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President

June 15, 2010

SENT VIA EMAIL and HAND DELIVERED
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ENVIRONMENTAL QUALITY BOARD

Environmental Quality Board
Pennsylvania Environmental Quality Board
P.O. Box 8477
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INDEPENDENT REGULATORY
REVIEW COMMISSION

RE: 25 *Pa. Code* Chapter 93
Ambient Water Quality Criterion Chloride (Ch)
40 *Pa. Bulletin* 2264 (May 1, 2010)

Dear Members of the Board:

The Pennsylvania Coal Association (PCA) submits the following comments in response to the above referenced proposed rulemaking.

PCA is the principal trade organization representing bituminous coal operators - underground and surface, large and small - as well as other associated companies whose businesses rely on a thriving coal economy. PCA member companies produce over 80 percent of the bituminous coal annually mined in Pennsylvania, which totaled 68 million tons in 2008.

Pennsylvania is the 4th leading coal producing state and its mining industry is a major source of employment and tax revenue. Latest data indicates it created 41,500 direct and indirect jobs with more than $7 billion in economic input stimulated by the activity of the industry.

General Comments

The proposed limit for chloride is premature because the PA Department of Environmental Protection (PADEP) has failed to provide a strong scientific basis for the limit, has failed to fully consider the immediate and long-range economic impact of the proposed limits on the Commonwealth and its citizens and industries, and has failed to consider less burdensome alternatives. For these reasons and the additional reasons below, PCA requests the EQB to disapprove PADEP's proposed chloride rulemaking.

The preamble to the above proposed rulemaking states:

> "The Department recommends adopting these national chloride criteria for protection of aquatic life due to increasing concerns about the statewide impact of natural gas extraction from the Marcellus Shale formation."[1]

This statement is misleading. First, it implies that the proposed in-stream criteria for chloride are actually national criteria imposed by the Environmental Protection Agency (EPA) which must be adopted by the various states. This is not the case. The chloride criteria proposed for adoption by PADEP are derived from a document prepared over 22 years ago, entitled *Ambient Water Quality Criteria for Chloride* (EPA, 1988) (hereafter referred to as *1988 EPA Recommended Criteria for Chloride*). This document does not establish national criteria, but instead sets out recommended guidelines which are not binding on Pennsylvania or any other state. Further, as discussed in more detail below, EPA no long even endorses the chloride criteria it recommended 22 years ago. Instead, as recently as 2008, EPA staff in discussions regarding the Iowa chloride and TDS water quality standards, concluded that its 1988 criteria were too stringent and based on flawed data and were developed using an inappropriate testing methodology.[2]

Second, the above statement is a misleading because it indicates that Marcellus Shale drilling activities are the reason why this new proposal is needed and, by implication, suggests it will have no impact on other industries in Pennsylvania. At the current time, Marcellus drillers are not generally authorized by PADEP to discharge any drilling (or other associated) waste waters containing chloride or other dissolved solids into any stream in the Commonwealth. Therefore, the proposed rulemaking should have little to no new impact on that industry. However, the proposed regulation does have the potential to again sweep in a wide range of many other Pennsylvania industries, including the mining industry, who to date have not been generally required to sample for, or treat chloride, in their wastewater discharges.

In addition, the Preamble to the proposed rule discusses the relationship between chlorides and osmotic pressure. PADEP states that the current osmotic pressure standard of 50 mOsm/kg is intended to protect aquatic life from the adverse impacts of parameters such as chlorides. They indicate the proposed new water quality standards for chloride are needed due to administrative challenges and are developing the proposed water quality standard for chlorides because it is better suited to the mass-balance approach in order to maintain the existing osmotic pressure standard, while still retaining the current osmotic pressure standard. Consequently, PADEP is developing a water quality standard that achieves the same objective as a current water standard. It is unclear why, aside from convenience, a second set of water quality standards for chloride is necessary to protect aquatic life when such protection is already provided by the water quality standard for osmotic pressure.

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[1] 40 *Pa. Bulletin* 2265.
[2] Gregory L. Sindt, P.E., "*Chloride and TDS Water Quality Standards,*" January 15, 2008.

In the recent comment and response document PADEP prepared in connection with the new chapter 95 wastewater discharge regulations for TDS, they rejected certain comments that urged more restrictive standards for TDS be adopted to protect aquatic life, stating that "the Department has reviewed the relevant data and determined that **the current osmotic pressure criterion in water quality standards regulations provides protection for aquatic life at the point of discharge"** [emphasis added].

Additionally, in spite of PADEP's basis and rationale for the chloride standard as a mechanism of achieving osmotic pressure protection, the proposed chloride water quality standard is more restrictive that the current osmotic pressure standard. Using the Morse equation, the concentration of chlorides required to exceed 50 mOsm/kg osmotic pressure is 1,642 mg/l, which is far in excess of the proposed acute and chronic chloride levels. If PADEP's intent is to issue a chlorides standard to ensure achieving the current osmotic pressure water quality standard, then the chlorides limits in the proposed Chapter 93 rule change are too restrictive and must be re-evaluated.

Specific Comments

1. The Proposed Rulemaking Is Not Based On The Best, Currently Available Data Related To The Aquatic Affects of Chloride Which Indicates That Far Higher In-stream Concentrations of Chloride Are Acceptable.

Section 304(a)(1) of the Clean Water Act requires EPA to develop criteria for water quality that accurately reflects the latest scientific knowledge. These criteria are based solely on data and scientific judgments on pollutant concentrations and environmental or human health effects. The preamble to the above rulemaking and the rationale document submitted to the Environmental Quality Board (EQB) by the Department make it abundantly clear that the **sole basis** for the proposed new chloride water quality criterion is the *1988 EPA Recommended Criteria for Chloride*.

On this issue, the preamble to this proposal states:

> "[t]he Department has reviewed the EPA ambient water quality criteria development document and agrees with the **data** ....used to develop the criteria." 40 Pa.B.2265.

A similar statement appears in the Regulatory Analysis Form submitted by PADEP to the Independent Regulatory Review Commission.

The Department's agreement with EPA's 1988 data is completely unjustified because even EPA no longer considers the data used to develop the *1988 EPA Recommended Criteria for Chloride* to be the best available data. Concerns with using this document in modern day range from a lack of standardization and quality assurance procedures to control mortality, temperature and culturing methods of test organisms, to inappropriate dilution waters and lack of other relevant information.

Subsequent work has confirmed that significant data was NOT considered by EPA when it developed the *1988 EPA Recommended Criteria for Chloride*. As result, many

EPA staff now consider that criteria to be too stringent. The following excerpt from a 2008 paper prepared by Gregory L. Sindt, P.E., EPA staff, in connection with the State of Iowa's recent development of a chloride water quality standard in that state confirms this:

> *"The US EPA 1988 national guideline for chloride toxicity are considered by IDNR [Iowa Department of Natural Resources] and many USEPA staff as too stringent."* [3]

The basis for Iowa Department of Natural Resources' (IDNR) and EPA's more recent 2008 conclusion is that the 1988 standard was significantly affected by data reviewed on a sensitive species (the fingernail clam) which was misleading because of the manner in which the tests on that species was conducted. More importantly, recent testing on this species indicates that the actual impacts only occur at a far higher concentrations of chloride (about 1,400 mg/L) and not at what was thought to be the case over 22 years ago (682 +/- mg/L) when the *1988 EPA Recommended Criteria for Chloride* was developed and published. Indeed, when the current data for chloride toxicity is considered, instead of a chronic value of 230 mg/L (the number proposed in the above rulemaking), a far higher chronic value (663 mg/L) is supportable.[4]

Furthermore, had PADEP done a reasonable search of available science it would also have reviewed the extensive testimony on this issue provided to the Iowa Environmental Protection Commission which included the following statement from Dr. Wesly Birge, a Professor at the University of Kentucky's Graduate Center for Toxicology and Department of Biology. Dr. Birge, an internationally recognized expert in aquatic toxicology, has worked extensively with the USEPA. His testimony before Iowa's Department of Natural Resources, Environmental Protection Commission in 2004[5] unequivocally undercuts PADEP's reliance on the *1988 EPA Recommended Criteria for Chloride*, Dr. Birge provided the following written statements:

> "Based on the available information, I feel that establishing a chronic aquatic life criterion for chloride of 564 mg/L is scientifically justifiable and is protective of aquatic life, and that establishing a chronic criterion of 372 mg/L based on only one chronic test with Daphnia pulex in reconstituted water is not justified."
>
> "US EPA proposed a chronic value of 230 mg chloride/L. This was based solely on laboratory toxicity tests and acute-chronic ratios. The former most always overestimates risk and the ratios are clearly invalid (emphasis added). The basic mechanisms involved in acute toxicity most always are significantly different from those involved in chronic toxicity."

Facing concerns that their initial proposed chlorides criteria were not scientifically defensible, IDNR continued to work with EPA. IDNR has also published data

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[3] Ibid.
[4] Ibid.
[5] http://www.iowadnr.gov/epc/archive/04feb16m.pdf. This document contains a wealth of other testimony and data which calls into question the use of the *1988 EPA Recommended Criteria for Chloride* and which supports far higher limits for Chlorides.

which was developed with the assistance of the EPA-Duluth, Office of Research and Development, which led Iowa, and EPA, to conclude that the *1988 EPA Recommended Criteria for Chloride* was far too stringent. This data is summarized at page 3 of an IDNR report[6], and confirms that test species (similar to those used to development the *1988 EPA Recommended Criteria for Chloride*) can tolerate far higher concentrations of chloride than was previously thought to be the case. A copy of this report is also attached to these comments.

PADEP did not conduct a thorough review of the current science on chloride aquatic toxicity before proposing this rulemaking resulting in a totally deficient review. Since several states and EPA themselves have questioned the use of the 1988 criteria, it is completely inappropriate for PADEP to adopt the 1988 criteria without evaluating the errors and limitations of the 1988 criteria and additional information generated since 1988. For this reason alone, the rule should be rejected by the EQB.

2. There Is No Rational Causal Link Between The Proposed Rulemaking And The Purported Harm.

In an attempt to disguise the lack of a solid technical basis for the proposed rulemaking, the Department references a sequence of sampling data on the Monongahela River in the fall of 2008. Page 3 of PADEP's rationale document for chlorides states:

> "Chlorides and Sulfates can be a significant source of TDS in wastewater discharges. During the fall of 2008, water quality issues related to these parameters emerged in the Monongahela River basin."[7]

A review of 22 pages of chloride data from 2008 until March 28, 2010 on PADEP's own website[8] indicates chloride values are nowhere near exceeding even the public drinking water standard.

Page 3 of PADEP's rationale document for chlorides also states:

> " Elevated Chloride levels were also observed in the Monongahela and on at least one major tributary - South Fork Tenmile Creek."

A review of the Final Report of the Comprehensive Ichthyofaunal Survey of Tenmile Creek Watershed[9] contains statements that are in conflict with PADEP's supporting data which they are using to move forward a chloride standard. These statements include:

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[6] Iowa Department of Natural Resources, *"Water Quality Standards Review: Chloride, Sulfate and Total Dissolved Solids,"* February 9, 2009. (http://www.iowadnr.gov/water/standards/files/ws_fact.pdf)
[7] See PA Department of Environmental Protection website.
[8] Data can be found at:
http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalfiles/monongahelarivertdschlorideandsulfatesamplingresults.pdf
[9] Argent, David G. and Kimmel, William G., *"A Comprehensive Ichthyofaunal Survey of Tenmile Creek Watershed Phase I"*, California University of PA, March 2008.

"Tenmile Creek Watershed located in Washington/Greene Counties, the second largest tributary to the Monongahela River in Pennsylvania, emerges as an area that may harbor a diverse ichthyofauna, but whose aquatic biota remains largely unassessed."[10]

"Our collections added nearly 30 species/hybrids to the ichthyofauna of Tenmile and its South Fork."[11]

"The ichthyofauna documented in this study nearly triples the historical species richness recognized by Cooper (1983)."[12]

In addition, neither the Tenmile Creek Watershed Phase I Report nor the Phase II Report[13] indicates any actual chloride sampling results, yet PADEP is using this as justification for setting a chloride standard.

Furthermore, and most importantly, these two Tenmile Creek studies were fish surveys to document the fishery that exists in the stream as a baseline, not to determine the need for a chloride limit.

In the Preamble, the Department "recommends adopting these national chloride criteria for protection of aquatic life." However, in the very next sentence the Department states, "Scientists at the US EPA are currently conducting research to determine if the national criterion for chloride should be updated." Given PADEP's desire to use EPA reports and research with respect to chloride standards, the lack of a robust dataset indicating a chloride problem, and the billions of dollars industry will spend in control technology, we suggest the more prudent course of action would be to wait for EPA to complete their research before setting a standard. This would give PADEP sufficient time to collect the appropriate samples and complete a series of statistically significant aquatic and benthic testing in the Commonwealth. We believe the small amount of data being used by PADEP lack scientific integrity and statistical appropriateness, and are insufficient and indefensible to support PADEP's decision to propose this rulemaking.

3. The Proposed Rulemaking Is Based On A Report Which Utilizes Outdated Methodology To Assess Chloride Toxicity.

§ 304(a)(1) of the Clean Water Act requires EPA to develop criteria for water quality that accurately reflects the latest scientific knowledge. These criteria are based solely on data and scientific judgments on pollutant concentrations and environmental or human health effects.

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[10] Ibid, page 1.
[11] Ibid, page 3.
[12] Ibid, page 10.
[13] Argent, David G. and Kimmel, William G., *"A Comprehensive Ichthyofaunal Survey of Tenmile Creek Watershed Phase I"*, California University of PA, March 2008.

PADEP's Preamble further states:

"[t]he Department has reviewed the EPA ambient water quality criteria development document and agrees with the....**methods** used to develop the criteria." 40 Pa.B.2265.

PADEP's reliance on the methodology used by EPA to develop the *1988 EPA Recommended Criteria for Chloride* is also completely unjustified because the method used to development its 1988 recommendation did not factor in the effect of water hardness on the potential toxicity of chloride.

To develop the *1988 EPA Recommended Criteria for Chloride*, EPA relied upon standard laboratory toxicity testing which used sodium chloride in laboratory reconstituted water at set concentrations.[14] However, the most recent testing methods, recommended by EPA, and used by Iowa, to develop a chloride criteria for water quality protection in that State, focuses on water hardness and states:

"Results of the research and toxicity testing completed for chloride showed that **chloride toxicity is heavily dependent on water hardness...**"[15](emphasis added). This data indicates that as water hardness increases larger amounts of chloride can be present without causing toxicity to aquatic species.[16]

Given the documented importance of water hardness on chloride toxicity, for the EQB to accept as appropriate for Pennsylvania (a state where surface water is often naturally hard) a standard which was developed without factoring in water hardness is completely unjustified and will lead to the imposition of needlessly stringent chloride effluent limits in NPDES Permits. Any chloride standard for Pennsylvania should factor in the hardness of the water to be protected.

4. The EQB Should Reject This Proposal And Insist That PADEP Consider Alternative Approaches To Regulating Chloride.

In response to the question on the Regulatory Analysis Form asking whether "any alternative regulatory provisions...have been considered and rejected" by the Department, it states: "**there are no alternative regulatory schemes to consider** in achieving the correct level protection for the aquatic life uses of water of this Commonwealth...."

First, there has been no generally documented decline in the overall health of aquatic life in this Commonwealth over the past 22 years, during which time the *1988 EPA Recommended Criteria for Chloride* were not in use, and the Department used osmotic pressure as the means for regulating chloride and other solids present in industrial discharges. This fact alone supports the conclusion that this is at least one alternative that should have been considered, namely the *status quo*.

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[14] Ibid.
[15] Ibid.
[16] Ibid.

Second, EPA's website[17] indicates "States may use the criteria that are developed by EPA to help set water quality standards that protect the uses of their waters **or they may develop their own water quality criteria.**" [emphasis added]

Third, and more importantly, if there is a true need to more aggressively regulate chloride in industrial discharges (which has yet to be proven), one clear available alternative is do what was recently done in Iowa and that is to open the subject up to a full and reasonable public debate and to consider each of the approaches which Iowa considered, including adopting an approach to regulating Chlorides which is premised upon the hardness and sulfate content of the receiving stream, an approach that is also now under consideration in the State of Missouri, where on March 3 of this year a petition was presented to that State's environmental regulatory agency to amend the chloride standard to follow the Iowa alternative approach.[18]

5. The Proposal's Economic Analysis Is Insufficient And Misleading And Doesn't Address/Understand Competition.

Nothing in the materials provided by PADEP assign any costs to the new monitoring requirements that would necessarily result if the proposed chloride standard was imposed. Currently, most dischargers regulated by PADEP are authorized to take periodic grab samples of their discharges, send these samples to outside labs, and report the test results on a monthly basis. However, to determine whether or not a discharge is in compliance with a chloride standard such as, a 1-hour average of 860 mg/L or a 4-day average of 230 mg/L, the discharger will need to install equipment that is capable of monitoring and sampling a waste water discharge 24 hours per day, seven days a week—continuous discharge monitors. Such equipment is costly to acquire and equally costly to operate. In addition, it requires a source of power to operate on a 24-hour basis which will not be present at remote locations were many discharges associated with mineral extraction activities are located. Consequently, the costs of providing power to such sites will also be a factor.

In addition, the only alternatives noted by PADEP are ones associated with oil and gas operations. PADEP has not reviewed the economic impact of this regulation on other major industrial or municipal sectors and, in particular, has not thought through all the implications of this proposed rulemaking including the adverse effects on the competitiveness of the coal industry. As PADEP knows from presentations by the various industry sectors involved with the TDS Chapter 95 Taskforce, the only type of technology that could meet the new chloride limits are ones involving evaporation, crystallization or reverse osmosis technologies. Installation and operation costs, the costs of which to install and operate are prohibitive at any currently operating mining operation in Pennsylvania.

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[17] Http://www.epa.gov/waterscience/criteria/basic/htm

[18] Missouri Agribusiness Association, Petition Requesting Revision to Chloride and Sulfate Water Quality Standards. February 5, 2010 to Missouri Clean Water Commission.

PCA presented to PADEP an impact analysis of the proposed TDS rulemaking on the bituminous mining sector.[19] The data received for this analysis accounted for 85 percent of the 68 million tons of coal produced annually in Pennsylvania and potential flows to be treated of 26,725 gallons per minute. This analysis and related costs are just as accurate for chloride removal as they were for TDS.

We would remind PADEP that the technologies available to treat chlorides are limited, depend upon the individual chemical constituents of the water to be treated, and have unique and significant technical and economic feasibility issues.

For the bituminous coal mining industry, the only technology potentially capable of achieving the chloride levels PADEP is proposing, is reverse osmosis combined with evaporation and crystallization and pretreatment. Based on the study conducted by CME Engineering for PCA[20], the cost to the bituminous coal mining industry to install technology to treat chlorides is:

- **$1.325 billion in capital costs,**
- **$133 million every year for operation and maintenance costs, and**
- **$134 million for bonding a 500 gallon per minute zero liquid discharge treatment system, as calculated with the AMD treat and bond/trust fund calculation spreadsheets.**
- These costs **do not** include dollars for land acquisition, site development, utility extensions, etc. necessary to construct a treatment plant.

PADEP indicates reverse osmosis facilities should produce satisfactory effluent at a cost of less than 1 cent per gallon.[21] PADEP has indicated publicly that this number is based on information from vendors whose sole purpose is to develop a market and sell their products. Notwithstanding the CME Report, several of our members have conducted studies based on specifics at their facilities that show the cost to be significantly higher. We would caution PADEP in giving higher value to sales representatives' pitches than to industries who have conducted studies based on their specific criteria and who answer to shareholders regarding expenditures and the operation of their facilities.

Furthermore, the imposition of the proposed chloride standard likely will have an immediate impact on publicly operated treatment works simply because, as noted in the Preamble, EPA itself has recognized that a major anthropogenic source of chloride is discharges from municipal wastewater plants and the use of salt on roads by municipalities. (EPA 1988) 40 Pa.B.2265. Yet, in the materials submitted by PADEP to

[19] J. Owsiany on behalf of the Pennsylvania Coal Association. *"Mining Sector: Impact Analysis of the High TDS Strategy on the Mining Industry."* Presentation, PA DEP Water Resources Advisory Committee, Ch. 95 Taskforce, Harrisburg, PA, September 22, 2009.

[20] A full copy of the report generated by CME Engineering which contains a more detailed analysis of the treatment options and associated costs was submitted on February 11, 2010 to the Environmental Quality Board as part of PCA's comments on the proposed Chapter 95 rulemaking and is incorporated by reference. Due to size, it is attached to the hard copy only.

[21] See IRRC Regulatory Analysis Form, page 5 submitted to Mr. Kim Kaufman on April 21, 2010 and page 4 of the Preamble.

the EQB the statement is made that the proposal will have no impact on municipalities. This is simply not the case and care should be taken to fully assess the impact of the proposal on not just industry (including the agricultural industry, which according to EPA is another major source of chloride) but also on state and local government.

Moreover, other states that provide competition for the coal mining industry do not have chloride regulations, thereby making their products more price friendly as they do not have to install costly control technology. Below are some of the surrounding states' limits:

Maryland	-	no limit
Ohio	-	no limit
Tennessee	-	no limit
WV	-	Acute 860 mg/l. Note however that the limits can be changed per site based on temperature and water flow.

In their haste to develop a regulation, PADEP has failed to consider the non-water quality indirect environmental and economic impacts including residual waste generation, management and disposal challenges as well as increased power usage.

6. The Proposal is Illogical and Fails to Address Major Sources of Chlorides Such as Deicing.

On page 8 of the Regulatory Analysis Form, PADEP indicated that no other state agencies are affected by this proposal. In fact, PADEP has overlooked the impacts of other major potential sources of chloride such as road salt used for deicing. Last year, PennDOT and the PA Turnpike Commission used over 1 million tons of road salt. This number does not take into account residential usage for sidewalks, softening systems and driveways or commercial uses such as parking lots. One million tons of salt is equivalent to 650,000 tons of chlorides potentially landing up in PA waterways. In reality, some salt will remain on land and leach down into the groundwater.

In addition, the assertion that a point source discharger may be able to offset operational costs somehow by marketing its waste salt is illogical and grounded in bureaucracy. The very suggestion that industry waste valuable resources and energies removing the chlorides only to have them deposited back into the stream is absurd. No company would expose itself to the liabilities implied by disposing of wastewater on public property to make a profit. If one follows PADEP's assertion that chlorides in our waterways stress aquatic life forms and that some of the Commonwealth streams exhibit NO assimilative capacity[22], won't those same aquatic life forms be stressed by spreading sodium chloride on the roads which ultimately ends up in streams? PADEP has not shown

[22] Page 3 of PADEP's Evaluation of Water Quality Criteria for Aquatic Life Use Protection Rationale Document date January 2010 and available on PADEP's website as noted in the Preamble.

that adding a standard for chloride will protect surface waters in view of this failure to address other chloride sources.

In light of these deficiencies, the proposed requirements need to be withdrawn and reconsidered in detail using current science. PCA appreciates the opportunity to comment.

Sincerely,

Josie Gaskey

Attachment

Cc: George Ellis

Water Quality Standards Review:

Chloride, Sulfate and Total Dissolved Solids

Iowa Department of Natural Resources
Consultation Package
February 9, 2009

Table of Contents

Iowa's Water Quality Standard Review: Chloride

1. Background

Chloride is one of the major anions commonly found in ambient and wastewater. Chloride may get into surface water from several sources including:

- wastewater from industries and municipalities;
- effluent wastewater from water softening;
- road salting;
- agricultural runoff; and
- produced water from oil and gas wells.

The current Iowa water quality standard for chloride is 250 mg/L for drinking water use only. There are no numeric chloride standards for aquatic life protection in Iowa. However, as part of the current interim site-specific TDS approach, if in-stream chloride concentrations reach a threshold level (in-stream threshold values: acute threshold is 860 mg/l, chronic threshold is 230 mg/L), Whole Effluent Toxicity tests are required. These threshold values are equivalent to EPA's 1988 304(a) national criteria.

2. Current EPA National Criteria

The most recent 304(a) national criteria for chloride were published in 1988. The national criterion for chloride was derived based on the toxicity test data of sodium chloride in laboratory reconstituted water given that it is the only chloride composition with enough data available to allow derivation of a water quality criterion. Also, it is likely that most anthropogenic chloride in ambient water is associated with sodium, rather than potassium, calcium, or magnesium (EPA, 1988). In the EPA 304(a) criteria document, the acute toxicity data of chloride are available for 12 different species (genus). Table 1 lists the current EPA national criteria for chloride for aquatic life protection (EPA, 1988).

Table 1. National Aquatic Life Criteria for Chloride

Parameter	National Criteria (mg/l)	
	Acute	Chronic
Chloride	860	230

3. New Toxicity Testing Data

Since the EPA national criteria were published in 1988, the derivation of the criteria was based on toxicity data available before 1987. The Iowa Department of Natural Resources started a review of the chloride criteria by looking at the most up-to-date toxicity information available in 2007. As part of the effort, IDNR working together with Charles Stephan, of the EPA-Duluth, Office of Research and Development (ORD), performed a literature search to update and recalculate the 1988 acute and chronic chloride criteria based upon new toxicity data deemed acceptable following the 1985 EPA Guidelines (U.S. EPA, 1985). The literature review revealed acceptable data for several new species, which were not part of the 1988 chloride criteria document. One particular study, conducted by Wurtz and Bridges (1961), included data for several species, including two of the four species suspected of being most sensitive to chloride (a planorbid snail, *Gyraulus circumstriatus*, and the fingernail clam, *Sphaerium tenue*). A second study (Khangarot 1991) included acute chloride toxicity data for the tubificid worm (*Tubifex tubifex*), which indicated that this species might also be highly sensitive to chloride, but the data were determined unacceptable for inclusion in the recalculation based on several factors. Given the importance of the Wurtz and Bridges (1961) data, the Khangarot (1991) data, and the lack of verification by other laboratories, it was determined that more toxicity data would be warranted to independently determine if those species are indeed sensitive to chloride.

EPA contracted with the Great Lakes Environmental Center (GLEC) in Columbus, OH and the Illinois Natural History Survey (INHS) at Champaign, IL to perform the additional toxicity testing. The acute toxicity of chloride to four freshwater invertebrate species: water flea (*Ceriodaphnia dubia*), fingernail clam (*Sphaerium simile*), planorbid snail (*Gyraulus parvus*), and tubificid worm (*Tubifex tubifex*), was determined under different levels of water hardness (all four species) and sulfate concentrations (*C. dubia* only). Tests with *C. dubia* acclimated and tested under different levels of total water hardness and sulfate were performed simultaneously by two different laboratories. Results were comparable. The final toxicity testing results for the four freshwater invertebrate species are published in the report "Acute Toxicity of Chloride To Select Freshwater Invertebrates, September 26, 2008".

The toxicity testing results indicate that the 48-h LC50 for *C. dubia* at 25 to 50 mg/L hardness is approximately half that of *C. dubia* exposed at 600 to 800 mg/L hardness. Conversely, sulfate over the range of 25-600 mg/L exerted only a small (inverse) effect on chloride toxicity to *C. dubia*. The mean 48-h LC50 at 25 mg/L sulfate was approximately 1,356 mg Cl/L, while at 600 mg/L sulfate, it was 1,192 mg Cl/L (reduction of 12%). Again, LC50 values between labs were consistent. Ninety-six hour LC50 values for three other freshwater invertebrate species ranged from a low of 740 mg Cl/L for *S. simile* exposed to chloride at 50 mg/L hardness, to a high of 6,008 for *T. tubifex* exposed to chloride at 200 mg/L hardness. For both species, increasing the acclimation and dilution of water hardness reduced the acute toxicity of chloride by approximately 1.4 to 1.5 times. Water hardness did not appear to influence the acute toxicity of chloride to the planorbid snail, *G. parvus*. Rank order of sensitivity to acutely lethal chloride at a given water hardness is in the order (most to least): *S. simile*>*C. dubia*>*G. parvus*>*T. tubifex*. The new toxicity testing results are shown in Table 2 and 3.

Table 2. Chloride acute toxicity to C. dubia at different water harnesses and single sulfate concentration

Chloride Toxicity Test	*C. dubia* 48 h LC50 (95%CI) GLEC (mg Cl/L)	*C. dubia* 48 h LC50 (95%CI) INHS (mg Cl/L)	Mean LC50 value (mg Cl/L)
Acclimated to and Tested at Various Total Hardness Levels (and 65 mg/L Sulfate)			
25 mg/L Hardness	947 (868-1034)	1007 (964-1052)	977
50 mg/L Hardness	955 (885-1031)	767 (684-861)	861
100 mg/L Hardness	1130 (1029-1231)	1369 (1246-1505)	1250
200 mg/L Hardness	1609 (1516-1707)	1195 (1148-1245)	1402
400 mg/L Hardness	1491 (1385-1606)	1687 (1587-1794)	1589
600 mg/L Hardness	1907 (Estimates not Reliable)	1652 (1536-1776)	1779
800 mg/L Hardness	1764 (1661-1874)	1909 (1791-2034)	1836
Acclimated to and Tested at Various Sulfate Levels (and 300 mg/L Hardness)			
25 mg/L Sulfate	1400 (1287-1523)	1311 (1210-1421)	1356
50 mg/L Sulfate	1720 (1634-1811)	1258 (1211-1306)	1489
100 mg/L Sulfate	1394 (1281-1516)	1240 (1203-1278)	1317
200 mg/L Sulfate	1500 (1370-1641)	1214 (1153-1278)	1357
400 mg/L Sulfate	1109 (1004-1225)	1199 (1120-1284)	1154
600 mg/L Sulfate	1206 (1161-1253)	1179 (1125-1235)	1192

Table 3. Chloride acute toxicity for fingernail clam, snail and tubificid worm

Test species	96 h LC50 (95%CI) at 50 mg/L total hardness (mg Cl/L)	96 h LC50 (95%CI) at 200 mg/L total hardness (mg Cl/L)
Fingernail clam (juveniles), *Sphaerium simile*	740 (678-807)	1100[a] (1040-1164)
Planorbid snail (mixed ages), *Gyraulus parvus*	3,078 (2,771-3,418)	3,009 (2,728-3,318)
Tubificid worm (mixed ages), *Tubifex tubifex*	4,278 (3,848-4,717)	6,008 (5,563-6,489)
[a] Result is from a repeat test because control mortality in the first test slightly exceeded maximum acceptable mortality of 10% (15% mortality recorded). LC50 was similar to the LC50 of the failed test (1098 mg Cl/L) which was based on nominal concentrations.		

4. Summary of Proposed Criteria Options

Four different procedures were used to derive potential freshwater aquatic life acute criteria for chloride, and three different Acute-Chronic Ratios (ACRs = Acute LC50/Chronic End Point) were used to derive the chronic criteria. As a result, there are a total of 4 options proposed for the **acute** criteria values and a total of 12 proposed options for the **chronic** criteria values.

Table 4 presents a summary of different proposed chloride criteria.

Proposed Cl Criteria	Different Options			
	A ($N^a = 35$)	B ($N = 35$)	C ($N = 23$)	D ($N = 29$)
Acute Value (CMC)	574	$283.17(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$254.3(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$195.7(\text{hardness})^{0.217736}$
Chronic Value -1 (CCC1)	238	$117.36(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$105.4(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$81.1(\text{hardness})^{0.217736}$
Chronic Value -2 (CCC2)	360	$177.70(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$159.6(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$122.8(\text{hardness})^{0.217736}$
Chronic Value -3 (CCC3)	342	$168.77(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$161.5(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$	$120.7(\text{hardness})^{0.217736}$

[a] N = number of genera used in the calculation

The following explains the different Options of A, B, C and D.

Option A. Acute values were not normalized for either hardness or sulfate and the criterion is **not** dependent on either hardness or sulfate;
Option B. Acute values were not normalized for either hardness or sulfate, but the criterion is dependent on both hardness and sulfate;
Option C. Acute values were normalized for both hardness and sulfate and the criterion is dependent on both hardness and sulfate;
Option D. Acute values were normalized for hardness (but not sulfate) and the criterion is dependent on hardness (but not sulfate).

For all procedures:

CCC1 was derived using ACR = 4.826, which is the geometric mean of the ACRs for Rainbow Trout and Daphnia. CCC1 is too high for species at the 5th percentile.
CCC2 was derived using ACR = 3.187, which is the ACR for Daphnia. CCC2 is appropriate for species at the 5th percentile.
CCC3 was derived from predicted Genus Mean <u>Chronic</u> Values that were calculated using ACR = 7.308 of Rainbow Trout for vertebrates and ACR = 3.187 of Daphnia for invertebrates. Then the similar procedure for deriving acute criterion was used to derive the chronic criterion.

The above CMCs and CCCs are expressed as "mg chloride/L".

5. Final Proposed Chloride Criteria

IDNR conducted the Technical Advisory Committee (TAC) meeting on December 8th, 2008 to discuss the proposed chloride criteria. After considering input from both EPA and the TAC as well as IDNR internal discussions, Option C is selected for the acute criterion, and CCC3 under Option C is selected as the chronic criterion based on the scientific justification. The final proposed chloride criteria are listed below.

Acute chloride criterion:

$254.3(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$

Chronic chloride criterion:

$161.5(\text{hardness})^{0.205797}(\text{sulfate})^{-0.0745}$

Statewide default values for hardness and sulfate will be used unless site specific data is available.

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   08ChloridePrB.pdf
   08ChloridePrC-T1.pdf
   08ChloridePrC-T3.pdf
   08ChloridePrD-T1.pdf
   08ChloridePrD-T3.pdf
   08ChlorideChronic.pdf
   08ChlorideRefs.pdf
   08ChlorideSulfate.pdf

Iowa's Water Quality Standard Review: Sulfate

1. Sulfate and TDS

Total Dissolved Solids (TDS) is a measure of all constituents dissolved in water. The inorganic anions dissolved in water include carbonates, chlorides, sulfates and nitrates. The inorganic cations include sodium, potassium, calcium and magnesium. Thus, sulfate is a constituent of TDS and may form salts with sodium, potassium, magnesium and other cations. Sulfate (SO_4^{2-}) is widely distributed in nature and may be present in natural waters at concentrations ranging from a few to several hundred milligrams per liter.

The IDNR ambient monitoring program routinely monitors TDS, chloride and sulfate. Table 1 shows a summary of monitoring data on TDS and its constituents from 2000 to 2007.

Table 1. TDS and Ion Concentrations in Iowa Streams

Chemicals	**Iowa Ambient Monitoring Data from 2000-2006, units in mg/L**		
	50^{th} percentile	90^{th} percentile	Maximum value
TDS	360	510	1,640
Chloride	23	40	170
Sulfate	**37**	**97**	**400**
Hardness (as $CaCO_3$)	300	410	820

Appendix I shows the statewide sulfate, chloride and hardness levels of surface waters in Iowa based on median values. The ambient monitoring data show that the NW region has the highest ambient sulfate concentrations.

Anthropogenic sources of sulfate may come from mine drainage wastes through pyrite oxidation, reverse osmosis reject water, cooling tower blow down, etc. Coal preparation facilities wash coal to reduce sulfur emissions prior to burning in coal-fired power plants and treat wastewaters for acid-soluble metals. This practice often produces a waste containing sulfuric acid that is usually neutralized by the addition of sodium hydroxide or sometimes quicklime (CaO) prior to release to a receiving stream, which could contain high sulfate and other ions.

2. Existing Water Quality Standards

Currently no federal water quality criteria exist for the protection of freshwater aquatic life for either sulfate or TDS. Iowa has never adopted numerical criteria for aquatic life protection. However, the state water quality standard includes a recommended livestock watering guideline value of 1,000 mg/L for sulfate as part of the TDS narrative criteria, which was adopted on June 16, 2004. The 1,000 mg/L sulfate guideline value is applied at the end of mixing zone for livestock watering protection.

The literature review conducted by IDNR indicates that individual ions rather than TDS criteria/limits are more appropriate to characterize toxicity related to TDS. Recent studies conducted by Illinois EPA reached the same conclusion. IDNR studied the Illinois proposed sulfate rule and recommends replacing the current site-specific TDS approach with numerical sulfate and chloride criteria.

3. The Illinois Approach

The Illinois EPA is proposing the final rule that deletes the TDS general use water quality standard of 1000 mg/L, and replaces the sulfate general use water quality standard of 500 mg/L with an equation that depends on chloride and hardness to be protective of aquatic life and livestock watering uses. Because sulfate toxicity is dependent on chloride and hardness concentrations, water quality chemistry and characteristics are taken into consideration when setting the sulfate standard throughout the State.

The agency asserts that in Illinois waters the toxicity associated with substances comprising a major portion of TDS is predominantly due to either chloride or sulfate. The toxicity of other ions that make up TDS, such as sodium, calcium, magnesium and carbonates is insignificant when compared to chloride and sulfate toxicity. The Illinois EPA believes that with the adoption of a sulfate standard and the existing chloride standard, the water quality standards adequately address toxicity of dissolved salts and the TDS standard is not necessary as TDS cannot predict the threshold of adverse effects to aquatic life. For example, a sample with a high chloride and TDS concentration of 2,000 mg/L is highly toxic to some species of aquatic life such as invertebrates but a sample with high sulfate at the same TDS concentration is nontoxic.

The State of Illinois worked with the USEPA Duluth Toxicity laboratory to search available toxicity test data on sulfate. Data for over 30 kinds of organisms from about 30 papers/sources were found. The literature research showed that essentially only two groups, fish and zooplankton crustaceans, were adequately represented in the database. Fish were found to be tolerant of sulfate therefore no further discussion or additional testing is necessary. Strong representation of the daphnids was expected since these are common, easily tested organisms. However, *Hyallela azteca* data was relatively scarce, and available data suggested this native species is most sensitive to sulfate. For credence to be given to the dataset of toxicity values, more data on a variety of invertebrate species was necessary to obtain, especially, since invertebrates show the highest sensitivity to sulfate.

Dr. David Soucek of the Illinois Natural History Survey was contracted to conduct the laboratory toxicity testing. Briefly summarized, his work entailed determining the acute toxicity of sulfate to four invertebrate species commonly found in Illinois and thought to fill the gaps in the existing valid database. These organisms were the water flea *Ceriodaphnia dubia*, a previously tested organism used as a gauge for comparison purposes, *Hyalella azteca*, an amphipod, *Chironomus tentans*, a midge fly, *Sphaerium simile*, a fingernail clam, and *Lampsilis siliquoidea*, a freshwater mussel. These organisms were selected based on presumed sensitivity to sulfate from literature values (*Hyalella*), the need to have data from an insect (*Chironomus*) and the perceived sensitivity of bivalve mollusks to toxicants in general (*Sphaerium* and *Lampsilis*).

Because sulfate toxicity is dependent on chloride and hardness concentrations, these water quality characteristics were taken into consideration when setting the sulfate standard throughout the State.

The State of Illinois also conducted a literature review of the adverse effects of sulfate on livestock. Based on the research, the Agency concluded that the protection of livestock watering will be achieved through the proposed standard of 2,000 mg/L sulfate over a 30-day average at locations where livestock watering occurs.

Based on new toxicity test data and available toxicity data from the literature search (a total of 11 species), to achieve aquatic life protection and livestock watering uses, the following concentrations for sulfate must not be exceeded except in receiving waters for which mixing is allowed.

1) At any point where water is withdrawn or accessed for purposes of livestock watering, the average of sulfate concentrations must not exceed 2,000 mg/L when measured at a required frequency over a 30 day period.

2) The results of the following equations provide sulfate water quality standards in mg/L for the specified ranges of hardness (in mg/L as $CaCO_3$) and chloride (in mg/L) and must be met at all times:

   A) If the hardness concentration of waters is greater than or equal to 100 mg/L but less than or equal to 500 mg/L and if the chloride concentration of waters is greater than or equal to 25 mg/L but less than or equal to 500 mg/L, then:

   Sulfate Criterion = [1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65

   B) If the hardness concentration of waters is greater than or equal to 100 mg/L but less than or equal to 500 mg/L, and if the chloride concentration of waters is greater than or equal to 5 mg/L but less than 25 mg/L, then:

   Sulfate Criterion = [-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65

3) The following sulfate standards must be met at all times when hardness (in mg/L as $CaCO_3$) and chloride (in mg/L) concentrations other than specified above are present:

   A) If the hardness concentration of waters is less than 100 mg/L or chloride concentration of waters is less than 5 mg/L, the sulfate standard is 500 mg/L.

   B) If hardness concentration of waters is greater than 500 mg/L and the chloride concentration of waters greater than or equal to 5 mg/L, the sulfate standard is 2,000 mg/L.

C) If the combination of hardness and chloride concentrations of existing waters are not reflected above, the sulfate standard will be determined on a case-by-case basis in conjunction with an applicable NPDES permitting process.

The following summarizes the proposed sulfate criteria stated above.

Table 2. Proposed Sulfate Criteria for Iowa Waters

Chloride / Hardness mg/L as $CaCO_3$	$Cl^- < 5$ mg/L	$5 <= Cl^- < 25$	$25 <= Cl^- <= 500$
H < 100 mg/L	500	500	500
100<=H<= 500	500	[-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65	[1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65
H > 500	500	2,000	2,000

The justification for the Illinois proposed sulfate standard is included in Appendix II.

4. Similarities between Iowa and Illinois Surface Water Quality

Similar to Illinois, TDS is dominated by the common ions of sulfate, chloride, sodium, calcium, carbonate, and magnesium. The Illinois EPA monitoring program shows average TDS of 452 mg/L. In Northern and Central Illinois streams, sulfate levels range from 30 to 150 mg/L in streams without significant human-induced sulfate sources, and mine areas typically do not exceed 500 mg/L. The average level of chloride in Illinois streams is in the 20 – 40 mg/L range. Streams impacted by road salting can seasonally be much higher. Most Illinois waters are generally classified as hard or very hard waters. These ion concentrations are comparable to that in Iowa surface waters shown in Table 1. As Illinois EPA research indicated, hardness mitigates the toxicity of sulfate to aquatic life.

As in Iowa, the sources contributing TDS and ions include discharges from ethanol plants, water treatment plants and cooling tower blow down. Another main source of sulfate and TDS in Illinois waters come from coal mining industries which no longer exist in Iowa. In addition, the aquatic life species occurrence in Iowa is similar to that in Illinois. Thus, the species included in the sulfate criteria derivation and the methodology should be applicable to Iowa waters.

5. Conclusions and Recommended Sulfate Standard

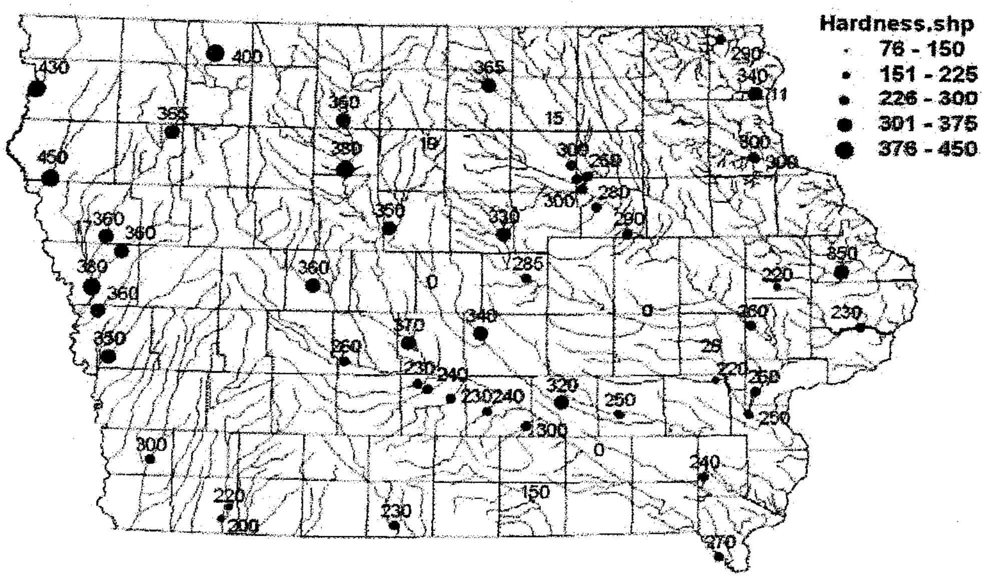
Based on the similarities in surface water quality and aquatic life species distributions between Iowa and Illinois, the same approach for TDS, sulfate and chloride criteria can be applied, that is replacing the current site-specific TDS approach with numerical sulfate and chloride criteria for aquatic life protection. Thus, between the chloride and sulfate water quality standards and the general narrative standard that regulates any discharged substance that could cause toxicity, there is no need for a TDS standard. In addition, the sulfate criteria for livestock watering will be changed from the current 1,000 mg/L to 2,000 mg/L. The guideline values of livestock watering for other ions will remain the same.

6. Proposed Sulfate Standard Implementation

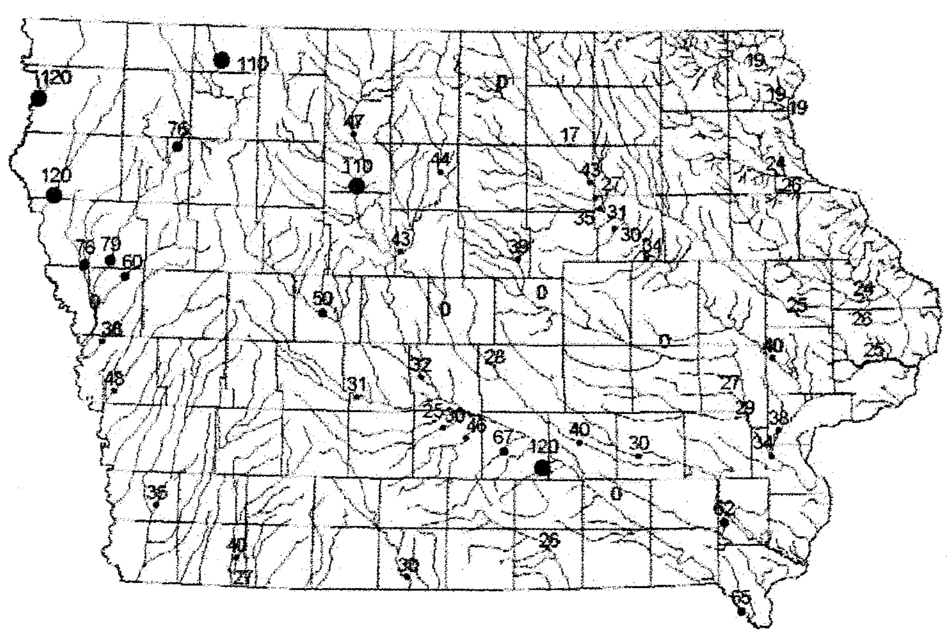
Sulfate is not a toxicant in the category of heavy metals, pesticides or other toxic natural or man-made substances, but rather is a common salt necessary for life at some concentrations. It is usually diluted in the waterbody rather quickly and is non-bioaccumulative. Also, since the sulfate standard was derived based on new toxicity data for targeted species thought to be most sensitive to sulfate, additional uncertainty was alleviated. Since the sulfate standard is derived based on acute toxicity testing data, it should be met after the allowed Zone of Initial Dilution.

Appendix A: Statewide hardness, chloride and sulfate distribution in IA surface waters

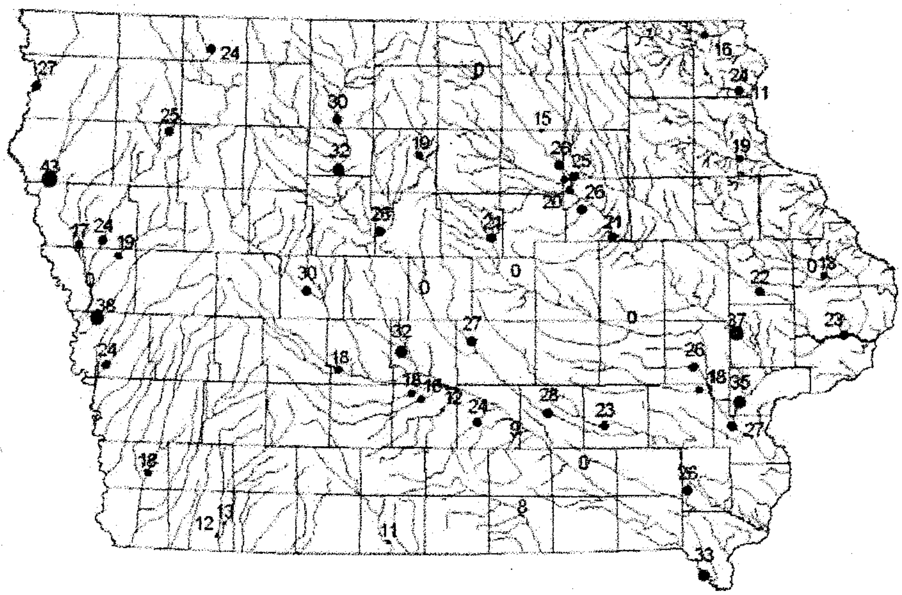
Statewide Hardness as CaCO3



Statewide Sulfate Monitoring Data



Statewide Chloride Monitoring Data



Appendix B:

Draft Justification for Changing Water Quality Standards for Sulfate, Total Dissolved Solids and Mixing Zones

Illinois Environmental Protection Agency

September 28, 2006

I. Introduction/Executive Summary

Water quality standards for sulfate (500 mg/L) and total dissolved solids (TDS) (1,000 mg/L) have existed in Illinois regulations since 1972. These standards were adopted to protect aquatic life and agricultural uses but without the benefit of modern scientific studies to determine appropriate values. Coal mine effluents in particular are often high in sulfate. The Illinois Pollution Control Board (IPCB or Board) developed standards for sulfate and chloride that are unique to mine discharges, 35 Ill. Adm. Code, Subtitle D, Mine Related Water Pollution. Use of the Subtitles C and D standards for sulfates to establish National Pollutant Discharge Elimination System (NPDES) permit limits has resulted in many conflicts. Permitting many mine discharges without the Subtitle D rules would be problematic because many mines cannot meet the General Use sulfate and TDS standards. Other industries also have difficulty meeting the general standards and many have received adjusted standards or site-specific water quality standards relief from the IPCB.

