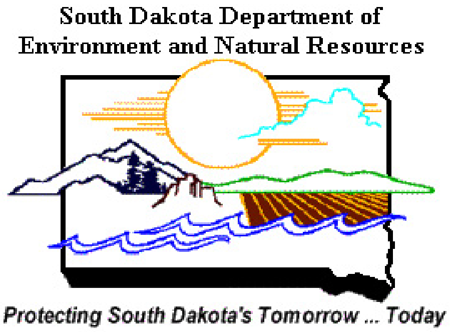
South Dakota Mercury
Total Maximum Daily Load



SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

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Acknowledgements

The development of this TMDL was possible due to of the efforts of many groups and individuals. Addressing impairments originating from anthropogenic sources inside and outside of a state requires a unique approach. Approved TMDLs from Minnesota and the Northeast States in cooperation with EPA has led to a framework that, to the extent practical, is followed in this TMDL document. Additionally, intrastate efforts were required to establish the thresholds for this TMDL. Dr. James Stone's *Final Report: Phase 1 Data Collection and Assessment for South Dakota Mercury TMDL Development* contributed significantly to this effort and much of his work is included.

List of Acronyms

AIC – Akaike's Information Criteria

AMSA- Association of Metropolitan Sewerage Agencies

ARSD – Administrative Rules of South Dakota

ASGM – Artisanal and Smallscale Gold Mining

BAF – Bioaccumulation Factor

BCF – Bioconcentration Factor

cm - Centimeters

CMAQ – Community Multi-scale Air Quality Model

DO – Dissolved Oxygen

DOC – Dissolved Organic Carbon

EPA – Environmental Protection Agency

FDA – Food and Drug Administration

FMSL – Feet Mean Sea Level

GIS – Geographic Information Systems

Hg – Mercury

HG0 – Elemental mercury vapor

HG2 – divalent mercury compounds in gas phase

HGP – divalent mercury compounds in particulate phase

HUC – Hydrologic Unit Code

ICIS - Integrated Compliance Information System

kg – kilogram

km - kilometer

L - Liter

LA – Load Allocation

MATS - Mercury Air and Toxics Standards

MDN – Mercury Deposition Network

MeHg - Methylmercury

mg – milligram

mg/L – milligrams per liter

mg/Kg - milligrams per kilogram which is equal to parts per million

MOS – Margin of Safety

MS4 – Municipal Separate Storm Sewer System

NLCD – National Land Cover Dataset

NPDES – National Pollutant Discharge Elimination System

ng – nanograms

NPSL – Nonpoint Source Load

NRCS – Natural Resources Conservation Service

NWI – National Wetland Inventory

OM – Organic Matter

p - estimated probability of rejecting the null hypothesis

POTW – Publicly Owned Treatment Works

PPTM – Particle and Precursor Tagging Methodology

REMSAD - Regional Modeling System for Aerosols and Deposition

RF – Reduction Factor

SDGFP – South Dakota Game Fish and Parks

SDDENR –South Dakota Department of Environment and Natural Resources

SDDOH – South Dakota Department of Health

SDSU – South Dakota State University

SDSM&T – South Dakota School of Mines and Technology

TDS – Total Dissolved Solids

TMDL – Total Maximum Daily Load

TPY – Tons Per Year

TS – Total Solids

TSL – Total Source Load

TSI – Trophic State Index

TSS – Total Suspended Solids

µg - Micrograms

µg/l – Micrograms per Liter

USDA – United States Department of Agriculture

USFWS – United States Fish and Wildlife Service

WE38 – Standard length walleye

WLA – Waste Load Allocation

WQS – Water Quality Standards

Executive Summary

Pursuant to Sections (§) 305(b), 303(d), and 314 of the Federal Water Pollution Control Act (P.L. 95-217) the State of South Dakota is required to biennially publish the Integrated Report which assesses the quality of the water in South Dakota lakes and streams (SDDENR 2014). Included in this report is a list of surface waters currently not meeting their designated uses (fishable, swimmable) because of some known cause or pollutant, referred to as the §303(d) Impaired Waterbody List. These waters require the development of Total Maximum Daily Loads (TMDLS) on the pollutants causing the impairment. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It includes an evaluation of the pollutant sources, a specific allocation of the load to each of the identified sources, and the necessary pollutant load reductions needed to meet water quality standards.

The 2014 South Dakota §303(d) List, included 18 waterbodies listed as impaired for elevated concentrations of methylmercury in fish tissue (Table ES-1). Fish consumption advisories were used as the basis for each of these impairment listings. In South Dakota, advisories have been issued when there is a potential for fish in a particular size category to have methylmercury levels exceeding the Food and Drug Administration (FDA) consumption advisory action level of 1.0 mg/Kg. Each waterbody with an impairment listing caused by a fish consumption advisory, whether listed in 2014 or in the future, will be required to have a TMDL.

Table ES-1. Assessment units included as impaired in South Dakota's 2014 Integrated Report.

Assessment Unit ID	Common Name-County
SD-BF-L-NEWELL_01	Newell Lake-Butte
SD-BS-L-BITTER_01	Bitter Lake-Day
SD-BS-L-ISLAND_N_01	North Island Lake – Minnehaha/McCook
SD-JA-L-LARDY_01*	Lardy Lake-Day*
SD-BS-L-LONG_COD_01	Long Lake-Codington
SD-JA-L-MID_LYNN_01**	Middle Lynn Lake-Day
SD-BS-L-MINNEWASTA_01	Minnewasta Lake-Day
SD-JA-L-OPITZ_01**	Opitz Lake-Day
SD-BS-L-REID_01	Reid Lake-Clark
SD-BS-L-SWAN_01	Swan Lake-Clark
SD-BS-L-TWIN_01	Twin Lakes/W. Hwy 81 - Kingsbury
SD-BS-L-TWIN_02	Twin Lakes-Minnehaha
SD-GR-L-PUDWELL_01	Pudwell- Corson
SD-GR-L-ISABEL_01	Isabel-Dewey
SD-JA-L-ELM_01	Elm Lake-Brown
SD-MI-L-HURLEY_01	Lake Hurley-Potter
SD-MI-L-ROOSEVELT_01	Roosevelt Lake-Tripp
SD-MU-L-COAL_SPRINGS_01	Coal Springs Reservoir-Perkins

* See Figure 4 caption regarding mapping error in 2014 Integrated Report. Also, for same reason discussed in the next footnote, SD-BS-L-LARDY_01 has been changed to SD-JA-L-LARDY_01.

**An error in the 2014 Integrated Report considered these waterbodies within the Big Sioux River Basin. The 2016 Integrated Report correctly placed them in the James River Basin and amended Assessment Unit ID's from SD-BS-L-OPITZ_01 and SD-BS-L-MID_LYNN_01 to SD-JA-L-OPITZ_01 and SD-JA-L-MID_LYNN_01. Opitz Lake and Middle Lynn Lake were correctly mapped in Figure 4, unlike Lardy Lake.

Mercury is a naturally occurring element that acts as a powerful neurotoxin affecting the nervous system that can cause cerebral palsy, deafness, blindness and other serious health effects in humans and animals. When inorganic mercury enters an aquatic ecosystem, under certain conditions, it can undergo a process known as methylation resulting in methylmercury (MeHg). Biomagnifying up through the food chain, it ultimately leads to elevated concentrations in the tissue of top predator fish exposing the general public when the fish are consumed. Methylmercury is a potent toxin because of its high solubility in fatty tissue in animals, resulting in significant potential for bioaccumulation and biomagnification. As a result, methylmercury is considered the most hazardous form of mercury, followed by the vapor phase of methylmercury. Since mercury is a global pollutant and 99% of the mercury loads to South Dakota are derived from atmospheric sources beyond the state boundaries, the most appropriate means to address all waterbodies listed because of fish consumption advisories was through a TMDL designed for statewide application. The sources and allocations for each of the waterbodies are the same and can be addressed with one document. This TMDL sets a statewide target for fish tissue methylmercury concentration, evaluates and allocates loads to the mercury sources, and provides the necessary mercury reductions needed to achieve the TMDL target.

This TMDL was written to decrease fish tissue methylmercury concentrations to the Environmental Protection Agency (EPA) recommended criterion of 0.3 mg/Kg rather than the FDA action level of 1.0 mg/Kg. The methylmercury criterion differs from the fish consumption advisory based on the FDA action level in that the EPA criterion considers all possible routes of human exposure to methylmercury, beyond just the ingestion of locally-caught freshwater fish. South Dakota chose to directly adopt the 0.3 mg/Kg criterion without modification into state rule, and is currently awaiting EPA approval of this standards action.

Section 1.2 further defines a set of seventy two assessment units which were used for development of this TMDL but not listed as impaired in the 2014 IR. Each of these units had at least one fish tissue sample greater than or equal to the TMDL goal of 0.3 mg/Kg. If through the adoption and implementation of the 0.3 mg/Kg criteria any of these units are found to be impaired, this TMDL will be applicable. Commonalities amongst these waters may be extended to additional waters in the future that exhibit similar characteristics. This TMDL may be applied through an addendum approved by EPA to additional waters of the state if all of the following conditions are met:

- It falls entirely within state jurisdiction,
- If jurisdiction is shared, it may only be applied to those portions of the water under the state's jurisdiction,
- The standard length fish tissue methylmercury concentration does not exceed 0.878 mg/Kg,
- There are no potential impacts from current or historic gold mining processes,
- If it is a river or stream, NPDES discharges do not exceed permitted limits,
- The TMDL will meet the water quality standards in the proposed water, and
- The original TMDL assumptions (e.g., source contributions, loading capacity, etc.) are still valid.

An integral part of the TMDL included a statistical analysis of all available fish tissue data collected from within the state of South Dakota. South Dakota has been collecting fish tissue data since 1994. This data was used to establish a baseline from which reductions could be calculated for individual waterbodies. The level of reduction was based on the 90th percentile of methylmercury fish tissue concentrations observed in a standard length walleye (*Sanders vitreus*) (15.1 inches or 38.4 cm) collected from South Dakota waterbodies. Selecting the 90th percentile of these values provides a concentration of 0.669 mg/Kg methylmercury. Using the methylmercury concentration from a single specific length from an apex predator species provides baseline (or existing condition) to compare waterbodies, calculate reductions, and track TMDL attainment going forward.

The basis of mercury deposition estimates for South Dakota commenced in 2009, when a project conducted by Dr. Stone of the South Dakota School of Mines and Technology expanded the air deposition monitoring throughout South Dakota. The year 2009 was used as the baseline loading to which future mercury loading will be compared for mercury TMDL attainment. The year 2009 also works with the fish tissue data, which were more intensively collected from 2010 to 2014. The more recent fish tissue data should incorporate some bioaccumulation of the methylmercury that resulted from 2009 emissions. It can be assumed that once the TMDL has been approved and implemented, future fish tissue mercury concentrations would be expected to decrease due to reductions in mercury loading.

The target level of 0.3 mg/Kg was applied to the single value of 0.669 mg/Kg representing all waters fish tissue data was collected from. The difference between the baseline condition calculated from a standard length walleye (0.669 mg/Kg) and the target level (0.3 mg/Kg) is the reduction factor (RF) needed to meet the water quality standard. The resulting reduction factor for the state is set at 55.2%. In other words, a 55.2% gross reduction from the aggregate sources of mercury is necessary to achieve the TMDL goal.

In general, the mercury loads to each waterbody vary across the state relative to the surface area and depositional rate, but the mercury sources do not. To apply this TMDL statewide it is assumed that through the Principle of Proportionality (see Section 3.3) proportional fish tissue mercury concentration reductions will occur for all waters of the state with concomitant reductions in air emissions.

A TMDL consists of a Load Allocation (LA), Waste Load Allocation (WLA), and Margin of Safety (MOS) components. The LA and WLA together constitute the Total Source Load or TSL. For this TMDL the LA component contributes over 99% of the TSL. This is all attributed to air deposition and is subject to all the reductions required for TMDL attainment. The point source loads (which included NPDES permitted facilities, mining, and municipal separate storm sewer systems) were factored into the total source load (TSL) and account for <1% of the TSL.

To achieve the RF of 55.2% a 79% reduction from all anthropogenic sources is required, as shown in Table ES-2. The background portion (1,230.67 kg/yr) includes both global natural and global anthropogenic sources. An estimate 30% of the global background was assumed to be from natural sources such as volcanoes and is not subject to reductions (UNEP 2013).

Due to the nature of South Dakota as a primarily rural state, over 99% of this pollutant enters the waterways from nonpoint sources. As a result, this TMDL requires all reductions to occur through the LA. The amount of mercury which can be attributed to point sources (WLA) is small enough that reductions in any form or amount would not yield a measureable effect on fish tissue samples.

Table ES-2. Total Source Load, Reduction Factor, and TMDL.

Sources from Baseline Year 2009	kg/yr
Nonpoint Sources or Atmospheric	1326.3
Point Sources	2.53
Total Source Load (TSL)	1328.83
Reduction Factor (RF)	55.20%
TMDL	595.32

The annual loads are significantly more important for expressing loading limits and reduction goals due to the chronic nature of mercury impairments and its long term bioaccumulation rates in fish. The conventional equation for a TMDL is: MOS + WLA + LA = TMDL. For this TMDL, the MOS is implicit.

