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MEMORANDUM
November 21, 2016

TO: Dorie Bolze and Jim Redwine, Harpeth River Watershed Association (HRWA)

FROM: Clifford W. Randall, Water Pollution Control Consultant

SUBJECT: Review of the 16 MGD TDEC, September 20, 2016 Draft Permit for the Proposed Modification of the City of Franklin, TN, Wastewater Treatment and Reuse Facility (WWRF)

1. As an initial matter, my report of May 15, 2015, remains valid and I incorporate it by reference in this memorandum.

2. I have reviewed the effluent criteria for the Franklin STP contained in the TDEC draft of the 16 MGD permit, and I don't see changes in this draft that will make significant positive differences in the Harpeth River water quality compared to the previous drafts that I have reviewed. In fact, if Franklin is allowed to discharge the amounts contemplated (as discussed below), measurable degradation of the water quality, including habitat alterations, of the Harpeth River will result. If Franklin is allowed to double its discharges of phosphorus, aquatic habitat will be substantially reduced, and desirable aquatic biota in the Harpeth will be substantially decreased.

3. The primary threat to water quality in the Harpeth River is from excessive growth of algae, and especially the excessive growth of blue-green algae, aka cyanobacters. The draft permit includes small increases in the removal of TSS and BOD_5, but there is little in this draft permit that will protect or improve the existing water quality in the Harpeth River. The effluent phosphorus (P) concentration it permits in the summer time is 1.30 mg/L, or 173.5 lbs per day for a single average day of the total yearly average of 63,393 lbs at the annual average design flow of 16 MGD. This quantity of P can stimulate the growth of 19,862.5 lbs of algal biomass, which is equivalent to 24,767 lbs of COD, per day. When combined with the permitted monthly average effluent CBOD concentration of 7.5 mg/L (1,500 lbs/COD per day in a flow of 16 MGD), the equivalent total daily COD input to the River would be 26,268 lbs per day, which is a large fraction of the COD assimilative capacity of the River, i.e. much greater than 5% of the Rivers assimilative capacity over its normal range of flows, and much greater than its assimilative capacity under '7day-10year' low flow conditions.

4. Also, because the P discharge can be averaged over an entire year, a much higher P concentration than 173.5 lbs/day could be discharged without violating the Permit, as presently drafted. This limit, included in the Draft Permit, does not represent good regulatory practice, and I am puzzled why such a high permissible P effluent concentration is in the Permit, considering <u>BioWin modeling by CDM Smith shows the</u>

Exhibit 10

new plant can achieve an effluent P concentration of 0.53 mg/L, if not lower, without the use of chemicals, when performing mass balance calculations for the 16 MGD biological nutrient removal (BNR) Design. Surely, such an option to significantly increase P discharge, should not be included in the final version of the Permit. A value significantly below 1.0 mg/L, such as 0.7 mg/L or lower, would be more consistent with efforts to improve the quality of water in the Harpeth River. The current regulatory value is inconsistent with the low value of effluent P obtained by computer modeling of the BNR process that will be the heart of the biological process designed for the 16 MGD modification of the treatment facility.

5. Further, with the use of settled sludge fermentation to produce volatile fatty acids to accomplish greater biological removal of phosphorus, the effluent TP concentration could be reduced to less than 0.1 mg/L TP without any addition of external chemicals. The high value of effluent P concentration in the Draft Permit indicates the fear that the BNR Process Operators lack experience with BNR processes and/or are not relying on the operators to actually operate the plant properly. My BNR team supervised the operation of a similar BNR system treating an average flow of 2.2 MGD for four years and kept track of the effluent total phosphorus for 22 years, and the annual average TP concentration over the entire period was always less than 0.25 mg/L, and the last time I compiled the yearly average (2008), it was 0.16 mg/L TP. Start-up year was 1988. The location was Bowie, MD. Operation of BNR processes is not at all difficult. Many other operations teams achieve similar results across the country. In short, technology exists that – and the new Franklin plant, if operated properly -- can reduce phosphorus to levels that should prevent massive algae (green and blue-green) blooms.

