        6. This is a semi-quantitative method.

7. No links established to regulatory limits.
8. Easy to employ.

iii. Questions/comments:

1. Andy asks: How can we relate this to our current task?
    - Astrid: At this point we don't know if there are toxins in HRL. SPATTs can be used to establish whether we are actually seeing toxins and provide information on the magnitude, frequency and duration of toxic events.
2. Nathan asks: When these SPATTs are left out in the water stuff tends to grow on them. Is there any concern of interference due to this?
    - Astrid: The SPATT filters are very durable and any sessile organisms that happen to latch on can be reliably removed without much impact on analysis of toxins.
3. Martin asks: Is the SPATT dependent on flow? Also, what is the detection threshold?
    - Astrid: Yes, it is flow dependent. There is a lower detection limit as would be expected with any method. The ultimate detection threshold is based on the ELISA method that is used in conjunction with the SPATT filters.
4. Bill asks:
    - Does the flow across the SPATT filter decrease over the exposure time?
        i. Astrid: Yes. Multiple SPATTs can be staggered to reduce this.
    - Is there information on how much toxin is released by algal cells vs what remains in the cell?
        i. Astrid: Studies show that as algal cells age they may become more permeable and leak toxin into the water column. There is little information differentiating between cell bound and dissolved toxins in cyanobacteria.
        ii. Nathan: There is the generality that most of the time the toxin is contained within the cell.
            1. Astrid: Yes. The little information that we have does show this, but most people measure for total toxins and do not differentiate between cell bound and dissolved.
5. James comments: References regarding water treatment plant flocculation suggest that it does not release the toxins.

- Astrid: This may also be affected by when in the life cycle of a bloom the cells are being manipulated. During the late stage of a bloom the cells may be degraded and be more likely to lyse.

6. Pam asks: If we use SPATTs this summer (2016) in HRL and we see or don't see toxins, can we assume that we will/won't in the future?
    - Astrid: That's the question. We would need to keep in a minimum number of bags in the lake past this summer study to gain a better idea of how this happens in HRL.
7. Marcelo asks: We previously discussed a paper that showed some microcystin was detected in HRL.
    - Nathan: There were four data points. I believe it was a very low mean concentration, maybe around 1 ug/L.
8. Bill comments: Something to keep in mind is that water treatment plants may be moving to monitor source water toxins in the future.

d. Dissolved Oxygen (Martin Lebo)
    i. See presentation here
    ii. Not sure if there is published data related to water supply or recreation uses.
    iii. For aquatic life:
        1. The current North Carolina standard for DO (daily average 5.0 mg/L, minimum instantaneous of 4.0 mg/L) is generally fine for the photic zone.
            - Literature review did not suggest that the photic zone DO standard would need to be modified.
        2. Most work where O2 has been examined is focused on the lower tolerances in deeper waters.
            - Reservoirs are known for having low DO in deeper portions. May want to consider a standard for DO in the lower reaches of the water column.
        3. Looking at the 24-hour monitoring data from the HRL special study that DWR will do during summer 2016 might help us to decide if DO is actually a concern for HRL.
        4. The work from the Chesapeake Bay has some information on DO concerning protection of habitat for fishes. These are areas that fish may swim in and out of as needed.
        5. We could also consider protection for the benthic organisms in deeper waters.
        6. Recommendation:
            - Maintain the current DO standard for the photic zone of HRL.
            - Consider establishing a daily average of 2.3 mg/L with a minimum of 1.0 mg/L during the summer season for deeper waters.
                i. Would set a precedent for other deep waters in the state?

iv. Questions/comments:
    1. Lauren asks: Are those deep water DO values (from the table, see presentation) from the Chesapeake?
        - Martin: Yes, for the protection of benthic communities.
    2. Nathan asks: Do we know if those types of benthic communities exist in HRL?
        - Martin: I don't think we know.
    3. Deanna asks: Would these values (from the Chesapeake report) be appropriate to use in HRL?
        - Martin: There are comparisons that can be made. The Chesapeake contains modified environments, such as deep channels as a result of dredging, that correspond to the artificially created deep waters that exist in HRL. This could provide a good starting point if we chose to go in this direction.
    4. Bill asks: Based on DO data that I will show during my presentation, in the bottom layers of HRL DO might go down to 0.0 mg/L DO for four months. If we were to establish the deep water DO criteria mentioned HRL would be impaired. Would we then have to monitor benthic organisms to show that the communities are there?
    5. James comments: Is there any data to suggest that a benthic community wouldn't be there?
        - Martin: No idea what the benthic community may or may not be in HRL.
    6. Marcelo comments: I spoke with Lawrence Dorsey (NC WRC) and he has stated that he has not seen fish kills, or had reports of fish kills, in HRL related to low DO. HRL is the first reservoir in the Yadkin basin. Due to this, the fish may be able to move into tributaries that are not as severely impacted by low DO. This may not be true for fish in the reservoirs further down the chain.
    7. Astrid asks: Most invertebrates tolerate low DO. Any idea how long they might be able to tolerate those conditions?
        - Martin: The 2.3 mg/L deep water limit mentioned earlier was a daily average.