Annual Calculation

TMDL(595.32 Kg/yr) = WLA (4.84 Kg/yr) + LA(590.48 Kg/yr)+MOS (implicit)

Compliance with the TMDL calculations is based on the annual loads. However, in order to comply with EPA guidance, the TMDL needs to be expressed as a daily load. The primary mechanism for the delivery of mercury to the South Dakota landscape is precipitation, or wet deposition. Since wet deposition is not a constant, but seasonal in nature and to a certain extent follow the annual rainfall patterns, it becomes necessary to incorporate a level of variability into the daily load. EPA guidance provides calculations, which are detailed in section 10, allowing for this variance to be accounted for. Including this variance through use of the EPA provided equations results in a maximum daily load of 3.21 Kg. It is assumed that through the course of the year, there will be days in which the load is significantly lower than this and that the sum of the daily loads will equate to the annual load.

In order for the TMDL goal to be reached, reductions in mercury emissions are necessary from sources within, as well as beyond South Dakota. South Dakota has a limited quantity of reductions which may be achieved in the state. In-state emissions data has consistently ranked as the third lowest emitter of mercury in the nation (USEPA 2008). Federal mandates are in line to account for the majority of the necessary 79% reduction from within the state.

The largest nonpoint source reductions in South Dakota will primarily result from existing and proposed federal rules and international agreements including the Mercury Air and Toxics Standards (MATS) rule (http://www.epa.gov/mercury/regs.htm and http://www.epa.gov/mats/powerplants.html) and the Minamata Convention on Mercury (http://www.mercuryconvention.org/). Throughout the last two decades, these rules and agreements target larger industry as well as coal fired power plants in larger population centers. In the 2012 Compendium of States Mercury Activities (ECOS 2012), it was reported that from 1990 to 2008 reductions in atmospheric mercury emissions reached up to 70% nationally and in some states 90%.

The single largest source of mercury in South Dakota is the Otter Tail Power Company (also known as Big Stone) located in the northeast corner of South Dakota which uses coal for the generation of power. EPA emissions mandates (MATS) are set to take effect on this plant during the 2015-2016 calendar years. EPA has predicted that the impacts of the MATS rule will result in approximately 90% cleaner emissions (USEPA 2015) from coal power plants such as this facility. Two additional facilities have made adjustments to their operations that further reduce mercury emissions within the state of South Dakota. In aggregate, reductions from these facilities are in line to account for approximately 70% of the necessary 79% reductions from within South Dakota to achieve the TMDL; which is reducing the concentration of methylmercury in fish tissue to 0.3 mg/Kg or less.

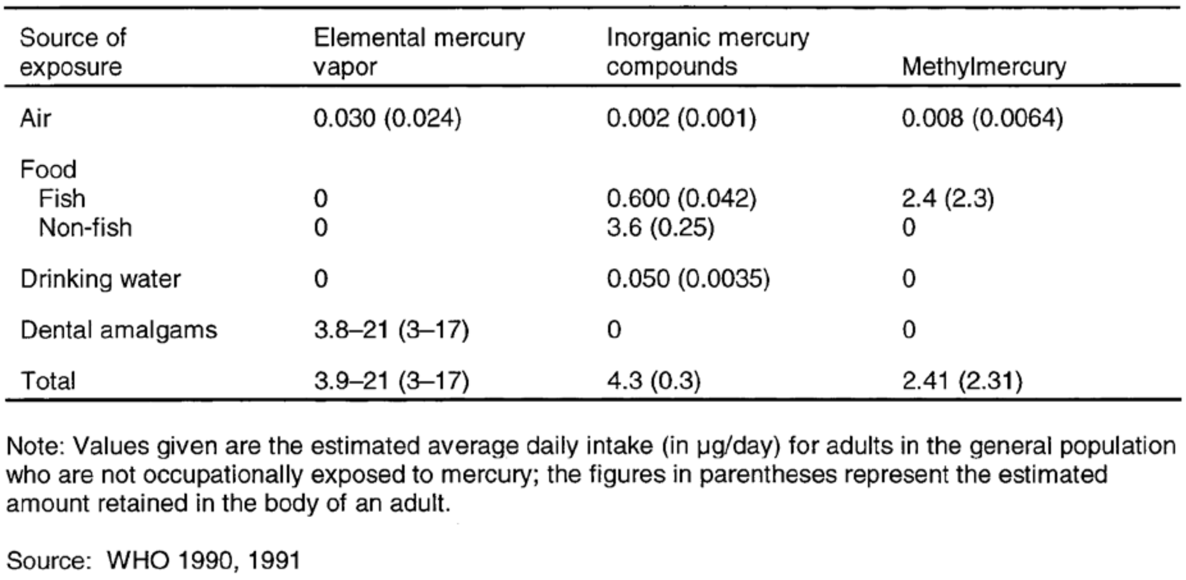
1.0 Introduction

The Clean Water Act requires that states must place waterbodies which do not meet water quality standards for a given pollutant on the Threatened and Impaired Waters list (also referred to as the 303d list). Once a waterbody is placed on this list, states are required to develop a Total Maximum Daily Load (TMDL) for that waterbody and the pollutant that caused its listing. A TMDL is a calculation of the maximum amount of a pollutant a waterbody may receive while still meeting the water quality standard. The calculation allocates the loads of the pollutant to point sources and non-point sources while incorporating a margin of safety for uncertainties in the calculation. This TMDL was developed to address the pollutant mercury, which through various pathways and process accumulates in fish tissue.

TMDLs are being put into place throughout the United States to help limit mercury emission on statewide and region-wide levels. These TMDLs look at mercury sources and limit the total anthropogenic emissions in an area to a specific, calculated amount or goal. For example, the Minnesota TMDL called for a 93% reduction in anthropogenic loadings starting from the baseline year of 1990. As of 2005, they had achieved a 76% reduction in anthropogenic loadings. (MPCA 2007).

Mercury is a naturally occurring element which acts as a powerful neurotoxin in humans and wildlife (Wentz et al. 2014). When inorganic mercury enters an aquatic ecosystem, under certain conditions, it can undergo a process known as methylation resulting in methylmercury (MeHg). In this form, it biomagnifies within the aquatic food chain and ultimately leads to elevated concentrations in fish tissue. Fish consumption is one of several means through which the U.S. population is exposed to mercury (Table 1).

Table 1. Estimated average daily intake and retention of total mercury and mercury compounds in the general population (WHO 1990; WHO 1991)



Source of exposure	Elemental mercury vapor	Inorganic mercury compounds	Methylmercury
Air	0.030 (0.024)	0.002 (0.001)	0.008 (0.0064)
Food			
Fish	0	0.600 (0.042)	2.4 (2.3)
Non-fish	0	3.6 (0.25)	0
Drinking water	0	0.050 (0.0035)	0
Dental amalgams	3.8–21 (3–17)	0	0
Total	3.9–21 (3–17)	4.3 (0.3)	2.41 (2.31)

Note: Values given are the estimated average daily intake (in µg/day) for adults in the general population who are not occupationally exposed to mercury; the figures in parentheses represent the estimated amount retained in the body of an adult.

Source: WHO 1990, 1991

This TMDL provides a general background on mercury sources and the rates at which atmospheric mercury is transported to South Dakota. It also calculates the maximum amount of mercury a waterbody can receive while still meeting water quality standards and the reductions from the various sources needed to meet the TMDL goal. Mercury, once deposited on the landscape, needs to have specific conditions present in order for methylation to take place. Several investigations conducted within the state of South Dakota and elsewhere have attempted to determine those variables that play the most significant role in controlling the methylation process and the rate at which it occurs. Similar analysis steps were used to help with the development of this TMDL, only with more recent data collected in South Dakota. Section 3.4 describes the complex processes that move and transform mercury through methylation as it pertains to South Dakota waterbodies. Because methylation involves bacteria, a host of other abiotic factors, and atmospheric deposition, controlling it is well beyond the scope of the usual best management practices (BMPs). A successful reduction strategy will need to focus on the atmospheric sources rather than localized landuse modifications within a watershed. Discussions in this document identify necessary efforts that need to be taken in order for the TMDL to be effective.

1.1 Background

Approximately 6,600 metric tons of mercury is emitted to the atmosphere world-wide each year (Driscoll et al. 2007). The neurotoxin mercury often exists in lakes and fish tissue and is a concern throughout the world (USEPA 1997). Humans and wildlife are exposed to mercury through the consumption of mercury polluted fish (Driscoll et al. 2007). As of 2004, fish consumption advisories due to mercury found in fish tissues had been issued in 44 states of the US (Driscoll et al. 2007). Mercury behavior within the atmosphere includes mercury emissions, transport, and deposition. After deposition the fate of mercury is highly dependent upon biogeochemical environmental factors responsible for transformation of inorganic mercury to the more hazardous form of methylmercury within aquatic systems (USEPA 1997). Methylmercury production varies greatly under high mercury loading due to differences in water chemistry of lake systems (Driscoll et al. 2007) (Krabbenhoft et al. 1999). For example, lakes having high total mercury loading can have low methylation efficiency leaving fish tissue concentrations far below advisory limits, and lakes having low mercury loading can have high methylation efficiency leaving fish tissue concentrations above state advisory limits (Krabbenhoft et al. 1999). Within aquatic systems, mercury bioaccumulation in fish was found to correlate positively with fish age, species, and position in the food chain (Watras and Bloom 1992). Methylmercury is the major form of fish tissue mercury, constituting approximately 83% of the total mercury mass (Driscoll et al. 2007) (Kannan et al. 1998). EPA’s recommended methylmercury criterion is set at levels necessary to protect consumers of fish and shellfish among the general population –children and women of childbearing age are more sensitive. Various studies and literature reviews have found neurodevelopmental effects to be the most sensitive endpoints which led EPA to develop a reference dose for methylmercury. The potential health effects of methylmercury toxicity are significant and exposure to mercury can cause severe effects to the nervous system (USEPA 1997).

Mercury emissions to the atmosphere have ranged dramatically from year to year but by 1990 regular decreases began to occur. EPA had proposed the Clean Air Mercury Rule, which was intended to limit mercury air emissions to 33 tons per year. However, the Washington D.C. District Court vacated EPA’s Clean Air Mercury Rule on February 8, 2008. On March 16, 2011, EPA proposed standards for air toxics emissions, including mercury, from coal- and oil-fired electric generating units. On February 16, 2012, the Mercury Air and Toxics Standards (MATS) rule was promulgated in 77 FR 9464. The recent U.S. Supreme Court decision *(Michigan v. US EPA)* adds uncertainty to MATS rule, however, this TMDL assumes its continued and full implementation.

1.1.1 Mercury Cycle

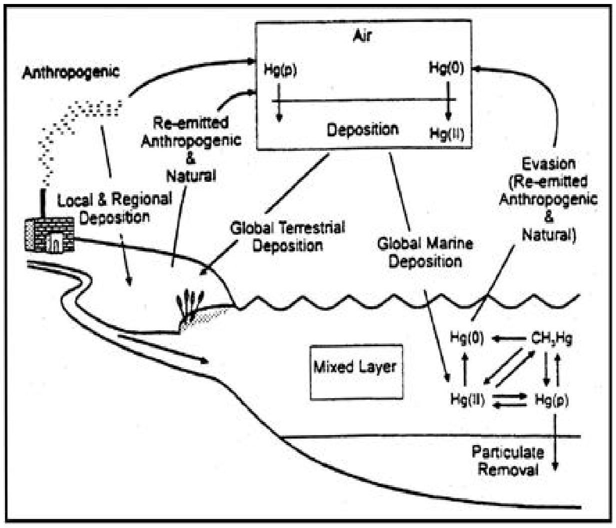


Figure 1. The global mercury cycle (USEPA 1997).

Approximately forty seven tons of mercury per year is emitted within the United States into the atmosphere from sources such as coal fired power plants and medical waste incinerators (USEPA 1997). Once released into the atmosphere, it can either be deposited close to the emission source, or enter into the atmospheric mercury stores and travel globally, although both of these scenarios are highly dependent upon oxidation states of mercury (Driscoll et al. 2007). A general schematic of the mercury cycle is shown in Figure 1. Mercury is generally considered to have three oxidation states, including elemental mercury (Hg^0), mercurous mercury (Hg_2^{2+}), and mercuric mercury [Hg^{2+}], and according to EPA (1997):

> "*The properties and chemical behavior of mercury strongly depend on the oxidation state. Mercurous and mercuric mercury can form numerous inorganic and organic chemical compounds; however, mercurous mercury is rarely stable under ordinary environmental conditions. Mercury is unusual among metals because it tends to form covalent rather than ionic bonds. Most of the mercury encountered in water/soil/sediments/biota (all environmental media except the atmosphere) is in the form of inorganic mercuric salts and organomercurics. Organomercurics are defined by the presence of a covalent C-Hg bond. The presence of a covalent C-Hg bond differentiates organomercurics from inorganic mercury compounds that merely associate with the organic material in the environment but do not have the C-Hg bond. The compounds most likely to be found under environmental conditions are these: the mercuric salts HgCl , Hg(OH) and HgS; the methylmercury compounds, methylmercuric 2 2 chloride (CH HgCl) and methylmercuric hydroxide (CH HgOH); and, in small fractions, other 3 3 organomercurics (i.e., dimethylmercury and phenylmercury).*"

A majority of mercury emissions are in the form of elemental mercury, which can travel thousands of miles from the source of emission (USEPA 1997). Mercury is deposited in the forms Hg^0 and Hg_2^{2+} with rain and snow as gasses and particles into watersheds (Driscoll et al. 2007). Once deposited, mercury eventually enters lakes and rivers, where, if appropriate environmental conditions exist, it can be transformed to its organic form, methylmercury, via sulfate reducing bacteria (Driscoll et al. 2007). Bioavailable methylmercury uptake by plankton occurs, and the methylmercury bioaccumulates within the food web. Almost all mercury in fish is in this bioavailable form.