6. A further reason to lower the required effluent TP concentration for the WWRF is that the total phosphorus load from the City of Franklin will include stormwater runoff contributions, and these are much harder to control, and will be much more variable, than the P concentrations and loads, contained in the WWRF effluent. Therefore, the WWRF should be regulated to provide a safety factor for the stormwater TP contributions. This is consistent with the goal of improving the water quality in the Harpeth River. While several methods can be used to reduce stormwater contributions, major storms can overload most of the methods, with the result that heavy loads of TP can enter the River during major storms, and stimulate the growth of large quantities of algae for one or more years before the River stabilizes through the flushing out of TP in the sediments. Lower WWRF effluent requirements for TP can be particularly effective for the Harpeth because the Franklin WWRF will often be 60 to 70 percent of the total River flow downstream of the WWRF. Thus, phosphorus discharge limits in the final permit are necessary to prevent algal blooms in the Harpeth.

7. It can be stated with near certainty that the phosphorus loads from the City of Franklin, i.e. WWRF effluent discharge plus stormwater runoff flows, will substantially exceed 50% of the Rivers assimilative capacity for phosphorus, given the current P limits in the Draft Permit. It needs to be remembered that phosphorus is a conservative element (has no gaseous form in nature), and it attaches to soil particles and accumulates in sediments as long as the oxidation reduction potential (ORP) of the sediments is positive and the stream pH does not exceed 10.0. However, the chemically attached P will become soluble and available to the algae again for new growth if the ORP becomes negative, or the in-stream pH at the sediment surface exceeds 10.0. High microbial activity by bacteria consuming the dead algae accumulating in the stream sediments will change the ORP

from positive to negative, thereby releasing the iron-bound P, and massive growth blooms of algae will increase the in-stream pH into the pH range of 10 to 12 on sunshiny days if the nutrients N & P are available, and the high pH values will solubilize the aluminum-bound P.

8. Once the phosphorus has become soluble, it is unlikely that it will re-attach to sediment particles before stimulating new algae growth because large suspended solids particle concentrations are unlikely to occur under the somewhat stagnant conditions. Consequently, phosphorus can recycle repeatedly in slow moving streams, lakes, estuaries and coastal ocean plains, and perpetuate algal blooms by recycling until the P is flushed out of the aquatic system. Because of the chemical mechanisms that control the soluble and insoluble fractions of P in the sediments, it is all the more essential that P inputs to natural streams such as the Harpeth River be minimized as much as reasonable, even if at present the algal blooms have not reached nuisance levels. Through P recycling, the amounts of soluble P available can continue to increase to nuisance levels unless positive actions are taken to reduce the total inputs.

9. Note that oxidized nitrogen (nitrates) is purposefully discharged by the Upper Occoquan Sewage Authority (UOSA) Advanced Wastewater Treatment (AWT) Plant into the Bull Arm of the Occoquan Reservoir of Northern Virginia to prolong the period of time that the sediments remain in a state of positive ORP, to reduce P release from the sediments in the upper reaches of the Reservoir. This practice has been in place since 1979. Further note that this practice also reduces the nitrates in the Reservoir effluent through denitrification while the water flows through the Reservoir. This method of operation has been repeatedly approved by USEPA and the VA State Water Control Board as a method of reducing nitrogen inputs into the Chesapeake Bay. The strategy could be used to the advantage of the Harpeth River water quality between the Franklin WWRF effluent discharge point and the Harpeth's confluence with the Cumberland River. It also would further reduce the cost of implementing denitrification in the effluent denitrification filter of the existing Franklin 12 MGD WWTP. A moderate concentration of nitrates (8 to 10 mg/L) in the WWRF effluent would actually be beneficial to the health of the Harpeth River, not detrimental.

10. Also note that the Permit for the UOSA AWT mandates that the effluent TP concentration cannot exceed 0.1 mg/L P, based on a weekly average. This is accomplished chemically because the UOSA Plant precedes the development of BNR processes. However, the nearby Loudoun County BNR Membrane Separation Activated Sludge Plant always maintains an effluent TP concentration of < 0.08 mg/L TP without chemical addition, as do the Culver City and Forsyth County Plants in the Atlanta Suburbs. The standard permitted effluent TP concentration along the Chattahoochee River in the area of Atlanta, including the City of Atlanta's three large plants, is 0.13 mg/L. The standard for the Chesapeake Bay Watershed is 0.3 mg/L TP, and several of the plants are required to meet an effluent TP concentration of 0.1 mg/L on an annual average basis. Several areas of the Southern Atlantic Coast States have similar requirements, and the Plants are meeting them.

