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Analysis of the Numeric Water Quality Criteria Adopted by the Ten States That Border Directly on the Mississippi River

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The findings presented in this document are based only on what was found in final, state WQS regulations as of May 1, 2009. Hence, though the existence of proposed changes to state water quality standards may be acknowledged, typically in footnotes, the contents of such potential modifications are not reflected in the various analyses contained in the report. Likewise, associated guidance documents, policy memoranda, and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards program or how WQS are applied in other water quality programs.

This report was written by Bill Painter and Yen Hoang, with oversight by John Pendergrass, of ELI. Mr. Painter was at the time of the research and writing of this report a Visiting Government Scholar at ELI under the Inter-governmental Personnel Act Mobility Program from the U.S. Environmental Protection Agency where he has since returned. This report has not been reviewed by the U.S. Environmental Protection Agency and does not represent the views of the Agency and no official endorsement should be inferred. The authors gratefully acknowledge the review and guidance provided by Judith Petersen, Albert Ettinger, Dana Wright, Jill Witkowski, Jon Devine, Jeff Grimes, Susan Heathcote, and Betsy Lawton. Drafts of the state Overviews were sent to the water quality standards staff of the respective state environmental agencies for comment. ELI received responses from Illinois, Kentucky, Louisiana, and Missouri and sought to correct all errors that were identified, but neither the Overviews nor the report represent the views of any of the states and no official endorsement by any state should be inferred. The Environmental Law Institute is responsible for the views and information contained in this publication.

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List of Acronyms

AWS	Agricultural Water Supply
BATEA (or BAT)	Best Available Treatment Economically Achievable
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CALM	Consolidated Assessment and Listing Methodology
CSO	Combined Sewer Overflows
CWA	Clean Water Act
DDT	Dichloro-dephenyl-trichloroethane
DO	Dissolved Oxygen
DU	Designated Use
DW	Drinking Water Standards
DWS	Drinking Water Supply
FC	Fish Consumption
GLI	Great Lakes Initiative
HHO	Human Health Organism
HHWO	Human Health: Water and Organism
IWS	Industrial Water Supply
LA	Load Allocation
MCL	Maximum Contaminant Level
MS4	Separate Sewage System
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbidity Unit
PAH	Polycyclic Aromatic Hydrocarbons
PBT	Persistent, Bioaccumulative and Toxic (EPA Program)
PCB	Polychlorinated biphenyl
PWS	Public Water System
SDWA	Safe Drinking Water Act
SRF	State Revolving Fund
SSM	Single Sample Maximum
STP	Sewage Treatment Plant
TBA	Technology-Based Approach
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TRI	Toxics Release Inventory
TSS	Total Suspended Solids
WLA	Wasteload Allocation
WQ	Water Quality
WQBA	Water Quality Based Approach
WQBEL	Water Quality Based Effluent Limits
WQC	Water Quality Criteria
WQS	Water Quality Standards

A. Introduction

This document is one of a number of state-specific reports resulting from an Environmental Law Institute (ELI) analysis of the numeric water quality criteria (WQC)[1] component of the water quality standards (WQS) of the ten states that border directly on the Mississippi River. In this report ELI compares the state numeric water quality criteria to recommended criteria and related standards[2] issued by the US Environmental Protection Agency. The findings presented in the documents produced for this report are based on the most recent version of the state's adopted, and EPA-approved, WQS regulations,[3] as of May 1st, 2009. Associated guidance documents, policy memoranda and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards program or how standards are applied in other water quality programs. This report addresses WQC applicable to waters that drain into the Mississippi River. It does not cover WQC applicable to the Great Lakes Basin.

This work was funded by a grant from the Mississippi River Water Quality Collaborative, a group of state, regional and national non-profit organizations working together to improve water quality in the Mississippi River basin.

B. Summary of Findings

The water quality criteria (WQC) specified in Wisconsin's water quality standards (WQS) regulations present a mixed picture when compared to the criteria published by EPA, in terms of: 1) pollutant /use combinations[4] covered, 2) the degree to which all key elements of criteria are clearly articulated, 3) criterion-concentrations compared to those of corresponding EPA WQC, and 4) level of protection likely afforded to applicable designated uses,

Wisconsin has adopted numeric water quality criteria (WQC) for a large array of pollutants and uses, though there are a number of instances in which the state has not established

[1] The terms "water quality criteria," "WQC," and "criteria" are used interchangeably in this report. Water quality criteria are closely associated with "designated uses" – another key element of water quality standards established under state law and the federal Clean Water Act. Criteria describe waterbody conditions, primarily pollutant levels, associated with full support of one or more of the designated uses (e.g., aquatic life, fish consumption, water contact recreation, drinking water supply) assigned to specific waters by a state's water quality standards regulations.

[2] The "recommended EPA criteria" referred to in this report are water quality criteria (WQC) issued as guidance to states, territories, and authorized tribes by the EPA under authority of the federal Clean Water Act. The "related EPA standards" are federal regulatory requirements applicable to finished (post treatment) drinking water that is delivered to homes and businesses by a public drinking water system. These standards are established by EPA under authority of the Safe Drinking Water Act (SDWA).

[3] The findings reported herein refer to the contents of the final regulations: Wisconsin Administrative Code, Chapter NR 105 – Surface Water Quality Criteria and Secondary Values for Toxic Substances (in *Register,* February, 2004, No. 578), and Wisconsin Administrative Code, Chapter NR 102 – Water Quality Criteria for Wisconsin Surface Waters (in *Register,* February, 1998, No. 506).

[4] As used in this report, "pollutant/use combination" or "pollutant/use pair" refers to designated use and a particular pollutant or other water quality parameter. Often states have just one WQC for a given pollutant and use; however, in the case of aquatic life criteria, more than one WQC per pollutant/use combination is common. This is usually due to: 1) having both acute and chronic criteria; 2) breaking aquatic life down into a number of sub-categories (e.g., cold and warm water habitat); 3) establishment of different criteria for different ecoregions within the state; and/or 4) setting waterbody-specific WQC.

criteria for pollutant/use combinations for which EPA has issued[5] WQC under the authority of Section 304(a) of the Clean Water Act. In particular, Wisconsin is missing[6] criteria for the majority of traditional pollutants[7] for which EPA has published criteria; notable among these are the nutrients phosphorous and nitrogen, and also chlorophyll a – an indicator of algal density which can be increased by excess loadings of nutrients. Excessive algal density resulting from overloading of surface waters with nutrients not only can adversely impact aquatic life, but also interfere with public water supply and water-based recreational uses. Wisconsin also lacks criteria for sediment levels in the water column and the stream bed. The state does, however, have numeric criteria for temperature, while EPA has issued only narrative temperature criteria.[8]

Wisconsin's WQS regulations contain criteria for a substantial number of toxic pollutants, particularly those that are human health-related. However, there are significant gaps in the regulations' coverage of the pollutants for which EPA has published aquatic life criteria. Indeed, Wisconsin has not adopted acute and/or chronic aquatic life criteria for more than half of the toxic pollutants for which EPA has issued corresponding aquatic life criteria – among which are several pollutants that fall into categories of chemical substances that have been frequently mentioned as potential endocrine disruptors. The state has no extra[9] aquatic life WQC for toxics.

There are also numerous pollutants for which the state has not adopted human health-related criteria, most of which are synthetic organic chemicals, a number of which are known or suspected carcinogens, bioaccumulators, and endocrine disruptors. Nevertheless, Wisconsin does have a number of extra WQC for toxic chemicals related to human health.

The state has no WQC for either traditional parameters or toxic substances that apply exclusively to raw drinking water supply. It does, however, have WQC for a number of toxic

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[5] Throughout this report, the water quality criteria (WQC) recommended by EPA under the Clean Water Act will be referred to as the EPA's "issued" or "published" criteria, interchangeably. Unlike Primary Drinking Water Standards promulgated according to the federal Safe Drinking Water Act, EPA WQC are not regulatory requirements; rather, they are guidance.

[6] For the purposes of this review, "missing" criteria are those pollutant/use combinations for which the state has not officially adopted WQC, whereas EPA has published recommended WQC of the type specified.

[7] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[8] Though Wisconsin's current WQS regulations include numeric temperature WQC, a state Supreme Court ruling has prevented the state agency from using these ambient WQC to establish water quality-based effluent limits (WQBELs) for steam electric power generating plants, and also generated confusion as to use of these WQC for setting WQBELs for other types of point source dischargers. At the time of the writing of this report, the state was in the process of establishing revised temperature WQC, as well as new procedures for setting WQBELs for heat discharges in NPDES permits. Such provisions were proposed in December 2008, but were not finalized as of May 2009.

[9] For the purposes of this review, "extra" criteria are those pollutant/designated use combinations for which the state has officially adopted criteria, but EPA has not issued corresponding criteria.

chemicals that apply to human consumption of: 1) drinking water, plus 2) fish and other aquatic life supply coming from the same waterbody.

On the other hand, Wisconsin has developed and included in its WQS regulations a method for deriving criteria for toxics aimed specifically at protecting semi-aquatic wildlife (e.g., bald eagle, kingfisher, herring gull, mink and otter). Neither EPA nor any of the other Mississippi River states examined in this review have wildlife-specific criteria for toxic substances that are applicable to all waters in a state.

Most of the state's aquatic life criteria for traditional pollutants/parameters have criterion-concentrations that are equal to, or very close to, EPA's corresponding criteria, as well as the criteria adopted by the other nine Mississippi River states examined in this study. One exception is Wisconsin's acute aquatic life criteria for ammonia for limited aquatic life communities, which have higher criterion-concentrations than any of the corresponding (same temperature and/or pH) EPA criteria for this pollutant.

Where the state has established aquatic life WQC for toxics chemicals, the criterion-concentrations for the majority of the pollutants with such criteria are either higher, or slightly lower, than the criterion-concentrations in the corresponding EPA criteria. The number of pollutants with aquatic life criterion-concentrations that are higher than those in the corresponding EPA criteria is greater than the number of those pollutants with criterion-concentrations that are lower. A higher proportion of the state's chronic criteria have concentrations higher than EPA's than is the case for acute WQC. There are also quite a few pollutants for which the aquatic life criterion-concentrations are equal to those in the corresponding EPA criteria.

There is one rather unique features of Wisconsin's WQC for toxic chemicals addressing risk to human health. Unlike EPA and most other states, Wisconsin has, for each particular human exposure pattern, more than one WQC for each pollutant. That is, whereas EPA has just one WQC for a given pollutant to address situations in which people are consuming fish and other aquatic organisms from a given waterbody, Wisconsin has three—one each for situations in which humans are eating organisms from: 1) cold water communities, 2) warm water sport fish communities, and 3) limited aquatic life. The variation in the criterion-concentrations results from the different species of organisms found in each type of aquatic community that typically are consumed by humans, and the consequent differences in: 1) average amounts of aquatic organisms that people consume—especially with regard to limited aquatic life waters versus the other two types, and 2) average lipid content of those organisms.

Where the state has adopted WQC to address human health risks associated with the ingestion of toxic substances via consumption of locally caught fish and other aquatic organisms (Non-Public Water Supply criteria), for WQC applicable to eating aquatic organisms taken from cold water there are twice as many with criterion-concentrations lower than those of the corresponding EPA criteria than ones with higher concentrations, while essentially equal numbers of the state's WQC dealing with consumption of organisms from *warm water* habitats have criterion-concentrations higher versus lower than EPA's most closely corresponding with.

And, a large majority of such criteria for human intake of organisms from *limited aquatic life* waters are higher than those of the most closely related EPA criteria.

Where the state has adopted WQC to address human health risks associated with the ingestion of toxic substances via 1) consumption of locally caught fish and other aquatic organisms and drinking water from the same waterbodies—Public Water Supply criteria, for WQC applicable to eating aquatic organisms taken from cold water environments, there are nearly seven times as many with criterion-concentrations lower than those of the corresponding EPA criteria, compared to state criteria with higher concentrations. As for the state's WQC regarding the consumption of organisms from warm water habitats, more than 3 times as many have criterion-concentrations lower than EPA's, rather than higher. The state does not have Public Water Supply WQC applicable to limited aquatic life waters, based on the presumption that waterbodies that are naturally too small to harbor organisms that are likely to be eaten by humans are also not large enough to serve as a raw water supply source for a drinking water utility.

Another interesting feature of Wisconsin's presentation of its WQC dealing with human health is that it has separate listings for Human Threshold Criteria (for non-carcinogenic properties of toxic substances) and Human Cancer Criteria. Some other states covered by this study distinguished between carcinogenic and non-carcinogenic substances, but did not split them out into two separate listings. Time did not allow the authors of this report to create separate charts of carcinogens and non-carcinogens, and then perform the kinds of comparisons provided immediately hereafter, with regard to Wisconsin. There are significantly more state Human Cancer Criteria with criterion-concentrations lower than those of the corresponding EPA criteria than there are state Human Threshold Criteria with concentrations lower than EPA's. Wisconsin bases its Human Cancer Criteria on a target incremental cancer risk of one in 100,000 [10^{-5}] exposed persons. EPA has a long-established policy of accepting state WQC addressing carcinogenic effects within an incremental risk range of 10^{-5} to 10^{-7}. Hence, in this study, the criterion-concentration of a given Wisconsin Human Cancer Criteria was compared to EPA's corresponding WQC at the 10^{-5} risk level. Readers of this report should be aware of the fact that in most of the WQC tables that EPA has issued, only the criterion-concentrations for the 10^{-6} cancer risk level are presented. These concentrations are one-tenth of the concentration of EPA's human health criteria for carcinogens based on a 10^{-5} level of protection.

The Wisconsin WQS regulations are not entirely clear as to what criterion-duration[10] might apply to most of the WQC that have been established for traditional pollutants. For toxic substances, there is only one minor ambiguity in Wisconsin's criterion-duration for its aquatic life WQC; in contrast, there is significant ambiguity associated with the criterion-duration for the state's human health-related WQC.

[10] According to terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion" – a specified time period over which the waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as four day average concentrations. The occurrence of one or more excursion (e.g., a four day period in which the instream concentration of, for example, cyanide was higher than the chronic criterion-concentration 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred.

The criterion-frequencies[11] applicable to some, but not all, of Wisconsin's WQC for traditional pollutants are stated quite clearly. In particular, it is clear what frequencies would apply to the aquatic life criteria for ammonia and chlorides, as well as the frequency for one of the recreation criteria and one of the aquatic life criteria for bacteria. The criterion-frequency for all of the state's aquatic life criteria for toxics is also articulated clearly – once in three years. In contrast, the human health-related WQC for toxic substances lack a specified criterion-frequency, which, for the purposes of this report, implies a frequency of zero.

As for the level of protection provided by a state WQC for a given pollutant/use combination in comparison to that of EPA (or another state), this cannot be done with any degree of confidence unless all three elements of both WQC are clearly articulated. And, even when the criterion-concentration, criterion-magnitude, and criterion-frequency of each of the two WQC being compared are precisely stated, their comparative degree of protectiveness can only be determined, simply by looking at the two WQC and nothing else, with certain combinations of relative criterion-concentration, concentration-duration, and combination-frequency. For instance, if a state and a comparable (same pollutant and same designated use) EPA criterion both have the same criterion-concentration, same criterion-duration, and the same criterion-frequency, they would provide equal levels of protection. If, however, the criterion-concentration of one of the two WQC were lower than the other, and the criterion-duration and criterion-frequency remained identical, then that WQC would provide the higher degree of protection. Likewise, if the criterion-concentrations are the same, the criterion-durations are identical, but one of the WQC has a lower acceptable criterion-frequency, then that criterion with the lower frequency would provide more protection. Also providing a higher level of protection would be a WQC with a shorter criterion-duration than a comparable WQC that had the same criterion-concentration and criterion-frequency. Appendix C provides a set of tables that list all possible combinations, in relative terms, of criterion-concentrations, criterion-durations, and criterion-frequencies, indicating which represent higher, lower, and identical levels of protection.

In the case of Wisconsin's chronic criteria for aquatic life, the criterion-duration is essentially equal to the duration for comparable EPA criteria and the criterion-frequency is exactly the same; hence, comparison of the state's and EPA's respective chronic aquatic life criterion-concentrations would be a good indicator of comparative level of protectiveness.

Wisconsin's acute aquatic life for toxics are significantly more challenging in this regard because the state's criterion-duration (one day) is considerably longer than EPA's (one hour), while the criterion-frequency is the same. This means that any state acute aquatic life WQC for a toxic pollutant with a criterion-concentration equal to or higher than EPA's would be less protective, because of the longer duration. On the other hand, if the state criterion-concentration were lower than EPA's, it would be difficult to determine whether or not the more-protective

[11] In EPA water quality standard terminology, the criterion-frequency specifies the maximum rate at which "excursions" can occur and the waterbody of concern can still fully supports the designated use to which the criterion applies. For instance, EPA guidance specifies a criterion-frequency of once in three years for both its acute and chronic aquatic life WQC for toxic chemicals. This means that only if two or more excursions occur during any three-year period has there actually been an exceedence of the WQC in question. For example, only if the four day average concentration of cyanide, for example, in a lake were higher than the chronic criterion-concentration of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

effect of the lower concentration would be offset by the less-protective effect of the longer criterion-duration.

Unfortunately, the relevance of the tables in Appendix C to Wisconsin's WQC is significantly limited by the fact that, a substantial number of the state's criteria lack a clearly-articulated criterion-duration and/or criterion-frequency. Further complicating comparison of the level of protection afforded to applicable designated uses by a state WQC is the fact that most of EPA's criteria for traditional pollutants lack a clearly-articulated criterion-duration and criterion-frequency. The absence of explicit criterion-duration and or criterion-frequency in one or both of two corresponding (same pollutant/use combination) criteria, renders a determination of the absolute or relative level of protection provided by one WQC versus another an exercise fraught with uncertainty. Any such effort would, of necessity, involve making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually settled upon, by the entities that established each of the criteria. In turn, the results of attempts to compare the protection provided by a state versus an EPA WQC would be greatly affected by whatever assumptions were made. Assumption of some short-term duration (e.g., one hour), rather than a longer term (e.g., 30 days), would tend to make a criterion more protective. Likewise, assumption of a lower frequency (e.g., once in five years), rather than a higher frequency (e.g., once in two years) would have the same effect—more protective than if the alternative were the case.