The biogeochemical cycle of mercury in aqueous systems is the key factor leading to the expansion of mercury pollution on a global scale (Nriagu 1994). In natural waters, much of the Hg^{2+} is attached to suspended particulates, and eventually is deposited in lake sediments. The mercuric ion Hg^{2+} forms covalent molecules rather than an ionic solid (Baird 1999). The methyl anion, CH_3^-, forms a covalent compound with Hg^{2+}, yielding the volatile molecular liquid dimethylmercury, $Hg(CH_3)_2$ (Baird 1999). Dimethylmercury formation occurs in the muddy sediments of rivers and lakes, especially under anaerobic conditions when anaerobic bacteria and microorganisms convert Hg^{2+} into $Hg(CH_3)_2$ (Baird 1999). The methylation process is a microbially-facilitated process; a derivative of vitamin B12 with a CH_3^- anion bound to cobalt and is called methylcobalamin (Baird 1999). Due to its volatility, dimethylmercury evaporates ("degasses") from water relatively quickly unless it is transformed by acidic conditions into the mono methyl form. The less volatile "mixed" compounds CH_3HgX or CH_3Hg^+ are called methylmercury (or mono-methylmercury), and are more readily formed than dimethylmercury (Baird 1999). The biogeochemical reaction pathway formation of methylmercury is presented in Figure 2. Methylmercury is a more potent toxin because of its high solubility in fatty tissue in animals, resulting in significant potential for bioaccumulation and bio magnification. As a result, methylmercury is considered the most hazardous form of mercury, followed by the vapor phase of methylmercury. The other inorganic ion of mercury, Hg^{2+}, is not considered toxic because it combines in the stomach with chloride ions to produce insoluble Hg_2Cl_2 (Baird 1999).

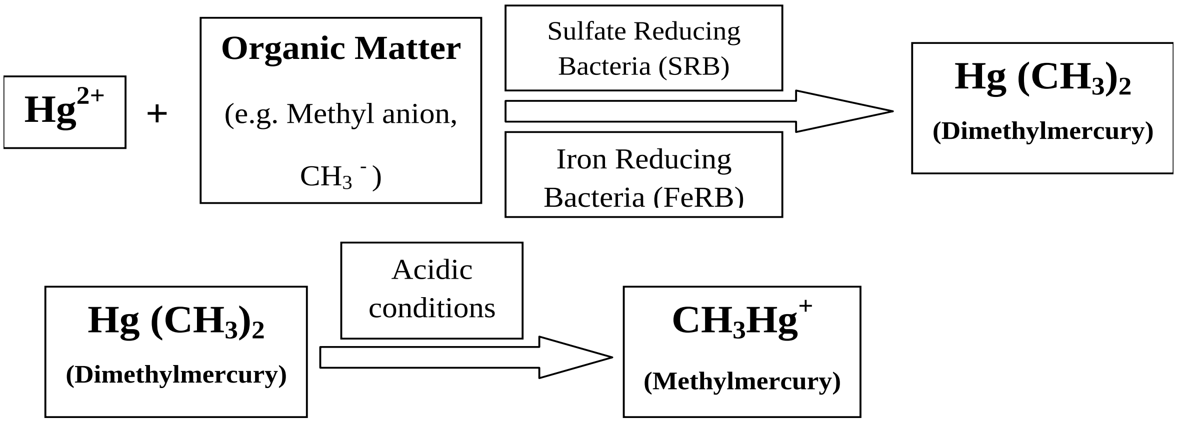


Figure 2. Diagram illustrating methylation in process under anaerobic conditions. (Betemariam 2010)

The methylmercury that is on the surface of the sediment would be transferred up through the food chain. Recent studies show this transfer proceeds by two processes: (1) insect larvae on the surface of the sediment, exposed to high concentrations of methylmercury, feed on partially degraded and mercury-rich organic matter, rapidly bioaccumulating significant amounts of mercury and methylmercury and transferring it to the higher aquatic organisms as they emerge (Plourde et al. 1997) (Tremblay et al. 1998); (2) diffusion to the water column and rapid adsorption onto suspended particles (Morrison and Therien 1991). The suspended particulate matter and the bio-film at the soil-water interface actively transfer methylmercury from the sediments to invertebrates (Tremblay 1999).

1.1.2 Atmospheric Mercury Transport and Deposition

Large quantities of mercury vapor are released into the air as a result of the historically unregulated burning of coal and fuel oil that typically contain trace amounts of mercury (reaching several hundred ppm in some coals) and the incineration of municipal wastes both within the US and abroad that contain mercury-containing products such as batteries. In air, the vast majority of mercury may be found in the vapor (gaseous) state, with only a tiny fraction of it bound to airborne particles. Airborne elemental gaseous mercury usually travels long distances and durations before being oxidized and dissolving in rain and subsequently being deposited on land or in water ways (Baird 1999). Most atmospheric mercury emissions are in the form of Hg^{2+}. Once mercury reaches the land surface, human disturbance may influence how mercury moves within a specific watershed. In general, increased erosion rates result in increased mercury loading to lakes. Some studies have shown land-use of a watershed is also a major determinant of a lake trophic status, which may in turn influence mercury behavior. Other studies have shown lakes in largely forested catchments with limited agriculture or built-up cover types typically have lower total phosphorus, chlorophyll-*a*, and higher Secchi depths. All of these have been shown to reduce the relative rate of mercury methylation, the mercury form of most concern due to its ability to bioaccumulate. Lakes with very small watersheds also tend to have higher water quality, even in cases where there is substantial lake-shore development or agricultural land-use (Engstrom et al. 1999). Mercury can also be leached from rocks and soil into water systems by natural processes, some of which may be accelerated by human activities. Further, flooding of vegetated areas may release mercury into water (Baird 1999).

Atmospheric deposition of mercury occurs as both wet deposition and dry deposition. Wet deposition is associated with rain and snow, and constitutes the largest pool of mercury in the atmosphere. Dry deposition includes both particulate-associated mercury and gaseous ionic mercury. Direct measurement of deposition from atmospheric sources is the most accurate but also the most labor intensive method for estimating mercury loadings into a watershed or water body. Mercury deposition rates are typically accomplished through the measurement of either wet, dry, or bulk (i.e., combination of wet and dry) mercury deposition. A more detailed review of deposition data is available in Section 5.0 Source Assessment – Nonpoint.

The Mercury Deposition Network (MDN 2014) , which operates samplers installed throughout the US, has been created to monitor wet mercury deposition. In 1996, the MDN joined the National Atmospheric Deposition Program (NADP) and currently has over 100 sites in operation (MDN 2014). For South Dakota, the only MDN site was commissioned in June of 2007 on the Cheyenne River Indian Reservation at Eagle Butte, South Dakota. Data from this site was not used for depositional estimates by NADP until after 2009. In 2009, there were no MDN sites in Iowa or North Dakota (the Lostwood, ND site was decommissioned in 2008), two sites in southern Nebraska, and multiple sites in Minnesota.

The intent of the project conducted by Dr. Stone of South Dakota SM&T was to improve estimates of mercury deposition rates for South Dakota that were otherwise estimated from monitors in surrounding states. MDN wet deposition rates for 2009 at a national scale is shown in Figure 3. This figure shows that atmospheric mercury deposition throughout South Dakota and most of the high plains was estimated from monitors in surrounding states. The map in Figure 3 is based on a single year of data which shows mercury deposition rates as higher in the south than the north. Review of other maps available at the MDN website (http://nadp.sws.uiuc.edu/mdn/) shows patterns similar to precipitation patterns in that the western United States is substantially lower than in the eastern United States.

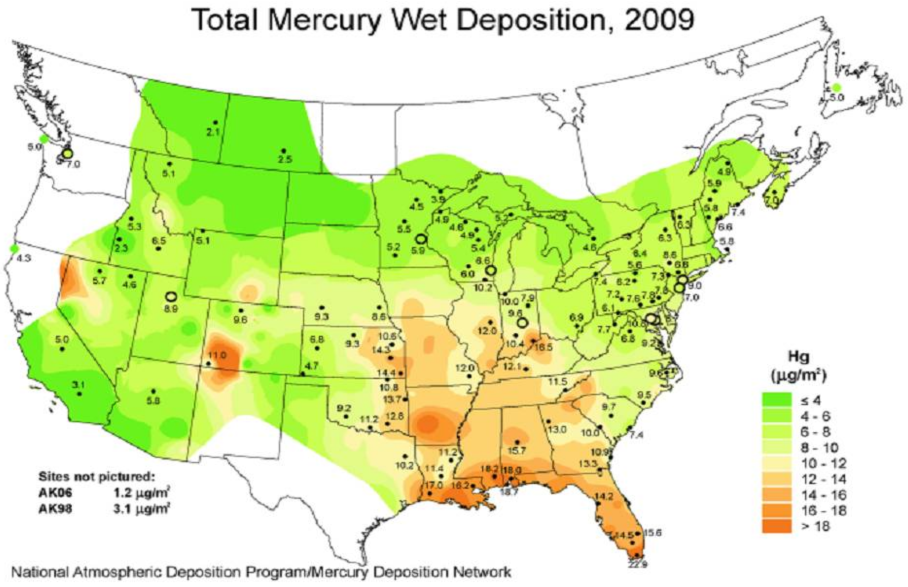


Figure 3. National total mercury wet deposition for 2009 from the MDN monitoring sites.

1.1.3 Global Trends in Mercury Emissions

Mercury is widely dispersed and transported in the atmosphere thousands of miles from existing emission sources. The ease with which mercury is mobilized into the atmosphere allows any global source to contribute to the deposition in South Dakota. While it is beyond the scope of this TMDL to completely address global sources, it is imperative for understanding the limitations of this TMDL to have an awareness of the mobile nature of mercury and the global trends associated with this persistent pollutant.

The United Nations Environment Program released the report "*Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport*." While acknowledging the limitations associated with changing inventory methods and new source accounting, it presents a review of global mercury trends for certain mercury emitting sectors. In general, the report indicates that after many years of reductions, the period of 2005 to 2010 may have seen an increase in aggregate mercury emissions. Some of these variables for the two largest emissions sectors (small scale gold mining and coal fired power) are discussed in the following excerpt from that report.

> *"Coal burning for power generation and for industrial purposes continues to increase, especially in Asia. However increases in the application of air pollution controls, including some mercury specific technologies, together with more stringent regulations in a number of countries have reduced mercury emissions from coal burning in power plants in particular, and thus offset some part of the emissions arising from increased coal consumption.*
>
> *In the United States, for example, emissions from coal burning at power plants have reportedly decreased from about 53 tonnes in 2005 to 27 tonnes in 2010. This decrease is largely due to new regulations that have resulted in changes in the sources of the coal that is burned in large power*

> *plants and the installation of mercury controls as well as controls on sulphur dioxide and particulates that have the co-benefit of further reducing mercury emissions.*
>
> *In China, many of the new coal-fired power plants have state-of-the-art pollution controls installed.*
>
> *Emissions of mercury from artisanal and small-scale gold mining (ASGM) reported for 2010 are more than twice those reported for 2005. While the rise in the price of gold (from USD 400 per ounce in 2005 to USD 1100 per ounce in 2010), along with increased rural poverty, may indeed have caused more activity in this sector, the increased estimate for mercury emissions is considered to be due primarily to some more and better data from many countries and regions. West Africa, for example, was regarded as having minimal ASGM in 2005, but is now recognized as a region with considerable activity. Thus, the baseline has improved, without necessarily any change in actual activity or emission levels.*
>
> *Waste from consumer products is affected by the amount of mercury used. For most products in which mercury is used, mercury-free alternatives exist. Consequently, many of these uses of mercury are declining, at least in some regions, as alternative products or processes are adopted. Compact fluorescent light bulbs are an exception. Even though the mercury content of individual light bulbs has decreased, use of this type of light bulb is increasing rapidly.*
>
> *In order to make valid assessments of trends in emissions from global inventories, comparable data on activity levels are required, together with information on changes in fuel and raw material characteristics and applied air pollution control technology. One aim of the 2010 inventory methods is to create a firmer foundation for such future trend analysis."* (UNEP 2013)

1.2 Impaired Waters

The 2014 South Dakota Integrated Report (also referred to as the State's 303d list) included eighteen waterbodies as impaired for elevated concentrations of methylmercury in fish tissue. Fish consumption advisories were used as the basis for each of these impairment listings. Fish consumption advisories are non-regulatory mechanisms used to inform the public that high concentrations of chemical contaminants, such as mercury, have been found in local fish. In South Dakota, the Department of Game, Fish & Parks; the Department of Environment and Natural Resources; and the Department of Health work together to establish fish consumption advisories and provide public education and outreach.

In South Dakota, advisories have been issued for fish in a particular size category when mercury levels exceed the Food and Drug Administration (FDA) consumption advisory action level of 1.0 mg/Kg of methylmercury. Typically, the advisories are species specific and reflect the largest size class present in the water body. These advisories use waterbody-specific fish tissue data and FDA action levels to derive a maximum weekly or monthly fish consumption recommendation. For example, children under age 7 are recommended not to eat more than 4 ounces per month of walleye over 17" from Long lake. The advisories indicate how much locally-caught fish can be safely consumed with no additional exposure. For methylmercury, the FDA action level of 1 mg/Kg is used to identify contaminated or adulterated food by the agency charged with protecting our nation's food supply. The South Dakota consumption advisories, and the FDA action level from which they are calculated, are similar to the EPA methylmercury criterion of 0.3 mg/Kg used in this TMDL analysis but use slightly different risk assumptions (USEPA 2010).