11. Technology to meet effluent requirements of less than 0.3 mg/L are well known and widely in use, and a high percentage do not require chemical addition to remove any of the phosphorus. Keys to maximizing biological phosphorus removal are to not reduce the BOD of the raw influent wastewater by primary sedimentation, or, to practice fermentation of the settled sludge to produce the volatile fatty acids necessary for

biological phosphorus removal. These techniques have been in wide spread use since the early 1980's, and are very well developed. Using fermentation of settled primary sludge can reliably produce effluent soluble phosphorus concentrations of less than 0.1 mg/L. The 40 MGD Bonnybrook Plant in Calgary, Alberta, Canada is an example of a plant that uses a sludge fermenter for biological phosphorus removal purposes.

12. It also can be stated that it has been repeatedly shown that soluble P concentrations of greater than 0.1 mg/L in natural waters can produce nuisance algae blooms. This was established by R.A.Vollenwieder more than 50 years ago using research results from a large number of lakes in Canada, and he then expanded the study to 18 different countries in the middle 1960s. His work was further extended, verified and refined by G. Fred Lee in the USA beginning in the late 1960s and continuing for several decades.

13. While there is a considerable threat to the health of the Harpeth River aquatic system from large algae blooms with the effluent total phosphorus discharges from the 16 MGD Franklin WWRF design as allowed in the Draft Permit, there is a much greater potential threat to the Harpeth River water quality than just the straight forward growth and decay of algal biomass from excessive phosphorus inputs.

14. **The number one threat to the Harpeth River water quality posed by the 16 MGD Draft Permit is its orientation towards the maximization of nitrogen (N) removal during treatment, coupled with its half-hearted, by comparison, orientation towards the removal of phosphorus.** This method of operation has and will continue to result in high concentrations of P in the effluent accompanied by low concentrations of N, relative to the growth requirements of algae. Operating the treatment system in this manner will result in a major imbalance between soluble N and soluble P concentrations in the River, i.e. high concentrations of soluble P and low concentrations of soluble N, relative to the nutritional needs of algae. When growing, algae require 16 moles of N compared to 1 mole of P to produce 1 mole of algal biomass. **On a weight basis this would be 16 lbs of N and 1 lb of P to produce 114.5 lbs of algal biomass, which is equivalent to a total COD mass of 142.5 lbs.** The 16 to 1 ratio of N to P is known in the scientific literature as the **Redfield Ratio**.

15. If the 16 MGD Franklin WWRF was operated to comply with the Draft Permit as written, the highest N to P ratio that would be discharged in the summer time would be 5 mg/L N to 1.3 mg/L P, **a ratio of 3.85 to 1,** much below the ratio needed for nutritionally balanced green algae growth. At first glance that might seem to be a good thing because it implies that algae growth would be limited by the small amount of available soluble N. **Unfortunately, this is not the case.** What will happen is that the small amount of soluble N in the River water will limit the growth of **green algae**, i.e. the type of algae that is good food for fish and is non-toxic, yet can grow profusely and result in low or zero DO concentrations further downstream if both N and P are available in large amounts. A much greater danger, unfortunately, is that there are several genera of **blue-green algae, i.e. cyanobacters**, that grow in fresh water environments like the Harpeth River, **that are able to obtain N for growth directly from the atmosphere, which provides a limitless source**. Thus, these cyanobacters utilize the limitless supply of N in the atmosphere by reducing it to ammonia (NH_3-N), and then using the soluble P available in the water to produce cyanobacter cells until the soluble P has been fully utilized.