All of Wisconsin's human health criteria for toxics lack a reference to a criterion-duration. For purposes of this report, this situation is taken to mean a criterion-duration of an instant. The EPA literature regarding the criterion-duration for its human health criteria for toxics is inconsistent, sometimes giving the impression that the duration for these categories of criteria is an instant, while at other times indicating a duration as long as 70 years. Neither the state nor EPA make any reference to a criterion-frequency for their human health criteria for toxics, suggesting not even one excursion would be consistent with fully supporting the use of concern. Those Wisconsin WQC having criterion-concentrations somewhat lower than that of the corresponding EPA WQC (e.g. twenty [20] of the state's Public Water Supply-Cold Water Communities criteria) would appear to provide somewhat greater protection than EPA's corresponding WQC, assuming both the state and EPA criteria have durations of an instant and frequencies of zero. If, on the other hand, the EPA criterion-duration were taken as 70 years, then the corresponding state WQC (assumed duration = instantaneous) would tend to be significantly more protective.

Also, with regard to aquatic life WQC, even with clearly articulated WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons (differences in water chemistry and/or indigenous species) that a state criterion can have a criterion-concentration higher or lower than that for the corresponding U S EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC were designed. This would not, however, mean that the two criteria would provide equal levels of protection to the relevant use. For example, ten of Wisconsin's chronic aquatic life WQC for toxics (see Appendix B, Table 5) have a criterion-concentration higher than EPA's, while the criterion-durations (four days) and frequency (no more than one in three years) for the state and EPA WQC are identical. These 10 state WQC would provide a lower degree of protection relative to that which would be provided

by application of EPA's criterion to the waterbody in question. Nevertheless, site-specific conditions may, at least in some waterbodies, have resulted in the corresponding EPA's WQC providing an even higher level of protection than that for which EPA designed them. The effect of the state's higher criterion-concentration could be to bring the level of protection back down to that intended by EPA.[12]

Turning from aquatic life to human health, safe levels of pollutants tend to vary less from waterbody to waterbody. The most obvious reason is that, unlike aquatic life WQC, human health criteria address impacts on just one species, regardless of the location of the waterbody to which the WQC apply.[13] The most common reason for need for variation in human health criteria from one locale to another is differences in patterns of human use. For example, regarding drinking water use, persons in hotter climates tend to consume more water, on average, than those in cooler areas. Also, the amount of fish and other aquatic life from local waters that are caught and eaten by people can differ by an order of magnitude from place to place and/or within subpopulations of humans. The type of aquatic life consumed by humans can also differ from waterbody to waterbody. And, of course, patterns of swimming and other water contact recreation can change considerably depending on difference in the climate in which one waterbody versus another is located, along with the type of waterbody (river, lake, ocean beach).

Unlike EPA's human health criteria for toxics for which there is one WQC that address consumption of aquatic life alone (HHO) and another dealing with fish consumption in combination with drinking water (HHWO), there are subsets of Wisconsin's human health criteria for toxics (both "threshold" and "cancer") for: 1) "non-public water supply" (equivalent to HHO WQC), and 2) "public water supply" (parallel to HHWO criteria). Which of the three sub-sets of human health criteria applies to a given type of waterbody depends on what types of fish would naturally inhabit said waterbodies – "cold water sport fish communities," "warm water communities," or "limited aquatic life."[14] And, in turn, the criterion-concentration for persistent bioaccumulative pollutants changes from one of these subcategories to the next. The fact that criterion-concentrations for Wisconsin's fish consumption—related WQC for cold water communities tend to be lower than those for warm water communities has to do with the tendency for a higher degree of bioaccumulation up food chains of which cold water fish are top predators, as compared to that in fish inhabiting warm waters. This, in turn, is due to the state's

[12] Wisconsin's WQS regulations list WQC for each of three subgroupings of aquatic life uses: 1) cold water; 2) warm water sport fish, warm water forage fish, and limited forage fish, as well as 3) limited aquatic life. For most of the toxic chemicals for which Wisconsin has such aquatic life WQC, the criterion-concentration does not change from one of these three groups to another. As expected, the criterion-concentrations for certain conventional parameters (e.g., dissolved oxygen and temperature) do change among the categories.

[13] Of course, within the human population in a given locale, there will be certain sub-populations that are more sensitive to certain pollutants than the average members. Small children, pregnant women, and the elderly are examples of such groups. Other groups worthy of special attention are persons who engage in hard physical labor and those who participate in vigorous outdoor exercise. In most cases, this fact would not, however, indicate a need for different human health WQC for one waterbody versus another, as the proportion of the total population represented by each of these subgroups would most likely not vary substantially from one location to another.

[13] Rates of consumption of drinking water and frequency of water contact recreation also can vary from one climate zone to another—being higher in hotter areas.

[14] The state's "warm water communities" criteria applicable to consumption of fish by humans further address three subcategories: a) Warm Water Sport Fish, b) Warm Water Forage, and c) Limited Forage. The criterion-concentration for a given toxic pollutant is, nevertheless, the same for these three sub-subcategories.

use of different average percent lipid values for cold water fish (0.044) versus warm water fish (0.013).

The criterion-concentrations for highly bioaccumulative pollutants for "limited aquatic life" waters tend to be higher than the criterion-concentrations of Wisconsin's fish-consumption-related WQC for cold and warm water habitats. The reason seems to be that the state assumes that considerably lower amounts of edible aquatic organisms are found in "limited aquatic life" waters. Consequently, rates of fish consumption by humans using these waters would likely be lower than waters that harbor substantial numbers of either cold water or warm water sport fish.

On the other hand, Wisconsin's WQS regulations give no indication of modification of criterion-concentrations for WQC related to fish consumption to account for higher rates of human fish consumption from some waterbodies to another. Perhaps there are no such differences within Wisconsin. If there, however, some areas where subsistence-fishing is more common than others, then persons in the former areas would be getting a lower level of protection than the latter areas, if the types of aquatic life present are the same (see previous paragraph). Conversely, persons taking fish from a given waterbody at a rate lower than that assumed by the state (20g/day) would be provided a higher level of protection than that for which the state WQC was designed.

Returning briefly to the effects of unaddressed or imprecisely-articulated criterion-durations and criterion-frequencies, in addition to making comparison of levels of protection difficult, if not impossible, such ambiguities can pose challenges to the implementation of CWA programs driven by WQS—303(d) and 305(b) reporting on the condition of a state's waters, total maximum daily loads (TMDLs), and water-quality based effluent limits. For instance, if a TMDL were being developed because of exceedences of one of Wisconsin's Human Threshold: Non-public Water Supply: Cold Water Communities criteria, the absence of a clearly-articulated criterion-duration for this category of WQC would create a quandary. What should the time-interval for the maximum loading set forth in the TMDL be? If one assumes, as has been done in this report, a default criterion-duration of an instant, then it would seem logical to state the TMDL as a maximum load over a very short interval, even just a second. On the other hand, if the criterion-duration for the state's WQC was one year, then setting a maximum yearly total load would seem appropriate.[15]

[15] In *Friends of the Earth v EPA,* 446 F.3d.145 (2006) the federal D.C. Circuit Court ruled that because of the specific reference to "daily" in the portion of Section 303(d) of the CWA that established the Total Maximum Daily Load program, all TMDLs should include, at least, a maximum daily load, though loads over other time spans might also be needed, in order for the TMDL to be consistent with attainment of the relevant WQC.

C. Traditional Pollutants/Parameters

1) *Coverage*

a) Aquatic Life / "Fish and Other Aquatic Life"[16]

Wisconsin lacks an acute and/or chronic WQC for a substantial fraction of the traditional pollutants for which EPA has published criteria. Currently among the missing pollutants are several that correspond to EPA's nutrient criteria – chlorophyll a, total phosphorous, total nitrogen and turbidity.[17] It also has no WQC for suspended or settleable solids or dissolved solids. On the other hand, the State has a number of "extra"[18] criteria for temperature,[19] for which there is no comparable EPA WQC.

Like EPA, Wisconsin has no chronic criteria for dissolved oxygen (DO). Both the state and the federal agency do have acute WQC for this parameter.

b) Human Health: Drinking Water Supply

Wisconsin has no drinking water supply criteria for any of the traditional pollutants or other water quality parameters studied in this report. In contrast, EPA has issued chronic standards under the Safe Drinking Water Act for eight (8) such pollutants. It should be noted that, with the exception of total coliforms, the EPA standards for the eight traditional parameters addressed in this section are "secondary" drinking water standards (related to taste, odor, and appearance of drinking water), rather than "primary" drinking water standards (related to health). Also, the EPA standards promulgated under the SDWA are applicable to "finished" (after treatment) drinking water; hence, they are not directly comparable to WQC established in concert with the Clean Water Act for "raw" (untreated) water for surface waterbodies like rivers and lakes.[20]

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[16] Throughout this document, generic names (e.g., "aquatic life," and "human health: drinking water supply," and "human health: water contact recreation") are used in reference to certain categories of uses. When a state uses different wording to refer to one of the generic uses, the name the state employs is listed in quotation marks, following the generic title. Wisconsin has several sub-categories under its "fish and other aquatic life" use category: cold water communities, warm water sport fish communities, warm water forage fish communities, limited forage fish communities, and limited aquatic life. With regard to its ammonia criteria, there are sub-groupings under "cold water communities," each with a different criterion-concentration. The other conventional parameters for which Wisconsin has aquatic life criteria that vary from one of these subcategories to another are temperature and dissolved oxygen, for which there are different criteria just for the cold water and warm water categories.

[17] At the time of this writing, Wisconsin has made considerable progress toward developing and adopting an extensive set of numeric WQC dealing with nutrient levels and their effects.

[18] For the purposes of this review, "extra criteria" are those pollutant/use combinations for which the state has formally proposed or officially adopted water quality criteria, while EPA has not published recommended WQC of the type specified.

[19] Id. at 11.

[20] Unlike the water quality criteria that it issues for CWA purposes, the drinking water standards EPA promulgates, via formal rulemaking, under authority of the Safe Drinking Water Act are regulatory requirements, not just recommendations. EPA lacks actual drinking water supply criteria for conventional, as well as toxic, pollutants – specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply

Wisconsin also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. High levels of algae in the raw water supply used by a public drinking water system can result in unpleasant taste and odor in finished drinking water, unless special care is taken in the drinking water treatment process. Such extra treatment efforts can, in turn, lead to increased costs to a drinking water utility and its customers.

c) Human Health: Water-contact Recreation / "Recreational Use"

Wisconsin has not adopted any criteria for the bacterial indicators *E. coli* and Enterococci applicable to the drainage of the Mississippi River. EPA issued criteria for these microbes in 1986. The state continues to rely on fecal coliform criteria, based on guidance issued by EPA in the 1970s.

The state also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. Such blooms can form mats on the water surface which can interfere with a variety of water-based recreational activities.

d) Human Health: Consumption of Fish and Other Aquatic Organisms

EPA has issued chronic WQC applicable to consumption of shellfish while Wisconsin has not.[21]

e) Agricultural Water Supply

EPA has issued criteria applicable to boron/borates for agricultural water supply uses while Wisconsin has not.

f) Industrial Water Supply

EPA has issued criteria applicable to calcium carbonate for industrial water supply uses while Wisconsin has not.

2) *Criterion-Concentrations, Compared to EPA's*

a) Aquatic Life / "Fish and Other Aquatic Life"

The state's aquatic life criteria for traditional pollutants/parameters have identical or very similar criterion-concentration to the corresponding criteria issued by EPA and to those of neighboring states covered by this study.

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to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

[21] The significance of the lack of such criteria depends upon whether or not any of Wisconsin's waters harbor beds of shellfish that are harvested and consumed for either recreational or commercial purposes.

The acute ammonia criterion-concentrations applicable to Wisconsin's acute aquatic life criteria for Cold Water Category 1 and 4 waters are identical (at the same pH) to those in EPA's acute aquatic life criteria for waters where salmonids are present, while its acute ammonia WQC for Cold Water Categories 2 and 3 waters have somewhat higher criterion-concentrations than the federal agency's criteria. Likewise, Wisconsin's acute ammonia criteria for Category 5 waters (warm water habitats) have criterion-concentrations that are equal to the criterion-concentrations in EPA's acute criteria for waters where salmonids are not present, while the criterion-concentrations, at the same pH, in the state's criteria for Limited Aquatic Life waters are slightly higher.

Wisconsin's two sets of chronic ammonia criteria (four-day and 30-day durations) for waters in which early life stages are present appear to have the same criterion-concentrations as corresponding EPA criteria, across a large number of combinations of waterbody pH and temperature. This same pattern appears to be true with regard to the state's and EPA's chronic criteria for waters in which early life stages are absent.

The state's acute aquatic life criterion for chloride has a somewhat lower criterion-concentration (757 mg/L) than EPA's acute criterion (860 mg/L), while the criterion-concentration for the state's chronic aquatic life criterion (397 mg/L) is somewhat higher than EPA's (250 mg/L).

Wisconsin employs a default criterion-concentration of 5.0 mg/L for dissolved oxygen which applies to all waters except those classified trout streams, to which a criterion-concentration of 6.0 mg/L applies, except during trout spawning season, when the criterion-concentration is 7.0 mg/L.[22]

Given the fact that EPA has published, in its package of "nutrient criteria," waterbody type-specific WQC for four pollutants/parameters (total nitrogen, total phosphorous, chlorophyll a, and turbidity) that are applicable to the two ecoregions present in Wisconsin (Ecoregion VII – Mostly Glaciated Dairy Region, and Ecoregion VIII – Nutrient Poor, Largely Glaciated Upper Midwest), comparison of the state's criterion-concentrations to EPA's could be instructive. However, such comparison is not possible because state has not adopted nor proposed criteria for any of these four pollutants/parameters.

b) Human Health: Consumption of Fish and Other Aquatic Organisms

Not Applicable. Wisconsin's WQS regulations do not include human health fish consumption criteria for traditional pollutants/parameters.

[22] The relationship between "trout streams" and "cold water sport fisheries" is not clear in the Wisconsin regulations, which means it is unclear whether the criterion-concentration for dissolved oxygen that applies to waters harboring cold water sport fisheries besides trout streams is the default (5.0 mg/L) or that applicable to trout streams (6.0 mg/L). Based on the definition of "cold water sport fish communities" in NR 102.04(3) of the state's WQS regulations, it would seem that the default of 5.0 mg/L applies to waters with this classification that are not also classified as trout streams by the state.

c) Human Health: Drinking Water Supply

Not Applicable. Wisconsin's WQS regulations do not include human health drinking water supply criteria for traditional pollutants/parameters.

d) Human Health: Water-contact Recreation / "Recreational Use"

Wisconsin's acute and chronic WQC for fecal coliform bacteria have the same criterion-concentrations as EPA's WQC for primary contact recreation (bathing waters).

e) Agricultural Water Supply

Not Applicable. Wisconsin's WQS regulations do not include criteria for traditional pollutants/parameters pertaining to agricultural water supply uses.

f) Industrial Water Supply

Not Applicable. Wisconsin's WQS regulations do not include criteria for traditional pollutants/parameters pertaining to industrial water supply uses.

3) *Articulation of Criterion-Duration*[23]

There is some level of ambiguity associated with the criterion-duration for most of Wisconsin's WQC for traditional pollutants. One exception is the criterion-duration in the state's WQC for ammonia.

a) Aquatic Life / "Fish and Other Aquatic Life"

Certain language in the Wisconsin WQS regulations appears to indicate that the criterion-duration applicable to some aquatic life criteria is an instant, though this is not entirely clear. For instance, the criterion for pH states, "The pH shall be in the range of 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum." Likewise, there are WQC for temperature expressed as follows: 1) "The maximum temperature rise…above the existing natural temperature shall not exceed…" and 2) "The temperature shall not exceed ___degrees F…"[24] In such a case, there is no indication that the cited values are anything other than levels not to be exceeded ever, not even for a second. By contrast, language stating that "Dissolved oxygen … shall not be artificially lowered to less than 6.0 mg/L at any

[23] According to terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion" – the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as 4 day average concentrations. The occurrence of one or more excursion (e.g., a four day period in which the instream concentration of, for example, cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred.

[24] Id. at 8.

time" (Section NR 102.04(4)(e)(2) of the Wisconsin WQS regulations) is an example of a clearly-stated "instantaneous" criterion-duration.

The criterion-duration for the acute criteria for ammonia and chloride is apparently 1 day, as it is expressed as "the maximum daily concentration." Most likely, this is intended to mean the average concentration over 24 hours, though this could be more clearly expressed as "daily average concentration." The current language could, alternatively, be taken to mean the highest instantaneous concentration to occur on any day, though if that were intent, it would say something along the line of: "concentration not to be surpassed at any time during any day."

There is also some ambiguity as to whether "daily" means "one calendar day" or "any consecutive 24 hour period." A calendar day would be presumed to be the period between 12:00 AM and 11:59 PM. The latter interpretation could be characterized as a "rolling 24 hour average."

The criterion-duration applicable to the chronic WQC for both ammonia and chloride is "4 days." There is also a second chronic WQC for ammonia, with a criterion-duration of 30 days. As noted above, this language creates some doubt as to whether "day" refers to a calendar day or any 24-hour period. In general, WQC with durations equal to time periods not linked to the timekeeping systems created by humans is more consistent with what is known about the biochemistry and physiology of plants and animals.