The 0.3 mg/Kg criterion was developed by EPA to serve as guidance for states while establishing water quality standards, as required under the Clean Water Act, which have regulatory implications (e.g. surface water discharge permit limits, 401 certifications, etc.). EPA requires states to adopt the 0.3 mg/Kg methylmercury criterion or a scientifically defensible modification of it in their water quality standards regulations. South Dakota chose to directly adopt the 0.3 mg/Kg criterion without modification. The methylmercury criterion was the first time EPA issued a water quality criterion expressed as a fish tissue value rather than a water column value due to the bioaccumulative nature of mercury and the limited pathways of exposure. The methylmercury criterion differs from the fish consumption advisory based on the FDA action level in that the EPA criterion considers all possible routes of human exposure to methylmercury, beyond just the ingestion of locally-caught freshwater fish. During criterion development, EPA demonstrated that methylmercury exposure through drinking water, non-fish dietary foods, air, and soil was negligible (USEPA 2001). The two most significant exposure routes identified were the ingestion of both marine and freshwater fish. Thus the EPA criterion assumes individuals are exposed to methylmercury from eating marine fish sold in stores, in addition to the freshwater fish they catch and eat locally, and a portion of the allowable methylmercury exposure is reserved for consumption of marine fish. As a result, the EPA criterion is more conservative than the FDA action level. For a complete description of the methodology and basis for the EPA criterion, please see *Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001). Table 2 includes the waters listed as impaired due to fish consumption advisories in the 2014 South Dakota Integrated Report (map included as Figure 4). This TMDL was written to attain the EPA recommended fish tissue criterion of 0.3 mg/Kg methylmercury.

Table 2. Assessment units included as impaired in South Dakota's 2014 Integrated Report.

Assessment Unit ID	Common Name-County
SD-BF-L-NEWELL_01	Newell Lake-Butte
SD-BS-L-BITTER_01	Bitter Lake-Day
SD-BS-L-ISLAND_N_01	North Island Lake – Minnehaha/McCook
SD-JA-L-LARDY_01*	Lardy Lake-Day*
SD-BS-L-LONG_COD_01	Long Lake-Codington
SD-JA-L-MID_LYNN_01**	Middle Lynn Lake-Day
SD-BS-L-MINNEWASTA_01	Minnewasta Lake-Day
SD-JA-L-OPITZ_01**	Opitz Lake-Day
SD-BS-L-REID_01	Reid Lake-Clark
SD-BS-L-SWAN_01	Swan Lake-Clark
SD-BS-L-TWIN_01	Twin Lakes/W. Hwy 81 - Kingsbury
SD-BS-L-TWIN_02	Twin Lakes-Minnehaha
SD-GR-L-PUDWELL_01	Pudwell- Corson
SD-GR-L-ISABEL_01	Isabel-Dewey
SD-JA-L-ELM_01	Elm Lake-Brown
SD-MI-L-HURLEY_01	Lake Hurley-Potter
SD-MI-L-ROOSEVELT_01	Roosevelt Lake-Tripp
SD-MU-L-COAL_SPRINGS_01	Coal Springs Reservoir-Perkins

* See Figure 4 caption regarding mapping error in 2014 Integrated Report. Also, for same reason discussed in the next footnote, SD-BS-L-LARDY_01 has been changed to SD-JA-L-LARDY_01.

**An error in the 2014 Integrated Report considered these waterbodies within the Big Sioux River Basin. The 2016 Integrated Report correctly placed them in the James River Basin and amended Assessment Unit ID's from SD-BS-L-OPITZ_01 and SD-BS-L-MID_LYNN_01 to SD-JA-L-OPITZ_01 and SD-JA-L-MID_LYNN_01. Opitz Lake and Middle Lynn Lake were correctly mapped in Figure 4, unlike Lardy Lake.

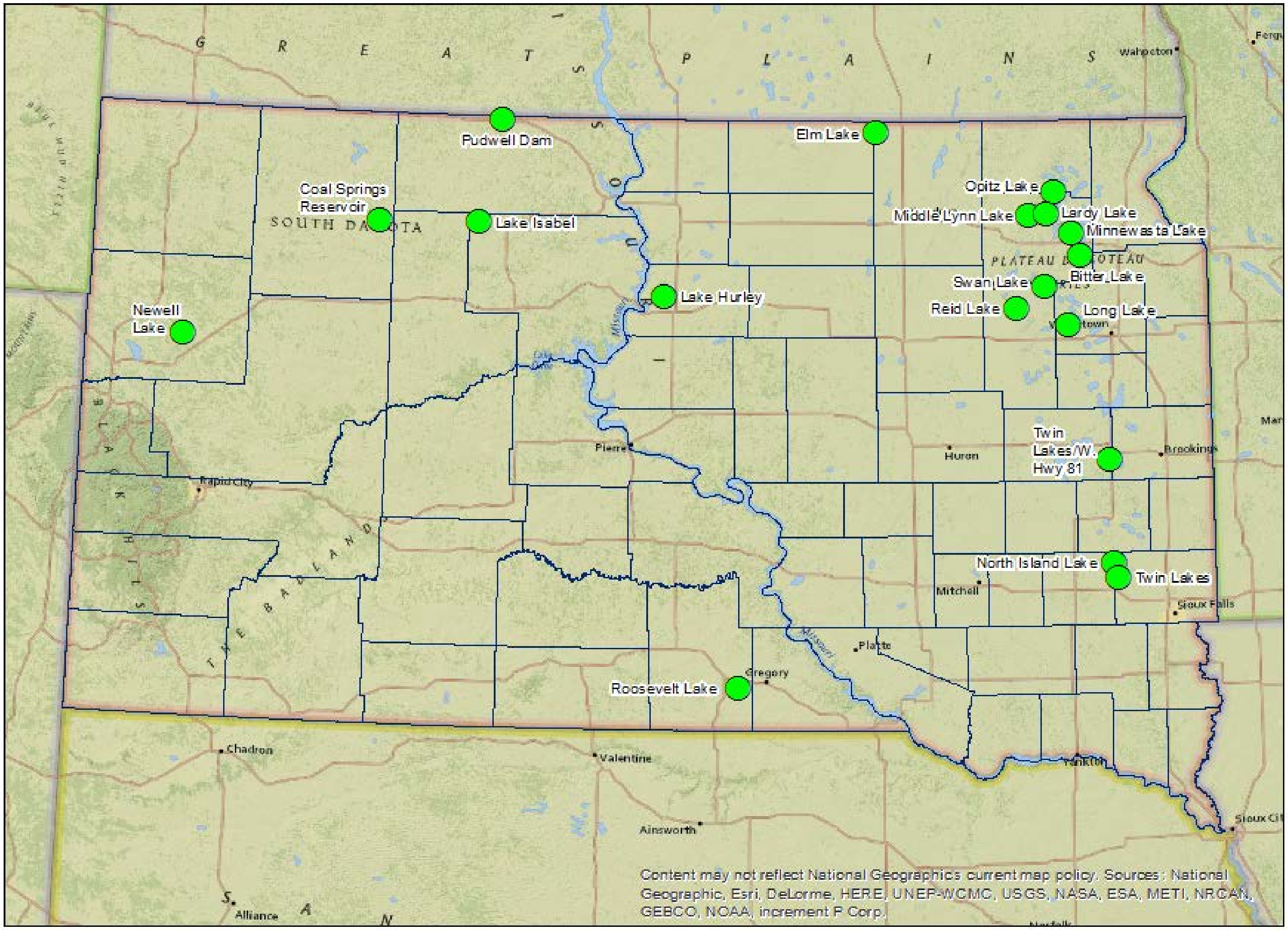


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Figure 4. Waters listed as impaired for fish tissue methylmercury in South Dakotas 2014 Integrated Report. Note, Lardy Lake was mapped incorrectly in the 2014 Integrated Report, this error has been corrected in this figure.

Assuming EPA will formally approve the new methyl mercury in fish tissue criterion, the State has moved forward with developing a 303(d) listing method for the 2016IR with consultation from EPA. To maintain consistency with the 2016 IR, the listing method was applied to all waters with fish tissue data collected from 2006 through the 2015 sampling season. Each assessment unit was evaluated based on the 95th percentile of all fish tissue methylmercury concentrations (inclusive of all species) provided there were a minimum of 10 fish tissue samples available for a given waterbody. A species specific fish consumption advisory for any waterbody was also considered grounds for an impairment determination. Using the 2016IR listing method, South Dakota has determined 61 new waters will be considered impaired in addition to the 18 waters previously mentioned. These waters are listed in Table 3 and presented in Figure 5. Two waterbodies with 95th percentiles above the 0.3 mg/Kg threshold were not included in the list in Table 3 and are further explained below.

Pactola Reservoir had a single fish out of ten northern pike sampled during 2011 that exceeded the 0.3 mg/Kg threshold with a concentration of 0.32mg/Kg. The remainder of the samples consisted of both larger and smaller (older/younger) fish that had a mean concentration of 0.16 mg/Kg. Data from the 1994 and 2005 sampling seasons expanded the dataset to 33 individual fish representing eight additional species. This supplementary data provided no additional exceedances of the threshold. Based on the weight of this evidence, Pactola Reservoir was not considered impaired for methylmercury in fish tissue.

Rosehill Dam in Hand County experienced heavy runoff in the spring of 2010 which overwhelmed the spillway and caused a significant breach in the dam. Rosehill Dam was reduced to intermittent stream flow and not considered a viable reservoir to support designated beneficial uses. As a result, Rosehill was removed from the 2012 303d list for not supporting the warmwater permanent fish life use. Plans were established to rebuild the structure during 2012; however the FEMA funds awarded were insufficient to completely replace the structure. As of 2015 SDGFP had resubmitted an application for additional FEMA funding. Due to the uncertainty of the future existence of this structure, it was not considered impaired for methylmercury in fish tissue.

For the remaining 61 assessment units listed as impaired in Table 3, the TMDL should be considered applicable to all but one. Included in the listed waters are several with conditions which EPA has expressed concerns over. Those concerns as well as the water the TMDL does not cover are addressed below:

1. Inclusion of riverine systems. The TMDL calculations included riverine systems as part of the statistical analysis. There were insufficient numbers of riverine samples to conduct extensive comparisons between them and the lentic systems included in the dataset. The riverine systems generally had lower concentrations of fish tissue mercury than many of the lakes or reservoirs. These systems are often interconnected and it is likely that there is fish migration between the two systems. Due to the interconnectivity and that data from these systems was used to develop the TMDL, South Dakota expects this TMDL to be applied to riverine systems.
2. Black Hills Waters. Sheridan and Stockade Lakes are the only waters on the list located in close proximity to historic mining processes. The Black Hills have an extensive history of mining activities, the most severe of which occurred in the northern hills, particularly in the area around Lead and Deadwood. Review of historic mine operations

(Allsman 1938) documented that there were many small claims in what would eventually become the Sheridan and Stockade Lake watersheds. These claims were small, short lived, and produced little gold, suggesting that the amount of material mined and thus their impact on the lakes after they were constructed would be minimal. Beyond the presence of historic mines, these impairments may be best explained by the species of fish which are most commonly caught. While most waters in the Black Hills are dominated by cold water species such as trout, Sheridan and Stockade Lake have a more diverse species base including largemouth bass, which is the species that resulted in the lakes impairment status on this list. Based on this information, South Dakota expects that this TMDL can be applied to Sheridan and Stockade Lakes.

3. Tribal Border Waters. Lake Oahe borders both the Cheyenne River and Standing Rock Reservations. To the states knowledge, neither of these reservations has adopted any standards relating to mercury. As such, the South Dakota water quality standards are more stringent than the tribal standards. Until a more restrictive water quality standard that is more restrictive than South Dakotas is implemented, the state expects the TMDL to apply to Lake Oahe within the State of South Dakota.
4. State Border Waters. The Missouri River below Gavins Point Dam forms a border with the state of Nebraska. Nebraska water quality standards include a fish tissue methylmercury concentration of 0.215 mg/Kg. This standard is more restrictive than the 0.3 mg/Kg standard used in this TMDL. It is not expected that this TMDL may be applied to SD-MI-R-LEWIS_AND_CLARK_01 at this time.

As the state continues to monitor fish flesh contaminants there will be previously unassessed waters where future sampling may indicate impairment due to methylmercury. If the data had been available during development, these waters would have been included in this TMDL. Any new impairment listings for waters exceeding the methylmercury listing method documented in this TMDL will be included through an addendum process described in section 1.3.

Table 3. Waters exceeding the criterion of 0.3 mg/Kg and thus considered impaired for methylmercury but not included as impaired in the 2014 South Dakota Integrated Report.

