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

Iowa

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Acknowledgements

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The findings presented in this document are based only on what was found in final state WQS regulations as of September 1, 2008. 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.

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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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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 U.S. Environmental Protection Agency (EPA). The findings presented in the documents produced for this report are based on the most recent version of the state's WQS regulations, as of September 1st, 2008. Hence, only water quality criteria contained in final state regulations were examined. 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 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 Iowa's water quality standards (WQS) regulations[3] 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; and 3) level of protection likely afforded to applicable designated uses.

Iowa has adopted numeric water quality criteria for a significant array of pollutants/use combinations. There are, however, a number of instances in which the state is missing[5] criteria

[1] The terms "water quality criteria," "WQC," and "criteria" are used interchangeably in this report. Water quality criteria are closely associated with another key element of water quality standards established under state law and the federal Clean Water Act designated uses. 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 that Agency 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, established by EPA under authority of the Safe Drinking Water Act (SDWA).

[3] Chapter 61, "Water Quality Standards," Iowa Administrative Code as amended in Notice of Intended Action ARC6352B in IAB 10/24/07.

[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.

[5] 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.

for pollutant/use combinations for which EPA has issued[6] WQC under the authority of Section 304(a) of the CWA. For example, Iowa has adopted aquatic life criteria for most of the toxic chemicals[7] for which EPA has published such criteria. On the other hand, the state is missing[8] aquatic life criteria for a number of traditional pollutants[9] for which EPA has issued such WQC, including the nutrients nitrogen and phosphorous, as well as the related indicator of algal growth, chlorophylla. High densities of algae resulting from excess nutrient loadings can interfere not only with aquatic life, but also impair drinking water supply and water-based recreational uses.

Also missing are human health criteria for several dozen toxic pollutants – criteria aimed at addressing risks associated with consumption of: 1) fish tissue alone and 2) drinking water and fish tissue combined. For example, Iowa lacks criteria pertaining to the combined consumption of water and aquatic organisms for about 50% of the total 113 pollutants for which EPA has published corresponding criteria.[10] Iowa has also specified criteria for toxic pollutants related drinking water supply use alone, but has done so for just over one-third of the contaminants for which EPA has issued somewhat related[11] standards under the Safe Drinking Water Act. It also has a drinking water supply for chlorides, but has no such WQC for the seven other traditional pollutants/parameters for which EPA is issued somewhat corresponding standards.

Among the pollutants with missing aquatic life criteria are tributyltin and methoxychlor, which fall into categories of chemicals frequently mentioned as possible endocrine disruptors. Among the pollutants with missing human health criteria are number of carcinogens and highly bioaccumulative substances, along with known or potential endocrine disruptors.

Iowa does have some "extra"[12] criteria. For example, the state has numeric WQC for temperature pertaining to aquatic life uses, while EPA has issued only narrative criteria. Iowa

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[6] Throughout this report, the criteria recommended by EPA will be referred to as the EPA's "issued" or "published" criteria, interchangeably. The Agency's WQC issued pursuant to the Clean Water Act are recommendations that the states can use in establishing numeric WQC. EPA's WQC are not regulatory requirements.

[7] In this report, "toxic pollutant" includes not only EPA's "priority toxic pollutants" but also all those toxics called, for CWA purposes, "non-priority pollutant," as well as all toxic chemicals not falling in either of these two EPA categories. (The one exception is ammonia; see footnote 9).

[8] 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.

[9] 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."

[10] EPA calls its corresponding (i.e., address combined consumption of drinking water and fish tissue) criteria Human Health: Water and Organisms (HHWO).

[11] The term "somewhat corresponding" has been used because water quality criteria and drinking water standards apply to different endpoints. WQC apply to surface waters within the jurisdiction of the Clean Water Act. Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. When a waterbody in Iowa is designated "Drinking Water Supply," then a certain set of WQC apply, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water being run through treatment processes aimed at removing contaminants.

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

also has both acute and chronic aquatic life criteria for dissolved oxygen, whereas EPA has published only an acute criterion. Also with regard to aquatic life criteria for toxic chemicals, the state also has eight acute criteria and six chronic criteria for pollutants for which EPA has not issued corresponding WQC.

The state's WQC for traditional pollutants generally have a criterion-concentration[13] that is equal to, or only slightly more or less than, the criterion-concentrations of corresponding EPA WQC and those of other states. Over half of Iowa's aquatic life criteria for toxic chemicals have criterion-concentrations that are identical to those in corresponding EPA criteria, while roughly an equal number of criteria have higher or lower criterion-concentrations than EPA's. As for criteria aimed at the protection of human health from adverse effects of toxic substances ingested by 1) eating fish and other aquatic organisms alone, or 2) the combination of drinking water and fish consumption, a large majority of the state's WQC have criterion-concentrations that are equal to those in corresponding EPA criteria, while a few have criterion-concentrations that are lower than EPA's. For most of the contaminants for which Iowa has adopted drinking water supply criteria, the state has adopted EPA's primary drinking water standard values.[14]

A small portion of the state's numeric aquatic life WQC for traditional pollutants has a clearly stated criterion-duration[15] (e.g., an instant or an hour), but most are worded in such a way as to leave considerable room for interpretation. Iowa's one drinking water supply criterion for a traditional pollutant also lacks a well-articulated duration. None of Iowa's WQC for toxic pollutants has clearly-articulated criterion-durations.

Of all the types of WQC specified in Iowa's WQS regulations, only one of the aquatic life criteria for traditional pollutants has a clearly stated criterion-frequency.[16] None of the state's criteria for toxic chemicals do.

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

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[13] According to EPA guidance, numeric water quality criteria consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these, criterion-magnitude, is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude".

[14] These standards have been promulgated by EPA pursuant to the Safe Drinking Water Act. They are often referred to as "maximum contaminant levels" (MCLs).

[15] According 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 four-day average concentrations. The occurrence of one or more excursion (e.g., a four-day period in which the instream concentration of 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.

[16] In EPA WQS terminology, the criterion-frequency specifies the maximum rate at which "excursions" (see above footnote re: criterion-duration) 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 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 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 in a lake were higher than 5.2 µg/L (criteria-concentration) more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

criterion-concentration, criterion-magnitude, and criterion-frequency of each of the two WQC being compared are precisely stated, their comparative degrees of protectivity 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.

Unfortunately, the relevance of the tables in Appendix C to Iowa's WQC is significantly limited by the fact that, though a majority of the state's criteria have a specified criterion-duration, the state's WQS regulations make no mention of a criterion-frequency for any of its water quality criteria. 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.

As for the level of protection provided to designated uses, given that most of the state's criteria for both traditional and toxic chemicals have criterion-concentrations that are equal to the criterion-concentrations in corresponding EPA aquatic life and human health WQC, it might at first seem that Iowa's criteria generally provide equal levels of protection as to EPA's. However, the reliability of such a conclusion is significantly compromised because Iowa lacks clearly defined criterion-durations and/or frequencies for most of its numeric criteria. (This is also the case with several EPA for traditional parameters and its human health WQC for toxics.) The absence of an explicit criterion-duration and criterion-frequency renders a determination of the absolute or relative level of protection provided by a state's versus EPA's criteria an exercise fraught with uncertainty. Any such effort would require 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 state. The results of attempts to compare the protection provided by a state versus an EPA would, therefore, be greatly affected by whatever assumptions were made. Assumption of some short-term duration (such as one hour), rather than a longer term (such as 30 days), would tend to make a criterion more protective. Likewise, assumption of a lower frequency (such as once in five years), rather than a higher frequency (such as once in two years) would have the same effect – more protective than if the alternative were use.

For example, Iowa has established chronic aquatic life criteria for 19 toxic pollutants that have the same criterion-concentration as that of the corresponding EPA WQC. According to the state's WQS regulations,[17] "the chronic criteria will be met as short term average conditions…" The criterion-duration of all of EPA's chronic aquatic life WQC is four days (96 hours). As for criterion-frequency, the state makes no mention of such, while EPA specifies a criterion-frequency of once in three years. If, for example, for Iowa's chronic aquatic life criteria for

[17] Section 567.61.2(5)

toxics, one assumed a criterion-duration of one day (24 hours) and a criterion-frequency of zero, then all of the state's WQC that have criterion-concentrations equal to or less than that in the corresponding EPA criterion would provide a higher level of protection to aquatic life than would EPA's WQC. By contrast, if the criterion-duration for the state's WQC were assumed to be seven days and the criterion-frequency were once in one year, then all of the state's WQC having a criterion-concentration equal to or greater than that of the corresponding EPA WQC would be less protective.

As for those state chronic aquatic life WQC for toxics with a higher criterion-concentration, if the criterion-duration were one hour and the criterion-frequency were zero, it would be hard to determine, without performing additional laboratory studies, whether the state WQC was more or less protective than the EPA criterion. That is, to what degree would the less-protective effect of the higher concentration be offset by the more protective effects of a shorter duration and lower frequency?

Also, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons (differences in water column chemistry, temperature, stream flow patterns, resident species of aquatic life) 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. For instance, the criterion-concentration for Iowa's dissolved oxygen WQC applicable to warm water aquatic life has the same criterion-concentration (5.0 mg/L) as EPA's sole dissolved oxygen WQC for inland waters; while Iowa's dissolved oxygen WQC for cold waters has a criterion-concentration of 7.0 mg/L. The mere fact that the criterion-concentration for cold water habitats is 2.0 mg/L higher than the criterion-concentration for warm water habitats does not mean that the state is trying to provide a higher level of protection[18] to those organisms that inhabit cold water habitats than those indigenous to warm water habitats. Rather, the criterion-concentration for dissolved oxygen is higher for cold water habitats because key cold water species require higher levels of oxygen in their environment than do species in warm water habitats.[19] Also, for a number of toxic pollutants, the state's aquatic life WQC have a different criterion concentration, depending on whether the water is designated cold water, warm water, limited warm water, or lakes and wetlands.