e. Aesthetics/ Taste & odor (James Bowen)
    i. For aesthetics: An approach used in multiple states for site-specific criteria involves tying user surveys into some form of indicator such as chlorophyll-a. See a list of references list here.
    ii. For taste & odor: A lot of qualitative information, but challenge is in turning it into criteria

iii. The problem with establishing a standard for aesthetics or taste & odor is in trying to determine an appropriate number.
iv. Some examples:
    1. Minnesota:
        - Aesthetics are tied to nuisance blooms (>50 ug/L chlorophyll-a).
        - Looked at criteria that would decrease the nuisance bloom to an acceptable chlorophyll-a level.
        - Nutrient criteria needed to be ecoregion specific.
            i. For the ecoregion that was most similar to HRL, Chlorophyll-a = 30 ug/L indicated a severe bloom.
            ii. They have user perception survey data that is tied to measured chlorophyll-a.
                1. >10 ug/L mild → >30 ug/L severe bloom → >60 very severe bloom.
    2. New York:
        - Based on a connection between chlorophyll-a concentrations and user questionnaires. Survey range went from "Beautiful to Awful". Chlorophyll-a levels <10 ug/L were rated "Good".
    3. Texas:
        - Similar approach.
        - Ranged from "Couldn't be nicer" to "Nearly Impossible"
        - Level D - "desire to swim substantially reduced", 25-30 ug/L chlorophyll-a.
    4. Recommendation:
        - We should not take these numbers as is. They represented the opinions of users of specific water bodies that are unlike the waters found in NC.
        - In HRL, a high turbidity lake where many of the users are not swimmers, but fishermen, it seems unlikely that there would be a recommendation to go to a lower chlorophyll-a level.
        - People in NC are generally accustom to colored water.
v. Questions/comments:
    1. Nathan asks: Were these rating for wadeable streams?
        - James: Yes. Tried to cover a broad swath of information.
    2. Marcelo: How did they estimate concentrations for the surveys?
        - James: Water quality measurements were linked to the user surveys.
    3. Connie asks: For Minnesota, were the surveys based on the visual perception of an actual bloom? Were there other factors such as taste & odor?

- James: Yes it was based on visual perception of blooms. No taste & odor component.

4. Bill: Do we know if these users were looking at beach areas versus boaters out on the water?
    - James: I don't recall the exact methodology of the studies.
5. Martin asks: This may be more relevant for the DWR staff, but can staff recognize varying chlorophyll-a levels (20-30 vs 60-80 ug/L) when they are in the field? Can this be done during periods of high turbidity?
    - Jason: We can probably tell the difference between 20-30 & 60-80 ug/L using a Secchi disk. More difficult with high turbidity.
    - Carrie: In the turbid areas it's a lot harder.

vi. Taste & odor

1. A lot of info as to what concentrations cause taste & odor issues in water.
2. Lists of compounds with thresholds for individual chemicals
3. Some info suggesting that taste & odor can be used as indicators of certain algal toxins
4. Survey of odor producing cyanotoxin
    - 60% produce odor only
    - 25% produce odor and toxin
5. Difficult to determine numeric criteria to reduce effects of taste & odor.
    - Only found one reference that was able to tie numeric criteria to taste & odor impacts. Several other papers that tried to do this failed to make this link.
        i. Kansas study showed good correlation between the presence of a particular cyanobacteria and a threshold (5 ng/L) for taste & odor issues. This also correlated to a chlorophyll-a level of 15 ug/L.
6. Lots of info on the treatability of taste & odor. This is more of a cost issue.

vii. Questions/comments:

1. Nathan comments: Toxins can be looked at the same way. They are treatable.
2. Astrid asks: Jason (Green), does High Rock Lake smell?
    - Jason: It smells like a Piedmont lake. It depends on seasonality. Areas of the lake could have a stronger odor at times.

f. Turbidity (Mike O'Driscoll)

i. See presentation here
ii. There's a lot of crossover with aesthetics/taste & odor. Some of the same references will be mentioned.
iii. Asking people what they think about unclear water and seeing what they think is good, bad, etc…Is it swimmable?