In order to resolve this conflict, the Illinois Environmental Protection Agency (Illinois EPA or Agency) proposes changes to several components of the Board regulations. First, the sulfate General Use water quality standard was extensively researched and new standards are proposed to protect aquatic life and livestock watering uses. Second, the total dissolved solids (TDS) General Use standard has been evaluated and found to be both ill-suited and unnecessary for the protection of aquatic life. Therefore, the Illinois EPA proposes to delete the TDS standard from the Board regulations. Third, changes to the Board's mixing zone regulations are proposed that will better allow the Illinois EPA to administer dilution allowances to dischargers that can demonstrate attainment of water quality standards whenever discharge occurs. Finally, our proposal ensures that the sulfate limits in NPDES permits for mine discharges are based on the Subtitle C General Use water quality standard; thus eliminating the conflict that existed in the past.

As Illinois was confronted with challenges to existing permitting practices for sulfate, the need for a thorough look at the basis of the water quality standard was in order. Agency biologists have long reported that aquatic life communities appear to tolerate concentrations of these pollutants higher than the existing water quality standards. Since no national criteria exist for these pollutants and few other states even have sulfate and TDS standards, an extensive process was undertaken to gather existing information on sulfate aquatic life toxicity. When available data proved inadequate to derive a standard, new studies were commissioned with sponsorship from the USEPA, the Illinois Coal Association and the Illinois EPA. At the same time, investigations on the tolerance of livestock to sulfate in drinking water were begun.

As suspected, this new research into sulfate toxicity found that high sulfate concentrations pose a problem of osmotic (salt) balance for some aquatic organisms. Many organisms, including all fish tested and some invertebrates, are very tolerant of sulfate, so much so that no known existing concentrations in Illinois would cause harm. Other species including the invertebrate water fleas (Daphnia and Ceriodaphnia) and scud (Hyalella) apparently have a harder time maintaining salt balance under high sulfate conditions, which leads to toxicity. Unlike many toxicants that exert toxic effects over both short term and long term periods (acute and chronic toxicity), sulfate has been demonstrated to affect only short term survival of organisms. In other words, organisms that survive the initial osmotic shock of exposure will survive indefinitely at that concentration. The new research also found that two common constituents of natural waters, chloride and hardness, are key to an understanding of the osmotic imbalance that leads to sulfate toxicity.

Upon the evaluation of dozens of tests on a total of 11 species, equations that determine the protective amount of sulfate to aquatic life were developed for the range of chloride and hardness concentrations in Illinois waters. If the hardness and chloride concentrations of a water body are known, the protective sulfate concentration may be determined. Sulfate permit limits based on local conditions of chloride and hardness may similarly be calculated. Under these proposed standards, allowable sulfate concentrations will vary from 500 mg/L for soft or low chloride waters, to over 2,500 mg/L in hard waters of average chloride concentration (See Exhibit A). Under the Illinois EPA proposal, most of the State's waters would have allowable concentrations of at least 1,500 mg/L, considerably higher than the existing standard allows. Aquatic life-based sulfate standards are proposed as concentration not to be exceeded at any time.

Livestock watering was another use requiring an updated sulfate standard, as the existing standard was loosely based on cathartic effects to humans and livestock. A review of literature found acute exposures to be irrelevant, as livestock are capable of withstanding sulfate concentrations much higher than the proposed aquatic life standards. However, recent studies suggested that extended exposures to drinking waters high in sulfate may lead to weight loss, disease, and death of livestock, thereby warranting a chronic standard. A chronic standard of 2,000 mg/L is considered protective of livestock watering, as surface waters supporting this concentration will not lead to adverse effects on livestock or economic effects to livestock operations. In many waters, aquatic life standards will require that sulfate concentrations are maintained below the 2,000 mg/L livestock standard. However, for waters where the instantaneously applied aquatic life standard is calculated to be above 2,000 mg/L, a 30 day or longer average sulfate standard of 2,000 mg/L will apply for protection of livestock in water bodies where livestock watering occurs.

While sulfate was being evaluated, it became increasingly obvious that TDS is a very inappropriate parameter for use in water quality standards. TDS is the sum of all dissolved substances in water and is dominated by the common ions of sulfate, chloride, sodium, calcium, carbonate and magnesium in various proportions. Our investigations into sulfate toxicity reinforced the notion that it makes little sense to have a standard that covers all these substances together when the toxicity of each constituent is really what is important. For example, a TDS concentration of 2,000 mg/L with chloride as the primary anion constituent is acutely toxic to aquatic life, but the same TDS concentration composed primarily of sulfate is nontoxic. With toxicity-based sulfate and chloride standards in force, there should be no need of a TDS standard that is incapable of predicting the threshold of adverse effects to aquatic life. The Illinois EPA is, therefore, proposing that the TDS water quality standard be deleted from the Board regulations.

Changes proposed to the mixing zone regulations will work in tandem with General Use standards to protect water body uses yet allow for economic growth. Most high sulfate mine discharges occur during wet weather events. Site drainage relatively high in suspended sediments is collected into treatment ponds where settling occurs. The treated water is then discharged to water bodies where General Use water quality standards apply. Water from the un-mined watershed also enters streams during these discharge events and provides dilution for sulfate and other substances in these effluents. For the past few years Illinois EPA has been granting wet weather discharges allowed mixing for sulfate and sometimes chloride, with consideration of these upstream flows. The Agency now proposes to amend the mixing regulations to make them clear in this regard. The changes to the mixing standards will allow mixing if it is verifiable that upstream dilution will exist whenever an effluent is discharged.

Considering the changes proposed for sulfate and TDS, the Agency is proposing to delete those portions of Subtitle D that address special water quality standards for sulfates and chlorides. Under the Agency's proposal, discharges from mines must be regulated in the same manner as other types of discharges. Water quality based permit limit decisions will now be required in lieu of special Subtitle D standards. As a housekeeping measure, an outdated portion of Subtitle D unrelated to water quality standards will also be deleted.

The changes to standards proposed in the Agency's petition are based on sound science and assure the protection of designated uses of waters of the State. These science-based standards will benefit mines and other dischargers of sulfate and other dissolved salts that are not amenable to treatment. Permit limits issued using the new sulfate and mixing regulations will be protective, yet not overly so, and will cause no unnecessary burden on economic activity.

II. Background: Sulfate and Total Dissolved Solids

Sulfate is an inorganic anionic substance that forms salts with sodium, potassium, magnesium and other cations. Sodium is the dominant cation in Illinois streams where sulfate concentrations are elevated due to human activities. The 19th Edition of Standard Methods for the Examination of Water and Wastewater (1995) (see Exhibit B) gives the following account for sulfate:

Sulfate (SO42-) is widely distributed in nature and may be present in natural waters at concentrations ranging from a few to several thousand milligrams per liter. Mine drainage wastes may contribute large amounts of SO42- through pyrite oxidation. Sodium and magnesium sulfate exert a cathartic action.

The Illinois EPA's Ambient Water Quality Monitoring Network (AWQMN) gathers chemical and physical water quality data from over 200 established stream stations across the State. Nine collections are made per year going back in many cases over a thirty year period. This database provides a means to study patterns of sulfate occurrence in Illinois along with other water quality information relevant to sulfate. In Northern and Central Illinois streams, sulfate levels range from 30 to 150 mg/L in streams without significant human-induced sulfate sources. In Southern Illinois, high readings occasionally exceed 5,000 mg/L in a few streams. Many other streams in this region have sulfate concentrations of up to 2,000 mg/L. These high sulfate streams receive effluents from coal mines. In many cases, these are abandoned, pre-law mines. Some Southern Illinois streams may have a natural component of sulfate that is higher than other parts of the State, but this is difficult to document given the extent of mining in this region. Coal mines in other regions of Illinois have only slightly elevated sulfate in their discharges and streams in mine areas typically do not exceed 500 mg/L sulfate. A few streams have elevated sulfate levels due to industrial discharges (see Table 1 on page 7 for the most pronounced examples). As in the coal mine effluents, the industrial discharges are dominated by sodium as the accompanying cation.

Total dissolved solids (TDS) is determined by filtering a water sample and measuring the residue upon evaporation of the filtrate. Sulfate, chloride, carbonate, calcium, magnesium and sodium are the main constituents of TDS in Illinois waters. Sulfate usually constitutes the majority of the TDS present when TDS is elevated over normal background levels. TDS is not usually measured by direct means in the Agency's AWQMN. In the approximately 1,000 samples collected at Intensive Basin Survey stations (another Illinois EPA monitoring program) throughout the State from 1999 to the present, where TDS is directly measured in the laboratory, TDS averaged 452 mg/L. A maximum value of 5,780 mg/L was recorded. The 95th percentile value was 1,075 mg/L meaning that about 5% of the samples did not meet the current standard of 1,000 mg/L.

Hardness is defined by Standard Methods as "the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter." Hardness is known to mitigate the toxicity of many metals to aquatic life and the Board standards are expressed accordingly. As was learned in the research to be described in this document (Section VII), hardness also mitigates the toxicity of sulfate to aquatic life. Most Illinois waters are generally classified as hard or very hard waters. USEPA recommends a reconstituted dilution water for use in toxicity testing termed "moderately hard" that has a hardness of 90 mg/L. As can be seen in Exhibit C, only about 2.5% of Illinois waters are expected to have hardness values below 90 mg/L during low flow events based on the findings of the Ambient Water Quality Monitoring Network. To produce the "Critical" hardness values in the attachment, data from a 15-year period from all stations in the network (approximately 135 samples per each of over 200 stations) were analyzed. Samples from the 10th percentile low stream flows were segregated and, of this data, the 10th percentile hardness value was determined. Therefore, the hardness values given in the attachment represent the lowest hardness expected in streams when they are at vulnerable low flows.

There is generally a north-south pattern to hardness in Illinois. Northern Illinois streams and lakes generally have hardness values in the 200-300 mg/L range. This is largely due to the limestone bedrock that underlies most of the northern 90% of the state. In contrast, several Southern Illinois streams are in areas where bedrock is comprised of sandstone or a limestone and sandstone mix that results in low hardness. Where mining occurs and sulfate values are elevated, hardness is also elevated due to exposure of the mine overburden to rainwater. None of the low hardness Illinois streams (<100 mg/L) have high sulfate concentrations. A water quality characteristic related to hardness is the calcium to magnesium ratio, a factor thought to be important in understanding sulfate toxicity. Illinois waters consistently have a calcium-to-magnesium ratio of between 2 and 2.5:1.

Illinois also has fairly high chloride concentrations in lakes and streams. As we will describe later in this document (Section VII), chloride, along with hardness, is a controlling factor in the degree of sulfate toxicity exerted on aquatic life. The average level in streams is in the 20 – 40 mg/L range. Streams impacted by road salting can seasonally be much higher. A few streams in far Southern Illinois have very low chloride relative to the rest of the state. Lusk Creek often has only about 1 mg/L chloride and averages about 2 mg/L but also has very low sulfate concentrations. Sugar Creek in Williamson County occasionally shows samples at 1 mg/L and averages about 6 mg/L. Sugar Creek is heavily impacted by abandoned mine discharges in the area of our sampling station and has very high sulfate concentrations during some flow conditions. However, when sulfate is elevated in Sugar Creek, chloride is also elevated. The Cache River, a stream flowing in part through cypress swamps, has occasional samples measured at less than 1 mg/L chloride and averages about 10 mg/L chloride.

III. Existing Water Quality Standards

The existing General Use and Lake Michigan Basin (other than for the open waters of Lake Michigan) sulfate standard is 500 mg/L. The standard was adopted by the Board in its 1972 standards rulemaking, "Water Quality Standards Revisions", R71-14. In the Board's adopting opinion, the need for this standard was described as follows:

> Sulfates. As in the case of chlorides, some limit seems desirable to protect stock watering and fish. Dr. Lackey suggested that 500 mg/L would afford adequate protection for fish; McKee and Wolf give this same figure for stock watering; and this level should avoid serious adverse effects on public water supplies as well according to McKee and Wolf.

Dr. Lackey was apparently an expert witness who testified before the Board. McKee and Wolf is an early water quality criteria document (See Exhibit D).

It is interesting to note that few other states have a water quality standard for sulfate for reasons other than to protect public water supplies. A summary of sulfate and TDS standards from neighboring states is found in Exhibit E. Illinois has two sulfate standards for the protection of water uses other than drinking water. One is set at 500 mg/L and covers all General Use Waters and Lake Michigan Basin waters other than the open waters of Lake Michigan. The other is a 24 mg/L sulfate standard based on background conditions in the lake and applies only to the open waters of Lake Michigan. Neither of the Lake Michigan standards are proposed for change in this petition.

The existing General Use and non-open water Lake Michigan Basin standard for TDS is 1,000 mg/L. The Board's adopting opinion gives this description:

Total Dissolved Solids. This level of 1,000 mg/L too is based largely on Dr. Lackey's testimony, confirmed by other witnesses and by McKee and Wolf, that aquatic life should not be harmed.

In addition to the General Use standard of 1,000 mg/L, there is an open waters of Lake Michigan standard of 180 mg/L and a Secondary Contact and Indigenous Aquatic Life standard of 1,500 mg/L. The open waters standard is based on the background condition of the lake rather than aquatic life protection. The Agency proposes to remove only the General Use standard from the Board regulations.

At this time, the Agency intends to address all standards for Secondary Contact and Indigenous Aquatic Life Use waters in a future rulemaking. Completion of the ongoing investigation into Use Attainability Analysis of the Des Plaines and Chicago waterways will lead to re-evaluation of the TDS standard for these waters as well as to consider inclusion of water quality standards for chloride and sulfate.

Both sulfate and TDS standards exist for Public and Food Processing Water Supply Intake waters. The sulfate standard is 250 mg/L and the TDS standard is 500 mg/L. These standards exist to protect the quality of human drinking water sources. The Agency is not proposing to change these standards.

IV. Site-Specific and Adjusted Standards for sulfate and TDS

The Board has granted special relief from the existing water quality standards for sulfate and TDS on several occasions to accommodate necessary industrial discharges. The highest stream concentration of sulfate allowed to date is 1,350 mg/L for Thorn Creek. The need for this relief was the establishment of an industrial discharge tributary to a municipal sewage treatment plant. Using the proposed sulfate standards later described in this petition, Thorn Creek would have a new standard of 1759 mg/L sulfate as a result of chloride and hardness concentration within the creek. The adjusted TDS standard at this site was 2,650 mg/L. Including this case, there are seven adjusted standards proceedings and two site specific water quality standards involving sulfate and/or TDS involving nine water bodies. A least one additional pending case before the Board involves a site specific rule for TDS. The highest TDS concentration allowed by special Board relief is 3,000 mg/L found at 35 Ill. Adm. Code 304.211. While this is an effluent standard (a permit limit rather than the standard that must apply in the water body), the receiving stream has a zero 7Q10 flow and would occasionally be expected to have a TDS concentration equal to the effluent concentration.

The following table lists the IPCB granted relief from sulfate and chloride water quality standards:

Table 1. Site-specific relief granted by the IPCB for sulfate and TDS to date.

Water Body	Docket #	Discharger	Parameter	Concentration now applied to water body or permit limit

				(mg/L)
Deer Creek	AS89-3	Aqua IL (formerly Consumers IL Water Co.) – University Park	TDS	2,100
Thorn Creek	AS01-9	Thorn Creek Sanitary District and Aqua IL – University Park	Sulfate TDS	1,160 to 1,350 2,360 to 2,650
Little Calumet River	AS01-9	Thorn Creek S.D. and Aqua IL – University Park	Sulfate TDS	1,000 2,020
Long Point Slough and its unnamed tributary	AS93-2 R86-14 303.431	Formosa Plastics (formerly Borden Chemical)	Sulfate TDS	1,000 3,000
Aux Sable Creek	AS93-8	Akzo Chemical	Sulfate TDS	1,000 3,000
Middle Fork North Branch Chicago River	AS99-5	Abbott Laboratories	TDS	1,500
McCook Drainage Ditch	AS02-1	Material Service Corp.	Sulfate TDS	850 1,900
Horse Creek	AS03-1	Exelon Generation	TDS	1,900
Sugar Creek	R91-23 303.323	Marathon Oil Refinery (now Marathon Ashland Petroleum	TDS	2,000

The Board also established special standards for coal mine discharges in 35 Ill. Adm. Code Subtitle D. Under these regulations, coal mine effluents are allowed to have sulfate concentrations of up to 3,500 mg/L. This regulation is also found in the listing of proposed rule changes in this petition.

V. Treatment to Reduce Concentrations of Sulfate and TDS

The Board has granted adjusted standards and site-specific relief for sulfate and TDS because there are no economically reasonable technologies that remove these parameters from water. Once salts are dissolved in water it is very difficult to get them back out again. Evaporation of solutions concentrated by reverse osmosis filtration would succeed to this end but would be extremely expensive. Deep well injection of high salt content waters has been used in the past, but this technique is increasingly difficult to implement due to groundwater protection regulations. In each and every petition for special Board relief, the Agency has concluded that there is no technically feasible or economically reasonable way to remove sulfates or TDS from water.

The best way to deal with salts is to prevent them from becoming dissolved in wastewaters. With the advent of reverse osmosis technology, many industries have abandoned the use of ion-exchange water softeners. This reduces the salt content of effluents because no regenerating solutions are needed. However, other basic industrial processes still must deal with solutions of salts that create high concentrations of sulfate and TDS. Recent advances in air pollution control technology have created, as an unfortunate byproduct, new wastestreams that are high in sulfate. Prevention of sulfate and TDS build up in coal mine waters is now part of the best management practices that must be implemented at the mines. Best management practices at mines that result in the minimization of overburden and waste pile exposure to rainwater have reduced levels in mine stormwater runoff. Dr. Chugh of Southern Illinois University at Carbondale is currently leading an effort to study coal mine refuse handling practices and find ways to better manage runoff. Mining companies are participating in the study conducted by Dr. Chugh that will serve to educate dischargers to achieve lower levels of sulfates and chlorides in effluents.

VI. Protection of Uses Potentially Impacted by Sulfate and TDS

Other than the public water supply uses covered by the Public and Food Processing Water Supply standards, there are two uses protected by sulfate and TDS standards, namely Agriculture (livestock) use and Aquatic Life use.

A. Livestock Uses

Sulfate - Livestock watering was envisioned as one of the uses to be protected by the existing sulfate standard, as sulfate has a cathartic (diarrheic) effect on humans and animals. The existing livestock standard was justified for its listing (McKee and Wolf, see Exhibit D) as a safe concentration for stock watering based on the following reasoning:

> 4. Summary. On the basis of the information gleaned from literature, it appears that the following concentrations of sulfate will not be detrimental for the indicated beneficial use:

Domestic water supply.................................... 500 mg/l
Irrigation...200 mg/l
Stock watering...500 mg/l

Upon review of referenced data within McKee and Wolf, it seems that 500 mg/L was chosen as a conservative value by the authors. Data within the document does not support this value, as nowhere is a justifiable reference for 500 mg/L sulfate found. Rather, it appears 500 mg/L was chosen as an arbitrary value to protect against cathartic effects to unacclimated livestock, as the same value was suggested for human consumption of drinking water.

It is evident that the existing sulfate standard is outdated and an updated livestock standard is necessary. Currently, human health is adequately protected from sulfate through public water supply intake standards, livestock protection will be provided through the incorporation of an updated General Use standard. High sulfates are of concern to those involved in animal husbandry where surface waters are utilized for livestock watering. Acute, short-term, exposure to elevated sulfate-waters produces temporary cathartic effects in livestock, but these effects are non-threatening and diminish as livestock are acclimated. Chronic exposure to high sulfate-waters is much more problematic, as extended exposure may lead to weight loss, disease, and death of livestock. Extended exposure of livestock to high sulfate-waters may be detrimental to livestock operations, therefore, a chronic standard must be implemented in surface waters utilized for livestock watering.

A literary review of the adverse effects of sulfates on livestock is summarized in Exhibit F. Much of the referenced literature is quite dated, but is nonetheless included due to the limited amount of available data. Earlier studies have widely contrasting results, with adverse effects being noted as low as 1,462 mg/L sulfate, and 'no adverse effects' measured as high as 7,000 mg/L sulfate. The contrasting toxicity results of early sulfate studies are confounding, as methods and results were often incomplete and lacked critical information such as study length, food and water consumption, and cation abundances. This information is necessary when considering a study's validity. Exposure duration is an especially important parameter when considering the results of a sulfate study. For example, Weeth and Capps (See Exhibit G) discovered reduced weight gains in cattle that consumed 1,462 mg/L sulfate-water over a 30-day period. However, the results are misleading due to the abbreviated study period. The study found that food consumption was unaffected at this concentration; therefore, decreased weight gain was likely attributed to the significant increase in water excretion throughout the study, as the short exposure period did not allow sufficient time for livestock to acclimate to elevated sulfates. Increased water excretion (diarrhea) is an initial response to elevated sulfate-water. However, continued exposure to elevated sulfates will lead to acclimation and will not adversely affect livestock unless concentrations are at severe levels.

The threshold concentration at which sulfate-water will adversely affect livestock is difficult to quantify due to the complexity of sulfate and the limited amount of reputable research. However, recent studies suggest that surface water concentrations in excess of 2,000 mg/L sulfate may be detrimental to livestock operations. Loneragan et al. (See Exhibit H) found that chronic exposure to 2,360 mg/L sulfate-water decreased carcass characteristics of cattle, signifying that chronic exposure to these concentrations may result in economic losses to livestock operations. Braul and Kirychuk (See Exhibit I) found that exposure to water with 2,500 mg/L sulfate results in poor conception of cattle. Patterson et al. (2004, See Exhibit J) found that concentrations near 2,600 mg/L sulfate result in weight loss and decreased body condition of cattle. As sulfate concentrations approach 3,000 mg/L cattle drink less water and become more prone to polioencephalomalacia (PEM), a neurological disorder which leads to anorexia, blindness, seizures, and eventually death (Patterson et al. 2002, See Exhibit K). It is apparent that the severity of adverse effects on cattle quickly accelerates at concentrations between ~2,300-3,000 mg/L sulfate, therefore, warranting a more conservative standard.

Due to a limited number of studies, assorted endpoints, and questionable validity of outdated studies, a mathematical derivation for sulfate toxicity to livestock is not practical. However, by observing recent studies, it is evident that a standard of 2,000 mg/L sulfate would adequately protect livestock from reductions in food consumption, water consumption, and growth. To verify the suitability of this proposed standard, Dr. Gavin Meerdink from the Department of Veterinary Medicine at University of Illinois Champaign-Urbana was contacted. Dr. Meerdink was supplied with the data from Attachment C and was informed of our plans of implementing 2,000 mg/L sulfate as a chronic, 30-day average standard. Dr. Meerdink questioned the validity of older studies within Attachment C. He stated that much more has been learned regarding the complexity of sulfur compounds and ruminants over the last 30 years, and that the recent studies likely had better detail in experimental design. He stated that sulfur compounds within the ruminant are a complicated issue, as much variability can be attributed the sulfur content of feed as well as the ability of rumen microbes to convert sulfur compounds into sulfides. Although limited animal taxa are represented in the literature, Dr. Meerdink acknowledged that cattle are a suitable study organism, as sulfur compounds in monogastric animals (pigs, rats, etc.) are much less of an issue. In summary, Dr. Meerdink stated that a 2,000 mg/L sulfate standard would adequately protect livestock. He related that unacclimated animals may exhibit diarrhea for several days immediately after initial exposure but will suffer no economically significant weight loss or other adverse condition. In his experience, livestock will soon adapt to the higher sulfate water and the temporary symptoms will disappear. Dr. Meerdink also stated that he would feel uncomfortable setting a standard at concentrations significantly higher than 2,000 mg/L sulfate.

Based on consideration of recent literature as well as Dr. Meerdink's professional experiences, the Agency concludes that 2,000 mg/L sulfate is a protective standard for livestock in Illinois. Although cathartic effects may occur to unacclimated animals consuming 2,000 mg sulfate/L water, referenced data suggests that chronic exposure to this concentration will not result in economic impacts such as reduced growth. Further, cathartic effects are likely to diminish or disappear over time. Given that sulfate ingested by animals would produce adverse impacts over a long period of time, the 2,000 mg/L standard for sulfate is proposed as an average concentration over at least a 30-day period. The standard is applicable only in areas where water is withdrawn or accessed for purposes of livestock watering. Daily sulfate concentrations greater than 2,000 mg/L are allowable for livestock provided a 30 day average of sulfate concentrations does not exceed 2,000 mg/L. Aquatic life sulfate standards will often supersede the livestock-based standard as explained in the following section.

Total Dissolved Solids - TDS is also of concern for livestock. Montana State University Extension Service produces a newsletter called "Beef Briefs". In it, Dr. Dave Hutcheson, PhD discusses water quality for cattle. The following table from this source contains:

Table 2. Montana State University recommendations for TDS in drinking water for cattle.

Total Dissolved Solids in mg/L	Effect on Cattle
1,000 – 2,999 (slightly saline)	Should not effect health or performance but may cause temporary mild diarrhea
3,000 – 4,999 (moderately saline)	Generally satisfactory, but may cause diarrhea, especially on initial consumption

Data within Table 2 concludes that TDS concentrations as high as ~5,000 mg/L will not adversely affect livestock. It is apparent that the existing TDS standard of 1,000 mg/L is over-protective, but the implementation of a higher TDS standard is equally inappropriate, provided that individual constituents of TDS are regulated. In Illinois waters, TDS is typically composed of sulfate as the predominant anion and sodium as the predominant cation. With enforcement of the existing chloride standard (500 mg/L) and the proposed sulfate standard (2,000 mg/L), a TDS concentration of ~5,000 mg/L cannot be achieved without violating these existing standards, as other anions such as magnesium and potassium are not found at concentrations high enough to contribute to an exceedance. Any TDS concentration found in Illinois waters would be suitable for livestock use provided that sulfate and chloride standards are met. Therefore, the Agency is proposing to delete the existing TDS standard from the Board regulations.

B. Aquatic Life Uses

Concern for protection of aquatic life is central to establishing water quality standards for sulfate or TDS. The Agency spent several years searching the literature and designing studies to definitively establish the maximum sulfate concentration that will be tolerated by sensitive species of aquatic life. A summary of the Agency's findings is presented in the sections that follow.

Water Quality Standard Derivation Methodology and Literature Search for Studies on Sulfate Toxicity to Aquatic Life. Salts containing sulfate are natural substances in the environment. It is not expected that sulfate would be highly toxic or to express toxicity in the way many synthetic industrial compounds (or natural toxic substances) do. Animals tolerate a large variation of sulfate in the aquatic environment. Sulfate is a necessary nutrient for plants, and therefore, for the stream community as a whole. However, it is not known to be limiting to the normal expression of aquatic life in aquatic ecosystems. It may also be a necessary nutrient for animals, e.g., in formation of chondroitin sulphate.

In testing the effects of variation in sulfate concentration, the sulfate is necessarily introduced in a salt form ($Na2SO4$) to a standard medium (as defined by USEPA and ASTM). The medium contains various cations, Na, K, Mg, and Ca, and anions, $HCO3$, chloride and sulfate. All of these ions are necessary for normal functioning of cells. Raising the sulfate level is not just a matter of increasing the level of the specific substances, sodium and sulfate. It also involves increasing the ionic strength of the solution as a whole. Also, the balance or ratios of some of the ions are being changed as $Na2SO4$ is raised. Thus, sulfate toxicity (as for other ions) is a complex phenomenon with toxicity dissimilar to most other kinds of substances.

Sulfate is a conventional pollutant, therefore, information concerning it has been in the literature for many years. This means there may be information in older, sometimes difficult-to-find, literature. Tests done decades ago would not have been standardized in ways that are routine now. The most important problem encountered in the older studies was that heavy metal contamination in the reagents might have exerted a toxic effect when a high level of the salt of interest is necessary to produce a response. Researchers prior to the 1980's were probably unaware that the purity of the sodium sulfate reagent used in their tests could have been a factor in the results obtained. Toxicity studies now use the most pure form available. The Agency also found that the literature contained studies done on unusual species that live in habitats with very little natural sulfate. In particular, a Canadian study was rejected because the test species was unique to an unusual mountain habitat, and was apparently very intolerant of what would be a normal level of sulfate in the Midwest. See Exhibit L for a discussion on the validity of all known studies.

The above concerns became apparent over the time as the Agency gathered data to determine a water quality standard. The USEPA aquatic life-based model ("Guidelines" See Exhibit M) requires gathering all data available and assessing their suitability to determine the water quality criterion. The Agency narrowed the search to Na2SO4 given that water quality data show that sodium is the predominant cation in Illinois waters. Mainly, the Agency searched the AQUIRE database, but also found other sources. After the Agency had assembled what seemed like a complete database, it went through a preliminary examination. The Agency determined that a number of values for various taxa appeared to be unrealistically low, knowing that there seems to be a fairly balanced aquatic community in many Illinois streams with sulfate concentrations higher than these supposedly toxic test solutions. The Agency contacted experts (Drs. David Mount and Charles Stephan) at the USEPA Duluth Toxicity Laboratory to see if any efforts on deriving a sulfate criterion had been attempted at the federal level. According to Duluth Laboratory staff, no federal criterion has been completed, but some work had been done to explore the role of sulfate and total dissolved solids in aquatic life toxicity. They related that they believed there was a metals contamination problem with some of the older studies, as described above. Recent papers describing the role of sulfate, chloride and different cations were brought to the Agency's attention. Duluth Laboratory personnel also indicated which of the older papers they consider to be suspect. Eventually, data for over 30 kinds of organisms from about 30 papers/sources were found. USEPA Region 5 and The Advent Group, Inc. (employed by the Illinois Coal Association) were also involved in the assessment. By the end of this consultation process, Dr. Stephan compiled a list of toxicity test results that were considered valid for standard derivation. Toxicity values and references for these studies are given in Attachment N. A complete list of all literature sources considered, along with a brief comment regarding the acceptability of each study, is provided in Exhibit O.

The literature research showed that essentially only two groups, fish and zooplankton crustaceans, were adequately represented in the database. Fish are so tolerant of sulfate that no further discussion or additional testing is necessary. Strong representation of the daphnids is expected since these are common, easily tested organisms. However, *Hyallela azteca* data was relatively scarce, and available data suggested this native species is most sensitive to sulfate. For credence to be given to the dataset of toxicity values, more variety of invertebrate species was necessary, especially, since invertebrates show the highest sensitivity to sulfate.

Based on the review of the available data, the Agency came to the following conclusions:

- Reliable toxicity data for additional invertebrate species were needed

- Few freshwater chronic tests exist. The method of toxicity exerted by sulfates is probably the sudden change of ionic concentration, i.e., the relative saltiness of the water, rather than other types of interference with organism metabolism. If an organism can withstand the osmotic shock initially, it will probably continue to survive and function at a given sulfate level indefinitely.

- Sulfate is not a toxicant in the category of heavy metals, pesticides or other toxic natural or man-made substances, but rather is a common salt necessary for life at some concentration (Goodfellow, See Exhibit P). It does not fit the model for derivation of water quality criteria using the standard federal "Guidelines" document, and may therefore, require a sulfate-specific derivation procedure.

- An examination of data from the Ambient Water Quality Monitoring Network found that when sulfate is elevated, sodium is the major cation. When sulfate is not elevated, either sodium or calcium is the major cation. Relative cation toxicity from highest to lowest is potassium, magnesium, calcium and sodium (Mount, et. al. See Exhibit Q). Therefore, the Agency concluded that tests using sodium sulfate are appropriate for Illinois conditions.

Newly Generated Sulfate Toxicity Data. The Agency met with USEPA Region 5 Standards Unit staff and a representative of the Illinois Coal Association to determine the direction to be taken concerning two very important aspects of developing a new sulfate standard for Illinois. Two specific issues were considered. The first was to decide who would conduct aquatic life toxicity tests on key invertebrate species, and what those species would be. The second was to agree on a method for determining the value of the new standard from the existing acceptable toxicity data and that data which would become available from the contracted research.

Dr. David Soucek of the Illinois Natural History Survey was contracted to conduct the laboratory toxicity testing. Dr. Soucek has worked extensively on mine discharge impacts to streams. His laboratory at the University of Illinois Urbana-Champaign was determined to be fully capable of conducting the necessary tests.

On the second matter, it was agreed that because sulfate does not behave as a conventional toxicant, the USEPA's "Guidelines" approach would be replaced by a more straightforward method. It was concluded that sulfate, being a natural salt component, does not carry the risk that a true toxic substance would have. With truly toxic substances, there is a risk that untested species may exhibit much more sensitivity than did the small group of species tested, thereby meriting a safety factor. Since our efforts in generating new data targeted species thought to be most sensitive to sulfate, additional uncertainty was alleviated. It was initially proposed that the LC_{10} (lethal concentration to10% of exposed organisms) for the most sensitive organisms would be used in derivation of the sulfate standard. However, this approach was met with opposition from USEPA, therefore, a modified approach of the Guidelines was utilized in its place. Details and justification for use of this sulfate-specific approach is summarized below in the equation formulation section.

Research conducted by Dr. Soucek was vital to the standard derivation, as the sensitivity of several organisms was thoroughly studied and greatly increased the amount of acceptable sulfate data. Possibly of greater significance was the finding that sulfate toxicity is dependent on water chemistry, thereby emphasizing the need for a water quality-based equation rather than a statewide numerical standard derived from typical procedures. Data obtained from research conducted by Dr. Soucek is summarized in Exhibit R, final and quarterly reports summarizing this research are found in Exhibits S, T, U, V and W. Briefly summarized, his work entailed determining the acute toxicity of sulfate to four invertebrate species commonly found in Illinois and thought to fill the gaps in the existing valid database. These organisms were the water flea *Ceriodaphnia dubia*, a previously tested organism used as a gauge for comparison purposes, *Hyalella azteca*, an amphipod, *Chironomus tentans*, a midge fly, *Sphaerium simile*, a fingernail clam, and *Lampsilis siliquoidea*, a freshwater mussel. These organisms were selected based on presumed sensitivity to sulfate from literature values (*Hyalella*), the need to have data from an insect (*Chironomus*) and the perceived sensitivity of bivalve mollusks to toxicants in general (*Sphaerium* and *Lampsilis*). The first phase of Dr. Soucek's testing was to conduct standard (methodology and test waters according to nationally accepted methods) acute tests on these organisms and establish the LC_{50} (the concentration lethal to 50 percent of the test organisms exposed) values for each species.

In the course of this first phase of testing, Dr. Soucek noted that the standardized Moderately Hard Reconstituted Water (MHRW) may be inadequate for the culture and testing of *Hyalella azteca*. (The version of MHRW used by Dr. Soucek in his studies was slightly higher in calcium sulfate than the nationally published formula resulting in a hardness of about 104 mg/L rather than the standard 90 mg/L.) He designed experiments to show that a slight increase in chloride and a different ratio of magnesium to calcium content increased the tolerance of this species to sulfate five fold. To a lesser degree, this improved balance of salts also increased the tolerance of *Ceriodaphnia* to sulfate. Further experiments showed that increasing hardness of the test water decreased toxicity of sulfate to these species. Additionally, acclimation experiments showed that *Ceriodaphnia* could be cultured at much higher sulfate concentrations than the standardized culture method would prescribe, and that this species thus acclimated had higher, though not significantly higher, tolerance to sulfate. Further tests would be needed to show statistically significant differences, however. Dr. Soucek also did limited chronic toxicity testing on *Ceriodaphnia dubia* (Second Quarterly report See Exhibit U), though not enough data has been compiled through literature review and Dr. Soucek's tests to propose a chronic standard at this time. However, results from Dr. Soucek's tests have shown that a chronic exposure period will not result in reduced survival compared to acute exposures. Additionally, Dr. Soucek has noted that he has a self-sustaining reserve culture of *Ceriodaphnia dubia* in MHRW spiked with 1,000 mg/L sulfate, therefore reproduction is not believed to be significantly impaired at this concentration.

Dr. Soucek's research clearly shows a relationship between sulfate toxicity and water chemistry parameters, namely chloride and hardness. It is believed that chloride and hardness influence the toxicity of sulfate to aquatic invertebrates due to alterations in osmoregulation. Invertebrates achieve ionic balance with surrounding water through active transport, an energy requiring activity. At intermediate chloride and higher hardness concentrations, ionic balance in the presence of elevated sulfate concentrations is achieved rather easily. At low chloride and higher hardness concentrations, osmoregulation is increasingly difficult, resulting in utilization of energy stores in an attempt by the organism to achieve ionic balance. High levels of chloride increase sulfate toxicity as well, primarily through increasingly unbalanced osmotic conditions.

Because sulfate toxicity is dependent on chloride and hardness concentrations, these water quality characteristics must be taken into consideration when setting a standard throughout the State. For example, a single statewide numeric standard for sulfate may be sufficiently protective in one stream, but under-protective in another depending on water chemistry. To adequately protect aquatic organisms from sulfate throughout the State, it is important that chloride and hardness be considered on a site by site basis. By creating an equation that relates sulfate toxicity to chloride and hardness, these two values can be measured in a water body and entered into the equation to determine the maximum amount of sulfate allowable for that water body.

Equation Formulation. Using acceptable data only, chloride and hardness specific LC50 equations for sulfate toxicity to *Hyalella azteca* and *Ceriodaphnia dubia* were calculated through multiple regression with analysis of covariance. These species exhibited the highest sensitivity to sulfate and had the most studies conducted under various hardness and chloride values. LC50 values for the two species were measured or estimated with the EPA Spearman-Karber program at various concentrations of sulfate, chloride, and hardness. The LC50 values were used to calculate equations for hardness in the range of 87 to 500 mg/L and chloride in the range of 25 to 526 mg/L, with a Ca-Mg ratio of 2.33. The equations are as follows:

C. dubia: LC50 = 1828 + 5.508(hardness) - 1.457(chloride)
H. azteca: LC50 = 1464 + 5.508(hardness) - 1.457(chloride)

Because toxicity data was acquired from tests with various concentrations of hardness and chloride, all acute values were normalized to the same water chemistry so that final acute values could be calculated. The slopes for hardness (+5.508) and chloride (-1.457) attained from the equations above were used to normalize acute values to hardness of 300 mg/L and chloride of 75 mg/L, which are typical concentrations found in Illinois waters. Normalization was performed by plugging the LC50, hardness, and chloride values for each test into the following equation:

Normalized LC50 = Test LC50 + (300 – hardness)(5.508) + (75 – chloride)(-1.457)

Only tests with hardness between 87 and 500 mg/L and chloride between 25 and 526 mg/L were capable of being normalized, as little data existed outside of these values. After normalization, genus mean acute values (GMAV) were obtained by calculating the geometric mean of all normalized values for each genera. Using the GMAVs for sulfate at hardness of 300 mg/L and chloride of 75 mg/L, the final acute value (FAV) for sulfate was calculated to be 2819.8 mg/L through procedures stated in 35 Ill. Adm. Code 302.615(c-g). With an FAV of 2819.8 mg sulfate/L, and by utilizing the slopes for hardness and chloride, the following equation was developed to estimate the acute aquatic toxicity criterion (AATC) of sulfate at ranges of hardness between 87 and 500 mg/L, and chloride between 25 and 526 mg/L. This is the final equation that will be used to predict site-specific sulfate standards within the aforementioned hardness and chloride range. After entering hardness and chloride values from a specific site, the resulting value will be the protective concentration of sulfate at that specific site under those water quality characteristics.

AATC = [1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65

It is important to note that a sulfate specific factor of 0.65 was added to the equation for proper protection, which deviates from the 0.5 factor specified in 302.618.i, as well as the Guidelines. Whereas, the Guidelines and Illinois Subpart F procedures use a factor derived from 219 acute toxicity tests on various toxics, a sulfate-specific factor is needed because sulfate is dissimilar from heavy metals, pesticides or other toxic natural or man-made substances used in factor derivation. The 0.65 value was derived by taking the highest tested sulfate concentrations with percent survival equal to or higher than the control treatments and dividing these values by the corresponding LC50s. The value is equivalent to the geometric mean of the quotients from 20 tests using two of the most sensitive species, H. azteca and C. dubia (See Exhibit R). In general, this value is a reflection of the average ratios between no observable adverse effect levels (NOAEL, 35 Ill. Adm. Code 302.603) and corresponding LC50s of acceptable sulfate data. Jim Keating of the USEPA has provided a justification for use of this sulfate specific factor, which is as follows:

> *Why is it acceptable to multiply the FAV for sulfate by 0.65 instead of dividing the FAV by 2 as specified in the USEPA 1985 Aquatic Life Guidelines?*
>
> The term "Final Acute Value", or FAV, is the value protective of at least 95% of the species at the LC50 level of effect (concentration which is lethal to 50 percent of the tested organisms). To obtain a protective "Criterion Maximum Concentration", or CMC (commonly referred to as an "acute criterion"), there must be an adjustment from an LC50 level of effect to a protective level of effect. EPA uses a factor of 0.5 as a multiplier to achieve this protective level of effect, based on an evaluation of data from numerous toxicity tests for a variety of pollutants and species where lethality data were used to determine the highest tested concentration that did not cause mortality greater than that observed in the control, which would be between 0 and 10% of the tested organisms. The steps of this evaluation may be duplicated for a separate set of toxicity data to derive a pollutant-specific adjustment factor where the data set is of sufficient quantity (multiple species represented) and quality and includes results from sensitive test species. Twenty data points from two of the most sensitive species were used in the pollutant-specific analysis for sulfate data and produced a multiplier of 0.65 to adjust from an LC50 level of effect to a protective level of effect. This value represents greater specificity and precision for sulfate than the general multiplier of 0.5. Its use with the FAV yields a criterion that is scientifically defensible and protective of aquatic life uses from the short-term lethal effects of sulfate.

Low chloride equation. Sulfate toxicity greatly increases at chloride levels below 25 mg/L, therefore, a separate equation was calculated for the range of 87 to 500 mg/L hardness and 5 to 25 mg/L chloride following similar procedures. All *H. azteca* data ($n = 28$) within these ranges were used to calculate an LC50 equation through multiple regression with analysis of covariance.

Although fewer data were available at these ranges, it should be noted that *H. azteca* was the most sensitive species tested. The equation is as follows:

AATC = [-57.478 + 5.79 (hardness) + 54.163(chloride)] * 0.65

Extreme concentrations. The two aforementioned equations will be acceptable for standard calculation in nearly all streams, except for rare instances where chloride and hardness values are extremely high or low and are therefore outside the acceptable range for standard calculation. Very little sulfate toxicity data is available at these water chemistry extremes, therefore, typical derivation procedures are impractical and numerical standards must be implemented. Through review of available data at these extremes, the following standards will offer adequate protection under the specified water chemistry conditions:

> If the hardness concentration of waters is less than 100 mg/L or chloride concentration of waters is less than 5 mg/L the sulfate standard is 500 mg/L.
>
> If hardness concentration of waters is greater than 500 mg/L the sulfate standard is 2,000 mg/L.

VII. Deletion of the TDS Standard

The Agency's research into existing ion concentrations in Illinois waters found that of the common substances comprising the major portion of total dissolved solids, toxicity is always associated with either sulfate or chloride. Sodium, calcium, magnesium and carbonates make up the other ions in the majority, but these are not sufficiently toxic to create the need for individual water quality standards. Simply put, if sulfate and chloride, alone or in combination, meet the proposed standards, toxicity from the other major ions comprising "total dissolved solids" is insignificant. Therefore, TDS concentration provides no additional useful information. The existing standard is cumbersome and results in restrictions where none should exist. For example, if the sulfate water quality standard for a water body was calculated to be 2,000 mg/L under a certain level of hardness and chloride (340 mg/L and 50 mg/L, respectively), the total dissolved solids concentration of that solution would be 2,390 mg/L without adding the sodium that is associated with the sulfate and chloride. Obviously, a TDS standard of 1,000 mg/L is incapable of indicating the concentrations of dissolved substances that are harmful to aquatic life in this example. In another example, where chloride is 5 mg/L and hardness is 90 mg/L, the sulfate standard is 500 mg/L. Here, a 1,000 mg/L TDS standard may be under protective. Because of the better understanding of major ion toxicity, the Agency is proposing to delete the existing TDS standard from the Board regulations.

VIII. Conclusions and Recommended Standards

By reviewing sulfate toxicity data, it is evident that sulfate is far less toxic than current standards indicate under most conditions found in Illinois. The current standard does not account for water chemistry conditions, which may significantly alter sulfate toxicity. Protection of aquatic life will be fully achieved through implementation of the water chemistry dependent equations as well as numerical standards. For illustrative purposes only, calculated sulfate standards at various increments of hardness and chloride are shown in Attachment L. Numeric standards are included as well, where applicable. Exact chloride and hardness concentrations must be entered into the appropriate equation to calculate the exact sulfate standard at a specific site. Also, it is to be noted that water chemistry at specific sites may allow for sulfate standards in excess of 2,000 mg/L. Protection of livestock watering will be achieved through the proposed standard of 2,000 mg/L sulfate over a 30-day average at locations where livestock watering occurs.

In light of recent sulfate findings, the TDS standard currently in place is inappropriate. By definition TDS is a measure of all dissolved solids, yet we know that the toxicity of TDS is exerted by its individual constituents. With the advent of a protective sulfate standard expressed by the aquatic life equations and numerical standards, total dissolved solids concentrations of 3,000 mg/L or more will not be toxic if sulfate is the predominant anion and sodium the predominant cation. This is the existing case in Illinois under most high TDS concentrations. The exception to this rule is when chlorides are high. The chloride standard of 500 mg/L is thought to be protective of aquatic life toxicity. Therefore, between the chloride and sulfate water quality standards and the narrative toxics control standard (35 Ill. Adm. Code 302.210) that regulates any discharged substance that could cause toxicity, there is no need for a TDS standard. While potassium or some other more toxic cation could occur in industrial discharges, this condition has not been identified in any ambient stream or effluent setting thus far. The existing TDS standard has always been ungainly since it is really based on a worst-case combination of minerals being present. The specific constituents of the mineral content of water are better regulated individually. Thus, the Agency recommends that the TDS standard be deleted from the Board's regulations.

Changes are also proposed to the Subtitle D Mine Related Water Pollution regulations. References to relief from water quality standards are proposed to be stricken. Mine discharges will now meet water quality standards as must other categories of discharges, except where site-specific relief is given by the Board or a mixing zone is granted. Part 407 of Subtitle D is being stricken for housekeeping purposes as these regulations are no longer pertinent.

IX. Changes to the Mixing Zone Standard

The Agency has proposed updates to the mixing regulations based on the increasing need to appropriately regulate storm water runoff related discharges and other discharges that may occur when streams are not at drought flow. These changes must be evaluated within the context of existing provisions of the mixing regulations at 35 Ill. Adm. Code 302.102. Most notably, the existing mixing regulations require that the best degree of treatment as specified in Section 304.102 has been applied by the discharger. The proposed changes are not in any way designed to interfere with this basic concept embedded in the regulations since their inception. The Agency's proposal would allow mixing for substances such as sulfate, boron, chloride, and fluoride, for which no practical and reasonable treatment exist, to occur whenever adequate flow exists to dilute such effluents. Under this proposal, other substances such as metals, however, would be subjected to the treatment requirements of Section 304.102 before a possibility of mixing could be considered.

<u>Section 302.102(b)(8):</u>

Section 302.102(b)(8) prohibits mixing in streams that have a zero flow for a minimum of seven consecutive days at a recurrence frequency of once in ten years ("zero 7Q10 flow"). The regulation exists to protect aquatic life from discharges occurring at drought flows that could cause water quality standards to be exceeded. However, during rainfall or snowmelt events, these smaller receiving streams receive significant storm water runoff from the watershed. During these events receiving streams temporarily contain flows that may be totally nonexistent during dry periods. Additionally, flows may exist in these streams seasonally, coinciding with periodic effluent discharges. A discharge of pollutants that occurs only under these conditions will have no adverse impact to aquatic life if flows in receiving streams consistently and demonstrably ensure attainment of water quality standards.

The Agency's proposal is based on the principle found in an existing Board definition.

Section 301.270 Dilution Ratio

"Dilution Ratio" means the ratio of the seven-day once in ten year low flow of the receiving stream or the lowest flow of the receiving stream when effluent discharge is expected to occur, whichever is greater, to the average flow of the treatment works for the design year.

(Source: Amended at 3 Ill. Reg. no. 25, page 190, effective June 21, 1979.)

The definition of dilution ratio implies that stream flow values other than 7Q10 may be used to determine mixing and dilution allowances provided that the lowest flow of the stream when the discharge is expected to occur is used. To allow mixing for discharges to zero 7Q10 flow streams, the Agency proposes the deletion of the last sentence of Section 302.102(b)(8). The basic intent of the proposal is that mixing is permissible in zero 7Q10 flow streams if the flow in the stream is sufficient to ensure attainment of water quality standards. The other concept contained in 302.102(b)(8) dictates the percentage of stream flow that may be allowed for dilution. The definition of dilution ratio and the corresponding instruction in 302.102(b)(8) will apply to all streams, 7Q10 zero flow or not, except for certain very small receiving streams described as follows.