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. 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

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[18] Unlike pollutants, for which higher concentrations tend to correspond with lower protection for aquatic life, with dissolved oxygen, the reverse is the case: higher dissolved oxygen concentrations tend to provide greater protection.

[19] This would not, however, mean that the two criteria would provide equal levels of protection to the relevant use. If, for example, a state's criterion-concentration were higher than EPA's, while the duration and frequency for the two WQC were identical, then the state's criteria 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 would have resulted in EPA's WQC providing an even higher level of protection than that for which EPA designed it. The effect of the state's higher criterion-concentration would be to bring the level of protection back down to that intended by EPA.

caught and eaten by people can differ by an order of magnitude from place to place and/or within subpopulations of humans. And, of course, patterns of swimming and other water contact recreation can change considerably depending on difference in the climate in which one waterbody verses another is located, along with the type of waterbody (river, lake, ocean beach).

An example of accounting for such difference in human use patters is Iowa's adoption of different WQC for indicator bacteria for waterbodies used for primary contact recreation as opposed to those used just for secondary contact recreation. Both Iowa's acute and chronic WQC for *E. coli* applicable to primary contact recreation have roughly an order of magnitude lower criterion-concentration than the corresponding WQC for secondary contact recreation. On the other hand, Iowa's WQC related to human consumption of fish and/or drinking water do not appear to reflect an effort to reflect such differences in human use patters from one waterbody to another, or even from one broad category to another.

Returning 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 exceedances of one of Iowa's Human Health-Fish and Water WQC, 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 in such circumstances, then it would seem logical to express 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 Human Health-Fish and Water WQC was twelve months, the averaging period used in determining compliance with federal Safe Drinking Water Act standards, then setting a maximum twelve month total load would seem appropriate.[20]

C. Traditional[21] Pollutants/Parameters

1) *Coverage*

[20] 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. Despite this ruling, maximum loads over other time spans would also be needed, in order for the TMDL to consistent with relevant WQC, when such criteria have criterion-durations other than 24 hours.

[21] 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".

a) Aquatic Life/ "Cold Water Aquatic Life," "Warm Water-Type 1," "Warm Water-Type 2," Warm Water-Type 3," "Lakes and Wetlands"[22]

Iowa 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"[23] pollutants are several criteria corresponding to published EPA criteria related to hyper-eutrophication due to excess loadings of nutrients chlorophyll a, total phosphorous, and total nitrogen.

Iowa does, however, have several extra[24] criteria. For example, although the state lacks acute criteria for dissolved oxygen (DO), it has chronic DO criteria, while EPA does not have criteria corresponding to the state's criteria. Iowa lacks chronic criteria for turbidity, for which EPA has published chronic criteria, as part of its set of criteria addressing excess eutrophication. However, the state does have a "quasi-numeric"[25] acute value for turbidity (measured as NTUs)[26] that applies to aquatic life.[27] Unlike EPA, Iowa does not have a turbidity criterion for lakes and reservoirs measured in terms of Secchi disk visibility. Iowa has acute aquatic life criteria for temperature, while EPA has only narrative criteria (Appendix A, Table 1).

b) Human Health: Shellfish Harvesting

EPA has issued chronic WQC applicable to consumption of shellfish, while Iowa has not.[28]

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[22] Throughout this document, generic names (e.g., "aquatic life", "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 use.

[23] 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.

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

[25] In this report a "quasi-numeric" criterion is one that is expressed as a specific 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). For example, a "quasi numeric" criterion for temperature might read "no more than a 1^{o}C increase above background temperature."

[26] Actually, in some sense, Iowa's turbidity value is not a true WQC, as envisioned in the CWA and described by EPA. Application of this particular "criterion" is limited, according to Section 61.3(2)f of the state's WQS regulations, to situations in which changes in water quality are caused by point sources. Hence, if non-point runoff from agricultural operations elevated turbidity by more than the 25 NTU specified by 61.3(2)f, the waterbody would not be considered as exceeding WQC. None of the other WQC adopted by Iowa are worded in such a way as to clearly limit their applicability just to adverse changes in water quality caused by a certain set of sources. (Some of the WQC for pH are stated in a way that could be read to impose such a limitation on their application; and all of the temperature WQC have wording that raises questions in this regard. The remainder of Iowa's WQC, like those issued by EPA, indicate or imply any such limitation. Rather, if ambient conditions are worse than those described by the vast majority of WQC, then the water is considered impaired for the designated use(s) to which the WQC apply, regardless of whether the lowered water quality is cause by one type of anthropogenic source versus another.

[27] The state does not have a turbidity WQC specific to one or more type of aquatic life use. Rather it has a "general water quality criterion" that applies to "general use segments." According to Section 61.3(1)a of the Iowa WQS regulations, such criteria provide protection for a number of uses, one of which is "aquatic life."

[28] The significance of the lack of such criteria depends upon whether or not any of Iowa's waters harbor shellfish that are, or could be, harvested and consumed, for either recreational or commercial purposes.

c) Human Health: Drinking Water Supply / "Drinking Water Supply"

Iowa has criteria applicable to drinking water supply use for chlorides, whereas EPA has promulgated standards under the Safe Drinking Water Act[29] for eight traditional and selected nontraditional pollutants and other water quality parameters (Appendix A, Table 2).

It should be noted that, with the exception of total coliform, the EPA standards for the eight traditional/nontraditional 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).

Iowa also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. It has no WQC for chlorophyll a, which is an indicator of bacterial densities. 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.

The state does have a quasi-numeric acute "general water quality criterion" for turbidity (NTU) that is intended to provide protection for a number of uses, including incidental withdrawals for domestic uses.[30]

d) Human Health: Water-Contact Recreation /"Primary Contact Recreational Use," "Secondary Contact Recreational Use," "Children's Recreational Use"

Iowa has adopted criteria for the bacterial indicators E.coli for recreational uses, but not for Enterococci. EPA published criteria for both of these indicator microbes in 1986. The state has both acute and chronic *E. coli* criteria, while EPA has only chronic.[31] Also, Iowa has one set of acute and chronic *E. coli* that apply to Primary Contact Recreation and Children's Recreational Use, and another set for Secondary Contact Recreation. EPA has only one criterion for E.coli, for all "bathing waters."

The state also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to un-natural blooms of aquatic algae. It also has no criterion for chlorophyll a, an indicator of algal density in the water. Such blooms can form mats on the water surface which can interfere with a variety of water-based recreational activities.

Iowa has instantaneous minimum and maximum criteria for pH applicable to recreational uses, as well as an acute quasi-numeric pH. The state also has a quasi-numeric acute "general water quality criterion" for turbidity (NTU) that, according to the regulations, is intended to

[29] 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 traditional 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.

[30] Id. at 27

[31] EPA has issued a set of four Single Sample Maximum Values (SSMs) in conjunction with its chronic criterion (30-day duration) for *E. coli*. Though these may appear to be water quality criteria, they are actually water quality assessment values, to be used only when there is just one grab sample available during a given 30-day period. Each of the SSM values represents a different level of confidence that the actual 30-day waterbody concentration is greater than the 126 colonies/100 ml specified by EPA's chronic criterion.

provide protection for a number of uses, including "non-contact recreation." These two quasi-numeric criteria are unusual, in that they apply only when lower water quality is the result of point source discharges. In a sense, these are not true WQC, in that they do not describe conditions not consistent with supporting a designated use, regardless of what mix of anthropogenic sources led to such conditions.

e) Agricultural Water Supply/ "General Use"

Iowa has a quasi-numeric acute "general water quality criterion" for turbidity (NTU) that is intended to provide protection for a number of uses, including "livestock and wildlife watering" and "crop irrigation," as well as incidental withdrawals for agricultural uses.[32]

EPA has issued agricultural water supply (irrigation) criteria for boron/borates, while Iowa has not. Agricultural water supply is not among the specific designated uses that can be assigned to waterbodies, though it is listed among the uses that fall under the state's General Use designation.

f) Industrial Water Supply

Iowa has a quasi-numeric acute "general water quality criterion" for turbidity (NTU) that is intended to provide protection for a number of uses, including incidental withdrawals for industrial use.[33]

EPA has issued an industrial water supply criterion for calcium carbonate. (Industrial water supply is not among the specific designated uses that can be assigned to waterbodies, though it is listed among the uses that fall under the state's General Use designation.)

2) *Criterion-Concentrations*[34]

a) Aquatic Life/ "Cold Water Aquatic Life", "Warm Water-Type 1," "Warm Water-Type 2," Warm Water-Type 3," "Lakes and Wetlands"

Iowa's criteria for dissolved oxygen, pH, and temperature have criterion-concentrations that are similar to corresponding criteria of most of the other nine states examined in this study, as well as EPA's (except for temperature, for which EPA has only narrative criteria). This includes the state's aquatic life WQC for ammonia. The criterion-concentrations are equal to those in the corresponding EPA WQC, which vary according to temperature and/or pH.

EPA has adopted ecoregion- and waterbody type-specific chronic (growing season average) WQC for the four parameters covered by the Agency's "nutrient criteria" (total phosphorous, total nitrogen, chlorophyll a, and turbidity) applicable to the two ecoregions present in Iowa, Ecoregion VI (Corn Belt and Northern Great Plains) and Ecoregion IX

[32] Id. at 27
[33] Id. at 27
[34] According to EPA guidance, numeric water quality criteria consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these, criterion-magnitude, is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude."