iv. Most of this data has been collected in places like Minnesota, Iowa, New Zealand…
    1. Could not find data for Piedmont reservoirs
    2. Most literature used Secchi disk measurements rather than turbidity
v. Virginia did a good review
    1. Undesirable
vi. There is a good literature review from Oregon that has data related to impacts of turbidity on fish.
vii. Literature findings:
    1. ~0.8 m was the lower end of what was considered swimmable.
    2. Good rule of thumb is that people like to be able to see their feet so a Secchi depth of ~ 1 m is good.
    3. We probably need more data for piedmont area. (surveys, etc.)
    4. From EPA's "Ambient Water Quality Recommendations - Information Supporting the Development of State and Tribal Nutrient Criteria for Lakes and Reservoirs in Nutrient Ecoregion IX" (EPA 822-B-00-011, December 2000) report
        - For piedmont lakes, you get ~1.7 m for the 75 percentile as a good number for the region.
        - Looking at HRL data from 2008-2010 the maximum was 1.4 m.
viii. Comparison of Secchi depth for HRL to other NC reservoirs (41 lakes):
    1. Average condition for piedmont lakes is eutrophic when you look at the trophic index.
        - Big difference between shallow vs deep lakes.
        - The less than 10 m deep lakes tend to filter out.
        - End up with 41 lakes to compare to HRL
            i. Median condition was hypereutrophic
            ii. 75 percentile = 1.28 m
            iii. HRL is at 0.6 m
            iv. Secchi depth of about 1 m would be eutrophic.
    2. Clean Lakes Classifications Survey (1982)
        - HRL secchi depth was 0.61 m.
ix. When looking at these lakes, those that are higher up in the Yadkin River are much more influenced by river influx.
    1. Is the turbidity in these higher lakes related more to mineral input from the river rather than chlorophyll-a?
        - We might be able to tease this out with the data.
x. Potential ranges:
    1. Difficult to give a range. Need to determine what exactly is causing the turbidity (chlorophyll-a, sediment, mineral, etc.).

2. A HRL user survey may be necessary to determine a range that would be appropriate for different uses (swimming, fishing, etc.).

xi. Question/comments:
   1. Martin asks: If HRL standard was met, what would the corresponding Secchi depth be?
      - Mike O.: Based on the EPA dataset it would be about 0.5 m.
   2. Clifton asks: You mentioned splitting the difference when considering a range. What were you splitting the difference between?
      - Mike O.: It would be a split between using the 1 m Secchi depth (generally considered good by most people), trophic index (lower Secchi depth corresponds to more eutrophic conditions), and user perception surveys (0.6 m was about the lowest Secchi depth that people weren't put off by).
      - Andy comments: So, 0.6 to 1.0 m might be an acceptable range.
   3. Bill asks: Was the trophic state index tracked for HRL?
      - Mike O.: Yes. They were tracking it as part of the Clean Lake Report. Found it was related to phosphorous, Secchi depth and chlorophyll-a. Also in the newer Tetratech report (See presentation slides for references).
   4. Marcelo asks: Considering the graph comparing chlorophyll-a and trophic state, what would the HRL chlorophyll-a be?
      - Mike O.: Long term average from the Tertratech spreadsheet was ~28 ug/L.
      - Marcelo: I thought the calculated chlorophyll-a average was closer to 40 ug/L based on that data.
         i. Mike O.: There were a few spreadsheets. We can look to see if we are looking at the same thing.

g. Fisheries (Marcelo Ardon)
   i. See fishery quality indicators document here
   ii. Went back to look at the existing data from the NC WRC
      1. Surveys every three years in HRL for crappie and largemouth bass.
         - Catch per unit effort
         - Weight/mass
      2. All WRC reports state that the HRL fishery is the best in the state.
      3. This provides a baseline that we want to maintain.
      4. No clear patterns:
         - Data may show an increase over time in the largemouth bass
         - Variability in the crappie
         - 2009 was lower than expected due to heavy rainfalls