One of Wisconsin's aquatic life criteria for pH is expressed as "no change greater than 0.5 units outside the estimated natural season maximum and minimum." A similar WQC for temperature states, "The maximum temperature rise at the edge of the mixing zone above the natural temperature shall not exceed 5^{o}F…" These are examples of what this report refers to as "quasi-numeric" criteria – that is, they are expressed in terms of a certain change from background conditions. Unlike the case of typical numeric WQC, determination of whether such criteria have been exceeded requires knowledge of not only current but also past water quality (or current concentration above and below a discharge or point of loading of pollutants to a waterbody). Also, the wording of such criteria provides no indication as to what duration(s) of time the "no change" standard is intended to apply. It would presumably apply to the overall natural background pattern of temperature, over time and space. Hence, attention would need to be paid not only to instantaneous minimum temperature levels, but also average temperatures over various periods of time (minutes, hours, days, etc).

b) Human Health: Consumption of Fish and Other Aquatic Organisms

Not Applicable. Wisconsin has not adopted criteria applicable to traditional pollutants/parameters for this designated use.

c) Public Water Supply

Not Applicable. Wisconsin has not adopted criteria applicable to traditional pollutants/parameters for this designated use.

d) Human Health: Water-contact Recreation / "Recreational Use"

Wisconsin's WQS regulations specify a water-contact recreation criterion for fecal coliform bacteria, which is stated as: "The … count may not exceed 400 per 100 ml in more than 10% of all samples during any month."[25] As such, the criterion-duration applicable to this WQC appears to be a second or instant. This is because the regulations' refer to a percentage of samples. Most ambient monitoring for bacteria takes the form of "grab" sampling – collecting a series of single aliquots of water, by manual or mechanical means. It takes only a second to collect each of these individual measurements. Hence, the criterion-duration is assumed to be an instant/second.

The state also has a fecal coliform WQC expressed as the geometric mean of samples collected over "a month" (NR 102.05(5)(a) of the Wisconsin WQS regulations). If "month" is intended to refer to a calendar month, then, depending on which month of the year in which a set of samples was collected, the duration could range from 28 days to 31 days. An alternative interpretation of "month" is 30 days. A "rolling 30 day average" would seem more consistent with what is known about the manner in which pathogenic organisms affect humans and other animals, in that it is the length of the exposure period that is most important, rather than the time at which such period begins.

e) Industrial Water Supply

Not Applicable. Wisconsin has not adopted criteria applicable traditional pollutants/ parameters for industrial water supply uses.

f) Agricultural Water Supply

Wisconsin has not adopted criteria applicable traditional pollutants/parameters (as opposed to toxics pollutants) for agricultural water supply uses.

4) *Articulation of Criterion-Frequency*[26]

The criterion-frequencies for ammonia and chlorides are clearly stated as no more than once in three years (no more than one excursion per three rolling-year periods). The frequency for those criteria expressed as "not to be surpassed" levels (e.g., pH and temperature) are

[25] Technically, this is not a water quality criterion because it describes the characteristics of a set of samples taken from a waterbody, rather than the desired condition of the waterbody itself. A true WQC would read something like, "The density of __ bacteria in surface waters shall be higher than __ no more than 10% of the time." What is presented in the state's WQS regulations as a WQC actually reads like a waterbody assessment methodology—a proscribed means of interpreting data collected from a waterbody in order to infer the true (but never completely knowable, with current technology) condition of the waterbody over time and space.

[26] In EPA water quality standard terminology, the criterion-frequency specifies the maximum rate at which "*excursions*" can occur and the waterbody of concern can still fully support the designated use to which the criterion applies. For instance, EPA guidance specifies a criterion-frequency of once in three (3) years for both its acute and chronic WQC for toxic chemicals aimed at aquatic life protection. This means that only if two or more excursions occur during any 3-year period has there actually been an *exceedence* of the WQC in question. For example, only if the 4-day average concentration of cyanide in a lake were higher than the chronic criterion-concentration of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

assumed (in this study) to allow no excursions, i.e., a frequency equal to zero. The fecal coliform criterion for recreational use has a clearly-specified frequency of 10%.

The Wisconsin WQS regulations contain conflicting language regarding the criterion-frequency for dissolved oxygen. On the one hand, the criteria are expressed as concentrations below which dissolved oxygen should not fall "at any time" (Section NR 102.04(4)(a) of the Wisconsin WQS regulations), which indicates a frequency of zero. On the other hand, language from Section NR 102.05(2)(b) of the same regulations stating, "the determination of water quality based effluent limitations or other management practices shall be based upon...In the case of dissolved oxygen … a 0.274% level of nonattainment," suggests a low, but nevertheless greater than zero, frequency.

A criterion-frequency applicable to all of Wisconsin's WQC could possibly be inferred from the discussion of "stream flows" under "Application of standards—Minimum Stream Flow," in Section NR 102.05(2)(a), which states: "The determination of water quality based effluent limitations or other management practices shall be based upon the average minimum seven-day low streamflow which occurs once in ten years (seven-day Q_{10})." This implies an acceptable frequency of excursions of roughly one every ten years. The validity of such an assumption is significantly undermined by the fact that, as noted, the state has clearly-articulated criterion-frequencies that are applicable to some WQC for traditional pollutants, none of which are equal, or even close to, just once in ten years.

5) *Discussion: Traditional Pollutants/Parameters*

Wisconsin has adopted numeric WQC for a fairly small portion of the traditional pollutant/use combinations for which EPA has issued WQC. (EPA has issued such values for two dozen pollutants, some of which have criteria for more than one use.)

The most significant gap in the state's coverage of criteria for traditional pollutants/parameters is the absence of numeric criteria for nutrients (total phosphorous or total nitrogen) and the related indicator of algal density, chlorophyll a. Algal blooms resulting from excess loadings of nutrients can adversely affect no only aquatic life, but also public water supply and water-based recreational uses. However, the state is well along in a process aimed at adopting a comprehensive set of nutrient-related numeric WQC. Wisconsin also lacks criteria for parameters related to suspended and bed sediments.

Despite lacking numeric criteria relevant to eutrophication and sediments, the state has included on its 303(d) list of impaired waters over 136 for "nutrients" and 195 waters for "sediments." These listings reflect the willingness of the state to put waters on the 303(d) list based on conditions considered inconsistent with one or more narrative WQC. Nevertheless, the adoption of numeric nutrient WQC would likely eventually result in the identification of additional nutrient-impaired waters. "Nutrients" and "sediment/sedimentation" are among the five most frequently mentioned causes of impairment for waters on state 303(d) lists nationwide, along with pathogens, mercury, and metals other than mercury.[27]

[27] EPA National Section 303(d) List Fact Sheet: Causes of Impairment. Available at: http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T.

Wisconsin has no WQC for traditional pollutants/parameters applicable to public water supplies. It should be noted that, with the exception of total coliforms, the EPA Safe Drinking Water Act (SDWA) standards[28] for the eight traditional parameters addressed in this section are "secondary" standards (related to taste, odor, and appearance of drinking water), rather than "primary" drinking water standards (related to health).

Most of the criterion-concentrations applicable to criteria that Wisconsin has adopted for pollutants/parameters are equal to, or only slightly higher, or lower, than the concentrations in corresponding EPA criteria and those of other states covered by this study. An exception is the acute ammonia criteria for "limited aquatic life" waters, which appear to have criterion-concentrations that are about 50% higher than related EPA criterion-concentrations (at the same pH levels). The state's WQS regulations define "limited aquatic life" waters as "waters of severely limited capacity and naturally poor water quality or habitat….capable of supporting only a limited community of aquatic life." The most likely explanation for the fact that Wisconsin's "limited aquatic life" ammonia criteria tend to have criterion-concentrations that are higher than the coldwater ammonia criteria is that species typically regarded by the state as residents in "limited aquatic life" waterbodies are less sensitive to short-term (24 hours) exposure to ammonia than are those species found in other types of waters.

Assuming the waters the state places in this category are intermittent or ephemeral, it follows that the species adapted to these environments could tolerate lower dissolved oxygen levels and a wider range of water temperatures than species that inhabit more permanent waterbodies. From an ecological and evolutionary standpoint, however, it would not be safe to assume that species found in these "limited" waters can tolerate higher levels of any and all chemicals than can those species found in typical warm water or cold water habitats. Species and chemical specific toxicity data would be needed to determine the situation with individual pollutants.

A sizeable portion of the criterion-durations in the criteria for conventional pollutants/parameters are not clearly stated. Most common are WQC expressed as "not to exceed" concentrations, which strongly implies a duration of just an instant; however, the Wisconsin WQS regulations do not make this entirely clear.

The criterion-frequencies for some of Wisconsin's WQC for conventional pollutants are stated quite clearly, including the aquatic life criteria for ammonia and chlorides (frequency =

[28] Unlike the water quality criteria that the Agency issues for CWA purposes, the drinking water standards EPA promulgates, via formal rulemaking, under authority of the Safe Drinking Water Act are regulatory requirements, not just recommendations. EPA lacks actual drinking water supply criteria; that is, EPA has not published anything that specifies acceptable levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards that are aimed solely at ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable. These Primary Drinking Water Standards apply to over 80 toxic contaminants, with the only such standard for traditional pollutants being that for fecal coliform bacteria. EPA does have a set of WQC for toxic chemicals that address levels in raw drinking water supplies, but these Human Health: Water and Organisms criteria address not only drinking water intake but also consumption of fish and other aquatic organisms.

maximum of one excursion in three years), one of the recreation criteria for bacteria (frequency = 10%) and one of the aquatic life WQC for dissolved oxygen (frequency = zero). However, several of the state's WQC for conventional pollutants/parameters do not have any explicit reference to a criterion-frequency, which indicates a de facto frequency of zero.

Turning to the level of protection provided to the applicable designated use(s) by a given state WQC and a corresponding WQC issued by EPA or adopted by another state, at first it might seem that a simple comparison of the criterion-concentrations of each of the WQC would suffice. This, however, is most definitely not the case—the criterion-durations and criterion-frequencies are equally important. For example, Wisconsin's acute aquatic life WQC for ammonia appear to have the same criterion-concentration as corresponding (at a given pH and/or temperature) EPA acute criterion. And, the criterion-frequency for the two sets of criteria are identical—no more than one "excursion in any given three year (36 month, 156 week, 1095 day) period. The criterion-durations are, however, different. Wisconsin's acute criteria have a criterion-duration of one day (24 hours), while EPA's corresponding WQC have a criterion-duration of one hour. The state's considerably longer (more than an order of magnitude) criterion-duration results in any of its acute criteria providing less protection than the corresponding EPA criterion, despite the fact that the criterion-concentrations are identical. On the other hand, the state has other sets of ammonia aquatic life WQC with durations (four days/96 hours and 30 days) identical to those of corresponding sets of EPA WQC. And, as with the acute ammonia WQC, the state and EPA WQC have the same criterion-frequency—once in 3 years. With these two groupings of WQC, the fact that corresponding state and EPA WQC have the same criterion-concentration does mean they can be expected to provide the same levels of protection to aquatic life.

As for most of the remainder of Wisconsin's WQC for conventional parameters, the previously- mentioned lack of clarity regarding criterion-duration and/or criterion-frequency in a number of Wisconsin's WQC for conventionals pollutants/parameters renders any attempt to determine the absolute level of protection afforded to the applicable designated use(s) an exercise with a high degree of uncertainty. Obviously, any attempt to perform such comparisons would require making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended by the state. The results of attempts to compare the protection provided by a state versus an EPA would, of course, be greatly affected by whatever assumptions were made. Assumption of some fairly long-term duration (e.g., 90 days), rather than a short-term (e.g., one hour), would tend to make a criterion less protective. Likewise, assumption of a higher frequency (e.g., once in six months), rather than a lower frequency (e.g., once in five years) would have the same effect—more protective than if the alternative were the case.

Further complicating the situation, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC were designed.[29] Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are

[29] Possible reasons include differences in waterbody chemistry and in species present in a given type of aquatic ecosystems, compared to what were used in studies on which EPA's criteria were based.

the same (e.g., duration is 24 hours, frequency is zero) and the state's criterion-concentration where higher than EPA's, then the state's criterion would indeed provide less protection to aquatic organisms in the waterbody or set of waterbodies than would EPA's, in relative terms. However, due to site-specific or watershed-specific conditions, the state's WQC would provide the same absolute level of protection as that for which the EPA WQC were designed, while use of the recommended EPA WQC in such waters would actually provide *greater* protection than that which EPA intended.

Lack of clearly-stated criterion-durations and criterion-frequencies also can render considerably more challenging the implementation of CWA programs that are driven largely by water quality criteria – including Section 303(d) and 305(b) assessment and reporting, TMDLs, and water quality-based NPDES permitting programs. Clearly, it would be difficult for someone implementing one of these "downstream" CWA programs to deal with a WQC having a criterion-concentration reading "levels no greater than approximately 40 mg/L - 60 mg/L." Though perhaps less immediately obvious, imprecisely-stated criterion-durations and criterion-frequencies can pose similar challenges to those presented by missing or vaguely-stated criterion-magnitudes.

For example, if over some 30 day period, four "grab" samples had been collected, passed quality assurance/quality control screening, and analyzed for levels of a certain pollutant, and one of those 4 samples had a concentration higher than a relevant criterion-concentration, the answer to "Was this pollutant exceeding this WQC?" would differ depending on the criterion-duration and criterion-frequency. If the duration were "instantaneous" and the frequency "zero," the WQC would have been exceeded, without question. But, if the duration were 30 days and the frequency remained at zero, the mere fact that one out of four instantaneous measurements surpassed the criterion concentration would not prove that an exceedence had occurred. Rather, only if the average of the concentrations in the four samples were higher than the criterion-concentration would there be strong evidence of an exceedence of WQC in the water from which the samples were collected. And, if the criterion-frequency were "two or more times per year," then the possibility that a WQC exceedence had not occurred should be considered.[30]

[30] Actually, depending on how much data had been collected, there could be a very good chance that more than one excursion had occurred, even if only one had been observed. This is because it would be contrary to the laws of probability to conclude that no additional excursions (30-day periods with average bacterial concentrations about the criterion-concentration) had occurred during any twelve-month period encompassing the 30 days in which the four grab samples had been collected, if these four individual samples were the only ones gathered during a given twelve-month period. The reason for this conclusion is that, given that there are 336 thirty (30)-day periods in any twelve-month period, the odds of having randomly chosen to collect samples during the only 30-day period in which an excursion occurred are very low. (Several times lower than randomly selecting a card from a well-shuffled deck of 52, and having that card turn out to be one named in advance.)

D. Toxic Chemicals

1) *Coverage*

a) Aquatic Life / "Fish and Other Aquatic Life"[31]

Unlike EPA and most states, Wisconsin does not have a single set of WQC for toxic chemicals that apply to all types of aquatic life. Rather, Wisconsin has specified three separate sets of criteria pertaining to the effects of toxics on aquatic life. The first set addresses "cold water" communities. The second set is aimed at protecting three different types of aquatic communities: a) "warm water sport fish," b) "warm water forage," and c) "limited forage fish." The third set applies to "limited aquatic life" communities.[32] Whenever it has established an acute or chronic aquatic life criterion for a toxic, Wisconsin as adopted such a criterion for each of these three groupings.

Acute Toxicity

The state has adopted acute criteria for 18 toxics. Of the 31 toxic pollutants for which EPA has issued[33] acute aquatic life criteria, Wisconsin has not adopted corresponding criteria for 13 pollutants (Appendix B, Table 1). These "missing"[34] pollutants are a combination of synthetic organophosphate pesticides, organochloride pesticides, and toxic metals. Seven (7) pollutants (aldrin, DDT, alpha-Endosulfan, beta-Endosulfan, chlordane, heptachlor and tributyltin) fall into categories of substances that have been frequently mentioned as potential endocrine disruptors. The state has no "extra" acute aquatic life WQC for toxics—pollutants for which EPA has not issued WQC but for which the state has.

Wisconsin actually has a total of 42 WQC addressing the acute effects of toxics, because for 12 pollutants, it has 3 sets of such criteria, one each for: 1) cold water, 2) warm water sportfish, warm water forage and limited forage fish and 3) limited aquatic life.

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[31] Id. at 16.

[32] As set forth in Section NR 102.04(3) of the Wisconsin WQS regulations, the "cold water" subcategory "includes surface waters capable of supporting a community of cold water fish and other aquatic life, or serving as a spawning area for cold water fish species. This subcategory includes, but is not restricted to, surface waters identified as trout water by the department of natural resources." The "warm water sport fish" subcategory "includes surface waters capable of supporting a community of warm water sport fish or serving as a spawning area for warm water sport fish." The "warm water forage fish communities" subcategory includes "surface waters capable of supporting an abundant diverse community of forage fish and other aquatic life." The "limited forage fish communities" subcategory includes "surface waters of limited capacity and naturally poor water quality or habitat. These surface waters are capable of supporting only a limited community of forage fish and other aquatic life." And finally, the "limited aquatic life" subcategory includes "surface waters of severely limited capacity and naturally poor water quality or habitat. These surface waters are capable of supporting only a limited community of aquatic life."

[33] Throughout this report, the criteria recommended by EPA are referred to as the EPA's "issued" or "published" criteria, interchangeably.

[34] For the purposes of this review, "missing criteria" are pollutant/use combinations for which the state has not officially adopted water quality criteria, whereas EPA has published recommended water quality criteria of the type specified.

Chronic Toxicity

The state has adopted chronic WQC for 16 toxic chemicals. Of the 35 toxic pollutants for which EPA has issued chronic aquatic life criteria, Wisconsin has not adopted corresponding criteria for 19 pollutants (Appendix B, Table 1). These "missing" pollutants are a combination of synthetic organophosphate pesticides, organochloride pesticides, and toxic metals – eight (8) pollutants (DDT, alpha-Endosulfan, beta-Endosulfan, chlordane, heptachlor, methoxychlor, toxaphene, and tributyltin) fall into categories of substances that have been frequently mentioned as potential endocrine disruptors. The state has no "extra" chronic aquatic life WQC for toxics—pollutants for which EPA has not issued WQC but for which the state has.

Wisconsin actually has a total of 38 WQC addressing the chronic effects of toxics, because for 11 pollutants, it has 3 sets of such criteria, one each for: 1) cold water, 2) warm water sportfish and warm water aquatic life, and 3) limited forage fish and limited aquatic life. For all but two pollutants--cadmium and nickel, the state chronic aquatic life WQC combines limited forage fish and limited aquatic life uses, while for its acute aquatic life WQC, limited forage fish is combined with warmwater sport fish and warmwater forage fish. For cadmium, warmwater forage fish, limited forage fish, and limited aquatic life are combined, while the chronic WQC for nickel, like all Wisconsin's acute WQC for aquatic life, has limited forage fish combined with warmwater sport and forage fish.

b) Semi-aquatic Wildlife

Wisconsin has developed and included in its regulations a method for deriving criteria for toxics aimed specifically at protecting semi-aquatic wildlife (e.g., bald eagle, kingfisher, herring gull, mink and otter). In particular, the state has specified numeric wildlife WQC for DDT and its metabolites, mercury, PCBs, and 2,3,7,8-TCDD. Neither EPA nor any of the other states examined at in this report have wildlife-specific criteria that are applicable to toxic substances for all waters in a state.

c) Human Health: Consumption of Fish and Other Aquatic Organisms

Wisconsin has no WQC for toxic chemicals that apply solely to exposure of humans to toxic chemicals via consumption of aquatic organisms from a given waterbody; rather, it has a set of criteria aimed at protecting humans who use a given waterbody not only for fish consumption but also for water-contact recreation. The state refers to these as "Non-Public Water Supply" criteria. (See Subsection D(1)(f) below).