(Southeastern Forested Plains and Hills). Iowa, however, has only an acute quasi-numeric "general use" criteria for turbidity (NTU). Because of differences in the manner of expression of EPA's and the state's NTU criteria, comparison of state criterion-concentration to a parallel EPA criteria is not feasible.

b) Human Health: Shellfish Harvesting

Not applicable. Iowa does not have any fish consumption criteria for "traditionals."

c) Human Health: Drinking Water Supply

Iowa's Drinking Water Supply chronic criterion for chloride has the same criterion-concentration as EPA's secondary drinking water standard for that substance.

d) Human Health: Water-Contact Recreation /"Primary Contact Recreational Use," "Secondary Contact Recreational Use," "Children's Recreational Use"

For primary contact and children's recreation uses, the state's acute criterion for *E. coli* (expressed as a "sample maximum") is 235 organisms/100 ml, which is identical to EPA's Single Sample Maximum value for a confidence level of 75 percent.[35] The criterion-concentration for its acute criterion applicable to secondary contact is 2880 organisms/100 ml; EPA has issued no criteria specific to secondary contact recreation.

The criterion-concentration (126 colonies/100 ml) for Iowa's chronic criteria for the indicator bacteria E.coli for Primary Contact Recreational Use and Children's Recreational Use is identical to EPA's chronic criterion for water contact recreation in general. The criterion for Secondary Contact Recreational use is 630 colonies/100 ml; EPA has issued no criteria specific to secondary contact recreation.

e) Agricultural Water Supply/ "General Use"

Not applicable. There are no traditional pollutants/parameters for which both Iowa and EPA have a criterion for this use.

f) Industrial Water Supply/ "General Use"

Not applicable. There are no traditional pollutants/parameters for which both Iowa and EPA have a criterion for this use.

3) *Articulation of Criterion-Duration*

[35] Both Iowa's and EPA's values are expressed in terms of sample characteristics, making them more like assessment methods than water quality criteria, which describe waterbody conditions. They differ in that the state's WQS regulations say nothing about the number of samples to which this "sample maximum" would apply, whereas EPA guidance indicates that its Single Sample Maximum values should be employed only when there is just one single grab sample available for a given 30-day period. Iowa's "sample maximum value" strongly implies a WQC stipulating an instantaneous waterbody bacterial level never to be surpassed.

There is some ambiguity associated with the criterion-duration for most of Iowa's WQC for traditional pollutants.

a) Aquatic Life/ "Cold Water Aquatic Life," "Warm Water-Type 1," "Warm Water-Type 2," Warm Water-Type 3," "Lakes and Wetlands"

There are a number of criteria that appear to have a duration of an instant, though this is not entirely clear. For example, the Iowa WQS regulations state that pH "shall not be less than 6.5 nor greater than 9.0." Also, "The rate of temperature change shall not exceed __C^o per hour." Criteria for turbidity and total dissolved solids are also expressed as "not to exceed" values. In these cases, 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, the following language from Table 2: Criteria for Dissolved Oxygen is a clearer statement of an instantaneous duration: "Minimum value at any time during every 24-hour period."

There is a WQC for temperature that appears to have a duration of one hour, but there is some ambiguity: "...shall not exceed the maximum limits in the table below during more than 1 percent of the hours in the twelve month period ending with any month." It is assumed that the above language is intended to mean that the one-hour average temperature should not exceed the values in the referenced table in more than one out of every 100 hours. It could, however, be taken to mean the highest temperature reached at any time, during any calendar hour, should be no higher than the level specified in said table, in more than one in 100 hours.

Iowa's acute and chronic WQC for ammonia lack clearly articulated criterion-durations. The acute criteria seem to have a criterion-duration of an instant, though the regulations do not specify this directly. The chronic criteria are to be treated as "short term" averages, but no quantitative definition of "short term" is provided.

Iowa has a criterion for pH is expressed as "the maximum change permitted as a result of a waste discharge shall not exceed 0.5 units." Likewise there are WQC for temperature stating that, "No heat shall be added that would cause an increase of more than ___^{o} C." These are examples of what this report calls "quasi-numeric" criteria – ones 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 "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 the instantaneous minimum temperature levels, but also average temperatures over various periods of time (minutes, hours, days, etc).

b) Human Health: Shellfish Harvesting

Not applicable. Iowa has no WQC for traditional parameters for this use.

c) Human Health: Drinking Water Supply

Iowa has one criterion for a traditional/nontraditional pollutant for drinking water supply for chloride. As with all of the state's criteria applicable to human health uses, no clearly stated criterion-duration is provided. Section 567-61.3.b(3) 3 of the Iowa WQS regulations specifies, "Instream concentrations in excess of the human health criteria will be allowed only within the boundaries of the mixing zone." This language strongly implies duration of an instant.[36]

However, Table 1 in the WQS regulations clearly states that the DWS (Class C) criterion for chlorides is based on the EPA Safe Drinking Water Act (SDWA) standard for chlorides. Given that compliance with drinking water standards under SDWA is based on the average of samples collected over four "rolling" calendar quarters (twelve months total), one might possibly assume that the same duration applies to this state water quality criterion.

d) Human Health: Water-Contact Recreation / "Primary Contact Recreational Use," "Secondary Contact Recreational Use," "Children's Recreational Use"

Iowa's acute criteria for *E. coli* for various types of water contact recreational uses appear to have an intended criterion-duration of just an instant. The criterion-concentrations for these WQC appear in a table "Bacteria Criteria Table" in Section 61.3(3)a(1) under a column labeled "sample maximum,"[37] which strongly implies that if any individual sample, regardless of the number of samples available for a given period of time, has a level of bacteria higher than that listed in said table, the WQC would be exceeded, and the water should be placed on the Section 303(d) list

Iowa's chronic criteria applicable to Primary Water Contact Recreational Use and Children's Recreational Use seem to have an eight-month duration, given that 1) they are stated as "Geometric Mean," and 2) they apply for the period from March 15 to November 15. Its chronic criterion for 1) Secondary Contact Recreational Use combined with Cold Water Aquatic Life, and 2) High Quality Waters, appears to have a 365-day duration, as the table indicates they apply year round and a geometric mean concentration is the target. One could possibly interpret the wording of this table to indicate an open-ended criterion-duration, i.e., a long-term average.

[36] This language in Iowa's WQS regulations seems to reflect a fairly common source of ambiguity in communication about water quality criteria – conflating "criterion" and "criterion-concentration." As a consequence, saying that waterbody concentrations shall not be higher than the "criterion" could be read in one of two ways: 1) no higher than the "criterion-concentration," or 2) no worse than the conditions described by the combination of the three elements of numeric criteria, the concentration, the duration, and the frequency. When a state fails to explicitly specify either a criterion-duration or a criterion-frequency (as is the case with many of Iowa's criteria) it becomes difficult to read regulatory language such as that quoted in the first sentence of this subsection to mean anything other than "waterbody concentrations shall not surpass the criterion-concentration at any time, even for an instant."

[37] Technically, by labeling the bacterial levels in the right hand column of the "Bacteria Criteria Table" as "Sample Maximum," the state has articulated a water quality assessment methodology rather than an actual water quality criterion. A WQC describes waterbody conditions thought to be consistent with protection of a given use, whereas an assessment methodology offers a way of using information from one or more samples/aliquots taken from a waterbody to infer actual waterbody conditions. Relabeling this column "Instantaneous Maximum" would be more consistent with articulation of a WQC.

e) Industrial Water Supply/ "General Use"

Iowa's one general use numeric criterion (turbidity as NTU) appears to have a criterion-duration of an instant.

f) Agricultural Water Supply

Iowa's one general use numeric criterion (turbidity as NTU) appears to have a criterion-duration of an instant.

4) *Articulation of Criterion-Frequency*

All but one of the WQC for "traditional" pollutants lack a statement regarding a criterion-frequency, in which case a default frequency of zero is indicated. The exception is one of the criteria for temperature, which states: "...shall not exceed the maximum limits in the table below during more than one percent of the hours in the twelve month period ending with any month."

5) *Discussion: Traditional Pollutants/Parameters*[38]

Iowa has adopted numeric WQC for a relatively small portion of the pollutant/use combinations for which EPA has issued WQC. (EPA has issued such values for some two dozen pollutants, some of which have criteria for more than one use.) The most significant gap as to the state's coverage for traditional pollutants is the absence of numeric criteria for the nutrients phosphorous and nitrogen. (There also is no criterion for chlorophyll a, an indicator of the density of algae in the water column.)

Despite lacking numeric criteria relevant to eutrophication, the state has included on its 303(d) list of impaired waters 21 for "algal growth" and sixteen for "nutrients." 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" are among the five most frequently mentioned causes of impairment for waters on state 303(d) lists nationwide, along with sediments/sedimentation, pathogens, mercury, and metals other than mercury).[39]

[38] 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."

[39] EPA National Section 303(d) List Fact Sheet: Causes of Impairment. Available at: (http://iaspub.epa.gov/waters/national_rept.control#TOP_IMP).

Iowa does have a "quasi-numeric" criterion (i.e., expressed as a specified change from background) for turbidity (NTU), and has identified turbidity as the reason for placing 28 waterbodies on its 303(d) list, along with another three waterbodies due to "sediment."

Iowa is one of a relatively small number of states that have replaced their freshwater fecal coliform criteria with one of the bacterial indicators (*E. coli* and enterococci) for which EPA has issued more current criteria. Iowa uses *E. coli*.

One unique feature of Iowa's set of water quality criteria is the inclusion of numeric criteria for *E. coli* bacteria applicable to "water which enters a sinkhole or losing stream segment." This "general water quality" criterion applies to such waters regardless of their designated use. Presumably, they are aimed at protecting persons who obtain their drinking water from private wells.