5. Little information on fisheries and water quality for reservoirs of the southeast.
    - Relationships b/w chlorophyll-a and fishery quality.
    - More eutrophic systems with higher chlorophyll-a tend to produce higher fisheries.
6. Compared DWQ chlorophyll-a data to WRC fishery data:
    - Only two overlapping data points were obtained.
    - Recommend that there be better coordination between DWQ water quality monitoring and WRC fishery surveys (1/3-years).
        i. Time sampling with WRC survey events.
        ii. This will provide a better understanding over time of how the fishery performs when compared to water quality measurements.
7. Study of 32 reservoirs in Alabama and Georgia
    - Looking at relationship between chlorophyll-a and fish productivity (crappie and largemouth bass)
    - Recommended chlorophyll-a concentrations of 10-50 ug/L were low enough to not effect aesthetics and clarity, but not so low as to negatively impact the quality of the fishery.
    - When chlorophyll-a levels go higher than ~50 ug/l water clarity becomes an issue for recreation.
    - This was why I was asking Mike about the long term average for chlorophyll-a in HRL based on the Tetratech report.
    - There seems to be some room for reducing chlorophyll-a without negatively impacting the health of the fishery.
8. Fishery vs. TP study
    - Based on collected data and modelling.
        i. Higher than ~100 ug/L TP, the fisheries begin to decline.
        ii. Below ~40 ug/L TP, the fisheries start to decline as well.
        iii. This suggests a possible range of 40-100 ug/L TP to maintain a healthy fishery.
        iv. HRL data shows long-term average TP range of 60-180 ug/L.
        v. This shows potential for TP reductions that would not negatively impact the health of the fishery.
9. Fish kills in HRL
    - Fish kills are rare in HRL.
        i. Per Lawrence Dorsey (WRC-Biologist). Based on his experience and opinion.
            1. Since 2002, he has only seen fish kills in HRL during periods of extreme drought. These kills were

related to low oxygen levels as fish became stuck in shallow pools.

2. Possible reason is that HRL is the first lake in the chain of lakes along the Yadkin. This may allow fish to migrate to the tributaries during low oxygen conditions.
3. There is some evidence based on literature to support this type of behavior in low DO conditions.

ii. It is important to note that a lack of fish kills is not necessarily evidence that conditions are good.

10. Regarding PCB availability and fish uptake
    - From NC DHHS presentation
        i. Sampling of PCB in HRL and other reservoirs
        ii. Exceedances of PCB's were in catfish species
        iii. Noted that Hg was a bigger concern for fish consumption.

iii. Questions/comments:

1. Linda asks: HRL is considered one of the best fisheries in the state. Do you know what that is based on?
    - Marcelo: Based on conversations with Lawrence Dorsey this is based on catch per effort and size, even though size has been declining in recent years.
2. Jing comments: Tributaries of HRL are impaired for invertebrates and fish. How can that information be related to HRL? Can it be related to HRL?

3. Jason comments: Regarding fish productivity of HRL. States that the public perspective is that HRL is the best fishery in NC.
4. Clifton asks: Any information on how much chlorophyll-a can be decreased while still maintaining a healthy fishery and whether it is specific to inter-lakes vs single lakes?
    - Marcelo: Most studies were about comparing various individual lakes.
    - Pam: In Jordan Lake, the fisheries folks said that as long as chlorophyll-a is >25 ug/L the fishery should be ok.
5. Andy: Would fisheries qualify as a stand-alone indicator as we try to narrow down the indicator list?
    - Marcelo: It could be as it is one of the most important uses in HRL. Could possibly come up with a limit based on catch per effort.
        i. Andy: Would there be some sort of range there?
            1. Marcelo: I put numbers for the largemouth bass and black crappie in the spreadsheet.

h. Chlorophyll-a (Bill Hall & Clifton Bell)
i. Bill's part:
    i. Looked at the existing state of HRL with the idea that, if we consider that the lake is currently meeting its uses, the existing conditions may be useful for establishing part of a chlorophyll-a criteria range.
    ii. See presentation here
    iii. Chlorophyll-a long-term trend in HRL
        1. Three stations on main stem (upper, mid, and lower)
            - Data going back to 1981 for middle of lake
        2. Data has not changed much over the long term, though there is a greater amount of data for more recent years.
    iv. Seasonal/monthly variability:
        1. DWR considers May-September as the "growing season" for algae.
        2. We may need to define the growing season period as part of the standard.
            - Since some stations in HRL show elevated chlorophyll-a up through October, it may be necessary to define the growing season as May-October for any criteria developed.
        3. Chlorophyll-a concentrations tend to decrease as the dam is approached.
    v. Water Supply considerations:
        1. The only water intake for the water supply associated with HRL is downstream of the dam.
        2. Since the long term data show that chlorophyll-a concentrations are lowest at the dam, any criteria established for the water supply use should be based on the concentration of chlorophyll-a measured at the sampling station closest to the dam.
    vi. Usually consider chlorophyll-a concentrations to be associated with nutrient levels.
        1. Monthly total phosphorous:
            - The monthly distribution of TP in HRL is lower toward the dam.
            - TP is flat throughout the year while chlorophyll-a fluctuates.
            - Seasonal chlorophyll-a fluctuation does not appear to be related to TP.
        2. Monthly total Nitrogen:
            - The monthly distribution of TN in HRL is flat.
            - Seasonal chlorophyll-a fluctuation does not appear to be related to TN.
    vii. Dissolved oxygen
        1. At one station YAD169B.
        2. In May the DO is high throughout the water column. 8.0 to 6.5 mg/L at ~12m.
        3. By June-September, the DO is ok at the surface, but can reach zero at ~12m.