EPA, on the other hand, has adopted human health WQC aimed at fish/aquatic organism consumption alone – so-called "human health: water and organisms" (HHO) criteria. EPA has not issued any WQC for toxic chemicals directed at water-based recreational use, either alone or in combination with other human health-related uses.

Technically, Wisconsin lacks WQC for all 108 of the pollutants for which EPA has issued "HHO" (fish consumption) criteria. It is, nonetheless, interesting to compare Wisconsin's "Non-Public Water Supply" criteria, which actually address human exposure due to the

combination of fish consumption and water contact recreation" to EPA's "human health: organisms only" (HHO) criteria, which address fish consumption exposure only. [35] (See Subsection D(1)(f), below.)

d) Human Health: Consumption of: a) Drinking Water plus b)Fish and Other Aquatic Organisms

Wisconsin has not adopted WQC for toxic chemicals aimed at protection of humans using a waterbody for just drinking water supply (DWS) and consumption of fish, shellfish, and other aquatic organisms (FC). The state does have criteria for the combination of these two uses, plus water contact recreation, called Human Threshold Criteria: Public Water Supply and Human Cancer Criteria: Public Water Supply (see Subsection D(1)(g) below).

EPA, on the other hand, has adopted human health WQC aimed at combined drinking water supply and fish/aquatic organism consumption called "human health: water and organisms" (HHWO) criteria. (EPA has not issued any WQC for toxic chemicals directed at water-based recreational use, either alone or in combination with other human health-related uses).

Technically, Wisconsin lacks WQC for all 113 of the pollutants for which EPA has issued "HHWO" (DWS + FC) criteria; however, it is, nonetheless, interesting to compare Wisconsin's "Public Water Supply" (PWS + FC + contact recreation) criteria to EPA's Human Health: Water and Organisms (HHO) criteria, as is done in Subsection D(1)(g) below.

e) Human Health: Drinking Water Supply

Though it has a set of criteria that are labeled "Human Threshold Criteria: Public Water Supply" in Table 8 of Section NR 105.08(4) and a set of criteria labeled "Human Cancer Criteria: Public Water Supply" in Table 9 of Section NR.105.09(3) of the Wisconsin WQS regulations, Wisconsin actually has no criteria dealing exclusively with exposure to toxics resulting from the source of one's drinking water supply. Rather, these are WQC dealing with the combination of drinking water supply, consumption of sport-caught fish, and water contact recreation uses. Evidence that these "public water supply" criteria actually address the combination of these three uses is found in the equations presented in Section NR105.08(4) and Section NR105.09(4) of the Wisconsin WQS regulations**,** from which the criterion-concentrations for these WQC are calculated. These equations include factors that can be used to account for intake of a pollutant from: 1) drinking water, 2) consumption of sport caught fish, and/or 3) water based recreation. This intent is also reflected in NR 105.08(1) and NR 105.09(1), both of which say, "The human … criterion is the maximum concentration of a substance

[35] Wisconsin's "Non-Public Water Supply" human health criteria are virtually equivalent to EPA's HHO criteria because the only difference between the exposure scenarios addressed by the two is the toxic chemicals ingested as the result of accidentally consuming some water in the course of water contact recreation. The volume of such water (Wisconsin assumes 0.01 L/d) is so small that the incremental amount of a toxic substance ingested as a result would be miniscule, in comparison to the amount that would be taken in by consuming contaminated fish. Hence, the effect on the applicable WQC would be miniscule. This is especially true in the case of persistent bioaccumulative pollutants.

established to protect humans from adverse effects resulting from contact with or ingestion of waters of the state and from ingestion of aquatic organisms taken from surface waters of the state."

f) Human Health: Fish Consumption and Water-Contact Recreation / "Human Threshold Criteria": Non-public Water Supply" and "Human Cancer Criteria: Non-Public Water Supply"[36]

Wisconsin has adopted two sets of human health criteria that are applicable to "non-public water supply" waters: 1) "Human Threshold Criteria: Non-public Water Supply," and 2) "Human Cancer Criteria: Non-public Water Supply." The "Human Threshold" criteria apply to toxic substances which are non-carcinogenic. As their title implies, the "Human Cancer Criteria" apply to toxic substances which are carcinogenic, as defined in Section NR 105.03(13) of the state's WQS regulations. These sets of criteria appear in Sections NR 105.08 and 105.09 of the WQS regulations, respectively. The criterion-concentrations for the "Non-public Water Supply" WQC are listed in three columns appearing on the right-hand side of Tables 8 and 9.

These "Non-public Water Supply" criteria are closely related to EPA's "Human Health: Organisms (HHO)" criteria. Both address the effect on humans of consumption of toxic chemicals present in the flesh of fish and other aquatic organisms that people take from a waterbody to which the criteria apply. Wisconsin's criteria differ slightly from EPA's HHO criteria because they also factor in the intake of toxic chemicals from a waterbody that results from incidental swallowing of an estimated 0.01 liters water per day during water contact recreational activities. This study compares Wisconsin's "Non-public Water Supply" criteria to EPA's HHO criteria despite this difference, because the effect of the very small amount of a toxic chemical that would be consumed by ingesting one one-hundredth of a liter (10 ml) of water should have only a miniscule impact on the appropriate criterion-concentration.

Wisconsin has adopted "Human Threshold" and/or "Human Cancer" criteria that are applicable to "non-public water supply"[37] uses for 73 pollutants.[38] Of these 73 pollutants, there

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[36] The state's name for this set of criteria can be misleading. Despite having an overall heading of "non-public water supply," the criteria listed under this heading (in Tables 8 and Table 9 of Section NR 105.08(4) and NR 105.09(3) respectively) are actually aimed at protecting humans eating fish and other aquatic organisms obtained from a given waterbody, but who do not obtain drinking water from that waterbody. They also account for accidental intake that would result from swimming or other water-contact recreation. Section NR105.08(4) and NR105.09(4) of the carcinogens) and "human cancer criteria" (for carcinogens), respectively. The factor F_H appears in both equations, and represents the "average per capita daily consumption of sport-caught fish by Wisconsin angles" – 0.02 kilograms (20 grams). Apparently this factor is not included when calculating "Non-public Water Supply criteria for Limited Aquatic Life waters, based on the expectation that such waters would not support sport fish. Another factor W_H also appears in both equations, and represents "average per capita daily water consumption." For waters not designated as public water supplies, the value of the factor W_H to be used in the equation is 0.01 liters of water per day—incidental ingestion assumed to result from water-based recreational uses. By contrast, for "Public Water Supply" criteria, a W_H value of two liters/day is used in the calculation.

[37] The state further divides its "Human Threshold" and "Human Cancer" criteria for "Non-Public Water Supply" waters into three subcategories, those applicable to waters harboring: 1) "cold water sport fish communities," 2) "warm water sport fish, warm water forage, and limited forage" fish communities, and 3) waters supporting "limited aquatic life" communities.

The reason for this subdivision is to "fine tune" the criteria aimed at addressing effects of human ingestion of toxic chemicals, via the pathway of consuming sport-caught fish, by accounting for two factors: 1) the different

are 12 pollutants for which EPA has not issued HHO criteria (Appendix B, Table 3). Conversely, there are 44 pollutants for which EPA has issued HHO criteria and for which the state has adopted neither "Human Threshold" nor "Human Cancer" criteria (Appendix B, Table 2).

i) Human Threshold Criteria

Wisconsin has adopted "Non-Public Water Supply: Human Threshold Criteria" for 44 pollutants in Section 105.08(4) of its WQS regulations, nine (9) of which are pollutants for which EPA has not issued corresponding HHO criteria (Appendix B, Table 3).

ii) Human Cancer Criteria

Wisconsin has adopted "Non-Public Water Supply: Human Cancer Criteria" for 39 pollutants in Section 105.09(3) of its WQS regulations, three of which are pollutants for which EPA has not issued corresponding HHO criteria: beryllium, BHC-technical grade, and halomethanes.

g) Human Health: Drinking Water Supply, Fish Consumption and Water-Contact Recreation / "Human Threshold Criteria: Public Water Supply" and "Human Cancer Criteria: Public Water Supply" [39]

Wisconsin has two sets of human health criteria that are applicable to waters with the "Public Water Supply" designation: Human Threshold Criteria and Human Cancer Criteria. (See Table 8 in Section NR 105.08(4) and Table 9 in Section NR 105.09(3) of the Wisconsin WQS regulations.) The Human Threshold Criteria (Table 8) have been derived for toxic substances which are non-carcinogenic. The Human Cancer Criteria (Table 9) are applicable to toxic substances which are carcinogens as defined in Section NR 105.03(13) of the state's WQS regulations. The criterion-concentrations for the "Public Water Supply" WQC are listed in two columns appearing on the left-hand side of Tables 8 and 9.

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levels of lipids (fats) typically found in the flesh of common sport fish in cold water versus warm water aquatic communities, and 2) the probable lack of consumption of sport fish from "limited aquatic life" waters due to the lack of such fish in waters so categorized. This sub-categorization of is discussed further in Sections D(2)(f) and D(2)(g) of this report.

[38] Among these 73 pollutants, there are ten pollutants for which the state has adopted both "Human Cancer" and "Human Threshold" criteria for waters designated as "non-public water supply." Thus, while there are technically 73 pollutants for which criteria have been adopted, the combined total number of "Human Cancer" and "Human Threshold" *criteria* adopted by the state is 83.

[39] The state's name for this set of criteria can be misleading. Those criteria that are labeled, in Tables 8 and 9 of the state's regulations, "Human criteria: Public Water Supply" actually are WQC dealing with the combination of drinking water supply , consumption of sport-caught fish, and water contact recreation uses. Section NR105.08(4) and Section NR105.09(4) of the Wisconsin WQS regulations present the equations used to calculate "human threshold criteria" (criteria for non-carcinogens) and "human cancer criteria," respectively. Both equations include a factor F_H, which represents the "average per capita daily consumption of sport-caught fish by Wisconsin anglers" – 0.02 kilograms (20 g). Another factor W_H also appears in both equations, and represents "average per capita daily water consumption." For waters designated as public water supplies, the value of the factor W_H to be used in the equation is an intake of 2.0 liters of water per day—the volume of water also used by EPA in its WQC calculations, to reflect drinking water intake. For calculating criteria for "non-public water supply" waters, the value of the factor W_H to be used in the equation is 0.01 liters of water per day—the amount the state estimates is incidentally consumed during water-contact recreation.

For the purposes of this study, relevant language referencing "ingestion of surface waters of the state and from ingestion of aquatic organisms taken from surface waters of the state" in Section NR 105.08 and Section NR 105.09 of the Wisconsin WQS regulations provides the basis for concluding that the state's "Human Threshold: Public Water Supply" and "Human Cancer: Public Water Supply" criteria correspond to EPA's 304(a) "human health: water and organisms" (HHWO) criteria.

Wisconsin has established "Human Threshold" and/or "Human Cancer" criteria that are applicable to waters designated "Public Water Supply"[40] uses for 73 pollutants. Of these 73 pollutants, there are twelve pollutants for which EPA has not established essentially corresponding (HHWO) criteria (Appendix B, Table 3). Conversely, there are 52 pollutants for which EPA has issued HHWO criteria and for which the state has neither adopted "Human Threshold" nor "Human Cancer" criteria for waters with the "Public Water Wupply" designation (Appendix B, Table 2).

i) Human Threshold Criteria

Wisconsin state has adopted "Public Water Supply: Human Threshold Criteria" for 44 pollutants in Section 105.08(4) of its WQS regulations, nine of which are pollutants for which EPA has not issued corresponding HHWO criteria (Appendix B, Table 3).

ii) Human Cancer Criteria

Wisconsin has adopted "Public Water Supply: Human Cancer Criteria" for 39 pollutants in Section 105.09(3) of its WQS regulations, three of which are pollutants for which EPA has not issued corresponding HHWO criteria: beryllium, BHC-technical grade, and halomethanes.

h) Industrial Water Supply

Not applicable. Wisconsin has not adopted WQC applicable to toxic chemicals for use of waterbodies as a water supply for industrial operations.

[40] The state further divides its "Human Threshold" and "Human Cancer" criteria for waters designated as "Public Water Supply" into two subcategories: "cold water communities" and those applicable to "warm water sport fish communities." Unlike its human health "Non-public Water Supply" criteria, Wisconsin does not have a third subcategory of criteria that apply to waters harboring "limited aquatic communities." Presumably the reason for the lack of such criteria for "Public Water Supply" is that the small, intermittent or ephemeral waters that would be classified "limited aquatic communities" would be a very unlikely choice as a source of water for a public water system. The purpose of this subdivision is to "fine tune" these criteria aimed at effects of human ingestion of toxic chemicals, via the pathway of consuming sport-caught fish, to account for the different levels of lipids (fats) typically found in the flesh of common sport fish in each of these two groups of aquatic organisms. Wisconsin's human health WQC labeled "public water supply" actually address the effects of the combination of consuming drinking water containing toxic chemicals and also eating fish whose flesh is tainted with toxics, as well as intake of toxics resulting from water contact recreation. The level of lipids is relevant because bioaccumulative pollutants like dioxins and PCBs tend to be stored in fatty tissue. Consequently, fish and other aquatic organisms with higher percentages of lipids in their tissues tend to have higher levels of organic bioaccumulative toxic compounds. This sub-categorization of Wisconsin's WQC is discussed further in Sections D(2)(c) and D(2)(d) of this report.

i) Agricultural Water Supply

Not applicable. Wisconsin has not adopted WQC applicable to toxic chemicals for use of waterbodies as a water supply for agricultural operations.

j) Human Health: Water-Contact Recreation

Not Applicable. Wisconsin has not adopted criteria applicable to toxic chemicals pertaining human health risks associated solely with various types of water-based recreation. However, as discussed earlier, it has established human health WQC addressing this use in combination with: i) fish consumption, and ii) fish consumption plus drinking water supply.

2) *Criterion-Concentrations*

a) Aquatic Life / "Fish and Other Aquatic Life"

Acute Toxicity

As discussed in Section D(1) of this report, the state has adopted three separate sets of criterion-concentrations for the: a) "cold water," b) "warm water sport fish, warm water forage, and limited forage fish," and c) "limited aquatic life" subcategories of its Fish and Other Aquatic Life use. In comparing the criterion-concentrations across the three subcategories, it is found that except for two pollutants (cyanide and cadmium), the acute criterion-concentrations for any given pollutant applicable to each of the three subcategories of aquatic communities are identical to one another. That is, except for cyanide, endrin, and cadmium, the acute criterion-concentration for a given pollutant is the same whether that criterion-concentration is to be applied to a "cold water" community, or a "warm water sport fish, warm water forage, and limited forage fish" community, or a "limited aquatic life" community.

Of the 18 toxic pollutants for which Wisconsin has adopted acute freshwater aquatic life WQC applicable to "warm water sport fish, warm water forage, and limited forage fish," ten pollutants have acute aquatic life WQC for which the criterion-concentrations are the same as those in the corresponding EPA criteria; three pollutants have acute aquatic life WQC for which the criterion-concentrations are lower than those in the corresponding EPA criteria (Appendix B, Table 4); and five pollutants[41] have acute aquatic life WQC for which the criterion-concentrations are higher than those in the corresponding EPA criteria (Appendix B, Table 5).

With regards to the pollutants cyanide and cadmium, the criterion-concentration applicable to each of them for the "warm water sport fish, warm water forage, and limited forage fish" subcategory and the "limited aquatic life" subcategory are identical, but are higher than the criterion-concentrations that apply to them for the "cold water" subcategory. All three criteria have concentrations higher than EPA's acute freshwater aquatic life criterion for cyanide.

[41] Because the pollutant endrin has two different sets of criterion-concentrations (two identical values that apply to the "cold water" and "warm water sport fish, warm water forage, and limited forage fish" subcategories and one different value that applies to the waters in the "limited aquatic life" subcategory and which is higher than the value in the corresponding EPA aquatic life criterion), it has been counted twice for the purposes of this report.

As for cadmium, a similar pattern prevails. All three WQC have concentrations higher than the EPA criterion. The only difference between the two chemicals is that the warm water/limited forage fish and limited aquatic life WQC for cyanide are the same, while the limited aquatic life WQC for cadmium has a higher concentration than the warm water/limited forage fish WQC. The cold water WQC for both pollutants has a lower criterion-concentration than the WQC for the other two subcategories of aquatic life.

Chronic Toxicity

Of the 16 toxic pollutants for which Wisconsin has adopted acute WQC for "warm water sportfish and warm water forage," one pollutant has a chronic aquatic life criterion for which the criterion-concentration is the same as that in the corresponding EPA criteria; four (4) pollutants have chronic aquatic life WQC for which the criterion-concentrations are lower than those in the corresponding EPA criteria (Appendix B, Table 4); and 9 pollutants have chronic aquatic life WQC for which the criterion-concentrations are higher than those in the corresponding EPA criteria (Appendix B, Table 5).