16. ONLY LOW CONCENTRATIONS OF PHOSPHORUS WILL STOP THE PRODUCTION OF CYANOBACTERS, unless there is the very rare circumstance where

sulfur or potassium become growth limiting. Thus, they use the ammonia to manufacture new cells using the energy obtained from the sun plus the soluble P that is available. **The important point is that the growth of cyanobacters (blue-green algae) will be limited by low concentrations of P, not by low concentrations of N.** Because N fixing cyanobacters are always present and are able to grow rapidly in nearly all freshwater streams, such as the Harpeth River, a failure to control soluble P in the River when N concentrations are low is likely to cause massive blooms of cyanobacters. **Another unfortunate aspect of the growth of cyanobacters is that all of them are toxic to some extent and a significant number of the genera are very toxic.** Genera such as ***Anabaena, Microsystis and Selenastrum*** are types that are very toxic.

17. It was confirmed last year that at least one genus of cyanobacters is already growing in the River, but, fortunately, one that is only mildly toxic compared to the three listed above. However, it can be said that conditions in the River have already passed the N to P ratio 'tipping point' at which cyanobacters will flourish. To continue with the current manner of nutrient removal at the City of Franklin treatment plant represents a form of cyanobacter 'Russian Roulette'.

18. There have been massive growths of ***Microsystis*** in the southern part of Florida this year with major impacts on both aquatic and terrestrial life forms. The following is a few news excerpts describing some of the cyanobacter blooms observed in Florida this past summer.

    www.npr.org/.../a-government-sponsored-disaster-**florida**-asks-for-federal-help-with-t...
    Jul 9, 2016 - It's called **blue-green algae**, but it's actually a type of bacteria called cyanobacteria. It typically thrives in freshwater. Under certain conditions, the bacteria can release a wide variety of toxins that affect the liver and nervous system. And **blue-green algae** occur naturally.

    Toxins from the **blue-green algae** blooms choking **Florida** waterways have now been found in the air, as well, officials say. Tests conducted by authorities in Martin County revealed that the toxin microcystin is in the air at sites along the St. Lucie River, which is coated with thick clumps of **algae** blooms.Jul 28, 2016

    articles.mercola.com/sites/articles/archive/2016/.../toxic-**blue-green-algae**-blooms.aspx
    Jul 19, 2016 - **Blue-Green Algae** Is Dangerous to People, Pets and the Environment. The **algae**, also known as cyanobacteria, is so prolific it can now be seen from space. Further, it can produce toxins that are harmful to humans and marine life.

    www.miamiherald.com/news/local/environment/article88302462.html
    Jul 7, 2016 - An aerial photo shows **blue-green algae** enveloping an area along the St. Lucie River in Stuart. Officials want federal action along the stretch of ...

19. Any increase in P discharges will push the N to P ratio even further beyond the 'tipping point' and increase the probability of highly toxic cyanobacter domination in the Harpeth River. The properties of cyanobacters and the conditions that stimulate their prolific growth are well known and fully described in the scientific literature, and there is a clear scientific consensus about their ability to fix nitrogen from the atmosphere for growth,

thus permitting them to grow profusely in the absence of soluble nitrogen forms in water environments. Clearly, their growth can be controlled only by controlling the concentrations of soluble phosphorus available to them. Because some algae growth is going to occur in nearly all natural Rivers that are not excessively turbid, it is critical that a 16 to 1 balance between N to P in the Harpeth River water be used to shift the growth advantage to the green algae, rather than the cyanobacters.

20. The unsolved problem for the Harpeth River is that the draft Permit proposed by TDEC for the 16 MGD wastewater reclamation facility (WWRF), if unchanged, would make it possible to operate the WWRF such that it could discharge an effluent with a N to P imbalance that could worsen the Harpeth water quality as described above, without violating the terms of the Permit. Thus, the Permit should be modified by specifying N and P effluent concentrations that have a ratio of 16 N to 1 P, or greater. This could be done, for example, by specifying an effluent total P concentration of 0.5 mg/L annual average, or lower, and a TN concentration of 8 mg/L, or higher. Then, the 0.5 mg/L P would limit the total growth of algae, and the 16 to 1 ratio of N to P in the effluent would shift the growth advantage to the green algae rather than the cyanobacters. Other combinations of effluent concentrations also could be used to obtain a desired ratio, while further restricting the possibility of massive green algae blooms. Note that during a drought period in July, 2014, the effluent discharged by the Franklin STP was as much as 64% of the total flow in the Harpeth River, and it exceeded 60% seven times during the month of October, 2016. Therefore, it is recommended that the N to P ratio in the effluent of the WWRF be maintained at 16 to 1 or greater as a safety factor against massive cyanobacter blooms.