SD-BA-L-HAYES_01	Hayes Lake-Stanley	SD-JA-L-COTTONWOOD_01	Cottonwood Lake-Spink
SD-BA-L-MURDO_01	Murdo Dam - Jones	SD-JA-L-FAULKTON_01	Lake Faulkton-Faulk
SD-BA-L-SHERIFF_01	Sheriff Dam - Jones	SD-JA-L-HANSON_01	Hanson Lake-Hanson
SD-BF-L-ORMAN_01	Belle Fourche Reservoir-Butte	SD-JA-L-HAZELDON_01	Hazeldon - Day
SD-BF-R-BELLE_FOURCHE_04	Belle Fourche River - Meade	SD-JA-L-HENRY_01	Lake Henry-BonHomme
SD-BS-L-ALBERT_01	Lake Albert-Kingsbury	SD-JA-L-HORSESHOE_01	Horseshoe Lake-Marshall
SD-BS-L-ANTELOPE_01	Antelope Lake-Day	SD-JA-L-LILY_01	Lily GPA-Day
SD-BS-L-BRUSH_01	Brush Lake-Brookings	SD-JA-L-LOUISE_01	Lake Louise-Hand
SD-BS-L-CLEAR_H_01	Clear Lake - Hamlin	SD-JA-L-LYNN_01	Lynn - Day
SD-BS-L-DIAMOND_01	Diamond Lake - Minnehaha	SD-JA-L-MINA_01	Mina Lake (Lake Parmley)-Edmunds
SD-BS-L-DRY_NO2_01	Dry Lake # 2-Clark	SD-JA-L-RAVINE_01	Ravine Lake-Beadle
SD-BS-L-DRY_01	Dry Lake-Codington	SD-JA-L-REETZ_01	Reetz Lake-Day
SD-BS-L-ENEMY_SWIM_01	Enemy Swim Lake-Day	SD-JA-L-RICHMOND_01	Richmond Dam-Brown
SD-BS-L-GOLDSMITH_01	Goldsmith Lake-Brookings	SD-JA-L-SOUTH_BUFFALO_01	Buffalo Lake, South-Marshall
SD-BS-L-GOOSE_01	Goose Lake-Codington	SD-JA-L-STAUM_01	Staum Dam-Beadle
SD-BS-L-HERMAN_01	Lake Herman-Lake	SD-JA-L-WILMARTH_01	Wilmarth Lake-Aurora
SD-BS-L-KAMPESKA_01	Lake Kampeska-Codington	SD-JA-R-JAMES_08	James River - Beadle
SD-BS-L-POINSETT_01	Lake Poinsett-Hamlin	SD-LM-R-LITTLE_MISSOURI_01	Little Missouri River-Harding
SD-BS-L-RUSH_01	Rush Lake-Day	SD-MI-L-BRAKKE_01	Brakke Dam-Lyman
SD-BS-L-SINAI_01	Lake Sinai-Brookings	SD-MI-L-COTTONWOOD_01	Cottonwood Lake-Sully
SD-BS-L-WAUBAY_01	Waubay Lake-Day	SD-MI-L-FATE_01	Fate Dam-Lyman
SD-BS-R-BIG_SIOUX_07	Big Sioux River-Moody	SD-MI-R-LEWIS_AND_CLARK_01	Missouri River-Fort Randall Dam to Sioux City-Yankton
SD-CH-L-CURLEW_01	Curlew - Meade	SD-MI-R-OAHE_01	Lake Oahe
SD-CH-L-SHERIDAN_01	Sheridan Lake-Pennington	SD-MN-L-ALICE_01	Lake Alice-Deuel
SD-CH-L-STOCKADE_01	Stockade Lake - Custer	SD-MN-L-SUMMIT_01	Summit Lake-Grant
SD-GR-L-SHADEHILL_01	Shadehill Reservoir-Perkins	SD-MU-L-LITTLE_MOREAU_NO1_01	Little Moreau Lake #1-Dewey
SD-JA-L-AMSDEN_01	Amsden Dam-Day	SD-VM-L-E_VERMILLION_01	Vermillion Lake-McCook
SD-JA-L-CARTHAGE_01	Lake Carthage - Miner	SD-VM-L-HENRY_01	Lake Henry-Kingsbury
SD-JA-L-CATTAIL_01	Cattail Lake-Marshall	SD-VM-L-THOMPSON_01	Lake Thompson-Kingsbury
SD-JA-L-CAVOUR_01	Cavour Lake-Beadle	SD-VM-L-WHITEWOOD_01	Whitewood - Kingsbury
SD-JA-L-CLUBHOUSE_01	Clubhouse Lake - Marshall		

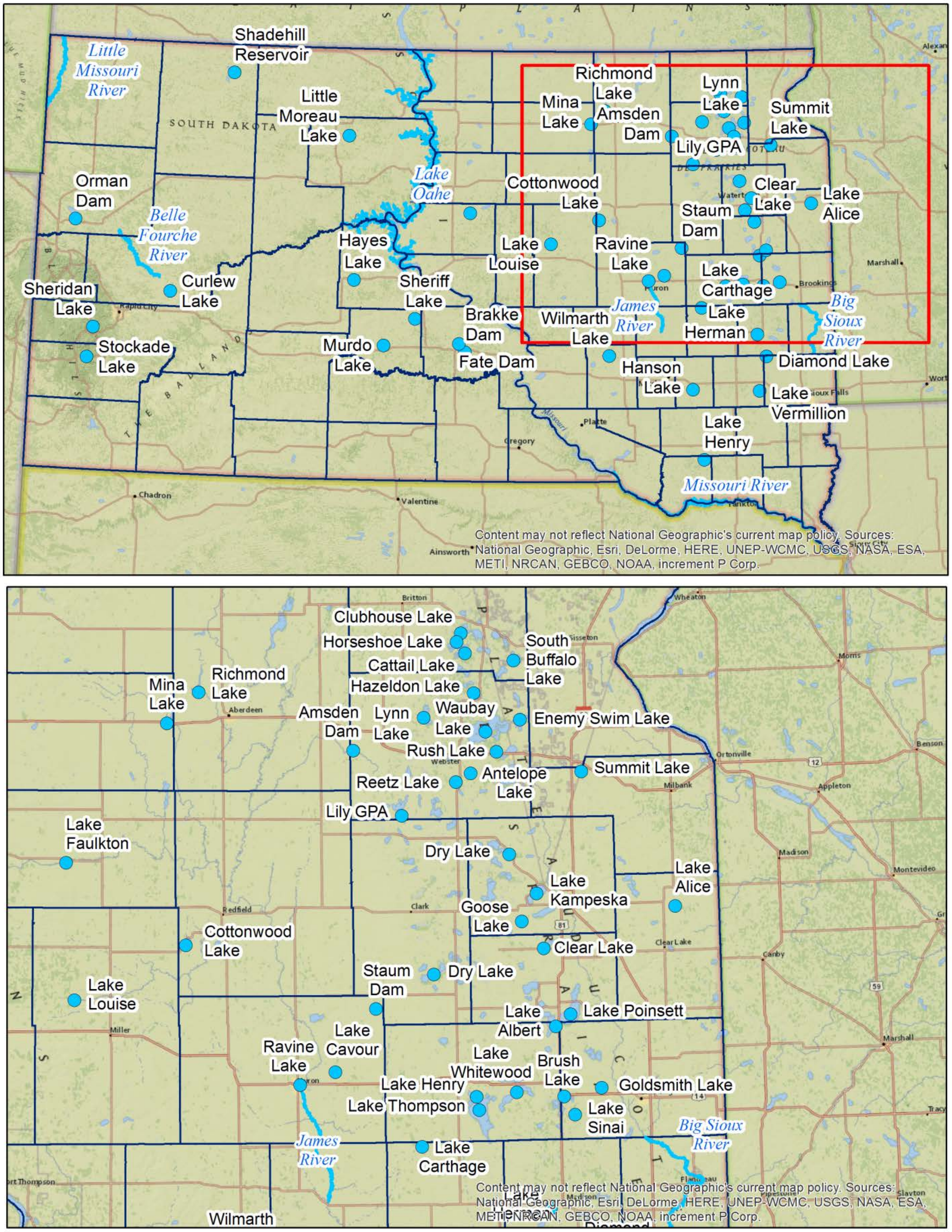

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Figure 5. Waters exceeding the criterion of 0.3 mg/Kg and thus considered impaired for methylmercury but not included as impaired in the 2014 South Dakota Integrated Report.

1.3 TMDL Approach for Multiple Waterbodies and Revision Process

South Dakota is subject to atmospheric mercury deposition from regional and global mercury emissions sources located outside the state's boundaries. This process occurs across the entire state and impacts both assessed and unassessed waters. Given this set of circumstances, a statewide approach is the most logical for addressing the methylmercury problem. This approach is not unique as several states have dealt with this problem in some regional fashion, e.g. Northeast Regional Mercury TMDL and Minnesota Statewide Mercury TMDL. In fact, EPA has issued guidance to help states develop TMDLs where mercury loadings are predominantly from air deposition (USEPA 2010; USEPA 2008). In support of this approach various factors including fish tissue data, landscape similarities, source and loading information, among others, can be used as the basis for this rationale. This basis serves both as the rationale for applying this TMDL to the waters included, and as the criteria for evaluating the applicability of this TMDL to waters that are assessed at a later date.

An essential part of South Dakota's statewide approach included all available fish tissue data (inclusive of lakes, reservoirs, rivers, and streams) collected from within the state. This data was used to establish a baseline from which reductions could be calculated. To apply this TMDL statewide it is assumed that proportional reductions will occur for all waters of the state. The level of reduction was based on the 90th percentile standard length walleye concentration as described in Section 3.3. Waterbodies that exhibit lower methylmercury fish tissue concentrations could be expected to meet the TMDL goal with fewer or less stringent reductions; however, this approach provides a higher degree of protection for all waters of the state.

The relationship(s) of the mercury fish tissue data with watershed landscape features and lake chemistry variables was also evaluated. Current research has indicated that certain combinations of these sets of factors can exacerbate the methylation of mercury. The question to answer, as part of the TMDL, was: Are there certain characteristics or combinations of characteristics that can explain why some waterbodies exhibit higher concentrations of methylmercury in fish tissue compared to others? It was necessary to determine if methylmercury as a response variable could be explained by various predictor variables on a statewide or waterbody specific level. Water level fluctuations and land cover characteristics such as areal wetland coverage were able to explain 35% of the variability within the distribution of methylmercury fish tissue concentrations producing a significant regression line. These characteristics can be used to predict the potential for methylation of mercury. However, they do not affect the statewide applicability of this TMDL. Although statewide, water level fluctuations and areal wetland coverage explain some of the variability in the fish tissue concentrations, these features cannot be changed. The primary driver of the methylation process is the presence of mercury by way of atmospheric deposition.

Past surveys conducted by the SDDENR have also indicated ecoregional differences in lake water quality (Stewart et al. 2000). Similar comparisons, for the purposes of the SD mercury TMDL, were made between water body type (lake vs. reservoir) and geographic location with regards to mean methylmercury fish tissue concentration. Differences were not significant (see Section 3.4.6.2 Lakes and Impoundments) resulting in a TMDL that can be applied to any waterbody type within the geographic boundary of South Dakota that fits the remainder of the criteria defined in this section.

At the point of drafting this TMDL, standard length fish from Bitter Lake exhibited the highest methylmercury concentrations measured for fish tissue in South Dakota. The design of this TMDL provides the necessary limit needed for this maximum observed range of concentrations. Fish tissue concentrations in Bitter Lake have exhibited a great deal of variability between sample years (ranging from 0.469 mg/Kg to 0.878 mg/Kg for standard length fish). To ensure that water quality standards are met, this TMDL is applicable only to waters with standard length fish tissue methylmercury concentrations less than the observed standard length fish concentration (0.878 mg/Kg).

Mining has the potential to release mercury into the environment through leaching and direct runoff from tailing sites. Although mines may result in elevated elemental mercury levels in downstream waters, this does not always result in elevated fish tissue concentrations. Methylation processes must work in concert with a source and bioaccumulation before elevations of fish tissue methylmercury levels are observed. Sites in the Black Hills region of South Dakota are the most likely to be impacted by historic mining. Methylmercury concentrations in fish tissue sampling in known mining areas (including Whitewood Creek, Spearfish Creek, and Bear Butte Creek) have shown no impairments as a result of methylmercury. Continued monitoring is planned for this region and though unlikely, a possibility remains that a stream segment may be found with impairments resulting from mine waste. In the event impairments are found in waters receiving discharge from a mine site, application of this TMDL would be deferred until such time as adequate data shows the cause of the impairment is not related to the mine or a site specific mercury TMDL is developed.

The State has reviewed water chemistry data from all NPDES discharges and found no correlation between their locations and methylmercury impairments. The lack of empirical evidence and the declining use of mercury in industry suggests the chances of a new discharge causing this type of impairment are unlikely. However, the application of this TMDL to newly assessed waters will include a review of those NPDES permits that discharge directly to the impaired reach. It should also be noted that South Dakota has existing regulations (74:51:01:27. Lakes not allowed a zone of mixing) which prohibit NPDES discharges to classified lakes.

In summary, this TMDL may be applicable to additional waters of the state if:

- It falls entirely within state jurisdiction,
- If jurisdiction is shared, it may only be applied to those portions of the water under South Dakotas' jurisdiction,
- The standard length fish tissue methylmercury concentrations from the water does not exceed 0.878 mg/Kg,
- There are no potential impacts from current or historic gold mining processes,
- If it is a river or stream, NPDES discharges do not exceed permitted limits,
- The TMDL will meet the water quality standards in the proposed water, and
- The original TMDL assumptions (e.g., source contributions, loading capacity, etc.) are still valid.

Once it is determined a new waterbody or set of waterbodies are appropriate to include in the statewide mercury TMDL, a revision process will be followed. To revise the original statewide mercury TMDL to include additional waters, SDDENR will provide appropriate public notice of the proposed changes, review and address any public comments, explain how the waters meet all of the applicability criteria described above, and obtain EPA approval of the changes. Other states have chosen to address revisions to their statewide mercury TMDL as part of the biennial Integrated Report (IR) submission and SDDENR may use the public notice and EPA approval pathways already established in the IR process, or may submit revisions using the same process but not through the IR submission.