Arsenic, chromium III, cyanide dieldrin, endrin, pentachlorophenol, and selenium are pollutants with chronic criterion-concentrations that vary across the "cold water," the "warm water sport fish, warm water forage," and "limited forage fish and limited aquatic life" subcategories. For five (arsenic,cyanide, dieldrin, endrin, and chromium (+3)) of these seven pollutants, the criterion-concentration applicable to the "warm water sport fish and warm water forage fish" and the "limited forage fish, and limited aquatic life" subcategories is the same, and all are higher than the criterion-concentrations that apply to them for the "cold water" subcategory. The cold water WQC for arsenic, dieldrin are just slightly higher than the corresponding EPA WQC, while that for chromium(+3) is significantly higher. The concentration of the state CW criterion for endrin is exactly the same as that for EPA's corresponding WQC, while the criteria for arsenic and dieldrin have concentrations that are slightly lower than EPA's.

b) Wildlife Protection

Since EPA has no criteria specific to wildlife protection addressing waters nationwide, no comparison between state and EPA criteria was performed.

c) Human Health: Consumption of Fish and Other Aquatic Organisms

Not Applicable. Wisconsin has no WQC for toxic chemicals that apply solely to exposure of humans to toxic chemicals via consumption of aquatic organisms taken from a given waterbody. But, it does have WQC that address human uptake of toxic chemicals from this exposure route plus incidental uptake associated with water contact recreation. (See subsection (e) below.)

d) Human Health: Consumption of: a) Drinking Water plus b)Fish and Other Aquatic Organisms

Not Applicable. Wisconsin has not adopted WQC for toxic chemicals aimed at protection of humans using a waterbody for just drinking water supply (DWS) and consumption of fish, shellfish, and other aquatic organisms (FC). But, it does have WQC that address human uptake of toxic chemicals from these two exposure routes plus incidental uptake associated with water contact recreation. (See subsection (f) below.)

e) Human Health: Consumption of Fish and Other Aquatic Organisms and Water-Contact Recreation/ "Human Threshold Criteria: Non-public Water Supply" and "Human Cancer Criteria: Non-public Water Supply"

As noted above, those human health criteria that Wisconsin lists under the heading "Non-Public Water Supply" in Tables 8 and 9 of its WQS regulations are actually aimed at protecting humans from ingestion of toxic chemicals by engaging in two activities in a given water body: 1) consumption of sport-caught fish and/or other aquatic organisms; and 2) water-contact recreation. As such, these WQC are closely related to US. EPA's "Human Health: Organisms (HHO)" criteria, which also address intake of toxic chemicals by way of eating fish taken from a given waterbody.

According to the formulas that Wisconsin uses to calculate these criteria, the amount of water that might accidentally be ingested during swimming and other water-contact recreation is very small, so the amount of a toxic chemical that might be taken into the body via this route would be very small, compared to the amount that would be consumed by eating toxics-contaminated fish. Hence, the effect of the recreational exposure route on the criterion-concentration would be minimal. Consequently, though EPA's HHO criteria do not account for accidental intake of toxics due to water-contact recreation, comparing the criterion-concentration in EPA's HHO criterion for a given toxics to the criterion-concentration in Wisconsin's "Non-PublicWater Supply" criteria appears reasonable.

Another way in which Wisconsin's human health criteria for toxics (both "threshold" and "cancer") for "non-public water supply" waters differ from EPA's closely corresponding HHO criteria is that the state has developed three subsets of criteria. Which of the three sub-types of human health criteria applies to a given type of waterbody depends on what types of fish would naturally inhabit said waterbodies: 1) "cold water sport fish communities," 2) "warm water communities,"[42] or 3) "limited aquatic life." Hence, Wisconsin has a grand total of 258 Non-public Water Supply WQC.

The criterion-concentration components of Wisconsin WQC for each of these three subgroups of "non-public water supply" waters are compared to the criterion-concentrations for the same pollutant in EPA's Human Health: Organisms (HHO) criteria, below. First, the "human threshold criteria" (non-carcinogens) are compared, and then the "human cancer criteria."

[42] The state's "warm water communities" criteria further address three subcategories: a) Warm Water Sport Fish, b) Warm Water Forage, and c) Limited Forage. The criterion-concentration for a given toxic pollutant is always the same for these three subcategories.

i) Human Threshold Criteria (Non-carcinogenic effects)

Cold Water Communities

Of the 46 toxic pollutants for which Wisconsin has adopted "Human Threshold: Non-Public Water Supply" criteria applicable to cold water communities, there are 36 pollutants for which there are EPA HHO criteria. [43] Within this subset, 20 pollutants have "Human Threshold: Non-Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 6), and fourteen pollutants have "Human Threshold: Non-Public Water Supply" WQC for which the criterion-concentrations are higher than those in the corresponding EPA WQC (Appendix B, Table 7).

Warm Water Communities[44]

Of the 46 toxic pollutants for which Wisconsin has adopted "Human Threshold: Non-Public Water Supply" criteria applicable to warm water sport fish communities, there are 36 pollutants for which there are corresponding EPA HHO criteria.[45] Within this subset, eleven pollutants have "Human Threshold: Non-Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 6), and 24 pollutants have "Human Threshold: Non-Public Water Supply" WQC for which the criterion-concentrations are higher than those in the EPA HHO WQC (Appendix B, Table 7).

Limited Aquatic Life

Of the 46 toxic pollutants for which Wisconsin has adopted "Human Threshold: Non-Public Water Supply" criteria applicable to "limited aquatic life" waters, there are 36 pollutants with EPA HHO criteria.[46] Within this subset, one (1) pollutant has "Human Threshold: Non-Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 6), and 33 pollutants have "Human Threshold: Non-Public Water Supply" WQC for which the criterion-concentrations are higher than those in the EPA HHWOWQC (Appendix B, Table 7).

In addition to comparing Wisconsin's "Non-Public Water Supply: Human Threshold" criteria to EPA's HHO criteria, it is also instructive to compare those "Non-Public Water Supply: Human Threshold:" criteria that are applicable to limited aquatic life communities and warm water sport fish communities to those that are applicable to cold water communities. Such a comparison indicates that criterion-concentrations in the state's "Human Threshold: Non-Public Water Supply" criteria for cold water communities are usually lower than those in such criteria for warm water sport fish communities. The criterion-concentration is the same for both cold and warm water fisheries for the pollutants antimony, cadmium, trivalent chromium, hexavalent chromium, cyanide, lead, mercury, nickel, selenium and silver. Furthermore, with the exception

[43] The other nine pollutants are those for which EPA has not issued corresponding HHO criteria.
[44] Id. at 44.
[45] Id. at 45.
[46] Id.

of silver, it is always the case that criterion-concentrations in the state's "Human Threshold: Non-Public Water Supply" criteria for waters naturally capable of supporting "limited aquatic life communities" are substantially higher (frequently ten to 100 times) than those in either of the criteria that are applicable to coldwater or warm water communities.

ii) Human Cancer Criteria[47]

Cold Water Communities

Of the 40 toxic pollutants for which Wisconsin has adopted "Human Cancer: Non-Public Water Supply" criteria applicable to warm water sport fish communities, there are 39 pollutants with EPA HHO criteria.[48] Within this subset, 25 pollutants have "Human Cancer: Non-Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 6), and seven (8) pollutants have "Human Cancer: Non-Public Water Supply" WQC for which the criterion-concentrations are higher than those in the corresponding EPA HHO WQC (Appendix B, Table 7).

Warm Water Communities[49]

Of the 40 toxic pollutants for which Wisconsin has adopted "Human Cancer: Non-Public Water Supply" criteria applicable to warm water sport fish communities, there are 35 pollutants for which there are EPA HHO criteria.[50] Within this subset, twelve pollutants have "Human Cancer: Non-Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 6), and 12 pollutants have "Human Cancer: Non-Public Water Supply" WQC for which the criterion-concentrations are higher than those in the corresponding EPA HHO WQC (Appendix B, Table 7).

Limited Aquatic Life

Of the 40 toxic pollutants for which Wisconsin has adopted "Human Cancer: Non-Public Water Supply" criteria applicable to "limited aquatic life" waters, there are 35 pollutants for which there are EPA HHO criteria.[51] Within this subset, five (5) pollutants have "Human Cancer: Non-Public Water Supply" WQC for which the

[47] Wisconsin's "Human Cancer" criteria for carcinogenic pollutants are based on an incremental cancer risk level of 10^{-5}. (EPA accepts WQC that are based on assumptions of cancer risk falling in the range of 10^{-5} to 10^{-7}.) Strict numerical comparison of the concentrations appearing in the state's WQC tables with those in EPA's summary table for Section 304(a) HHWO criteria (http://www.epa.gov/waterscience/criteria/nrwqc-2006.pdf) would show that the criterion-concentrations for the Wisconsin criteria covering these carcinogenic pollutants are greater than the EPA's values by exactly ten fold. However, this is only because there is ten-fold difference between the cancer risk level that the state uses and that which EPA typically publishes in its summary tables of WQC. (EPA publishes criterion-concentrations corresponding to a 10^{-6} cancer risk—the middle of the 10^{-5} to 10^{-7} range that the Agency accepts). It is more instructive, therefore, to compare Wisconsin's numeric human health WQC to the EPA values that are based on a 10^{-5} cancer risk level, as was done in this report.

[48] The other three pollutants are those for which EPA has not issued corresponding HHO criteria.

[49] The state's "warm water communities" criteria further address three subcategories: a) Warm Water Sport Fish, b) Warm Water Forage, and c) Limited Forage. The criterion-concentration for a given toxic pollutant is always the same for these three subcategories.

[50] Id. at 50.

[51] Id. at 50.

criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 6), and 30 pollutants have "Human Cancer: Non-Public Water Supply" WQC for which the criterion-concentrations are higher than those in the EPA HHO WQC (Appendix B, Table 7).

In addition to comparing Wisconsin's "Non-Public Water Supply: Human Cancer"criteria to EPA's HHO criteria, it is also instructive to compare those "Non-Public Water Supply: Human Cancer" criteria applicable to cold water communities, warm water communities, and limited aquatic life waters. Such a comparison indicates that criterion-concentrations in the state's "Human Cancer: Non-Public Water Supply" criteria for cold water communities are usually lower than those in such criteria for warm water communities. The criterion-concentrations applicable to cold and warm water communities are the same for arsenic, beryllium, N-Nitrosodimethylamine and N-Nitrosopyrrolidine. Furthermore, it is generally the case that criterion-concentrations in the state's "Human Cancer: Non-Public Water Supply" criteria for waters capable of supporting only limited aquatic life communities are substantially higher (in many cases, one or two orders of magnitude higher) than those in the criteria that are applicable to cold water and warm water communities.

f) Human Health: i) Drinking Water Supply, ii) Consumption of Fish/Other Aquatic Organisms, and iii) Water-Contact Recreation/ "Human Threshold Criteria: Public Water Supply" and "Human Cancer Criteria: Public Water Supply"

As noted previously, those human health criteria that Wisconsin lists under the heading "Public Water Supply" in Tables 8 and 9 of its WQS regulations are actually aimed at protecting humans from uptake of toxic chemicals via three routes: 1) consumption of toxics-tainted sport-caught fish; 2) intake of drinking water containing toxics; and 3) intake of toxics as result of water contact recreation. As such, these WQC are closely parallel to EPA's "Human Health: Water and Organisms (HHWO)" criteria, which also address intake of toxic chemicals by way of consuming fish and water taken from a given waterbody.

According to the formulas that Wisconsin uses to calculate these criteria, the amount of water that might accidentally be ingested during swimming and other water-contact recreation is very small, so the amount of a toxic chemical that might be taken into the body via this route would be very small, compared to the amount that would be consumed by eating toxics-contaminated fish. Hence, the effect of the recreational exposure route on the criterion-concentration would be minimal. Consequently, though EPA's HHWO criteria do not account for accidental intake of toxics due to water-contact recreation, comparing the criterion-concentration in EPA's HHWO criterion for a given toxics to the criterion-concentration in Wisconsin's "Public Water Supply" criteria appears reasonable.

Another way in which Wisconsin's human health "Public Water Supply" criteria for toxics (both "threshold" and "cancer") differ from EPA's corresponding HHWO criteria is that the state has developed two subsets of criteria. Which of the two sub-types of human health criteria applies to a given type of waterbody depends on what types of fish would naturally inhabit said waterbodies: "cold water communities," or "warm water sport fish communities." No "Public Water Supply" WQC was developed for waterbodies with naturally occurring

"limited aquatic life" because of the presumption that the low volume of such waters would not only limit the type of aquatic species present but also make them inadequate as a source of raw water supply.

The criterion-concentration components of Wisconsin WQC for each of these three subgroups of "non-public water supply" waters are compared to the criterion-concentrations for the same pollutant in EPA's Human Health: Water and Organisms (HHWO) criteria, below. First, the "Human Threshold" criteria are compared, and then the "Human Cancer" criteria.

i) Human Threshold Criteria:

Cold Water Communities

Of the 46 toxic pollutants for which Wisconsin has adopted "Human Threshold: Public Water Supply" criteria applicable to cold water communities, there are 36 pollutants for which there are EPA HHWO criteria.[52] Within this subset, 20 pollutants have "Human Threshold: Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 8), and fifteen pollutants have "Human Threshold: Public Water Supply" WQC for which the criterion-concentrations are higher than those in the US HHWO EPA WQC (Appendix B, Table 9).

Warm Water Sport Fish Communities

Of the 46 toxic pollutants for which Wisconsin has adopted "Human Threshold: Public Water Supply" criteria applicable to warm water sport fish communities, there are 36 pollutants for which there are corresponding EPA's HHWO criteria.[53] Within this subset, 20 pollutants have "Human Threshold: Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 8), and fourteen pollutants have "Human Threshold: Public Water Supply" WQC for which the criterion-concentrations are higher than those in the corresponding EPA WQC (Appendix B, Table 9). There are two pollutants for which the criterion-concentration of the state and EPA WQC are identical.

In addition to comparing Wisconsin's "Human Threshold: Public Water Supply" criteria to EPA's HHWO criteria, it is also instructive to compare those "Human Threshold: Public Water Supply" criteria that are applicable to warm water sport fish communities to those that are applicable to cold water communities. Such a comparison indicates that, for 29 of the 46 pollutants for which Wisconsin has established "Human Threshold Criteria: Public Water Supply" WQC, the criterion-concentrations for cold water communities are equal to, or only slightly lower than, those in such state criteria for warm water sport fish communities. For the remaining fifteen pollutants, the WQC for cold waters are lower than those for cold waters by two or three fold—none are lower by more than one order of magnitude.

[52] The other 10 pollutants are those for which EPA has not issued corresponding HHWO criteria.
[53] The other nine (9) pollutants are those for which EPA has not issued corresponding HHWO criteria.

ii) Human Cancer Criteria:

Cold Water Communities

Of the 40 toxic pollutants for which Wisconsin has adopted "Human Cancer Criteria: Public Water Supply" WQC applicable to cold water sport fish communities, there are 35 pollutants for which there are EPA HHWO criteria.[54] Within this subset, two (2) pollutants have a "Human Cancer: Public Water Supply" criterion for which the criterion-concentration is equal to that in the corresponding EPA criterion, 26 pollutants have "Human Cancer: Public Water Supply" WQC for which the criterion-concentrations are lower than those in the corresponding EPA WQC (Appendix B, Table 8), seven pollutants have "Human Cancer: Public Water Supply" WQC for which the criterion-concentrations are higher than those in the EPA HHWO WQC (Appendix B, Table 9).

Warm Water Sport Fish Communities

Of the 40 toxic pollutants for which Wisconsin has adopted "Human Cancer: Public Water Supply" criteria applicable to warm water sport fish communities, there are 35 pollutants for which there are EPA HHWO criteria.[55] Within this subset, four (4) pollutants have "Human Cancer: Public Water Supply" WQC for which the criterion-concentrations are equal to those in the corresponding EPA WQC, 19 pollutants have "Human Cancer: Public Water Supply" WQC for which the criterion-concentrations are lower than those of the EPA HHWO WQC (Appendix B, Table 8), twelve pollutants have "Human Cancer: Public Water Supply" WQC for which the criterion-concentrations are higher than those in the corresponding EPA WQC (Appendix B, Table 9).

In addition to comparing Wisconsin's Human Cancer: Public Water Supply criteria to EPA's HHWO criteria, it is also instructive to compare those Human Cancer: Public Water Supply criteria that are applicable to warm water sport fish communities to those that are applicable to cold water communities. For nineteen of the 40 pollutants for which Wisconsin has established Human Cancer: Public Water Supply WQC, the criterion-concentrations for cold water communities are equal to, or only slightly lower than, those in such state criteria for warm water sport fish communities. For the remaining 21 pollutants, the WQC for cold waters are lower than those for cold waters by two or three fold—none are lower by more than one order of magnitude.

g) Human Health: Drinking Water Supply

Not Applicable. Though it has a set of criteria that are labeled "Human Threshold Criteria: Public Water Supply" in Table 8 of Section NR 105.08(4) and a set of criteria labeled "Human Cancer Criteria: Public Water Supply" in Table 9 of Section NR.105.09(3) of the

[54] The other three (3) pollutants are beryllium, BHC-technical grade, and halomethanes – for all of which EPA has not issued corresponding HHWO criteria.

[55] The other three pollutants are beryllium, BHC-technical grade, and halomethanes – for all of which EPA has not issued corresponding HHWO criteria.

Wisconsin WQS regulations, Wisconsin actually has no criteria dealing *exclusively* with exposure to toxics resulting from the source of one's drinking water supply.

h) Industrial Water Supply

Not Applicable. Wisconsin has not adopted criteria applicable to toxic chemicals for industrial water supply uses.

i) Agricultural Water Supply

Not Applicable. Wisconsin has not adopted criteria applicable to toxic chemicals for agricultural water supply uses.

j) Water-based Recreation

Not Applicable. Wisconsin has not adopted criteria applicable to toxic chemicals pertaining human health risks associated solely with various types of water-based recreation. However, as discussed earlier, it has established human health WQC addressing this use in combination with: i) fish consumption, and ii) fish consumption plus drinking water supply.

3) *Articulation of Criterion-Duration*s

A greater portion of Wisconsin's criteria for toxic chemicals have fairly clearly specified criterion-duration, compared to those for "traditional" pollutants/parameters. However, there are still some areas of ambiguity.

a) Aquatic Life / "Fish and Other Aquatic Life"

Section NR105.03(2) of the Wisconsin WQS regulations states, "Acute toxicity criterion or ATC means the maximum daily concentration." Most likely, this is intended to mean the average over 24 hours, though this could be more clearly expressed as "daily average concentration." The current language could, alternatively, be taken to mean the highest instantaneous concentration to occur on any day, though a more transparent way of stating this would be "not to be surpassed at any time during any day." Yet, if this were the intended meaning, then it would seem simpler to say "not to be surpassed at any time."