There are criteria for pH and turbidity (NTU) which seem to apply only to point source discharges (as opposed to nonpoint sources). None of the other WQC adopted by Iowa are conditioned in this manner, nor are any of those issued by EPA. Rather, if ambient conditions are worse than those described by a typical WQC, then the water is considered impaired for the designated use(s) to which the WQC applies, regardless of whether the lowered water quality is cause by one type of anthropogenic source versus another.

Neither in the WQS regulations, nor by reference to other documents, does the Iowa offer reasons to believe that the effects of these water quality parameters would be less likely to impair one or more designated uses when they originate from nonpoint sources, as opposed to point sources.

The criterion-concentrations in the WQC for traditional pollutants that Iowa has adopted are comparable to the criterion-concentrations in corresponding EPA criteria and those of other states, including those covered by this study. One rather unique feature of Iowa's ammonia criteria is that it specifies in the WQS regulations the periods of the year in which early life stages of aquatic organisms are presumed to be present in different categories of waters or individual waters. Like EPA's chronic ammonia criteria, Iowa's differs depending on whether or not such life stages are present.

A sizeable portion of the criterion-durations in the criteria for traditional pollutants are not clearly stated. Most of the state's WQC for "traditional pollutants" do not have clearly articulated criterion-frequencies.

Such lack of clarity regarding criterion-duration and/or criterion-frequency renders any attempt to determine the absolute level of protection afforded to the applicable designated use(s) an exercise with an inherent 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 (say 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 (say 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.

For example, Iowa's chronic aquatic life WQC for ammonia have criterion-concentrations equal to those of corresponding EPA WQC. The criterion-duration for EPA's chronic ammonia criteria is clearly stated as 30 days, while Iowa's WQS regulations just say that its chronic aquatic life criteria apply to "short term average conditions", without ever

quantitatively defining "short term." Hence, if one assumed that by "short term," Iowa meant "seven days," then its chronic ammonia WQC would be more protective than EPA's, assuming the criterion-frequencies are identical. If one takes Iowa's criterion-frequency to be zero, while EPA's is clearly once in three years, then this would render Iowa's WQC more protective to an even greater degree. On the other hand, if "short term" meant 45 days, for instance, then if the state and EPA had identical criterion-frequencies, Iowa's chronic ammonia WQC would be less protective. The situation becomes more difficult if the duration were 45 days (or any other period longer than the 30-day duration for the EPA WQC) and Iowa's criterion-frequency were assumed to be zero, as compared to EPA's once in three years. It would be impossible say whether the Iowa ammonia WQC were more, equally, or less protective than the EPA criteria, without having toxicity data on the effect of the specific combination of concentration, duration, and frequency specified by the Iowa WQC. In the absence of such data, there is no way to know the degree to which the less-protective effect of the longer duration in Iowa's criteria would be offset by the more-protective effect of the lower criterion-frequency.

Also, 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.[40] Iowa's acute dissolved oxygen aquatic life WQC for cold water habitats (criterion-concentration of 7.0 mg/L) and for warm water habitats (criterion-concentration of 5.0 mg/L) are an example of incorporation of such differences among waterbodies into the WQC setting process.

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 WQC (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, "not too high" or "levels no greater than approximately 40 µg/L - 60 µg/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, analyzed for levels of a certain pollutant, and met the state's quality assurance/quality control requirements, and one of those samples had a concentration higher than a relevant criterion-concentration, the answer to the question, "was this pollutant exceeded 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.[41] 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 said samples were collected. And, if the criterion-frequency were

[40] 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.

[41] This statement assumes that all four of the samples passed the state's quality assurance/quality control (QA/QC) tests.

"two or more times per year," then one might not conclude that WQC exceedence had occurred based on the above evidence.[42]

D. Toxic Chemicals

1) *Coverage*

a) Aquatic Life/ "Cold Water Aquatic Life (B(CW))," "Warm Water-Type 1 (B(WW-1))", "Warm Water-Type 2(B(WW-1))," Warm Water-Type 3(B(WW-1")), and "Lakes and Wetlands (B(LW))"

Instead of a singular aquatic life use designation, Iowa has specified separate categories of aquatic life use designations to specifically protect warm water aquatic communities, coldwater aquatic communities, and lake and wetland aquatic communities. In particular, the state has specified the use designation B(LW) and applicable criteria to protect lake and wetland aquatic communities. To protect warm water aquatic communities, Iowa has specified the use designations "B(WW-1)," "B(WW-2)," and "B(WW-3)" and applicable WQC for each of these designate uses. To protect coldwater aquatic communities, the state has specified the use designations "CW-1" and "CW-2". However, the distinction between these two designated uses is unclear. Furthermore, Iowa has only specified criteria for toxic pollutants that apply to waters with the "CW-1" use designation and has not specified any WQC to be applicable to waters with the "CW-2" use designation.

As a consequence, the total number of sets of acute and chronic aquatic life WQC for toxics adopted by Iowa is considerably higher (nearly 300: 153 acute and 140 chronic), than the number of toxic pollutants for which there are acute and/or chronic aquatic life WQC (31). This report focuses on the number of pollutants for which states have at least one WQC of a certain general type, such as aquatic life, rather than the total number of criteria taking into account subcategories of a generic designated use, such as protection of aquatic life.

Acute Toxicity

Iowa has adopted at least one acute aquatic life WQC for each of 31 toxic pollutants. Of the 31 toxic pollutants for which EPA has issued[43] acute aquatic life criteria, Iowa has not adopted corresponding criteria for five pollutants (Appendix B, Table 2). Of these missing pollutants, one pollutant, tributyltin, has been mentioned among those chemicals that could be endocrine disruptors.

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[42] 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 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.

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

On the other hand, Iowa has adopted acute aquatic life criteria to protect cold and warm water aquatic communities for eight pollutants for which EPA has not issued corresponding criteria pursuant to Section 304(a) of the CWA (Appendix B, Table 1).

Chronic Toxicity

Iowa has adopted at least one chronic aquatic life WQC for each of 28 toxic pollutants. Of the 35 toxic pollutants for which EPA has issued *chronic* aquatic life criteria, Iowa has not adopted corresponding criteria for ten pollutants (Appendix B, Table 2). These "missing" pollutants are a combination of synthetic organophosphate pesticides, organochloride pesticides, and toxic metals.

On the other hand, state has adopted chronic aquatic life criteria protect cold and warm water aquatic communities for seven pollutants for which EPA has not published corresponding criteria pursuant to Section 304(a) of the CWA (Appendix B, Table 1).

(Note: Iowa is listed as having an extra WQC for total residual chlorine, while also listed as missing WQC for "chlorine". EPA has criteria for "chlorine," but not for total residual chlorine. Though these are obviously quite similar parameters, they are not exactly the same. On the other hand, one could reasonably say simply that both Iowa and EPA have acute and chronic life WQC for some form of chlorine.)

b) Human Health: Consumption of Fish and Other Aquatic Organisms/"Human Health – Fish" [44]

Iowa has not adopted Human Health – Fish criteria for 56%, or 59 pollutants, of the total 106 pollutants for which EPA has issued corresponding Human Health: Organisms (HHO) criteria (Appendix B, Table 3). These "missing" pollutants are mostly synthetic organic chemicals, including many organophosphate pesticides, organochloride pesticides, herbicides, and toxic metals.

On the other hand, the state has adopted Human Health – Fish criteria for 54 pollutants to protect consumption of fish tissue. Of those, there are seven pollutants for which EPA has not issued corresponding (HHO) Section 304(a) criteria. They are 1,1,1-trichloroethane, cadmium, chromium (VI), copper, endosulfan[45], mercury (II)[46], and polynuclear aromatic hydrocarbons (PAHs).

c) Human Health: Consumption of: 1) Water plus 2) Fish and Other Aquatic Organisms/ "Human Health – Fish & Water"[47]

[44] Iowa has a set of criteria comparable to EPA's set of "Human Health: Organisms Only" criteria, which it calls "Human Health – Fish." These criteria are intended to address human health risks from consumption of fish and other aquatic organisms from surface waters. Such criteria are also referred to as "fish consumption" criteria in this review and elsewhere.

[45] While EPA does not have an HHO criterion for "endosulfan" as does Iowa, it has separate, though identical, HHO criteria for endosulfan sulfate, alpha and beta forms of endosulfan.

[46] While EPA does not have an HHO criterion for "mercury (II)" as does Iowa, it has a criterion for methylmercury to protect human consumption of aquatic organisms from surface waters.

[47] Iowa has a set of criteria comparable to EPA's set of "Human Health: Water and Organisms" criteria, which it calls "Human Health – Fish and Water." These criteria are intended for the protection of people who consume both water and aquatic organisms from surface waters.

Iowa has not adopted Human Health – Fish and Water criteria for approximately 53%, or 60 pollutants, of the total 113 toxic pollutants for which EPA has issued corresponding Human Health: Water and Organisms (HHWO) criteria (Appendix B, Table 4). These "missing" pollutants are mostly synthetic organic chemicals, including many organophosphate pesticides, organochloride pesticides, herbicides, and toxic metals.