Other situations may arise where revisions to this statewide TMDL will require similar public notice and EPA approval components as adding new waters to the TMDL. As noted in EPA's draft *Consideration for Revising and Withdrawing TMDLs* memo (USEPA 2012), these situations may include:

- Re-allocations between WLAs and LAs (except where a non-regulated LA source is re-categorized as a regulated point source and given a WLA of the same magnitude; for example, storm water)
- Changes to the MOS, loading capacity, or method for calculating loading capacity
- Changes in the applicable water quality standards such that the original TMDL is no longer sufficient to meet the new standard

2.0 Water Quality Standards

South Dakota water quality standards establish 11 beneficial uses which are assigned to individual waters based on their characteristics. All waters (both lakes and streams) are assigned the beneficial use of fish and wildlife propagation, recreation, and stock watering. All streams are assigned the beneficial use of irrigation. Additional uses are assigned by the state based on a beneficial use analysis of each water body. Each beneficial use has a set of water quality standards to protect those uses. The Administrative Rules of South Dakota (ARSD) contain the water quality standards in Chapter 74:51.

For the evaluation of chronic standards, including geometric means and 30-day averages, a calendar month is used. While not explicitly described within the water quality standards, this is the method used in the South Dakota Integrated Water Quality Report (IR) as well as in permit development.

South Dakota water quality standards specifically address mercury concentrations in the water column designed to address both human health as well as aquatic health. The more restrictive concentrations are for human health. Beneficial use (1) Domestic water supply waters, utilizes a chronic standard of 0.050 µg/L for total mercury. This concentration is based on two routes of exposure; ingestion of contaminated aquatic organisms and drinking water. The second human health standard is based on a single route of exposure, ingestion of contaminated aquatic organisms and is slightly higher at 0.051 µg/L total mercury and applies to beneficial uses:

(2) Coldwater permanent fish life propagation waters;
(3) Coldwater semipermanent fish life propagation waters;
(4) Warmwater permanent fish life propogation waters;
(5) Warmwater semipermanent fish life propagation waters;
(6) Warmwater marginal fish life propagation waters; and
(9) Fish and wildlife propagation, recreation, and stock watering waters.

South Dakota Mercury Water Quality Criteria associated with Beneficial Uses 1-9 prior to 2015

Beneficial Uses	Human Health Criteria for Use (1)	Freshwater Aquatic life criteria for uses (2), (3), (4), (5), (6) and (9)	Human health criteria for uses (2), (3), (4), (5), (6) and (9)	FDA based Advisory threshold for uses (2), (3), (4), (5), (6) and (9)
WQ criteria	0.050 µg/L (water column, total mercury)	1.4 µg/L (acute, dissolved mercury) 0.77 µg/L (chronic, total recoverable mercury)	0.051 µg/L (water column total mercury)	1.0 mg/Kg (fish flesh methylmercury

Additional water quality regulations which apply to mercury impairments include the biological integrity of waters. Elevated levels of mercury may impair biological integrity, such as through reduced reproductive success of walleye (Selch 2008). ARSD Section 74:51:01:12 ascertains that all waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities. Additionally, ARSD Section 74:51:01:55 also states that toxic pollutants (including mercury) may not exist at levels which are or may become injurious to public health, safety, or welfare. Protection of these narrative criteria is best accomplished by meeting the most stringent numeric water column criteria 0.050 µg/L of total mercury.

As a part of the 2014 triennial review, SDDENR proposed and the Water Management Board adopted into the states Surface Water Quality Standards a fish flesh MeHg standard of 0.3 mg/Kg. This concentration is the EPA recommended human health criterion and applicable to beneficial uses 2, 3, 4, 5, 6, and 9.

A fish flesh based concentration standard requires a linkage to ensure protection of the existing water column standards. This linkage is accomplished through application of a bioaccumulation factor (BAF). Bioaccumulation refers to the uptake and retention of a chemical by an aquatic organism from all surrounding media including water, sediment, and the foods it consumes. It is similar to, but not the same as a bioconcentration factor (BCF), which differs by only considering the organisms uptake from the surrounding water as opposed to including the foods it consumes.

BAFs can vary significantly throughout the nation and even between waterbodies within a region. The optimal evaluation would involve a BAF based on the specific waters that are addressed in this TMDL. In the absence of sufficient data, the draft national BAF was evaluated for applicability in this TMDL.

Due to regional variability, the draft national BAF is typically considered the least preferred option for developing water quality standards. An exception for use consideration includes when it will be used as a temporary measure (USEPA 2010). This exception is applicable in the case of this TMDL. It is expected that the fish tissue criterion will be adopted and the application of the draft national BAF was used as a verification tool for confirmation that the 0.3 mg/Kg criterion is protective of South Dakotas existing water quality standards.

The draft national BAFs were derived through three approaches: direct, indirect, and conversions (modified direct) approaches. Each approach has its own limitation summarized in greater detail along with the steps used in the development of the values in *Appendix A of Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001). The resulting BAFs were based on the geometric mean of field data collected from across the United States and reported in literature (Table 4).

Table 4. Summary of draft national BAFs and BCF expressed as L/kg for dissolved mercury (USEPA 2001)

Value[a]	BCF	BAF_2	BAF_3	BAF_4
5th percentile	5,300	18,000	74,300	250,000
50th (GM) percentile	33,000	117,000	680,000	2,670,000
95th percentile	204,000	770,000	6,230,000	28,400,000
GSD	3.03	3.15	3.84	4.21
Draft National Values	3.3E+04	1.2E+05	6.8E+05	2.7E+06

[a] GM=geometric mean; GSD=geometric standard deviation

The three $BAF_{(x)}$ values presented in Table 4 address 2nd through 4th order trophic levels. Trophic levels are the feeding position of organisms in the food chain and higher orders represent organisms higher in that chain. In the case of this TMDL, it is based on the accumulation of methylmercury in top predator fish which are a higher trophic order. Thus the BAF_4 is the most applicable for determining if the 0.3 mg/Kg is protective of the existing water quality standards.

The methylmercury bioaccumulation factor (BAF) can be calculated using the following generalized equation:

$$BAF = \frac{C_t}{C_w}$$

Where:

C_t = Concentration of total methylmercury in the wet tissue
C_w = Concentration of dissolved methylmercury in water

To solve this equation for the most conservative water column standard of 0.050 µg/L total mercury, the equation is rewritten as:

$$\frac{C_t}{BAF} = C_w$$

Where:

BAF = Draft national BAF for trophic level 4 = 2.7×10^6 L/kg
C_t = Methylmercury criterion = 0.3 mg/Kg
C_w = Concentration of dissolved methylmercury in water in mg/L

Solving this equation using the values as presented, results in 1.1×10^{-7} mg/L or 1.1×10^{-4} µg/L dissolved MeHg in the water column. The state's water quality standard is written for total mercury, therefore the dissolved methylmercury concentration must be further converted for comparison. This conversion is accomplished by using mercury translators as provided by EPA and presented in Table 5.

Table 5. Summary of mercury translators for mercury in water. (USEPA 2001)

f_d value	Lentic	Lotic
f_d Hg_d/Hg_t	0.600	0.370
f_d $MeHg_d/Hg_t$	0.032	0.014
f_d $MeHg_d/MeHg_t$	0.613	0.490

$_d$=dissolved $_t$=total

Table 5 includes values for both lentic and lotic systems. Lentic waters are defined as "still" waters such as lakes, ponds, pools, and most reservoirs. Lotic systems are defined as those with flowing waters such as springs, creeks, and rivers. Bioaccumulation trends are expected to be different for these two types of systems due to inherent difference in methylation processes, food web dynamics, mercury loadings, and watershed variables among other factors (USEPA 2001).

The equation used for the conversion of dissolved methylmercury to total mercury is presented below:

$$\frac{MeHg_d}{Hg_t} = Translator$$

Solving the equation for the total mercury (Hg_t) factor the following equation is used:

$$\frac{MeHg_d}{Translator} = Hg_t$$

Where:

$MeHg_d$ = Concentration of dissolved methylmercury
Hg_t = Concentration of total mercury

Using the translators as presented in Table 5 (0.032 for lentic systems and 0.014 for lotic systems) with the dissolved methylmercury concentration previously calculated (1.1×10^{-4} µg/L) the following solutions are generated:

Lentic

$$\frac{1.1\,x10^{-4}}{0.032} = 0.003\left(\frac{\mu g}{L}\right)\ total\ mercury$$

Lotic

$$\frac{1.1\,x10^{-4}}{0.014} = 0.008\left(\frac{\mu g}{L}\right)\ total\ mercury$$

These concentrations are then compared to the most protective water column standard used in South Dakota (0.050 µg/L total mercury). The water quality standard is over 16 times greater than the lentic calculation and over 6 times greater than the lotic. It is important at this point to reiterate regional BAFs may be significantly different than the draft national BAFs from which these were derived. Discussion of uncertainty in *Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001) included that there was at least an order of magnitude in variability. Considering the uncertainty in the draft national numbers, the large margins between the water quality standard and the calculated values add reasonable certainty that using the fish tissue concentration 0.3 mg/Kg methylmercury is providing adequate protection for the existing water quality standards.

3.0 Data Analysis

To determine the necessary mercury reductions needed to attain the TMDL, a single methylmercury concentration representing current conditions must be derived so a reduction factor can be calculated to meet the water quality standards. It must be demonstrated that this concentration is protective of all fish. Common to other regional and statewide mercury TMDLs, the approach involves selecting a standard length of a single representative species. These processes are described in Sections 3.1 and 3.2.

In Section 3.3, the Principal of Proportionality explains how changes in atmospheric mercury deposition are linked to changes in fish tissue methylmercury concentrations. This discussion outlines a common approach in Stone's 2011 report and other regional and statewide Hg TMDLs.

An important link in the process of atmospheric deposition of mercury to its accumulation in aquatic life is the methylation process which converts mercury into methylmercury, the form which most readily bioaccumulates. Section 3.4 includes research summaries conducted partially or entirely within South Dakota, as well as additional analysis conducted by SDDENR to expand the results of the individual studies. The intent of this review and analysis was to determine if additional measures could be taken to reduce the methylation rates, thus limiting the amount of methylmercury available for uptake into the food web.

3.1 Fish Tissue Mercury

A single predator fish species was selected to calculate a consistent level of reductions for the Hg TMDL. Top predator fish are defined as those species whose position is at the top of the food chain. These top predator species are the most appropriate as they exhibit the highest levels of toxin bioaccumulation of methylmercury and are most commonly consumed. In South Dakota, there are several species which fit this description and the following section describes the selection process. Differences in the selection for this TMDL, from those suggested by Stone in *Phase I Data Collection and Assessment for South Dakota Mercury TMDL Development* can be most adequately explained by the four additional years of data collection which greatly expanded the useable dataset. A summary of all individual fish tissue samples is available in Appendix D.

Regional mercury TMDLs in Minnesota, New Jersey, and the Northeast United States each examined several species of top predator fish. Species distribution and relative fish tissue mercury concentrations were used as a basis for selection. These species are typically the most sought after and consumed by anglers making them the species of greatest concern. The two most widely distributed top predator fish in South Dakota are walleye (*Sander vitreus*) and northern pike (*Esox lucius*) representing over 50% of individual fish sampled. Largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) have been selected in other mercury TMDLs. The *Micropterus* genus is found throughout South Dakota, but was not evaluated due to low numbers of individual fish in the dataset.

In South Dakota, thirty three species of fish have been sampled for mercury since 1994. Seventeen of those species had at least one fish that exceeded the 0.3 mg/Kg threshold (Table 6). Individual samples separate the *Sander* genus into walleye, sauger, and hybrids of the two referred to as saugeye. For the purposes of this assessment, walleye (n=2533) and the other members of the *Sander* genus (n=55) were grouped together.

Table 6. Number of fish samples with methylmercury concentrations above 0.3 mg/Kg 1994-2014 and mean length of population (mm).

Species	Total N	N>0.3 mg/Kg MeHg	Length (mm)	Species	Total N	N>0.3 mg/Kg MeHg	Length (mm)
Bigmouth Buffalo	2	1	*Insf*[1]	Northern Pike	1034	761	615
Black Bullhead	687	25	274	Shorthead Redhorse	25	2	*Insf*[1]
Black Crappie	401	86	242	Smallmouth Bass	108	27	299
Bluegill	285	34	189	Walleye/Sauger	2637	1238	384
Channel Catfish	472	68	446	White Bass	215	118	350
Common Carp	177	7	472	White Crappie	22	6	244
Freshwater Drum	12	4	*Insf*[1]	White Sucker	204	10	417
Goldeye	20	4	*Insf*[1]	Yellow Perch	690	139	232
Largemouth Bass	503	372	373				

1 –Insufficient sample size: Population variance of walleye (highest), northen pike (lowest), and largemouth bass indicated a minimum sample size of 60 -135 individuals is required to calculate a mean with an accuracy of 95%. Other species are expected to have a similar variance and a minimum N of 100 was set for calculating mean lengths.

Fish tissue sampling methodologies changed between initial data collection in 1994 and more recent collections. Historic data collection (prior to 2010) primarily utilized a process in which five similar length fish of the same species were composited to obtain a single mean mercury concentration for all five fish. This method is poorly suited for data analysis as it does not provide any kind of data distribution. However, in instances where studies were conducted in which individual fish were analyzed, or where multiple five fish datasets were collected at different sizes (creating variability between the measurements) the data was included in the analysis. As a result of this qualification for using the pre 2010 data, the majority of fish tissue analysis used for this TMDL focused on collections between 2010 and 2014. In 2010, the methodologies changed, where up to 10 individual fish of a species were sampled. Each individual fish was then analyzed separately creating variability within the datasets.