Likewise, Section NR 105.03(16) of the Wisconsin WQS regulations defines "chronic toxicity criterion" in terms of "maximum four day concentration."

There is also some ambiguity as to whether "daily" is supposed to mean "one calendar day" or "any consecutive 24 hour period." A calendar day would be presumed to be the period between 12:00 AM (midnight) and 11:59 PM. The latter interpretation might also be characterized as "rolling 24 hour average." For the same reason, the exact meaning of the duration applicable to the state's chronic aquatic life criteria (four day) is also not entirely clear.

b) Semi-aquatic Wildlife/ "Wildlife Criteria"

Wisconsin's four criteria for protecting semi-aquatic wildlife (e.g., bald eagle, herring gull, kingfisher, mink, and otter) are expressed in Section NR.105.07 of the state's WQS regulations as "concentration of a substance which if not exceeded protects." This language strongly implies a criterion-duration of an instant, though it does not clearly state such.

c) Human Health: Consumption of Fish and Other Aquatic Organisms

Not Applicable. Wisconsin has no WQC for toxic chemicals that apply solely to exposure of humans to toxic chemicals via consumption of aquatic organisms taken from a given waterbody.

d) Human Health: Drinking Water Supply

Not Applicable. Though it has a set of criteria that are labeled "Human Threshold Criteria: Public Water Supply" in Table 8 of Section NR 105.08(4) and a set of criteria labeled "Human Cancer Criteria: Public Water Supply" in Table 9 of Section NR.105.09(3) of the Wisconsin WQS regulations, Wisconsin actually has no criteria dealing *exclusively* with exposure to toxics resulting from the source of one's drinking water supply.

e) Human Health: Consumption of: a) Drinking Water plus b)Fish and Other Aquatic Organisms

Not Applicable. Wisconsin has not adopted WQC for toxic chemicals aimed at protection of humans using a waterbody for just drinking water supply (DWS) and consumption of fish, shellfish, and other aquatic organisms (FC).

f) Human Health: Consumption of Fish and Other Aquatic Organisms and Water-Contact Recreation/ "Human Criteria: Non-Public Water Supply"

The duration applicable to the human health-related criteria in Table 8 of the Wisconsin WQS regulations is indicated in Section NR.105.08(1) of the same regulations: "The human threshold criterion (HTC) is the maximum concentration of a substance established to protect humans…." The duration applicable to the criterion-concentrations presented in Table 9 is indicated by Section NR. 105.09(1) of the Wisconsin WQS regulations: "The human cancer criterion (HCC) is the maximum concentration of a substance established to protect humans.…"

Because both of these refer simply to "maximum concentration" (rather than some sort of average concentration) they are taken, for purposes of this study, to specify a criterion-duration of an instant, though this is not explicitly stated in the state's regulation. (Clearer ways to indicate a duration of an instant include language along the lines of "instantaneous concentration no higher than ___" or "concentration never to go above ___, at any time.")

g) Human Health: Consumption of Water plus Fish and Other Aquatic Organisms *and* Water-Contact / "Human Criteria: Public Water Supply"

The duration applicable to the human health-related criteria in Table 8 of the Wisconsin WQS regulations is indicated in Section NR.105.08(1) of the same regulations: "The human threshold criterion (HTC) is the maximum concentration of a substance established to protect humans." The duration applicable to the criterion-concentrations presented in Table 9 is indicated by Section NR.105.09(1) of the Wisconsin WQS regulations: "The human cancer criterion (HCC) is the maximum concentration of a substance established to protect humans…."

Because both of these refer simply to "maximum concentration" (rather than some sort of average concentration) they are taken, for purposes of this study, to specify a criterion-duration of an instant, though this is not explicitly stated in the state's regulation. Clearer ways to indicate a duration of an instant include language along the lines of "instantaneous concentration no higher than ___" or "concentration never to go above ___, at any time."

h) Industrial Water Supply

Not Applicable. Wisconsin has not adopted criteria applicable toxic chemicals for industrial water supply uses.

i) Agricultural Water Supply

Not Applicable. Wisconsin has not adopted criteria applicable toxic chemicals for agricultural water supply uses.

j) Water-based Recreation

Not Applicable. Wisconsin has not adopted criteria applicable to toxic chemicals pertaining human health risks associated solely with various types of water-based recreation. However, as discussed earlier, it has established human health WQC addressing this use in combination with: i) fish consumption, and ii) fish consumption plus drinking water supply.

4) *Articulation of Criterion-Frequencies*

The criterion-frequencies applicable to Wisconsin's aquatic life criteria for toxic chemicals are clearly stated as once in three years. The definition of "acute toxicity criterion" in Section NR 105.03(2) of the Wisconsin WQS regulations includes, "maximum daily concentration of a substance which … will adequately protect the designated … aquatic life use ... if not exceeded more than once every three years." The definition of "chronic toxicity criterion" provided in Section NR 105.03(16) of the Wisconsin WQS regulations states, in part, "maximum 4-day concentration of a substance which … will adequately protect the designated … aquatic life use … if not exceeded more than once every three years." Also, Section NR 105.04(2) of the Wisconsin WQS regulations states, "A substance will be deemed to have adverse effects on fish or other aquatic life if it exceeds any of the following more than once

every three years: (a) The acute criterion[56] as specified in Section NR 105.05, or (b) the chronic criterion as specified in Section NR 105.05 of the Wisconsin WQS regulations."

Since the state's WQS regulations refer to the criterion-concentrations for toxic substances related to the human health-related uses of drinking water supply and/or consumption of aquatic life as "maximum concentrations" (see discussion of duration for toxics criteria pertaining "Public Water Supply" and "Non-Public Water Supply," above), the intended criterion-frequency would appear to be zero. This conclusion is reinforced by the following language from Section NR 105.04(4) of the Wisconsin WQS regulations**,** "A substance shall be deemed to have adverse effects on public health and welfare if it exceeds any of the following … human threshold criterion … human cancer criterion, or … taste and odor criterion."

Wisconsin's four wildlife WQC for toxic pollutants are also taken to have a criterion-frequency of zero because of regulatory language almost identical to that just quoted for human health criteria.

5) ***Discussion: Criteria for Toxic Chemicals***

Wisconsin's WQS regulations contain criteria for a substantial number of toxic pollutants, particularly those that are human health-related. However, there are significant gaps in the regulations' coverage of the pollutants for which EPA has published aquatic life criteria. The criterion-duration and criterion-frequency of aquatic life criteria for toxics are clearly stated,

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[56]Regulatory language referring to "adverse effects on … [a given use] **…** if it exceeds … the following more than once every three years: (a) the acute criterion … or (b) the chronic criterion" represents a common source of confusion regarding water quality standards. As noted in this report, EPA guidance, as well as common sense, indicate that a water quality criterion (or any description of waterbody conditions at a given location over time) consists of three parts: 1) a concentration (or magnitude), 2) a duration (often expressed as an averaging period), and 3) a frequency.

Failure to meet a WQC expressed in this fashion would, by definition, occur when actual waterbody conditions are "worse than" those specified by the combination of the criterion-concentration, criterion-duration, and criterion-frequency. The term most often used in EPA publications to describe failure to meet a water quality criterion is "exceedence." It follows that, if a particular WQC has a concentration of 25 µg/L, a duration of 30 days, and a frequency of once in five years, that an "exceedence" would have occurred if, during any 5-year period, there was more than one stretch of 30 consecutive days in which the average concentration of the pollutant of concern were greater than 25 µg/L. But, there would *not* have been an "exceedence" according to these EPA terms, if during a given five-year period, the concentration had spiked above 25 µg/L for just a second on two or more occasions, but had never averaged 25 µg/L over any period of 30 days or more.

This hypothetical example illustrates the need for terms describing two distinct situations, neither of which is an "exceedence" according to the just-mentioned EPA terminology: 1) times when the ambient concentration goes above the criterion-concentration for just an instant; and 2) times when the ambient concentration over a period equals to the criterion-duration averages more than the criterion-concentration. The term that EPA has used in recent guidance to describe situation #1 is "digression." For situation #2, the term most frequently employed by EPA is "excursion."

The problem with language referring to an "exceedence of a criterion" is that it is often taken to mean "ambient concentration higher than the criterion-concentration for just a second." Quite often, any grab sample with a concentration above the criterion-concentration is incorrectly referred to as "an exceedence." This interpretation of language like that from the Wisconsin WQS regulations cited above is fostered by the practice of both EPA and states to present tables of "water quality criteria" that are actually just listings of criterion-concentrations. Tables 8 and 9 in the WQS regulations are examples of such—no mention of criterion-durations or criterion-frequencies are made in either the table itself or in any footnotes to said table.

while there is no explicit mention of either a criterion-duration or criterion-frequency in the state's criteria for human health.

Criteria Related to Aquatic Life Protection

Wisconsin has not adopted acute and/or chronic aquatic life criteria for more than half of the pollutants for which EPA has issued corresponding criteria. Among the pollutants without acute and/or chronic aquatic life criteria are several pollutants that fall into categories of chemical substances that have been frequently mentioned as potential endocrine disruptors (aldrin, DDT, alpha-Endosulfan, beta-Endosulfan, chlordane, methoxychlor, heptachlor, toxaphene, and tributyltin).

Where the state has established criteria comparable to EPA's chronic aquatic life criteria, the criterion-concentrations for the majority of the pollutants with such criteria are either higher or slightly lower than the criterion-concentrations in the corresponding EPA criteria. There are more pollutants with chronic criterion-concentrations that are higher than those in the corresponding EPA aquatic life criteria that there are those with chronic criterion-concentrations that are lower than EPA's. Given that the criterion-duration (four days/96 hours) and criterion-frequency (once in three years) applicable to Wisconsin's chronic aquatic life WQC are the same as the duration and frequency applicable to the corresponding EPA criteria, comparison of the state's and EPA's respective chronic criterion-concentrations can reliably indicate the relative level of protection that their chronic WQC afford to aquatic organisms. Indeed, it is reasonable to conclude that the ten state chronic aquatic life criteria having higher criterion-concentrations than EPA's are less protective than EPA's, while those eight with lower criterion-concentrations than EPA's are more protective than EPA's.

Where the state has established criteria corresponding to EPA's acute aquatic life WQC, the criterion-concentrations for the majority of the pollutants with such state criteria are the same as the criterion-concentrations in the corresponding EPA criteria. The number of pollutants with acute aquatic life criterion-concentrations that are higher than those in the corresponding EPA criteria is greater than the number of those pollutants with criterion-concentrations that are lower.

With regard to Wisconsin's acute aquatic life WQC for toxics, in some cases it is possible to reach a conclusion about the relative protectiveness of the state's and EPA's criteria, but in others it is not. The difficulty is due to the fact that, though the criterion-frequency applicable to both the state's and EPA's acute aquatic life WQC are the same (once in three years, maximum), the criterion-duration applicable to Wisconsin's acute aquatic life WQC for toxics (one day) is considerably longer than that which applies to EPA's acute aquatic life WQC (one hour).

This difference in the criterion-duration for Wisconsin's acute criteria and EPA's acute criteria means that, with regard to those four pollutants where the state and EPA criterion-concentrations are equal (along with the criterion-frequency), less protection would be provided to aquatic life by attainment of the state's criterion than by meeting EPA's. The reason is that organisms living in a waterbody with ambient levels of a toxic pollutant identical to those proscribed by the state's WQC would have been exposed to an average concentration of the pollutant equal to the (identical) criterion-concentration of both WQC for a period (24 hours) that

is substantially longer than organisms in a waterbody with ambient conditions exactly identical to those set forth in EPA's criteria (one hour). Likewise, the ten state acute aquatic life criterion with a criterion-concentration higher than EPA's would be less protective than would a corresponding EPA criterion because a waterbody could be meeting the state's criterion while having an average concentration higher than the EPA criterion-concentration over a length of time longer than the period (an order of magnitude longer, in fact) specified by EPA's criterion-duration. Determining whether one of the state's five Wisconsin acute criteria with a criterion-concentration lower than the criterion-concentration in the EPA acute criterion for the same pollutant would be more or less protective than EPA's would require obtaining more data about the toxicity of the pollutant in question than is typically available. Data showing the toxic effects on several different aquatic species of the lower level of the pollutant specified in Wisconsin's criterion-concentration over a 24 hour period would need to be compared to data on the effect of exposure to EPA's higher criterion-concentration over just one hour, in order to determine whether or not the more protective effect of the lower state criterion-concentration would be offset by the less protective effect of the longer state criterion-duration.

Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (for example, if the duration is 96 hours, the frequency is once in three years) and the state's criterion-concentration where higher than EPA's, then the state's criterion would indeed provide less protection to aquatic organisms in the waterbody or set of waterbodies than would EPA's, in relative terms. However, due to site-specific or watershed-specific conditions (e.g., water chemistry, indigenous species), the state's WQC could provide the same absolute level of protection as that for which the EPA WQC were designed, while use of the recommended EPA WQC in such waters would actually provide greater protection than that which EPA intended.

Criteria Related to Human Health Protection

Wisconsin's WQS regulations specify human-health related criteria for a large number of toxic pollutants. Indeed, the state has established either a "Human Threshold" and/or "Human Cancer" criteria applicable to "Public Water Supply" for 73 pollutants – twelve of which are pollutants for which EPA has not established corresponding criteria. However, there is also a number of pollutants for which the state has not adopted these types of human health-related criteria. The state has not adopted Human Cancer: Public Water Supply or Human Threshold: PublicWater Supply for 46% of the total number of pollutants for which EPA has published corresponding Human Health: Water and Organisms (HHWO)" criteria.[57]

Also, Wisconsin not has adopted Human Cancer: Non-public Water Supply: Human Cancer and/or Human Threshold: Non-public Water Supply criteria for 41% of the total number of pollutants for which EPA has published corresponding "Human Health: Organisms Only (HHO)" criteria.[58] The majority of the pollutants lacking state criteria corresponding to EPA's HHO and/or HHWO criteria are synthetic organic chemicals, including many known or

[57] See Subsection D(1)(g) and D(2)(g) of this report for the rationale behind this report's comparison of the state's human health "Public Water Supply" criteria to the HHWO criteria issued by EPA.
[58] See Subsection D(1)(f) and D(2)(f) of this report for the rationale behind this report's comparison of the state's human health "Non-Public Water Supply" criteria to the HHO criteria issued by EPA.

suspected carcinogens and/or bioaccumulators. Among the pollutants lacking state criteria are benzo-a-pyrene and several other polycyclic aromatic hydrocarbons (PAHs), which are not only carcinogenic and bioaccumulative, but are also commonly found in urban stormwater and have been mentioned as potential endocrine disruptors. Also on the list of suspected endocrine disruptors are aldrin, endrin, heptachlor, and pentachlorophenol – all pollutants for which Wisconsin has not adopted criteria. The state also lacks such criteria for three phthalate esters, which fall into categories of chemical substances that are frequently mentioned as potential endocrine disruptors.

In theory, the absence of a human health criterion for a pollutant might not be essential to ensuring that people are protected from exposure (via ingestion of drinking water and/or eating aquatic organisms) to levels of that pollutant that pose a significant risk. In particular, if Wisconsin has an acute and/or a chronic aquatic life criterion for the pollutant with a criterion-concentration lower than that in EPA's human health criteria for the pollutant of concern, attainment of the aquatic life criterion would ensure that waterbody levels of the pollutant would remain below those specified in EPA's human health criteria. This statement is based upon the assumption that EPA's human health criteria have a criterion-duration equal to or longer than the 96 hour duration of the state's chronic aquatic life WQC. This is a reasonable assumption, given that the EPA methodology for developing human health WQC for toxics specifies an assumed duration of exposure of an average human lifetime—70 years, which strongly suggests a criterion-duration of as long as seven decades. On the other hand, there is language in various parts of EPA guidance documents that can be read in such a way as to imply a criterion-duration of just an instant for the Agency's human health WQC for toxics. If the criterion-duration were just a second—a much shorter period than 96 hours—then it would not follow that any state WQC having a criterion-concentration lower than EPA's would provide greater protection than application of the federal agency's WQC.

In Wisconsin's case, the metals copper and zinc are the only pollutants for which the state lacks human health criteria but has aquatic life criteria. For copper, the criterion-concentrations applicable the state's acute aquatic life WQC (16.92 µg/L) and chronic aquatic life WQC (11.91µg/L) are lower than the lowest EPA human health criterion-concentration (1,300µg/L for the HHWO WQC). For zinc, the criterion-concentrations for the state's acute and chronic aquatic life WQC (both 120.4µg/L) are lower than the lowest EPA human health criterion-concentration (7,400µg/L for the HHWO WQC). Hence, it appears that attainment of Wisconsin's aquatic life WQC for these two metals would indeed provide a considerably greater level of protection to humans than the level for which EPA's corresponding WQC were designed.

Where criteria have been adopted, the criterion-concentrations in Wisconsin's Public Water Supply human health criteria for carcinogenic toxic substances ("Human Cancer Criteria") in cold water fish communities are mostly lower than the criterion-concentrations in the corresponding EPA "Human Health: Water & Organisms" (HHWO) criteria.[59] This general pattern also applies to the criterion-concentrations in Wisconsin's Public Water Supply criteria for toxic non-carcinogens ("Human Threshold Criteria") – the state's WQC applicable to cold water fisheries tend to have criterion-concentrations lower than those in EPA's HHWO WQC. With regard to such WQC applicable to waters with warm water aquatic life, the proportion of

[59] Id. at 43

pollutants with criterion-concentrations higher than that of corresponding U S EPA is greater than the number with concentrations lower than EPA's.

The criterion-concentrations in a majority of Wisconsin's "Non-public Water Supply" criteria for toxic carcinogens ("Human Cancer Criteria") for waterbodies with cold or warm water fish communities are lower than the criterion-concentrations in the EPA "Human Health: Organisms" (HHO) criteria, for the same pollutant. In contrast, the criterion-concentrations in most of the state's Human Cancer Criteria: Non-public Water Supply WQC for waters with "limited aquatic life communities" are significantly higher than the criterion-concentrations in the corresponding HHO criteria issued by EPA. This general pattern also applies to the criterion-concentrations in Wisconsin's "Non-Public Water Supply" human health criteria for toxic non-carcinogens ("Human Threshold Criteria"). There are more non-carcinogens for which the warm water "Non-public Water Supply" criterion-concentrations are higher than those in EPA's corresponding HHO criteria than there are non-carcinogens with "Non-public Water Supply" WQC applicable to cold water fish habitat having criterion-concentrations higher. And, as with the state's "Human Cancer Criteria: Non-public Water Supply WQC, most of the criterion-concentrations for Wisconsin's "Human Threshold Criteria: Non-public Water Supply WQC applicable to "limited aquatic life" waters are higher than those in EPA's HHO criterion for the same pollutant.