Section 302.102(b)(6):

The Agency is proposing changes to Section 302.102(b)(6) to allow mixing in very small streams without imposing the zone of passage requirement. These small streams are zero flow streams in dry weather and they are also, by nature, narrow streams. The mixture of effluent and stream water will quickly encompass the entire width of the stream bed since the stream flows present when effluents are discharged are often high velocity, typical of runoff events. Due to the high velocity effluent coming in contact with the runoff from the watershed, mixing of an effluent with the receiving stream is instantaneous during these wet weather events. One way to identify these types of streams is to compare them to 7Q10 zero flow streams using an analogous method of identification. A 7Q1.1 zero flow stream means a stream that has at least a one week period of no flow that recurs at least once annually in nine out of ten years. 7Q1.1 zero streams have very limited aquatic life habitats for the simple reason that their flow is too ephemeral to support balanced aquatic life communities. 7Q1.1 zero flow streams may support some fish species on a seasonal basis as long as some water remains. These species are adapted to the "flashiness" of these habitats, with very low flow or zero flow conditions present one day and relatively high flow, turbulent conditions the next. Fish species that may want to migrate past an effluent outfall usually will not exist in 7Q1.1 zero flow streams. Even if migrating fish do exist, instantaneous mixing that would occur in these streams may not pose a barrier. For these reasons, the Agency's proposal specifies that no zone of passage is required in 7Q1.1 zero flow streams. Therefore, mixing in 7Q1.1 zero flow streams would not be required to conform to containment in 25% of the area or volume of stream flow, if the dilution is greater than 3:1 or greater. Streams with greater than 7Q1.1 zero flow conditions would be subject to the provisions of Section 302.102(b)(8) that determine how much stream flow is available for mixing with an effluent.

302.102(b)(10):

The Agency is proposing changes to 302.102(b)(10) to ensure consistency with the changes made to Sections 302.102(b)(6) and (b)(8). The Agency's proposal provides that no body of water may be used in its entirety for mixing purposes unless it is a 7Q1.1 zero flow stream.

X. Economic Impact of the Proposed Changes to the Standards

Water quality standards are developed to protect designated uses, in this case, agricultural uses and aquatic life uses. Once these values are determined, impact on economic activities can be evaluated. In the case of the proposals in this petition, there is an economic relief to be gained. The existing standards were recognized to have an impact on discharges from coal mines shortly after adoption. The IPCB responded to what would have been severe economic hardship to most mines by adopting exceptions to the standards in the Subtitle D Mine Related Water Pollution Regulations. This gave needed relief to coal mines; industrial discharges did not receive this relief and had to pursue adjusted standards/site-specific standards relief. Challenges have been entered against the relief provided by Subtitle D, hence the proposed revocation of that regulation in this petition. In light of these challenges and in the absence of this revision to update sulfate standards to scientifically justifiable levels and to delete the unnecessary TDS standards, extreme economic impact to the coal industry would ensue. Requiring coal mines to meet the existing water quality standards would result in a majority of the active mines and almost all reclamation projects to be shut down.

There is also a cost associated with the repeated granting by the Board of adjusted standards and site-specific relief to industrial dischargers, overriding water quality standards that are not scientifically justified. With new air quality regulations for sulfur emissions, these petitions may become more common.

Exhibit D: Sulfate and TDS water quality standards of neighboring states.

Inquiries were made to other states as to their existing or proposed water quality standards for sulfate and TDS. Michigan, Wisconsin, Minnesota, Iowa, Missouri, Indiana, Ohio and Kentucky were surveyed.

Michigan, Wisconsin, Iowa and Kentucky have no numeric aquatic life or general use standards for these substances. All these states have public water supply intake standards similar to those in Illinois. Most of the states surveyed have some sort of narrative standard that prohibits impairment from total dissolved solids or conductivity in the water.

Minnesota has a standard of 250 mg/L sulfate that applies to public water supply intakes and trout waters. For other waters, MN uses a site-specific guideline value of 1,000 mg/L which is said to come from the Canadian Water Quality guidelines manual. It is to protect young livestock, specifically young cattle, from getting diarrhea. MN also has a sulfate standard of 10 mg/L to protect wild rice. In their reply to our survey, they relate however, that MN staff believes there is little scientific justification for this low value and they seek to change the standard as part of their next Triennial Review of standards. MN has no TDS standard for waters other than public water supply intakes.

Missouri has a combined water quality standard for sulfate and chloride of 1,000 mg/L to protect aquatic life in streams with a 7Q10 flow of less than one cubic foot per second (cfs). For larger streams, the sulfate plus chloride concentration must not exceed the estimated natural background concentration by more than 20% at the 60 Q10 low flow. If higher concentrations of sulfate plus chloride can be demonstrated to protect indigenous aquatic life, then the appropriate higher concentration will be allowed. Missouri has no TDS standard to protect aquatic life or general uses.

Until recently, Indiana had standards that applied to all waters; 250 mg/L for sulfate and 750 mg/L for TDS. A rulemaking to change these standards that were described as "unworkable" by the Indiana Department of Environmental Management was proposed and adopted with USEPA approval. The TDS standard was dropped as an aquatic life protection standard and changed to 500 mg/L applicable at public water supply intakes. This creates a standard similar to those found in other states for TDS at water supply intakes. A sulfate standard of 250 mg/L is to be established at public water supply intakes and an interim standard of 1,000 mg/L was be put into effect in other waters to protect aquatic life. USEPA region 5 approved these changes under the Clean Water Act.

Ohio has a TDS standard for aquatic life of 1,500 mg/L to be met on an average basis outside of a mixing zone. No sulfate standard exists for aquatic life or general uses.

Exhibit E: Literature review of the adverse effects of sulfates on livestock.

Animal	Treatment	Sulfate (mg/L)	Effect	Reference
Cattle and weanling pigs	Water	7,000	No adverse effect	Embry et al. 1959
Cattle	Water	10,000	Reduced water and food consumption	Embry et al. 1959
Cattle	Water – 30 day	5,000	30% decrease in food consumption	Weeth and Hunter, 1971
Cattle	Water – 30 day	5,000	35% decrease in water consumption	Weeth and Hunter, 1971
Cattle	Water – 30 day	2,814	No affect on water consumption	Weeth and Capps, 1972
Cattle	Water – 30 day	2,814	12.4% reduction in food consumption	Weeth and Capps, 1972
Cattle	Water – 30 day	1,462	No reduction in food consumption	Weeth and Capps, 1972
Cattle	Water – 30 day	1,462	Reduction in weight gain	Weeth and Capps, 1972
Cattle	Water – 30 day	1,462	Increased excretion of water	Weeth and Capps, 1972
Cattle	Water – 30 day	1,450	Discriminated against drinking water	Weeth and Capps, 1972
Cattle	Water – 30 day	2,150	Rejected drinking water	Weeth and Capps, 1972
Cattle	Water – 90 day	2,500	No affect on weight gain	Digesti and Weeth, 1976
Cattle	Water – 90 day	2,500	No affect on water consumption	Digesti and Weeth, 1976

Animal	Treatment	Sulfate (mg/L)	Effect	Reference
Cattle	Water – 90 day	2,500	No affect on food consumption	Digesti and Weeth, 1976
Cattle	Water – 90 day	2,018	Discriminated against drinking water	Digesti and Weeth, 1976
Cattle	Water – 90 day	3,317	Rejected drinking water	Digesti and Weeth, 1976
Weanling pigs	Water	2,402	No decreased performance	Anderson and Stothers, 1978
Gilts and sows	Water	3,000	No affect on weight gain	Patterson et al. 1979
Gilts and sows	Water	3,320	No affect on reproduction	Patterson et al. 1979
Mice	Water	5,000	No reproductive effect, no effect on growth	Andres and Cline, 1988
Neonatal piglets	Liquid diet – 18 day	2,200	No affect on weight gain	Gomez et al. 1995
Cattle	Water - 113 day	2,360	Decreased carcass characteristics (dress-out)	Loneragan et al. 2001
Cattle	Water	2,500	Poor conception	Braul and Kirychuk 2001
Cattle	Water	3,000	Decreased water consumption	Zimmerman et al. 2002
Cattle	Water – 85 day	3,087	Decreased water intake and growth, 15% PEM occurrence	Patterson et al. 2002
Cattle	Water – 54 day	2,608	Weight loss and decreased body condition	Patterson et al. 2004

Literature Cited

Anderson, DM and SC Stothers. 1978. Effects of saline water high in sulfates, chlorides, and nitrates on the performance of young weanling pigs. J Anim Sci. 49:664-667.

Andres, DJ and TR Cline. 1988. Influence of sulfate in drinking water on mouse reproduction during two parities. J Anim Sci. 67:1313-1317.

Braul, L and B Kirychuk. 2001. Water Quality and Cattle. Publication ENH-111-2001-10. Prairie Farm Rehabilitation Office, Agriculture and Agri-Food Canada.

Digesti, RD and HJ Weeth. 1976. A defensible maximum for inorganic sulfate in drinking water of cattle. J Anim Sci. 42:1498-1502.

Embry, LB, MA Hoelscher, RC Wahlstrom, et al. 1959. Salinity and livestock water quality. S D Agric Ex Str Bull. 481:5-9.

Gomez, GG, RS Sandler, and E Seal, Jr. 1995. High levels of inorganic sulfate cause diarrhea in neonatal piglets. J Nutr. 125:2325-2332.

Loneragan, GH, JJ Wagner, DH Gould, FB Garry, and MA Thoren. 2001. Effects of water sulfate concentration on performance, water intake, and carcass characteristics of feedlot steers. J Anim Sci. 79:2941-2948.

Patterson, DW, RC Wahlstrom, GW Libal, et al. 1979. Effects of sulfate in water on swine reproduction and young pig performance. J Anim Sci. 49:664-667.

Patterson, HH, PS Johnson, TR Patterson, DB Young, and R Haigh. 2002. Effects of water quality on performance and health of growing steers. Proc West Sec Amer Soc Anim Sci. 53:217-220.

Patterson, HH, PS Johnson, EH Ward, and RN Gates. 2004. Effects of sulfates in water on performance of cow-calf pairs. Proc West Sec Amer Soc Anim Sci. 55:265-268.

Weeth, HJ and DL Capps. 1972. Tolerance of growing cattle for sulfate-water. J Anim Sci. 34:256-260.

Weeth, HJ and JE Hunter. 1971. Drinking of sulfate-water by cattle. J Anim Sci. 32:277-281.

Exhibit M: **Literature toxicity values considered valid for standard derivation.**

Common Name	Scientific Name	Acute Value (mg/L)	Chloride (mg/L)	Ca-Mg ratio (weight)	Hardness (mg/L)	Reference
Water flea[1]	*Ceriodaphnia dubia*	2,083	1.9	1.15	84	Mount et al. 1997
Water flea[1]	*Ceriodaphnia dubia*	1,038	931	1.15	84	Mount et al. 1997
Water flea	*Ceriodaphnia dubia*	2,130	NA[2]	NA	NA	Warne and Schifko 1999
Water flea	*Ceriodaphnia dubia*	1,827	NA	NA	NA	Warne and Schifko 1999
Water flea	*Daphnia magna*	6,173	NA	NA	NA	Arambasic et al. 1995
Water flea[1]	*Daphnia magna*	3,097	1.9	1.15	84	Mount et al. 1997
Water flea[1]	*Daphnia magna*	1,927	1729	1.15	84	Mount et al. 1997
Water flea	*Daphnia magna*	5,816	NA	NA	563	Meyer et al. 1985
Water flea	*Daphnia magna*	5,218	NA	NA	105	BC Research 1998; Pickard et al. 1999
Water flea[3]	*Daphnia magna*	1,262	2.4	1.15	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	1,307	2.4	1.15	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	1,513	2.4	6.26	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	1,628	2.4	6.26	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	1,893	2.4	11.6	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	2,111	2.4	11.6	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	3,045	0.4	1.15	100	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	3,247	2.4	1.15	100	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	3,835	2.4	6.26	100	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	3,842	2.4	6.26	100	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	4,295	2.4	11.6	100	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	4,541	2.4	11.6	100	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	957	2.4	NA	25	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	1,768	2.4	NA	50	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	3,155	2.4	NA	75	Davies 2002; Davies et al. 2003
Water flea[3]	*Daphnia magna*	537.2	0.7	1.16	27	PESC 1996; Davies 2002
Water flea[3]	*Daphnia magna*	6,281	108	11	100	PESC 1996; Davies 2002
Water flea[3]	*Daphnia magna*	7,442	112	6.27	250	PESC 1996; Davies 2002
Amphipod	*Hyalella azteca*	1,226	NA	NA	111	BC Research 1998; Pickard et al. 1999
Amphipod[3]	*Hyalella azteca*	491	8.9	5.45	28	Davies 2002; Davies et al. 2003
Amphipod[3]	*Hyalella azteca*	1,518	17.8	5.4	56	Davies 2002; Davies et al. 2003
Amphipod[3]	*Hyalella azteca*	1,700	27	5.4	84	Davies 2002; Davies et al. 2003
Amphipod[3]	*Hyalella azteca*	2,971	36	5.4	112	Davies 2002; Davies et al. 2003
Amphipod[3]	*Hyalella azteca*	4,864	89	5.42	281	Davies 2002; Davies et al. 2003
Amphipod[3]	*Hyalella azteca*	205	0.7	1.16	27	PESC 1996; Davies 2002
Amphipod[3]	*Hyalella azteca*	3,711	108	11	100	PESC 1996; Davies 2002
Amphipod[3]	*Hyalella azteca*	6,787	112	6.27	250	PESC 1996; Davies 2002
Midge[3]	*Chironomus tentans*	6,667	0.7	1.16	27	PESC 1996; Davies 2002
Midge[3]	*Chironomus tentans*	5,868	108	11	100	PESC 1996; Davies 2002
Midge[3]	*Chironomus tentans*	4,173	112	6.27	250	PESC 1996; Davies 2002
Fathead minnow[1]	*Pimephales promelas*	5,383	1.9	1.15	84	Mount et al. 1997
Fathead minnow[1]	*Pimephales promelas*	2,059	1,847	1.15	84	Mount et al. 1997
Fathead minnow	*Pimephales promelas*	10,280	NA	NA	563	Meyer et al. 1985
Channel catfish	*Ictalurus punctatus*	11,000	87	4.9	412	Reed and Evans 1981
Largemouth bass	*Micropterus salmoides*	13,000	87	4.9	412	Reed and Evans 1981
Bluegill	*Lepomis macrochirus*	12,000	87	4.9	412	Reed and Evans 1981
Bluegill[4]	*Lepomis macrochirus*	9,130	9.5	2.9	44	Trama 1954
Bluegill	*Lepomis macrochirus*	8,792	9.5	2.9	44	Cairns and Scheier 1959
Bluegill	*Lepomis macrochirus*	8,623	9.5	2.9	44	Cairns and Scheier 1959
Bluegill	*Lepomis macrochirus*	8,454	9.5	2.9	44	Cairns and Scheier 1959
Mosquitofish[5]	*Gambusia affinis*	11,159	NA	NA	NA	Wallin et al. 1957

Notes:
1. The acute values for C. dubia, D. magna, and the fathead minnow indicate the relative sensitivities of the three species to sulfate.
2. NA = not available.
3. Although some important information concerning test conditions is not available regarding tests reported by Davies (2002), Davies et al. (2003), and PESC (1996), these tests are considered acceptable because ASTM, U.S. EPA, and/or Canadian standard procedures were followed.
4. See also: Academy of Natural Sciences (1960) and Patrick et al. (1968)
5. The test organism were undoubtedly stressed, but the test demonstrates that this species is not sensitive to sulfate.
6. This table does not contain any acute values for salmonids because such values will not be used in Illinois criteria calculations.
7. C. Stephan created this table by revising a table that was prepared by ADVENT.

Literature Cited

Arambasic, MB et al. 1995. Acute Toxicity of Heavy Metals (Copper, Lead, Zinc), Phenol and Sodium on Allium cepa L., Lepidium sativum L. and Daphnia magna ST.: Comparative Investigations and the Practical Applications. Water Res 29:497-503.

BC Research Inc. 1998. Brenda mines sulphate and molybdenum toxicity testing. Prepared for Noranda Mining and Exploration Inc., Brenda Mines Division. Project No. 2-11-825/826.

Cairns, JCJ and A Scheir. 1959. The relationship of bluegill sunfish body size to its tolerance for some common chemicals. Proc 13th Ind Waste Conf, Purdue Univ Eng Bull 96:243-252.

Davies, TD. 2002. Sulphate Toxicity to Freshwater Organisms and Molybdenum Toxicity to Rainbow Trout (Oncorhynchus mykiss). Master's Thesis, Dept. of Resource Management and Environmental Studies, Univ. of British Columbia.

Davies, T.D., J.S. Pickard, and K.J. Hall. Undated. Sulphate Toxicity to Freshwater Organisms and Molybdenum Toxicity to Rainbow Trout Embryos/alevins. Available at: www.trcr.bc.ca/docs/2003-davies_etal.pdf

Meyer, JS et al. 1985. Chemistry and Aquatic Toxicity of Raw Oil Shale Leachates from Peceannce Basin, Colorado. Environ Toxicol Chem 4:559-572.

Mount, DR, DD Gulley, JR Hockett, TD Garrsion, and JM Evans. 1997. Statistical Models to Predict the Toxicity of Major Ions to Ceriodaphnia dubia, Daphnia magna and Pimephales promelas (Fathead Minnows). Environ Toxicol Chem 16(10):2009-2019.

Pacific Environmental Science Centre (PESC). 1996. Analysis of Laboratory Bioassays. (Cited as "1996" by Singleton (2000) and Davies (2002).

Pickard, J, P McKee, and J Stroiazzo. 1998. Site specific multi-species toxicity testing of sulphate and molybdenum spiked with mining effluent and receiving water. Aquatic Toxicity Workshop, Quebec City.

Reed, P and R Evans. 1981. Acute Toxicity of Chlorides, Sulfates and Total Dissolved Solids to Some Fishes in Illinois. State Water Survey Division, Water Quality Section, Peoria, IL, IL Dept of Energy and Natural Resources, SES Contract Report 283.

Trama, FB. 1954. The acute toxicity of some common salts of sodium, potassium and calcium to the common bluegill. Proc Acad Nat Sci Philadelphia 106:185-205.

Wallen, IE et al. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Ind Wastes 29(6):695-711.

Warne, M St. J, and AD Schifko. 1999. Toxicity of Laundry Detergent Components to a Freshwater Cladoceran and Their Contribution to Detergent Toxicity. Ecotoxicol Environ Saf. 44:196-206.

Exhibit K

The following table is a list of references compiled by Dr. Charles Stephan that contain data regarding the toxicity of sulfate to aquatic animals. The table also contains various documents that were cited in various sources as possibly containing data regarding the toxicity of sulfate to aquatic animals. A comment for each reference is also included that explains the rationale for acceptance or rejection of these studies.

A number in parentheses at the end of the citation is the AQUIRE reference number of the document.

For the purposes of this project, the only chemicals that are considered acceptable for use in aquatic toxicity tests on sulfate are calcium sulfate, magnesium sulfate, potassium sulfate, and sodium sulfate. Interpreting results obtained with these four salts is not straightforward because potassium and magnesium apparently are sufficiently toxic to impact the results of tests in which their salts are used.

All LC50s and EC50s given below are for sulfate, not for the salt used in the test. In some cases the results do not take into account the concentration of sulfate in the dilution water.

Reference	**Comment**
Abraham, T.J., K.Y.M. Salih, and J. Chacko. 1986. Effects of Heavy Metals on the Filtration Rate of Bivalve Villorita cyprinoides (Hanley) Var. Cochinensis. Indian J. Mar. Sci. 15:195-196. (A: 12315)	No results concerning sulfate.
Academy of Natural Sciences. 1960. The Sensitivity of Aquatic Life to Certain Chemicals Commonly Found in Industrial Wastes. Final Report No. RG-3965(C2R1). Academy of Natural Sciences, Philadelphia, PA. (A: 5683)	All relevant test results are acceptable.
Anderson, B.G. 1944. The Toxicity Thresholds of Various Substances Found in Industrial Wastes As Determined by the Use of Daphnia magna. Sewage Works J. 16(6):1156-1165. (A: 2171)	No test results are acceptable because the test duration was only 16 hr.
Anderson, B.G. 1946. The Toxicity Thresholds of Various Sodium Salts Determined by the Use of Daphnia magna. Sewage Works J. 18(1):82-87. (A: 2130)	Test results with D. magna but they probably are not useful.

Reference	Comment
Anderson, B.G. 1948. The Apparent Thresholds of Toxicity of Daphnia magna for Chlorides of Various Metals When Added to Lake Erie Water. Trans. Amer. Fish. Soc. 78:96-113.	No results concerning sulfate.
Anderson, K.B., R.E. Sparks, and A.A. Paparo. 1978. Rapid Assessment of Water Quality, Using the Fingernail Clam, Musculium transversum. WRC Research Report No. 133. University of Illinois, Water Resources Center, Urbana, IL.	The results of tests on sulfate are not acceptable because the observed effect was on ciliary beating rate.
Arambasic, M.B., S. Bjelic, and G. Subakov. 1995. Acute Toxicity of Heavy Metals (Copper, Lead, Zinc), Phenol and Sodium on Allium cepa L., Lepidium sativum L. and Daphnia magna St.: Comparative. Water Res. 29(2):497-503. (A: 13712)	Test results with D. magna but they probably are not useful.
Battelle's Columbus Laboratories. 1971. Water Quality Criteria Data Book - Vol 3. 18050GWV05/71. Water Pollution Control Research Series, U.S. EPA.	All results are secondary information.
BC Research Inc. 1998. Brenda Mines Sulphate and Molybdenum Toxicity Testing. Prepared for Noranda Mining and Exploration Inc., Brenda Mines Division. Project No. 2-11-825/826.	Rainbow trout eggs were sensitive to sulfate in creek water. Concentration of chloride is unknown, but cations were measured.
Beauchamp, R.S.A. 1953. Sulphates in African Island Waters. Nature 171:769-771.	No results concerning sulfate.
Becker, A.J.J., Jr., and E.C. Keller, Jr. 1973. The Effects of Iron and Sulfate Compounds on the Growth of Chlorella. Proc. W. Va. Acad. Sci. 45(2):127-135. (A: 8598)	All tests were with algae.
Bell, T.A., C.S. Arume, and D.V. Lightner. 1987. Efficacy of Formalin in Reducing the Levels of Peritrichous Ciliates on Cultured Marine Shrimp. J. Fish Dis. 10(1):45-51. (A: 963)	No results concerning sulfate.
Black, H.H., G.N. McDermott, C. Henderson, W.A. Moore, and H.R. Pahren. 1957. Industrial Wastes Guide: By-Product Coke Industry. Sewage Ind. Wastes 29:53-75.	No results concerning sulfate.

Reference	Comment
Boge, G., A. Rigal, and G. Peres. 1982a. Effects of the sulphate ions on some enzymatic activities in the gut and the gill of the eel (Anguilla anguilla) in a constant temperature culture. Ann. Inst. Michel Pacha, Lab. Marit. Physiol. 13:1-11.	Not obtained because data concerning enzyme activities are not relevant.
Boge, G., A. Rigal, and G. Peres. 1982b. Effects of the sulphate ions on some enzymatic activities in the gut and the gill of the eel (Anguilla anguilla) during thermal stress. Ann. Inst. Michel Pacha, Lab. Marit. Physiol. 13:12-19.	Not obtained because data concerning enzyme activities are not relevant.
Boge, G., A. Rigal, and G. Peres. 1982c. Effects of the calcium sulphate and potassium sulphate upon different enzyme activities in the intestine of the trout (Salmo gairdneri R.) maintained at constant temperature. Cah. Lab. Hydrobiol. Montereau No. 14:7-11.	Not obtained because data concerning enzyme activities are not relevant.
Boge, G., A. Rigal, and G. Peres. 1982d. Effects of calcium sulphate and potassium sulphate upon different enzyme activities of trout (Salmo gairdneri R.) after the production of thermal shocks. Cah. Lab. Hydrobiol. Montereau No. 14:13-16. (See: Nijman, R.A. 1993)	Not obtained because data concerning enzyme activities are not relevant.
Bringmann, G., and R. Kuhn. 1959. The Toxic Effects of Waste Water on Aquatic Bacteria, Algae, and Small Crustaceans. Gesund. Ing. 80:115-120. (English Translation: TR-TS-0002). (A: 607)	No tests on calcium, magnesium, potassium, or sodium sulfate.
Brown, E.R., L. Keith, J.J. Hazdra, and T. Arndt. 1973. Tumors in Fish Caught in Polluted Waters: Possible Explanations. IN: Y. Ito and R.M. Dutcher (eds.), Comparative Leukemia Research 1973, Leukemogenesis, Bibl. Haematol. No. 40, Univ. of Tokyo Press, Tokyo/Karger, Basel 47-57. (A: 2143)	The results of tests on sulfate are not acceptable because very little information is available.
Buikema, A.L. Jr., B.R. Niederlehner, and J. Cairns, Jr. 1981. The Effects of a Simulated Refinery Effluent and Its Components on the Crustacean, Mysidopsis bahia. Arch. Environ. Contam. Toxicol. 10:231-240. (A: 14256)	No results concerning sulfate.
Cairns, J.C.J., and A. Scheier. 1959. The Relationship of Bluegill Sunfish Body Size to its Tolerance for Some Common Chemicals. Proc.13th Ind. Waste Conf., Purdue Univ, Eng. Bull 43:243-252. (A: 930)	All relevant test results are acceptable.

Reference	Comment
Chapman, P.M., H. Bailey, and E. Canaria. 2000. Toxicity of Total Dissolved Solids Associated with Two Mine Effluents to Chironomid larvae and early life stages of rainbow trout. Environ. Toxicol. Chem. 19:210-214.	All tests were on synthetic effluents.
Davies, T.D. 2002. Sulphate Toxicity to Freshwater Organisms and Molybdenum Toxicity to Rainbow Trout (Oncorhynchus mykiss). Master's Thesis, Dept. of Resource Management and Environmental Studies, Univ. of British Columbia.	All relevant tests with D. magna and H. azteca are acceptable. Test results with striped bass are very interesting.
Davies, T.D., J.S. Pickard, and K.J. Hall. Undated. Sulphate Toxicity to Freshwater Organisms and Molybdenum Toxicity to Rainbow Trout Embryos/alevins. Available at: www.trcr.bc.ca/docs/2003-davies_etal.pdf	Same data as Davies (2002).
Den Dooren de Jong, L.E. 1965. Tolerance of Chlorella vulgaris for Metallic and Non-Metallic Ions. Antonie Leeuwenhoek J. Microbiol. Serol. 31:301-313. (A: 2849)	All results are for an algal species.
Deniseger, J. 1997 Draft. In-situ Coho Egg Bioassays and Chronic Daphnia Bioassays Done in the Vicinity of Quinsam Coal in Response to an Increasing Trend in Sulphate Levels. Ministry of Environment, Lands and Parks. Nanaimo. BC.	All toxicity tests were on river waters, most of which contained one or more effluents.
Department of Scientific and Industrial Research. 1953. Water Pollution Research 1952. Report of the Water Pollution Research Board, Water Pollution Research Laboratory, H.M. Stationary Office, London. (A: 20590)	Rainbow trout were exposed for only 24 hr. In addition, little additional information is available regarding the test method used.
Dickerson, K.K., W.A. Hubert, and H.L. Bergman. 1996. Toxicity Assessment of Water from Lakes and Wetlands Receiving Irrigation Drain Water. Environ. Toxicol. Chem. 15:1097-1101.	Additional validation of the models developed by Mount et al. (1996).
Dietz, T.H., and R.A. Byrne. 1999. Measurement of Sulfate Uptake and Loss in the Freshwater Bivalve Dreissena polymorpha Using a Simi-microassay. Can. J. Zool. 77:331-336. (A: 48713)	No toxicity test results
Doudoroff, P., and M. Katz. 1950. Critical Review of Literature on the Toxicity of Industrial Wastes and Their	All results are secondary information.

Components to Fish. Sewage Ind. Wastes 22:1432-1458.

Reference	**Comment**
Doudoroff, P., and M. Katz. 1953. Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish. II. The Metals, as Salts. Sewage Ind. Wastes 25:802-839.	All results are secondary information.
Dowden, B.F. 1960. Cumulative Toxicities of Some Inorganic Salts to Daphnia magna as Determined by Median Tolerance Limits. Proc. La. Acad. Sci. 23:77-85. (A: 2465)	The dilution water was from a drainpipe-fed lake on the LSU campus.
Dowden, B.F., and H.J. Bennett. 1965. Toxicity of Selected Chemicals to Certain Animals. J. Water Pollut. Control Fed. 37(9):1308-1316. (A: 915)	Results are not acceptable if the duration was too long or too short or if the dilution water was from a drainpipe-fed lake on the LSU campus. Test results with D. magna but they probably are not useful.
EG&G Bionomics. 1978. The effects of sulfate on eggs and fry of rainbow trout (Salmo gairdneri) during continuous aqueous exposure. Report #BW-78-1-006.	Chronic test on calcium sulfate using eggs and fry (through 60 days post-hatch) of rainbow trout in poorly characterized well water. No toxicity at highest tested concentration of 732 mg/L.
EG&G Bionomics. 1979. The chronic toxicity of sulfate to the water flea (Daphnia magna). Report #BW-79-10-546.	Chronic test on calcium sulfate using D. magna in poorly characterized reconstituted water. No toxicity at highest tested concentration of 1600 mg/L.
Fisher, S.W., P. Stromberg, K.A. Bruner, and L.D. Boulet. 1991. Molluscicidal Activity of Potassium to the Zebra Mussel, Dreissena polymorphia: Toxicity and Mode of Action. Aquat. Toxicol. 20:219-234. (A: 11011)	For zebra mussels and potassium sulfate, 24-hr LC50 = 112 mg/L, but the potassium is said to be the cause of the toxicity.
Frahm, J.P. 1975. Toxicity Tolerance Studies Utilizing Periphyton. (Toxitoleranzversuche an Wassermoosen). Gewasser Und Abwasser 57/58:59-66. (A: 7922)	Results for ammonium sulfate, but not for calcium, magnesium, potassium, or sodium sulfate.
Freeman, L. 1951. The Toxicity Thresholds of Certain	CS requested this.

Sodium Sulfonates for Daphnia magna Straus. Thesis, Louisiana State University, Baton Rouge, LA.

Reference	**Comment**
Freeman, L., and I. Fowler. 1953. Toxicity of Combinations of Certain Inorganic Compounds to Daphnia magna (Straus). Sewage Ind. Wastes 25(10):1191-1195. (A: 2462)	Test results with D. magna but they probably are not useful.
Gannon, J.E., and S.A. Gannon. 1975. Observations on the Narcotization of Crustacean Zooplankton. Crustaceana (Leiden) 28(2):220-224. (A: 2585)	Magnesium sulfate was an ineffective narcotizing agent.
Goetsch, P.A., and C.G. Palmer. 1997. Salinity Tolerances of Selected Macroinvertebrates of the Sabie River, Kruger National Park, South Africa. Arch. Environ. Contam. Toxicol. 32(1):32-41. (A: 17845)	96-hr LC50 = 446 mg/L but river water and industrial-grade Na2SO4 were used, organisms were not identified to species and not obtained in North America, some control mortalities were >10%, temperature varied by 3 to 6 C, and the field-collected organisms were not adequately acclimated.
Gohar, H.A.F., and H. El-Gindy. 1961. Tolerance of Vector Snails of Bilharziasis and Fascioliasis to Some Chemicals. Proc. Egyptian Acad. Sci. 16:37-48.	The results of tests on sulfate are not acceptable because the tests were 24-hr exposures to high concentrations.
Goodfellow, W.L. et al. 2000. Major Ion Toxicity in Effluents: A Review with Permitting Recommendations. Environ. Toxicol. Chem. 19:175-182.	No toxicity test results.
Hancher, C.W., P.A. Taylor, A. Stewart, K.R. Zabelsky, and J.M. Napier. 1987. Development and Operational Performance of the Central Pollution Control Facility II/S-3 Liquid Treatment Facility. Oak Ridge Y-12 Plant. ORNL/M-609.	No test result is acceptable because too little information is available
Hart, W.B., P. Doudoroff, and J. Greenbank. 1945. The Evaluation of the Toxicity of Industrial Wastes, Chemicals and Other Substances to Fresh-Water Fishes. Waste Control Lab, Atlantic Refining Co., Philadelphia, PA.	No toxicity test results.

Harukawa, C. 1922. Preliminary report on the toxicity of colloidal sulphur to fish. Trans. Amer. Fish. Soc. 52:219-224.	No test results are acceptable because only two fish were exposed to one concentration for 24 hr and very little information is available.
Reference	**Comment**
Haydu, E.P., H.R. Amberg, and R.E. Dimick. 1952. The Effect of Kraft Mill Waste Components on Certain Salmonid Fishes of the Pacific Northwest. TAPPI 35:545-549.	Even if it cannot be used in the calculation of an SMAV, the 120-hr LC50 of about 8687 for silver salmon implies that this species is not sensitive to sulfate. Test results for cutthroat trout are probably not useful.
Henderson, C., Q.H. Pickering, and J.M. Cohen. 1959. The toxicity of synthetic detergents and soaps to fish. Sewage Ind. Wastes 31:295-306.	Even if they cannot be used to calculate a SMAV, the 96-hr LC50s of 6087 and 9130 mg/L imply that the fathead minnow is not sensitive to sulfate.
Henderson, C., Q.H. Pickering, and C.M. Tarzwell. 1960. The toxicity of organic phosphorus and chlorinated hydrocarbon insecticides to fish. IN: Biological Problems in Water Pollution, C.M. Tarzwell (ed), Robt. A. Taft San. Eng. Center, Cincinnati, OH., Tech. Rept. W60-3:76-88. (A: 936)	No results concerning sulfate. Probably an incorrect citation in "Battelle's Columbus Laboratories (1971)".
Herbert, D.W.M., and A.C. Wakeford. 1962. The Effect of Calcium Sulfate on the Survival of Rainbow Trout. Water Waste Treat. J. 8:608-609.	No rainbow trout died during a 28-day exposure to 1456 mg/L.
Hirsch, E. 1914. Untersuchungen uber die biologische Wirkung einiger Salze. Zool. Jahrbucher, Abt. f. allgem. Zool. u. Physiol. 34:559-682.	Not obtained because it probably does not contain useful information. See Doudoroff and Katz (1953).
Hodgson, E.S. 1951. Reaction Thresholds of an Aquatic Beetle, Laccophilus maculosus Germ., to Salts and Alcohols. Physiol. Zool. 24:131-140.	No useful results.

Hughes, J.S. 1969. Toxicity of Some Chemicals to Striped Bass (Roccus saxatilis). Proceedings of the Twenty-second Annual Conference of the Southeastern Association. (A: 5990) The methodology is also described in Hughes (1971).	For striped bass the 96-hr LC50 is 250 mg/L for larvae and 3500 mg/L for fingerlings, but the sodium sulfate was technical grade and the fish were not adequately acclimated.

Reference	**Comment**
Hughes, J.S. 1973. Acute Toxicity of Thirty Chemicals to Striped Bass (Morone saxatilis). Louisiana Wild Life and Fisheries Commission. (A: 2012)	Same data as above.
Ingersoll, C.G. et al. 1992. The Use of Freshwater and Saltwater Animals to Distinguish between the Toxic Effects of Salinity and Contaminants in Irrigation Drain Water. Environ. Toxicol. Chem. 11:503-511.	No test results are specifically relevant to sulfate.
Jaffe, R.L. 1995. Rapid Assay of Cytotoxicity Using Tetramitus flagellates. Toxicol. Ind. Health 11(5):543-558. (A: 5895)	All results are for an unicellular species.
Jaworska, M., J. Sepiol, and P. Tomasik. 1996. Effect of Metal Ions Under Laboratory Conditions on the Entomopathogenic Steinernema carpocapsae (Rhabditida: Steinernematidae). Water Air Soil Pollut. 88(3/4):331-341. (A: 17002)	The dilution water was distilled water.
Jaworska, M., A. Gorczyca, J. Sepiol, and P. Tomasik. 1997. Effect of Metal Ions on the Entomopathogenic Nematode Heterorhabditis bacteriophora Poinar (Nematoda: Heterohabditidae) Under Laboratory Conditions. Water Air Soil Pollut. 93:157-166. (A: 40155)	The dilution water was distilled water.
Jayaraj, Y.M., B. Aparanji, and P.M. Nimbargi. 1992. Amelioration of Heavy Metal Toxicity on Primary Productivity of Aquatic Ecosystems by Calcium, Magnesium and Iron. Environ. Ecol. 10(3):667-674. (A: 8019)	These were studies of antagonism. The observed effect was reduction in primary productivity.
Jones, J.R.E. 1941. A Study of the Relative Toxicity of Anions, with Polycelis nigra As Test Animal. J. Exp. Biol. 18:170-181. (A: 10013)	The dilution water was distilled water.

Jones, J.R.E. 1947. The Oxygen Consumption of Gasterosteus aculeatus L. in Toxic Solutions. J. Exp. Biol. 23:298. (Water Pollut. Abs. 20, June 1947).	No test results concerning sulfate.
Jones, J.R.E. 1948. A Further Study of the Reactions of Fish to Toxic Solutions. J. Exp. Biol. 25:22.	No test results concerning sulfate.

Reference	**Comment**
Kanta, S., and T.A. Sarma. 1980. Biochemical Studies on Sporulation in Blue-Green Algae II. Factors Affecting Glycogen Accumulation. Z. Allg. Mikrobiol. 20(7):459-463. (A: 5052)	All results are for an algal species.
Kemp, H.T., R.L. Little, V.L. Holoman, and R.L. Darby. 1973. Water Quality Criteria Data Book - Vol. 5. 18050HLA09/73. Water Pollution Control Research Series, U.S.EPA.	All results are secondary information.
Kennedy, A.J., D.S. Cherry, and R.J. Currie. 2003. Field and Laboratory Assessment of a Coal Processing Effluent in the Leading Creek Watershed, Meigs County, Ohio. Arch. Environ. Contam. Toxicol. 44:324-331.	No test results are specifically relevant to sulfate.
Kennedy, A.J., D.S. Cherry, and R.J. Currie. 2004. Evaluation of Ecologically Relevant Bioassays for a Lotic System Impacted by a Coal-mine Effluent, using Isonychia. Environ. Monitor. Assess. 95:37-55.	In 7-day exposures to a simulated effluent high in sulfate, a mayfly was more sensitive than C. dubia.
Kennedy, A.J., D.S. Cherry, and C.E. Zipper. 2005. Evaluation of Ionic Contribution to the Toxicity of a Coal-Mine Effluent Using Ceriodaphnia dubia. Arch. Environ. Contam. Toxicol. 48:155-162.	Increased hardness reduced the acute and chronic toxicity of sodium sulfate in waters that simulated the effluent from a specific mine. A model, which is probably the Mount et al. (1996) model, did not fit the data.
Khangarot, B.S. 1991. Toxicity of Metals to a Freshwater Tubificid Worm, Tubifex tubifex (Muller). Bull. Environ. Contam. Toxicol. 46:906-912. (A: 2918)	LC50 = 626 mg/L; concentration of sulfate in dilution water is unknown; magnesium sulfate was used; chloride = 10 mg/L; hardness = 900 mg/L.

Reference	Comment
Khangarot, B.S., and P.K. Ray. 1989. Investigation of Correlation Between Physicochemical Properties of Metals and Their Toxicity to the Water Flea Daphnia magna Straus. Ecotoxicol. Environ. Saf. 18(2):109-120. (A: 6631)	LC50 = 1359 mg/L, concentration of sulfate in dilution water is unknown; magnesium sulfate was used; chloride = 7 mg/L; hardness = 1660 mg/L.
Koel, T.M., and J.J. Peterka. 1995. Survival to Hatching of Fishes in Sulfate-saline Waters, Devils Lake, North Dakota. Can. J. Fish. Aquat. Sci. 52:464-469.	Sodium-sulfate waters limit the hatching success of several species of fish.
LeBlanc, G.A., and D.C. Surprenant. 1984. The influence of mineral salts on fecundity of the water flea (Daphnia magna) and the implications on toxicity testing on industrial wastewater. Hydrobiologia 108:25-31.	All relevant test results are acceptable.
Linden, E., B.E. Bengtsson, O. Svanberg, and G. Sundstrom. 1979. The Acute Toxicity of 78 Chemicals and Pesticide Formulations Against Two Brackish Water Organisms, the Bleak (Alburnus alburnus) and the Harpacticoid. Chemosphere 8(11/12):843-851. (A: 5185)	All toxicity tests were performed in brackish water.
Luther, M., and C.J. Soeder. 1991. 1-Naphthalenesulfonic Acid and Sulfate as Sulfur Sources for the Green Alga Scenedesmus obliquus. Water Res. 25(3):299-307. (A: 91)	All results are for an algal species.
Masnado, R.G., S.W. Geis, and W.C. Sonzogogni. 1995. Comparative Acute Toxicity of a Synthetic Mine Effluent to Ceriodaphnia dubia, larval Fathead Minnow, and the Freshwater Mussel Anodonta imbecilis. Environ. Toxicol. Chem. 14:1913-1920.	All toxicity tests were on a synthetic mine effluent.
McKee, J.E., and H.W. Wolf. 1963. Water Quality Criteria, 2nd ed. California State Water Quality Control Board. Publication No. 3-A.	All results are secondary information.
Meyer, J.S., et al. 1985. Chemistry and Aquatic Toxicity of Raw Oil Shale Leachates from Peceannce Basis, Colorado. Environ. Toxicol. Chem. 4:559-572.	All relevant test results are acceptable.
Mount, D.R., D.D. Gulley, J.R. Hockett, T.D. Garrison, and J.M. Evans. 1997. Statistical Models to Predict the Toxicity of Major Ions to Ceriodaphnia dubia, Daphnia magna and Pimephales promelas (Fathead Minnows).	All relevant test results are acceptable.

Environ. Toxicol. Chem. 16(10):2009-2019. (A: 18272)	
Muegge, O.J. 1956. Physiological Effects of Heavily Chlorinated Drinking Water. Jour. Amer. Water Works Assoc. 48:1507-1509.	No results concerning sulfate. Probably an incorrect citation in McKee and Wolf (1963).

Reference	**Comment**
Mukai, H. 1977. Effects of Chemical Pretreatment on the Germination of Statoblasts of the Freshwater Bryozoan, Pectinatella gelatinosa. Biol. Zentralbl. 96:19-31. (A: 705)	This species is not known to exist in North America and the organisms were not obtained in North America. The dilution water was distilled water; exposure duration was 2 hr.
National Council for Stream Improvement. 1947. The Toxicity of Kraft Pulping Wastes to Typical Fish Food Organisms. Tech. Bull. 10.	Not obtained because it probably does not contain any primary data concerning the sulfate salts of calcium, magnesium, potassium, or sodium.
National Council for Stream Improvement. 1948. A Study of the Toxic Components of the Waste Waters of Five Typical Kraft Mills. Tech. Bull. 16.	No information concerning sulfate.
National Council for Stream Improvement. 1949. The Toxicity of Kraft Pulping Wastes to Important Fish Food Species of Insect Larvae. Tech. Bull. 25.	Not obtained because it probably does not contain any primary data concerning the sulfate salts of calcium, magnesium, potassium, or sodium.
Nijman, R.A. 1993, Ambient Water Quality Objectives for the Yakoun River and its Tributaries. Ministry of Environment, Lands and Parks, British Columbia.	No test results concerning sulfate.
Oshima, S. 1931. On the toxic action of dissolved salts and their ions upon young eels (Anguilla japonica). Jour. Imperial Fisheries Exp. Sta. 2:139-193.	Not obtained because it probably does not contain useful information. See Doudoroff and Katz (1953).
Pacific Environmental Science Centre (PESC). 1996. [Cited as "1996" by Singleton (2000) and Davies (2002).]	All relevant test results are acceptable.

Patrick, R., J. Cairns Jr., and A. Scheier. 1968. The Relative Sensitivity of Diatoms, Snails, and Fish to Twenty Common Constituents of Industrial Wastes. Prog. Fish-Cult. 30(3):137-140. (A: 949)	All relevant test results are acceptable.
Pickard, J, P McKee, and J Stroiazzo. 1998. Site specific multi-species toxicity testing of sulphate and molybdenum spiked with mining effluent and receiving water. Aquatic Toxicity Workshop, Quebec City.	All relevant test results are acceptable.
Reference	**Comment**
Pillard, D.A. et al. 2000. Predicting the Toxicity of Major Ions in Seawater to Mysid Shrimp (Mysidopsis bahia), Sheepshead Minnow (Cyprinodon variegatus), and Inland Silverside Minnow (Menidia beryllina). Environ. Toxicol. Chem. 19:183-191.	All data are for saltwater species.
Reed, P., and R. Evans. 1981. Acute toxicity of chlorides, sulfates, and total dissolved solids to some fishes in Illinois. Illinois Department of Energy and Natural Resources, State Water Survey Division. SWS Contract Report 283. (A: 60643)	All relevant test results are acceptable.
Reimschuessel, R., R.O. Bennett, E.B. May, and M.M. Lipsky. 1989. Renal Histopathological Changes in the Goldfish (Carassius auratus) After Sublethal Exposure to Hexachlorobutadiene. Aquat. Toxicol. 15(2):169-180. (A: 2046)	No results concerning sulfate. Possibly an incorrect reference because the first author has done much work with medicines that are sulfates.
Reinfelder, J.R., and N.S. Fisher. 1994. The Assimilation of Elements Ingested by Marine Planktonic Bivalve Larvae. Limnol. Oceanogr. 39(1):12-20. (A: 20560)	No toxicity test results.
Robinson, D.J.S., and E.J. Perkins. 1977. The Toxicity of Some Wood Pulp Effluent Constituents. Cumbria Sea Fish. Comm., Sci. Rep. No.74/1, The Courts, Carlisle, England:22. (A: 15285)	All toxicity tests were in sea water.
Rudolfs, W., et al. 1950. Review of Literature on Toxic Materials Affecting Sewage Treatment Processes, Streams, and B.O.D. Determinations. Sewage Ind. Wastes 22:1157-1187(?).	No results concerning sulfate.
Saliba, L.J., and M. Ahsanullah. 1973. Acclimation and Tolerance of Artemia salina and Ophryotrocha labronica	All toxicity tests were on copper sulfate.

Reference	Comment
to Copper Sulphate. Mar. Biol. 23(4):297-302. (A: 5168)	
Sanders, D.F. 1993. Letter and attachments to S. LaDieu regarding chronic toxicity tests using Ceriodaphnia dubia and the fathead minnow in connection with Thorn Creek.	7-day life-cycle test with C. dubia and 7-day "chronic" test with fathead minnow on sodium sulfate in creek water. No toxicity at highest tested concentration of 1301 mg/L.
Reference	**Comment**
Scheuring, L, and H. Stetter. 1950/51. Experiments on the effect of sodium sulphate on water organisms. Vom Wasser 18:78-100. [Water Pollut. Abs. 27(8):191 (1952) says "concentrations of sodium and other sulphates such as would be found in streams have no serious damaging effect on the biology of the water.]	Not obtained. Doudoroff and Katz (1953) summarize the results as "Sodium sulfate also is not very toxic to fish and fish eggs."
Selitrennikova, M., and Sachurina, E. 1953. Experiences in the Organization of Sewage Fields in the Hot Climate of Uzbekistan. Hygiene and Sanitation (Moscow) 7:17	Not obtained because it probably does not contain any useful information.
Sheplay, A.W., and T.J. Bradley. 1982. A Comparative Study of Magnesium Sulphate Tolerance in Saline-Water Mosquito Larvae. J. Insect Physiol. 28(7):641-646. (A: 15695)	All tests were performed in 50% seawater.
Singleton, H. 2000. Ambient Water Quality Guidelines for Sulfate. Ministry of Environment, Lands and Parks (BC MELP), Province of British Columbia, Canada.	All test results are secondary information. There is an extensive table of test results.
Soucek, D.J. 2005. Third Quarterly Progress Report.	All test results are acceptable.
Soucek, D.J., and A.J. Kennedy. 2005. Effects of Hardness, Chloride, and Acclimation on the Acute Toxicity of Sulfate to Freshwater Invertebrates. Environ. Toxicol. Chem. 24:1204-1210.	All test results are acceptable.
Staub, R.S., J.W. Appling, and J. Haas. 1973. Effects of Industrial Effluents on Primary Phytoplankon Indicators. PB220741. NTIS.	All tests were with phytoplankton.
Stanley, R.A. 1974. Toxicity of Heavy Metals and Salts to Eurasian Watermilfoil (Myriophyllum spicatum L.). Arch. Environ. Contam.Toxicol. 2(4):331-341. (A: 2262)	All tests were with Eurasian watermilfoil.

Reference	Comment
Stark, J. 1999. Letter and attachments to S. LaDieu regarding chronic toxicity tests using Ceriodaphnia dubia and the fathead minnow in connection with Thorn Creek.	7-day life-cycle test with C. dubia and 7-day "chronic" test with fathead minnow on sodium sulfate in creek water. No toxicity at highest tested concentration of 1381 mg/L.

Reference	**Comment**
Stora, G. 1975. Contribution a L'Etude de la Notion de Concentration Lethale. Limite Moyenne Appliquee a Des Invertebrea Marins. II. CL50 et Determination de la Toxicite de produits Polluants. Rev. Int. Oceanogr. Med. 37-38:97-123. (A: 5928)	No results for calcium, magnesium, potassium, or sodium sulfate.
Stora, G. 1978. Evolution Compree de la Sensibilite de Deux Polychetes Soumises a L'Action de Detergents En Fonction D'Une Augmentation de la Temperature Notion D'Indice de Sensibilite. Rev. Int. Oceanogr. Med. 51/52:101-133. (A: 5852)	No results for calcium, magnesium, potassium, or sodium sulfate.
Stribling, J.M. 1997. The Relative Importance of Sulfate Availability in the Growth of Spartina alterniflora and Spartina cynosuroides. Aquat. Bot. 56(2):131-143. (A: 19969)	All tests were with marsh cordgrass.
Sunila, I. 1988. Acute Histological Responses of the Gill of the Mussel, Mytilus edulis, to Exposure by Environmental Pollutants. J. Invertebr. Pathol. 52(1):137-141. (A: 13066)	All tests studied histological effects on a saltwater mussel.
Surber, E.W., and T.O. Thatcher. 1963. Laboratory Studies of the Effects of Alkyl Benzene Sulfonate (ABS) on Aquatic Invertebrates. Trans. Amer. Fish. Soc. 92(2):152-160. (A: 62090)	The highest concentration tested was 216 mg/L, and it was not toxic to three invertebrate species in 96 hr.
Taylor, P.A., A.J. Stewart, and L. Holt. 1988. Toxicity of Common Salts to Three Biotoxicity Test Organisms. Oak Ridge Y-12 Plant, Oak Ridge, TN. Y/DZ-420.	No test results are acceptable because too little information is available.
Tietge, et al. 1997. Major ion toxicity of six produced waters to three freshwater species: application of ion toxicity models and TIE procedures. Environ. Toxicol. Chem. 16(10):2002-2008.	Additional validation of the models developed by Mount et al. (1996).