To determine the more protective species, a comparison between walleye and northern pike was completed. The population used for evaluation was limited to fish of both species greater than 15 inches (38 cm). Larger fish exhibit higher concentrations of mercury and the length of 15 inches is a common minimum harvest length limit for walleye in South Dakota. Northern pike reach longer lengths more quickly than walleye, and minimum length limits for northern pike are uncommon in South Dakota, but generally anglers target larger fish. Limiting the dates to 2010 to 2014 removed bias attributed to composite sampling.

Data in Table 7 presents both the mean and median concentrations of methylmercury in individual fish for walleye and northern pike. Mean values observed in catchable walleye were higher than those observed in northern pike while median concentrations were equal. Using the walleye data to establish the reduction target would provide a margin of safety inclusive of the other predator species.

Table 7. Methylmercury concentration in northern pike and walleye greater than 15 inches (38 cm) collected in South Dakota during 2010-2014.

Species	N	Mean Hg (mg/Kg)	Median Hg (mg/Kg)
Northern Pike	473	0.470	0.40
Walleye/Sauger	431	0.489	0.40

3.2 Standard Size Predator Fish

After selecting walleye as the most protective species, a methylmercury concentration must be derived or calculated for this population. The reduction factor needed to meet the TMDL is based on this standardized methylmercury concentration. This process uses a standard length walleye for which methylmercury concentrations may be calculated. Both the selection of the standard length walleye and the method for calculating the methylmercury concentrations are described below.

Bioaccumulation of methylmercury is a chronic issue where as a fish ages the concentration of methylmercury in its tissue increases. Fish length is correlated to age and in South Dakota, walleye may be expected to reach a length of 15 inches between 3 and 4 years of age. It may take up to 7 years to reach 20 inches of length (Wolf et al. 1994). It becomes important to select a single, specific length to represent the methylmercury concentration. This specific length is the standard length for that species (walleye). Developing a standard length for concentration calculations provides the potential for comparisons to be drawn between waterbodies. More importantly, it allows for comparisons from year to year for any individual waterbody. Comparisons through time will provide insight into TMDL attainment in the future. As interim goals are reached for reducing mercury, concentrations of methylmercury calculated for the standard length walleye should diminish.

To calculate the standard length, South Dakota used the walleye lengths collected as part of the mercury dataset (Appendix D) to establish a mean length (n=2,637). The sampling methods used for the mercury dataset targeted fish lengths most likely to be consumed by the public. This is consistent with the Northeast and New Jersey TMDLs where the mean population lengths of predator fish were also used to derive a protective methylmercury level in fish most likely to be consumed. Using the South Dakota dataset, the mean length of walleye was calculated at 15.1 inches (38.4 cm).

Harvest regulations in South Dakota vary between waterbodies, however the most commonly used minimum length limit for walleye harvest is 15 inches. This is typically accompanied with a regulation where only one fish greater than 20 inches may be harvested. The mean length of 15.1 inches (38.4 cm) for the mercury dataset falls within the size class of most commonly harvested and consumed walleye. It is also similar to the size selected for the Minnesota Statewide Mercury TMDL where a 40 cm walleye was chosen. A distinction between the minimum harvest length of 15 inches (as implemented from fisheries management objectives created by SDGFP) and the standard length calculated from the mercury dataset of 15.1 inches needs to be emphasized. The standard length of 15.1 inches (38.4 cm) calculated from the mercury dataset was used to develop the TMDL target. The standard length of 38.4 cm was referred to as “WE38” for the remaining steps in the TMDL reduction process.

To generate the methylmercury concentrations for a WE38 (standard length) walleye in each waterbody for a given sample year, a best fit trend line was plotted. The methylmercury fish tissue concentration is plotted on the y-axis and the corresponding fish length is plotted on the x-axis. Once the trend line is plotted, the intercept of that trend line with WE38 equates to the concentration used for the reduction goal from that waterbody. The use of WE38 “standardizes” the data and provides a baseline to assess attainment of the TMDL.

The best fit trend line (regression) approach was used to determine the annual WE38 mercury concentration where sufficient walleye samples were available for individual waterbodies. In the mercury dataset some waterbodies were sampled more than once. This resulted in multiple WE38 calculations for those waterbodies. Four of the equations resulted in negative values and were omitted from all further calculations. The equations for the trend lines may be found in Appendix C. Using the WE38 calculations, a single value representing all waters was selected to calculate the reduction factor. Selecting the 90th percentile of these values (Appendix C) provides a concentration of 0.669 mg/Kg methylmercury. .

Table 8. Bitter Lake standard length walleye (WE38) methylmercury concentrations.

Site	MeHg (mg/Kg)	Year
Bitter Lake-Day	0.469	2006
Bitter Lake-Day	0.536	2005
Bitter Lake-Day	0.558	2013
Bitter Lake-Day	0.567	2003
Bitter Lake-Day	0.649	2007
Bitter Lake-Day	0.724	2001
Bitter Lake-Day	0.878	2000

To ensure that a methylmercury concentration of 0.669 mg/Kg provides an existing condition that encompasses most waterbodies, it was compared to Bitter Lake, which has exhibited the highest WE38 values in South Dakota. Bitter Lake, as a result of the high concentrations, is the most intensively sampled (for methylmercury) water in the state of South Dakota. Table 8 shows the WE38 concentrations calculated from Bitter Lake. The 0.669 mg/Kg exceeds the concentrations observed from the five most recent years of Bitter Lake sample data and provides a significant level of protection for South Dakota waterbodies.

Considering the high variability observed in Bitter Lake, other waters in the state may be expected to exhibit similar variations from year to year. For this TMDL to effectively apply to a waterbody the standard length fish concentrations should not exceed those measured in Bitter Lake. If subsequent samples from waters exceed the maximum measured standard length walleye concentration observed from Bitter Lake (>0.878 mg/Kg in Table 8), individual TMDLs will need to be drafted to address them.

The WE38 calculation of 0.669 mg/Kg was compared to all the individual fish tissue samples across all species (Appendix D), in which it fell at the 92nd percentile. Using 0.669 as the value from which to calculate reductions will result in all species of fish attaining the TMDL goal. Therefore, the 90th percentile of WE38, established at 0.669 mg/Kg, will be used to calculate the reduction factor needed to meet the water quality standard and the TMDL.

3.3 Principle of Proportionality

The principal of proportionality for mercury in air and biota states that a decrease in atmospheric mercury deposition should decrease mercury in fish tissue. Multiple states, including Minnesota, Wisconsin, and Florida, have reported a decrease in fish methylmercury concentrations when mercury emissions or loadings were reduced from baseline levels (MPCA 2007). Several dynamic, ecosystem scale models such as the Mercury Cycling Model (MCM) and IEM-2M assume that, at steady state (i.e., over long time scales), reductions in fish mercury concentrations will be proportional to reductions in mercury inputs. When atmospheric deposition is the main source of mercury to a given water body, these models predict a linear response between changes in deposition, ambient concentrations in water and sediments, and fish mercury levels. Below, an approach is outlined, deriving a simplified relationship between percent reductions in air deposition load and fish tissue concentrations at steady state that draws on this same assumption of long-term proportionality from more complex modeling frameworks (Northeast Regional Mercury TMDL 2007).

For this to be applicable for estimating mercury load reductions in South Dakota, the following assumptions must be applied:

- Decreases in emissions from sources lead to comparative decreases in the deposition rate in South Dakota.
- Decreases in deposition lead to comparative decreases in mercury loading to lakes and rivers.
- A decrease in the mercury loading to a lake or river leads to a comparative decrease in mercury concentrations in the fish of that lake or river (MPCA 2007).

An example of a proportional reduction is explained in the Minnesota Statewide Mercury TMDL where a 50% reduction of mercury emissions in Minnesota was expected to result in a 5% reduction in mercury deposition in Minnesota. The 5% reduction in Minnesota mercury deposition is then assumed to cause a 5% reduction in methylmercury in fish (MPCA 2007). Also, if global anthropogenic mercury emissions were reduced by 50%, Minnesota's mercury deposition and fish tissue mercury would be expected to decrease by 35% (MPCA 2007). The principle of proportionality assumes environmental factors such as bioavailability to be constant and unaffected by atmospheric deposition rates (MPCA 2007).

The reduction factor (RF) will be used to establish the mercury reductions necessary to attain the fish tissue standard of 0.3 mg/Kg. The current fish tissue concentration, as established previously, for WE38 is 0.669 mg/Kg. To calculate the RF, the following equation was used. The resulting RF from this equation is 55.2%.

$$\mathrm{RF} = (\mathrm{WE38} - 0.3)/\mathrm{WE38}$$

$$55.2\% = (0.669 - 0.3)/0.669$$

3.4 Factors Affecting Methylation Processes in South Dakota

Methylation is the process through which inorganic forms of mercury are converted by microbes to the more harmful organic form, methylmercury. Methylation, a complex process in itself, occurs at different rates in different water bodies. Water chemistry, land use, habitat features and other potential factors which could affect the rate of methylation, are complex and interact with each other in ways unknown. These potential factors also change through time. Deposition rates vary throughout the state, and are presented in greater detail in section 5.1 and shown in Figure 16. Likewise, methylmercury fish tissue concentrations vary throughout the state. However, these variations are not coincident; the majority of waters with the highest concentrations (waters listed in the 2014 integrated report) are located in the Northeast part of the state while the areas which receive the greatest deposition rates are located in the Southeast part of the state.

Use of a single mercury reduction factor for multiple water bodies that clearly have different fish tissue concentrations and do not follow mercury depositional patterns necessitates a review of the factors that influence the variance in methylation rates. A great deal of research has been conducted across the nation's ecosystem types addressing the variables which influence methylation rates. Assessments that focused partially or entirely on South Dakota waters include a doctoral dissertation by Trevor Selch (Selch 2008), graduate studies by McCutcheon (McCutcheon 2009) and Betemariam (Betemariam 2010), a peer-reviewed journal article by Hayer (Hayer et al. 2011), as well as a USGS report released in 2014 (Wentz et al. 2014). These studies were reviewed and a summary of pertinent findings is provided in the following section. Where sufficient data was available, additional analysis was conducted by SDDENR to test the conclusions that were drawn in these studies.

3.4.1 Selch 2008

This study investigated the influence of fluctuating water levels on Hg concentrations in adult walleye. Evaluated parameters included watershed area to lake surface area ratio, lake volume to surface area ratio, chlorophyll *a* concentration, pH, alkalinity, and percent change in surface area between wet (2000) and dry (1987) years. These parameters were compared to mercury concentrations in adult walleye (35-50 cm in length). The only significant relationship ($p<.05$) found was between fish mercury and percent change in lake surface area (Table 9).

Table 9. Results from Pearson Correlation Analysis comparing mean walleye mercury concentrations with environmental variables from 10 glacial lakes in Eastern South Dakota (Selch 2008).

Parameter	*r*	*p*
Watershed area to Lake surface area ratio	-0.45	0.192
Lake volume to surface area ratio	0.397	0.257
Chlorophyll *a* concentration	0.391	0.263
pH	-0.006	0.987
Alkalinity	0.45	0.192
Conductivity	0.252	0.483
Percent change in surface area wet to dry years	**0.759**	**0.011**

The report also discussed differences between the date of water level expansions in northeastern South Dakota amongst lakes despite nearly uniform rainfall. *"Although the region experienced relatively uniform precipitation during the extended wet period of the mid-1990's, some lakes expanded faster and several years earlier than others. Lakes from early water-level expansions may be receding in MeHg production, and reduced MeHg production within a lake should result in lower total Hg concentrations in the resident fish communities."* (Selch 2008).

3.4.2 McCutcheon 2009

McCutcheon (2009) evaluated the link between water quality parameters and fish tissue mercury for walleye and pike in South Dakota lakes and impoundments. The best predictors for fish tissue mercury were tested in four models to find the model that best predicted fish tissue mercury. Water quality data was divided into lakes or impoundments and fish tissue into either walleye or northern pike. Phosphorus was the best predictor of fish tissue mercury in the northern pike-impoundment scenario. The other scenarios, northern pike-natural lakes, walleye-impoundments and walleye-natural lakes did not show any significant relationship between phosphorus and fish tissue mercury.

McCutcheon's (2009) water quality data included alkalinity, pH, dissolved oxygen (DO), dissolved organophosphate as P, total phosphorus, total dissolved phosphorus, Secchi disk depth (SDD), specific conductance, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), turbidity, trophic state index for phosphorus (TSI-P) and Secchi disk depth (TSI-SDD), sulfate, and dissolved organic carbon (DOC). Two methods, linear regression and AIC model selection, were used to select variables. Advisory lakes (more than one exceedance of fish mercury >1.0 mg/Kg) were compared to non-advisory lakes (fish mercury <1.0 mg/Kg) using boxplot screening and correlations based on linear regression with composite data that included all fish species and all waterbodies. The composite data was later divided into species, walleye or pike; and lake type, impoundment or natural. Lakes were divided into impoundments and natural lakes to assess any difference in fish mercury response between the two. Water quality parameters of impoundments and natural lakes were found to be "comparable but not identical."

3.4.3 Betemariam 2010

Betemariam (2010) compared land cover and habitat characteristics in ten advisory and non-advisory (based on mean Hg fish tissue > 1 mg/Kg) lakes' watersheds to determine if links existed between land cover and advisory status. Though no significant differences in land cover were found, advisory lakes tended to have lower wetland cover, shallower slope, higher organic matter (OM) and higher shoreline to lake area ratio than non-advisory lakes.