21. I have designed and implemented nutrient removal WWTPs in many political jurisdictions of the USA and in several countries around the world, and I know of no WWTP other than the one owned and operated by the City of Franklin where the managers are attempting to control algae blooms in a freshwater body of water by the removal of N without commensurate P removal. This is the greatest folly of the proposed Draft Permit for Franklin's 16 MGD WWRF. It is scientifically clear that the removal of nitrates in the existing effluent denitrification filter to very low concentrations (< 5 mg/L) should no longer be used to reduce the effluent nitrate concentrations from the WWTP. I recommend that the effluent nitrate concentration be maintained between 8 to 10 mg/L NO_3-N, and I would be comfortable if denitrification in the effluent filter was stopped altogether. Instead, utilize the nitrate reduction that can be accomplished by a 1:1 or less internal nitrate recycle rate of the nitrified effluent from the end of the aerobic zone be used to recycle the nitrates back to the head of the anoxic zone of the BNR process.

22. All you have to do to accomplish significant denitrification in the Franklin's WWTP is establish an anoxic zone within the existing Oxidation Ditches wherein nitrification is balanced with denitrification during the circular flow patterns. Again, this is easily accomplished in oxidation ditch systems, and is widely practiced in both the USA and around the World. The important point is that the discharge of nitrates in the Franklin WWTP effluent will actually be beneficial to the Harpeth River rather than detrimental.

23. There are already signs in the River that removal of nitrates without the commensurate removal of phosphorus is detrimental to the water quality of the River, as shown by the growth of blue-green algae (cyanobacters). The recommended change in denitrification practice will reduce the energy costs of aeration, reduce the amount of WAS production at any chosen SRT, and eliminate the need for methanol addition to the existing effluent

filter, at the proposed 16 MGD upgraded WWRF. It also will feedback alkalinity during biological denitrification, and reduce the amount of alkalinity that has to be added through addition lime, or some other source of chemical alkalinity, if alkalinity addition is needed to maintain the effluent pH in the right range. The utilization of denitrification in the anoxic zone also will provide better buffering capacity for the mixed liquor pH, i.e. keep it in a more favorable range.

24. While the effluent ratio of N to P specified by the TDEC 16 MGD draft Permit is the bad news for the Harpeth River and needs to be changed, the good news is that the modified design of the 16 MGD City of Franklin WWRF will change the facility to a biological nutrient removal (BNR) activated sludge plant if operated appropriately. That is, if the biological system is operated in accordance with design intent, both P and N will be removed biologically, i.e. without chemical addition, and achieve very low concentrations of phosphorus discharge, as noted above.

25. If the designed treatment system is operated for optimum removal of P and N by biological processes, the actual effluent concentrations of P and N will be a function of the process influent concentrations of BOD, P and N. The actual ratios of these three parameters in the Plant influent are not accurately known to my knowledge because <u>the influent streams to the Plant have never been directly sampled and measured before mixing</u> with recycle streams from within the treatment processes of the Plant. Additionally, the frequency of composite sampling and analysis of influent streams that could be directly sampled has been entirely inadequate for statistical analysis. This is also true for the composite sampling and analysis of the effluent discharge of the Franklin STP.

26. <u>I have never before seen a permit for a 12 to 16 MGD municipal wastewater treatment plant with effluent limitations of N and P that did **not** collect composite influent and effluent samples</u> and analyze them 3 to 7 times per week for N and P concentrations, with daily sampling and measurements being the most common.. The preceding statements highlight two clear failings of the Draft TDEC 16 MGD Permit for the proposed upgraded Franklin WWRF. The permit should mandate modification of the influent pipes and structures so that direct sampling of the combined influent flows is possible prior to mixing with process recycles, and that daily 24 hour composite sampling and analysis of both the influent and effluent streams for N and P forms are mandated. This level of information is essential for optimum operation and monitoring of a 16 MGD BNR municipal sewage treatment facility.