In addition to comparing criterion-concentrations of various types of state human health WQC to those of corresponding EPA WQC, it is interesting to look at criterion-concentrations across certain subcategories of Wisconsin's criteria pertaining to human health. With regard to the state's "Non-public Water Supply" criteria (address combination of fish consumption and recreational exposure) for both carcinogens and non-carcinogens ("Threshold Criteria), WQC applicable to waters with Cold Water Communities had lower criterion-concentrations than did WQC applicable to "Warm Water Forage, Limited Forage and Warm Water Sport Fish Communities." And for every pollutant, the "Non-public Water Supply" criteria applicable to "Limited Aquatic Life" had a criterion-concentration higher than that of such WQC applicable to either of the other two categories of aquatic life communities. In some cases, there was a difference of several orders of magnitude between the criterion-concentration for the Limited Aquatic Life WQC and those for the other two categories.

As for the state's "Public Water Supply" criteria (address combination of drinking water supply, fish consumption, and recreational uses) for both carcinogens and non-carcinogens ("Threshold Criteria"), the pattern was a little different than that with the corresponding "Non-public Water Supply criteria. The first difference is that there are no Wisconsin "Public Water Supply" WQC for Limited Aquatic Life waters. Presumably because flow in such waters is usually intermittent or ephemeral, a pattern not lending these waters as useful as public water supplies. The second difference is that, compared to the WQC for "Non-public Water Supply," criteria for "Public Water Supply" tended to have closer criterion-concentrations between those applicable to Cold Water Sport Fish Communities and those applicable to "Warm Water Sport Fish Communities." In the Case of the Human Threshold Criteria: Public Water Supply, a slight majority of the pollutants for which there were such criteria had identical, or almost identical, criterion-concentrations for the cold water and the warm water subcategories. Just slightly less than half the Human Cancer Criteria: Public Water Supply had, for a given pollutant, the same, or nearly the same, criterion-concentration.

Turning from criterion-concentrations to the other two elements of numeric WQC—criterion-duration and criterion-frequency, all of Wisconsin's human health WQC for toxics lack explicit reference to either of these two key elements. Sections NR 105.08(1) and NR 105.09(1) of the state's WQS regulations say, "The ... criterion is the maximum concentration of a substance established to protect humans." (Apparently, here the word "criterion" is actually a reference to just one component of a fully-articulated numeric WQC—the criterion-concentration.) No mention is made of a criterion-duration or an averaging period. Nor is there mention of a criterion-frequency or recurrence interval. The most straightforward interpretation of this regulatory text is that the concentrations of pollutants presented in Tables 8 and 9 of Wisconsin's WQS regulations are not to be surpassed, even for an instant, at any time. That is, the criterion-duration is an instant, and the criterion-frequency is zero.

Because of the uncertainty regarding the duration and frequency elements of Wisconsin's human health criteria, any attempt to determine the relative degree of protection provided by corresponding state and EPA human health criteria would also carry high degree of uncertainty. The tenuous nature of such analysis is further aggravated by the fact that EPA's human health criteria suffer from the same ambiguities. The EPA literature regarding the criterion-duration for its human health criteria for toxics is inconsistent, sometimes giving the impression that the duration for these categories of criteria is an instant, while at other times indicating a duration as long as 70 years. And, like the state, EPA makes no reference to a criterion-frequency for their human health criteria for toxics, suggesting not even one excursion would be consistent with fully supporting the use of concern.

If one assumed, for purposes of discussion, that the criterion-durations and criterion-frequency applicable to Wisconsin's human health criteria for toxics are identical to those applicable to EPA's HHWO and HHO criteria—whatever those might happen to be, then Wisconsin human health criteria for toxic chemicals having higher criterion-concentrations would less protective than EPA's, while those with lower criterion-concentrations are more protective. Hence, where a EPA human health criterion had a criterion-concentration higher than the criterion-concentration in the corresponding state WQC, then attainment of the EPA criterion in a given waterbody would result in a lower level of protection than would meeting the Wisconsin WQC.

Different assumptions about the criterion-duration and/or criterion-frequency applicable to corresponding Wisconsin and EPA human health WQC would, of course, have an effect on which WQC provided the greater level of protection. For example, if the criterion-duration for Wisconsin's WQC were, for example, 365 days, while EPA's WQC had a duration of just an instant, then any state WQC having a criterion-concentration equal to that of the corresponding EPA criterion would provide a lower level of protection than would the parallel EPA criterion, assuming that the criterion-frequencies were identical, for example, zero. On the other hand, if the state WQC criterion-duration were taken to be an hour, while EPA's was taken to be 10 years, then the Wisconsin WQC would provide a higher level of protection, assuming the criterion-concentration and the criterion-frequency for the two WQC were the same.

In addition to frustrating attempts to determine the relative levels of protection provided by a state criterion compared to an equivalent EPA criterion, lack of clearly-stated criterion-

durations and criterion-frequencies can lead to inconsistency in the application of Clean Water Act programs that are "driven by" water quality criteria. For instance, if one assumes that the criterion-duration for the human health criterion is an instant and the frequency is zero, then any waterbody from which just one valid (meets QA/QC requirements/guidelines) grab sample, out of several such samples, with a concentration of a pollutant higher than the criterion-concentration should be included in the state's Section 303(d) list. On the other hand, if the criterion-duration applicable to the state's human health criteria were 365 days, then exceedence of WQC would not be indicated by having just one sample out of several collected over any 365 day period with a concentration above the criterion-concentration. In this latter case, the appropriate determinant of criterion exceedence would be having a set of samples collected over some 365-day periods with an average concentration higher than the criterion-concentration.

Other possible ways in which different outcomes could result from different assumptions about the criterion-duration for the state's human health criteria could be manifested in the TMDL and NPDES programs. For instance, it would seem that meeting TMDL wasteload allocation or an NPDES permit limit of "no higher than 10 µg/L for an instant, at any time" would be considerably more difficult, and presumably more expensive, than keeping the 365-day average concentration at or below 10 µg/L.

Returning to the issue of the level of protection provided by Wisconsin's WQC, as already discussed regarding aquatic life WQC, waterbody-specific conditions can have an effect of the level of protection provided by a given human health WQC. That is, the risk to humans resulting from attainment of a specific WQC (with a given criterion-concentration, criterion-duration, and criterion-frequency) differ from one waterbody to another. Site specific factors that could change the level of protection provided by a certain WQC include: 1) differences in rates and patterns of different human activities, such as fish consumption, intake of drinking water, and water-contact recreation, 2) differences in the makeup of fish and other edible aquatic organisms living in the waterbodies.

Wisconsin is the only one of the ten states covered by this study that incorporates, to some degree, aspects of both of these sets of factors into setting of human health water quality criteria. Differences in human rates of fish consumption is apparently taken into account when calculating Non-Public Water Supply criteria for Limited Aquatic Life waterbodies, as compared to calculating such WQC for waters harboring communities cold or warm water sport fish. Incorporation of the different rates of eating of fish is likely the reason that all of Wisconsin's Non-public Water Supply WQC for Limited Aquatic Life waters have a criterion-concentration higher than that of the Non-public Water Supply criteria for the same pollutant applicable to cold or warm waters. In several instances, the criterion-concentration for Limited Aquatic Life waters is several orders of magnitude higher than those applicable to cold or warm water systems. Take mercury, for instance—the Non-public Water Supply criterion for Limited Aquatic Life waters has a criterion-concentration of 336 µg/L, while the corresponding WQC for both cold and warm water ecosystems is 0.0015 µg/L. (This degree of difference in criterion-concentrations also occurs with other persistent bioaccumulative pollutants, such as lindane (gamma-BHC), toxaphene, and DDT.) The most likely explanation for this large difference is that, while it applies a rate of human consumption of fish and other aquatic foods of 20g/day for

cold water and warm water waterbodies, the state assumes a zero rate of such consumption associated with Limited Aquatic Life waterbodies.[60]

The effect of including or not including a particular exposure pathway in the calculation of one set of WQC versus another is manifest in another way in Wisconsin's human health WQC. For both Human Threshold Criteria (non-carcinogenic) and Human Cancer Criteria, the criterion-concentrations for Public Water Supply waters are lower than those for Non-public Water Supply designated waters, for most toxic pollutants, for comparable types of aquatic communities. For example, the Cold Water Communities Non-public Water Supply criterion for chloroethene (vinyl chloride) has a criterion-concentration of 6.8 µg/L, while the Cold Water Communities Public Water Supply criterion's concentration is 0.18 µg/L. Presumably, the lower criterion-concentration for the Public Water Supply WQC results from factoring in an assumed drinking water intake of 2 liters/day, along with any chloroethene that might contaminate that water. On the other hand, for Non-public Water Supply designated waterbodies, the only water intake that is accounted for is the 0.01 L/day "for exposure through body contact or ingestion of small volumes of water during swimming or other recreational activities."

There is a set of pollutants for which this relationship does not hold—highly bioaccumulative persistent toxics such as PCBs and dioxin. For such pollutants, there is little, if any difference in the criterion-concentration for Public Water Supply (PWS plus fish consumption plus recreation) and Non-public Water Supply (fish consumption plus recreation). The reason is that the levels of such toxic substances in the tissue of higher trophic level fish are typically several orders of magnitude higher than the levels in the surrounding water. Hence, the consumption of 20 g/day of the contaminated flesh of such fish results in intake of much, much higher amounts of such toxics than the intake resulting from drinking two liters/day of water containing a far lower level of the pollutant. In other words, the intake of a highly bioaccumulative pollutant through the fish consumption route totally overwhelms the vastly smaller intake due to drinking water from the same waterbody from where the fish were taken. Hence, the inclusion of drinking water on top of fish consumption has, at most, a tiny effect on the criterion-concentration.

Also, Wisconsin adjusts the bioaccumulation factor (BAF) it employs in establishing the criterion-concentration for a given pollutant and a given use scenario: (a) fish consumption and water contact recreation versus b) fish consumption and water contact recreation plus drinking water supply—depending on the type of fish found in broad categories of aquatic habitat--cold water versus warm water.[61] The state applies a "fraction lipid factor" of 0.044 to waters harboring cold water species and a factor of 0.013 to waters that provide suitable habitat for

[60] There actually is no mention of an assumed zero rate of human fish consumption from Limited Aquatic Life waters in its WQS regulations, the definition of Limited Aquatic Life provided in the regulations implies as much. NR 102.04(03)(e) reads: "*Limited aquatic life.* (Marginal surface waters.) This subcategory includes surface waters of severely limited capacity and naturally poor water quality or habitat. These surface waters are capable of supporting only a limited community of forage fish and other aquatic life."

[61] The state's Non-public Water Supply WQC for both carcinogens and threshold chemicals applicable to warm water communities actually covers three kinds of habitats: a) Warm Water Sport Fish, b) Warm Water Forage, and c) Limited Forage. The criterion-concentration for a given toxic pollutant is always the same for these three sub-subcategories. The state's Public Water Supply WQC applicable to warm water communities, however, applies only to "warm water sport fish communities."

warm water species. Given that persistent organic toxic substances (e.g., dioxins, hexachlorobenzene and PCBs) tend to bioaccumulate to a greater degree in the fish flesh with higher lipid contents, the bioaccumulation factors (BAFs) that Wisconsin uses in calculating human health WQC for waters harboring cold water fish are three-times higher than the BAFs the state uses when setting such WQC for waters that provide habitat to warm water fish. The difference in BAFs results from applying the just mentioned "fraction lipid factors in a BAF calculation formula set forth in NR 105.10(4)(b). As a consequence, a significant portion of the state's human health WQC for toxic substances (all sets of which address consumption of pollutants in tissue of fish) that apply to waters providing habitat to cold water species have criterion-concentrations lower than the criterion-concentrations of corresponding WQC applicable to warm water habitat waterbodies.

By contrast, the human health criterion-concentrations for mercury, a metal that is highly bioaccumulative, are identical for warm and cold waters. This reflects the fact that, unlike most organic compounds, the tendency of inorganic/metallic substances to bioaccumulate in fish tissue is not proportional to the lipid contend of said tissue.

The intended effect of this lipids-related adjustment is to have WQC that provide equal levels of protection to consumers of fish and other aquatic organisms taken from one type of aquatic habitat versus another (cold water communities, warm water communities). That is, the concentration of a given organic persistent bioaccumulative toxic chemical in the tissues of representative fish in a cold water habitat waterbody exactly meeting the state's human health criteria for the water column in such waters should be the same as the concentration of that toxic chemical in the tissues of representative fish taken from warm water habitat waterbodies for which the ambient levels of the chemical are exactly meeting the comparable human health WQC. The fish tissue concentrations would be the same even though the ambient concentration of the pollutant in the waterbody supporting warm water fish was higher than that in the water supporting cold water fish. For example, the Human Cancer Criterion: Warm Water Sport Fish Communities WQC for hexachlorobutadiene is 0.59 μg/l, while the corresponding Cold Water Communities WQC has a criterion-concentration of 0.19 μg/L.

Likewise, the adjustment in the manner that the Non-public Water Supply human health WQC for limited aquatic life waters as compared to that for cold and warm water fish habitats is designed at equalizing the level of protection across waterbody types. Because people are unlikely to consume the types of species found in limited aquatic life communities, there is no reason to factor in the intake of toxic chemicals from the fish consumption route. On the other hand, with cold and warm water fisheries, the consumption of whatever amount of toxics might be found in the average daily fish consumption rate of twenty grams needs to be accounted for when calculating safe levels of toxics in the water column.

There is another aspect of patterns of human fish consumption that does not appear to have been addressed in any of Wisconsin's human health WQC. For waters likely to harbor fish that humans are inclined to eat, Wisconsin assumes a fish consumption rate of 20 g/day, in all such waters. (EPA's human health criteria dealing with fish consumption [HHO and HHWO] assume a per-person daily intake of 17.5 grams of fish and other aquatic organisms, which is thought to be a reasonable estimate of the average rate of fish consumption across the nation.

However, EPA's guidance documents acknowledge the fact that there are subpopulations that consume locally-caught "fish" at considerably higher rates than this national average. (Native Americans, Cajuns, immigrants from Southeast Asia, and low income persons of all ethnic racial backgrounds are widely-recognized examples.) For such subsistence fisherpersons, the EPA estimates that the fish consumption rate can be as high as ten times the 17.5 g/day national average. If a state simply adopts the EPA HHO and HHWO criteria for a waterbody that is used by subsistence fishers, those people will face a higher risk of illness than that upon which EPA's human health criteria are based. In order to compensate for this situation, the criterion-concentrations for criteria related to fish consumption need to be set at considerably lower levels than the national average estimated by EPA.

Wisconsin assumes a fish consumption rate of 20 g/day, which would tend to lower its criterion-concentrations for bioaccumulative pollutants compared to those of equivalent EPA human health, which are based on the slightly lower rate of 17.5 g/day, which would provide a slightly higher level of protection than would the use of the EPA WQC. However, this average rate is apparently applied to all waters in the state thought to support species of fish that are popular food sources for humans. It seems, therefore, that Wisconsin has not made any site-specific adjustments in its human health WQC to account for situations in which the local human population is consuming local aquatic food stuffs at a significantly higher rate than the statewide average. If there are any such situations, persons in those locales who engage in subsistence fishing would likely be getting a lower level of protection than those persons who consume fish at an average rate.

Appendix A

Missing and Extra Criteria for Traditional Pollutants: WISCONSIN

Table 1 - Aquatic Life

i) MISSING POLLUTANTS[62]

	ACUTE	CHRONIC
Warm/cold water[63]	$CaCO_3$.	chlorophyll a (TD) gases hydrogen sulfide nitrogen(total) phosphorous(tot.) turbidity

ii) EXTRA POLLUTANTS[64]

	ACUTE	CHRONIC
Warm/cold water	temperature	

[62] For the purpose of this review, "missing pollutants" are those pollutants for which EPA has issued WQC while the state has neither adopted nor officially proposed corresponding criteria. In situations where a state has adopted and submitted to EPA a set of state-adopted changes but EPA has either not acted on the changes or has disapproved the changes, this fact is noted in this document.

[63] EPA's criteria do not distinguish between warm and cold water habitats.

[64] For the purposes of this review, "extra pollutants" are those pollutants for which the state has formally proposed or officially adopted WQC, while EPA has not published recommended WQC of the type specified.