On the other hand, the state has adopted Human Health – Fish and Water criteria for 56 pollutants to protect consumption of water in combination with fish tissue. Of those, there are three pollutants for which EPA has not issued corresponding (HHWO) Section 304(a) criteria. They are endosulfan,[48] mercury (II), and polynuclear aromatic hydrocarbons (PAHs)[49].

d) Human Health: Drinking Water Supply

Iowa has not adopted drinking water supply criteria (applicable to "Class C" waterbodies) for 63%, or 53 pollutants (Appendix B, Table 5), of the total 84 toxic pollutants for which EPA has promulgated primary drinking water standards (aka MCLs) pursuant to the Safe Drinking Water Act.[50]

On the other hand, of the 32 pollutants for which Iowa has adopted drinking water criteria, there is one pollutant for which EPA has not issued a corresponding MCL criterion: nitrate plus nitrite as N.

e) Human Health: Water-based Recreation

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to water-based recreational use. Similarly, EPA has no WQC for toxic chemicals applicable to water-based recreation.

f) Industrial Water Supply

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to the use of waterbodies as a water supply for industrial operations. Similarly, EPA has no WQC for toxic chemicals applicable to this use.

g) Agricultural Water Supply (for irrigation and/or livestock watering)

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to the use of waterbodies as a water supply for agricultural operations. Similarly, EPA has no WQC for toxic chemicals applicable to this use.

[48] While EPA does not have a HHWO criterion for "endosulfan" as does Iowa, it has separate, though identical, HHWO criteria for endosulfan sulfate and the alpha and beta forms of endosulfan.

[49] While EPA does not have a HHWO criterion for total "PAHs" as does Iowa, it has issued separate and identical WQC for benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and ideno(1,2,3-cd)pyrene.

[50] Six of the missing pollutants are pollutants for which EPA has issued secondary drinking water standards.

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

a) Aquatic Life: "Cold Water Aquatic Life (B(CW-1))," **"Warm Water-Type 1 (B(WW-1)),"** **"Warm Water-Type 2 (B(WW-2)),"** **Warm Water-Type 3 (B(WW-3)),"** **and "Lakes and Wetlands B(LW))"**

Because Iowa has a number of subcategories of aquatic life uses, along with corresponding WQC, in addition to the usual approach in this study of doing counts according to the number of pollutants with criterion-concentrations equal to, higher than, or lower than the corresponding EPA WQC (see below under acute and chronic WQC), this description of Iowa's criterion-concentrations for it's aquatic life WQC starts with counts of criteria. That is, the following paragraphs address characteristics of the entire set of aquatic life WQC, of which there are 293 total,153 acute and 140 chronic. By contrast, these nearly 300 WQC address levels of just 31 toxic pollutants.

For several pollutants (aldrin, chloropyrifos, dieldrin, heptachlor epoxide, lindane (gamma-BHC), parathion, pentachlorophenol, PCBs, trichloroethylene) the criterion-concentration is the same for all subcategories of aquatic life uses for which Iowa has published criteria. The chronic, but not the acute, WQC for heptachlor have the same criterion-concentration across all five subcategories of aquatic life use. For PAHs, the reverse is true: the criterion-concentration of all five acute aquatic life WQC are identical, while there are differences across the chronic criteria.

With the exception of one pollutant (toluene), the criterion-concentrations of the WQC applicable to the three warm water aquatic life DUs ["B(WW-1)", "B(WW-2)", "B(WW-3)"] are identical to one another. That is, the criterion-concentrations in these criteria do not change from one warm water subcategory to another. This is true for both the 93 acute and the 87 chronic WQC applicable to these three subcategories of aquatic life use. In the case of toluene, the criterion-concentration for waters classified B(WW-1) is lower than the criterion-concentration for waters classified B(WW-2) or B(WW-3).

In contrast, there are differences when the criterion-concentrations in the warm water aquatic life criteria are compared to those in the coldwater aquatic life criteria [Class B(CW-1)] and the lakes and wetlands criteria [B(LW)]. Of the 150 cold water aquatic life WQC (total of acute plus chronic), some 34 of these B(CW-1) WQC have criterion-concentrations different from the criterion-concentration for the corresponding warm water subcategories. Of these, there are a dozen B(CW-1) WQC with concentrations lower than the corresponding warm water criteria. The rest of the CW-1 criteria have criterion-concentrations higher than those of the corresponding warm water aquatic life subcategories.

As for the total number (acute and chronic) of 56 WQC for lakes and wetlands WQC, 30 of these have criterion-concentrations that differ from the concentrations for comparable warm water WQC. Out of these thirty, ten (or one-third) have criterion-concentrations lower than that of the corresponding warm water WQC. The other two-thirds have higher criterion-concentrations compared to their warm water counterparts.

As well, there are differences when the criterion-concentration in the coldwater aquatic life criteria [B(CW-1)] are compared to the criterion-concentration in the criteria for lakes and wetlands aquatic life [B(LW)], for 21 criteria. Of these, five of the cold water WQC have criterion-concentrations lower than the corresponding criteria for lakes and wetlands. The

remaining sixteen CW-1 criteria have concentrations higher than their lakes and wetlands counterparts.

In comparison to EPA's criteria, the criterion-concentrations in most of Iowa's aquatic life criteria are equal to those in the corresponding EPA's 304(a) freshwater aquatic life criteria (for both acute and chronic WQC). Given that Iowa has several different sub-categories of aquatic life for which there are WQC, in order to simplify, this analysis deals only with one of the three warm water subclasses (Class B(CW-1)) and one cold water use (Class B(CW-1))

Acute Criteria

Of the 31 pollutants for which Iowa has adopted acute aquatic life criteria for toxics applicable to waters in class B(WW-1), there are 26 for which there are corresponding EPA criteria.[51] Within this group, there are nineteen pollutants with acute criterion-concentrations that are equal to EPA's, no pollutants with acute criterion-concentrations that are lower than EPA's (Appendix B, Table 7), and five pollutants with acute criterion-concentrations that are higher than EPA's (Appendix B, Table 6).

Of the 31 pollutants for which Iowa has adopted acute aquatic life criteria for toxics applicable to waters in class B(CW-1), there are 26 for which there are corresponding EPA criteria.[52] Within this group, there are nine pollutants with acute criterion-concentrations that are equal to EPA's, four pollutants with acute criterion-concentrations that are lower than EPA's (Appendix B, Table 7), and thirteen pollutants with acute criterion-concentrations that are higher than EPA's (Appendix B, Table 6).

Chronic Criteria

Of the 30 pollutants for which Iowa has adopted chronic aquatic life criteria applicable to waters in class B(WW-1) there are 24 pollutants for which there are corresponding EPA criteria.[53] Within this subset, there are nineteen pollutants with criterion-concentrations that are equal to EPA's, no pollutants with criterion-concentrations that are lower than EPA's (Appendix B, Table 7), and five pollutants with criterion-concentrations that are higher than EPA's (Appendix B, Table 6).

Of the 30 pollutants for which Iowa has adopted chronic aquatic life criteria applicable to waters in class B(CW-1) there are twenty-three pollutants for which there are corresponding EPA criteria.[54] Within this subset, there are ten pollutants with criterion-concentrations that are

[51] Iowa has aquatic life WQC for total residual chlorine (TRC), while EPA's closest corresponding WQC are for chlorine. Because these two parameters are not exactly identical, comparison of the criterion-concentrations may not be totally appropriate. Nevertheless, we note that both the state Class B(WW-1) use and EPA acute WQC have the same criterion-concentration.

[52] Iowa has aquatic life WQC for total residual chlorine (TRC), while EPA's closest corresponding WQC are for chlorine. Because these two parameters are not exactly identical, comparison of the criterion-concentrations may not be totally appropriate. Nevertheless, it is worth noting that Iowa's acute cold water aquatic life WQC (Class B(CW-1)) has a higher concentration than that of the corresponding EPA criterion.

[53] Iowa has aquatic life WQC for total residual chlorine (TRC), while EPA's closest corresponding WQC are for chlorine. Because these two parameters are not exactly identical, comparison of the criterion-concentrations may not be totally appropriate. Nevertheless, we note that both the state Class B(WW-1) and EPA chronic WQC have the same criterion-concentration .

[54] Iowa has aquatic life WQC for total residual chlorine (TRC), while EPA's closest corresponding WQC are for chlorine. Because these two parameters are not exactly identical, comparison of the criterion-concentrations may not

equal to EPA's, two pollutants with criterion-concentrations that are lower than EPA's (Appendix B, Table 7), and eleven pollutants with criterion-concentrations that are higher than EPA's (Appendix B, Table 6).

b) Human Health: Consumption of Fish and Other Aquatic Organisms / "Human Health – Fish" [55]

Of the 54 toxic pollutants for which Iowa has adopted Human Health – Fish criteria, there are 47 pollutants[56] for which there are corresponding HHO EPA WQC. Within this subset, the criterion-concentrations in the WQC for 45 pollutants are equal to EPA's recommended values[57] and the criterion-concentration in the WQC for two pollutants (1,2-trans-dichloroethylene and DDD) are lower than EPA's.

c) Human Health: Consumption of: 1) Water plus 2) Fish and Other Aquatic Organisms /"Human Health – Fish & Water" [58]

Of the 56 pollutants for which Iowa has adopted Human Health – Fish and Water criteria, there are 53 pollutants[59] for which there are corresponding HHWO EPA recommended WQC. Of these, the criterion-concentrations for 52 pollutants are equivalent to EPA's recommended values,[60] and criterion-concentration for one pollutant, DDD, is lower than EPA's.

d) Human Health: Drinking Water Supply

Of the 32 toxic pollutants for which Iowa has adopted drinking water supply criteria applicable to "Class C" waters in the state, there are 31 pollutants[61] for which there also are

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be totally appropriate. Nevertheless, we note that the state Class B(CW-1) WQC has a higher criterion-concentration than and EPA chronic WQC.

[55] Iowa has a set of criteria comparable to EPA's set of "Human Health: Organisms Only" criteria, which it calls "Human Health – Fish." These criteria are intended to address human health risks from consumption of fish and other aquatic organisms from surface waters. Such criteria are also referred to as "fish consumption" criteria in this review and elsewhere.