4. By October the DO in the lower water column starts to increase.

j. Clifton's part:

1. Conducted a literature survey for information on criteria ranges.
2. Many of the information here is similar to what's been heard regarding the other indicators discussed today.
3. Literature themes:
    - Fisheries
    - Variation among regions
    - Sources not clear on type of statistics being used
4. Many lakes/reservoirs in different regions are managed for the same uses such as water supply, fisheries, and recreation.
    - An oligotrophic lake and a more productive lake might still be managed for the same uses.
    - Flies in the face of the paradigm that "this number goes with this use".
5. Hydraulic Residence time and TP loading can make a big difference for establishing goals for particular lakes.
6. For warm water fisheries:
    - Direct relationship with fish and TP and chlorophyll-a.
    - If asking the question: If we reduce chlorophyll-a, will we reduce the fish? That's a different question than: "If we reduce chlorophyll-a, will HRL no longer meet its fishing use?"
        i. There is a possibility that if you reduce chlorophyll-a you will reduce fish, but at what point will you reduce the fishing use?
            1. We recommended ~25-60 ug/L in the indicators spreadsheet for warm water fisheries support.
7. For aesthetics
    - Chlorophyll-a concentrations for impact to swimming and aesthetics can be as low as half the warm water fisheries range.
    - Impact is often termed "Nuisance" and nuisance is often described as just clarity. Sometimes defined as a mat or a scum. Do we know if HRL gets scums or mats?
        i. Jason (DWR scum expert): We do not get reports of scums or mats in HRL.
8. Water Supply
    - Three areas of concern: Taste & odor, toxins, and disinfection byproducts.
    - Varies on whether particular water bodies produce these compounds.

- The chlorophyll-a concentrations related to impacts from these are generally lower than those for maintaining healthy fisheries.
- Looking at HRL chlorophyll-a concentrations suggests that we are already at a level where impacts are known to occur in other lakes.
- Does HRL have these issues?

ii. Question/comments:

1. Raj comments: For Cape Fear River modelling, we used mid-April to mid-October as the growing season.
2. Nathan: Was there a high end for chlorophyll-a?
   - Clifton: For warm water fisheries it is 60 ug/L based on literature. For combined fishery-recreation uses, 20-30 ug/L. For water supply, it would be hard to pick a high end because it would depend on things like toxin production. Also, as Bill suggested, we could consider the existing conditions in HRL as one end of a range if we assume the existing conditions are supportive of the uses. We would need to determine if the existing conditions would be at the low end (uses are being met) or high end (antidegradation) of the range.
3. Bill asks: With regard to the upper limit of 60 ug/L for warm water fisheries, but we need to associate with that a duration and frequency. Is the 60 an individual measurement, a growing season mean, a monthly average?
   - Clifton: For fisheries support I would use it as a geometric mean.
4. Astrid asks: Do we need to consider DO when we discuss chlorophyll-a? A high chlorophyll-a concentration may be result in little impact on its own if the system is flushing itself and hypoxic conditions do not occur. Would higher levels of chlorophyll-a be ok so long as DO, toxins, etc… are good?
   - Clifton: In the literature there is a good amount of discussion as to how much of the habitat is available based on DO and chlorophyll-a. Warm water fisheries, and even cool water fisheries, tend to be more food limited as opposed to habitat limited.

4. **Short List for Indicators** (Andy Sachs, SAC members)

i. Andy asks each SAC member to provide a list of indicators that they feel are appropriate for further consideration as standards.