Table 2 - Drinking Water Supply[65]

i) MISSING POLLUTANTS

ACUTE	CHRONIC
total coliforms	bromates chlorides color foaming agents nitrate-N nitrite-N odor sulfate TDS

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
---	---

Table 3 - Water-Based Recreation

i) MISSING POLLUTANTS

ACUTE	CHRONIC
---	*E. coli* Enterococci

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
---	---

[65] EPA lacks actual drinking water supply criteria for conventional pollutants – specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

Appendix B

Table 1

	Aquatic Life Protection	
	Acute	*Chronic*
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Wisconsin Has Not	4,4'-DDT Aldrin alpha-Endosulfan Aluminum beta-Endosulfan Chlordane Diazinon Heptachlor Heptachlor Epoxide Nonylphenol Silver Selenium Tributyltin	4,4'-DDT alpha-Endosulfan Aluminum beta-Endosulfan Chlordane Chloropyrifos Demeton Diazinon Guthion Heptachlor Heptachlor Epoxide Iron Malathion Methoxychlor Mirex Nonylphenol PCBs Toxaphene Tributyltin

Table 2

	Human Threshold and Human Cancer Criteria	
	Non-Public Water Supply (Compared to EPA's list of pollutants with "Human Health: Organisms Only" criteria)	*Public Water Supply (Compared to EPA's list of pollutants with "Human Health: Water and Organisms" criteria)*
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Wisconsin Has Not	1,1-Dichloroethylene 1,2,4-Trichlorobenzene 1,2-Dichloropropane 2-Chloronaphthalene 2-Chlorophenol 4,4'-DDD 4,4'-DDE Acenaphthene Aldrin alpha-Endosulfan[66] Anthracene Benzo(a)Anthracene Benzo(a)Pyrene Benzo(b)Fluoranthene Benzo(k)Fluoranthene beta-BHC beta-Endosulfan[66] Bis(2-Ethylhexyl)Phthalate Bromoform Butylbenzyl Phthalate Chlorodibromomethane Chrysene Dibenzo(a,h)Anthracene Dichlorobromomethane Di-n-Butyl Phthalate Endosulfan Sulfate Endrin Endrin Aldehyde Fluorene Heptachlor Heptachlor Epoxide Hexachlorocyclo-hexane-Technical Ideno(1,2,3-cd)Pyrene Manganese Methyl Bromide Methylmercury Nitrobenzene Nitrosamines N-Nitrosodi-n-Propylamine Pentachlorophenol Phenol Pyrene Thallium Zinc	1,1-Dichloroethylene 1,2,4-Trichlorobenzene 1,2-Dichloropropane 2,4,5,-TP 2,4-D 2-Chloronaphthalene 2-Chlorophenol 4,4'-DDD 4,4'-DDE Acenaphthene Aldrin alpha-Endosulfan[66] Anthracene Asbestos Barium Benzo(a)Anthracene Benzo(a)Pyrene Benzo(b)Fluoranthene Benzo(k)Fluoranthene beta-BHC beta-Endosulfan[66] Bis(2-Ethylhexyl)Phthalate Bromoform Butylbenzyl Phthalate Chlorodibromomethane (dibromochloromethane) Chrysene Copper (s) Dibenzo(a,h)Anthracene Dichlorobromomethane Di-n-Butyl Phthalate Dinitrophenols Endosulfan Sulfate Endrin Endrin Aldehyde Fluorene Heptachlor Heptachlor Epoxide Hexachlorocyclo-hexane-Technical Ideno(1,2,3-cd)Pyrene Iron Manganese Methoxychlor Methyl Bromide (bromoethane) Nitrates Nitrobenzene Nitroamines N-Nitrosodi-n-Propylamine Pentachlorophenol Phenol Pyrene Thallium Zinc

[66] While the state has not adopted criteria for alpha-endosulfan and beta-endosulfan as separate pollutants, it has adopted a criteria for endosulfan.

Table 3

	Non-Public Water Supply *(Compared to EPA's list of pollutants with "Human Health: Organisms Only" criteria)*		**Public Water Supply** *(Compared to EPA's list of pollutants with "Human Health: Water and Organisms" criteria)*	
	Human Threshold	Human Cancer	Human Threshold	Human Cancer
EXTRA POLLUTANTS: Pollutants for which Wisconsin Has Adopted WQC where EPA Has Not	1,1,1−Trichloroethane Cadmium Chromium (+3) Chromium (+6) 1,2-Dichloroethene (cis) Endosulfan Halomethanes Lead Mercury Silver	Beryllium BHC, technical grade Halomethanes	1,1,1−Trichloroethane Cadmium Chromium (+3) Chromium (+6) 1,2-Dichloroethene (cis) Endosulfan Halomethanes Lead Mercury Silver	Beryllium BHC, technical grade Halomethanes

Table 4

	Aquatic Life Protection *	
	Acute	*Chronic*
Pollutants with a state criterion-concentration **lower** than that of EPA's	Chlorpyrifos Mercury Parathion	Chlorine Mercury Parathion

Table 5

	Aquatic Life Protection*	
	Acute	*Chronic*
Pollutants with a state criterion-concentration **higher** than that of EPA's	Cadmium Chromium (VI) Copper Cyanide Lead	Arsenic III Cadmium Chromium III Copper Cyanide Dieldrin Endrin Lead Pentachlorophenol

Tables 4 and 5 are based on comparison of the criterion-concentrations of the WQC for Wisconsin's Warmwater Sportfish and Warmwater Forage (WW) designated uses to the criterion-concentrations of the corresponding EPA WQC. The state also has WQC for Cold Water aquatic life (CW) and another set of criteria for Limited Forage Fish/Limited Aquatic Life (L). For most of the toxic pollutants for which Wisconsin has aquatic life WQC, the criterion-concentration is the same for each of these three

subcategories of aquatic life uses. (Of course the criterion-concentration for acute exposure is always higher than the criterion-concentration for chronic exposure, for a given aquatic life classification.)

However there are some pollutants for which the criterion-concentration is not the same for Cold Water (CW) and/or for Limited Forage Fish and Limited Aquatic Life (L) as it is for Warm Water--Sportfish and Forage(WW).

For arsenic (+3), while the state's chronic WW and L criteria have concentrations higher than that of EPA's chronic WQC for freshwater aquatic life, the state's CW criterion has a criterion-concentration lower than EPA's.

For cadmium, the criterion-concentration for each of the acute WQC for the 3 subcategories of aquatic life is higher than EPA's, the WW criterion has a concentration over two times higher than that of the CW criterion, and the criterion for the "limited" uses (L) is seven-fold higher than the CW WQC.

Likewise, for chromium (+3), the criterion-concentration for each of the chronic WQC for the 3 subcategories of aquatic life is higher than EPA's, the CW criterion has a concentration lower than that for the other two subcategories, but it is still higher than the EPA criterion-concentration.

For cyanide, the acute CW WQC has a concentration around ½ that of the WW criterion, but this still is slightly higher than the corresponding EPA WQC's criterion-concentration. For the chronic WQC for cyanide, the CW aquatic life criterion has a concentration equal to that of EPA's chronic freshwater aquatic life WQC, while the WQC for the "limited" uses, like that for the warm water uses has a higher concentration than that of the EPA chronic WQC.

For dieldrin, while the chronic criterion-concentration for WW and L are identical and higher than that of the chronic EPA WQC for freshwater aquatic life, for cold water the state WQC has a concentration identical to that of the EPA criterion.

Likewise, for endrin, while the chronic criterion-concentration for WW and L are identical and higher than that of the chronic EPA WQC for freshwater aquatic life, for cold water the state WQC has a concentration identical to that of the EPA criterion.

For pentachlorophenol, the chronic Wisconsin criteria for WW and L subcategories of aquatic life uses are higher than that of the chronic EPA WQC for freshwater aquatic life, the state's CW criterion has a lower concentration than EPA's.

For selenium, the state's chronic criteria for CW and WW are the same, and also have the same criterion-concentration as EPA's chronic freshwater aquatic life WQC for this pollutant. The state's L criterion has a criterion-concentration several times higher than its CW and WW criteria, as well as EPA's corresponding WQC.

Table 6

	Non-Public Water Supply *(Compared to EPA's list of pollutants with "Human Health: Organisms Only" criteria)*					
	Human Threshold Criteria			**Human Cancer Criteria**		
	Cold Water Communities	Warm Water Sport Fish Communities	Limited Aquatic Life	Cold Water Communities	Warm Water Sport Fish Communities	Limited Aquatic Life
Pollutants with a state criterion-concentration **lower** than that of EPA's	1,2,4,5−Tetrachlorobenzene 1,2−Dichlorobenzene 1,3−Dichlorobenzene Bis (2-chloroisopropyl)ether 2,3,7,8−TCDD 2,4,5−Trichlorophenol 2,4−Dichlorophenol Acrolein Antimony Benzene Chlordane Chlorobenzene Dieldrin Diethyl phthalate Dimethyl phthalate Dinitrophenols (2,4−Dinitrophenol) Endosulfan Ethylbenzene Fluoranthene gamma−BHC (lindane) Hexachlorocyclopentadiene Pentachlorobenzene Selenium Toluene	1,2,4,5−Tetrachlorobenzene Bis (2-chloroisopropyl)ether Acrolein Antimony Chlorobenzene Dinitrophenols (2,4−Dinitrophenol) Ethylbenzene gamma−BHC (lindane) Hexachlorocyclopentadiene Pentachlorobenzene Selenium	Acrolein	1,1,2,2−Tetrachloroethane 1,1,2−Trichloroethane 1,2−Dichloroethane 1,2−Diphenylhydrazine 1,3-Dichloropropene 1,4−Dichlorobenzene 2,3,7,8 TCDD (Dioxin) 2,4−Dinitrotoluene 4,4'−DDT Acrylonitrile Arsenic alpha−BHC Benzene Bis(2−chloroethyl) ether Chlordane Chloroform Dieldrin gamma−BHC (lindane) Hexachlorobenzene Hexachlorobutadiene Hexachloroethane N−Nitrosodi−n−butylamine N−Nitrosodiethylamine N−Nitrosodimethylamine N−Nitrosopyrrolidine PCBs Toxaphene	1,1,2−Trichloroethane 1,2−Dichloroethane 1,4−Dichlorobenzene 1,3-Dichloropropene 2,3,7,8 TCDD (Dioxin) 2,4−Dinitrotoluene 4,4'−DDT Arsenic alpha−BHC Benzene Bis(2−chloroethyl) ether Chloroform Dieldrin gamma−BHC (lindane) Hexachlorobenzene Hexachlorobutadiene Hexachloroethane N−Nitrosodi−n−butylamine N−Nitrosodiethylamine N−Nitrosodimethylamine N−Nitrosopyrrolidine PCBs Toxaphene	alpha−BHC N−Nitrosodi−n−butylamine N−Nitrosodiethylamine N−Nitrosodimethylamine N−Nitrosopyrrolidine

Table 7

	Non-Public Water Supply *(Compared to EPA's list of pollutants with "Human Health: Organisms Only" criteria)*					
	Human Threshold Criteria			**Human Cancer Criteria**		
	Cold Water Communities	Warm Water Sport Fish Communities	Limited Aquatic Life	Cold Water Communities	Warm Water Sport Fish Communities	Limited Aquatic Life
Pollutants with a state criterion-concentration **higher** than that of EPA's	1,3 Dichlorobenzene 1,3-Dichloropropene 2,4 Dimethyl phenol 2,4 Dinitrotoluene 4,4'-DDT Benzene Chlorobenzene Cyanide, Total Dichloromethane Dieldrin Hexachlorobenzene Hexachloroethane Isophorone Nickel	1,2−Dichlorobenzene 1,3−Dichlorobenzene 1,3-Dichloropropene 2,3,7,8−TCDD(dioxin) 2,4-Dichlorophenol 2,4−Dimethylphenol 2,4-Dinitrotoluene 2,4,5−Trichlorophenol 4.4'−DDT Benzene Chlorobenzene Cyanide, Total Dichloromethane Dieldrin Diethyl phthalate Dimethyl phthalate Endosulfan Ethylbenzene Fluoranthene Hexachlorobenzene Hexachloroethane Isophorone Nickel Toluene	1,2,4,5−Tetrachlorobenzene 1,2−Dichlorobenzene 1,3−Dichlorobenzene 2,3,7,8−TCDD (dioxin) 2,4−Dichlorophenol 2,4−Dimethylphenol 2,4−Dinitrotoluene 2,4,5−Trichlorophenol 4.4'−DDT Antimony Benzene Bis(2−chloroisopropyl) ether Chlordane Chlorobenzene Cyanide, Total Dichloromethane 1,3-Dichloropropene Dieldrin Diethyl phthalate Dimethyl phthalate Dinitrophenols (2,4−Dinitrophenol) Endosulfan Ethylbenzene Fluoranthene gamma−BHC (lindane) Hexachlorobenzene Hexachlorocyclopentadiene Hexachloroethane Isophorone Nickel Pentachlorobenzene Selenium Toluene	2,4,6−Trichlorophenol 3,3'−Dichlorobenzidine Benzidine Bis(chloromethyl) ether Carbon tetrachloride Chlordane Chloroethene N−Nitrosodiphenylamine	1,1,2,2−Tetrachloroethane 1,2−Diphenylhydrazine 2,4,6−Trichlorophenol 3,3'−Dichlorobenzidine Acrylonitrile Benzidine Bis(2−chloroethyl) ether Bis(chloromethyl) ether Carbon tetrachloride Chloroethene Chlordane N−Nitrosodiphenylamine	1,1,2,2−Tetrachloroethane 1,1,2−Trichloroethane 1,2−Dichloroethane 1,2−Diphenylhydrazine 1,3-Dichloropropene 1,4−Dichlorobenzene 2,3,7,8−TCDD(dioxin) 2,4,6−Trichlorophenol 2,4−Dinitrotoluene 3,3'−Dichlorobenzidine 4,4'−DDT Acrylonitrile Arsenic Benzene Benzidine Bis(2−chloroethyl) ether Bis(chloromethyl) ether Carbon tetrachloride Chloroethene Chloroform Chlordane Dichloromethane Dieldrin gamma−BHC (lindane) Hexachlorobenzene Hexachlorobutadiene Hexachloroethane N−Nitrosodiphenylamine Polychlorinated biphenyls Toxaphene

Table 8

	Public Water Supply *(Compared to EPA's list of pollutants with "Human Health: Water and Organisms" criteria)*			
	Human Threshold Criteria		**Human Cancer Criteria**	
	Cold Water Communities	Warm Water Sport Fish Communities	Cold Water Communities	Warm Water Sport Fish Communities
Pollutants with a state criterion-concentration **lower** than that of EPA's	1,2,4,5-Tetrachlorobenzene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 2,3,7,8-TCDD 2,4,5-Trichlorophenol 2,4-Dichlorophenol Acrolein Bis(2-chloroisopropyl) ether Chlorobenzene Cyanide, Total Dichloromethane Diethyl phthalate Dimethyl phthalate Dinitrophenols gamma-BHC Hexachlorocyclopentadiene Nickel Pentachlorobenzene Selenium Toluene	1,2,4,5-Tetrachlorobenzene 1,3-Dichlorobenzene 2,4-Dichlorophenol 2,4,5-Trichlorophenol Acrolein Bis(2-chloroisopropyl) ether Chlorobenzene Cyanide, Total Dichloromethane Diethyl phthalate Dimethyl phthalate Dinitrophenols Ethylbenzene gamma-BHC Hexachlorocyclopentadiene Hexachloroethane Nickel Pentachlorobenzene Selenium Toluene	1,1,2,2-Tetrachloroethane 1,2-Diphenylhydrazine 1,4-Dichlorobenzene 2,3,7,8-TCDD 2,4-Dinitrotoluene 4,4'-DDT Acrylonitrile alpha-BHC Benzene Bis(2-chloroethyl) ether Carbon tetrachloride Chlordane Chloroethene Chloroform Dichloromethane Dieldrin gamma-BHC Hexachlorobenzene Hexachlorobutadiene Hexachloroethane N-Nitrosodiethylamine N-Nitrosodimethylamine N-Nitrosodi-n-butylamine N-Nitrosodiphenylamine Polychlorinated biphenyls Toxaphene	1,4-Dichlorobenzene 2,3,7,8-TCDD 2,4-Dinitrotoluene 4,4'-DDT alpha-BHC Benzene Chlordane Chloroethene Chloroform Dichloromethane Dieldrin gamma-BHC Hexachlorobenzene Hexachlorobutadiene Hexachloroethane N-Nitrosodiethylamine N-Nitrosodimethylamine PCBs Toxaphene

Table 9

	Public Water Supply *(Compared to EPA's list of pollutants with "Human Health: Water and Organisms" criteria)*			
	Human Threshold Criteria		**Human Cancer Criteria**	
	Cold Water Communities	Warm Water Sport Fish Communities	Cold Water Communities	Warm Water Sport Fish Communities
Pollutants with a state criterion-concentration **higher** than that of EPA's	1,3-Dichlorobenzene 2,4-Dimethylphenol 2,4-Dinitrotoluene 4,4'-DDT Benzene Chlordane Chlorobenzene Dichloromethane Dieldrin Dichloropropenes (1,3-Dichloropropene) Ethylbenzene Fluoranthene Hexachlorobenzene Hexachloroethane Isophorone	1,3-Dichlorobenzene 2,4-Dimethylphenol 2,4-Dinitrotoluene 2,3,7,8 TCDD (dioxin) 4,4'-DDT Benzene Dichloromethane Dichloropropenes (1,3-Dichloropropene) Dieldrin Endosulfan Fluoranthene Hexachlorobenzene Hexachloroethane Isophorone	1,1,2-Trichloroethane 2,4,6-Trichlorophenol 3,3'-Dichlorobenzidine Arsenic Benzidine Bis(chloromethyl) ether N-Nitrosopyrrolidine	1,1,2-Trichloroethane 1,2-Diphenylhydrazine 2,4,6-Trichlorophenol 3,3'-Dichlorobenzidine Acrylonitrile Arsenic Benzidine Bis(2-chloroethyl) ether Bis(chloromethyl) ether Carbon tetrachloride N-Nitrosodiphenylamine N-Nitrosopyrrolidine

Appendix C

SITUATIONS IN WHICH STATE WQC ARE CLEARLY LESS PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vs. EPA[i]	**higher**	**longer**	**higher**
" " "	equal	**longer**	**higher**
" " "	**higher**	equal	**higher**
" " "	**higher**	**longer**	equal
" " "	**higher**	equal	equal
" " "	equal	equal	**higher**
" " "	equal	**longer**	equal

SITUATIONS IN WHICH STATE WQC ARE CLEARLY MORE PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vs. EPA	**lower**	**shorter**	**lower**
" " "	equal	**shorter**	**lower**
" " "	lower	equal	**lower**
" " "	**lower**	**shorter**	equal
" " "	**lower**	equal	equal
" " "	equal	equal	**lower**
" " "	equal	**shorter**	equal

SITUATIONS IN WHICH COMPARATIVE LEVEL OF PROTECTION CANNOT BE DETERMINED BY SIMPLY LOOKING AT THE TWO CRITERIA

	Concentration	Duration	Frequency
State vs. EPA	**lower**	**shorter**	**higher**
" " "	equal	**shorter**	**higher**
" " "	**lower**	equal	**higher**
" " "	**lower**	**longer**	equal
" " "	**higher**	equal	**lower**
" " "	**higher**	**shorter**	equal
" " "	equal	**longer**	**lower**

[i] The state WQC's component (e.g., duration) compared to the component for corresponding EPA WQC.

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