Tomiyama, T., and Yamagawa, A. 1950. The Effect of pH on Toxic Effects of Sulphide and of Sulphite on Young Carp. Bull. Jap. Soc. Sci. Fish. 15:9, 491. (Water Pollut. Abs. 26:5, 140, 1953).	Not obtained because it probably does not contain any primary data concerning the sulfate salts of calcium, magnesium, potassium, or sodium.

Reference	**Comment**
Tsuji, S., Y. Tonogai, Y. Ito, and S. Kanoh. 1986. The Influence of Rearing Temperatures on the Toxicity of Various Environmental Pollutants for Killifish (Oryzias latipes). J. Hyg. Chem./Eisei Kagaku 32(1):46-53. (A: 12497)	All tests used a species that is not resident in North America.
Turnbull, H., J.G. DeMann, and R.F. Weston. 1954. Toxicity of Various Refinery Materials to Fresh Water Fish. Ind. Eng. Chem. 46:324-333.	No results for calcium, magnesium, potassium, or sodium sulfate.
Turoboyski, L. 1960. Attempt to Determine the Influence of High Doses of some Chemical Compounds upon Carp Fry. Rocz. Nauk Roln. 75B(3):401-445. (A: 2540)	No test results are acceptable because all tests were for six hours at high concentrations.
Umezu, T. 1991. Saponins and Surfactants Increase Water Flux in Fish Gills. Bull. Jpn. Soc. Sci. Fish. (Nippon Suisan Gakkaishi). 57(10):1891-1896. (A: 7136)	No results for calcium, magnesium, potassium, or sodium sulfate.
Van Horn, W.M., J.B. Anderson, and M. Katz. 1949. The Effect of Kraft Pulp Mill Wastes on Some Aquatic Organisms. Trans. Amer. Fish. Soc. 79:55-63. (A: 663)	67 mg/L killed some emerald and/or spotfin shiners in 120 hr in stabilized Fox River water, but the quality of the test material and the dilution water is unknown.
Van Horn, W.M., J.B. Anderson, and M. Katz. 1950. TAPPI 33:209-212.	CS requested this.
Wallen, I.E., W.C. Greer, and R. Lasater. 1957. Toxicity to Gambusia affinis of Certain Pure Chemicals in Turbid Waters. Sewage Ind. Wastes 29(6):695-711. (A: 508)	Even if they cannot be used in the calculation of a SMAV, the 96-hr LC50s of >11,000 and >30000 mg/L imply that the mosquitofish is not sensitive to sulfate.

Reference	Comment
Wang, W.X., and N.S. Fisher. 1996. Assimilation of Trace Elements by the Mussel Mytilus edulis: Effects of Diatom Chemical Composition. Mar. Biol. 125:715-724. (A: 7332)	No toxicity test results.
Wang, W. 1986. Toxicity Tests of Aquatic Pollutants by Using Common Duckweed. Environ. Pollut. (Ser. B) 11(1):1-14. (A: 11789)	All tests were with duckweed.

Reference	**Comment**
Wells, M.M. 1915. The reactions and resistance of fishes in their natural environment to salts. Jour. Exp. Zool. 19:243-283.	All tests were preference-avoidance tests in tanks with gradients.
Wheeler, A.E., R.A. Zingaro, K. Irgolic, and N.R. Bottino. 1982. The Effect of Selenate, Selenite, and Sulfate on the Growth of Six Unicellular Marine Algae. J. Exp. Mar. Biol. Ecol. 57:181-194. (A: 58895)	All tests were with saltwater algae.
Williams, J.E. 1948. The Toxicity of Some Inorganic Salts to Game Fish. MS Thesis, Louisiana State University, Baton Rouge, LA.	CS requested this.
Wright, A. 1976. The Use of Recovery as a Criterion for Toxicity. Bull. Environ. Contam Toxicol. 15(6):747-749. (A: 5558)	No results for calcium, magnesium, potassium, or sodium sulfate.
Yamane, A.N., M. Okada, and R. Sudo. 1984. Inhibitory Effects of Laundry Detergents on the Growth of Freshwater Algae. Suishitsu Odaku Kenkyu 7(9):576-528. (A: 9715)	All tests were with algae.
Young, R.T. 1923. Resistance of Fish to Salts and Alkalinity. Amer. Jour. Physiol. 63:373-388.	No test results are acceptable because the methods used were unusual.

Exhibit P: Sulfate toxicity data from research conducted by Dr. Soucek.

Common Name	Scientific Name	Acute Value (mg/L)	Chloride (mg/L)	Ca-Mg ratio (weight)	Hardness (mg/L)	Reference
Water flea	*Ceriodaphnia dubia*	2,526	10	2.33	100	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,357	10	2.33	100	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,526	10	2.33	102	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,223	15	2.33	92	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,243	15	2.33	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,402	15	2.33	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,470	20	2.33	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,295	20	2.33	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,494	20	2.33	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,153	25	2.33	100	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,563	25	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,868	25	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,799	25	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,458	25	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,357	100	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,784	100	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,112	100	2.33	104	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,895	300	2.33	98	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,798	300	2.33	102	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,049	300	2.33	102	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,400	500	2.33	96	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,933	500	2.33	98	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,157	500	2.33	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,030	1.9	1.46	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	1,868	1.9	1.46	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,269	1.9	1.46	94	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,538	34	5.4	107	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,607	34	5.4	107	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,436	34	5.4	107	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,059	1.9	1.46	194	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,706	1.9	1.46	194	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,265	1.9	1.46	194	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,383	1.9	1.46	288	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,361	1.9	1.46	288	Soucek 2004
Water flea	*Ceriodaphnia dubia*	2,853	1.9	1.46	288	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,297	1.9	1.46	288	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,369	1.9	1.46	390	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,073	1.9	1.46	390	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,091	1.9	1.46	390	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,716	1.9	1.46	484	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,506	1.9	1.46	484	Soucek 2004
Water flea	*Ceriodaphnia dubia*	3,338	1.9	1.46	484	Soucek 2004
Amphipod	*Hyalella azteca*	1,785	33	2.33	96	Soucek 2004
Amphipod	*Hyalella azteca*	1,865	33	2.33	100	Soucek 2004
Amphipod	*Hyalella azteca*	1,749	33	2.33	96	Soucek 2004
Amphipod	*Hyalella azteca*	1,919	100	2.33	98	Soucek 2004
Amphipod	*Hyalella azteca*	1,833	100	2.33	100	Soucek 2004
Amphipod	*Hyalella azteca*	2,062	100	2.33	100	Soucek 2004
Amphipod	*Hyalella azteca*	1,739	300	2.33	98	Soucek 2004
Amphipod	*Hyalella azteca*	1,614	300	2.33	96	Soucek 2004
Amphipod	*Hyalella azteca*	1,721	300	2.33	100	Soucek 2004
Amphipod	*Hyalella azteca*	1,435	500	2.33	98	Soucek 2004
Amphipod	*Hyalella azteca*	1,503	500	2.33	100	Soucek 2004
Amphipod	*Hyalella azteca*	1,472	500	2.33	100	Soucek 2004
Amphipod	*Hyalella azteca*	2,030	25	2.33	106	Soucek 2004
Amphipod	*Hyalella azteca*	1,919	25	2.33	100	Soucek 2004

Common Name	Scientific Name	Acute Value (mg/L)	Chloride (mg/L)	Ca-Mg ratio (weight)	Hardness (mg/L)	Reference
Amphipod	*Hyalella azteca*	1,615	25	2.33	98	Soucek 2004
Amphipod	*Hyalella azteca*	2,057	25	2.33	102	Soucek 2004
Amphipod	*Hyalella azteca*	2,655	25	2.33	194	Soucek 2004
Amphipod	*Hyalella azteca*	2,076	25	2.33	192	Soucek 2004
Amphipod	*Hyalella azteca*	2,887	25	2.33	196	Soucek 2004
Amphipod	*Hyalella azteca*	2,189	25	2.33	296	Soucek 2004
Amphipod	*Hyalella azteca*	3,358	25	2.33	292	Soucek 2004
Amphipod	*Hyalella azteca*	2,978	25	2.33	292	Soucek 2004
Amphipod	*Hyalella azteca*	2,612	25	2.33	392	Soucek 2004
Amphipod	*Hyalella azteca*	4,026	25	2.33	396	Soucek 2004
Amphipod	*Hyalella azteca*	4,314	25	2.33	396	Soucek 2004
Amphipod	*Hyalella azteca*	4,234	25	2.33	486	Soucek 2004
Amphipod	*Hyalella azteca*	4,320	25	2.33	482	Soucek 2004
Amphipod	*Hyalella azteca*	3,825	25	2.33	482	Soucek 2004
Fingernail clam	*Spherium simile*	1,857	1.9	1.46	89	Soucek 2004
Fingernail clam	*Spherium simile*	2,069	1.9	1.46	81	Soucek 2004
Fingernail clam	*Spherium simile*	2,633	1.9	1.46	83	Soucek 2004
Fingernail clam	*Spherium simile*	2,278	33	5.4	89	Soucek 2004
Fingernail clam	*Spherium simile*	2,122	33	5.4	96	Soucek 2004
Fingernail clam	*Spherium simile*	2,671	1.9	2.33	274	Soucek 2004
Fingernail clam	*Spherium simile*	2,509	1.9	2.33	285	Soucek 2004
Fingernail clam	*Spherium simile*	3,025	33	1.46	90	Soucek 2004
Fingernail clam	*Spherium simile*	2,582	33	1.46	87	Soucek 2004
Fingernail clam	*Spherium simile*	2,343	33	1.46	94	Soucek 2004
Fingernail clam	*Spherium simile*	3,139	1.9	1.46	274	Soucek 2004
Fingernail clam	*Spherium simile*	2,712	1.9	1.46	264	Soucek 2004
Fingernail clam	*Spherium simile*	2,297	1.9	1.46	195	Soucek 2004
Fingernail clam	*Spherium simile*	2,082	1.9	1.46	191	Soucek 2004
Fatmucket	*Lampsilis siliquoidea*	3,377	25	2.33	100	Soucek 2005
Fatmucket	*Lampsilis siliquoidea*	3,525	25	2.33	300	Soucek 2005
Fatmucket	*Lampsilis siliquoidea*	3,729	25	2.33	500	Soucek 2005
Fatmucket	*Lampsilis siliquoidea*	1,727	5	1.46	100	Soucek 2005
Fatmucket	*Lampsilis siliquoidea*	1,822	33	1.46	100	Soucek 2005

<u>Exhibit V</u>: Maximum allowable concentrations of sulfate at various concentrations of hardness and chloride calculated from equations proposed as water quality standards. Italicized values are numerical standards that apply under corresponding hardness and chloride concentrations. Values represent the concentration of sulfate not to be exceeded at any time dependent of specified water chemistry.

Chloride (mg/L)	Hardness (mg/L)										
	<100	100	150	200	250	300	350	400	450	500	>500
0-5	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*
5	*500*	515	703	891	1080	1268	1456	1644	1832	2020	*2000*
10	*500*	691	879	1067	1256	1444	1632	1820	2008	2196	*2000*
15	*500*	867	1055	1243	1432	1620	1808	1996	2184	2372	*2000*
20	*500*	1043	1231	1419	1608	1796	1984	2172	2360	2549	*2000*
25	*500*	1164	1343	1522	1701	1880	2059	2238	2417	2596	*2000*
50	*500*	1141	1320	1499	1678	1857	2036	2215	2394	2573	*2000*
100	*500*	1093	1272	1451	1630	1809	1988	2167	2346	2525	*2000*
150	*500*	1046	1225	1404	1583	1762	1941	2120	2299	2478	*2000*
200	*500*	998	1177	1356	1535	1715	1894	2073	2252	2431	*2000*
250	*500*	951	1130	1309	1488	1667	1846	2025	2204	2383	*2000*
300	*500*	904	1083	1262	1441	1620	1799	1978	2157	2336	*2000*
350	*500*	856	1035	1214	1393	1572	1751	1930	2109	2288	*2000*
400	*500*	809	988	1167	1346	1525	1704	1883	2062	2241	*2000*
450	*500*	762	941	1120	1299	1478	1657	1836	2015	2194	*2000*
500	*500*	714	893	1072	1251	1430	1609	1788	1967	2146	*2000*
>500	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*	*302.208g*

Iowa's Water Quality Standard Review: Total Dissolved Solids

1. Background

Total Dissolved Solids (TDS) is a measure of all constituents dissolved in water. The inorganic anions dissolved in water include carbonates, chlorides, sulfates and nitrates. The inorganic cations include sodium, potassium, calcium and magnesium.

Prior to 2004 rule making efforts, several NPDES permittees have noted that Iowa's long standing Total Dissolved Solids (TDS) numerical criteria of 750 mg/l was inconsistent with current toxicity information. The criterion was listed as one of the General Water Quality Criteria that are applicable to all waters. Data that was provided by permittees indicated that warm water aquatic species are tolerant of a more relaxed TDS level.

During 2004, the Department conducted rule making to revise the TDS criteria and adopt chloride criteria for aquatic life protection. The rule package received considerable opposition from environmental groups and the regulated communities. As a result, the EPC adopted a site-specific approach for TDS as an interim criterion to replace the old 750 mg/L general criteria and rejected the proposed chloride criteria. The intent of the site-specific approach is to gather information based on recommendations made by the EPC, as specified in ARC 3281B, published in the April 14, 2004, Iowa Administrative Bulletin. The Department was requested to utilize the information gathered during the three-year period to propose a new standard.

The purpose of this issue paper is to recommend replacing the interim site-specific TDS general standard with numerical specific ion criteria for chloride and sulfate based on new toxicity testing information. The justification for the revision is based on the evidence that the TDS toxicity is caused by specific ions. As a result, specific ion criteria are better indicators than the integrative parameters such as TDS, conductivity and salinity for water quality protection.

2. The Current Interim TDS Site-Specific Approach

The interim 2004 TDS site-specific approach became effective on June 16th, 2004 and was approved by EPA on December 6th, 2004. The interim 2004 TDS site-specific approach is a general water quality criterion applies to all waters of the state and is listed in IAC 61.3(a)"g" as follows:

g. Acceptable levels of total dissolved solids (TDS) and constituent cations and anions will be established on a site-specific basis. The implementation approach for establishing the site-specific levels may be found in the "Supporting Document for Iowa Water Quality Management Plans," Chapter IV, July 1976, as revised on June 16, 2004.

The implementation procedure of the site-specific TDS approach is discussed on pages 40 and 41 of the *Supporting Document for Iowa Water Quality Management Plans.* Appendix A includes the implementation procedure of the site-specific TDS approach.

Based on the site-specific TDS approach for point sources that discharge directly into a general use stream (undesignated), a facility's discharge that causes the in-stream TDS concentration to be above 1000 mg/L, would require acute toxicity tests to demonstrate that the discharge will not result in toxicity to aquatic life at an in-stream concentration greater than 1,000 mg/L. This demonstration consists of collecting a sample of the discharge and having a laboratory perform a whole effluent toxicity (WET) test. The results would be used to establish an effluent limit for TDS that will be included in an NPDES permit.

For point sources that discharge directly into a designated stream, the site-specific TDS approach allows the Department to establish a site-specific TDS effluent limit following a demonstration that the discharge will not result in toxicity to aquatic life at an effluent concentration for TDS and/or its constituent chloride that could result in an in-stream level higher than threshold levels. The in-stream threshold level for TDS is 1,000 mg/L. The in-stream threshold levels for chloride are 860 mg/L and 230 mg/L (equivalent to the 1988 304(a) criteria), as the acute and chronic threshold values respectively. This demonstration consists of collecting a sample of the discharge and having a laboratory perform a whole effluent toxicity (WET) test (both acute and chronic WET tests are required if both acute and chronic thresholds are exceeded in the receiving stream). The results will be used to establish an effluent limit for TDS that will be included in an NPDES permit.

3. Literature Review on TDS Toxicity Data

The purpose of this review was to examine relevant published literature and other scientific reports to determine the best approach for the development of specific TDS criteria and/or ion specific criteria for the State of Iowa.

Mount *et al.* (1997) states that the toxicity of fresh waters with high dissolved solids has been shown to be dependent on the species ionic composition of the water. Integrative parameters such as conductivity, TDS, or salinity are not robust predictors of toxicity for a range of water qualities. Mount *et al.* (1997) developed regression models to predict the toxicity attributable to major ions such as K^+, $HCO3^-$, Mg^{2+}, Cl^-, and $SO4^{2-}$. The study found that the presence of multiple cations tended to be less toxic than comparable solutions with only one cation. Also, as the hardness increases, TDS toxicity may decrease. The regression models provided highly accurate predictions for *Ceriodaphnia dubia* toxicity, but overpredict the toxicity for *Daphnia magna* and fathead minnows.

Weber-Scannell and Duffy (2007) states that TDS causes toxicity through increases in salinity, changes in the ionic composition of the water, and toxicity of individual ions. Increases in salinity have been shown to cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species, and cause acute or chronic effects at specific life stages. Changes in the ionic composition of water can exclude some species while promoting population growth of others. Concentrations of specific ions may reach toxic levels for certain species of life history stages. The research paper states that it is recommended that different limits for individual ions, rather than TDS, be used for salmonid species.

The paper also states that a water quality standard for TDS can take several approaches: 1) The standard can be set low enough to protect all species and life stages exposed to the most toxic ions or combination of ions; 2) The standard can be set to protect most species and life stages for most ions and combinations of ions; or 3) Different limits can be defined for different categories of ions or combinations of ions, with a lower limit during fish spawning, if salmonid species that have been shown to be sensitive to TDS during fertilization and egg development are present. Approach (1) may be unnecessarily restrictive, although simpler to define and implement. Approach (2), although less restrictive, may lead to adverse effects to aquatic communities. Approach (3) is more complicated to define and would require that the potential discharger determine the composition of the effluent and which species and life stages are present downstream of the effluent. Overall, Approach (3) would provide the greatest protection to aquatic species and the least unnecessary restriction to potential dischargers.

McCulloch et al. (1993) states that depending on the discharge situation, effluent toxicity due solely to TDS may be less of a regulatory problem, due to rapid dilution below toxic levels and the absence of human health or biomagnification concerns.

Chapman et al. (2000) studied TDS toxicity with two mine effluents to early life stages of rainbow trout and chironomid larvae. The toxicity tests were conducted with synthetic effluents formulated to match the ionic composition of each mine discharge. No toxicity was observed at >2000 mg/l of TDS with embryos or developing fry, but chironomids exhibited effects above 1100 mg/l of TDS (NOAECs were 1134 mg/l and 1220 mg/l for the two effluents). Chapman et al. (2000) indicated that the toxicity related to the ions in TDS is due to the specific combination and concentration of ions and is not predictable from TDS concentrations.

Hoke et al. (1992) studied the potential effects of alkalinity on cladocera. The test results indicate that the toxicity of $HCO3^-$ to D. magna might be the inhibition of the active uptake of Cl^- from water. The study also suggest that pore water alkalinity should be considered when interpreting the results of sediment pore water and effluent toxicity tests with D. magna, other cladocerans, and perhaps, other invertebrates and fish.

The United States Environmental Protection Agency (US EPA) currently does not have a national criterion for TDS. According to Dr. Zipper (2007), to date, 27 states have enacted a state-specific and or watershed specific criterion; however, target TDS levels and the designated uses they are intended to protect vary greatly from state to state. For example, Alaska has a criteria of 1,000 mg/L TDS to protect aquatic life throughout the state; Mississippi has a criteria of 750 mg/L monthly average for protection fish, wildlife and recreation criteria, and Illinois has a 1,500 mg/L TDS criteria supporting designated use of secondary contact and indigenous aquatic life standards (Illinois EPA is in the process of removing TDS and replace it with sulfate standard). Water quality TDS concentrations are highly dependent on flow conditions. TDS criteria for the protection of aquatic life have only been developed in 15 of the 27 states. The lowest TDS criteria found for the protection of aquatic life was in the state of Oregon, which uses a standard of 100 mg/L for all freshwater streams and tributaries in order to protect aquatic life, public water use, agriculture, and recreation purposes. Oregon also allows the criteria in individual streams or watersheds to be increased when approved by the Oregon Division of Environmental Quality.

The impact of aberrant levels of ions differs markedly with the ion in question as well as the organism being tested. Some ions, Ca^{2+} and K^{+} for example, cause significant acute toxicity when they are deficient in the exposure media, while other ions appear to have demonstrable effects only at excess levels (API, 1999). The Colorado Department of Public Health and Environment has prepared a draft of its "Whole Effluent Toxicity Permit Implementation Guidance Document" that specifically addresses TDS as a toxicant. Permittees can follow the procedures to identify and address toxicity due to TDS ions. If the acute WET test is passed using Daphnia magna (which is more tolerant than C. dubia to TDS ions), then the permittee may request a permit amendment to change WET test species. If D. magna cannot tolerate the elevated TDS, or if the required test is chronic, permittees may be required to conduct an Aquatic Impairment Study (AIS) of the receiving stream. Following the AIS, WET tests may be modified to switch or remove TDS. Additional mitigation measures also may be needed.

A similar approach is used in Texas. If testing shows that the primary cause of toxicity is TDS ions, the State will evaluate, or require the permittee to evaluate, the use of an alternative test species or modified test protocol. If TDS is not coming from source water, the permittee may conduct a biological study to evaluate instream impacts. The evaluation should follow USEPA's Rapid Bioassessment Protocols. The *in situ* evaluation of aquatic communities via impairment studies can be important because laboratory WET caused by TDS ions does not necessarily reflect adverse impacts in receiving waters.

Goodfellow W.L. et al. (2000) indicate that cost-effective waste treatment control options for a facility whose effluent is toxic because of TDS or specific ions are scarce at best. However, depending on the discharge situation, TDS toxicity may not be viewed with the same level of concern as other toxicants. These discharge situations often do not require the conservative safety factors that other toxicants do. Regulatory solutions to ion imbalance toxicity when no other toxicants are present may include modifications to the site-specific exposure through discharge modification, use of alternative models (e.g., dynamic models), exposure-specific toxicity tests, or alternate mixing zones for TDS or specific ions.

The State of Illinois currently has a general use standard of 1000 mg/l for TDS, a sulfate standard of 500 mg/l, and a chloride standard of 500 mg/l for aquatic life protection. Illinois EPA is in the process of rule making to replace the TDS standard with numerical sulfate standard (Illinois EPA, 2006). Illinois EPA states that the chloride standard of 500 mg/l is thought to be protective of aquatic life toxicity. No change is proposed for the chloride standard at this time. The Illinois EPA states that the existing TDS standard has always been ungainly since it is really based on a worst-case combination of minerals being present. The specific constituents of the mineral contents of water are better regulated individually. The Illinois EPA has recommended that the TDS standard be deleted from the Board regulations.

After reviewing available sulfate toxicity data, Illinois EPA determined more reliable toxicity data for additional invertebrate species were needed. Dr. David Soucek of the Illinois Natural History Survey was contracted to conduct the laboratory toxicity testing. Acute toxicity of sulfate to five invertebrate species was conducted. These organisms were the water flea *Ceriodaphnia dubia*, a previously tested organism used as a gauge for comparison purposes, *Hyalella azteca*, an amphipod, *Chironomus tentans*, a midge fly, *Sphaerium simile*, a fingernail clam, and *Lampsilis siliquoidea*, a freshwater mussel. The new toxicity data on sulfate clearly shows a relationship between sulfate toxicity and water chemistry parameters, namely chloride and hardness. It is believed that chloride and hardness influence the toxicity of sulfate to aquatic invertebrates due to alterations in osmoregulation. Invertebrates achieve ionic balance with surrounding water through active transport, an energy requiring activity. At intermediate chloride and higher hardness concentrations, ionic balance in the presence of elevated sulfate concentrations is achieved rather easily. At low chloride and higher hardness concentrations, osmoregulation is increasingly difficult, resulting in utilization of energy stores in an attempt by the organism to achieve ionic balance. High levels of chloride increase sulfate toxicity as well, primarily through increasingly unbalanced osmotic conditions.

Because sulfate toxicity is dependent on chloride and hardness concentrations, these water quality characteristics must be taken into consideration when setting a standard throughout the state. For example, a statewide numeric standard for sulfate may be sufficiently protective in one stream, but underprotective in another depending on water chemistry. To adequately protect aquatic organisms from sulfate throughout the state, it is important that chloride and hardness be considered on a site by site basis. By creating an equation that relates sulfate toxicity to chloride and hardness, these two values can be measured in a water body and entered into the equation to determine the maximum amount of sulfate allowable for that water body.

Summary of Literature Review:

The TDS concentration that causes adverse effects varies substantially with the ion composition. For example, the TDS lethal concentration that causes 50% mortality for an invertebrate species (*Ceriodaphnia dubia*) during 48-hour tests ranges from 390 mg/l to over 4,000 mg/l depending on the ion composition. Studies have shown that, in general, for freshwaters the relative ion toxicity was $K^+ > HCO3^- = Mg^{2+} > Cl^- > SO4^{2-}$. Ca^{2+} and Na^+ did not produce significant toxicity.

One of the difficulties in developing TDS criteria is that there are no national criteria or toxicity database available.

Since TDS toxicity depends on the ion composition, it is recommended that different limits for individual ions, rather than TDS, be used. The State of Illinois is in the process of rule making that replaces the TDS criterion of 1000 mg/l with sulfate criteria (a chloride criterion of 500 mg/l is already in the rules). The challenge is what specific ion criteria should be used to replace TDS. Among the potentially most toxic ions, K^+ , $HCO3^-$,Mg^{2+}, Cl^- and $SO4^{2-}$, the effluent concentrations for the first three ions are usually relatively low. Also, the toxicity data for these ions are scarce. The only national criterion available for ions is chloride. It is possible the TDS criteria could be replaced with chloride and sulfate ion criteria. This is the approach that State of Illinois is taking with the EPA Region 5 support.

4. Justification for Replacing TDS Standard by Specific Ion Criteria

A. Implementation Issues with the Interim TDS Site-Specific Approach

The current site-specific TDS approach uses the Whole Effluent Toxicity (WET) test results to develop a numeric effluent limitation for TDS, a particular pollutant. WET testing is designed to measure the toxicity of the whole effluent including synergistic and antagonistic interactions of pollutants. It is not designed to measure the toxicity of a single pollutant in a sample.

Since the adoption of the site-specific TDS approach, there are several issues with the implementation process:

1. Chronic testing with *Ceriodaphnia* has shown inconsistent testing results for the same discharge. The chronic testing would pass at 100% effluent concentration and fail at a lower TDS concentration (higher dilution).
2. A facility does not know at the time it collects an effluent sample what the concentrations of various pollutants are in that sample as the Department requires the toxicity test to start no later than 36 hours after sample collection. However, the lab typically does not have the analytical results for that sample prior to starting the toxicity test. This has resulted in a number of cases where the toxicity test is completed only to find that the concentration of TDS in the test sample was significantly less than the highest TDS concentration measured in the discharge. In these cases, the toxicity test results cannot be used to establish a permit limit. There have been other cases where the concentration of ammonia or chlorine was high enough that the measured toxicity was likely due to one of these pollutants rather than TDS.
3. There are currently no laboratories certified by the State of Iowa to perform chronic toxicity testing. There are only 5 laboratories certified by the State of Iowa to perform acute toxicity testing and only one of these is located in Iowa.
4. The lack of laboratory capability has resulted in facilities having to schedule a test with the laboratory as much as 3-6 months before the test will actually be

performed. This is especially problematic for a controlled discharge lagoon that cannot know whether conditions will be right for discharge 3-6 months in advance. Controlled discharge lagoons only discharge every 6 months.

5. The current approach can cause difficulties for new facilities and for facilities that operate seasonally (e.g. parks, campgrounds, children's camps). If the first toxicity test does not produce valid or useful data there is a considerable delay before another test can be performed.
6. We often require facilities to change their operations such as increasing the number of cycles in order to collect the highest sample TDS concentration to be used to establish a TDS limit. The condition at which the samples are collected does not represent the normal operating conditions.
7. Variability among WET testing results is significant.

After EPA approved the interim site specific TDS approach on December 6, 2004, the Department started to implement the adopted standard. Since December 7, 2004, the Department has received TDS toxicity test data from approximately 70 facilities. All 70 facilities conducted acute toxicity tests. Chronic toxicity test data was submitted by 33 of the facilities. In general, the toxicity test data is relatively scattered. The highest TDS concentration that passed an acute toxicity test is 5,098 mg/L, and the lowest TDS concentration that passed the acute test is 325 mg/L. The highest chloride concentration that passed the acute test is 1200 mg/L and the lowest chloride concentration that passed the acute test is 14 mg/L. For chronic tests, the highest and lowest TDS concentrations that passed the chronic tests are 1980 mg/L and 29 mg/L, respectively. The highest and lowest chloride concentrations that passed the chronic tests are 930 mg/L and 5 mg/L, respectively. The summary table is shown below.

Table 1. Summary of TDS/Cl Toxicity Test Data Submitted by Facilities in Iowa

Chemicals		Concentration Acute Test Passed (mg/L)	Concentration Chronic Test passed (mg/L)
TDS	Max.	5,098	1,980
	Min.	325	29
Chloride	Max.	1,200	930
	Min.	14	5.0

These testing data show significant variability in the WET results from facility to facility. It is fairly difficult to draw any meaningful conclusions from these data. It is even more challenging to derive a TDS limit from the uncertain toxicity testing results. Several TDS toxicity testing results showed pollutant sources other than TDS were the possible sources for the failure of the toxicity testing, especially those tests failed at relatively low TDS levels.

B. Lack of Scientific Support

Total dissolved solids (TDS) is a term used to describe the combination of all dissolved inorganic or organic ions or molecules in water, and often consists of a complex mixture of cations such as sodium, calcium, magnesium, and anions including chloride and sulfate. While these ions are present in most freshwater systems, at elevated concentrations they are potentially toxic to aquatic life. Currently, there are no federal water quality criteria for TDS for the protection of aquatic life.

The IDNR research into existing ion concentrations in Iowa waters found that of the common substances comprising the major portion of total dissolved solids, toxicity is always associated with either sulfate or chloride. Sodium, calcium, magnesium and carbonates make up the other ions in the majority, but these are not sufficiently toxic to create the need for individual water quality standards. Simply put, if sulfate and chloride, alone or in combination, meet the proposed standards, toxicity from the other major ions comprising "total dissolved solids" is insignificant. Therefore, TDS concentration provides no additional useful information. The existing standard is cumbersome and results in restrictions where none should exist. For example, if the sulfate water quality standard for a water body was calculated to be 2,000 mg/L under a certain level of hardness and chloride (340 mg/L and 50 mg/L, respectively), the total dissolved solids concentration of that solution would be greater than 2,100 mg/L without adding the sodium that is associated with the sulfate and chloride. Obviously, a TDS standard of 1,000 mg/L is incapable of indicating the concentrations of dissolved substances that are harmful to aquatic life in this example. In another example, where chloride is 5 mg/L and hardness is 90 mg/L, the sulfate standard is 500 mg/L. Here, a 1,000 mg/L TDS standard may be under protective.

Natural waters consist of numerous ionic constituents which, under the direct influence of many natural (from geologic formations) and anthropogenic (from industrial and municipal wastewater discharges, agricultural run-off, sediments, etc.) sources, may become elevated to levels toxic to aquatic life (Mount et al. 1997). Because the toxicity of the collective ionic constituents in surface waters is complex and dependent upon the concentrations of individual cations and anions and their relative proportions in a surface water matrix, integrative measures of ionic constituents such as specific conductance, total dissolved solids (TDS) and salinity have typically been used to assess toxicity to aquatic life. Unfortunately, these integrative measures of ionic composition are typically not robust predictors of toxicity for a range of water quality characteristics despite a highly significant correlation between the integrative measure and toxicity in some waters (Mount et al. 1997). Therefore, as indirect measures of the presence of inorganic dissolved solids such as chloride, bicarbonate, nitrate, sulfate, phosphate, sodium, magnesium, calcium, potassium and iron, specific conductance, TDS, and salinity have only been used as indicators of water pollution, and not as the basis for ambient water quality criteria. As such, there are no federal water quality criteria for specific conductance, TDS or salinity for the protection of aquatic life. Among the various individual ionic constituents in surface water, potassium, bicarbonate, sodium, magnesium, chloride and sulfate are most significant in terms of toxicity (Mount et al. 1997). For example, EPA has a recommended Clean Water Act 304(a) criterion for chloride (USEPA 1988), and at least two states (Illinois and Minnesota) have developed aquatic life criteria for sulfate (Soucek and Kennedy 2005).

C. Protection of Designated Uses by Individual Ion Criteria

Aquatic Life Uses
According to CFR131.11, States must adopt those water quality criteria that protect the designated use. Such criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use.

Since the start of the site-specific TDS standard implementation, the TDS sample data submitted by point sourced discharge facilities have shown that elevated TDS is often caused by high chloride and/or sulfate. The adoption of the numerical standard of chloride and sulfate for aquatic life protection will ensure that the resident species in Iowa waterbodies are protected. Thus, the TDS general criteria as an integrative component, becomes unnecessary.

After March 22, 2006 WQS rule, almost all waterbodies are classified as designated uses. Only a very limited number of waterbodies will remain as general use. The general use narrative criteria will still apply to these waterbodies, including that no discharge should cause acutely toxic conditions.

Livestock Watering Uses
The current site-specific TDS standard includes specific ion guideline values for the protection of livestock watering. Since the implementation of the interim site-specific standard, only sulfate concentrations are occasionally elevated to raise concern. For chloride, the numerical criteria will be more stringent than livestock watering guideline values. Other ion concentrations are usually below the guideline values and do not cause potential concerns. Thus, to protect the livestock watering, the sulfate livestock watering guideline will remain, but will be replaced with a different value based on new research data.

Therefore, between the chloride and sulfate water quality standards and the narrative general criteria (IAC 61.3(2)) that regulates any discharged substance that could cause toxicity, there is no need for a TDS standard.

D. TDS/Chloride Monitoring Study

In 2005, the Iowa Water Pollution Control Association, wastewater facilities from across Iowa, the Iowa DNR – Water Quality Bureau, and the Iowa DNR – Water Monitoring and Assessment Program conducted a cooperative study to monitor point source outfalls and receiving streams mainly for total dissolved solids and chloride. The study also analyzed several other common ions such as sulfate, ammonia nitrogen and phosphorous. This study was conducted to accurately and objectively assess the ion and total dissolved solid (TDS) concentrations in the outfalls of point source facilities across Iowa, upstream of outfalls, and downstream of outfalls. Sampling for this study occurred under low-flow conditions, when the impact of point source outfalls on receiving streams is the greatest.

This data collection effort was initiated in order to satisfy a recommendation from the Iowa Environmental Protection Commission to IDNR to prepare an economic analysis as part of the development of TDS and chloride standards.

There were two phases to the data collection for the project: a pilot study and a full study. Samples for the pilot study were collected during late winter at low-flow conditions (February 21 through March 6, 2005). A total of 21 wastewater dischargers participated in this 2-week pilot study. For the full study, samples were collected from 100 facilities. The one hundred facilities in the study were selected based on the associated municipal drinking water TDS and hardness levels, nature of the wastewater treated, type of treatment process, geographic location and receiving stream characteristics. The selected facilities represent a subset of Iowa wastewater dischargers that could potentially be affected by the proposed TDS and chloride water quality standards.

The study did not show a significant difference between effluent 24-hour composite samples and effluent grab samples for TDS and chloride. The data analysis seems to show that the effluent TDS and chloride levels are quickly diluted below the threshold values (TDS < 1000 mg/L, chloride < 230 mg/L) by the stream flow beyond the mixing zone under the sampling conditions. Table 2 shows a summary of effluent ion concentrations for the point sources discharges participated in the full study. More details can be found in the TDS and Chloride Study Report (IDNR, 2007).

In addition to the special TDS/chloride study, the DNR through its Ambient Monitoring Program has monitored a network of streams statewide on a monthly basis since 2000 to assess ambient stream quality conditions, identify regional differences, and determine trends in water quality. Included in the list of parameters analyzed are several ions and TDS. The number of stream sites sampled has varied from 80 to 84 from 2000 through 2007. This data set provides an indication of what typical ion and TDS concentrations are for Iowa streams. Table 3 shows a summary of TDS, chloride, sulfate and hardness values for the Iowa ambient monitoring data from 2000-2007. These monthly monitoring data represent different stream flow conditions.

Table 2. Effluent Ion Concentrations from Full Chloride Study

Parameter	Unit	# of samples	Min Value	Percentile 10th	25th	50th	75th	90th	Max Value	Average
Calcium	mg/l	131	27.6	44.7	60.4	79.7	117.5	152.0	869.0	101.0
Chloride	mg/l	244	20.4	87.7	179.5	371.5	604.0	756.4	8800.0	458.0
Fluoride	mg/l	244	0.5	0.5	0.5	0.5	0.5	0.7	7.7	0.6
Magnesium	mg/l	131	6.2	16.5	23.0	33.6	44.9	56.8	388.0	38.0
Nitrate-N	mg/l	244	1.0	1.0	1.0	3.0	15.0	22.1	125.0	11.4
Nitrite-N	mg/l	244	0.5	0.5	0.5	5.0	12.5	12.5	50.0	6.5
Phosphate	mg/l	244	2.0	2.0	2.3	3.4	5.0	10.0	36.4	5.7
Potassium	mg/l	131	5.0	8.7	11.5	15.7	21.7	40.5	84.5	20.2
Sodium	mg/l	131	26.4	64.6	140.0	240.0	357.0	500.0	5280.0	307.8
TDS	mg/l	244	392.0	553.6	856.3	1285.0	1885.0	2417.0	15600.0	1488.0
Sulfate	mg/l	244	2.5	46.3	64.4	168.0	345.5	448.0	801.0	211.1

Table 3. TDS and Ion Concentrations in Iowa Streams

Chemicals	**Iowa Ambient Monitoring Data from 2000-2007, units in mg/L**		
	50th percentile	90th percentile	Maximum value
TDS	360	510	1,640
Chloride	23	40	170
Sulfate	37	97	400
Hardness (as CaCO3)	300	410	820

The effluent monitoring data show that chloride and sulfate are the anions could potentially contribute to high effluent TDS levels. The ambient monitoring data indicate that that point source contributions of TDS, chloride and sulfate could dilute quickly downstream of the discharge after mixing. There is no significant impact on overall surface water quality downstream of the discharges. However, numerical criteria for specific ions such as chloride and sulfate are necessary to prevent near-field toxicity.

E. Measures to Reduce TDS Concentrations

Measures to reduce TDS discharges range from source reduction (low cost) to treatment technologies (high cost). Alternative implementation approaches to assess compliance are dependent on the criteria that are proposed, but could include toxicity testing and flow-variable limits. Current treatment technologies available for TDS include the following:

- Source reduction: may not be feasible in some cases
- Reverse osmosis technology: costly, need to determine how to handle the waste stream

- Thermo method: evaporation, costly
- Chemical precipitation: usually used for metals
- Integrated membrane/recycling methods: the final solids are removed by a crystallizer and the effluent used results in zero discharge.

TDS reduction should start from control in order to prevent TDS from entering the water system in the first place. This may be difficult to achieve since Iowa has relatively hard ground water. If source reductions are not possible, technological advancements may be required to remove TDS. The most widely used TDS removal technique is reverse osmosis, including single reserve osmosis operation, and integrated membrane/recycling methods. The latter are mostly used in the pilot test phase. All other methods are either relatively new, in the research stage, or only apply in specific sites and settings. Research on measures to reduce TDS in wastewater discharge shows that cost-effective technology to treat TDS is very limited.

5. Recommendations for Specific Ion Criteria

As the literature review indicates, integrative parameters such as TDS, conductivity and salinity are not robust predictors of toxicity for a range of water qualities. Since individual ions contribute to the TDS toxicity, specific ion criteria are better indicators than TDS for water quality protection.

Because of the better understanding of major ion toxicity, IDNR is proposing to delete the existing TDS standard (a threshold of 1,000 mg/l) from the current regulations, and to replace it with specific ion standards.

Based on the examination of available effluent ion analysis and literature review, the TDS site-specific approach may be replaced with specific ion criteria for chloride and sulfate. There is a national criterion available for chloride that was published in 1988. Since then, new toxicity data have become available. The proposed chloride criteria will be recalculated based on the national toxicity database and new toxicity data. The proposed chloride criteria are summarized in the chloride criteria review.

Mount *et al.* (1997) developed regression models to predict the toxicity attributable to major ions such as K^+, $HCO3^-$, Mg^{2+}, Cl^-, and $SO4^{2-}$. The toxicity of Na^+ and Ca^{2-} salts was primarily attributable to the corresponding anion and they are not identified as toxic by themselves. Monitoring data for effluents and ambient waters in Iowa show that the anions of chloride and sulfate could be elevated to raise concern for designated use protection.

For chloride, the numerical criteria will be updated using additional toxicity testing data performed in September of 2008 by EPA contractors in addition to the toxicity data in the 1988 304(a) criteria as well as the new toxicity data from the most recent literature review. For sulfate, the Illinois approach will be used. The proposed chloride and sulfate criteria are summarized in the chloride and sulfate criteria work element reports, respectively.

The recommended specific ion criteria for chloride and sulfate are based on the most up-to-date toxicity data and are scientifically defensible. In addition, Mount et al. (1997) found that the presence of multiple cations ameliorate the toxicity of Cl^-, $SO4^{2-}$ and K^+. The increase in hardness also reduces the toxicity of these ions. The laboratory toxicity tests are usually conducted using moderately hard water that has hardness below 100 mg/L as CaCO3. However, the median hardness for Iowa streams is 300 mg/L as CaCO3. Both chloride and sulfate criteria will be hardness dependent in order to take into account for site-specific Iowa water conditions.

Appendix A: TDS Site-Specific Approach Standard Implementation

Total Dissolved Solids: Total Dissolved Solids (TDS) numerical criteria will be determined by applying a site specific approach for the protection of Iowa's surface waters and their specified uses. The site specific approach would first consider a guideline value of 1000 mg/l (TDS) as a threshold in-stream level at which negative impacts may begin to occur to the uses of the receiving stream. (Note, for some unusual situations where sensitive in-stream uses occur or where uses are sensitive to the ion composition of the TDS, a more restrictive guideline value may be warranted.) Sources of TDS potentially elevating a receiving stream above 1000 mg/l (TDS) would be required, upon application for a discharge permit or permit renewal, to clearly demonstrate that their discharge will not result in toxicity to the receiving stream.

The following represents the site-specific requirements to demonstrate compliance with the narrative criteria and defined uses noted in the Water Quality Standards.

1. Passage of a Whole Effluent Toxicity Test – Each source discharging TDS that may potentially elevate a receiving stream above 1000 mg/l (TDS) will be required to complete and pass an acute or an acute and chronic Whole Effluent Toxicity (WET) test with the results submitted to the Department with the application for discharge permit or permit renewal. The WET test shall be conducted using EPA approved test procedures.

    - For dischargers directly entering a Class B designated water body, acute and chronic WET tests will be conducted using a mixed combination of effluent and receiving stream water. For the acute WET test, the mixed combinations will be in the proportion of the effluent flow to 2.5 % of the natural one-day, ten-year low flow (1Q10) or protected flow or the results of a site-specific zone of initial dilution stream study. For the chronic WET test, the mixed combinations will be in the proportion of the effluent flow to 25 % of the natural seven-day, ten-year low flow (7Q10) or protected flow or the results of a site-specific mixing zone stream study.

    - For dischargers directly entering a water body classified only as a General Water of the state, an acute WET test will be conducted using 100% of the effluent flow.

2. Submit a chemical analysis of the WET test water for selected cations and anions, including Calcium, Magnesium, Potassium, Sodium, Chloride, Sulfate and Iron. Also to be included is the Total Dissolved Solids contained in the test sample. The concentration for specific ions will be evaluated to determine if exceedances occur to defined uses. Potential threshold levels where impacts to uses may occur are noted in the following Table.

Recommended Water Quality Guidelines for Protecting Defined Uses

Ions	Recommended Guidelines Values* (mg/l)
Calcium	1000
Chloride	1500
Magnesium	800
Sodium	800
Sulfate	1000
Nitrate+Nitrite-N	100

* Based on the guidelines for livestock watering.

3. The protection of the defined uses requires application of the ion guidelines as 'end-of-pipe' limits in general waters. In designated waters, the guideline values would be met at the boundary of the mixing zone.

Appendix B: Definitions

TDS: Total Dissolved Solid (TDS) is a measurement of inorganic salts, organic matter and other dissolved materials in water. The amount of TDS in a water sample is measured by filtering the sample through a 2.0 µm pore size filter, evaporating the remaining filtrate and then drying what is left to a constant weight at 180°C.

NOAEC: is the highest tested concentration of an effluent or a toxicant at which no adverse effects are observed on the aquatic test organisms at a specific time of observation. Determined using hypothesis testing.

LC50: Lethal Concentration that is the point estimate of the toxicant concentration that would be lethal to 50% of the test organisms during a specific period, usually 96 hours or 48 hours.

IC25: The inhibition concentration that is a point estimate of the toxicant concentration that would cause a 25% reduction in a nonlethal biological measurement of the test organisms, such as reproduction or growth.

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Revising Criteria for Chloride, Sulfate and Total Dissolved Solids

By revising Iowa's water quality standards, the Iowa Department of Natural Resources (DNR) is working for improved water quality and safety in Iowa. Water Quality Standards are the goals that we set for Iowa's streams, rivers and lakes.

Water Quality Standards have three components:

- Designate the use or uses of the waterbody (aquatic life and recreational uses)
- Set the criteria for protecting those uses
- Protect and maintain existing water quality

Recently, the DNR began to compile all research related to toxicity of total dissolved solids, chloride and sulfate. The purpose was to update and develop criteria for these parameters to better protect aquatic life based on new scientific information.

The DNR worked with the U.S. Environmental Protection Agency to ensure that the research compiled met certain scientific standards. Gaps were identified in the research and resulted in new toxicity tests being performed in 2008.

With the availability of new research and toxicity data, the information is now available to propose numeric criteria for chloride and sulfate to better protect river, stream and lake aquatic life uses and revaluate the current interim approach for total dissolved solids criteria.

Chloride Criteria

Results of the research and toxicity testing completed for chloride showed that chloride toxicity is heavily dependent on water hardness, and to a lesser degree, sulfate levels in the water. Using all of the literature and this most recent toxicity testing, EPA developed an equation (see below) for the acute and chronic chloride criteria to protect Iowa's waters.

Proposed chloride criteria

To calculate the applicable acute and chronic criteria for chloride, use the equations below. Statewide default values for hardness and sulfate will be used unless site specific data is available. The DNR updated its proposed chloride criteria on March 3, 2009, based on new EPA toxicity data.

Acute Chloride Criteria Equation

$287.8(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$ = Acute Criteria Value (mg/L)

Chronic Chloride Criteria Equation

$177.87(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$ = Chronic Criteria Value (mg/L)

The following statewide background values were determined by analyzing DNR ambient water monitoring data from 2000 to 2007:

- Hardness: 200 mg/L as $CaCO_3$
- Sulfate: 63 mg/L
- Chloride: 34 mg/L

For example, if a Hardness value of 200 mg/L and a Sulfate value of 63 mg/L are used:

The acute criteria value for chloride would be:
$287.8(200\text{ mg/L})^{0.205797}(63\text{ mg/L})^{-0.07452}$
= 629 mg/L Chloride

The chronic criteria value for chloride would be:
$177.87(200\text{ mg/L})^{0.205797}(63\text{ mg/L})^{-0.07452}$
= 389 mg/L Chloride

Sulfate Criteria

In 2005 and 2006, the State of Illinois worked with U.S. EPA

Chloride is a major ion commonly found in streams and wastewater. Chloride may get into surface water from several sources, including:

- Wastewater from certain industries
- Wastewater from communities that soften water
- Road salting
- Agricultural runoff
- Produced water from oil and gas wells

to complete a review of research related to sulfate toxicity similar to the work done for chloride. The result of that work was a proposed criteria equation for sulfate based on background hardness and chloride levels. The similarities between the landscape and waterbodies of Iowa and Illinois and the high level of scientific review of this data allow for the same sulfate criteria proposed by Illinois to apply to protect aquatic life in Iowa's waters.

The proposed sulfate criteria also incorporates an upper limit of 2,000 mg/L to ensure that other beneficial uses of the waterbody, such as livestock watering, are protected in addition to aquatic life.

Total Dissolved Solids

The current interim approach for total dissolved solids levels through Whole Effluent Toxicity Testing will be replaced by the proposed criteria for chloride and sulfate.

This revision is based on scientific review that demonstrates individual ions cause toxicity to aquatic life. This review revealed that in Iowa, chloride and sulfate are the specific ions of concern.

As a result, ion criteria for chloride and sulfate are better indicators than integral parameters such as TDS, conductivity and salinity for water quality protection.