[56] The other seven pollutants are those for which EPA has not issued HHO criteria.

[57] Of the pollutants with human health: organisms/ "human health: fish" criteria that are equivalent to EPA's recommended WQC, there are 26 pollutants which Iowa considers to be carcinogenic (Appendix B, Table 9). Strict numerical comparison of the concentrations appearing in the state's WQC tables with those in EPA's summary table for Section 304(a) criteria (http://www.epa.gov/waterscience/criteria/nrwqc-2006.pdf) would show that the criterion-concentrations for the Iowa criteria covering these carcinogenic pollutants are greater than the EPA's values by exactly ten fold. However, this is because Iowa assumes an incremental cancer risk level of 10^{-5} for human health criteria that cover carcinogenic pollutants/parameters, while the EPA's criteria for these pollutants shown are based a 10^{-6} cancer risk level. (EPA accepts assumptions of cancer risk level within the range of 10^{-5} to 10^{-7}.) Hence, it is more instructive to compare Iowa's numeric human health WQC to the EPA values that are based on a 10^{-5} cancer risk level. The Iowa criterion-concentrations for those 26 carcinogenic pollutants are *equal to* EPA's 10^{-5} values.

[58] Iowa has a set of criteria comparable to EPA's set of "Human Health: Water and Organisms" criteria, which it calls "Human Health – Fish and Water." These criteria are intended to address human health risks from consumption of fish and water.

[59] The other three pollutants are those for which EPA has not issued HHWO criteria.

[60] See footnote 45 regarding cancer risk levels associated with Iowa's human health: organisms/ "human health: fish" criteria.

[61] The remaining pollutant, nitrate plus nitrite as N, is one for which the EPA has not issued an MCL criterion.

Primary Drinking Water Standards (MCLs) established by EPA under the authority of the Safe Drinking Water Act. Within this subset, the criterion-concentrations for 28 pollutants are equal to EPA's corresponding MCL values; the criterion-concentration for two pollutants (silver and Silvex) are lower than EPA's MCL values; and the criterion-concentration for one pollutant (lead) is higher than the EPA's MCL value.

e) Human Health: Water-based Recreation

Not applicable. Iowa does not have WQC for toxic chemicals pertaining to water-based recreational use. Similarly, EPA has no WQC for toxic chemicals applicable to water-based recreation.

f) Industrial Water Supply

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to the use of waterbodies as a water supply for industrial operations. Similarly, EPA has no WQC for toxic chemicals applicable to this use.

g) Agricultural Water Supply

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to the use of waterbodies as a water supply for agricultural operations. Similarly, EPA has no WQC for toxic chemicals applicable to this use.

3) *Articulation of Criterion-Durations*

None of Iowa's numeric water quality criteria for toxic chemicals have clearly stated criterion-durations.

a) Aquatic Life/ "Cold Water Aquatic Life," "Warm Water-Type 1," "Warm Water-Type 2," Warm Water-Type 3," "Lakes and Wetlands"

Acute criteria

With reference to Table 1 in the Iowa WQS regulations ("Criteria for Chemical Constituents"), Section 567.61.3(3)(b)(3)(1) states, "Instream concentrations above the acute criteria will be allowed only within the boundaries of the zone of initial dilution." This language provides no indication of any specific duration that applies to the criteria-concentrations listed in Table 1; hence, a default assumption of an instantaneous duration appears to be appropriate.

A duration of one day (though it could be one hour) could perhaps be inferred from the $1Q_{10}$ stream design low flows parameter specified in Section 567.61.2(5).

Chronic criteria

With reference to Table 1 in the WQS regulations ("Criteria for Chemical Constituents"), Section 567.61.3(3)(b)(3)(2) states, "Excursions above the chronic criteria will be allowed only

inside of mixing zones or for short term periods outside of mixing zones. The chronic criteria will be met as short term average conditions at all times the flow equals or exceeds the design flow."

The term "short term period" is not defined here or elsewhere in the regulations; hence it could be taken to mean anything from minutes, to an hour, to days, weeks, or even months.

A duration of seven days could perhaps be inferred from the $7Q_{10}$ stream design low flows specified in Section 567.61.2(5).

b) Human Health: Consumption of Fish and Other Aquatic Organisms / "Human Health – Fish" [62]

With reference to Table 1 in the WQS regulations ("Criteria for Chemical Constituents"), Section 567.61.3(3)(b)(3)(3) states, "Instream concentrations in excess of the human health criteria will be allowed only within the boundaries of the mixing zone." This language provides no indication of any specific duration that applies to the criteria-concentrations listed in Table 1; hence, a default assumption of an "instantaneous" duration appears appropriate.

Given that Iowa's WQS regulations clearly specify that the state's human health criteria are based on EPA's 304(a) criterion, once might assume that the same duration applicable to the EPA criteria would apply to the state's. Unfortunately, EPA guidance regarding a criterion-duration for its human health criteria is unclear. Some text strongly suggests an instantaneous duration, while other portions of relevant guidance seem to indicate durations of either a year (365 days, not a calendar year), or even 70 years (average human life span).

The criterion-duration applicable to Iowa's criteria for Human Health Protection could also perhaps be inferred from the design low flows parameter specified in Section 567.61.2(5), with regard to application of the state's human health criteria. The harmonic mean stream flow parameter is the design flow parameter to be used when applying the human health criteria for carcinogenic chemicals. This suggests a criterion expressing some sort of long term average concentration. In such a case, the criterion-duration would be determined by the period of time over which stream flow data is available for a given waterbody.

Section 567.61.2(5) specifies use of the 30Q5 as the design stream flow parameter for applying criteria for non-carcinogens. This could imply a duration of 30 days.

c) Human Health: Consumption of: 1) Water plus 2) Fish and Other Aquatic Organisms/"Human Health – Fish and Water"

A default criterion-duration of an instant has been assumed for purposes of this study, though there is basis for other possible assumptions. (See discussion under Subsection D(3)(b) immediately above.)

[62] Iowa has a set of criteria comparable to EPA's set of "Human Health: Organisms Only" criteria, which it calls "Human Health – Fish." These criteria are intended to address human health risks from consumption of fish and other aquatic organisms from surface waters. Such criteria are also referred to as "fish consumption" criteria in this review and elsewhere.

d) Water-based Recreation

Not applicable. Iowa does not have any WQC for toxic chemicals to address human health risks associated with various types of water-based recreation. Similarly, Iowa has no WQC for toxic chemicals applicable to water-based recreation.

e) Industrial Water Supply

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to the use of waterbodies as a water supply for industrial operations.

f) Agricultural Water Supply

Not applicable. Iowa does not have any WQC for toxic chemicals pertaining to the use of waterbodies as a water supply for agricultural operations.

4) *Articulation of Criterion-Frequency*[63]

None of Iowa's numeric WQC for toxic chemicals has explicitly specified criterion-frequencies. In the absence of such specificity in the state's own regulation, this study employs a default criterion-frequency of zero.

A criterion- frequency of once-in-ten-years for aquatic life criteria could perhaps be inferred from the stream design low flows parameter specified in Section 567.61.2(5), with regard to the Aquatic Life Protection-Acute ($1Q_{10}$) criteria and with regard to Aquatic Life Protection-Chronic ($1Q_{10}$) criteria. Following to this logic, the criterion-frequency for the state's human health criteria for non-carcinogens would be once in five years, since a stream design flow of $30Q_5$ is indicated.

The harmonic mean flow stipulated for human health criteria for carcinogens would seem to render the concept of a criterion-frequency moot, which supports this report's default frequency of zero for such criteria.

5) *Discussion: Criteria for Toxic Pollutants*[64]

[63] 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 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 , say, 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.

[64] In this report, the term "toxic pollutant" includes not only EPA's "priority" toxic pollutants but also all those toxics called – for CWA purposes – "non-priority" pollutants, as well as all toxic chemicals falling into neither of these two EPA classifications. The one exception is ammonia, which is addressed under "traditional pollutants" in this report.

While Iowa has adopted WQC for a number of toxic pollutants for which EPA has adopted acute and chronic aquatic life criteria, there are several pollutants for which EPA has published aquatic life criteria while the state has not. Among these pollutants, there are more of those with missing state chronic aquatic life criteria than there are those with missing acute state aquatic life criteria. Furthermore, the pollutants with missing state aquatic life WQC are mostly organochloride pesticides (e.g., methoxyclor, mirex) and organophosphate pesticides (e.g., malathion, demeton, diazinon). Also among those lacking state aquatic life WQC are tributyltin and methoxychlor, which both fall into categories that are frequently mentioned as possible endocrine disruptors.

Iowa has established separate categories of aquatic life use designations and criteria to specifically protect warm water aquatic communities, coldwater aquatic communities, and lake and wetland aquatic communities. One feature worth noting is that while the state has two separate use designations aimed at protecting coldwater aquatic communities, labeled "CW-1" and "CW-2", it is not clear from the current WQS regulations what the distinction between these two use designations might be. Furthermore, Iowa has only specified WQC for toxics that apply to waters designated as belonging to the "CW-1" category and has not specified any WQC covering toxic chemicals for the "CW-2" category.

With regards to human health risks, Iowa lacks criteria for slightly less than one-half of the toxic pollutants for which EPA has issued criteria to address risks from human consumption of fish tissue alone and from consumption of water and fish tissue combined. Among the pollutants without human health-related criteria for fish consumption alone as well as criteria for fish and water consumption are synthetic organic carcinogens (e.g., 1,3-dichloropropene, acrylonitrile, 2,4-dinitrotoluene, etc.) and highly bioaccumulative substances (e.g., alpha-BHC, 1,2,4,5-tetrachlorobenzene, and hexachlorobutadiene).