1. Jim: pH, toxins, DO, chlorophyll-a, clarity, nutrients of some sort.
2. Astrid: pH, toxins, DO, chlorophyll-a, clarity, TN, algal community structure, fisheries. For fisheries consider optimizing WRC's fish surveys with HRL data collection.
3. Marcelo: pH, toxins, DO, chlorophyll-a, clarity, nutrients of some sort, fisheries, turbidity

4. Bill: pH, toxins, DO, chlorophyll-a, clarity, nutrients of some sort, turbidity. Leave fisheries out.
5. Mike: pH, toxins, DO, chlorophyll-a, clarity, nutrients of some sort, fisheries, turbidity. Exclude aesthetics, taste, odor.
6. Lauren: pH, toxins, DO, chlorophyll-a, clarity, nutrients, fisheries, turbidity
7. Martin: Chlorophyll-a and pH, toxins, aesthetics, fisheries (these all speak to chlorophyll-a).
8. Clifton:
    - As numeric standards: pH, toxins, DO, chlorophyll-a, turbidity
    - As narrative standards: Aesthetics and fisheries
9. Linda: Fisheries, algal communities, toxins, chlorophyll-a
10. Deanna: pH, DO, chlorophyll-a, turbidity
11. Nathan: Fisheries, chloropyll-a, pH, DO. Toxins by itself would be good for water supply.

ii. Final indicators list:
1. Numeric:
    - pH, toxins, DO, chlorophyll-a, turbidity, total nutrients
2. Narrative:
    - Algal communities, fishery

iii. Discussion:
1. Astrid: The monitoring and analysis of cyanotoxins is a fast growing area. Analysis of algal communities is seen as being an important component of this.
2. Lauren: Many of the proposed indicators can be written as narrative criteria.
3. Bill: May have difficulty accounting for all of the variables that might make up narrative criteria.
4. Connie: Narrative criteria can be written to account for these complexities.
5. Elizabeth: Aesthetics is a good indicator of algae
6. Deanna: I'm not understanding how we would set criteria for fisheries.
    - Bill: Florida uses a narrative metric.
    - Marcelo: Marine fisheries management uses harvest numbers.
    - Martin: Controlled by food supply and management.
    - Clifton: Should arrange as numeric vs. narrative
7. Clifton: Concerns about algal community as an indicator
    - Bill: Algal community should be narrative
    - Lauren: This can be something like % dominant
    - Martin: Numeric criteria might be inflexible as once it is in code it would be difficult to change based on current information. Narrative should cover it well
    - Astrid: Agree that narrative would be better

- Marcelo: Concerned that not having numeric criteria for algal community could have negative effect.

8. Bill: The information that was discussed today regarding algal toxins (EPA and WHO guidelines) relates to finished drinking water (after treatment). How can this be used to establish numeric values for things like recreation and source waters?
    - Connie: EPA will be releasing guidelines for cyanotoxins in recreational waters later this year (2016).
9. Astrid: Do these indicators have to be considered individually or can they be used to inform each other?
    - Connie: Yes, they can be used in many ways.
10. More discussion of total nutrients is needed. Next meeting!
    - What nutrients do we need to talk about?

5. **Revised HRL Summer Study Plan** (Jason Green)
    a. See HRL summer study plan notes here
    b. Jason asks SAC members or any questions or comments concerning the proposed study plan.
    c. Questions/comments:
        i. Bill asks: We have had problems using probes for measuring chlorophyll-a. How will you compare concentrations provided by the probes vs. those provided by analytical methods?
            1. Jason: We have methods established that will allow us to do this. We will take an average of the photic zone and will also do side-by-side measurements with clean, lab calibrated probes.
        ii. Mike O. asks: Will there be weather and lake level data?
            1. Jason: Hope to have lake level data. Division of Air Quality has a climate center nearby and we will use that data for weather events.
        iii. Mike: Will we have N isotope data available?
            1. Jason: No. We do not have that capability and we have not explored that yet. We should have a defined goal before we consider doing this as it would require additional planning and work. NC State may be able to run these samples. Will look into this more.
6. **Central Cape Fear Overview** (Nora Deamer)
    a. See presentation here
    b. Nora provides an overview of the middle portion of the Cape Fear River that the SAC will be focusing on.
        i. Geographic location of the middle Cape Fear River (CFR)
        ii. Locations of dams along the CFR
    c. Why was this portion of the CFR chosen as a focus for the SAC?
        i. Algal blooms (started ~2009)
            1. 2010 algal study.

- Found different types of algae from the Deep River down to lock #1.
- Toxins have been identified in some blooms.
- Chlorophyll-a standard is not violated often. May not be the most appropriate measure of the nutrient issues in the Cape Fear.