27. Even though there is an inadequate record of influent concentrations to the existing Franklin STP, the probable performance of the 16 MGD WWTF can be reasonably projected using experience and data from similarly sized municipal WWTPs. Given the inclusion of both anaerobic and anoxic zones in the proposed design of the modified 16 MGD WWTF of the Franklin STP, if the anaerobic and anoxic zones are operated such that anaerobic and anoxic conditions, respectively, dominate the zones so designated, the effluent concentrations of total P should be less than 0.6 mg/L total P (TP), and possibly lower than 0.5 mg/L TP, while the effluent total N (TN) following anoxic zone denitrification only (no denitrification in the effluent filter) should be in the range of 8 to 10 mg/L TN. This manner of operation would eliminate the cost of chemicals for P precipitation and the cost of methanol for denitrification. Additionally, removal of BOD by denitrification within the anoxic zone will reduce the aeration energy costs of removing BOD and accomplishing nitrification in the aerobic zone by up to 20%.

Operation in this manner will significantly reduce the costs of operating the WWRF compared to operating it with the use of methanol in the effluent denitrification filter, and produce an effluent T to P ratio closer to the 16 to 1 ratio needed to discourage the growth of toxic cyanobacters (blue-green algae) in the Harpeth River.

28. The important take-away messages from the above are that:

1)the modified 16 MGD plant (WWRF) can remove both N and P by biological methods;

2) The very low effluent N concentrations required by the 16 MGD Permit will actually be detrimental to the water quality of the Harpeth because the resulting N to P ratio will encourage growth of toxic forms of blue-green algae (cyanobacters) unless the soluble P concentrations in the effluent are also reduced sufficiently to maintain a N to P ratio of 16 to 1, or higher, in the effluent discharged to the Harpeth River;

3) If only the removals that can be obtained by BNR mechanisms are used, i.e. without the use of chemicals for P precipitation or denitrification using methanol, the effluent N and P concentrations obtained by the modified 16 MGD WWRF would decrease the total biomass of algae growing annually in the Harpeth River, discourage the growth of cyanobacters relative to green algae, and both improve and protect the water quality in the Harpeth River;

4) The low effluent TN concentrations required by the 16 MGD Permit should be removed from the Permit and the effluent TP concentrations should be lowered to control the growth of algae biomass in the Harpeth River downstream of the Franklin WWRF;

5) the permitted effluent concentration of TP in the 16 MGD permit should be less than 0.5 mg/L. If concentrations less than 0.5 mg/L TP cannot be accomplished by purely biological means, then the effluent concentrations should be reduced below 0.5 mg/L by the addition of small amounts of P precipitating chemicals directly to the activated sludge immediately before final clarification, as needed;

6) Final effluent TN concentrations of 8 to 10 mg/L will still reduce the effluent TN concentrations by 50+ percent, and improve the Harpeth water quality downstream of the Franklin wastewater discharge by retarding anaerobic conditions and soluble P release from the sediments;

7) The above changes will reduce the cost of wastewater treatment compared to denitrification operation of the effluent filter, but the filter should continue to be used for the removal of effluent TSS; and

8) The current Draft Permit must be substantially revised to maintain, if not speed up the restoration of, the water quality in the Harpeth River.

29. I don't know the circumstances that motivated the TDEC Division of Water Resources to want such stringent effluent nitrogen requirements without commensurate effluent phosphorus removals. It is common for treatment plants around bodies of water such as Long Island Sound, Chesapeake Bay and Tampa Bay to be operated in this manner, but

all three of those bodies of water, and the Gulf of Mexico offshore of Louisiana, Texas and Mississippi, are N limited for algae growth, and cyanobacters do not grow well, if at all, at high salinities. The reason that such bodies of water are N limited for algae growth is actually because the high loads of P in the bottom sediments are continuously recycled by the typical effects of algae growth and death. Indeed, in my experience, the principal factor in ensuring that plant operators continue to achieve the low levels of nutrient – nitrogen and phosphorus – discharge that they are capable of achieving is establishing a discharge limit in the permit that requires them to achieve those capabilities.