In theory, the absence of a human health criterion for a pollutant might not be important in ensuring that people are protected from exposure (via ingestion of drinking water and/or aquatic organisms) to levels of that pollutant which would pose a significant risk. In particular, if the state has an acute and/or a chronic aquatic life criterion for the pollutant that has a lower criterion-concentration than the criterion of the EPA human health criteria for the pollutant of concern, attainment of the aquatic life criterion should ensure that waterbody levels of the pollutant would remain below those specified in EPA's human health criteria. However, this is not relevant to Iowa because there are no pollutants for which the state is missing human health criteria, but does have aquatic life criteria. Indeed, of all those pollutants for which Iowa lacks human health criteria, none has an aquatic life criterion.

Turning to criterion-concentrations, while Iowa has specified criteria for toxic chemicals for three separate subsets of warm water aquatic life, the criterion-concentrations in these criteria for a given pollutant usually do not change from one warm water subset to another. In contrast, there are differences between the criterion-concentrations in the state's warm water aquatic life criteria and those in its coldwater aquatic life criteria ("CW-1") and its lakes and wetlands criteria ["B(LW)"]. There are also differences between the criterion-concentrations in state's coldwater aquatic life criteria ("CW-1") and those in its criteria for lakes and wetlands aquatic communities ["B(LW)"].

When compared to EPA's criteria, the criterion-concentrations in most of Iowa's warm water aquatic life criteria are equal to those in EPA's 304(a) acute and chronic freshwater aquatic life criteria. In contrast, a significant fraction of the pollutants for which Iowa has specified cold water aquatic life criteria have criterion-concentrations that are higher than those EPA's

freshwater aquatic life criteria. This same pattern applies to the criterion-concentrations in the state's aquatic life criteria for lakes and wetlands.

Having accounted for all of the variations across the different subsets of the state's aquatic life criteria, it seems that most of Iowa's acute and chronic aquatic life criteria for toxic chemicals have criterion-concentrations that are either equal to or higher than the criterion-concentrations for the corresponding EPA values. There are also a few toxic pollutants with acute and/or chronic aquatic life criteria for which the criterion-concentration are lower than EPA's.

Where numeric human health criteria covering toxic pollutants have been specified in Iowa's WQS regulations, the state has adopted criterion-concentrations that have been recommended by EPA for all of the pollutants it considers to be non-carcinogenic. With regards to known or suspected carcinogens (Appendix B, Table 9), Iowa has adopted human health criteria for which the criterion-concentrations are exactly the same as those in the corresponding EPA's recommended values based on a target of a one (1) in 100,000 ($10^{-5)}$ cancer risk level.

To protect waters designated drinking water supply sources, the Iowa has adopted WQC for more than one-third of the pollutants for which EPA has published MCL values. The criterion-concentrations in the WQC for all but one of these pollutants, silver, are equal to EPA's MCL values.

As for the other two elements of numeric WQC besides the criterion-concentration, none of Iowa's criteria for toxic chemicals, either those applying to aquatic life or human health, have a clearly articulated criterion-duration. In some cases, such as the acute aquatic life criteria and the three categories of human health WQC, no direct mention is made of a criterion-duration or an averaging period. With the chronic aquatic life criteria for toxics, an averaging period is specified, but it stated simply as "short term," which could mean anything from minutes to hours to days, or even longer.

Likewise, none of the state's WQC for toxic chemicals applicable to either aquatic life or human health uses mention a criterion-frequency. For purposes of this report, an assumed criterion-frequency of zero is used.

Given that none of Iowa's numeric aquatic life WQC for toxic chemicals have clearly stated criterion-durations or clearly stated criterion-frequencies, directly comparing the state's criterion-concentrations to those of EPA's is not a reliable means of determining the relative protectiveness of their water quality criteria. However, if one assumes that the criterion-durations and criterion-frequencies for Iowa's aquatic life WQC are the same as those for EPA's aquatic life criteria (acute duration of one hour, chronic duration of 96 hours; frequency of once in three years), then one would conclude that those Iowa aquatic life criteria having higher criterion-concentrations than EPA's are less protective than EPA's, while those with lower criterion-concentrations than EPA's are more protective.

Also, 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 was designed. For instance, the level of a given pollutant consistent with a healthy ecosystem can vary significantly from one waterbody to another. If, for example, a waterbody has naturally high iron, the plants and animals inhabiting it will have evolved to live in such conditions, even though organisms living in a river or lake with a lower natural level of iron could be severely stressed by exposure to such higher levels. Differences, from one waterbody to another, in the mix of indigenous species also could explain the need for

criteria with different concentrations, as could differences in waterbody chemistry affecting the bioavailability of metals and other chemicals. Such site-specific differences could result in the need for higher or lower criterion-concentrations compared to a statewide or EPA nationwide WQC, in order to provide equal levels of protection for organisms in a given type of waterbody.[65]

Indeed, Iowa has taken such differences into account when setting it's acute and chronic aquatic life water quality criteria for a number of toxic substances. The state has four subcategories of aquatic life use: 1) cold water, 2) warm water, 3) limited warm water, and 4) lakes and wetlands. The aquatic life WQC for some toxics have a different criterion-concentration for each of the subcategories. For instance, for aluminum, the acute criterion for cold waters is 1106 ug/L, for warm water it's 750 ug/L, and for lakes and wetlands the concentration is 983 ug/L.

The lack of clearly stated criterion-durations and criterion-frequencies is also a factor for each of the three categories of Iowa WQC addressing human health effects of toxic chemicals: human health – fish, human health – fish and water, and drinking water supply. Even though the criterion-concentrations in most of Iowa's human health criteria for toxic chemicals are numerically equivalent to those in EPA's, it is not entirely certain that the state's human health criteria are as protective as EPA's, because none of Iowa's numeric WQC for toxic chemicals have a clearly-stated duration or criterion-frequency. Nevertheless, one might assume – based on language in the Iowa's WQS regulations stating clearly that the state's human health criteria are based on EPA's 304(a) human health criteria – that the criterion-durations and criterion-frequencies in Iowa's human health criteria for toxic chemicals are identical to those of the corresponding EPA criteria. Using such an assumption, it appears that most of the Iowa's human health criteria for toxic pollutants would be as protective as EPA's. However, this conclusion is compromised by the fact that EPA's guidance regarding the criterion-duration of its human health criteria is unclear and subject to multiple interpretations.

Another point regarding the degree of protection provided by the state's fish consumption-related criteria (Human Health – Fish and Human Health – Fish and Water) is that 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. This estimate is based on national data, and represents the average rate of fish consumption. However, there are subpopulations that consume locally-caught "fish" at considerably higher rates. 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 the HHO and HHWO criteria need to be set at lower levels than that which has been set by EPA.

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[65] Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (say, a duration of 96 hours, a frequency of 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. However, due to site-specific or watershed-specific conditions, 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.

It does not seem that such differences in fish consumption patterns have been taken into account in establishing either of Iowa's sets of WQC for toxics that address potential human exposure via eating fish and other aquatic organisms, Human Health – Fish criteria and Human Health – Fish and Water criteria. For both these sets of WQC, there is no difference in the criterion-concentrations from one waterbody to another. That is, for Human Health – Fish WQC, the criterion-concentration for a given toxic substance is the same for all waterbodies in the state. The same is true with regard to Iowa's Human Health – Fish and Water criteria.

As previously noted, lack of clarity regarding any of the three elements of a numeric water quality criteria makes judgments about the relative level of protection provided by one criterion versus another difficult, if not impossible. In addition, lack of clearly stated criterion-durations and criterion-frequencies can result in lack of consistency 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 for 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 regarding 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.

Appendix A

Missing and Extra Criteria for Traditional Pollutants: IOWA

Table 1 - Aquatic Life

i) MISSING[66] POLLUTANTS (US EPA-Y/STATE-N)

	ACUTE	CHRONIC
Warm/cold water[67]	calcium carbonate. D.O.	chlor a dissolved gases hydrogen sulfide nitrogen(total) phosphorous(tot.) turbidity (NTU) turbidity (Secchi)

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ii) EXTRA POLLUTANTS[68] (US EPA-N/STATE-Y)

	ACUTE	CHRONIC
Warm/cold water	temperature temperature	D.O.

[66] For the purpose of this review, "missing pollutants" are those pollutants for which US 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 US EPA a set of state-adopted changes but US EPA has either not acted on the changes or has disapproved the changes, this fact is noted in this document.

[67] US EPA's criteria do not distinguish between warm and cold water.

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

Table 2 - Drinking Water Supply[69]

i) MISSING POLLUTANTS

ACUTE	CHRONIC
total coliforms	color foaming agents odor pH (dissolved) solids sulfate

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
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Table 3 - Water-Contact Recreation

i) MISSING POLLUTANTS

	ACUTE	CHRONIC
Primary Contact		Enterococci
Secondary Contact		Enterococci
Children's Recreation		Enterococci

ii) EXTRA POLLUTANTS

	ACUTE	CHRONIC
Primary Contact	E. coli	--
Secondary Contact	E. coli	E. coli
Children's Recreation	E. coli	E.coli
Waters entering sinkholes & Losing Stream Segments	E. coli	E.coli

[69] US 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 US 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.