Proposed Sulfate Criteria for Iowa Waters

The results of the following equations provide sulfate water quality standards in mg/L for the specified ranges of hardness (in mg/L as $CaCO_3$) and chloride (in mg/L) and must be met at all times:

- If the hardness concentration of waters is between 100 mg/L and 500 mg/L and if the chloride concentration of waters is between 25 mg/L and 500 mg/L:

  [1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65

- If the hardness concentration of waters is between 100 mg/L and 500 mg/L and if the chloride concentration of waters ranges between 5 mg/L and less than 25 mg/L:

  [-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65

The following sulfate standards must be met at all times when hardness (in mg/L as $CaCO_3$) and chloride (in mg/L) concentrations other than specified are present:

- If the hardness concentration of waters is less than 100 mg/L, or chloride concentration of waters is less than 5 mg/L, the sulfate standard is 500 mg/L.

- If hardness concentration of waters is greater than 500 mg/L, the sulfate standard is 2,000 mg/L.

PROPOSED SULFATE CRITERIA FOR IOWA WATERS

Chloride / Hardness mg/L as $CaCO_3$	Cl- < 5 mg/L	5 ≤ Cl- < 25	25 ≤ Cl- ≤ 500
H < 100 mg/L	500	500	500
100 ≤ H ≤ 500	500	[-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65	[1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65
H > 500	500	2,000	2,000

Total Dissolved Solids is a measure of all constituents, or elements, dissolved in water. This can include inorganic anions (negatively charged ions) like carbonates, chlorides, sulfates and nitrates. The inorganic cations (positively charged ions) include sodium, potassium, calcium and magnesium.

Sulfate is a constituent of TDS and may form salts with sodium, potassium, magnesium and other cations. Sulfate is widely distributed in nature and may be present in natural waters at concentrations ranging from a few to several hundred milligrams per liter.

For more information:

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IMPACT ANALYSIS OF THE PROPOSED STRATEGY FOR HIGH TDS WASTEWATER DISCHARGES ON THE BITUMINOUS COAL MINING INDUSTRY OF PENNSYLVANIA

Prepared for:

COAL

PENNSYLVANIA COAL ASSOCIATION

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September 21, 2009

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EXECUTIVE SUMMARY

CME Engineering LP (CME) was engaged by the Pennsylvania Coal Association (PCA) to assess the impact that the Total Dissolved Solids (TDS) Strategy and subsequent Chapter 95 regulations, as proposed by the Pennsylvania Department of Environmental Protection (PA DEP), would have on the Pennsylvania bituminous coal mining industry. The proposed regulations establish effluent limits for TDS, sulfates, and chlorides which historically had not been set for the coal mining industry. A survey was sent to members of the PCA to determine the number and status of existing discharges, annual production, number of employees, and the timetable of any expansions, major modifications, and/or NPDES permits at their existing and proposed mines. CME also researched available treatment options, public water supply intake data, EPA data, and other studies addressing TDS, sulfates, and chlorides.

PA DEP Data

The statewide TDS Strategy appears to be primarily based on a data set collected from the Monongahela River during a two and a half month period in the fall of 2008 during an exceptionally low flow period. The TDS strategy did not identify sample data for every other river in the Commonwealth. Sampling in the Monongahela River ceased when tests indicated that TDS and sulfates levels were no longer elevated. Inadequate evidence was presented in support of the Strategy that showed elevated levels of TDS and sulfates were present throughout the state, or at other times on the Monongahela River, or that adverse impacts had occurred as a result. PA DEP has reportedly continued monitoring on the Monongahela River at a few locations since the initial data set was collected in 2008.

EPA Secondary Maximum Containment Limits

The U.S. Environmental Protection Agency (EPA) has established maximum contaminant limits (MCLs) for substances in drinking water. Primary MCLs are established based on the hazard potential to human health. Secondary MCLs, or SMCLs, are established for non-hazardous substances. The EPA has established limits on TDS, sulfates, and chlorides as secondary SMCLs. The EPA does not enforce these limits as they are guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. The EPA's limits for TDS, sulfates, and chlorides are 500 mg/l, 250 mg/l, and 250 mg/l, respectively. CME investigated Consumer Confidence Reports and the PA DEP website for public water supplies with intakes on the Monongahela River, Beaver River, and West Branch of the Susquehanna River and found no reports or violations identifying a TDS, sulfates or chlorides problem.

Regulatory Approach

The TDS Strategy and proposed Chapter 95 revisions place "end-of-pipe" discharge limits of 500 mg/l TDS, 250 mg/l sulfates, and 250 mg/l chlorides. According to PA DEP, the proposed Chapter 95 limits were set in response to the elevated TDS levels in the Monongahela River in the fall of 2008 during a period of low flow and the large volume of new Marcellus shale gas well permits submitted to PA DEP by the gas industry. Each Marcellus gas well requires between two and four million gallons of water for fracturing the Marcellus shale. The disposal of the high TDS fracture water into streams with an existing TDS concentration (primarily from abandoned mine drainage) was cause of concern for PA DEP. PA DEP fast-tracked the Chapter

95 revisions with an implementation date of January 2011 for all new discharges and an interim period beginning in April 1, 2009 for any discharges over 2000 mg/l TDS.

The TDS Strategy will have a crippling impact on the coal mining industry. By nature, coal mining requires expanded, additional, and increased discharges throughout the life of the mine, and therefore all active surface and deep mines eventually will be subject to the proposed Chapter 95 rules, if adopted. In addition, mining is a progressive industry constantly requiring new permits to mine new reserves. All new mines will be subject to the proposed regulations.

Treatment Technology Limitations
Currently, the only technology realistically available to reduce TDS, sulfates, and chlorides from mine water to the PA DEP proposed limits is reverse osmosis (RO) in combination with evaporation and crystallization. RO treatment results in a recovery of approximately 75% of incoming wastewater under optimal conditions resulting in 25% of the initial volume of wastewater a concentrated TDS waste stream.[1] A secondary RO system can further condense this waste stream by another 75% leaving only 6.25% of the original volume as a super concentrated waste. The final step in the treatment process is to remove the remaining water from the super concentrated waste from the RO systems in an evaporator and a crystallizer. This process results in a solid waste requiring disposal.

Coal Mining Industry Impact
The surveys CME received from active PCA mining companies accounted for 85% of the 68 million tons of coal produced annually in Pennsylvania. All companies surveyed would have at least one PA DEP defined "new" discharge by January 2011 and all discharges would be classified as "new" within 3-5 years due to permit renewals. Some of the impacts to the coal industry as a result of these proposed regulations are:

- The capital cost to treat the existing wastewaters of only the PCA participating member companies will be in excess of $1,200,000,000 with an annual O&M cost of over $96,000,000; and this is only a fraction of what the cost would be to the entire mining industry. Combine this with the perpetual treatment bonding required by PA DEP and the total exceeds $4,900,000,000. This does not include costs associated with land acquisition, site development, utility extensions, etc. necessary to construct the plants; nor does it include treatment costs at future mine sites.
- There is a potential loss of thousands of coal mining industry jobs if mines close or scale back production as a result of the TDS Strategy. Job losses are a very real outcome of the TDS strategy because Pennsylvania mines will be at an economic disadvantage to neighboring coal producing states that do not have such requirements.
- The energy required to treat the discharges will be 429,000 megawatts per year and the residual solid waste will be generated at a rate of 650 tons per day (237,000 tons annually); and this is only the volume generated by the participating PCA membership for existing discharges.
- Disposal of the solid waste is not addressed in the TDS Strategy. It is uncertain if Pennsylvania's landfills will accept this waste for disposal. The solubility of the RO

[1] Raw water quality from mining operations varies significantly from region to region and seam to seam. Accordingly, the treatment results presented in this report are to be considered approximate.

waste has the potential to concentrate the leachate produced, thereby increasing the leachate treatment cost for the landfill and creating more solid waste that they must address.

- The lead time required to design, construct, and implement a TDS treatment system is 2.5 – 3 years, or 2013 if permitting started immediately.

Evaluation
We believe PA DEP does not have adequate scientific justification for the TDS Strategy and proposed Chapter 95 regulations, and it has not done the required economic analysis to determine the effect the TDS Strategy and proposed regulations would have on the coal mining industry. PCA submitted a written request to PA DEP on August 4, 2009 to provide the scientific data and economic analysis used to formulate the TDS Strategy and proposed regulation. The data received from PA DEP is marginal and does not appear to justify the rationale for the proposed Chapter 95 regulation change. PA DEP should withdraw the proposed revisions to Chapter 95 and proceed with the studies mentioned above. Upon conclusion of the studies, PA DEP should evaluate if Chapter 95 revisions are necessary, and if so, they should work with the regulated community to develop regulations that protect water resources without crippling Pennsylvania's mining industry.

The potential loss of thousands of coal mining jobs at any time, but especially during the current economic down turn, demands further investigation into the TDS issue. PA DEP should step back and collect and evaluate the appropriate data and complete the scientific and economic inquiry necessary to support any action on TDS.

PA DEP should review literature studies and toxicity tests to determine what in-stream parameters should be regulated to protect the aquatic life and stream use and what the appropriate in-stream concentrations should be, before developing Chapter 95 wastewater treatment requirements.

PA DEP should identify and evaluate all technologies available, including alternative and innovative measures for TDS control. PA DEP should identify and evaluate the feasibility of these technologies including availability and installation times, and costs of treating TDS in wastewater streams. This evaluation should also take into consideration procurement, design, testing, permitting, fabrication and construction times associated with each treatment technology, and energy usage, greenhouse gases, and solid residuals resulting from the treatment facility installations.

1.0 INTRODUCTION

The PA DEP introduced the *Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges* dated April 11, 2009 (the "TDS Strategy" - see Appendix A, Page 29) and the subsequently proposed revisions to 25 Pa. Code Chapter 95 in response to a seasonal 2008 event of elevated TDS levels in the Peters Township public water system. Peters Township receives water from PA American Water who has an intake on the Monongahela River. During the fall of 2008, the Monongahela River was experiencing a period of extreme low flow. The TDS Strategy and proposed Chapter 95 revisions set "end-of-pipe" effluent limits of 500 mg/l TDS, 250 mg/l sulfates, and 250 mg/l chlorides. Although this document was billed as a "Strategy", it apparently is being enforced as regulation and the effluent limits set therein are currently being applied to new permits and permit revisions. PA DEP is establishing conditions in the permits that require discharges to be in compliance with the new TDS limits by January 2011.

The Pennsylvania Coal Associated [PCA] engaged CME Engineering LP [CME] to gather and compile data from PCA members in order to assess the impact that the proposed TDS, sulfate, and chloride limits will have on the Pennsylvania bituminous coal mining industry. CME surveyed the PCA members requesting information regarding their annual production, number of employees, current mining permit effluent limits and associated data and the date of future new permits and/or expansions of existing permits.

The key points that CME addresses in this report are:

- description of TDS, sulfates, and chlorides,
- PA DEP regulatory approach,
- summary of proposed 25 Pa. Code, Chapter 95 regulations,
- treatment options, equipment and costs, and associated timeframes,
- membership survey, and
- mining industry impact.

The PCA member companies who participated in this study produce over 85 percent of the bituminous coal mined in Pennsylvania. The Federal Energy Information Administration estimates the Pennsylvania coal reserve at 27 billion tons (see Table 15, Page 26). Pennsylvania is the fourth leading coal producing state, mining 68 million tons in 2008. At that rate of production, Pennsylvania has nearly 400 years of coal reserve. There were a total of 571 active bituminous coal mining permits as of January 2009. In 2007, the coal mining industry employed 7,649 employees (see Table 21, Page 27) for a total of 54,000 direct and indirect jobs and a total payroll in excess of $2.2 billion.[2]

[2] PCA WRAC letter, June 19, 2009

2.0 DESCRIPTION OF TDS, SULFATES & CHLORIDES

The EPA has established maximum contaminant limits (MCLs) for substances in drinking water. Primary MCLs are established based on the hazard potential to human health. Secondary MCLs (or SMCLs) are established for non-hazardous substances. The EPA has established limits on TDS, sulfates, and chlorides as SMCLs. The EPA does not enforce these limits as they are guidelines to assist public water systems in managing their drinking water for aesthetic considerations such as taste, color and odor.

2.1 TDS

EPA defines TDS as all of the dissolved solids in water. Another definition for TDS is the total amount of all inorganic and organic substances – including minerals, salts, metals, cations or anions – that are dispersed within a volume of water. Total dissolved solids are differentiated from total suspended solids (TSS), in that the suspended solids cannot pass through a sieve two micrometers in size, and are indefinitely suspended in solution.

TDS is typically measured by passing a sample of water through a very fine mesh filter to remove suspended solids. The water that has been filtered is then evaporated and the residue represents the dissolved solids.

Sources for TDS include agricultural runoff, urban runoff, industrial wastewater, sewage, and natural sources such as leaves, silt, plankton, and rocks. Piping or plumbing may also release metals into the water. In areas where oil and gas drilling is prevalent, the discharged water and brines from drilling operations and well maintenance can be a major contributor to TDS. Coal mine drainage is also a contributor of TDS within mining regions. Chlorides and sulfates are major constituents of TDS.

A number of studies have been conducted that identify various fish and aquatic life species' reactions due to elevated TDS. **These results must be interpreted cautiously, since true toxicity outcomes relate to specific chemical constituents rather than TDS as a whole. Most aquatic ecosystems involving mixed fish fauna can tolerate TDS levels of 1000 mg/l.**[3]

The Fathead minnow (Pimephales promelas), for example, has an LD50 concentration of 5,600 ppm based upon a 96-hour exposure. LD50 is the concentration required to produce a lethal effect on 50 percent of the exposed population. Daphnia magna, a small planktonic crustacean about five millimeters in length, has an LD50 of about 10,000 ppm TDS for a 96-hour exposure.[4]

While TDS is not considered a primary pollutant, high TDS levels typically indicate hard water and may lead to scale buildup in pipes, reduced efficiency of water filters, hot water heaters, etc., and aesthetic problems such as a bitter or salty taste. EPA recommends treatment when TDS

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[3] Boyd, Claude E. (1999). Water Quality: An Introduction. The Netherlands: Kluwer Academic Publishers Group. ISBN 0-7923-7853-9.)

[4] Position Paper on Total Dissolved Solids, State of Iowa, IAC 567 61.3 (2)g et sequitur updated March 27, 2003

concentrations exceed 500 mg/l. The TDS concentration is considered a Secondary Drinking Water Standard, which means that it is not a health hazard.[5]

EPA has set MCLs for substances in drinking water. Primary MCLs are established based on hazard to human health. Secondary MCLs or SMCLs are established for non-hazardous substances. The EPA has established limits on TDS and sulfate as SMCLs. The following is from the EPA publication "Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals, EPA 810/K-92-001, July 1992" (*emphasis added*).

> The U.S. Environmental Protection Agency (EPA) has established National Primary Drinking Water Regulations that set mandatory water quality standards for drinking water contaminants. These are enforceable standards called "maximum contaminant levels" or "MCLs", which are established to protect the public against consumption of drinking water contaminants that present a risk to human health. An MCL is the maximum allowable amount of a contaminant in drinking water which is delivered to the consumer.
>
> In addition, EPA has established National Secondary Drinking Water Regulations that set *non-mandatory* water quality standards for 15 contaminants. *EPA does not enforce these* "secondary maximum contaminant levels" or "SMCLs." *They are established only as guidelines* to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor. *These contaminants are not considered to present a risk to human health at the SMCL.*

2.2 Sulfate

Sulfate is a substance that occurs naturally in drinking water. It is an ionic compound composed of sulfur and oxygen with the chemical formula SO_4^{2-}. When naturally occurring, it is often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals, or of atmospheric deposition from the burning of fossil fuels and from volcanic eruptions. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills. Runoff from fertilized agricultural lands also contributes sulfates to water bodies. Oil and gas drilling brines contain sulfates. Coal mine discharges may also contain high concentrations of sulfate.

Health concerns regarding sulfates in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfates. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfates when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.

The EPA currently has an SMCL of 250 mg/l for sulfates in drinking water, based on aesthetic effects (i.e., taste and odor). This regulation is not a federally-enforceable standard, but is provided as a guideline for states and public water systems. EPA estimates that about 3% of the

[5] Total Dissolved Solids (TDS)", Wellcare report, January 2007, Water Systems Council, Washington DC, developed under USEPA Assistance Agreement X-83256101-0

public drinking water systems in the country may have sulfate levels of 250 mg/l or greater. As a reference, the maximum limit for sulfates in Canada has been set at 500 mg/l (see Appendix B, Page 40).

In the 1996 amendments to the Safe Drinking Water Act, Congress mandated that the EPA determine, by August 2001, whether to regulate sulfates in drinking water. If EPA decided to regulate sulfates, the agency must propose the MCL by August 2003 and issue a final standard by February 2005. Congress also directed EPA to conduct a study with the Centers for Disease Control and Prevention (CDC) to establish a reliable dose-response relationship for health effects from exposure to sulfate and to examine effects in sensitive subpopulations (infants and transients). The directive indicated that the study must "be based on the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices," "be conducted in consultation with interested States," and be completed by February 1999.

EPA and CDC completed this study, *Health Effects from Exposure to High Levels of Sulfate in Drinking Water Study* ("Sulfate Study") in January, 1999. The overall purpose of this study was to examine the association between consumption of tap water containing high levels of sulfate and reports of osmotic diarrhea in susceptible populations (infants and transients). Specifically, CDC researchers designed field investigations of infants naturally exposed to high levels of sulfate in the drinking water provided by public water systems and an experimental trial of exposure in adults.

As a supplement to the Sulfate Study and literature review, CDC, in coordination with EPA, convened an expert workshop ("Sulfate Workshop"), open to the public, in Atlanta, Georgia on September 28, 1998. The expert scientists reviewed the available literature and the Sulfate Study results, and provided their opinions in response to a series of questions about the health effects from exposure to sulfates in drinking water.

These joint studies conducted by EPA and CDC found that there was no statistically significant association between the concentration of sulfate in the drinking water and the frequency of diarrhea.[6]

In *Health Effects from Exposure to Sulfate in Drinking Water Workshop EPA 815-R-99-002 January 1999*, a panel of scientists was asked: Is there enough scientific evidence that there are adverse health effects from sulfates in drinking water to support regulation? [Congress directed EPA to use the best available science to set drinking water goals and regulations.] Their conclusion was there was not enough scientific evidence on which to base a regulation, but panelists favored a health advisory in places where drinking water has sulfate levels over 500 mg/l.

PA Code Ch. 93 Water Quality Standards has set limits based on the critical use of the water. Where the critical use is drinking water, the limits are 250 mg/l for sulfates, and 500 mg/l for TDS *as a monthly average* and 750 mg/l maximum. Where the critical use is aquatic life, the TDS limit is 1,500 mg/l.

[6]Health Effects from Exposure to High Levels of Sulfate in Drinking Water Study, EPA 815-R-99-001 January 1999

2.3 Chloride

Chloride is another substance that occurs naturally in both surface water and ground water. Chloride is the ionic form of the element chlorine when dissolved in water, occurring as the ion Cl^-. The most common source of chlorides in water is dissolution of salt (sodium chloride, NaCl). Natural sources of chlorides are primarily weathering of salts from rock and soil, and brines that reach the surface in some locations. These salt springs or "salt licks" occurred naturally in Pennsylvania and some surrounding states, but have diminished due to oil and gas development. In addition to natural sources there are a number of man-made sources of chlorides including highway runoff containing road salt, disposal of brines and drilling fluids produced in oil and gas drilling, agricultural runoff, effluent from municipal waste water treatment plants, and industrial waste water disposal.

EPA has set an SMCL for chloride at 250 mg/l. Criteria for protection of aquatic life require levels of less than 600 mg/l for chronic (long-term) exposure and 1,200 mg/l for short-term exposure. The LD_{50} exposure limits for specific species are reported below (all concentrations in mg/l):

Chloride Concentration (mg/l)

Short Term Exposure	Long Term Exposure	Species
2,540	400	Snail
6,570	430	Fathead minnow
6,740	900	Rainbow trout
8,000	800	Channel catfish
8,390	850	Carp

3.0 SUMMARY OF PROPOSED 25 PA. CODE, CHAPTER 95 REGULATIONS

The proposed 25 Pa. Code Chapter 95 regulations define milestone dates of compliance. The first date was April 1, 2009. All permitted discharges before that date are considered an "existing discharge" and are not subject to the new regulations. Any new discharge permitted between April 1, 2009 and January 1, 2011 will be considered an "interim discharge" and will be subject to the proposed TDS Strategy. An interim discharge will have a threshold trigger of 2000 mg/l TDS or 100,000 lbs TDS/day loading. If the discharge stays below this limit, the discharge will not be subject to the proposed Chapter 95 effluent limits of TDS 500 mg/l, sulfates 250 mg/l, and chlorides 250 mg/l. If the interim discharge is over 2000 mg/l it will be subject to the proposed limits. Any "new discharge" permitted after January 1, 2011 will be subject to the proposed Chapter 95 effluent limits and will not be able to use the interim 2000 mg/l TDS threshold. All new discharges permitted after April 1, 2009 will require a non-discharge alternative analysis.

The proposed Chapter 95 definition of "new discharge" set forth in Section 95.10(a) is:

> "*shall include, an additional discharge, an expanded discharge, and an increased discharge from a facility in existence prior to April 1, 2009.*"

This definition does not protect existing mines from having to comply with the new effluent limits because additional, expanded, and increased discharges are common at surface and underground mines during the active life of the mine. The proposed regulations will affect every mine site either through permit modification, permit renewal, or new applications which operators submit every year. Also the TDS Strategy and the proposed Chapter 95 revision do not address how DEP will handle sites with multiple discharges.

Mining permit applications are received by the DEP-Bureau of Mining and Reclamation (DEP-BMR). One of many criteria evaluated by DEP-BMR is the anticipated post-mining water quality from the mine. DEP-BMR will not issue a permit if the anticipated post-mining water quality will not meet effluent criteria; historically defined as acid mine drainage (AMD). DEP-BMR and the scientific community have established scientific methodology to help predict the potential for a mine to produce AMD. However, as stated in the TDS Strategy (Appendix A, Page 29), DEP admits:

> "*It is not possible to predict what the concentrations of TDS, sulfates, and chlorides will be in mine water.*"

Post-mining discharges that do not qualify as AMD but contain sulfate limits in excess of 250 mg/l are common. This situation obviously presents a permitting problem for both DEP-BMR and mining permit applicants. PA DEP admits the science does not exist to predict the post-mining concentrations of TDS, sulfates, and chlorides in mine water yet mining permit applicants must demonstrate to PA DEP that post-mining discharges will meet effluent limits.

4.0 <u>PA DEP REGULATORY APPROACH</u>

The TDS Strategy (Appendix A, Page 29 – Statement of the Problem), was written primarily for the oil and gas industry's Marcellus extraction. It states:

> *"Development of gas wells in the Marcellus play requires the use of large volumes of water for hydraulic fracturing operations. This hydraulic fracturing has the potential to generate a considerable amount of waste water, both initial flow back water from fracturing and longer term production brines."*

It goes on to state:

> *"Brine and fracturing wastewater have high concentrations of dissolved solids, and considering the already elevated levels of dissolved solids in the acid mine drainage affected surface waters, the need to stringently control these dissolved solids likely will prevent other pollutants from exceeding water quality standards on a cumulative basis."*

Then (Page 4 – Permitting Strategy) it states:

> *"The Department's interim strategy over the next two years for permitting discharges of new sources of High-TDS wastewaters will focus on those new sources that have the greatest potential to adversely affect the quality of Pennsylvania's receiving streams. Currently, those sources are wastewaters generated from fracturing and production of oil and gas wells in the Marcellus Shale Formation."*

The Department's effort to enact regulations quickly to control discharges of brine from the Marcellus play also impacts all other Pennsylvania industries. PA DEP did not allow enough time to thoroughly research the statewide in-stream concentrations of TDS, sulfates, and chlorides; the high cost of treating wastewaters to reach the proposed limits; the power requirements necessary to achieve the proposed limits; the lead time required to begin treatment; the economic impact from the loss of jobs; and the problems of disposing the residual waste.

4.1 <u>PA DEP Data</u>

As a result of the proposed Chapter 95 regulatory package, on August 4, 2009 the PCA sent PA DEP Secretary John Hanger a letter requesting the support data and information used by PA DEP in the development of the proposed amendments to Chapter 95. Secretary Hanger responded on September 3, 2009. (A copy of this letter and the PA DEP response is provided in Appendix C, Page 44: PCA Data Request).

CME, in conjunction with the PCA Technical Committee, analysis of this information indicates a number of issues with the PA DEP's response. In response to the PCA question regarding which streams and waterways in bituminous coal areas were "at risk" for sustained elevated concentrations of TDS, sulfates and chlorides from July 1, 2008 through April 2009, PA DEP indicated there were 36 active water quality networks in those areas during the time period requested, and 28 were considered "at risk" and 8 were not. (See Appendix C, Page 44). The 8 not-at-risk "reference" sites include the following locations and threshold sample values:

- Kettle Creek, Clinton County (HQ-TSF)
- Mill Run, Fayette County (HQ-CWF)
- Mill Creek, Westmoreland County (EV, HQ-CWF, CWF)
- Youghiogheny River, Somerset County (CWF)
- Killbuck Run, Cambria County (CWF)
- Tionesta Creek, Forest County (HQ-CWF, CWF)
- Havens Run, McKean County (CWF)
- First Fork Sinnemahoning Creek, Potter County (HQ-CWF)

    - specific conductivity < 132 µmho/cm
    - sulfates <20 mg/l
    - chlorides < 9mg/l
    - TDS <96 mg/l

It is important to note that the Chapter 93 classification of these 8 streams identify these waters as EV: Exceptional Value, HQ-TSF: High Quality Waters-Trout Stocking, HQ-CWF: High Quality Waters-Cold Water Fishes and CWF: Cold Water Fishes. Accordingly, these are some of the best water quality streams in Pennsylvania.

PA DEP also indicated the at-risk sites were chosen because one or more of the chlorides, sulfates or TDS values were magnitudes higher than the values at the reference sites, but don't seem to signify any impairment of water quality to an active site. PA DEP gives no explanation as to why the threshold concentrations are significantly lower than the proposed Chapter 95 limits thereby prompting belief that they were arbitrarily chosen.

An evaluation was conducted to determine the mean chloride, sulfates and TDS concentrations data provided by PA DEP for the 28 at risk sites. Of the 28 at risk sites identified by PA DEP, only 6 of those had TDS and/or sulfate concentrations that exceeded the proposed limits. In addition, **none** of the water quality sampling data provided by PA DEP in response to question 1 shows a chloride concentration greater than 250 mg/l.

Assuming that PA DEP's response included all their sampling data, the spreadsheets in Appendix C, Page 44 shows that sampling for the 36 sites was not conducted on a regular basis and PA DEP confirmed that the sampling conducted from October to December 2008 actually ceased in December 2008, so data requested by PCA regarding public water supply intakes on the Monongahela River were not available through April 2009. If no public water supply intake data is available, it calls into question how PA DEP knows whether public water exceeded the TDS, sulfates and chlorides secondary maximum contaminant level.

According to PA DEP, it was this incomplete data set on which they relied that prompted their April 16, 2009 press release and the proposed Chapter 95 limits for TDS, sulfates and chlorides.

In addition, Page 2 of the Preamble to Chapter 95 states that elevated chloride levels were observed on the South Fork Tenmile Creek. PA DEP conducted biological surveys on Tenmile Creek and Dunkard Creek during the same exceptionally dry, low flow period in fall of 2008. In both cases, water chemistry was sampled only once. South Fork Tenmile Creek was sampled on November 11, 2008, and Dunkard Creek was sampled on October 21, 2008. Conclusions were based on this single set of samples.

Page 3 of the Preamble lists the Beaver, Shenango, Neshannock, Moshannon and West Branch of the Susquehanna Rivers as having "upward trends in TDS concentrations" and being "severely limited in the capacity to assimilate new loads of TDS and sulfates". Data supplied in response to PCA's request reveals TDS and sulfates levels on the Beaver, Shenango and West Branch of the Susquehanna Rivers significantly below the proposed 500 mg/l and 250 mg/l, respectively. No data was provided for the Neshannock or Moshannon rivers.

PCA requested that PA DEP identify the sampling methodology used to determine TDS concentrations and why that methodology was chosen. PA DEP indicated that USGS-1-1749 was the methodology used to determine TDS concentrations. This methodology requires the water sample to be dried at 105°C. Pursuant to 40 CFR Part 136 and 40 CFR Part 143.3(b), the following are the only EPA-approved methods for determining TDS concentrations:

- Standard Method 2540 C
- USGS Method I-1750-85

These sampling methods require the water sample to be dried at 180°C. In addition, the PA DEP laboratory accreditation bureau does not consider the lower temperature test method acceptable.

PCA requested all information and support data that PA DEP used in setting the proposed limits for TDS, sulfates and chlorides. Section 5 of The Clean Streams Law (35 P.S.§691.5) requires PA DEP perform an economic analysis when setting new standards. PCA received no economic analysis as part of PA DEP's response.

4.2 Additional Data Analysis

CME researched public water supply violations through the PA DEP website to determine if any violations were reported for TDS, sulfates, or chlorides. The Monongahela River has numerous public water treatment facilities and no violations were reported. The water systems withdrawing water from the West Branch of the Susquehanna were also examined for violations. No violations or problems associated with TDS, sulfates, or chlorides were reported.

Every water system in the Commonwealth of Pennsylvania is required to submit a Consumer Confidence Report to its customers. The Consumer Confidence Reports for 2008 were examined for the water systems utilizing the Monongahela River. There was no mention in the reviewed reports of TDS, sulfates, or chlorides violations or problems. A copy of a Consumer Confidence Report for one of the larger water suppliers on the Monongahela River is included in Appendix D, Page 76. PA DEP reports to the EPA on numerous water quality parameters from the lower Monongahela River. The data for sulfates and chlorides was collected from the EPA website STORET for the past 10 years at the South PGH MP 4.5 monitoring station and at no time did either rise above 180 mg/l (see Graph 1, Page 28).

PA DEP also produced a study in February 2009 titled, "*Aquatic Survey of Lower Dunkard Creek, Greene County, October – November 2008*". In this study PA DEP investigated the effects of a high TDS and sulfate discharge on the stream. The TDS threshold for impairment to fish was reported to be in the range of 2,000 to 2,300 mg/l. Upstream from the discharge the investigation found "very large numbers of fish" in water with measured sulfates of 570 mg/l and TDS of 1,182 mg/l, both more than double the proposed effluent limits. The study found that impairment occurred at a point where the discharge entered the stream and in-stream measured water quality reached a sulfate level of over 6,000 mg/l and TDS level over 9,000 mg/l. This study was based on only one round of sampling during a period of extremely low flow in the stream, and when the mine discharge contributed a major portion of the total stream flow. Continued study with both biological and water quality sampling conducted periodically throughout the year, and at a range of flow conditions, would be necessary to evaluate the true impact to the stream's aquatic system.

A number of researchers have also conducted studies into the toxicity of TDS on aquatic organisms. One study cited found no significant effects on salmonid species up to 2,000 mg/l, while midge larvae were affected above 1,100 mg/l.[7] In another study, TDS LD_{50} (96-hour exposure) for fathead minnows was found to be 5,600 mg/l.[8]

The following table is presented as a general compilation of available research regarding TDS toxicity limits:

Compilation of reported TDS Limits for Aquatic and Animal Life

Species	**Concentration (mg/l)**	**Limit Type**
Daphnia magna	9,500-11,500	96-hr LC_{50}
Hyalella azteca	11,500	96-hr LC_{50}
Bigmouth and black Buffalo (emerging fry)	9,000	Upper tolerance limit
Channel catfish	14,000	Upper tolerance limit
Black bullhead	8,000	Median toxicity threshold
	10,000	Probable lethal limit
Yellow perch	11,500	No adverse effects
Fathead minnow	6,000-7,000	Acute lethal
	5,300-5,900	96-hr LC_{50}
Green Sunfish	10,700	Median toxicity threshold
	20,000	Lethal
Bluegill	11,900	Lethal limit
Golden Shiner	5,600	Upper tolerance limit
Common Carp	12,000	No observed effect
	18,500-19,000	Upper tolerance limit
Beef cattle	10,000	Safe upper limit

[7] Weber-Scannell et. al. 2007, "Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species", American Journal of Environmental Sciences 3 (1): 1-6
[8] Position Paper on Total Dissolved Solids, State of Iowa, IAC 567 61.3 (2)g et sequitur updated March 27, 2003

Dairy cattle	7,150	Safe upper limit
Poultry	2,860	Safe upper limit

From these limits it is clear that the concentrations measured in the Monongahela River and other rivers in Pennsylvania are not approaching levels of concern for aquatic life or agricultural use. The proposed TDS effluent limit of 500 mg/l is much more restrictive than necessary to prevent further impacts.

The West Virginia University's West Virginia Water Research Institute (WVWRI) has collected and analyzed data from the Monongahela River over a period of years. The Institute has produced presentations on the subject of TDS and sulfate concentrations in the river, including two produced in 2009 titled *TDS from Mines and Wells, WVWRI Project 119: Mon River Water Quality Monitoring and Presentation*; and *Background: TDS in the Monongahela River.*

WVWRI monitored the Monongahela River at Point Marion, PA during the period between 1999 to 2006. During this time period, the data from this monitoring location showed declining trends in chlorides, sulfates and TDS concentrations, with the most dramatic decline being in sulfate concentrations. Average chloride concentration was seen to decline at a rate of 0.1 mg/l/yr, while average sulfate concentrations decreased at a rate of 5 mg/l/year. This is an observed decline of about 50 mg/l in the 10 year period of the study. Average TDS was seen to be decreasing at a rate of 6.2 mg/l/year, a decrease of over 60 mg/l over 10 years. This was based on 34 samples collected over a period of nearly 8 years, from March 1999 to December 2006. The lowest flow measured was 555 cfs (250,000 gpm). No sulfate concentration was found to be over the SMCL of 250 mg/l in any of the samples. Only one sample had TDS over the 500 mg/l SMCL, and this occurred at the lowest flow.

The following table compares the results of the longer WVWRI study with the data collected from Point Marion in the shorter PA DEP study of 2008.

Comparison of Data – Monongahela River at Point Marion, PA						
	Number of samples analyzed	Mean Concentration (mg/l)	Median Concentration (mg/l)	Minimum Concentration (mg/l)	Maximum Concentration (mg/l)	Number of Samples Exceeding SMCL
WVU Study 1999 - 2006						
Sulfate	34	98	84	38	230	0
TDS	33	322	297	209	558	1
Chloride	34	9	10	4	17	0
DEP Study Oct.-Dec. 2008						
Sulfate	10	169	198	40	269	2
TDS	11	388	466	112	570	3
Chloride	11	16	16	6	31	0

The WVWRI also monitored the Monongahela River at Elizabeth, PA from 2003 to 2008. These results showed that when flow in the river was less than 2,000 cfs (897,660 gpm), approximately 1/3 of the samples exceeded the SMCL of 500 mg/l TDS, with an overall range of 200-900 mg/l. The average TDS concentration remained below 500 mg/l down to a flow of approximately 600 cfs (269,298 gpm). When flow was greater than 2,000 cfs (897,660 gpm), exceedance of the SMCL was rare, and at flows beyond 6,000 cfs (2,692,980 gpm) only one exceedance event was identified. Between flows of 300-5,000 cfs (134,649-2,244,150 gpm), the average TDS declined from 500 mg/l down to 250 mg/l. Above 5,000 cfs (2,244,150 gpm), the average TDS leveled out at 200 mg/l with exceedance events becoming rarer with increasing flow. This is evidence of assimilative capacity which PA DEP apparently discounted based on their limited low-flow data set. During the last two weeks of the PA DEP data set, flows had increased and levels of TDS and sulfates had returned to normal levels, at which point sampling and data collection ended. Historical USGS discharge data for the Monongahela River indicates that flow is lower than 2,000 cfs (897,660 gpm) approximately 20 percent of the time. This means that 80% of the time the river has adequate assimilative capacity to accept both existing and additional loads without exceeding SMCLs.

The treatment options to reduce wastewater TDS concentrations to the levels in the TDS Strategy are limited and the capital and O&M costs are high. PA DEP has stated in a recently released document (Proposed Notice of Proposed Rulemaking, Department of Environmental Protection, Environmental Quality Board, 25 Pa. Code Chapter 95, Wastewater Treatment Requirements, included in Environmental Quality Board Agenda for the August 18, 2009 meeting) that:

> *"The regulation will impose new costs on new or increased discharges of high TDS wastewater. New or increased discharges will be required to install advanced treatment to meet the requirements of this proposed rulemaking. It is anticipated that treatment costs could be on the order of $0.25/gallon. Since*

there is currently no treatment required for TDS, chlorides, and sulfates, any cost is an increase over the existing cost."

It is not clear if this estimate is based solely on operational cost or if it includes capital costs for construction and bonding. If not, then the cost would be substantially higher. While a quarter per gallon does not sound like an unreasonable amount, when put in perspective of the volumes of water that would need to be treated at typical mining operations, the real costs become evident. A $0.25/gallon increase for a 1000 gpm discharge would cost a mining facility $131,400,000 per year. It's not uncommon for a mining facility to have a discharge, or combined discharges, greater than 1000 gpm.

The same document goes on to state:

"Existing facilities will have minimal additional costs as a result of this proposed rulemaking. The additional costs will be the result of additional monitoring and recordkeeping that will be required to comply with this rulemaking."

It is apparent that PA DEP does not have a clear understanding of the life cycle of a coal mine and that the process of mining coal will trigger the discharges to be considered "new discharges." Mining is not like an industrial plant; new mine permit applications are submitted daily. These new permits will be subject to these regulations.

Unilateral regulatory actions like the TDS Strategy that raise the cost of mining in PA creates a competitive imbalance for the state's coal operators when competing for contracts with operators in adjacent coal producing states in which similar requirements are not in place.

5.0 TREATMENT OPTIONS

Treatment options depend on both the concentration of TDS and the nature of the cations and anions present in the water. For example, a water softener can reduce problems associated with calcium, magnesium, and iron. However, a reverse osmosis system operated with an evaporation/distillation unit is needed to treat elevated TDS levels associated with high levels of sodium or potassium. In addition, this treatment process produces a concentrated waste stream that requires proper disposal. The most common treatments for TDS are electrodialysis and reverse osmosis.

5.1 Treatment Technologies

CME conducted research of available technologies potentially capable of treating mine water to the proposed Chapter 95 limits; summaries describing the available treatment methods are listed below.

Electrodialysis deionizes water using an electric current to separate ions by their electric charge, while controlling the movement of TDS using selectively permeable membranes that are also electrically conductive. It can be effective for removing specific contaminants; however, electrodialysis is not suitable for high levels of iron and other metals. Distillation or freezing may also be used for areas with higher TDS concentrations. Ion exchange is another option, but is not as effective for treating concentrations lower than 3,000 mg/l.[9]

Electrodialysis is generally more expensive than reverse osmosis at volumes greater then 1000 gpm. Electrodialysis is typically used in arid settings where the supply volume is limited and a high water recovery rate is necessary. Electrodialysis also has problems with membrane fouling in waters with high calcium, magnesium, suspended solids and silicon. It is not effective at removing non-polarized ions and molecules.[10] Therefore, electrodialysis is not suited for treatment of mine wastewaters in Pennsylvania.

Precipitation is one potential option for treating discharges with high sulfate concentrations by removing the sulfate by precipitating it as gypsum. In this treatment method, first the pH is raised and the water is aerated to oxidize and remove metals, as in traditional mine drainage treatment. The pH is then raised further and excess calcium is added, to bring the water into the range where the water is supersaturated for gypsum. The gypsum then precipitates as a solid, removing sulfates from the water. The pH is then adjusted to lower it into the acceptable range for discharge.

This process is able to bring waters with very high sulfate content down to within the range of 2000-3000 mg/l, but it is unable to lower the concentration to the proposed effluent limit of 250 mg/l.

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[9] Water Systems Council, Wellcare® Information on Total Dissolved Solids, January 2007.

[10] GE Water and Process Technologies, 2005, Technical Paper "Half a Century of Desalination with Electrodialysis", TP1038EN0603

Reverse osmosis (RO) is a process where pressure is used to force a solution through a membrane in order to separate the solute from the solvent. RO is an effective treatment process for TDS with concentrations less than 40,000 mg/l. The membranes have pore openings as small as 0.0006 microns and have been documented to remove up to 98% of dissolved or suspended particles. Membranes are usually formed from hollow fibers or thin film composite sheets with the membrane allowing passage of pure water and rejecting the dissolved solids contained in the water. Treatment systems are pre-packaged and consist of a pre-treatment filtration unit, high-pressure pump and membrane assembly. Under optimal conditions, approximately 75% of the solution is recovered resulting in 25% waste concentrate. This process is currently used for drinking water purification, in the food and pharmaceutical industries, and maple syrup production among others. Depending on raw water quality, mine wastewater would have 40-70% recovered solution resulting in 30-60% waste concentrate.

As water is passed along the membrane surface, the solids concentration increases to a point where it exceeds the solubility resulting in precipitation of the solid onto the membrane. The process of solids formation on the membrane is called "scaling." Scaling is most susceptible when treating water with a wide variety of removable parameters. Membrane scaling is a result of organics, silica, and calcium compounds. Once scaling occurs, the pore openings in the membrane become restricted causing pressure to increase in the unit resulting in damaged membranes and mechanical failures of the units. To reduce the risk of scaling of the membranes, pre-treatment filtration is required. Anti-scaling agents are used to prevent membrane scaling, but add additional cost to the treatment.

RO pre-treatment using micro-filtration units does not completely remove all suspended solids in the water. Pre-treatment for settle-able metals (ie. iron, aluminum, manganese, magnesium, etc.) is vital to the proper operation of an RO system. Metals removal using pH adjustment, oxidation, and clarification is still required as pre-treatment for an RO system as precipitated iron. Other metals are membrane foulants that adversely affect the performance of many anti-scalants. It is anticipated that pretreatment will be required for the coal mining industry.

5.2 Equipment and Costs

AquaTech, a worldwide manufacturer of industrial and wastewater treatment equipment, has packaged RO systems with feed rates ranging from 16 GPM to 500 GPM for single systems (LRL series) and up to 700 GPM for a duplex system (XL series). For flows greater than 700 GPM, multiple units can be installed in parallel.

Equipment prices were obtained from AquaTech for a 16 GPM single unit. This system includes an LFM series multi-media filtration unit with a capacity of 90 GPM, a single RO unit with an inflow of 16 GPM generating 4 GPM of concentrate, and a secondary RO unit for additional waste stream treatment resulting in 1-2 GPM of waste concentrate (based upon dissolved solids concentration). The total design, permitting, equipment, and construction cost for this small system is $390,100 and is detailed as follows:

- Design $25,000
- Permitting $17,500

- Equipment $180,000
- Construction $120,000
- Contingency (15%) $47,600
- Total Project Cost $390,100

The above cost includes $85,000 for construction of a building to house the treatment unit.

The operation and maintenance (O&M) cost for yearly operation of the facility is detailed as follows:

- On-site operation and labor $582,000
- Chemical Costs $25,000
- Energy costs (49,012 kW/hr) $4,901
- Total Annual O&M Cost $611,901

The energy costs are based upon a kW-hr rate of $0.10.

A 16 GPM unit produces 12 GPM water and 4 GPM of waste concentrate. Further treatment of the concentrate results in a waste of 1-2 GPM which requires either additional treatment through evaporation/crystallization or disposal at an approved facility. The costs detailed previously do not include further treatment of the final concentrate.

Equipment prices were also obtained from AquaTech for a 500 GPM single unit with a 2000 mg/l TDS concentration. This system includes two LFM series multi-media filtration units in parallel with a capacity of 270 GPM per unit, a duplex RO unit with a total inflow capacity of 500 GPM generating 120 GPM of concentrate, and a secondary RO unit for additional waste stream treatment resulting in 30-45 GPM of waste concentrate (based upon dissolved solids concentration). The total design, permitting, equipment, and construction cost for this system is $4,140,000 and is detailed as follows:

- Design $250,000
- Permitting $100,000
- Equipment $2,000,000
- Construction $1,250,000
- Contingency (15%) $540,000
- Total Project Cost $4,140,000

The above cost includes $150,000 for construction of a building to house the treatment unit. However, it does not include the cost of a conventional system to remove solids.

The operation and maintenance (O&M) cost for yearly operation of the facility is detailed as follows:

- On-site operation and labor $728,000
- Chemical Costs $250,000
- Energy costs (849,544 kW/hr/yr) $84,954

- Total Annual O&M Cost $1,062,954

The energy costs are based upon a kW-hr rate of $0.10.

RO treatment, if economically feasible, contains one major disadvantage - it creates a liquid super concentrated waste stream. This waste must be processed. Methods to process and dispose of this waste are described below.

Evaporation involves converting the RO waste into a more concentrated form. Evaporation produces 50% water and 50% waste. Assuming 100 GPM is treated using a series of two RO systems, the waste generated by the RO is 6.25 GPM. Evaporation may reduce this number to 3.13 GPM. Evaporation in Pennsylvania, due to the precipitation and humidity, can only be accomplished by forced evaporation (i.e. applying heat to generate steam). This requires significant energy. Following the evaporation process, the remaining super-concentrated liquid must be crystallized to produce a dry, solid waste.

Crystallization involves transforming the concentrate produced by evaporation into a solid form. Crystallization, like RO, separates the dissolved solids from the solution such that a crystal is formed. For maximum effectiveness of a crystallizer, the concentrate must have high TDS concentration (greater than 200,000 mg/l). Once formed, the issue is solids disposal. It is anticipated that few landfills in Pennsylvania will be willing to accept such material considering the proposed Chapter 95 regulations affect discharges from their facilities. If disposal is available, estimates for disposal of the solid waste generated by RO, evaporation, and crystallization, ranges from $56 to $85 per ton, excluding transportation costs.

As stated previously, the project cost of a 500 GPM RO treatment plant is $4,140,000. The waste stream generated by the system described previously is 30-45 GPM. AquaTech manufactures a crystallization unit with a capacity of 60 GPM. The cost to construct a 60 GPM crystallization unit is $20,700,000, not including RO treatment, as follows:

- Design $1,000,000
- Permitting $500,000
- Equipment $12,000,000
- Construction $4,500,000
- Contingency (15%) $2,700,000
- Total Project Cost $20,700,000

The operation and maintenance (O&M) cost for yearly operation of the facility is detailed as follows:

- On-site operation and labor $1,248,000
- Chemical Costs $300,000
- Energy costs (7,188,456 kW/hr) $718,846
- Total Annual O&M Cost $2,266,846

The energy costs are based upon a kW-hr rate of $0.10.

The projected total capital cost of an RO system, evaporator and crystallization for a 500 gpm discharge is $24,840,000.[11] The projected overall annual operating cost for this system is $2,601,800.[12]

5.3 Timeframes

The time to design, permit and construct a system capable of meeting the proposed regulations is extensive. Most mining facilities have several discharge points with varying raw water quality. Each mine will have to be evaluated and a feasibility study performed to determine the most cost effective method(s) for handling and treating the mine waters. Following this feasibility study, system design, site layout and permitting will be necessary. Finally, equipment must be ordered and construction commenced. Estimated timeframes for these tasks are presented below:

Feasibility study .... 6 months
Design .... 6 months
Permitting .... 12 months
- Land Development
- Zoning Permits (dependence on site location)
- Sewage Facilities Planning Modules and Approvals
- NPDES Permit
- Water Quality Management Permit

Equipment Acquisition & Construction .... 18-24 months
- RO System
- Evaporator
- Crystallizer

Total .... 2.5–3 years

Few technologies are available to reduce TDS to the limits established in the proposed Chapter 95 regulations. Reverse osmosis, combined with evaporation and crystallization, is the technology most suited for this process. However, the significant capital costs associated with the construction, coupled with required increased energy demand and limited disposal options for the significant increase in waste makes these treatments for TDS questionable, not only from a financial standpoint, but also with respect to the overall goal of a greener Commonwealth.

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[11] This cost is only for the treatment system. It does not include costs associated with land acquisition, site development, power and other utility extensions, etc. These costs are also significant.

[12] The annual O&M costs include an anticipated reduction in labor expense because one workforce could operate both the RO and evaporation/crystallization systems.

6.0 MEMBERSHIP SURVEY

CME conducted a survey of the PCA membership to forecast the potential effects of the proposed regulations on the mine operators. CME received results from a group of producers that accounted for 57.8 million tons of coal in 2008. Compared to the 68.1 million total tons produced in 2008, this group produces for 84.7 percent of the 2008 total Pennsylvania coal production. The group also employs a work force of 5,816 persons.

Summary information of the PCA members participating in this survey is provided below:

- 84.7 percent of Pennsylvania 2008 total coal production.
- 57.1 million tons produced in 2008
- 5,816 employees in 2008

PCA members were also surveyed as to the need for future permit revisions, expansion, and/or new permits. The results of the survey show that 100% of the participating members indicated a need for an expansion, major modification or new NPDES permit by or before 2011. Since it is common practice for mining activity to require additional, expanded or increased discharges the proposed regulations target of "new discharges", as it applies to the mining industry, is essentially every discharge within the five-year life of the permit and every new mining permit.

7.0 MINING INDUSTRY IMPACT

CME reviewed the returned surveys with regard to new permits, expansions, major modifications, and NPDES permits. The review concluded that all existing coal mine discharges would be considered a "new discharge" under the proposed regulation within 3 to 5 years and would have to comply with the PA DEP proposed effluent limits for TDS, sulfates, and chlorides. All of the mining companies surveyed would have at least one discharge that would be required to comply by January 2011, and all new mines would have to comply with the proposed regulations.