2. Recent thesis work by UNC-Wilmington student identified various algal species via DNA techniques.

ii. Nutrient over enrichment.
1. See presentation for graphics.
2. High concentrations of N & P.

iii. Taste & odor issues at water treatment plants.
iv. Many NPDES permits with minimal nutrient limitations.
v. The large number of CAFO and agriculture operations.
vi. Highly turbid and light limited estuary system.
vii. Complex hydrologic system with multiple dams and associated flow alterations.
viii. Increasing water draw-off due to growing populations and industry.
ix. Minimal buffer requirements.
x. Presence of state and federal endangered species.
1. Many species of fish and mussels.

xi. Fish passage issues

d. Review of pollution sources on the CFR
i. Typical sources: Industrial, agricultural, municipal, stormwater.

e. Goal of the NCDP
i. To develop appropriate nutrient criteria by December 2021.
ii. We know we need a model.
1. To do this we will need additional monitoring and data.
2. We will need to select appropriate nutrient models.
3. Developing the models and reviewing the models.
4. Using this information to develop nutrient criteria.

f. Defined uses of CFR
i. Class C waters: Aquatic life, fish consumption, secondary recreation
ii. Class B waters: Primary recreation
1. Not many Class B waters, but primary recreation does occur in most of the Class C waters in the Cape Fear.

iii. Water Supply III, IV, and V waters.
1. 16 water withdrawal points.

iv. High Quality Waters in some places.
v. Shellfish waters downstream.
vi. Primary nursery areas.
1. Atlantic and Shortnose Sturgeon Downstream of lock & dam #1.
2. Inland primary nursery areas from above lock & dam #1.
3. Fish passage on lock & dam #1 finished in 2015.

4. Efforts underway to install fish passages on lock/dams #2 & 3 and to improve water quality in the area.

vii. See presentation for map of classification areas and surface water intakes.

g. Sampling efforts
   i. Four groups that do monitoring:
      1. DWR (collect samples monthly to quarterly, began sampling in 1968)
      2. Three monitoring coalitions (monthly + second sample for physical parameters during the summer)
         - Upper Cape Fear Association (Began in 2000)
         - Middle Cape Fear Association (Began in 1998)
         - Lower Cape Fear Association (Began in 1996)
   ii. 65 Ambient monitoring stations
   iii. Data types:
      1. Metals, physical parameters, nutrients, fecal coliform, bioassessment (invert & fish)
      2. Algal study in 2010.

h. CFR has many dischargers.
   i. 19 major dischargers
   ii. 38 minor dischargers
   iii. CFR has 127 permitted CAFOs (primarily swine, not allowed to track poultry operations, but they are present).

i. CFR currently has multiple impairments or issues related to nutrients (see presentation for graphics)
   i. Some issues include:
      1. Deep River
         - High chlorophyll-a
         - High amounts of periphyton
      2. Rocky River
         - High nutrient concentrations in-stream.
         - Chlorophyll-a behind dam otherwise it's high amounts of periphyton.
         - No appropriate standard to address excessive periphyton growth
      3. Middle Cape Fear
         - High nutrients
         - High chlorophyll-a behind dams
         - Historical blooms
         - Don't see algal bloom issues in faster moving segments
      4. Buckhorn Dam
         - Flow related issues such as algal blooms
      5. Central Cape Fear

- Algal blooms (2009-2012)
- Cyanotoxins found
- Taste & odor issues
- High nutrients

j. Questions/comments:
   i. Astrid asks: Has anyone looked at cyanotoxin loading in the fish and invertebrates collected during the bioassessment studies? Do you have some frozen samples?
      1. Nora: I do not think that has been looked at. Not sure if we have any frozen samples.
   ii. Mike asks: Are there trends in the river to show if nitrates or organics are increasing?
      1. Nora: Nathan will get into trends in the Cape Fear.
   iii. Andy: When will the council be coming back to the Cape Fear?
      1. Carrie: Planning on gradually phasing CFR in as we wrap up HRL. Information will keep coming. We will use the same pattern as we did for HRL. We will present information to the SAC, then supply data and have discussions about possible indicators and criteria.
         - Pam: the first big project we are looking at is to get a monitoring plan set up. We need to identify data gaps so we can develop models.