Table 4 – Non-contact Recreation

i) MISSING POLLUTANTS

	ACUTE	CHRONIC

ii) EXTRA POLLUTANTS

	ACUTE	CHRONIC
turbidity(NTU)[70]		---

Table 5 – Livestock and Wildlife Watering

i) MISSING POLLUTANTS

	ACUTE	CHRONIC

ii) EXTRA POLLUTANTS

	ACUTE	CHRONIC
turbidity(NTU)[71]		---

Table 6 – Irrigation

i) MISSING POLLUTANTS

	ACUTE	CHRONIC

ii) EXTRA POLLUTANTS

	ACUTE	CHRONIC
turbidity(NTU)[72]		---

[70] Id. at 4
[71] Id. at 4
[72] Id. at 5

Appendix B

Table 1

	Aquatic Life Protection - Freshwater	
	Acute	*Chronic*
EXTRA POLLUTANTS: Pollutants for which Iowa Has Adopted WQC where the US EPA Has Not	Endosulfan (total) Endosulfan sulfate PCBs Phenols Polynuclear Aromatic Hydrocarbons Toluene Total Residual Chlorine (TRC) Trichloroethylene	Endosulfan Endosulfan sulfate Phenols Polynuclear Aromatic Hydrocarbons (PAHs) Toluene Total Residual Chlorine Trichlooroethylene

Table 2

	Aquatic Life Protection	
	Acute	*Chronic*
MISSING POLLUTANTS: Pollutants for which US EPA Has Adopted WQC where Iowa Has Not	Chlorine Chromium (III) Diazinon Nonylphenol Tributyltin	Chromium (III) Chlorine Demeton Diazinon Guthion Heptachlor Iron Malathion Methoxychlor Mirex Nonylphenol Tributyltin

Table 3

	Human Health Organisms Only/ "Human Health – Fish"		
MISSING POLLUTANTS: Pollutants for which US EPA Has Adopted WQC where Iowa Has Not	1,1,2,2-Tetrachloroethane 1,1,2-Trichloroethane 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Diphenylhydrazine 1,3-Dichlorobenzene 1,3-Dichloropropene 1,4-Dichlorobenzene 2,4,6-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2-Chloronaphthalene 2-Chlorophenol 2-Methyl-4,6-Dinitrophenol Acenaphthene Acrolein Acrylonitrile Butylbenzyl Phthalate	Dibenzo(a,h)Anthracene* Diethyl Phthalate Dimethyl Phthalate Di-n-Butyl Phthalate Dinitrophenols Endrin Aldehyde Fluoranthene Fluorene Hexachlorobutadiene Hexachlorocyclo-hexane-Technical Hexachloroethane Ideno(1,2,3-cd)Pyrene* Isophorone Methyl Bromide alpha-BHC Anthracene Benzidine Benzo(a)Anthracene* Benzo(b)Fluoranthene*	Benzo(k)Fluoranthene* beta-BHC Bis(2-Chloroethyl)Ether Bis(2-Chloroisopropyl)Ether Ether, Bis(Chloromethyl) Methylene Chloride Methylmercury Nitrobenzene Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Nitrosopyrrolidine,N N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Pentachlorobenzene Pyrene Tetrachlorobenzene,1,2,4,5- Trichlorophenol,2,4,5
Total # of Pollutants	59		

* While Iowa does not have "human health: organisms only"/ "human health: fish" criteria for benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and ideno(1,2,3-cd)pyrene, the state has adopted a WQC for "Polynuclear Aromatic Hydrocarbons" as a sum of these individual PAHs. In contrast, while EPA has issued separate and identical WQC for individual PAHs, including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and ideno(1,2,3-cd)pyrene, it does not have a "human health: organisms only"/ "human health: fish" criterion for total PAHs.

Table 4

	Human Health Water and Organisms / "Human Health – Water & Fish"		
MISSING POLLUTANTS: Pollutants for which US EPA Has Adopted WQC where Iowa Has Not	1,1,2,2-Tetrachloroethane 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Diphenylhydrazine 1,3-Dichlorobenzene 1,3-Dichloropropene 2,4,6-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2-Chloronaphthalene 2-Chlorophenol 2-Methyl-4,6-Dinitrophenol Acenaphthene Acrolein Acrylonitrile alpha-BHC Anthracene Benzidine	Benzo(a)Anthracene* Benzo(b)Fluoranthene* Benzo(k)Fluoranthene* beta-BHC Bis(2-Chloroethyl)Ether Bis(2-Chloroisopropyl)Ether Butylbenzyl Phthalate Chlorophenoxy Herbicide (2,4,5,-TP) Chrysene* Dibenzo(a,h)Anthracene* Diethyl Phthalate Dimethyl Phthalate Di-n-Butyl Phthalate Dinitrophenols Endrin Aldehyde Ether, Bis(Chloromethyl) Fluoranthene Fluorene Hexachlorobutadiene Hexachlorocyclo-hexane-Technical	Hexachloroethane Ideno(1,2,3-cd)Pyrene Iron Isophorone Manganese Methyl Bromide Methylene Chloride Nitrates Nitrobenzene Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Nitrosopyrrolidine,N N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Pentachlorobenzene Pyrene Tetrachlorobenzene,1,2,4,5- Trichlorophenol,2,4,5-
Total # of Pollutants			60

* While Iowa does not have "human health: water and organisms"/ "human health: water and fish" criteria for benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and ideno(1,2,3-cd)pyrene, the state has adopted a WQC for "Polynuclear Aromatic Hydrocarbons" as a sum of these individual PAHs. In contrast, while EPA has issued separate and identical WQC for individual PAHs, including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and ideno(1,2,3-cd)pyrene, it does not have a "human health: water and organisms"/ "human health: water and fish" criterion for total PAHs.

Table 5

	Drinking Water Supply Criteria		
MISSING POLLUTANTS: Pollutants for which US EPA Has Adopted WQC where Iowa Has Not	1,1,2-Trichloroethane 1,2,4-Trichlorobenzene 1,2-Dichloroethane 1,2-Dichloropropane 2,4-D Alpha particles Antimony Arsenic Asbestos Barium Benzene Benzo(a)pyrene (PAHs) Beta particles & photon emitters Bromate Carbon tetrachloride Chloramines Chlordane Chlorine Chlorine dioxide Chlorite Cyanide (as free cyanide) Di(2-ethylhexyl) phthalate Dichloromethane	Endrin Ethylbenzene Haloacetic acids (HAA5) Heptachlor Heptachlor epoxide Hexachlorobenzene Hexachlorocyclopentadiene Lindane Mercury Methoxychlor PCBs p-Dichlorobenzene Pentachlorophenol Radium 226 and Radium 228 (combined) Selenium Tetrachloroethylene Thallium Toluene Toxaphene trans-1,2-Dichloroethylene Trichloroethylene Uranium Vinyl chloride	Dioxin (2,3,7,8-TCDD) Zinc (s) Aluminum (s) Copper (s) Iron (s) Manganese (s) Sulfate (s)
Total # of Pollutants			53

Note: Pollutants labeled with the "(s)" notation are those for which US EPA has issued secondary drinking water criteria.

Table 6

	Aquatic Life Protection - Fresh Water Class B (WW-1)		Human Health	
	Acute	*Chronic*	*Water and Organism*	*Organism Only*
Pollutants with a state criterion-concentration **higher** than EPA's	Cadmium Copper Lead Mercury (II) Silver	Cadmium Copper Lead Mercury (II) Toxaphene	---	---

Table 7

	Aquatic Life Protection - Fresh Water Class B (WW-1)		Human Health	
	Acute	*Chronic*	*Water and Organism*	*Organism Only*
Pollutants with a state criterion-concentration **lower** than EPA's			4,4'-DDD	1,2-Trans-Dichloroethylene 4,4'-DDD

Table 8

	Aquatic Life Protection—Fresh Water Class B (CW-1)	
	Acute	*Chronic*
Pollutants with a state criterion-concentration **higher** than US EPA's	Aluminum Arsenic (III) Cadmium Chromium (IV) Copper Endrin Lead Mercury Nickel Selenium (III) Silver Total Residual Chlorine Zinc	Arsenic (III) Cadmium Chromium (IV) Copper Endrin Lead Mercury Nickel Selenium (III) Toxaphene Zinc .

Table 9

	Aquatic Life Protection—Fresh Water Class B (CW-1)	
	Acute	*Chronic*
Pollutants with a state criterion-concentration **lower** than US EPA's	Cyanide DDT alpha-Endosulfan beta-Endosulfan Heptachlor	Chlordane Cyanide.

Table 10

	Human Health	
	Water and Organism	*Organism Only*
Pollutants designated as suspected or known carcinogens by Iowa	1,1,2-Trichloroethane 1,2-Dichloroethane 1,2-Dichloropropane 2,3,7,8-TCDD (Dioxin) 3,3'-Dichlorobenzidine 4,4'-DDT 4,4'-DDE 4,4'-DDD Arsenic (III) Benzene Benzo(a)Pyrene Bis(2-Ethylhexyl)Phthalate Bromoform Carbon Tetrachloride Chlordane Chlorodibromomethane Chloroform Dichlorobromomethane Dieldrin Heptachlor Heptachlor epoxide Hexachlorobenzene Pentachlorophenol PCBs Tetrachloroethylene Toxaphene Trichloroethylene Vinyl Chloride	1,2-Dichloroethane 1,2-Dichloropropane 2,3,7,8-TCDD (Dioxin) 3,3'-Dichlorobenzidine 4,4'-DDT 4,4'-DDE 4,4'-DDD Aldrin Arsenic (III) Benzene Benzo(a)Pyrene Bis(2-Ethylhexyl)Phthalate Bromoform Carbon Tetrachloride Chlordane Chlorodibromomethane Chloroform Dichlorobromomethane Dieldrin Heptachlor Heptachlor epoxide Hexachlorobenzene Pentachlorophenol PCBs Tetrachloroethylene Toxaphene Trichloroethylene Vinyl Chloride

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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