Two coal mining companies surveyed supplied CME with calculations of the cost of RO treatment systems. Through an RO manufacturer, CME independently calculated the capital and O&M cost of a 500 gpm system. The three estimates were then averaged to arrive at an estimated cost. The estimated cost to the mining industry to construct the equipment necessary to meet the proposed limits will equal approximately **$46,000 per gpm**. The O&M estimated cost will equal approximately $3,600 per gpm. Based on a review of mining company monitoring reports, CME estimates the average discharge flow from just the PCA member companies participating in the survey is 26,725 gpm.[13] Treating the 26,725 gpm will cost just the PCA participating member companies in excess of $1,200,000,000 to construct and $96,000,000 per year to operate treatment systems to comply with the proposed regulations.

A coal company with 3,000 gpm total combined flow using the estimated gpm cost increase listed above would realize a treatment cost increase of $138,000,000 to construct and $10,800,000 per year to operate. The capital cost divided over 20 years would equal $6,900,000 for a total annual cost increase of $17,700,000. These costs do not include interest or inflation. If the coal company has an annual coal production of 1,000,000 tons, it will realize a cost increase of $17.70 per ton of coal produced. The bond required for a 500 gpm RO system with a crystallizer is $134,400,000 (See Appendix E, Pages 81 & 82). If the coal company in the example above would be required to perpetually treat their discharges, they would need 6 systems with a total bond of $806,000,000.

The capital and O&M cost to the participating PCA member companies over the next 20 years to treat the 26,725 gpm of discharges will be in excess of $3,100,000,000. If 25 percent of the discharges require perpetual treatment, which is a conservative estimate, the bonding cost will total an additional $1,800,000,000.[14] With the 18-month implementation deadline mandated by the TDS strategy and the current status of the economy and lending markets, the ability of the mining industry to raise the funds to comply with the proposed regulations is in serious doubt. Even if the funds are available, all but the largest companies will be forced to terminate operations or relocate to other states. The companies that survive will do so by passing the increase on to their customers (power companies). The power companies will be required to comply with the proposed limits and will pass that additional cost plus the increased coal costs on to the public in the form of higher electrical rates.

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[13] This does not include all the treated mine water flow in Pennsylvania; accordingly, this volume is a fraction of all the mine water currently treated in Pennsylvania.

[14] This perpetual treatment bonding cost is based upon PA DEP's current bond calculator model.

Even if it is ultimately concluded that additional treatment of TDS, sulfates, and chlorides is appropriate, the equipment necessary to treat the mining wastewater statewide is not an "off-the-shelf" item. The equipment would have to be engineered, ordered, fabricated and shipped. The companies included in this study alone would require a minimum of twenty-two (22), 500 gpm RO systems with evaporation and crystallization within 3 years and many additional smaller systems. All other affected industries in the state would also be competing with the mining industry for the same limited equipment resources. The January 1, 2011 deadline for compliance does not allow enough time for the required equipment to be engineered, permitted, shipped, constructed, and tested. Each discharge site would involve a complex and very time consuming design, engineering, and permitting analysis. Each system would be custom designed and tested to determine and assure that the specific chemical composition of the wastewater stream could be effectively treated. Design of the pre-treatment of wastewater streams would be required to avoid fouling, scaling, or breakdown of the RO membranes and evaporator tube heat exchangers. The current lead time for a crystallizer alone is 18 months minimum. If ordered on October 1, 2009, the earliest it would be delivered would be April 1, 2011. Permitting and engineering will require 18 to 24 months and construction will require 12 months bringing the total lead time to 3 years.

The TDS Strategy does not mention any avenue for the disposal of the waste residuals from the treatment of the wastewater. The volume from just the companies included in this study is 14 billion gallons annually. The surveyed mining companies provided information on their wastewater discharges. The waste product from RO with evaporation/crystallization treatment of participating member company wastewater may equal approximately 650 tons of solid waste per day or an estimated 237,000 tons of solid waste annually. If the wastewater is not evaporated to a solid, the volume of residuals in the form of concentrated brine will equal nearly 1 billion gallons annually. It is uncertain if the concentrated brine could be discharged to any treatment facility in Pennsylvania because the facility also would be required to comply with the proposed regulations. Therefore, the brine would have to be trucked out of state to an industrial waste water facility or a solid waste facility that would solidify and dispose of the solids. Either solution or some combination of the two would require a vast infrastructure of trucks, trains, and storage facilities to accommodate the volume of residual waste created by the mining industry. The final disposal of thousands of tons of solid residuals in landfills, who already face considerable TDS challenges in their existing leachate management, is daunting and may be unachievable.

The power consumption to reduce 14 billion gallons of wastewater annually to a solid is enormous. Unlike the gas industry, the coal industry does not have a gas supply readily available to help with the evaporation of the waste stream to a solid. Acquiring air quality permits for coal-fired evaporators would be nearly impossible, leaving the evaporation to be accomplished by electricity. The electricity required to treat 500 gpm of wastewater by RO is 849,544kW/hr per year. To evaporate/crystallize requires an additional 7,188,456 kW/hr per year for a total of 8,038,000 kW/hr per year or approximately $803,800. The 26,725 gpm of wastewater created by the participating member companies will require 429,631,100 kW/hr per year or 429,631 megawatt/hrs per year, costing approximately $42,963,000.

8.0 <u>CONCLUSIONS</u>

In adopting regulations and taking other actions under the Clean Streams Law, PA DEP is required to consider a number of factors including the state of scientific and technical knowledge and the immediate and long-range impact upon the Commonwealth and its' citizens. The TDS Strategy and proposed Chapter 95 regulations' ramifications are broad and enormous, not supported by evidence, lack economic analyses, and have not been adequately analyzed by PA DEP as to the effect these proposed regulations would have on the mining industry.

In August, PCA submitted a written request to PA DEP to provide the scientific data and economic analysis used to formulate the TDS Strategy and proposed regulation. Their response indicates not only the lack of a comprehensive study regarding this issue, but a lack of supporting water quality data as described in more detail in Section 4.1 of this report. PA DEP's available data indicates the "TDS problem" to be sporadic at best and isolated to only one or a few watersheds and only during periods of extreme low flow.

Aside from a lack of water quality data to support the proposed rulemaking, it is evident that alternatives to the proposed regulations have not been thoroughly evaluated. For example, nowhere in the TDS Strategy or proposed Chapter 95 regulations does PA DEP discuss Best Management Practices options such as managed discharges—a considerably more economically feasible way of treating TDS. The technologies available to address high TDS wastewaters are limited and create **significant** technical, economic and feasibility issues.

PA DEP should undertake the necessary studies to determine if there truly is a TDS problem, the extent to which the active mining industry contributes to the problem, and a cost/benefit analysis including an evaluation of the additional environmental and carbon footprints. A review of literature studies and toxicity tests to determine what in-stream parameters should be regulated to protect the aquatic life use and what the appropriate in-stream concentrations should be needs to be performed before developing proposed TDS, sulfates and chlorides rulemaking.

The staggering cost to the mining industry, the potential loss of thousands of mining jobs and the utter lack of any scientific basis to justify imposition of the TDS rule on the mining industry demands a more deliberate approach to this issue. PA DEP should withdraw the proposed revisions to Chapter 95 and proceed with a more holistic and complete scientific analysis of the TDS issue before it develops additional rulemaking.

Source: Energy Information Administration

Table 15. Recoverable Coal Reserves at Producing Mines, Estimated Recoverable Reserves, and Demonstrated Reserve Base by Mining Method, 2007

(Million Short Tons)

Coal-Resource State	Underground - Minable Coal			Surface - Minable Coal			Total		
	Recoverable Reserves at Producing Mines	Estimated Recoverable Reserves	Demonstrated Reserve Base	Recoverable Reserves at Producing Mines	Estimated Recoverable Reserves	Demonstrated Reserve Base	Recoverable Reserves at Producing Mines	Estimated Recoverable Reserves	Demonstrated Reserve Base
Alabama	275	485	963	52	2,264	3,178	327	2,749	4,141
Alaska	-	2,335	5,423	W	496	684	W	2,831	6,107
Arizona	-	-	-	W	-	-	W	-	-
Arkansas	W	127	272	-	101	144	W	228	417
Colorado	W	5,946	11,331	W	3,746	4,761	328	9,692	16,092
Georgia	-	1	2	-	1	2	-	2	4
Idaho	-	2	4	-	-	-	-	2	4
Illinois	1,253	27,893	87,811	33	10,064	16,536	1,286	37,957	104,347
Indiana	272	3,603	8,699	129	398	681	401	4,001	9,379
Iowa	-	807	1,732	-	320	457	-	1,127	2,189
Kansas	-	-	-	W	680	971	W	680	971
Kentucky Total	886	7,265	16,770	296	7,417	12,848	1,182	14,682	29,618
Eastern	503	553	990	166	5,154	9,229	669	5,707	10,219
Western	383	6,712	15,780	130	2,263	3,619	513	8,975	19,399
Louisiana	-	-	-	W	306	412	W	306	412
Maryland	W	313	571	W	41	60	24	354	631
Michigan	-	55	123	-	3	5	-	59	128
Mississippi	-	-	-	W	-	-	W	-	-
Missouri	-	689	1,479	W	3,157	4,509	W	3,846	5,988
Montana	W	35,922	70,957	W	38,934	48,166	1,251	74,856	119,123
New Mexico	W	2,788	6,128	W	4,156	5,929	483	6,944	12,057
North Carolina	-	5	11	-	-	-	-	5	11
North Dakota	-	-	-	1,252	6,849	8,978	1,252	6,849	8,978
Ohio	230	7,692	17,484	103	3,755	5,736	333	11,447	23,220
Oklahoma	W	573	1,229	W	224	320	155	797	1,549
Oregon	-	6	15	-	2	3	-	9	17
Pennsylvania Total	427	10,595	23,006	105	1,026	4,222	532	11,621	27,228
Anthracite	W	340	3,843	W	419	3,352	28	759	7,195
Bituminous	W	10,255	19,164	W	606	870	504	10,861	20,034
South Dakota	-	-	-	-	277	366	-	277	366
Tennessee	2	277	506	10	176	260	12	454	766
Texas	-	-	-	737	9,449	12,276	737	9,449	12,276
Utah	211	2,465	5,028	-	212	268	211	2,676	5,295
Virginia	208	596	1,062	48	171	536	256	767	1,598
Washington	-	674	1,332	-	6	8	-	681	1,340
West Virginia Total	1,285	15,395	28,845	543	2,274	3,605	1,828	17,669	32,450
Northern	271	NA	NA	32	NA	NA	303	NA	NA
Southern	1,014	NA	NA	511	NA	NA	1,525	NA	NA
Wyoming	W	22,946	42,493	W	16,728	20,198	7,330	39,674	62,692
U.S. Total	**5,827**	**149,457**	**333,277**	**12,757**	**113,232**	**156,118**	**18,584**	**262,689**	**489,395**

- = No data are reported.
W = Data withheld to avoid disclosure.
NA = Not Available.

Notes: • Recoverable coal reserves at producing mines represent the quantity of coal that can be recovered (i.e. mined) from existing coal reserves at reporting mines. • EIA's estimated recoverable reserves include the coal in the demonstrated reserve base considered recoverable after excluding coal estimated to be unavailable due to land use restrictions or currently economically unattractive for mining, and after applying assumed mining recovery rates; see Glossary for criteria. • The effective date for the demonstrated reserve base, as customarily worded, is "Remaining as of January 1, 2008." These data are contemporaneous with the Recoverable Reserves at Producing Mines, customarily presented as of the end of the past year's mining, that is in this case, December 31, 2007. • The demonstrated reserve base includes publicly available data on coal mapped to measured and indicated degrees of accuracy and found at depths and in coalbed thicknesses considered technologically minable at the time of determinations; see Glossary for criteria. • All reserve expressions exclude silt, culm, refuse bank, slurry dam, and dredge operations. • Reserves at Producing Mines exclude mines producing less than 10,000 short tons, which are not required to provide reserves data.

Source: • Energy Information Administration Form EIA-7A, "Coal Production Report," and U.S. Department of Labor, Mine Safety and Health Administration, Form 7000-2, "Quarterly Mine Employment and Coal Production Report," and EIA estimates.

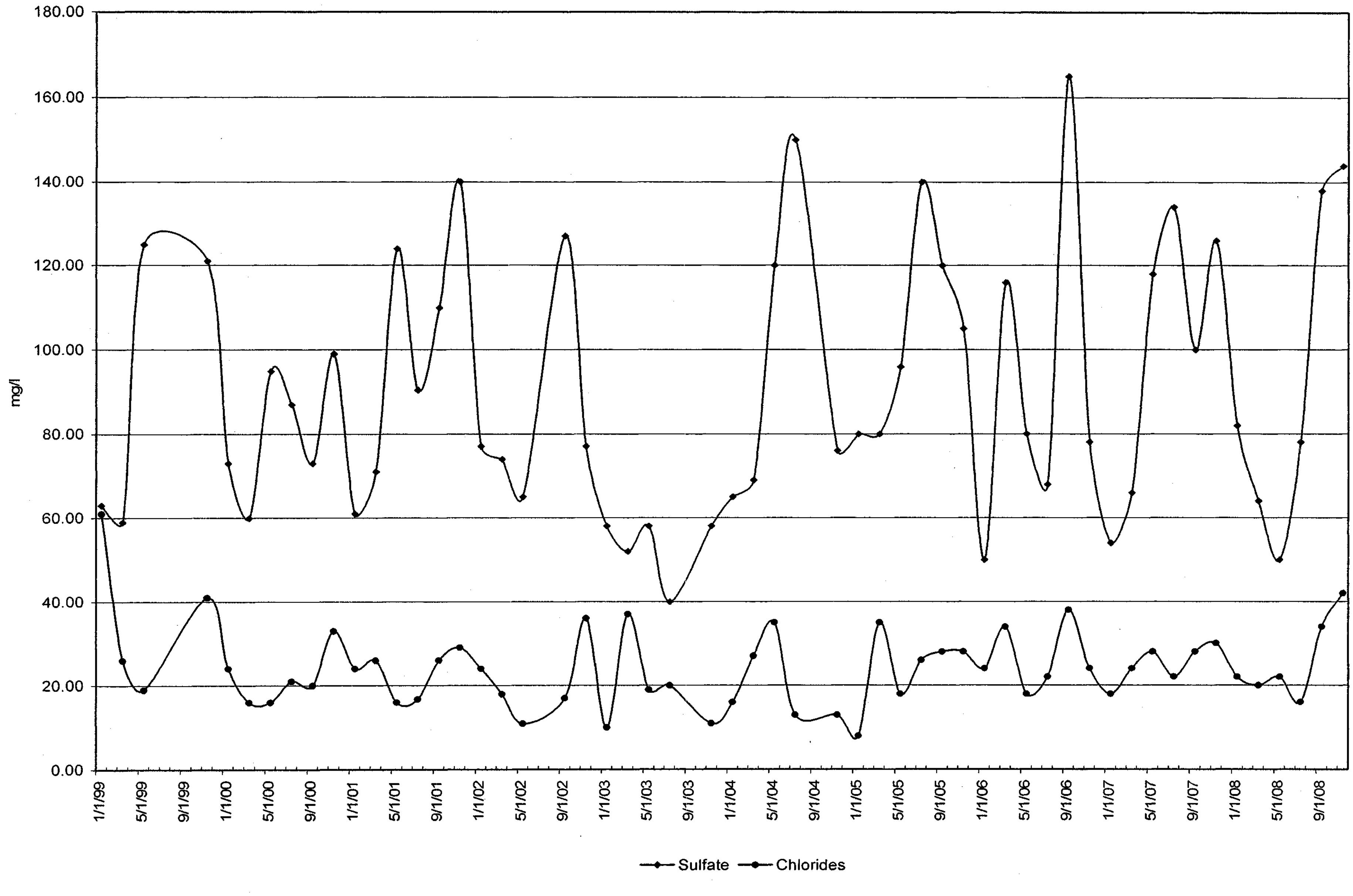
Source: Energy Information Administration

Table 21. Coal Mining Productivity by State and Mine Type, 2007, 2006

Coal-Producing State, Region[1], and Mine Type	Number of Mining Operations[2]			Number of Employees[3]			Average Production per Employee per Hour (short tons)[4]		
	2007	2006	Percent Change	2007	2006	Percent Change	2007	2006	Percent Change
Alabama	61	68	-10.3	3,850	4,195	-8.2	2.23	2.01	11.1
Underground	13	14	-7.1	2,458	2,621	-6.2	2.08	1.74	19.2
Surface	48	54	-11.1	1,392	1,574	-11.6	2.49	2.51	-0.8
Alaska	1	1	-	99	96	3.1	5.83	6.48	-10.0
Surface	1	1	-	99	96	3.1	5.83	6.48	-10.0
Arizona	1	2	-50.0	430	418	2.9	7.92	7.69	2.9
Surface	1	2	-50.0	430	418	2.9	7.92	7.69	2.9
Arkansas	2	2	-	87	43	102.3	0.42	0.24	76.1
Underground	1	1	-	85	41	107.3	0.41	0.19	118.3
Surface	1	1	-	2	2	-	1.65	2.48	-33.4
Colorado	13	13	-	2,249	2,229	0.9	7.51	7.90	-5.0
Underground	9	8	12.5	1,729	1,682	2.8	7.36	7.72	-4.7
Surface	4	5	-20.0	520	547	-4.9	8.05	8.46	-4.9
Illinois	29	33	-12.1	3,946	3,977	-0.8	3.67	3.70	-0.8
Underground	19	21	-9.5	3,488	3,507	-0.5	3.48	3.52	-1.2
Surface	10	12	-16.7	458	470	-2.6	4.95	4.89	1.4
Indiana	44	45	-2.2	2,968	2,858	3.8	4.55	4.81	-5.4
Underground	15	15	-	1,291	1,231	4.9	3.18	3.46	-8.0
Surface	29	30	-3.3	1,677	1,627	3.1	5.60	5.82	-3.7
Kansas	3	3	-	65	61	6.6	3.25	3.64	-10.9
Surface	3	3	-	65	61	6.6	3.25	3.64	-10.9
Kentucky Total	554	592	-6.4	16,986	17,959	-5.4	2.97	2.96	0.5
Underground	266	300	-11.3	11,146	11,902	-6.4	2.69	2.68	0.3
Surface	288	292	-1.4	5,840	6,057	-3.6	3.53	3.51	0.6
Eastern	521	556	-6.3	14,106	15,010	-6.0	2.75	2.78	-1.1
Underground	251	280	-10.4	8,661	9,303	-6.9	2.31	2.37	-2.6
Surface	270	276	-2.2	5,445	5,707	-4.6	3.45	3.45	*
Western	33	36	-8.3	2,880	2,949	-2.3	3.96	3.78	4.9
Underground	15	20	-25.0	2,485	2,599	-4.4	3.86	3.69	4.6
Surface	18	16	12.5	395	350	12.9	4.83	4.54	6.3
Louisiana	2	2	-	239	243	-1.6	6.08	7.84	-22.5
Surface	2	2	-	239	243	-1.6	6.08	7.84	-22.5
Maryland	22	22	-	375	490	-23.5	2.80	4.82	-41.9
Underground	4	5	-20.0	131	205	-36.1	2.09	6.10	-65.7
Surface	18	17	5.9	244	285	-14.4	3.19	3.81	-16.1
Mississippi	1	1	-	177	178	-0.6	9.99	10.38	-3.8
Surface	1	1	-	177	178	-0.6	9.99	10.38	-3.8
Missouri	2	2	-	14	20	-30.0	6.96	10.20	-31.8
Surface	2	2	-	14	20	-30.0	6.96	10.20	-31.8
Montana	6	6	-	986	942	4.7	22.20	21.98	1.0
Underground	1	1	-	16	58	-72.4	1.46	2.65	-45.0
Surface	5	5	-	970	884	9.7	22.55	23.30	-3.2
New Mexico	6	5	20.0	1,356	1,372	-1.2	9.03	8.62	4.7
Underground	2	2	-	374	368	1.6	9.11	8.07	12.9
Surface	4	3	33.3	982	1,004	-2.2	9.00	8.85	1.7
North Dakota	5	5	-	975	947	3.0	15.70	16.91	-7.2
Surface	5	5	-	975	947	3.0	15.70	16.91	-7.2
Ohio	73	71	2.8	2,496	2,413	3.4	4.05	4.04	0.4
Underground	21	20	5.0	1,481	1,384	7.0	4.76	4.81	-1.0
Surface	52	51	2.0	1,015	1,029	-1.4	3.01	3.06	-1.7
Oklahoma	9	10	-10.0	237	224	5.8	2.78	3.35	-16.9
Underground	2	2	-	84	73	15.1	2.65	2.44	8.8
Surface	7	8	-12.5	153	151	1.3	2.85	3.78	-24.6
Pennsylvania Total	349	358	-2.5	7,649	7,526	1.6	3.73	3.90	-4.3
Underground	82	87	-5.7	5,206	5,099	2.1	4.39	4.52	-2.8
Surface	267	271	-1.5	2,443	2,427	0.7	2.20	2.44	-9.9
Anthracite	120	124	-3.2	910	869	4.7	0.89	0.95	-6.6
Underground	30	35	-14.3	192	226	-15.0	0.68	0.68	*
Surface	90	89	1.1	718	643	11.7	0.94	1.04	-10.2
Bituminous	229	234	-2.1	6,739	6,657	1.2	4.05	4.21	-3.7
Underground	52	52	-	5,014	4,873	2.9	4.50	4.65	-3.3
Surface	177	182	-2.7	1,725	1,784	-3.3	2.67	2.87	-7.2
Tennessee	28	36	-22.2	566	660	-14.2	2.10	2.06	2.0
Underground	9	16	-43.8	220	333	-33.9	1.92	1.97	-2.2
Surface	19	20	-5.0	346	327	5.8	2.21	2.14	3.3
Texas	11	12	-8.3	2,216	2,138	3.6	8.82	9.90	-10.9
Surface	11	12	-8.3	2,216	2,138	3.6	8.82	9.90	-10.9
Utah	18	20	-10.0	2,012	2,036	-1.2	5.79	6.15	-5.8
Underground	17	19	-10.5	2,006	2,030	-1.2	5.81	6.18	-5.9

See footnotes at end of table.

Graph 1
Mon River @ South PGH.PA MP4.5



APPENDIX A

Permitting Strategy for
High Total Dissolved Solids (TDS) Wastewater Discharges
April 11, 2009

Statement of the Problem

As the natural gas industry responds to increased energy market demands, Pennsylvania has become a hot-bed for gas exploration and development. Drilling and exploration have the potential to create a significant boost to the local economy, as they also provide opportunities for service companies such as earthmoving contractors, drilling companies, pipe and equipment suppliers and maintenance workers. The Commonwealth fully supports these activities and the development of the Marcellus play.

Development of gas wells in the Marcellus play requires the use of large volumes of water for hydraulic fracturing operations. This hydraulic fracturing has the potential to generate a considerable amount of wastewater, both initial flow back water from fracturing and longer term production brines. Estimates from the industry indicate that demand for brine water treatment in Pennsylvania will reach approximately nine Million Gallons per Day (MGD) in 2009, 16 MGD in 2010, and 19 MGD in 2011. Estimates from the Susquehanna River Basin Commission are 20 MGD for that same timeframe. The need for disposal pathways for these wastewaters has resulted in a rethinking of historic practices.

There are many pollutants of concern in the wastewater associated with hydraulic fracturing. The pollutants that are expected to dictate the allocation of the available assimilative capacity of surface waters are Total Dissolved Solids (TDS), sulfates and chlorides. Many of the areas where the drilling for natural gas is proposed have a history of mining activity and are affected by Abandoned Mine Drainage (AMD). Brine and fracturing wastewater have high concentrations of dissolved solids, and considering the already elevated levels of dissolved solids in the AMD-affected surface waters, the need to stringently control these dissolved solids likely will prevent other pollutants from exceeding water quality standards on a cumulative basis.

Background

TDS are a measurement of inorganic salts, organic matter and other dissolved materials in water. They can be naturally present in water or the result of mining or some industrial or municipal treatment of water. TDS contain minerals and organic molecules that provide benefits such as nutrients, but also may contain contaminants such as toxic metals and organic pollutants. The concentration and composition of TDS in natural waters is determined by the geology of the drainage, atmospheric precipitation and the water balance (evaporation/precipitation).

TDS cause toxicity through increases in salinity, changes in the ionic composition of the water, and toxicity of individual ions. The composition of specific ions determines toxicity of elevated TDS in natural waters. Also, as the hardness increases, TDS toxicity may decrease. The major concern associated with high TDS concentrations relates to direct effects of increased salinity on the health of aquatic organisms.

Water quality analyses performed for the major watersheds of the Commonwealth to date show that many of the rivers and streams of Pennsylvania have a very limited ability to assimilate additional TDS, sulfates and chlorides because of elevated levels from historic practices. This phenomenon was most evident during the fall of 2008, when actual water quality issues related to these parameters emerged in the Monongahela River basin. While river flows reached seasonal lows, the concentrations of TDS and sulfates in the river increased to historic highs, exceeding the water quality standards at all of the 17 Potable Water Supply (PWS) intakes from the border with West Virginia to Pittsburgh. Violations of water quality standards for TDS and Sulfate persisted in the river through November and December of 2008. Elevated chloride levels were observed on at least one major tributary – South Fork Tenmile Creek – and for the first time, elevated bromide levels were observed in these streams.

During this period, several environmental agencies performed studies on the effects of TDS, sulfate and chloride discharges on the Monongahela and some of its tributaries. A study[1] conducted by the Environmental Protection Agency (EPA), the Pennsylvania Department of Environmental Protection (DEP) and the Allegheny County Health Department (ACHD) also identified bromides as a key parameter of concern in these waters. The study concluded that a high percentage of the Disinfection By-Products (DBPs) being formed in the drinking water systems were brominated DBPs, which pose a greater health risk than chlorinated DBPs; and, subsequent formation of brominated DBPs increases overall DBP concentrations, specifically trihalomethanes (THMs). The study also concluded that based on the speciation there appears to be a strong correlation between THM formation and elevated source water bromide concentrations in the Monongahela River.

Several studies[2,3] on the potential impacts to aquatic life from these large TDS discharges also were conducted on major tributaries flowing into the Monongahela River in Greene County, Pennsylvania. Each of these studies documents the adverse effects of discharges of TDS, sulfates and chlorides on the aquatic communities in these receiving streams. The former concludes that there is a high abundance of halophilic organisms (salt-loving) downstream from the discharges of TDS and chlorides and a clear transition of fresh water organisms to brackish water organisms in the receiving stream from points above the discharge to points below. It is evident from this study that increases in salinity have caused a shift in biotic communities.

The Monongahela River watershed is being adversely impacted by TDS discharges and many points in the watershed are already impaired, with TDS, sulfates and chlorides as

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[1] Trihalomethane Speciation And The Relationship To Elevated Total Dissolved Solid Concentrations Affecting Drinking Water Quality At Systems Utilizing The Monongahela River As A Primary Source During The 3rd And 4th Quarters Of 2008, PA-DEP, February 2009.
[2] Cause and Effect Survey, South Fork Tenmile Creek, PA-DEP, February 2009.
[3] Aquatic Survey of Lower Dunkard Creek, PA-DEP, October – November 2008.

the cause. However, the Monongahela is not an anomalous situation. Recent reports on the water quality of the Beaver and Conemaugh Rivers in southwestern Pennsylvania also show upward trends in TDS concentrations. In addition, watershed analyses conducted by DEP of the West Branch of the Susquehanna River watershed has documented that it is also severely limited in the capacity to assimilate new loads of TDS and sulfates.

The surveys, analyses and studies referenced establish that the extent of existing and potential pollution from TDS, sulfates and chlorides is widespread. DEP is constrained from approving any significant portion of the pending proposals and applications for new sources[4] of discharge high-TDS wastewater, including sulfates and chlorides, and still protect the quality of Pennsylvania's streams. In addition, it is also clear that in many watersheds, existing discharges of TDS, sulfates and chlorides will have to be reduced and limited, to assure that watershed restoration is accomplished and that the purity of our streams is protected.

The Commonwealth's Clean Streams Law (P.L. 1987, No. 394) delegates the authority to preserve and improve the purity of its waters and develop remedies to purify those waters currently polluted to DEP, in the form of adopting rules and regulations as necessary to accomplish these tasks. This paper outlines the foundation and scientific rationale for promulgation of such rules and regulations necessary to address the existing and potential pollution of Pennsylvania's waters from large sources of TDS, sulfates and chlorides. That approach will rely upon the basic water quality management premise that discharges of these pollutants must be controlled through permit limitations required by the more stringent of treatment-based or water quality-based standards.

Pennsylvania's Water Quality Standards for TDS and Chlorides

Title 25 regulations currently have a numeric criterion for Osmotic Pressure (OP) in Chapter 93 that is supposed to provide protection to aquatic life from TDS. But OP effects can vary from effluent to effluent, depending on the actual constituents present in the discharge/stream matrix. DEP has evaluated these parameters with respect to the fish and aquatic uses, specifically their toxicity to these organisms, and has begun development of instream numeric criteria (concentrations) for TDS and chlorides that are designed to protect the aquatic life use, which may be applied in individual permitting decisions for the specific local points of discharge.

In addition to protection of aquatic life uses, TDS and chlorides are secondary contaminants under Pennsylvania's safe drinking water program. Adverse affects of secondary contaminants are usually related to taste and odor. Although water with TDS and chloride levels greater than the standards may have the potential to cause health affects, no reliable data exist currently that support this and no health-based (primary contaminant) standard will be proposed at this time. Pennsylvania's water quality

[4] As used in this strategy the term "new sources" or "New Sources" shall have a generic meaning to include, but not be limited to, a new source, a new discharge, an additional discharge, an expanded discharge and an increased discharge. The term as used is not intended, nor shall it be construed, to refer to the regulatory definition of the term as set forth in 40 CFR §122.2 and 92 Pa Code § 92.1.

standards address this designated use through numeric criteria. At any potable water supply (PWS) surface intake, the criteria for TDS (500 mg/L as a monthly average value), sulfates (250 mg/l as a maximum value) and chlorides (250 mg/L as a maximum value) apply. The effects of the cumulative loads from all upstream discharges of TDS, sulfates and chlorides must be evaluated at each PWS intake.

Technology-based Discharge Standards

Methods that have historically been used to control wastewater discharges containing TDS, sulfates and chlorides in Pennsylvania have been limited to simple dilution, i.e. adjusting discharge flow rates in proportion to stream flows on any given day. In addition, federal Effluent Guidelines and Standards (ELGs) for the industrial categories of greatest concern to Pennsylvania do not address TDS, sulfates or chlorides. Therefore, to develop a treatment-based water quality management approach that properly addresses these pollutants, DEP will rely on the authority it has been given under the Pennsylvania Clean Streams Law. This approach must be tailored to specific categories of industrial discharges of greatest concern, and is described below.

Permitting Strategy

As with the current NPDES permitting procedure, final effluent limitations are to be set at the more stringent of the effluent standard and the Water Quality-based effluent Limitation (WQBEL). However, a strategy for permitting these discharges also must involve an allocation strategy to address those situations in which multiple discharges cause or contribute to downstream water quality standards violations, even if only predicted through modeling. An allocation strategy is the plan to allocate the assimilative capacity of the watershed (the acceptable loading in lbs/d of TDS and/or chlorides) among multiple sources.

The goal of this permitting strategy is that by January 1, 2011, new sources of High-TDS wastewaters will be prohibited from Pennsylvania's waters. To achieve this goal, the Department proposes to amend Chapter 95 – relating to wastewater treatment requirements – to establish new effluent standards. In addition, to assuring the current protection afforded to the use of streams as Potable Water Supplies, the Department proposes to develop new numeric water quality criteria for TDS and Chlorides for the protection of all designated stream uses in Chapter 93 and to amend Chapter 93 – Water Quality Standards – to include these criteria. Changes to both Chapters 93 and 95 necessary to accomplish these tasks will be submitted to the Environmental Quality Board (EQB) as proposed rulemaking in the next few months and will be completed prior to January of 2011.

The Department's interim strategy over the next two years for permitting discharges of new sources of High-TDS wastewaters will focus on those new sources that have the greatest potential to adversely affect the quality of Pennsylvania's receiving streams. Currently, those sources are wastewaters generated from fracturing and production of oil and gas wells in the Marcellus Shale formation.

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During the interim period between April 1, 2009 and January 1, 2011, the interim strategy will be to maximize the use of available assimilative capacity of receiving streams where that is feasible. Effective January 1, 2011, all new sources of high-TDS wastewater will be subject to new regulations as described above. Specifically, DEP's interim permitting strategy is as follows:

(1) New Sources of High-TDS Wastewater

(a) DEP will not issue permits for new sources of High-TDS industrial waste unless the applicant proposes to install adequate treatment for TDS on or before January of 2011.

(b) For new sources of High-TDS industrial waste proposing treatment for TDS, an allocation of available assimilative capacity may be authorized (see subsections (i) and (ii) below). Such an allocation will terminate on January 1, 2011. Beyond that date, the discharge of TDS will be limited to the more stringent of the effluent standards established under regulation as described above. Wastewaters discharged from these facilities also must meet any other applicable treatment standards and requirements.

(i) Where analysis of a watershed determines that sufficient assimilative capacity exists to allow short-term discharges of TDS and other pollutants of concern from oil and gas wastewaters, such capacity will be allocated as allowable maximum daily mass loads, and permit limitations will be set using these allocations. Actual allocation strategies may vary by watershed, based on the specific characteristics and existing water quality of each watershed.

(ii) Where analysis of a watershed determines that sufficient assimilative capacity does not exist to allow new discharges of TDS or any other pollutants of concern from new sources, meaning that the receiving stream is impaired, federal regulations prohibit discharges from new sources of pollutants that cause or contribute to the impairment. In these cases, new sources can only be authorized if permits limits are set equal to the numeric water quality criteria for the pollutant(s) of concern.

(c) Pretreatment Facilities – New Pretreatment facilities that accept new sources of High-TDS wastewaters and discharge pretreated wastewater to a Publicly Owned Treatment Works (POTW) will be subject to local limits established by the receiving POTW, in accordance with (2)(b) below.

(2) Existing Facilities - DEP will permit the continued treatment and disposal of existing sources of High-TDS wastewaters at existing permitted facilities as follows:

(a) Existing industrial sources of High-TDS wastewaters will be able to continue to operate under their existing permit limits and conditions until such time as they propose to expand or to increase their existing daily discharge load of any pollutant of concern[5]. At that point, such a facility would be subject to the following schedule:

(i) Prior to January 1, 2011, the New Sources strategy in (1)(b) above.

(ii) After January 1, 2011, the more stringent of the applicable effluent standards or water quality based effluent limitations.

(b) POTWs –POTWs currently accepting through an approved permit, or planning to accept High-TDS wastewaters, an allocation of available assimilative capacity may be authorized, where analysis of a watershed determines that sufficient assimilative capacity exists to allow short-term discharges of TDS and other pollutants of concern from these wastewaters (see (1)(b) above).

(i) Such an allocation would terminate on January 1, 2011. Beyond that date, the discharge will be limited to the more stringent of the applicable effluent standards.

(ii) Wastewaters discharged from these facilities also must meet any other applicable treatment requirements.

(iii)These facilities must obtain EPA approval of a Pretreatment Program and install appropriate pre-treatment facilities prior to January 1, 2011.

(c) Pretreatment Facilities – Existing sources of High-TDS wastewaters will be able to continue to operate under their existing permit limits and conditions until such time as they propose to expand their existing daily discharge load of any pollutant of concern. At that point, such a facility would be subject to local limits established by the receiving POTW, in accordance with (2)(b) above.

[5] Note that monitoring and reporting requirements for TDS will likely be added to the permit to track existing discharge loads.

APPENDIX A

Oil & Gas Well Wastewaters

To support development of the Marcellus Shale formation, acceptable wastewater treatment and disposal pathways must be clearly defined. DEP staff have met with numerous industry representatives seeking to participate in the wastewater treatment and disposal market related to Marcellus Shale development. Some of the proposed treatment and disposal pathways do not involve the discharge of high-TDS wastewaters (non-discharge options). Other proposals involve the partial removal of TDS from wastewater (low-discharge options). Both non-discharge and low-discharge options may be designed to maximize reuse of wastewater, and production of a viable end product from the recovered solids (e.g. road salt). Still, proper treatment and disposal of these wastewaters via surface discharge will be necessary.

Methods that have historically been used to treat and discharge brine wastewater in the Commonwealth involve the use of Centralized Waste Treatment (CWT) facilities, Publicly-owned Treatment Works (POTWs), or a combination of the two (Pretreatment). Numerous additional facilities using these same treatment options have been proposed to address brine wastewater discharges and for which applications are pending. The challenge is that nearly all of the existing and proposed facilities do not treat the main pollutants of concern – these are passed through the treatment system with little or no reduction in pollutant loading – as TDS and chlorides are not removed using current treatment methods.

EPA Headquarters recommends that POTWs not accept this type of wastewater due to the potential for "pass through" or "interference." (See 40 CFR Part 403.5.) However, there is no prohibition (no pretreatment standards) for transporting oil and gas wastewaters to a POTW. In these instances, existing industrial pretreatment programs must still comply with the general pretreatment standards in 40 CFR Part 403. All non-domestic discharges to publicly owned treatment works (POTWs) ("indirect dischargers"), even those not subject to categorical pretreatment standards, are subject to general pretreatment standards, including a prohibition on discharges causing "pass through" or "interference." All POTWs with approved pretreatment programs must develop local limits to implement the general pretreatment standards. All other POTWs must develop such local limits where pollutants have contributed (or will contribute) to "pass through" or "interference" and where water quality violations are likely to recur.

Discharges from a CWT facility treating gas extraction produced waters are subject to the effluent limitations and pretreatment standards established under 40 CFR Part 437. However, additional limits and conditions are needed to address pollutants that were not considered in developing the federal CWT Effluent Guidelines and Standards (ELGs). For example, there is the potential for several pollutants to be found in produced waters (e.g., TDS, radionuclides, chlorides) that were not regulated or considered in the development of the CWT ELGs.

Consequently, for a CWT facility that accepts produced waters or other waste from oil and gas extraction facilities, the permitting authority (DEP) needs to develop technology-based effluent limits to address those pollutants not considered or regulated by the CWT Effluent Guidelines and incorporate these limits in the facility's NPDES permit. This process requires a great deal of individual professional judgment, takes a great deal of time, and does not result in a level playing field for all CWTs with regard to required treatment levels.

In addition, permits must also contain limitations necessary to assure that the receiving stream's designated water uses are protected. Designated uses in Pennsylvania include aquatic life, water supply and recreation. These uses are protected with narrative and, for some parameters, numeric criteria. Where numeric criteria exist, permit limitations can be calculated to assure that these criteria are met.

When developing this wastewater management approach, DEP considered the need to protect the aquatic life use, the industrial water use, and the potable water supply use. Collectively, these specific uses comprise what DEP believes to be the most sensitive of the possible water quality constraints on any discharge or combination of discharges of TDS, sulfates and chlorides. In addition, DEP proposes to require an effluent standard for TDS, sulfate and chloride discharges. Each discharge would have to meet the more stringent of the water quality-based limitations or the effluent standards.

DEP proposes to establish such an effluent standard through development of a revision to the regulations at Chapter 95. The following is a general description of the proposed regulation change.

- Add effluent standards for Oil and Gas wastewaters of 500 mg/L for TDS, 250 mg/L for sulfates and 250 mg/L for chlorides as daily maxima. In addition, add effluent standards of 10 mg/L for Total Barium and Total Strontium, as these pollutants are also prevalent in Marcellus waste waters.

- POTWs that accept wastewater from this Category will be required to have an EPA-approved pretreatment program, which addresses TDS through local limits on these sources and at the above standards.

Existing wastewater treatment facilities, industrial waste and sewage, would be given two years to come into compliance with these new requirements, if their existing discharge does not comply with these standards.

Mining Wastewaters

As stated above, this strategy applies primarily to new sources of High-TDS wastewaters. While there are many existing sources of mine discharges in the Commonwealth, water discharged from existing mine sites generally falls within a few discrete categories, which are described below.

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(1) New Sources (New Mines)

It is not possible to predict what the concentrations of TDS, sulfates and chlorides will be in mine water and sampling currently is typically not required for TDS, sulfates and chlorides. Therefore, for new mine sources (discharges) authorized after the implementation of this policy, permittees must sample the discharge for TDS, Sulfates and Chlorides on a monthly basis for a period of one (1) year and submit the results within 30 days of the anniversary date of the discharge authorization. If the discharge shows or is known to contain levels of TDS/Sulfates/chlorides that would indicate that the discharge is a High-TDS discharge, that discharge will be subject to the standards established by this strategy as set forth above under "Permitting Strategy, (1) New Sources of High-TDS Wastewater."

(2) Existing Sources

(a) Abandoned Mines

Under this strategy no action will be required to reduce TDS, sulfates and chlorides at Abandoned Mine Discharge (AMD) sites (which includes mine sites where bonds have been forfeited) for the following reasons. There is no responsible party for abandoned mine sites and, therefore, no party with legal responsibility for the pollutant discharge emanating from the sites. Sulfate, chloride and TDS loading from abandoned mines are not amenable to being managed through a discharge permit because there is no responsible party available to hold a permit. Due to geologic and hydrogeologic reasons it is not possible to relocate the discharge or cause the generation of mine drainage to cease. Abandoned mines typically have no funds associated with them (some discharges are being treated by volunteers) to address mine drainage treatment or only a finite amount of money available for this purpose.

The above facts demonstrate that imposition of a TDS, sulfates and chloride standard and permit, for abandoned discharges that currently are being treated to some degree, would be futile and counter productive to the AMD remediation strategy and this TDS control strategy. Costs would increase exponentially, likely resulting in abandonment of the existing treatment due to the lack of funds, and fewer treatment facilities would be constructed for abandoned discharges that are currently not treated.

(b) Funded Forfeited Mines

Under this strategy no action will be required to reduce TDS, sulfates and chlorides at former mines where the responsible party no longer exists but some money is available to treat the discharge. These are not new sources and subjecting these sites to new effluent limits also would be contrary to the mine drainage control strategy and to this TDS control strategy. The available money comes from bonds or trust funds posted for the operation by the now defunct operator. The amount of money available for continued treatment at these sites varies, but the best funded are based on the cost of perpetually treating standard AMD parameters to meet the mine sites former permitted effluent limits. Imposing new requirements to treat for TDS, sulfates and chlorides would result in an accelerated depletion of the full cost bond funds. The net result would be no treatment once the funds were exhausted and a discharge of metals and acidity as well as the TDS.

(c) Inactive Mines Treating Post-mining Discharges

Under this strategy no action will be required to reduce TDS, sulfates and chlorides at mine sites where reclamation has been completed except for the treatment of the post-mining discharge. These mines were permitted, bonded and mined based on the water being treated to meet the sites former permitted effluent limits. The mines no longer provide a source of revenue to generate additional funding to pay for treatment to reduce TDS, sulfates and chlorides. Due to geologic and hydrogeologic reasons it is not possible to relocate the discharge or to stop the generation of mine drainage.

(d) Existing Active Mines Discharging Storm Water Runoff

Many active mines are equivalent to a construction site as the discharge is composed of storm water runoff and typically does not contain high TDS, sulfates and chlorides. Accordingly, all mining sites with storm water runoff only NPDES permits are beyond the scope of this strategy.

(e) Active Mines Discharging More Than Storm Water Runoff

The final group of existing mine discharges consists of those at permitted mines that include more than storm water runoff. These mines were designed and planned based on the current ELG or WQBEL. They are typically transitory in nature and will cease discharging when the mine is closed and reclaimed. DEP will allow existing active mines discharging "high TDS" to continue to do so under their permit as follows:

(i) Mining permits typically do not contain limits or monitoring for TDS, sulfates and chlorides. Beginning no later than October 1, 2009 the permittee of an existing mine is to sample the discharge for TDS, sulfates and chlorides on a monthly basis for a period of one year and immediately thereafter submit the results to DEP. Permittees that are discharging "high TDS," as shown by the one year of monitoring data, will be subject to the strategy set forth in paragraph (1) above. Permittees which implement measures to reduce their discharges of TDS in order to be below the "high TDS" threshold will be able to continue to discharge at that lower amount.

(ii) Existing active mines discharging "high TDS" will be able to continue to operate under their existing permit limits until such time as their NPDES permit is to be reissued or they propose to increase their existing daily discharge load for TDS, sulfates or chlorides. At that time the permittee will develop a compliance schedule to be implemented over the next five years to meet the more stringent of the applicable effluent standards or water quality based effluent limits.

Other High TDS Wastewater Discharges

Other sources of high-TDS wastewaters, including sulfates and chlorides, with existing ELGs should continue to use those ELGs as technology-based limitations. These discharges may still be subject to any water quality-based effluent limitations should those be more stringent.

For additional information, please contact the Bureau of Water Standards and Facility Regulation at 717-787-5017.

Environmental and Workplace Health

Guidelines for Canadian Drinking Water Quality - Summary Table

Guidelines for chemical and physical parameters

Table 4 provides the complete list of all current numerical Guidelines for chemical and physical parameters. Guidelines are either health-based and listed as Maximum Acceptable Concentrations (MAC), based on aesthetic considerations and listed as aesthetic objectives (AO) or established based on operational considerations and listed as Operational Guidance Values (OG). Parameters for which the health-based guideline was developed as an interim maximum acceptable concentration (IMAC) are identified with an asterisk (*) in the table below. The use of these 'interim' MACs was discontinued by the Federal-Provincial-Territorial Committee on Drinking Water in 2003. For more information on specific guidelines, please refer to the guideline technical document for the parameter of concern.

Table 4. Health-based and aesthetic guidelines

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of approval (or reaffirmation)
Aldicarb	0.009		1994
Aldrin + dieldrin	0.0007		1994
Aluminum[a]		[0.1/0.2]	1998
*Antimony[b]	0.006		1997
Arsenic	0.010		2006
*Atrazine + metabolites	0.005		1993
Azinphos-methyl	0.02		1989 (2005)
Barium	1		1990
Bendiocarb	0.04		1990 (2005)
Benzene	0.005		1986
Benzo[a]pyrene	0.00001		1988 (2005)
*Boron	5		1990
*Bromate	0.01		1998
Bromodichloromethane (BDCM)	0.016		2006
*Bromoxynil	0.005		1989 (2005)
Cadmium	0.005		1986 (2005)
Carbaryl	0.09		1991 (2005)
Carbofuran	0.09		1991 (2005)
Carbon tetrachloride	0.005		1986
Chloramines--total	3		1995

APPENDIX B

Chlorate	1.0		2008
Chloride		≤250	1979 (2005)
Chlorite	1.0		2008
Chlorpyrifos	0.09		1986
Chromium	0.05		1986
Colour[d]		≤15 TCU	1979 (2005)
Copper[b]		≤1.0	1992
*Cyanazine	0.01		1986 (2005)
Cyanide	0.2		1991
Cyanobacterial toxins-Microcystin-LR[c]	0.0015		2002
Diazinon	0.02		1986 (2005)
Dicamba	0.12		1987 (2005)
1,2-Dichlorobenzene[e]	0.2	≤0.003	1987
1,4-Dichlorobenzene[e]	0.005	≤0.001	1987
*1,2-Dichloroethane	0.005		1987
1,1-Dichloroethylene	0.014		1994
Dichloromethane	0.05		1987
2,4-Dichlorophenol,	0.9	≤0.0003	1987 (2005)
*2,4-Dichlorophenoxyacetic acid (2,4 -D)	0.1		1991
Diclofop-methyl	0.009		1987 (2005)
*Dimethoate	0.02		1986 (2005)
Dinoseb	0.01		1991
Diquat	0.07		1986 (2005)
Diuron	0.15		1987 (2005)
Ethylbenzene		≤0.0024	1986 (2005)
Fluoride	1.5		1996
*Glyphosate	0.28		1987 (2005)
Haloacetic Acids-Total (HAAs)	0.080		2008
Iron		≤0.3	1978 (2005)
Lead[b]	0.01		1992
Malathion	0.19		1986 (2005)
Manganese		≤0.05	1987
Mercury	0.001		1986
Methoxychlor	0.9		1986 (2005)
Methyl tertiary-butyl ether (MTBE)		0.015	2006
*Metolachlor	0.05		1986
Metribuzin	0.08		1986 (2005)
Monochlorobenzene	0.08	≤0.03	1987
Nitrate[f]	45		1987
Nitrilotriacetic acid (NTA)	0.4		1990
Odour		Inoffensive	1979 (2005)
*Paraquat (as dichloride)[g]	0.01		1986 (2005)
Parathion	0.05		1986

Pentachlorophenol	0.06	≤0.030	1987 (2005)
pH[h]		6.5-8.5	1995
Phorate	0.002		1986 (2005)
*Picloram	0.19		1988 (2005)
Selenium	0.01		1992
*Simazine	0.01		1986
Sodium[i]		≤200	1992
Sulphate[j]		≤500	1994
Sulphide (as H_2S)		≤0.05	1992
Taste		Inoffensive	1979 (2005)
Temperature		≤15°C	1979 (2005)
*Terbufos	0.001		1987 (2005)
Tetrachloroethylene	0.03		1995
2,3,4,6-Tetrachlorophenol	0.1	≤0.001	1987 (2005)
Toluene		≤0.024	1986 (2005)
Total dissolved solids (TDS)		≤500	1991
Trichloroethylene	0.005		2005
2,4,6-Trichlorophenol	0.005	≤0.002	1987 (2005)
*Trifluralin	0.045		1989 (2005)
Trihalomethanes-total (THMs)[k]	0.100		2006
Turbidity[l]			2004
*Uranium	0.02		1999
Vinyl chloride	0.002		1992
Xylenes--total		≤0.3	1986 (2005)
Zinc[b]		≤5.0	1979 (2005)

[a]This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.
[b]Faucets should be thoroughly flushed before water is taken for consumption or analysis.
[c]The guideline is considered protective of human health against exposure to all microcystins that may be present.
[d]TCU = true colour unit.
[e]In cases where total dichlorobenzenes are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.
[f]Equivalent to 10 mg/L as nitrate-nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.
[g]Equivalent to 0.007 mg/L for paraquat ion.
[h]No units.
[i]It is recommended that sodium be included in routine monitoring programmes, as levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients.
[j]There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.
[k]Expressed as a running annual average. The guideline is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water.
[l]Refer to section on Guidelines for microbiological parameters for information related to various treatment processes.