7. **Data Analysis in the Central CFR** (Nathan Hall)
   a. See presentation here
   b. Two projects just starting
   c. Project #1 - Drivers, trends and water quality parameters in the CFR
      i. There is a lot of data for the CFR, but no one has looked at it to determine if/where water quality is improving or getting worse in the river.
      ii. If we can see where trends are occurring in the river and we can see where they are occurring, we can then link that to what we know is going on and possibly determine what might be causing these problems.
      iii. Using two different trend analysis techniques
         1. Traditional non-parametric
         2. Weighted regression technique
      iv. Looking at data from 19 different monitoring sites
         1. Did not go above the confluence of the Hall and Deep Rivers
         2. Stations prioritized based on the following criteria:
            - Stations had to have flow gauges nearby for trend analysis techniques to work
            - Length and completeness of the data records
            - Stations that have had chlorophyll-a measurements
            - Spatial distribution across middle CFR

i. Also included some stations in the eastern part of the basin where the CAFOs are located.
ii. Included one estuarine station

v. Weighted regression on time, discharge and season
    1. Takes conventional model of discharge and modifies the weighting system to minimize errors.
        - Samples that are closer in time to the point that you are trying to determine a concentration for are weighted more heavily
        - Samples that closer in the discharge regime receive more weight
        - Samples that are closer in season receive more weight.
    2. For example, this provides good estimation of the flux of a nutrient down the river system.
    3. Allows to describe how concentrations change over time with regard to flow.
        - High concentrations under low flow conditions would suggest a strong point source origin for nutrients
        - High concentrations under high flows would suggest more non-point source origins delivering nutrients

vi. Trend analyses project
    1. Looking at just two stations
        - One at the head of the middle CFR
        - At the bottom end of middle CFR near lock & dam #1
        - Planning on looking at 12 different parameters:
            i. Including: sediment, pH, DO, chlorophyll-a, TN, TP.
    2. Near lock & dam #1
        - Total Nitrogen
            i. Strong correlation with flow
            ii. Minimal seasonal effect
            iii. Increasing trend in TN
                1. 30% change over 19-year period
                2. High degree of confidence.
            iv. May be an increase load from non-point sources during recent years
                1. There is an overall increase of TN independent of flow for this 19-year data set, but, during the more recent years, TN seems to be increasing more sharply during higher flow periods.
        - Chlorophyll-a
            i. Data collected earlier than 2005 was for May-October only

ii. Don't see high chlorophyll during high flows nor during the winter
iii. Model shows increasing trend in chlorophyll-a over the 19-year period. High degree of confidence.
iv. Slight bias in data vs model estimates
1. This is because the samples were only collected in the summer during the early part of the record

3. Buckhorn Dam
- Total Nitrogen
i. Increasing trend
- Chlorophyll-a
i. Weak trend, not significant.

4. Questions/comments:
- Mike asks: What form of nitrogen is increasing?
i. Nathan: Both nitrate and TKN at lock & dam #1. At Buckhorn Dam it was TKN. Planning on looking at more parameters.
- Marcelo asks: Are you going to estimate fluxes?
i. Nathan: Yes, but don't think that fluxes in a river are all that important. They are very important if looking at the downstream receiving water, but looking at a flux to describe changes in a water body segment is probably not as useful as looking at concentrations.

vii. Cape Fear Microcystis Bloom Project (funded by NOAA Sea Grant)

1. No one knows why blooms have begun appearing
- System is generally light limited and does not normally support blooms
- A few samples have been collected that show toxins were present
- Three water treatment plants are involved in the project to determine if they should be concerned
- Hans, Nathan, and Astrid are working on this
- Study will take place this summer (2016) and next summer (2017)
- Water plants will sample every two weeks for dissolved and particulate toxins along with SPATTs.

2. Two hypotheses:
- Flow could be leading to these blooms
i. Clarity increases, shallow water column and slower travel time
- The amount of toxin is going to be related to the amount of microcystis that's there.

i. Will measure how fast mycrocystis grows as it travels down the river. Will measure light and temperature.

8. **Wrap-up**
   a. Next SAC meeting will be on June 15, 2016
   b. Carrie will refine the indicator ranges based on discussion from today
   c. We will discuss nutrients as an indicator during the next meeting
   d. We will discuss the Cape Fear River more.
9. **Attachments**
   a. Meeting agenda

SACCondensedAgenda-April2016.pdf

   b. HRL TAC Update

HRL TAC Mtg Review.pdf

   c. Indicator discussion
      i. pH

Bell Slides on pH.pdf

      ii. Algae & toxins

SAC_SPATT Approach_April20.p

      iii. DO

2016-0420 Lebo - DO Range Slides.pp

      iv. Aesthetic/taste & odor

CriteriaReferences-jbowen.pdf

      v. Turbidity

Water Clarity Candidate Indicator

vi. Fisheries

Fishery quality indicators.pdf

vii. Chlorophyll-a

High Rock Lake - Chlorophyll-a Data a

d. Revised HRL summer study plan

HRL-Special-Study-04-19-2016.pdf

e. Overview of middle CFR

Cape_ Fear_April_20_ 2016_

f. Data analysis in the central CFR

Hall_NCDPtalk20Apr2016.pdf