Parameters without guidelines

Some chemical and physical parameters for which a Guideline Technical Document is available have been identified as not requiring a numerical guideline, because currently available data indicate that it poses no health risk or aesthetic problem at the levels generally found in drinking water in Canada.

APPENDIX B

Table 5. Parameters without numerical guidelines

Ammonia	Asbestos
Calcium	Formaldehyde
Gasoline	Hardness[a]
Magnesium	Radon
Silver	

[a]Public acceptance of hardness varies considerably. Generally, hardness levels between 80 and 100 mg/L (as $CaCO_3$) are considered acceptable; levels greater than 200 mg/L are considered poor but can be tolerated; those in excess of 500 mg/L are normally considered unacceptable. Where water is softened by sodium ion exchange, it is recommended that a separate, unsoftened supply be retained for culinary and drinking purposes.

Archived parameters

The Federal-Provincial-Territorial Committee on Drinking Water has established a science-based process to systematically review older guidelines and archive older guidelines which are no longer required. Guidelines are archived for parameters which are no longer found in Canadian drinking water supplies at levels that could pose a risk to human health, including pesticides which are no longer registered for use in Canada, and for mixtures of contaminants that are addressed individually. Table 6 provides the list of parameters whose guidelines have been archived as a result of this review.

Table 6. Parameters that have been archived[a]

Chlordane (total isomers)[b]	Polychlorinated biphenyls (PCBs)
Dichlorodiphenyltrichloroethane (DDT) + metabolitesb	Polycyclic aromatic hydrocarbons (PAH)[c]
Endrin[b]	Resin acids
Heptachlor + heptachlor epoxide[b]	Tannin
Lignin[b]	Temephos[d]
Lindane[b]	Total organic carbon (TOC)
Methyl-parathion[b]	Toxaphene[b]
Mirex	Triallate[d]
Pesticides (total)	2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)[d]
Phenols (total)	2,4,5-Trichlorophenoxypropionic acid (2,4,5-TP)[b]
Phthalic acid esters (PAE)	

[a]Published in the 1978 version of the *Supporting Documentation* for these parameters (available upon request).

[b]In 1978 'Pesticides' Supporting Documentation.
[c]Other than benzo[a]pyrene.
[d]No documentation available.

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Date Modified: 2008-08-05

APPENDIX C

Pennsylvania Coal Association
212 North Third Street • Suite 102 • Harrisburg, PA 17101

(717) 233-7900
FAX (717) 231-7610
pacoal1@aol.com

George L. Ellis
President

August 4, 2009

The Honorable John Hanger
PA Department of Environmental Protection
P.O. Box 2063
Harrisburg, PA 17105-2063

Dear Secretary Hanger:

The Pennsylvania Coal Association (PCA) appreciates the Department of Environmental Protection's (DEP) willingness to cooperate with PCA and other industry stakeholders groups to address a number of concerns that the regulated community has with DEP's new "TDS Strategy" and accompanying proposed rulemaking.

To help PCA better understand the reasons that led DEP to move forward with the initiative, to be able to define the scope of the problem as it relates to mining discharges, and to more fully assess the industry implications in complying with the strategy, PCA respectfully requests copies of the following:

1. List of all PA streams and waterways located within the bituminous coal fields that are considered by PA DEP to be at risk for sustained elevated concentrations of TDS, sulfates and chlorides. Please provide the sampling data and results for TDS, sulfates, chlorides, specific conductance (including temperature of sample analysis), flow and sampling location for each of these streams and waterways for July 1, 2008 through April 2009.

2. TDS, flow, sulfates, chlorides, specific conductance (including temperature of sample analysis) and location from each public water supply intake on the Monongahela River from July 1, 2008 through April 2009.

3. TDS, sulfates, chlorides, specific conductance (including temperature of sample analysis) , flow and sample location from the Monongahela River between the West Virginia border and the confluence of the Youghiogheny and the Monongahela rivers in McKeesport, Allegheny County from July 1, 2008 through April 2009.

4. The TDS test methodology used for the data in item numbers 2 and 3 above. Please explain the decision to use that particular test methodology.

5. All water sampling data and test methodology which led the Department to conclude in its January 21, 2009 press release that TDS levels, "...in the Monongahela River have dropped and remain well below state and federal guidelines."

6. All water sampling data and test methodology which led the Department to announce in its April 16, 2009 press release that, "High TDS solids in industrial waters have been a problem in the Monongahela River recently and are an impending problem on a state-wide basis"; and which resulted in the Department establishing base standards for high TDS water discharges, chlorides and sulfates.

7. All information and support data that the Department used in setting the new permitting limits for discharges of high TDS wastewater (500 mg/l), chlorides (250 mg/l) and sulfates (250 mg/l).

Thank you for your prompt consideration of this request. PCA will be available to you or your staff at your convenience should any clarifications regarding the requested information be required.

Sincerely,

George Ellis

cc: Deputy Secretary John Hines
Deputy Secretary J. Scott Roberts

Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
P.O. Box 2063
Harrisburg, PA 17105-2063
September 3, 2009

Secretary 717-787-2814

Mr. George L. Ellis
Pennsylvania Coal Association
212 North Third Street Suite 102
Harrisburg, PA 17102

Dear Mr. Ellis:

Thank you for your recent letter requesting additional information on the data and decision-making process that informed the development of the Department of Environmental Protection's (DEP) High Total Dissolved Solids (TDS) Strategy and proposed Chapter 95 amendments.

In addition to the TDS strategy and Chapter 95 amendments you note, I want to inform you about other efforts DEP is undertaking to examine this issue. On a parallel track to the proposed changes to Chapter 95, the Water Resources Advisory Committee (WRAC) has formed a subcommittee to examine the economic impacts by sector and technology available to treat TDS. This subcommittee initially met on August 27 and will likely meet through early Spring 2010 at which point the subcommittee's findings will be presented to WRAC.

In addition to this stakeholder process, DEP is working with West Virginia, the Environmental Protection Agency, and numerous regional stakeholders to address the TDS situation in the Monongahela specifically. This group met on August 24 to begin these discussions.

I have enclosed a document summarizing the monitoring results from October 2008, through December 2008, which will supplement the responses to several of your questions. This document is also available on our Web site at http://www.depweb.state.pa.us/southwestro/lib/southwestro/monongahelarivertdschlorideandsulfatesamplingresults.pdf .

In response to your specific concerns:

1. *List of all PA streams and waterways located within the bituminous coal fields that are considered by PA DEP to be at risk for sustained elevated concentrations of TDS, sulfates and chlorides. Please provide the sampling data and results for TDS, sulfates, chlorides, specific conductance (including temperature of sample analysis), flow and sampling location for each of these streams and waterways for July 1, 2008 through April 2009.*

[redacted]

From: Aunkst, Dana
Sent: Wednesday, September 09, 2009 12:38 PM
To: josie gaskey
Subject: RE: letter from Secretary Hanger

Hi Josie,

I'm not sure what happened, but it appears that there was a printing error. The first sentence from question 1 is missing. Here is the full response and an electronic copy of the letter.

There were 36 active WQNs in the bituminous coal area during the time period requested. Twenty-eight were considered at risk and eight were not. All samples for the eight sites had specific conductivity < 132 umho/cm, chloride < 9 mg/l, sulfate < 20 mg/l, and total dissolved solids < 96 mg/l. The at risk sites were selected because one or more of their chloride, sulfate, or total dissolved solids concentrations were magnitudes higher than the concentrations observed at the eight non-risk (reference) sites. Field temperature is included but both specific conductance (SPC @ 25_0 C) and total dissolved solids (TDS @105 C) are reported at standardized temperatures by the lab. The enclosed spreadsheets titled Generalized summary listing the 28 at risk sites and mean concentrations and Individual sample results provide the data you are requesting.

Hope that helps!

Dana

-----Original Message-----
From: Josie Gaskey
Sent: Wednesday, September 09, 2009 9:32 AM
To: Aunkst, Dana
Subject: letter from Secretary Hanger

Hi Dana,

We received a letter from Secretary Hanger yesterday in response to our data request letter dated August 3, 2009. It appears that something is missing between the bottom of page 1 and the top of page 2. Also, do you have all this electronically? Thanks!

Josie Gaskey
Director, Regulatory and Technical Affairs
Pennsylvania Coal Association

samples for the eight sites had specific conductivity < 132 umho/cm, chloride < 9 mg/l, sulfate < 20 mg/l, and TDS < 96 mg/l. The at risk sites were selected because one or more of their chloride, sulfate, or TDS concentrations were magnitudes higher than the concentrations observed at the eight nonrisk (reference) sites. Field temperature is included but both specific conductance (SPC @ 25°C) and TDS (TDS @105°C) are reported at standardized temperatures by the lab. The enclosed spreadsheets titled *Generalized summary listing the 28 at risk sites and mean concentrations* and *Individual sample results* provide the data you are requesting.

2. *TDS, flow, sulfates, chlorides, specific conductance (including temperature of sample analysis) and location from each public water supply intake on the Monongahela River from July 1, 2008 through April 2009.*

   From October 14, 2008, through December 30, 2008, DEP monitored TDS, flow, sulfates, chlorides, specific conductance, and location. I am also enclosing a copy of those results. The results are also available on our Web site at the address listed above. The testing ceased in December 2008, so data is not available through April 2009, as requested.

3. *TDS, sulfates, chlorides, specific conductance (including temperature of sample analysis), flow and sample location from the Monongahela River between the West Virginia border and the confluence of the Youghiogheny and the Monongahela rivers in McKeesport, Allegheny County from July 1, 2008 through April 2009.*

   The results noted in our response to Item 2 above also list the sample locations. Please see the enclosed sample results for this information.

4. *The TDS test methodology used for the data in item numbers 2 and 3 above. Please explain the decision to use that particular test methodology.*

   The analytical method used to determine TDS for the Monongahela sampling was USGS-I-1749 used by Water Quality programs for stream analysis.

5. *All water sampling data and test methodology which led the Department to conclude in its January 21, 2009 press release that TDS levels, "... in the Monongahela River have dropped and remain well below state and federal guidelines."*

   As you will note in the enclosed monitoring results, starting in early December 2008, the TDS concentration at the various monitoring stations began to decline and after several weeks of continued low concentrations of TDS at monitoring stations throughout the Monongahela, DEP issued the January 21, 2009, press release you cite.

6. *All water sampling data and test methodology which led the Department to announce in it April 16, 2009 press release that, "High TDS solids in industrial waters have been a*

Mr. George L. Ellis 3 September 3, 2009

problem in the Monongahela River recently and are an impending problem on a state-wide basis"; and which resulted in the Department establishing base standards for high TDS water discharges, chlorides and sulfates.

See response to Items 1 and 2 above.

7. *All information and support data that the Department used in setting the new permitting limits for discharges of high TDS wastewater (500 mg/l), chlorides (250 mg/l) and sulfates (25 mg/l).*

Much of the information you are requesting is available on our Marcellus Shale Wastewater Partnership Web page, http://www.depweb.state.pa.us/watersupply/cwp/view.asp?a=1260&Q=545730&watersupplyNav=|30160|. I am enclosing a spreadsheet containing facilities that currently accept high TDS wastewater from oil and gas wells.

Thank you for your continued interest and willingness to work with us to address this high priority area. Should you have any questions, please contact Dana Aunkst, Bureau Director, Water Standards and Facility Regulation, by e-mail at daunkst@state.pa.us or by telephone at 717-787-5017.

Sincerely,

John Hanger
Secretary

Enclosures

[redacted]

From: Josie Gaskey
Sent: Friday, September 11, 2009 9:43 AM
To
Cc: George Ellis
Subject: Hanger TDS 8 reference sites

Good morning,

In the letter Secretary Hanger sent in response to our TDS data request, his response to our first question regarding at-risk streams discusses 28 at-risk streams and 8 non-risk or "reference" sites. In response to my email questioning the identity of the 8 sites, they responded with the following 8 reference site identifications:

Kettle Creek- Clinton Co
First Fork Sinnemahoning Creek- Potter Co
Killbuck Run- Cambria Co
Youghiogheny River, Somerset Co
Mill Run- Fayette Co
Tionesta Creek- Forest Co
Mill Creek- Westmoreland Co
Havens Run- McKean Co

Josie Gaskey
PA Coal Association

APPENDIX C

trash

Individual sample results

WQN	NAME	LONGITUDE	LATITUDE	SPC @ 25 deg C	CHLORIDE -IC	Stream Flow	SULFATE - IC	TDS @ 105 deg C	Water Temp
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	458	15		181	349	11
406	W BR SUSQUEHANNA RV	-78.677521	40.89719	426	16	67	127	296	6
422	CLEARFIELD CRK	-78.405937	40.986003	586	15	64	254	449	6
701	MONONGAHELA RVR	-79.880989	40.405596	442	33	19789	331	295	8
702	MONONGAHELA RVR	-79.904123	40.15201	423	16	7703	131	285	8
706	YOUGHIOGHENY RVR	-79.805358	40.241192	296	36	3097	55	185	8
714	DUNKARD CRK	-79.972879	39.760453	2377	25	29	1198	2119	9
725	MONONGAHELA RVR	-79.9118	39.7268	424	12	9068	139	294	10
726	CASSELMAN RVR	-79.100551	39.732376	216	36	19	25	138	6
727	CHEAT RVR	-79.900093	39.741596	202	5	5279	64	139	9
801	ALLEGHENY RVR	-79.8464	40.5271	258	24	12557	43	173	12
810	CONEMAUGH RVR	-79.390839	40.454069	947	52	73	281	674	15
820	REDBANK CRK	-79.393051	40.994618	351	21	2534	90	250	8
822	CLARION RVR	-79.208781	41.331617	293	14	233	76	193	6
843	CLARION RVR	-79.554229	41.129907	327	17	130	105	212	8
861	MAHONING CRK	-79.006109	40.92217	427	30	42	100	290	6
880	QUEMAHONING CREEK	-79.109143	40.068964	490	112	7	16	310	8
882	SOUTH FORK PINE CRK	-79.3637	40.8473	233	20	25	60	202	11
883	LITTLE YELLOW CRK	-79.0058	40.5565	279	10	25	66	185	8
884	ALLEGHENY RVR	-79.5226	40.8126	184	14	20648	25	124	11
902	OHIO RVR	-80.187562	40.53337	349	26	42967	73	219	13
903	RACCOON CRK	-80.337151	40.628259	1136	51	19	445	887	10
905	BEAVER RVR	-80.316945	40.766293	456	54	2720	52	295	14
907	CONNOQUENESSING CRK	-80.242144	40.816759	813	65	35	92	578	10
909	SHENANGO RVR	-80.355902	41.003298	306	35	644	25	203	9
915	MAHONING RVR	-80.440405	41.018472	652	85	548	70	437	9
917	CONNOQUENESSING CRK	-79.965282	40.806008	1371	130	19	132	1171	13
922	SLIPPERY ROCK CRK	-80.233723	40.884089	466	22	86	102	313	11

APPENDIX C

trash2

Generalized summary listing the 28 at risk sites and mean concentrations

WQN	NAME	LONGITUDE	LATITUDE	DATE COLLECTED	TIME COLLECTED	CHLORIDE -IC	SPC @ 25 deg C	Stream Flow	SULFATE - IC	TDS @ 105 deg C	Water Temp
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	7/14/2008	7:10:00 AM		519.0		221.0	400.0	24.4
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	8/11/2008	7:55:00 AM		582.0		240.0	466.0	23.1
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	9/15/2008	8:15:00 AM		507.0		202.0	382.0	22.6
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	10/14/2008	8:10:00 AM		740.0		334.0	590.0	14.7
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	11/11/2008	7:20:00 AM		697.0		300.0	532.0	7.9
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	12/8/2008	7:35:00 AM		415.0		138.0	314.0	1.5
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	1/14/2009	10:06:00 AM	15.2	334.0		115.0	250.0	0.2
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	2/11/2009	10:00:00 AM	22.7	316.0		92.1	220.0	2.1
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	3/16/2009	11:00:00 AM	12.7	311.0		119.0	228.0	7.2
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	4/5/2009	4:30:00 PM	13.8	305.0		104.0	204.0	
404	WEST BRANCH SUSQUEHANNA RIVER	-78.10884	41.116759	4/15/2009	11:00:00 AM	11.6	317.0		124.0	250.0	8.5
406	W BR SUSQUEHANNA RV	-78.677521	40.89719	8/19/2008	11:15:00 AM		614.0	67.0	197.0	446.0	20.3
406	W BR SUSQUEHANNA RV	-78.677521	40.89719	11/18/2008	10:30:00 AM		397.0		112.0	264.0	2.3
406	W BR SUSQUEHANNA RV	-78.677521	40.89719	1/27/2009	10:15:00 AM	16.7	393.0		115.0	274.0	0.1
406	W BR SUSQUEHANNA RV	-78.677521	40.89719	3/3/2009	10:15:00 AM	14.4	298.0		84.7	200.0	0.0
422	CLEARFIELD CRK	-78.405937	40.986003	8/19/2008	12:00:00 PM		816.0	64.0	391.0	668.0	21.6
422	CLEARFIELD CRK	-78.405937	40.986003	11/18/2008	1:00:00 PM		632.0		278.0	472.0	3.3
422	CLEARFIELD CRK	-78.405937	40.986003	1/27/2009	12:15:00 PM	15.1	525.0		211.0	396.0	0.0
422	CLEARFIELD CRK	-78.405937	40.986003	3/3/2009	1:00:00 PM	14.0	372.0		134.0	260.0	0.4
701	MONONGAHELA RVR	-79.880989	40.405596	7/24/2008	1:30:00 PM		378.0	24300.0	99.8	252.0	25.6
701	MONONGAHELA RVR	-79.880989	40.405596	11/19/2008	12:00:00 PM	54.8	1014.0	5880.0	348.0	698.0	9.5
701	MONONGAHELA RVR	-79.880989	40.405596	12/22/2008	12:00:00 PM	21.2	221.0	27900.0	38.9	156.0	3.8
701	MONONGAHELA RVR	-79.880989	40.405596	1/27/2009	1:00:00 PM	37.0	393.0	10820.0	1792.0	252.0	1.1
701	MONONGAHELA RVR	-79.880989	40.405596	1/27/2009	1:07:00 PM	38.3	394.0	10820.0	87.1	250.0	1.1
701	MONONGAHELA RVR	-79.880989	40.405596	2/11/2009	12:30:00 PM	33.5	289.0	54800.0	53.7	190.0	4.3
701	MONONGAHELA RVR	-79.880989	40.405596	3/26/2009	12:30:00 PM	38.3	576.0	4000.0	166.0	374.0	9.9
701	MONONGAHELA RVR	-79.880989	40.405596	4/15/2009	1:30:00 PM	18.0	267.0		64.0	184.0	10.5
702	MONONGAHELA RVR	-79.904123	40.15201	7/22/2008	11:20:00 AM		415.0	2640.0	103.0	258.0	26.1
702	MONONGAHELA RVR	-79.904123	40.15201	12/1/2008	10:30:00 AM	26.7	636.0	2000.0	225.0	424.0	6.0
702	MONONGAHELA RVR	-79.904123	40.15201	12/11/2008	11:00:00 AM	28.3	700.0	9780.0	247.0	482.0	3.8
702	MONONGAHELA RVR	-79.904123	40.15201	1/6/2009	12:20:00 PM	12.5	292.0	4940.0	79.5	196.0	3.7
702	MONONGAHELA RVR	-79.904123	40.15201	2/10/2009	12:00:00 PM	15.0	267.0	20000.0	69.6	188.0	2.0
702	MONONGAHELA RVR	-79.904123	40.15201	3/4/2009	2:30:00 PM	17.5	425.0	6860.0	127.0	304.0	2.9
702	MONONGAHELA RVR	-79.904123	40.15201	4/13/2009	10:45:00 AM	8.3	227.0		62.7	144.0	9.4
706	YOUGHIOGHENY RVR	-79.805358	40.241192	8/26/2008	2:50:00 PM		236.0	991.0	55.9	156.0	23.8
706	YOUGHIOGHENY RVR	-79.805358	40.241192	11/18/2008	11:45:00 AM	26.6	325.0		74.0	206.0	5.8
706	YOUGHIOGHENY RVR	-79.805358	40.241192	12/4/2008	12:15:00 PM	40.9	311.0	1450.0	50.2	174.0	3.4
706	YOUGHIOGHENY RVR	-79.805358	40.241192	1/7/2009	12:30:00 PM	49.9	356.0	6850.0	50.6	218.0	3.7
706	YOUGHIOGHENY RVR	-79.805358	40.241192	2/25/2009	12:00:00 PM	27.7	241.0		42.6	156.0	0.7

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APPENDIX C

trash2

WQN	NAME	LONGITUDE	LATITUDE	DATE COLLECTED	TIME COLLECTED	CHLORIDE -IC	SPC @ 25 deg C	Stream Flow	SULFATE - IC	TDS @ 105 deg C	Water Temp
706	YOUGHIOGHENY RVR	-79.805358	40.241192	3/31/2009	1:15:00 PM	41.3	317.0		52.7	204.0	7.7
706	YOUGHIOGHENY RVR	-79.805358	40.241192	4/13/2009	2:00:00 PM	30.7	287.0		56.8	180.0	8.9
714	DUNKARD CRK	-79.972879	39.760453	8/25/2008	10:30:00 AM		6940.0	29.0	3890.0	6780.0	22.5
714	DUNKARD CRK	-79.972879	39.760453	11/3/2008	2:15:00 PM		6080.0		3247.0	5478.0	11.9
714	DUNKARD CRK	-79.972879	39.760453	12/18/2008	12:00:00 PM		465.0		141.0	316.0	4.5
714	DUNKARD CRK	-79.972879	39.760453	2/18/2009	10:30:00 AM	23.6	806.0		282.0	588.0	2.3
714	DUNKARD CRK	-79.972879	39.760453	2/18/2009	10:35:00 AM	23.6	805.0		284.0	572.0	2.3
714	DUNKARD CRK	-79.972879	39.760453	3/31/2009	10:15:00 AM	23.0	628.0		211.0	448.0	7.6
714	DUNKARD CRK	-79.972879	39.760453	4/14/2009	10:00:00 AM	27.9	915.0		334.0	654.0	9.1
725	MONONGAHELA RVR	-79.9118	39.7268	8/12/2008	9:30:00 AM		496.0	650.0	169.0	352.0	24.9
725	MONONGAHELA RVR	-79.9118	39.7268	11/3/2008	1:30:00 PM		697.0	470.0	265.0	500.0	13.6
725	MONONGAHELA RVR	-79.9118	39.7268	11/3/2008	1:35:00 PM		698.0	470.0	264.0	504.0	13.6
725	MONONGAHELA RVR	-79.9118	39.7268	12/18/2008	10:50:00 AM		219.0	29000.0	50.8	136.0	3.8
725	MONONGAHELA RVR	-79.9118	39.7268	1/28/2009	10:45:00 AM	12.0	342.0		101.0	236.0	0.6
725	MONONGAHELA RVR	-79.9118	39.7268	2/18/2009	12:45:00 PM	9.7	271.0	5346.0	76.5	176.0	4.3
725	MONONGAHELA RVR	-79.9118	39.7268	3/31/2009	9:15:00 AM	18.1	432.0		124.0	298.0	10.0
725	MONONGAHELA RVR	-79.9118	39.7268	4/14/2009	12:15:00 PM	6.9	234.0	18470.0	65.1	152.0	9.7
726	CASSELMAN RVR	-79.100551	39.732376	8/18/2008	9:45:00 AM		226.0	19.0	35.4	152.0	16.4
726	CASSELMAN RVR	-79.100551	39.732376	11/17/2008	10:30:00 AM		251.0		25.1	160.0	2.9
726	CASSELMAN RVR	-79.100551	39.732376	12/16/2008	10:15:00 AM		165.8		16.8	112.0	3.5
726	CASSELMAN RVR	-79.100551	39.732376	1/26/2009	11:30:00 AM	49.7	278.0		28.3	182.0	0.0
726	CASSELMAN RVR	-79.100551	39.732376	2/26/2009	11:20:00 AM	39.4	224.0		24.4	128.0	1.4
726	CASSELMAN RVR	-79.100551	39.732376	3/2/2009	11:45:00 AM	33.4	201.0		23.7	128.0	0.0
726	CASSELMAN RVR	-79.100551	39.732376	4/28/2009	2:45:00 PM	23.1	164.9		22.4	106.0	19.0
727	CHEAT RVR	-79.900093	39.741596	8/12/2008	11:00:00 AM		296.0	212.0	97.6	204.0	22.8
727	CHEAT RVR	-79.900093	39.741596	11/4/2008	10:15:00 AM		496.0	213.0	178.0	356.0	13.3
727	CHEAT RVR	-79.900093	39.741596	12/18/2008	10:10:00 AM		91.3	13000.0	19.9	56.0	3.8
727	CHEAT RVR	-79.900093	39.741596	1/28/2009	11:30:00 AM	6.5	125.4		35.2	96.0	0.8
727	CHEAT RVR	-79.900093	39.741596	2/18/2009	12:00:00 PM	3.9	86.7	10000.0	21.9	60.0	4.6
727	CHEAT RVR	-79.900093	39.741596	3/10/2009	1:00:00 PM	6.8	222.0	250.0	71.5	142.0	6.9
727	CHEAT RVR	-79.900093	39.741596	4/14/2009	1:30:00 PM	3.7	93.2	8000.0	23.4	58.0	9.1
801	ALLEGHENY RVR	-79.8464	40.5271	8/6/2008	12:00:00 PM		274.0	5770.0	50.1	182.0	26.4
801	ALLEGHENY RVR	-79.8464	40.5271	12/2/2008	10:45:00 AM	34.0	305.0	14500.0	47.8	204.0	2.8
801	ALLEGHENY RVR	-79.8464	40.5271	3/23/2009	12:30:00 PM	19.0	195.6	17400.0	32.5	134.0	7.1
810	CONEMAUGH RVR	-79.390839	40.454069	8/26/2008	12:30:00 PM		1189.0	73.0	376.0	920.0	23.6
810	CONEMAUGH RVR	-79.390839	40.454069	11/13/2008	9:00:00 AM		1116.0		310.0	736.0	8.7
810	CONEMAUGH RVR	-79.390839	40.454069	3/19/2009	2:00:00 PM	52.0	537.0		156.0	366.0	11.3
820	REDBANK CRK	-79.393051	40.994618	8/20/2008	10:30:00 AM		424.0	97.0	105.0	312.0	20.2
820	REDBANK CRK	-79.393051	40.994618	11/17/2008	11:00:00 AM		526.0		139.0	340.0	4.8
820	REDBANK CRK	-79.393051	40.994618	1/13/2009	10:45:00 AM	24.3	274.0	835.0	73.9	194.0	0.0
820	REDBANK CRK	-79.393051	40.994618	3/9/2009	11:10:00 AM	17.4	180.8	6670.0	41.0	152.0	5.7

APPENDIX C

trash2

WQN	NAME	LONGITUDE	LATITUDE	DATE COLLECTED	TIME COLLECTED	CHLORIDE -IC	SPC @ 25 deg C	Stream Flow	SULFATE - IC	TDS @ 105 deg C	Water Temp
822	CLARION RVR	-79.208781	41.331617	8/27/2008	1:30:00 PM		420.0	233.0	114.0	280.0	21.7
822	CLARION RVR	-79.208781	41.331617	12/9/2008	10:30:00 AM		320.0		81.0	204.0	0.0
822	CLARION RVR	-79.208781	41.331617	12/9/2008	10:37:00 AM		323.0		81.1	210.0	0.0
822	CLARION RVR	-79.208781	41.331617	1/14/2009	9:15:00 AM	16.6	224.0		54.9	146.0	0.0
822	CLARION RVR	-79.208781	41.331617	3/31/2009	12:45:00 PM	11.8	176.7		47.0	124.0	6.6
843	CLARION RVR	-79.554229	41.129907	8/28/2008	2:10:00 PM		388.0	130.0	125.0	256.0	20.7
843	CLARION RVR	-79.554229	41.129907	11/25/2008	1:15:00 PM	33.2	492.0		164.0	302.0	3.7
843	CLARION RVR	-79.554229	41.129907	1/13/2009	1:20:00 PM	14.0	200.0		58.6	134.0	0.5
843	CLARION RVR	-79.554229	41.129907	3/31/2009	9:15:00 AM	13.1	228.0		72.7	154.0	5.5
861	MAHONING CRK	-79.006109	40.92217	8/19/2008	8:00:00 AM		542.0	42.0	129.0	374.0	20.4
861	MAHONING CRK	-79.006109	40.92217	11/18/2008	9:30:00 AM		410.0		91.9	272.0	2.3
861	MAHONING CRK	-79.006109	40.92217	1/27/2009	8:45:00 AM	31.2	429.0		107.0	294.0	0.1
861	MAHONING CRK	-79.006109	40.92217	3/3/2009	9:15:00 AM	28.8	327.0		73.2	220.0	0.0
880	QUEMAHONING CREEK	-79.109143	40.068964	7/9/2008	1:00:00 PM	108.0	497.0	1.7	13.3	290.0	19.8
880	QUEMAHONING CREEK	-79.109143	40.068964	8/18/2008	12:30:00 PM	120.0	551.0	0.6	13.7	372.0	17.0
880	QUEMAHONING CREEK	-79.109143	40.068964	9/17/2008	10:00:00 AM	106.0	494.0	1.2	16.1	334.0	12.8
880	QUEMAHONING CREEK	-79.109143	40.068964	10/27/2008	12:45:00 PM	139.0	605.0	0.4	17.4	372.0	7.1
880	QUEMAHONING CREEK	-79.109143	40.068964	11/17/2008	1:30:00 PM	134.0	584.0	0.7	18.3	370.0	3.1
880	QUEMAHONING CREEK	-79.109143	40.068964	12/16/2008	1:00:00 PM	88.8	382.0	23.4	16.3	238.0	3.4
880	QUEMAHONING CREEK	-79.109143	40.068964	1/26/2009	1:00:00 PM	154.0	604.0	4.3	17.0	372.0	0.0
880	QUEMAHONING CREEK	-79.109143	40.068964	2/17/2009	1:00:00 PM	83.3	375.0	17.5	14.8	242.0	0.2
880	QUEMAHONING CREEK	-79.109143	40.068964	3/2/2009	1:30:00 PM	110.0	456.0	12.5	15.6	280.0	0.3
880	QUEMAHONING CREEK	-79.109143	40.068964	4/28/2009	12:45:00 PM	74.2	354.0	4.6	15.0	228.0	15.3
882	SOUTH FORK PINE CRK	-79.3637	40.8473	7/16/2008	11:15:00 AM	23.9	369.0	2.0	82.0	258.0	21.2
882	SOUTH FORK PINE CRK	-79.3637	40.8473	7/16/2008	11:30:00 AM	0.5	1.5		1.0	20.0	
882	SOUTH FORK PINE CRK	-79.3637	40.8473	8/20/2008	12:45:00 PM	35.5	466.0	0.6	101.0	354.0	18.4
882	SOUTH FORK PINE CRK	-79.3637	40.8473	9/17/2008	11:00:00 AM	25.3	371.0	1.2	73.8	258.0	15.2
882	SOUTH FORK PINE CRK	-79.3637	40.8473	10/7/2008	11:15:00 AM	40.7	535.0	0.8	122.0	392.0	9.4
882	SOUTH FORK PINE CRK	-79.3637	40.8473	11/17/2008	1:00:00 PM	22.4	320.0	3.3	63.3	200.0	4.7
882	SOUTH FORK PINE CRK	-79.3637	40.8473	12/15/2008	10:30:00 AM	14.3	196.8	33.1	37.1	148.0	4.3
882	SOUTH FORK PINE CRK	-79.3637	40.8473	2/18/2009	11:00:00 AM	10.3	205.0	33.4	50.6	136.0	1.6
882	SOUTH FORK PINE CRK	-79.3637	40.8473	3/9/2009	1:30:00 PM	12.0	142.9	122.0	27.3	120.0	5.9
882	SOUTH FORK PINE CRK	-79.3637	40.8473	4/27/2009	10:30:00 AM	10.2	185.6	24.5	43.8	132.0	14.8
883	LITTLE YELLOW CRK	-79.0058	40.5565	7/21/2008	2:00:00 PM	8.0	341.0	6.5	86.8	242.0	20.3
883	LITTLE YELLOW CRK	-79.0058	40.5565	8/18/2008	3:30:00 PM	7.7	458.0	2.1	126.0	306.0	18.7
883	LITTLE YELLOW CRK	-79.0058	40.5565	9/16/2008	2:15:00 PM	8.0	343.0	3.2	84.7	232.0	15.5
883	LITTLE YELLOW CRK	-79.0058	40.5565	10/28/2008	1:30:00 PM	9.2	352.0	3.7	86.4	220.0	6.5
883	LITTLE YELLOW CRK	-79.0058	40.5565	11/18/2008	8:00:00 AM	11.8	327.0	5.4	80.3	202.0	2.3
883	LITTLE YELLOW CRK	-79.0058	40.5565	12/17/2008	8:00:00 AM	21.0	186.3	91.9	25.6	132.0	3.5
883	LITTLE YELLOW CRK	-79.0058	40.5565	2/23/2009	1:30:00 PM	9.4	178.6	21.0	38.8	116.0	0.0
883	LITTLE YELLOW CRK	-79.0058	40.5565	3/3/2009	8:30:00 AM	9.7	177.6	10.6	38.4	122.0	0.0

APPENDIX C

trash2

WQN	NAME	LONGITUDE	LATITUDE	DATE COLLECTED	TIME COLLECTED	CHLORIDE -IC	SPC @ 25 deg C	Stream Flow	SULFATE - IC	TDS @ 105 deg C	Water Temp
883	LITTLE YELLOW CRK	-79.0058	40.5565	4/7/2009	2:00:00 PM	7.3	139.2	38.1	29.6	90.0	4.4
884	ALLEGHENY RVR	-79.5226	40.8126	8/4/2008	2:00:00 PM		199.8	4850.0	26.7	134.0	25.0
884	ALLEGHENY RVR	-79.5226	40.8126	8/4/2008	2:05:00 PM		199.7	4850.0	26.8	130.0	25.0
884	ALLEGHENY RVR	-79.5226	40.8126	11/24/2008	11:00:00 AM		223.0	9040.0	23.3	136.0	2.5
884	ALLEGHENY RVR	-79.5226	40.8126	1/8/2009	1:00:00 PM	18.1	181.6	24400.0	29.7	124.0	0.8
884	ALLEGHENY RVR	-79.5226	40.8126	3/11/2009	1:00:00 PM	10.3	116.3	60100.0	16.8	94.0	3.7
902	OHIO RVR	-80.187562	40.53337	7/24/2008	11:20:00 AM		386.0	32000.0	90.1	256.0	27.2
902	OHIO RVR	-80.187562	40.53337	11/19/2008	10:00:00 AM	46.1	462.0	22100.0	95.4	278.0	8.2
902	OHIO RVR	-80.187562	40.53337	3/12/2009	11:30:00 AM	16.6	197.8	74800.0	33.6	124.0	4.4
903	RACCOON CRK	-80.337151	40.628259	8/11/2008	2:30:00 PM		1214.0	19.0	496.0	966.0	22.8
903	RACCOON CRK	-80.337151	40.628259	11/24/2008	12:00:00 AM		1355.0		560.0	1084.0	0.1
903	RACCOON CRK	-80.337151	40.628259	3/26/2009	2:15:00 PM	50.7	840.0		279.0	612.0	7.5
905	BEAVER RVR	-80.316945	40.766293	8/13/2008	11:30:00 AM		466.0	1290.0	53.2	314.0	22.2
905	BEAVER RVR	-80.316945	40.766293	11/5/2008	10:30:00 AM	61.7	525.0	1070.0	59.7	324.0	11.5
905	BEAVER RVR	-80.316945	40.766293	3/17/2009	12:45:00 PM	49.7	377.0	5800.0	43.8	248.0	6.9
907	CONNOQUENESSING CRK	-80.242144	40.816759	8/18/2008	10:45:00 AM		1014.0	35.0	118.0	770.0	22.0
907	CONNOQUENESSING CRK	-80.242144	40.816759	11/24/2008	11:20:00 AM		924.0		98.9	660.0	0.3
907	CONNOQUENESSING CRK	-80.242144	40.816759	3/26/2009	12:30:00 PM	65.4	500.0		58.2	304.0	6.7
909	SHENANGO RVR	-80.355902	41.003298	8/21/2008	2:30:00 PM		345.0	238.0	26.0	232.0	23.3
909	SHENANGO RVR	-80.355902	41.003298	11/20/2008	12:45:00 PM	35.8	320.0	555.0	23.5	198.0	5.5
909	SHENANGO RVR	-80.355902	41.003298	1/20/2009	1:40:00 PM	37.0	306.0	1000.0	25.4	192.0	0.1
909	SHENANGO RVR	-80.355902	41.003298	3/24/2009	12:30:00 PM	28.3	253.0	783.0	23.8	190.0	6.9
915	MAHONING RVR	-80.440405	41.018472	8/21/2008	10:15:00 AM		611.0	461.0	64.5	416.0	22.6
915	MAHONING RVR	-80.440405	41.018472	11/20/2008	10:15:00 AM		778.0		71.6	502.0	6.7
915	MAHONING RVR	-80.440405	41.018472	1/20/2009	11:30:00 AM	96.5	661.0	635.0	75.3	444.0	0.6
915	MAHONING RVR	-80.440405	41.018472	3/24/2009	10:15:00 AM	73.2	557.0		66.6	386.0	6.5
917	CONNOQUENESSING CRK	-79.965282	40.806008	8/27/2008	11:30:00 AM		1677.0	19.0	188.0	1548.0	20.8
917	CONNOQUENESSING CRK	-79.965282	40.806008	8/27/2008	11:35:00 AM		1682.0	19.0	188.0	1534.0	20.8
917	CONNOQUENESSING CRK	-79.965282	40.806008	11/24/2008	10:00:00 AM		1493.0		102.0	1190.0	2.3
917	CONNOQUENESSING CRK	-79.965282	40.806008	3/26/2009	10:45:00 AM	130.0	632.0		49.0	410.0	6.5
922	SLIPPERY ROCK CRK	-80.233723	40.884089	8/18/2008	1:00:00 PM		441.0	86.0	88.0	290.0	21.1
922	SLIPPERY ROCK CRK	-80.233723	40.884089	11/13/2008	11:30:00 AM		548.0		118.0	372.0	6.7
922	SLIPPERY ROCK CRK	-80.233723	40.884089	3/25/2009	12:15:00 PM	22.3	409.0		99.2	276.0	6.4

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Monongahela River TDS, Chloride, and Sulfate Sampling Results

SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
90.0	Mon River RMI 90.0 near Point Marion, PA	0593-011	10/14/2008	719	486	15.9	NA
		0593-027	10/22/2008	631	438	13.7	228
		NA	10/28/2008	512	NA	NA	NA
		NA	11/3/2008	550	NA	NA	NA
		0593-080	11/5/2008	531	516	16.4	255.9
		NA	11/7/2008	774	NA	NA	NA
		NA	11/10/2008	525	NA	NA	NA
		0593-083	11/12/2008	699	486	17.8	222.9
		NA	11/14/2008	550	NA	NA	NA
		NA	11/17/2008	500	NA	NA	NA
		0593-088	11/19/2008	442	416	16.8	172.9
		NA	11/21/2008	432	NA	NA	NA
		0552-881	11/25/2008	733	502	18.2	238.9
		NA	12/1/2008	846	NA	NA	NA
		0593-089	12/4/2008	954	570	22.7	269.2
		NA	12/8/2008	825	NA	NA	NA
		0552-883	12/11/2008	570	466	30.8	163.3
		NA	12/15/2008	197	NA	NA	NA
		0552-884	12/18/2008	285	148	11.1	46.9
		0552-885	12/23/2008	165	112	6.6	40.1
		0552-886	12/30/2008	188	130	6	50.3

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Monongahela River TDS, Chloride, and Sulfate Sampling Results
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SAMPLE INFORMATION				PARAMETER (UNITS)			
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	SPECIFIC CONDUCTANCE (uS/cm)	TDS @ 105C (mg/L)	CHLORIDE (mg/L)	SULFATE (mg/L)
46.0	Mon River RMI 46.0 near Fayette City, PA	0594-117	10/22/2008	865	708	49.2	351
		0585-156	10/22/2008	NA	708	49.9	351
		1523-053	10/30/2008	NA	850	47.8	448
		1523-065	11/5/2008	1060	862	51.3	424
		1523-083	11/12/2008	1095	852	49.3	417
		1523-095	11/19/2008	925	698	37.6	367
		1507-276	11/25/2008	980	678	41.5	331
		1523-107	12/4/2008	599	400	27.3	197
		1523-119	12/11/2008	666	520	32.1	264
		1523-131	12/18/2008	224	138	15.4	52.1
		1523-143	12/23/2008	224	144	9.53	51.9
		1523-155	12/30/2008	258	196	11.3	77.9
43.0	Mon River RMI 43.0 upstream of Charleroi, PA	0585-154	10/22/2008	NA	696	47.6	348
		1523-058	10/30/2008	NA	842	49.3	451
		1523-067	11/5/2008	1165	854	51.8	433
		1523-081	11/12/2008	1115	838	49.2	425
		1523-093	11/19/2008	980	730	40.3	391
		1507-274	11/25/2008	977	646	39.3	331
		1523-105	12/4/2008	558	378	26.4	183
		1523-117	12/11/2008	614	504	29.6	254
		1523-129	12/18/2008	185	112	13.3	42.4
		1523-141	12/23/2008	180	108	7.78	44.4
		1523-153	12/30/2008	276	184	10	75

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Monongahela River TDS, Chloride, and Sulfate Sampling Results
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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
42.0	Mon River RMI 42.0 Charleroi, PA	0594-116	10/22/2008	838	682	40	354
		0585-152	10/22/2008	NA	644	42	341
		1523-055	10/30/2008	NA	860	48.4	455
		1523-069	11/5/2008	1161	856	47.9	436
		1523-079	11/12/2008	1133	854	45.7	420
		1523-091	11/19/2008	973	730	38.8	401
		1507-272	11/25/2008	871	648	39.2	350
		1523-103	12/4/2008	515	362	27	176
		1523-115	12/11/2008	662	500	28	249
		1523-127	12/18/2008	177	112	12.5	41.8
		1523-139	12/23/2008	183	132	8.08	45.8
		1523-151	12/30/2008	241	174	9.61	69
41.0	Mon River RMI 41.0 downstream of Charleroi, PA	0552-864	10/15/2008	934	752	62	411.3
		NA	10/25/2008	734	NA	NA	NA
		0592-198	10/26/2008	783	726	55.4	381.2
		NA	10/27/2008	1065	NA	NA	NA
		NA	10/28/2008	1141	NA	NA	NA
		NA	10/29/2008	1196	NA	NA	NA
40.0	Mon River RMI 40.0 near Monessan, PA	0594-124	10/22/2008	1018	722	46.1	356

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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
36.0	Mon River RMI 36.0 near Donora, PA	0594-125	10/22/2008	1053	738	54.9	363
		0594-152	11/3/2008	1203	NA	NA	NA
		NA	11/5/2008	1212	NA	NA	NA
		NA	11/7/2008	1188	NA	NA	NA
		NA	11/10/2008	1195	NA	NA	NA
		NA	11/12/2008	820	NA	NA	NA
		NA	11/14/2008	1210	NA	NA	NA
		NA	11/17/2008	825	NA	NA	NA
		NA	11/19/2008	768	NA	NA	NA
		NA	11/21/2008	678	NA	NA	NA
		NA	11/25/2008	960	NA	NA	NA
		NA	12/1/2008	669	NA	NA	NA
		NA	12/4/2008	450	NA	NA	NA
		NA	12/8/2008	763	NA	NA	NA
		NA	12/11/2008	779	NA	NA	NA
		NA	12/15/2008	204	NA	NA	NA
		NA	12/18/2008	184	NA	NA	NA
		NA	12/23/2008	166	NA	NA	NA
		NA	12/30/2008	228	NA	NA	NA
34.2	Mon River RMI 34.2 upstream of Sunfish Run	0594-126	10/22/2008	1066	732	58.7	362
32.5	Mon River RMI 32.5 upstream of Pigeon Creek	0594-127	10/22/2008	1090	738	62.6	367
30.0	Mon River RMI 30.0 upstream of Mingo Crk	0594-128	10/22/2008	1160	804	64.5	399
26.0	Mon River RMI 26.0 upstream of Kelly Run	0594-129	10/22/2008	1120	800	46	391

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SAMPLE INFORMATION				PARAMETER (UNITS)			
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	SPECIFIC CONDUCTANCE (uS/cm)	TDS @ 105C (mg/L)	CHLORIDE (mg/L)	SULFATE (mg/L)
25.0	Mon River RMI 25.0 near Elrama, PA	0585-150	10/22/2008	NA	828	51.3	388
		1523-060	10/30/2008	NA	742	55.9	362
		NA	11/3/2008	1088	NA	NA	NA
		1523-071	11/5/2008	1067	860	53.7	416
		NA	11/7/2008	1263	NA	NA	NA
		NA	11/10/2008	1267	NA	NA	NA
		1523-077	11/12/2008	1156	900	56.7	467
		NA	11/14/2008	1261	NA	NA	NA
		NA	11/17/2008	900	NA	NA	NA
		1523-089	11/19/2008	973	862	54.9	439
		NA	11/21/2008	798	NA	NA	NA
		1507-270	11/25/2008	977	778	43.6	403
		NA	12/1/2008	808	NA	NA	NA
		1523-101	12/4/2008	614	472	28.9	227
		NA	12/8/2008	580	NA	NA	NA
		1523-113	12/11/2008	399	400	31.4	187
		NA	12/15/2008	240	NA	NA	NA
		1523-125	12/18/2008	211	138	15.4	50.8
		1523-137	12/23/2008	195	142	9.97	47.8
		1523-149	12/30/2008	258	178	12.9	69.4

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SAMPLE INFORMATION				PARAMETER (UNITS)			
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	SPECIFIC CONDUCTANCE (uS/cm)	TDS @ 105°C (mg/L)	CHLORIDE (mg/L)	SULFATE (mg/L)
24.0	Mon River RMI 24.0 USGS Gage Sta Elizabeth	NA	10/22/2008	1110	NA	NA	NA
		NA	10/29/2008	1080	NA	NA	NA
		NA	10/30/2008	1080	NA	NA	NA
		NA	10/31/2008	1050	NA	NA	NA
		NA	11/1/2008	1050	NA	NA	NA
		NA	11/2/2008	1060	NA	NA	NA
		NA	11/3/2008	1070	NA	NA	NA
		NA	11/4/2008	1070	NA	NA	NA
		NA	11/5/2008	1090	NA	NA	NA
		NA	11/6/2008	1160	NA	NA	NA
		NA	11/7/2008	1220	NA	NA	NA
		NA	11/10/2008	1280	NA	NA	NA
		NA	11/12/2008	1260	NA	NA	NA
		NA	11/14/2008	1260	NA	NA	NA
		NA	11/17/2008	1250	NA	NA	NA
		NA	11/19/2008	1200	NA	NA	NA
		NA	11/25/2008	1100	NA	NA	NA
		NA	12/1/2008	873	NA	NA	NA
		NA	12/4/2008	686	NA	NA	NA
		NA	12/8/2008	586	NA	NA	NA
		NA	12/11/2008	609	NA	NA	NA
		NA	12/15/2008	229	NA	NA	NA
		NA	12/18/2008	196	NA	NA	NA
		NA	12/23/2008	181	NA	NA	NA
		NA	12/30/2008	241	NA	NA	NA

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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
23.0	Mon River RMI 23.0 below dam	0594-130	10/22/2008	1120	762	56.5	384
20.5	Mon River RMI 20.5 upstream of Peters Creek	0594-131	10/22/2008	1097	752	55.8	368
17.5	Mon River RMI 17.5 near Glassport, PA	0594-132	10/22/2008	1152	776	64.9	384
16.7	Mon River RMI 16.7 @ W.D. Mansfield Memorial Bridge	NA	10/25/2008	1200	NA	NA	NA
		NA	10/26/2008	1140	NA	NA	NA
		NA	10/27/2008	1141	NA	NA	NA
		NA	10/28/2008	1145	NA	NA	NA
		NA	10/29/2008	1253	NA	NA	NA
		NA	11/3/2008	1160	NA	NA	NA
		NA	11/5/2008	1174	NA	NA	NA
		NA	11/7/2008	1118	NA	NA	NA
		NA	11/10/2008	1122	NA	NA	NA
		NA	11/12/2008	880	NA	NA	NA
		NA	11/14/2008	1317	NA	NA	NA
		NA	11/17/2008	900	NA	NA	NA
		NA	11/19/2008	883	NA	NA	NA
		NA	11/21/2008	819	NA	NA	NA
		NA	11/25/2008	1162	NA	NA	NA
		NA	12/1/2008	898	NA	NA	NA
		NA	12/4/2008	855	NA	NA	NA
		NA	12/8/2008	516	NA	NA	NA
		NA	12/11/2008	536	NA	NA	NA
		NA	12/15/2008	240	NA	NA	NA
		NA	12/18/2008	186	NA	NA	NA
		NA	12/23/2008	182	NA	NA	NA
		NA	12/30/2008	241	NA	NA	NA

Beginning 11/25 all specific conductance field measurements temperature corrected to 25 degree C.

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Monongahela River TDS, Chloride, and Sulfate Sampling Results
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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
12.0	Mon River RMI 12.0 upstream of Turtle Creek	0594-135	10/22/2008	746	480	48.1	225
11.0	Mon River RMI 11.0 downstream of Turtle Creek	0552-868	10/17/2008	666	524	52.3	279.2
9.0	Mon River RMI 9.0 dwnstrm of dam	0594-137	10/22/2008	793	526	51.3	239
4.5	Mon River RMI 4.5 near Glenwood, PA	0594-138	10/22/2008	644	414	41.1	186
3.1	Mon River RMI 3.1 Hot Metal Street Bridge	NA	11/3/2008	797	NA	NA	NA
		0594-158	11/5/2008	737	494	55.8	194.4
		NA	11/7/2008	700	NA	NA	NA
		NA	11/10/2008	662	NA	NA	NA
		0592-225	11/12/2008	590	532	56.5	198.8
		NA	11/14/2008	752	NA	NA	NA
		NA	11/17/2008	550	NA	NA	NA
		0594-169	11/19/2008	734	750	62.6	349.1
		NA	11/21/2008	706	NA	NA	NA
		0594-178	11/25/2008	950	734	58.1	334.9
		NA	12/1/2008	872	NA	NA	NA
		0592-237	12/4/2008	677	478	52	207.2
		NA	12/8/2008	557	NA	NA	NA
		0594-189	12/11/2008	709	522	46	243
		NA	12/15/2008	243	NA	NA	NA
		0592-248	12/18/2008	225	150	19.4	42.9
		0592-249	12/23/2008	189	136	13.1	41.4
		0594-205	12/30/2008	229	166	16	51.7

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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
88.2	Mon River RMI 88.2 upstream of Dunkard Creek	0593-028	10/22/2008	584	406	12.4	213
		1630-166	10/22/2008	NA	486	15	226
		1620-191	10/29/2008	NA	462	14.6	233
		NA	11/3/2008	350	NA	NA	NA
		1620-210	11/5/2008	693	488	21.5	263
		1630-216	11/12/2008	513	356	11.7	189
		NA	11/14/2008	510	NA	NA	NA
		NA	11/17/2008	200	NA	NA	NA
		1630-228	11/19/2008	246	142	4.89	79.1
		1630-240	11/25/2008	567	412	15.7	220
		1630-252	12/4/2008	353	254	11.6	127
		1630-264	12/11/2008	505	354	23.2	169
		1630-276	12/18/2008	198	132	10.4	48.1
		1630-288	12/23/2008	153	112	6.55	41.2
		1630-298	12/30/2008	190	130	6.05	53
85.5	Mon River RMI 85.5 upstream of Georges Creek	0593-030	10/22/2008	942	666	18.4	374
84.0	Mon River RMI 84.0 upstream of Jacobs Creek	0593-031	10/22/2008	812	580	16.3	316

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SAMPLE INFORMATION				PARAMETER (UNITS)			
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	SPECIFIC CONDUCTANCE (uS/cm)	TDS @ 105°C (mg/L)	CHLORIDE (mg/L)	SULFATE (mg/L)
83.0	Mon River RMI 83.0 downstream of Jacobs Creek	1630-162	10/22/2008	NA	630	19.6	333
		1620-189	10/29/2008	NA	602	18.7	315
		NA	11/3/2008	525	NA	NA	NA
		1620-208	11/5/2008	650	506	17.2	274
		NA	11/7/2008	812	NA	NA	NA
		NA	11/10/2008	525	NA	NA	NA
		1630-214	11/12/2008	687	474	14.3	258
		1630-226	11/19/2008	489	312	13.4	168
		NA	11/21/2008	332	NA	NA	NA
		1630-238	11/25/2008	383	268	10.9	139
		NA	12/1/2008	512	NA	NA	NA
		1630-250	12/4/2008	446	316	15.4	172
		NA	12/8/2008	475	NA	NA	NA
		1630-262	12/11/2008	425	296	15.9	147
		NA	12/15/2008	190	NA	NA	NA
		1630-274	12/18/2008	163	114	8.74	41.2
		1630-286	12/23/2008	146	104	24	45
		1630-296	12/30/2008	159	110	5.42	47.2
82.1	Mon River RMI 82.1 upstream of Grays Landing L/D	0593-017	10/15/2008	974	676	22.7	NA
		0593-032	10/22/2008	934	680	18.7	374
80.5	Mon River RMI 80.5 upstream of Whiteley Creek	0552-878	10/22/2008	759	672	20.6	384

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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
79.5	Mon River RMI 79.5 upstrm downstream of Whiteley Creek	0552-877	10/22/2008	785	696	26.1	391
		1630-158	10/22/2008	NA	734	29.9	392
		1620-187	10/29/2008	NA	574	19.9	304
		1620-206	11/5/2008	813	620	29.8	323
		1630-212	11/12/2008	734	544	22.4	296
		1630-224	11/19/2008	544	380	17.6	212
		1630-236	11/25/2008	468	312	13.4	168
		1630-248	12/4/2008	923	682	31.2	378
		1630-260	12/11/2008	369	272	14.9	131
		1630-272	12/18/2008	149	114	8.07	37
		1630-284	12/23/2008	147	104	5.6	38
		1630-294	12/30/2008	167	114	5.74	52
78.0	Mon River RMI 78.3 downstream Little Whiteley Creek	0593-021	10/15/2008	976	676	24.2	NA
		0552-876	10/22/2008	792	710	26.9	393
76.0	Mon River RMI 76.0 upstrm Middle Run near Carmichael	0552-875	10/22/2008	805	720	25.5	398

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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
75.0	Mon River RMI 75.0 near Carmichael, PA	1630-170	10/22/2008	NA	800	29.9	409
		1620-193	10/29/2008	NA	702	29.7	399
		NA	11/3/2008	770	NA	NA	NA
		1620-204	11/5/2008	947	734	26.1	407
		NA	11/7/2008	916	NA	NA	NA
		NA	11/10/2008	650	NA	NA	NA
		1630-218	11/12/2008	907	638	31	342
		NA	11/14/2008	800	NA	NA	NA
		NA	11/17/2008	600	NA	NA	NA
		1630-230	11/19/2008	744	492	18.2	274
		NA	11/21/2008	312	NA	NA	NA
		1630-242	11/25/2008	421	286	13.7	139
		NA	12/1/2008	490	NA	NA	NA
		1630-254	12/4/2008	801	584	28	314
		NA	12/8/2008	497	NA	NA	NA
		1630-266	12/11/2008	410	272	16.4	135
		NA	12/15/2008	183	NA	NA	NA
		1630-278	12/18/2008	164	116	8.87	39.9
		1630-290	12/23/2008	141	100	6.1	40.2
		1630-300	12/30/2008	193	132	6.42	53.3
73.5	Mon River RMI 73.5 dwnstrm of Wallace Run	0552-874	10/22/2008	847	770	27.1	420

Beginning 11/25 all specific conductance field measurements temperature corrected to 25 degree C.

APPENDIX C

Monongahela River TDS, Chloride, and Sulfate Sampling Results

SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
71.0	Mon River RMI 71.0 near Crucible, PA	1630-174	10/22/2008	NA	768	26.2	388
		1620-187	10/29/2008	NA	676	22.5	363
		1620-202	11/5/2008	867	638	23.7	320
		1630-220	11/12/2008	854	592	26.2	313
		1630-232	11/19/2008	794	586	22	328
		1630-244	11/25/2008	424	278	13.1	138
		1630-256	12/4/2008	679	300	27.2	254
		1630-268	12/11/2008	659	452	23.1	229
		1630-280	12/18/2008	160	122	8.64	37.6
		1630-302	12/30/2008	177	128	5.82	47.7
69.0	Mon River RMI 69.0 upstream of Pumpkin Run	0552-873	10/22/2008	906	786	38	429
66.0	Mon River RMI 66.0 upstream of Tenmile Creek	0552-872	10/22/2008	895	794	39.5	416

Beginning 11/25 all specific conductance field measurements temperature corrected to 25 degree C.

APPENDIX C

Monongahela River TDS, Chloride, and Sulfate Sampling Results
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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
64.5	Mon River RMI 64.5 downstream of Tenmile Creek	0593-023	10/15/2008	2009	852	45.4	NA
		1630-178	10/22/2008	NA	874	50.6	440
		0552-870	10/22/2008	958	844	51.1	436
		0592-201	10/26/2008	904	812	47.9	415
		1620-197	10/29/2008	NA	850	49.9	428
		NA	11/3/2008	850	NA	NA	NA
		1620-200	11/5/2008	991	756	37.4	395
		NA	11/7/2008	1133	NA	NA	NA
		NA	11/10/2008	775	NA	NA	NA
		1630-222	11/12/2008	956	696	32.5	364
		NA	11/14/2008	825	NA	NA	NA
		NA	11/17/2008	600	NA	NA	NA
		1630-234	11/19/2008	852	554	28.6	308
		NA	11/21/2008	639	NA	NA	NA
		1630-246	11/25/2008	650	438	23.8	231
		NA	12/1/2008	912	NA	NA	NA
		1630-258	12/4/2008	508	266	20.9	172
		NA	12/8/2008	615	NA	NA	NA
		1630-270	12/11/2008	549	374	26.4	181
		NA	12/15/2008	236	NA	NA	NA
		1630-282	12/18/2008	200	116	14.3	42
		1630-292	12/23/2008	203	126	13.9	47
		1630-304	12/30/2008	249	180	10.9	60

Beginning 11/25 all specific conductance field measurements temperature corrected to 25 degree C.

Monongahela River TDS, Chloride, and Sulfate Sampling Results
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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
60.5	Mon River Pool-4 RMI 60.5 upstream of Kelly Run	0594-123	10/22/2008	1012	862	44.9	455
57.5	Mon River Pool-4 RMI 57.5 upstream of Dunlap Creek	0594-122	10/22/2008	993	858	46.3	458
		0585-158	10/22/2008	NA	908	45	480
		1523-061	10/30/2008	NA	820	45.6	431
		1523-073	11/5/2008	1229	832	51.4	427
		1523-087	11/12/2008	952	784	34.7	408
		1523-099	11/19/2008	865	606	31.6	325
		1507-278	11/25/2008	832	574	23.9	307
		1523-112	12/4/2008	652	492	34.2	263
		1523-123	12/11/2008	549	318	17.7	158
		1523-135	12/18/2008	164	104	10.7	40.7
		1523--159	12/30/2008	115	136	7.21	55.1
55.5	Mon River Pool-4 RMI 55.5 upstream of Redstone Creek	0594-121	10/22/2008	985	864	42.1	455
52.5	Mon Riverl RMI 52.5 downstream of Redstone Creek	0594-119	10/22/2008	988	862	45.9	460

Beginning 11/25 all specific conductance field measurements temperature corrected to 25 degree C.

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Monongahela River TDS, Chloride, and Sulfate Sampling Results
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SAMPLE INFORMATION				PARAMETER (UNITS)			
				SPECIFIC CONDUCTANCE	TDS @ 105°C	CHLORIDE	SULFATE
RMI	SAMPLE LOCATION	SAMPLE ID#	DATE COLLECTED	(uS/cm)	(mg/L)	(mg/L)	(mg/L)
50.5	Mon River RMI 50.5 near Newell, PA	0594-118	10/22/2008	969	830	49.8	431
		1630-185	10/23/2008	NA	844	49.3	433
		1523-063	10/30/2008	NA	832	49.9	431
		NA	11/3/2008	900	NA	NA	NA
		1523-075	11/5/2008	1155	816	48	423
		NA	11/10/2008	800	NA	NA	NA
		1523-085	11/12/2008	952	842	53.9	429
		NA	11/14/2008	900	NA	NA	NA
		NA	11/14/2008	725	NA	NA	NA
		1523-097	11/19/2008	978	676	34.6	384
		1507-280	11/25/2008	931	616	37.1	320
		1523-109	12/4/2008	707	542	29.6	285
		NA	12/8/2008	440	NA	NA	NA
		1523-121	12/11/2008	549	446	26.3	211
		NA	12/15/2008	370	NA	NA	NA
		1523-133	12/18/2008	360	194	15.8	77.2
		1523-145	12/23/2008	281	188	11.6	68.2
		1523-157	12/30/2008	298	194	11	77.5

Beginning 11/25 all specific conductance field measurements temperature corrected to 25 degree C.

APPENDIX C

Oil & Gas Facility Summary

Facility Designation

MSW - Currently accepts Marcellus Shale Waste Water

O&G - Currently accepts Oil and Gas Waste Water not in the Marcellus Shale Formation.

P - Proposed Facility (i.e. PMSW, PO&G means Proposed Marcellus Shale Waste and Proposed Oil and Gas Waste not in the Marcellus Shale Formation)

SW - Stripper Well

SWRO

NAME	Permit Number	Receiving Stream	Flow (GPD)	County	Latitude	Longitude	Municipality	TYPE	Status / NOTES	Facility Designation
Shallenberger Construction	PA0253669	Rankin Run	0.125 mgd	Fayette	39.9574	-79.8083	Dunbar Township	Existing IW	Facility not constructed WQM Part II pending--Rankin Run Tophole Water	PMSW, PO&G
Shallenberger Construction	PA0253723	Monongahela River	0.5 mgd.	Fayette	39.8744	-79.9177	German Township	Existing IW	Facility not constructed WQM Part II pending--RONCO CWT	PMSW, PO&G
PA Brine Josephine (Franklin Brine)	PA0095273	Blacklick Creek	0.155 mgd	Indiana	40.4797	79.1703	Burrel Township	Existing IW	Oil and Gas wastewaters. Currently under detailed compliance review.	O&G, MSW
Hart Resource	PA0095443	McKee Run	0.045M	Indiana	40.675	-79.1875	Washington Township	Existing IW	Oil and Gas wastewaters. Currently under detailed compliance review.	O&G, MSW
Tunnelton Liquids	PA0091472	Conemaugh River	1M	INDIANA	40.4539	-79.3767	Conemaugh Twp	Existing IW	Renewal Pending--Acid Mine Drainage, Oil and Gas Wastes, Storm Water Runoff and Mine Drainage	O&G, MSW
Mon Valley Brine	PA0253782	Monongahela River	0.2 mgd	WASHINGTON	40.1661	-79.8567	Donora Boro	IW Application	Oil and Gas wastewaters-CWT--Proposed Facility	PMSW, PO&G
Green Earth Wastewater	PA0253821	Dunkard Creek	0.25 mgd	GREENE	39.7439	-80.0624	Center Twp	IW Application	Oil and Gas wastewaters-CWT--Proposed Facility	PMSW, PO&G
Shallenberger Construction	PA0253863	Youghiogheny River	1.0 mgd	FAYETTE	40.0453	-79.6086	Upper Tyrone Twp	IW Application	Oil and Gas wastewaters-CWT--Proposed Facility	PMSW, PO&G
Somerset Regional Water Resources, LLC	PA0253987	East Branch Coxes Creek	1M AVE / 1.3 M MAX	SOMERSET	40 00 27.6	79 04 17.4	Somerset Twsp	IW Application	RO and evaporators are proposed to treat oil and gas and mine drainage.	PMSW, PO&G
Clairton Municipal Authority	PA0026824	Peters Creek	6M	Allegheny	40 18 13	79 52 57	Clairton	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order.	O&G, MSW
Municipal Authority City of McKeesport	PA0026913	Monongahela River	11.5M	Allegheny	40 21 11	79 52 19	City of McKeesport	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order.	O&G, MSW
Municipal Authority of Belle Vernon	PA0092355 and PA0092355-A1	Monongahela River	0.5M, 1M respectively	Fayette	40 07 10	79 52 36	Belle Vernon	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of oil and gas wastewater.	O&G, MSW
Brownsville Municipal Authority	PA0022306	Dunlap Creek	0.96M	Fayette	40 01 11	79 52 58	Brownsville Borough	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of oil and gas wastewater.	O&G, MSW
Waynesburg Borough	PA0020613	South Fork Tenmile Creek	0.8M	Greene	39 53 48	80 09 53	Franklin Township	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of oil and gas wastewater.	O&G, MSW
Borough of California	PA0022241	Monongahela River	1M	Washington	40 04 11	79 53 46	California Borough	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of oil and gas wastewater.	O&G, MSW
Franklin Township Sewer Authority	PA0046426	South Fork Tenmile Creek	1.25M	Greene	39 54 09	80 09 01	Franklin Township	POTW	O&G waste flow will be limited to 50,000gpd by DEP order. Waste is pretreated but not for TDS or Chlorides. Chronic WETT may be required quarterly.	O&G, MSW
Authority of the Borough of Charleroi	PA0026891	Monongahela River	3M	Washington	40 08 51	79 54 10	Charleroi Borough	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of oil and gas wastewater.	O&G, MSW
Allegheny Valley Joint Sanitary Auth.	PA0026255	Allegheny River	5.5M	Allegheny	40 31 48	79 50 53	Harmar Township	POTW	Limiting O&G waste flow to 25,000 gpd and chlorides to 24000 mg/l	O&G, MSW
Johnstown Redevelopment Authority - Dornick Point STP	PA0026034	Conemaugh River	12M	Cambria	40 21 52	78 57 13	West Taylor Twp.	POTW	Limiting oil and gas waste flow to 1% of avg. daily flow.	O&G, MSW

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NWRO

NAME	Permit Number	Receiving Stream	Flow (GPD)	County	Latitude	Longitude	Municipality	TYPE	Status / NOTES	Facility Designation
Allegheny Environmental Corp.	PA0102903	Allegheny River	42000	Venango	41° 22' 13.8"	79° 48' 13"	Sandycreek Twp	Existing IW Facility	Existing facility which treats only oil well production fluids from own wells where permitee let NPDES expire January 25, 2009. New application to be submitted soon.	O&G
Minard Run Oil Company	PA0105295	Lewis Run	18000	McKean	41° 50' 41.9"	78° 41' 24.4"	Lafayette Twp	Existing IW Facility	Existing facility which treats only oil well production fluids from own wells. NPDES renewal application currently being reviewed.	O&G
Big Sandy Oil Company	PA0222011	Allegheny River	6000	Venango	41° 24' 17.7"	79° 44' 11.2"	Cranberry Twp	Existing IW Facility	Existing facility which treats only oil well production fluids from own wells.	O&G
Titusville Oil and Gas Associates, Inc. - Hilton Hedley Lease	Approval No. 6105001 for coverage under GP PAG310001	Allegheny River	2000	Venango	41° 27' 22.4"	79° 36' 39.3"	Cornplanter Twp	Proposed Facility	Proposed facility to treat only oil well production fluids from own wells. Approval under general NPDES issued 1/16/2007, no Part II issued and facility not built.	SW, PO&G
Vavco LLC	Application No. 1009001 for coverage under GP PAG310001	Little Connoquenessing Creek	2000	Butler	40° 49' 41"	80° 02' 34"	onnoquenessing Tw	Proposed Facility	Proposed facility to treat only oil well production fluids from own wells. Application for coverage under GP PAG310001 submitted 2/9/09	SW, PO&G
Synergy Oil & Gas Co. Inc.	Approval No. 6103002 for coverage under GP PAG310001	Pithole Creek	1000	Venango	41° 29' 8"	79° 35' 47"	President Twp	Existing IW Facility	Existing facility which treats only oil well production fluids from own wells. Administratively incomplete application for approval under GP PAG310001 pending.	SW, O&G
James M. Bryerton	Approval No. 6295001 for coverage under GP PAG310001	Brokenstraw Creek	1000	Warren	41° 51' 8.2"	79° 18' 8.6"	Brokenstraw Twp	Existing IW Facility	Existing facility which treats only oil well production fluids from own wells.	SW, O&G
Ridgway Borough	PA0023213	Clarion River	2,200,000 *	Elk	41° 25' 10"	78° 45' 00"	Ridgway Borough	POTW	3 Sanitary Sewer Overflows	O&G, MSW
Punxsutawney Borough	PA0020346	Mahoning Creek	2,400,000 *	Jefferson	40° 56' 29"	79° 00' 6.6"	unxsutawney Boroug	POTW	4 Combined Sewer Overflows	O&G
Brockway Area Sewage Authority	PA0028428	Toby Creek	1,500,000 *	Jefferson	41° 15' 11"	78° 47' 59"	Brockway Borough	POTW	No CSOs / SSOs. Currently 14,000 GPD to POTW. Considering addition of chemical precipitation and flow expansion to 60,000 GPD.	O&G
Reynoldsville Boro	PA0028207	Sandy Lick Creek	800,000	Jefferson	41.05.41	78.53.48	Reynoldsville Boroug	POTW	6 Combined Sewer Overflows, have taken in approx 14,000 gpd of brine to POTW for a long time	O&G
New Castle City	PA0027511	Mahoning River	17,000,000	Lawrence	40° 58' 00"	80° 23' 22.1"	New Castle City	POTW	3 Sanitary Sewer Overflows	O&G, MSW
Advanced Waste Services / Castle Environmental	-	New Castle STP	200000	Lawrence	40° 58' 07"	80° 23' 22"	New Castle City	Indirect to POTW	Possible expansion plans from 0.2 MGD to 2.2 MGD	O&G, MSW
Waste Treatment Corporation	PA0102784	Allegheny River	400000	Warren	41° 50' 19"	79° 09' 41"	Warren City	Existing IW Facility	Existing permit allows 213,000 gpd. Requesting 400,000 gpd in pending renewal application.	O&G, PMSW
PA Brine Treatment - Franklin Facility	PA0101508	Allegheny River	300000	Venango	41° 22' 20"	79° 48' 01"	Cranberry Twp	Existing IW Facility	Existing permit allows 205,000 gpd. Requesting 300,000 gpd in pending renewal application.	O&G, PMSW
Dominion Transmission Corp - Div V	PA0101656	Stump Creek	10080	Jefferson	40° 59' 14.6"	78° 50' 36.8"	Henderson Twp	Existing IW Facility	Facility only treats Dominion's own wastewater. Most likely no Marcellus water.	O&G
PA Brine Treatment - Punxsutawney Facility	PA0263486	Mahoning Creek	50000	Jefferson	40° 55' 45"	79° 00' 21"	Young Twp	Proposed IW Facility	Application rec'd 12/15/08.	PO&G
Rock Well Petroleum Production	PA0263427	Oil Creek	125000	Crawford	41° 37' 26.33"	79° 39' 27.26"	City of Titusville	Proposed IW Facility	Wastewater is from shallow oil wells from oil mining. Rock Well filed for Chapter 15 bankruptcy on 12/16/2008. Permit being held until further notice.	O&G
PA Brine Treatment - Rouseville Facility	PA0263516	Oil Creek	80000	Venango	41° 27' 37"	79° 41' 23"	Cornplanter Twp	Proposed IW Facility	Application rec'd 3/13/2009.	PO&G

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NAME	Permit Number	Receiving Stream	Flow (GPD)	County	Latitude	Longitude	Municipality	TYPE	Status / NOTES	Facility Designation
Central PA Water Treatment, LLC	PA0233617	West Branch Susquehanna River	504,000	Clinton	41° 08' 53"	77° 22' 37"	Wayne Township	Direct Discharge	Consultant is ARM Group.	PMSW
Central PA Water Treatment, LLC	PA0233684	Moshannon Creek	504,000	Centre	40° 59' 59"	78° 03' 49"	Rush Township	Direct Discharge	Consultant is ARM Group.	PMSW
Eureka Resources / Williamsport Sanitary Authority	(PA0027057)	West Branch Susquehanna River	300,000	Lycoming	41° 14' 16"	76° 59' 24"	City of Williamsport	Indirect Discharge to POTW	EPA Approved Pretreatement Program. WSA Central WWTP (8.4 MGD)	MSW
Water Treatment Solutions	TBD	Daugherty's Run	TBD	Lycoming	TBD	TBD	City of Williamsport	Direct Discharge	Consultant is RETTEW Engineering.	PMSW
Economy Locker / Lycoming County Water & Sewer Authority	(PA0209228)	West Branch Susquehanna River	250,000	Lycoming	41° 14' 00"	76° 52' 21"	Muncy Township	Indirect Discharge to POTW	LCWSA WWTP (1.5 MGD)	PMSW
Sunbury Generation	PA0008451	Susquehanna River	80,000	Snyder	40° 49' 43"	76° 50' 08"	Monroe Township	Existing IW, Direct Discharge	Taking 80,000 gpd, approved by letter.	MSW
Jersey Shore Borough	PA0028665	West Branch Susquehanna River	100,000	Lycoming	41° 12' 25"	77° 15' 07"	Jersey Shore Borough	POTW	Consultant is Larson Design Group.	MSW
Clearfield Municipal Authority	PA0026310	West Branch Susquehanna River	10,000	Clearfield	41° 01' 31"	78° 24' 02"	Clearfield Borough	POTW	CMA WWTP (4.5 MGD) This facility has claimed to have historically taken oil & gas wastewater.	PMSW
Moshannon Valley Joint Sewer Authority	PA0037966	Moshannon Creek	30,000	Clearfield	40° 54' 27"	78° 13' 27"	Rush Township	POTW	MVJSA WWTP (1.5MGD) This facility has claimed to have historically taken oil & gas wastewater.	PMSW
Lock Haven City Authority	PA0025933	Bald Eagle Creek	25,000	Clinton	41° 07' 44"	77° 25' 50"	Castanea Township	POTW	LHCA WWTP (3.75 MGD)	PMSW
Valley Joint Sewer Authority *	PA0043681	Susquehanna River	25,000	Bradford	41° 57' 59"	76° 30' 59"	Athens Borough	POTW	VJSA WWTP (2.0 MGD)	PMSW
Pine Creek Municipal Authority	PA0027553	West Branch Susquehanna River	50,000	Clinton	41° 10' 15"	77° 18' 56"	Pine Creek Township	POTW	PCMA WWTP (1.3 MGD) This facility has claimed to have historically taken oil & gas wastewater.	PMSW
Dannic Energy Corp.	PA0233781	West Branch Susquehanna River	250,000	Clinton	41° 18' 38"	77° 38' 05"	Chapman Township	Recycle, Direct Discharge	Hyner Drilling Fluid Recycling Facility Consultant is Nittany Engineering.	PMSW
Dannic Energy Corp. *	PA0233773	Tioga River	250,000	Tioga	41° 43' .98"	77° 4' 52.6"	Covington Township	Direct Discharge	Tioga Drilling Fluid Recycling Facility. Consultant is Nittany Engineering.	PMSW
Dannic Energy Corp.	PA0233765	Pine Run	250,000	Lycoming	41° 12' 52"	77° 11' 03"	Woodward Township	Recycle, Direct Discharge	Pine Run Drilling Fluid Recycling Facility. Consultant is Nittany Engineering. Pine Run discharges to W. Branch Susquehanna.	PMSW
TerrAqua Resource Management	PA0233650	West Branch Susquehanna River	400,000	Lycoming	41° 14' 43"	76° 59' 09"	City of Williamsport	Direct Discharge	Water Tower Square Gas Well Wastewater Processing Facility. Consultant is Larson Design Group.	PMSW
Central PA Wastewater, Inc.	PA0233706	UNT to West Branch Susquehanna River	400,000	Clinton	41° 10' 24"	77° 19' 12"	Pine Creek Township	Direct Discharge	Central PA Wastewater Inc. Gas Well Wastewater Processing Facility. Consultant is Larson Design Group. Discharge is proposed to intermittent stream less than 0.5 miles from the river.	PMSW
Dannic Energy Corp.	PA0233790	Hawk Run	250,000	Clearfield	40° 55' 19.23"	78° 11' 34.83"	Morris Township	Recycle, Direct Discharge	Hawk Run Drilling Fluid Recycling Facility Consultant is Nittany Engineering. Hawk Run discharges to Moshannon Creek, which discharges to W. Branch Susquehanna.	PMSW
Somerset Regional Water Resources	PA0233820	Chemung River	1,000,000	Bradford	41° 37' 39.4"	75° 56' 36.4"	Athens Township	Recycle, Direct Discharge	Chemung River empties into North Branch Susquehanna River. Consultant: MWH Americas, Inc.	PMSW
Homer Enterprises	PA0233854	West Branch Susquehanna River	50,000	Clearfield	40° 44' 31.01"	78° 47' 41.66"	Burnside Township	Recycle, Direct Discharge	To be located at the Harmony Gas, Oil and Timber Company, Cherry Tree, PA	PMSW

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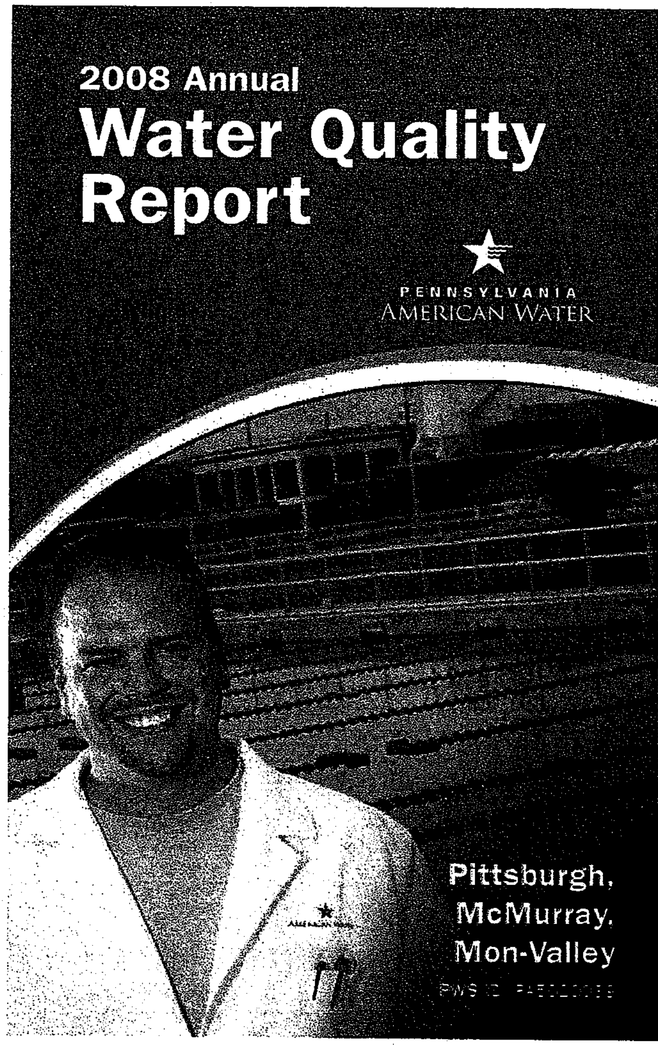
NAME	Permit Number	Receiving Stream	Flow (GPD)	County	Latitude	Longitude	Municipality	TYPE	Status / NOTES	Facility Designation
Greater Hazleton Joint Sewer Authority	PA0026921	Black Creek	35,000	Luzerne	40° 58' 04"	76° 01' 28"	West Hazleton Borough	POTW	Application for NPDES Amendment rec'd 4/27/09. Admin. Incomplete.	PMSW
North Branch Processing, LLC	Applic. No. PA0065269	Susquehanna River	800,000	Wyoming	41° 31' 31"	75° 56' 19"	Eaton Township	CWT	NPDES IW Application rec'd 12/12/08. Accepted Admin. Complete 1/20/09.	PMSW
Wyoming Valley Sanitary Authority	PA0026107	Susquehanna River (estimated Lat/long)	150,000	Luzerne	41° 14' 07"	75° 55' 45"	Hanover Township	POTW	Application for NPDES Amendment rec'd 3/20/09. Accepted Admin. Complete.	PMSW
Brine Treatment Services, Inc.		Susquehanna River	200,000	Wyoming	41° 32' 25"	75° '57' 51"	Tunkannock area	CWT	Info taken from Hart Technologies 10/1/2008 letter. NPDES IW Application not rec'd yet	PMSW
Wyoming-Somerset Regional Water Resources LLC	Applic. No. PA0065293	Meshoppen Creek at the SR 29 Bridge	500,000	Wyoming	41°37'39.4"	75°56'36.4"	Lemon Township	CWT	NPDES IW Applic. rec'd 4/16/09. Acc'd Admin. Complete 4/17/09. Flow schematic indicates chemical treatment followed by reverse osmosis to treat frac and brine wastewaters.	PMSW



A Message from Kathy Pape, President

As a trusted leader in the industry, Pennsylvania American Water places a strong emphasis on sharing information with customers about the quality of the water service we provide.

One way we do this is by providing annual reports with the results of the tests that we perform on the water delivered to your home. Please review this Consumer Confidence Report (CCR), which outlines information that is applicable to your local water system for tests completed through December 2008. You'll find that we provide water that surpasses or meets all federal and state water quality regulations. In fact, we often address regulations well before they go into effect.

Just as important, Pennsylvania American Water makes the necessary investments to maintain and upgrade its facilities, so that we can deliver quality water directly to your tap 24 hours a day, seven days a week.

Our customers are our top priority, and we are committed to providing you with the highest quality drinking water and service possible now and in the years to come. In addition to this written report, you can view information about Pennsylvania American Water and your water system on our website at www.pennsylvaniaamwater.com. For more information or if you have any questions about this report, please contact Pennsylvania American Water's Customer Service Center at (800) 565-7292.

Sincerely,

Our Mark of Excellence

Founded in 1886, American Water is the largest investor-owned U.S. water and wastewater utility company. With headquarters in Voorhees, N.J., the company employs more than 7,000 dedicated professionals who provide drinking water, wastewater and other related services to approximately 15 million people in 32 states and Ontario, Canada.

We are once again proud to present our annual water quality report. This edition covers all testing completed from January through December 2008. Over the years, we have dedicated ourselves to producing drinking water that meets or surpasses all state and federal drinking water standards. We continually strive to adopt new and better methods of delivering the best quality drinking water to you. As regulations and drinking water standards change, it is our commitment to you to incorporate these changes system-wide in an expeditious and cost-effective manner, while maintaining our objective of providing quality drinking water at an affordable price.

We are pleased to tell you that our compliance with all state and federal drinking water laws remains exemplary. To that end, we remain vigilant in meeting the challenges of source water protection, water conservation, and community education while continuing to serve the need of all our water users.

For more information about this report, or for any questions relating to your drinking water, please feel free to call our Customer Service Department at 800-565-7292.

Source Water Information

The Monongahela River is the sole source of supply for the Pittsburgh, McMurray, Mon-Valley service area. Pennsylvania American Water maintains treatment facilities on the Monongahela River capable of processing a maximum of 110 million gallons of water per day (MGD). The water supply is distributed for residential, commercial, and industrial use.

Protecting Your Water Source

The Pennsylvania Department of Environmental Protection (DEP) and PAW completed an assessment of the drinking water sources for the Pittsburgh, McMurray, and Mon-Valley system in May 2002. No man-made contaminants have been detected in the surface water supplies. The water sources are considered most vulnerable to the following activities (although not associated with any detected chemicals): transportation corridors, boating, barge traffic, salt storage, auto repair, utility substations, power plants, combined sewer outfalls, and runoff from non-point sources such as residential developments, farms and abandoned mines.

A copy of the completed Source Water Assessment may be viewed by calling the local office of the Pennsylvania DEP at 412-442-4000. PAW encourages you to take an active part in protecting your water supply by participating in local activities as they occur in your local area.

Other Water Quality Parameters of Interest

Is there lead in your water?

If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. Pennsylvania American Water is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead.

Does your water contain nitrates?

PAW's normal range of nitrate levels is below the MCL of 10 ppm. Nitrate enters the water supply from fertilizers used on farms and natural erosion of deposits in the watershed. Levels above 10 ppm are a health risk for infants under six months of age and can cause blue baby syndrome. Check with your physician if you have questions.

How hard is your water?

Hardness is a measure of the concentration of two minerals naturally present in water – calcium and magnesium. High hardness levels cause soap not to foam as easily as it would at lower levels. Hardness levels range from 68 ppm to 320 ppm, or 4 to 19 grains per gallon of water.

How much sodium is in your water?

The average sodium level is approximately 73 ppm. This was the average result of samples collected from both treatment plants in August and October of 2008.

What is the pH (acidity) range of your water?

Water in the distribution system averages 7.4 pH units. A pH of 7.0 is considered neutral, neither acidic nor basic.

Is there fluoride in your water?

PAW adds fluoride to a level of near 1 ppm to assist in the prevention of dental cavities.

Partnership for Safe Drinking Water Program

In 2005 the Pittsburgh, McMurray and Mon-Valley system facilities were awarded the prestigious "Five-Year Director's Award" under the Partnership for Safe Water program administered by the U.S. EPA, Pennsylvania Department of Environmental Protection, and other water related organizations. The award honors water utilities for achieving operational excellence, by voluntarily optimizing their treatment facility operations and adopting more stringent performance goals than those required by federal and state drinking water standards. We are proud to report that we have maintained those standards throughout 2008.

How to Contact Us

Additional copies of this report can be obtained by calling our Customer Service Department at 1-800-565-7292. Electronic copies of this document can be obtained by visiting our website, www.pennsylvaniaamwater.com, selecting the 'Ensuring Water Quality' tab, then selecting 'Water Quality Reports' and choosing the report for your service area. Added information can be gathered by calling our Customer Service Department or by viewing the following information on the Internet:

Pennsylvania American Water
www.pennsylvaniaamwater.com

Pennsylvania Department of Environmental Protection
www.dep.state.pa.us

United States Environmental Protection Agency
www.epa.gov/safewater

Safe Drinking Water Hotline: 1-800-426-4791

Centers for Disease Control and Prevention
www.cdc.gov

American Water Works Association
www.awwa.org

APPENDIX D

Water Quality Statement

We are pleased to report that during the past year, the water delivered to your home or business complied with all state and federal drinking water requirements. For your information, we have compiled a list in the table below showing what substances were detected in your drinking water during 2008. The Pennsylvania DEP allows us to monitor for some contaminants less than once per year because the concentration of the contaminants does not change frequently.

Some of our data, though representative, are more than one year old. Although all of the substances listed below are under the Maximum Contaminant Levels (MCL) set by the U.S. Environmental Protection Agency and the Pennsylvania DEP, we feel it is important that you know exactly what was detected and how much of each substance was present in the water.

Water Quality Results

Turbidity – A Measure of the Clarity of the Water at the Treatment Facility (Facilities)

LOCATION		MCL	MCLG	Level Found	Range	Sample Date	Violation	Typical Source
HAYS MINE STATION	Turbidity (NTU) [1]	TT= NTU For a single measurement	NA	0.14 [2] NTU	NA	06/06/08	N	Soil Runoff
		TT= at least 95% of monthly samples </= 0.3 NTU			NA			
ALDRICH STATION	Turbidity (NTU) [1]	TT= NTU For a single measurement	NA	0.40 NTU	NA	05/06/08	N	Soil Runoff
		TT= at least 95% of monthly samples </= 0.3 NTU		99.5%	NA	05/08		

[1] Turbidity is a measure of the cloudiness of the water. We monitor it because it is a good indicator of the effectiveness of the filtration system.
[2] All turbidity samples met the turbidity limit of 0.3 NTU.

Regulated Substances (Measured on the Water Leaving the Treatment Facility)

Substance (units)	Year Sampled	Violation Y/N	MCL	MCLG	Maximum Amount Detected	Range Low-High	Compliance Achieved	Typical Source
Arsenic (ppb)	2008	N	10	0	3	2 - 3	Yes	Erosion of natural deposits; runoff from orchards; runoff from glass and electronics production wastes
Barium (ppm)	2008	N	2	2	0.07	0.04 – 0.07	Yes	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Nitrate (ppm) as Nitrogen	2008	N	10	10	0.66	0.64 – 0.66	Yes	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Fluoride (ppm)	2008	N	2	2	1.42	1.08 – 1.42	Yes	Added to water to promote healthy teeth
Selenium (ppb)	2008	N	50	50	14	8 – 14	Yes	Discharge from petroleum and metal refineries; erosion of natural deposits; discharge from mines

Chlorine Measured on Water Leaving the Treatment Plant

Free Chlorine (mg/L) [1]	Violation Y/N	MRDL	MRDLG	Minimum	Range	Typical Source
Aldrich Treatment Plant	N	4	4	0.3	0.3 to 1.5	Water additive used to control microbes
Hays Mine Treatment Plant	N	4	4	0.2	0.2 to 1.5	Water additive used to control microbes

[1] Monitored continuously at treatment plant and the lowest daily reading reported to regulatory agency each month.

Total Organic Carbon Removal

Location	Substance (units)	Violation Y/N	Year Sampled	TT	Range of Percent Removal Required	Range of Percent Removal Achieved	Compliance Achieved	Typical Source
Hays Mine	Total Organic Carbon (TOC) (% removal)*	N	2008	Meet EPA Removal Requirements	25 to 35	13 [1] to 46	Yes	Naturally decaying vegetation
Aldrich	Total Organic Carbon (TOC) (% removal)*	N	2008	Meet EPA Removal Requirements	25 to 35	17 [1] to 34	Yes	Naturally decaying vegetation

[1] In months that the percent achieved was below required, there was no exceedance of the MCL because PAW met alternative compliance criteria as required by the PA Safe Drinking Water Act.
* Adequate removal of TOC may be necessary to control the unwanted formation of chlorinated by-products. Naturally occurring organic matter present in the source water can react with the disinfectants used at the treatment facility to form these by-products.

Bacterial Results (From The Distribution System)

Substance (units)	Violation Y/N	Year Sampled	MCL	MCLG	Highest Percentage Detected	Compliance Achieved	Typical Source
Total Coliforms (% of positive samples)	N	2008	No more than 5% of the monthly samples can be positive	Zero bacteria	0.36	Yes	Naturally present in the environmen

Tap Water Samples: Lead and Copper Results

Substance (units)	Violation Y/N	Year Sampled	Action Level	MCLG	Max Results	Number of Samples	90th Percentile	Number of Samples Above Action Level	Typical Source
Lead (ppb)	N	2007	15	0	17	58	5	1	Corrosion of household plumbing systems; erosion of natural deposits
Copper (ppm)	N	2007	1.3	1.3	0.41	58	0.25	0	Corrosion of household plumbing systems; erosion of natural deposits

[1] Maximum result of required individual distribution samples collected.

APPENDIX D

Other Compounds (Measured in the Distribution System)								
Substance (units)	**Violation Y/N**	**Year Sampled**	**MCL**	**MCLG/ MRDL**	**Results**	**Range Low-High**	**Compliance Achieved**	**Typical Source**
Combined Radium (pCi/L)	N	2003	5	0	1.4	SS [7]	Yes	Erosion of natural deposits
Strontium-90 (pCi/L)	N	2003	8	0	0.6	SS [7]	Yes	Decay of natural and man-made deposits
Tritium (pCi/L)	N	2003	20,000	0	500	SS [7]	Yes	Decay of natural and man-made deposits
Total Trihalomethanes (ppb) [2]	N	2008	80	NA	74 [4]	34 – 156 [6]	Yes	By-product of drinking water chlorination
Haloacetic Acids (ppb) [2]	N	2008	60	NA	14 [4]	2 – 51	Yes	By-product of drinking water chlorination
Free Chlorine Residual (ppm) [3]	N	2008	NA	4	1.1 [5]	0.7 – 1.1	Yes	Added as a disinfectant to the treatment process

[2] Range represents sampling at individual sample points.
[3] MRDL (maximum residual disinfectant level) applies.
[4] Highest annual running average for individual sample points.
[5] Highest monthly average for individual sample points.
[6] Non compliance sample site.
[7] SS - Only single sample required.

How to Read This Table

Starting with a **Substance**, read across. **Year Sampled** is usually in 2008 or year prior. **MCL** shows the highest level of substance (contaminant) allowed. **MCLG** is the goal level for that substance (goal may be set lower than what is allowed). **Amount Detected** represents the measured amount (less is better). **Range** tells the highest and lowest amounts measured. A **Yes** under **Compliance Achieved** means the amount of the substance met government requirements. **Typical Source** tells where the substance usually originates.

Definitions of Terms Used in This Report

- **AL (Action Level):** The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.
- **MCL (Maximum Contaminant Level):** The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.
- **MCLG (Maximum Contaminant Level Goal):** The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.
- **MRDL (Maximum Residual Disinfectant Level):** The highest level of disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- **MRDLG (Maximum Residual Disinfectant Level Goal):** The level of drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contamination.
- **NA:** Not applicable
- **NTU (Nephelometric Turbidity Units):** Measurement of the clarity, or turbidity, of the water.
- **pCi/L (picocuries per liter):** Measurement of the natural rate of disintegration of radioactive contaminants in water (also beta particles).
- **mrem/yr (Millirems Per Year):** A measure of radiation absorbed by the body.
- **ppm or mg/L (parts per million):** One part substance per million parts water, or milligrams per liter.
- **ppb or µg/L (parts per billion):** One part substance per billion parts water, or micrograms per liter.
- **SS:** Single sample
- **TT (Treatment Technique):** A required process intended to reduce the level of a contaminant in drinking water.
- **%:** means percent
- **>:** means greater than
- **<:** means less than

Cryptosporidium

Cryptosporidium is a microbial pathogen found in surface water throughout the U.S. Although filtration removes Cryptosporidium, the most commonly-used filtration methods cannot guarantee 100 percent removal. If the organism was detected, current test methods do not allow us to determine if the organisms are dead or if they are capable of causing disease. Ingestion of Cryptosporidium may cause cryptosporidiosis, an abdominal infection. Symptoms of infection include nausea, diarrhea and abdominal cramps. Most healthy individuals can overcome the disease within a few weeks.

Based on the results of our Cryptosporidium monitoring, no additional treatment will be required by the new US EPA regulation.

APPENDIX D

Substances Expected to be in Drinking Water

In order to ensure that tap water is safe to drink, EPA prescribes regulations which limit the amount of certain contaminants in water provided by public water systems. U.S. Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health. Pennsylvania American Water's treatment processes are designed to reduce any such substances to levels well below any health concern and the processes are controlled to provide maximum protection against microbial and viral pathogens which could be naturally present in surface and groundwater. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the U.S. Environmental Protection Agency's Safe Drinking Water Hotline (800) 426-4791.

The source of drinking water (both tap water and bottled water) includes rivers, lakes, streams, ponds, reservoirs, springs and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in source water include:

Microbial Contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.
Inorganic Contaminants, such as salts and metals, which can be naturally-occurring or may result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.
Pesticides and Herbicides, which may come from a variety of sources, such as agriculture, urban stormwater runoff, and residential uses.
Organic Chemical Contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and also may come from gas stations, urban stormwater runoff, and septic systems.
Radioactive Contaminants, which can be naturally occurring or may be the result of oil and gas production and mining activities.

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants may be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. EPA/CDC guidelines on appropriate means to lessen the risk of infection by Cryptosporidium and other microbial contaminants are available from the EPA's Safe Drinking Water Hotline (800) 426-4791.

PENNSYLVANIA AMERICAN WATER

800 W. Hershey Park Drive
Hershey, PA 17033

Este informe contiene información muy importante sobre su agua potable. Tradúzcalo o hable con alguien que lo entienda bien.

APPENDIX E

Printed on 08/13/2009

Company Name PCA
Project TDS Study
Site Name 500 GPM System

AMD TREAT
RECAPITIZALITION COST

AMDTREAT

Calculation Period 75 yrs Inflation Rate 3.10 % Net Return Rate 6.00 %

Recapitizalition Name

A. Description of Item	B Unit Cost Per Item	C Quantity	D Total Item Cost	E Life Cycle	F Number of Periods	G Total PV
1. Clarifier and Chemical Feeds	2,000,000	1	2,000,000	25	3	1,749,050
2. Evaporator / Crystallizer	7,000,000	1	7,000,000	15	5	11,871,205
3. Reverse Osmosis	2,000,000	1	2,000,000	15	5	3,391,773
4. Misc. Tankage	400,000	1	400,000	25	3	349,810
5. Sludge Thickener	500,000	1	500,000	25	3	437,263
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	0	0	0	0	0
9.	0	0	0	0	0	0
10.	0	0	0	0	0	0
11.	0	0	0	0	0	0
12.	0	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	0	0	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	0	0	0	0	0
20.	0	0	0	0	0	0

Total Capital Cost 11,900,000 $ PV Grand Total 17,799,101 $

TREATMENT BOND/TRUST CALCULATOR

Prepared For:	PCA TDS Study	Date (mm/dd/yy):	7//2009
Treatment System(s) ID:	500 gpm RO with Crystallizer		

Inflation Rate:		3.1%
Yrs to Treat start:		0
Annual Treatment Cost:		$2,600,000.00
Trust Fees:		1.50%
Bond (not needed for rec):		$100,000.00
Investment Ratios:		
	stock:	80%
	bond:	20%
Effective Rate of Return:		8.43%
Volatility Index:		1.16
Rec Bond Rate of Return:		6.00%
Remaining Time on Permit:	5	years

Options	O&M only	Total with Recap	Total with Recap & Insurance	
option #1				
conventional bond:	$107,469,208.72	$128,203,604.97	$134,376,718.54	bond in year
bond adjustment:	$107,369,208.72	$128,103,604.97	$134,276,718.54	6
option #2				
fully funded trust:	$59,601,365.85	$77,400,466.85	$79,174,764.37	trust in year 1

PV of Recap (todays $$) @	8.43%	Eff RoR &	3.1%	Inf:	$17,799,101.00	for trust in year 1		
PV of Recap (todays $$) @	6.00%	Eff RoR &	3.1%	Inf:	$17,799,101.00	for bond in year 1	$20,734,396.24	for bond in year 6

Liability Insurance Factor @	$1.00	per year, per $1000 in the total PV of the Trust:	$77,400.47	per year	PV Insurance:	$1,774,297.52
Liability Insurance Factor @	$1.00	per year, per $1000 in total Bond:	$128,203.60	per year	PV Insurance:	$5,299,207.69

Fields in RED can be updated
Fields in BLUE are fixed or calculated
Fields in GREEN are partial amounts
Highlighted Fields in GREEN are final amounts