This study further compared six non-advisory lakes to four advisory lakes to discern possible land use differences between the lakes that might point to a mechanism for increased fish tissue mercury in advisory lakes. There was no statistical difference between advisory and non-advisory lakes in catchment area to lake area ratio (C/L) (p=0.517), wetland cover (p=0.352), slope (p=0.927), or shoreline to lake area ratio (p=1.000). Non advisory lakes had higher mean wetland coverage, lower C/L ratios, shallower slopes, lower grass and higher cultivated land than advisory lakes although none of the differences were significant.

3.4.4 Hayer 2011

Hayer (2011) examined relative contributions of water quality parameters, watershed attributes, and lake habitat characteristics to variability in walleye fish mercury in 17 glacial lakes in northeast South Dakota (Table 10). Water quality data included alkalinity (ALK), total dissolved solids (TDS), trophic state index phosphorus (TSI-P), ammonium (AMM), pH, and N:P (nitrogen to phosphorus ratio). Water quality data did not have a significant linear relationship with fish tissue mercury and were poor predictors overall (p=0.1300) and explained only 57% of the variation in fish tissue mercury. Conductivity, total phosphorus and total Kjedjahl nitrogen were also considered as water quality parameters. Local habitat characteristics such as detritus (DET), silt (SILT) and maximum water depth (DMAX) explained 80% of the variation (p=0.0002) in fish tissue mercury. Watershed features such as lake surface area change (SACH), slope (SLOPE) of basin, percent agriculture land cover (AG) and watershed-to-surface area (WSSA) were better predictors than water quality and explained up to 81% (p=0.0001) of the variation in fish tissue mercury. Wetlands within 1 kilometer and watershed size were also considered as watershed parameters.

Table 10. Results from Hayer's (2011) combined regression model and watershed-only model. The model parameters include alkalinity(ALK), total dissolved solids(TDS), Trophic State Index (TSI-P), ammonium (AMM), nitrogen to phosphorus ratio(N:P), surface area change (SACH), watershed slope (SLOPE), maximum depth of the lake (DMAX), percent agriculture in the watershed (AG), watershed to surface area ratio (WSSA), percent detritus in lake habitat (DET), and percent silt within lake habitat (SILT).

Predictor category					
Water Quality Parameter	Parameter Estimate	Partial R^2	Combined Model Parameter	Parameter Estimate	Partial R^2
ALK	0.003	0.22	SACH	0.003	0.21
TDS	0.0006	0.09	TSI-P	-0.007	0.16
TSI-P	-0.022	0.1	SLOPE	-0.129	0.16
AMM	-0.72	0.04	DMAX	0.48	0.22
pH	0.406	0.08			
N:P	-0.014	0.03			
Model R^2= 0.57, p=0.13, intercept=-2.46			Model R^2=0 .76, p=.013, intercept =0.594		
Watershed Only Parameter	Parameter Estimate	Partial R^2	Habitat Only Parameter	Parameter Estimate	Partial R^2
SACH	0.005	0.59	DET	0.022	0.45
SLOPE	-0.142	0.11	SILT	0.012	0.08
AG	-0.01	0.08	DMAX	0.04	0.26
WSSA	-0.278	0.04			
Model R^2= .81, p=0.001, intercept= 0.982			Model R^2= .80, p=0.002, intercept= -0.925		

A combined model using SACH, TSI, SLOPE and DMAX explained 76% of the variation. Fish mercury decreased when TSI-P, the only water quality parameter in the model, increased. This would indicate that nutrients are not an important direct driver in fish mercury changes. This combined model was then compared to watershed-only, habitat-only and water quality-only models. Using AIC model selection, the local habitat model was found to best predict walleye fish mercury concentration. Water quality parameters were found to be poor predictors of walleye mercury concentrations due either to variability in measurements, time-scale factors, or complex chemical interactions. Watershed and habitat characteristics are more predictive of fish mercury than water quality parameters but further investigation is needed outside of the northeast region of South Dakota.

3.4.5 Wentz 2014

The 2014 USGS report, '*Mercury in the Nations Streams- Levels, Trends, and Implications*', provided a broad summary of mercury related issues and survey of possible factors controlling methylmercury production. The report referenced three studies in which methylmercury concentrations in streams showed a strong correlation with wetland abundance. For each 10% increase in upstream wetland area, increases of approximately 0.1 part per trillion of methylmercury were found in stream water.

3.4.6 Methylation Rate Analysis

While studies of factors affecting methylation have been completed in South Dakota (Selch 2008, McCutcheon 2009, Betemariam 2010, Hayer 2011) and elsewhere (Greenfield 2001 and Wentz 2014), the South Dakota studies focused on a limited number of lakes that tended to be clustered in the northeast region. A statewide approach with 4-7 years of additional data beyond the South Dakota specific studies was needed to expand the conclusions of those authors in order to determine how water quality, watershed, and habitat factors affect fish tissue methylmercury. Including more lakes in the regression analysis (SDDENR n=84 vs. Hayer's n=17) is vital to capturing the statewide response. Water quality, land use, and habitat data was compiled and compared to standard length fish mercury to assess correlations and identify important factors controlling methylation. Standard length fish calculations from the preceding section (Standard Size Predator Fish) were used to develop reductions for the TMDL. Those calculations resulted in a dataset that could be used to compare methylation rates between waterbodies.

3.4.6.1 Methylation Rate Data

Fish tissue methylmercury data was standardized and analyzed according to the Standard Size Predator Fish section. Included in the data set were all standard length fish calculations for walleye, northern pike, and largemouth bass. These species are all considered top predator fish and are likely to have higher methylmercury concentrations relative to other fish species. To provide for the largest dataset and include as many water bodies as possible, MeHg concentrations in these three species were compared at their standard lengths, which were calculated as the mean length for the species population sampled. Due to low numbers of waters with adequate paired samples for a correlation between largemouth bass and walleye, comparisons were only drawn between northern pike and walleye as well as northern pike and largemouth bass. Correlations between northern pike and walleye were strongest (n=27, r^2=0.6805, p=0.0000). Northern pike to largemouth bass exhibited a slightly lower correlation (n=11, r^2=.5059, p=0.0141).

Water chemistry data collected within South Dakota was used to complete the chemical attributes analysis. Watershed data included HUC 12 – scale land use from the 2013 Cropland Data Layer (USDA 2014), wetland area from National Wetland Inventory (NWI) (USFWS 2014), and delineated HUCs using the National Hydrological Dataset (NHD) (USDA NRCS 2014). Habitat data included lake elevations for analysis of water level fluctuations from SDDENR Water Rights database (SDDENR 2014). Other lake habitat data such as shoreline, lake surface area, maximum depth and elevation were obtained from a variety of sources: the DENR Lake Assessment report (SDDENR 1995), South Dakota Game Fish and Parks Lake Surveys (SDGF&P 2014) and Bureau of Reclamation's (BOR) online database (BOR 2014). SDGF&P provided the most comprehensive lake information but if the survey was from a very wet year, the lake data was adjusted if the other sources listed very different numbers. Lake surface area can change drastically from year to year in shallow lakes. Two lake area outliers, Lake Thompson and Waubay Lake were corrected using the USGS's NHD layer. SDDENR's Lake Assessment report and SDGF&P Lake Survey do not list the data points by year, and instead include an estimate for the above parameters. The data from Water Rights and BOR is of greater detail and there is access to lake depth data points by month and year which provides a more reliable estimate of water level fluctuations by providing an interannual standard deviation of the lake elevation.

Watershed-scale factors that could affect methylation rates are the percent cover of land use types found within each lake's 12 digit HUC, watershed area, and lake area to watershed ratio. Land use type includes open water, developed land, forest, wetland, herbaceous non-ag, cultivated crop, and hay percent cover. Habitat variables include lake area, shoreline perimeter, maximum lake depth, wetland cover within 500m of the lake, and lake level fluctuations. Some lakes had more than one year of data on mean fish tissue mercury and up to three fish species, walleye, northern pike, and largemouth bass. Lakes with multiple years of measurement were weighted with a year-weight variable and lakes with multiple fish species and/or years were weighted with a species-year-weight variable so that each lake had a total weight of one in the analysis. An example of this would be Bitter Lake in which 7 independent sample years are represented, thus the weight of each sample year in the final calculation is 0.143 (1/7).

3.4.6.2 Lakes and Impoundments

McCutcheon (2009) analyzed lakes and impoundments separately. With a larger dataset and using a statewide approach, all lakes and impoundments would potentially be subjected to the same TMDL reduction. Mercury advisory lakes, defined by Betemariam (2010), are currently found throughout the state. It was suspected that the lake type (impoundment vs. natural) would have no bearing on whether a lake would be listed for fish tissue methylmercury. First, it was necessary to determine if there were any differences in water chemistry or fish tissue methylmercury between lake types, impoundments and natural. T-tests and Chi-square tests were used to evaluate differences between lake types. SDDENR found that natural lakes and impoundments do have some differences in water column chemistry. Mean Total Kjeldahl Nitrogen (TKN), mean log chlorophyll *a* and mean pH differ between natural lakes and impoundments. There was no significant difference between natural lakes and impoundments exhibited in the remaining parameters of Table 12. Significant water chemistry differences were not exhibited between advisory and non-advisory lakes (Table 11).

Table 11. Mean water chemistry differences between non-advisory lakes and advisory lakes, lakes and impoundments (n=59 for walleye fish mercury, n=36 for water quality) .

	Advisory and Non-Advisory Lakes		Lakes and Impoundments	
	t-test	p	t-test	p
Total Phosphorus (TP)	0.7995	0.4292	-1.8880	0.0671
Total Kjeldahl Nitrogen (TKN)	0.1433	0.8868	**-5.6619**	**0.0000**
Log Chlorophyll *a*	-0.7630	0.4514	**-3.9649**	**0.0004**
pH	1.4671	0.1510	**-6.5006**	**0.0000**
Secchi	1.7083	0.0973	1.1214	0.2704
Ammonia (NH_3)	-0.8002	0.4288	-1.6604	0.1055
Nitrates (NO_2+NO_3)	0.6067	0.5478	-0.9587	0.3441
Walleye Fish Tissue Mercury	**12.0796**	**0.0000**	-0.5761	0.5668

A Chi-squared test of independence was used to assess if the small subset of impoundments differed from the larger pool of all lake types according to the advisory status outcome. If a lake has a fish tissue measurement equal to or greater than 0.3 mg/Kg, it was given the advisory lake status for the year in which the sample was taken. If the fish tissue measurement is less than 0.3mg/Kg, then it is classified as a non-advisory lake. The Chi-squared test for independence was not significant, as shown in Table 12, indicating that the outcome (>0.3 vs. <0.3) was independent of lake type and that natural lakes and impoundments can be treated as a single group (Chi-squared=0.3725, p=0.5416).

Table 12. Chi-squared independence test between lake type and outcome >0.3 (yes or no). Insignificance indicates independence, i.e., the outcome is independent of lake type.

Lake Type x advisory status [mean WE38>.3)(Yes,No)	(Impoundment n=9, Lake n=52)		
	Chi-square	df	p
Pearson Chi-square	0.372549	df=1	0.5416
M-L Chi-square	0.380518	df=1	0.5373

Mean mercury concentrations in walleye (WE38) were slightly higher in natural lakes than impoundments with a mean value of 0.3077 mg/Kg vs. 0.2657 mg/Kg, respectively. However, the difference exhibited between lake types was not significant, (t=-0.5760, p=0.5667) and their group variance was similar (F= 1.7354, p=0.4149) (Figure 6).

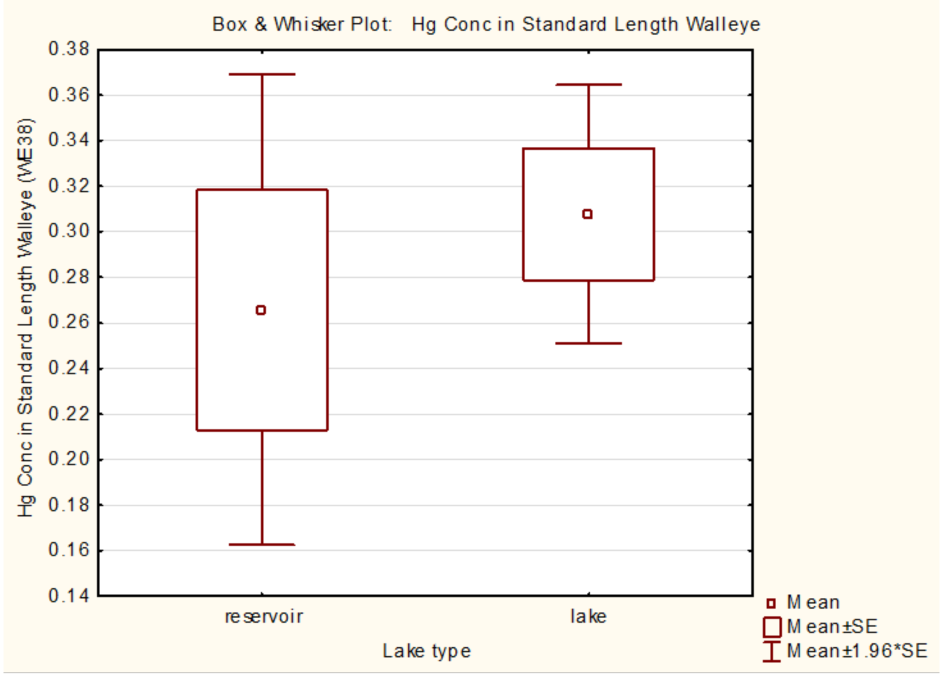


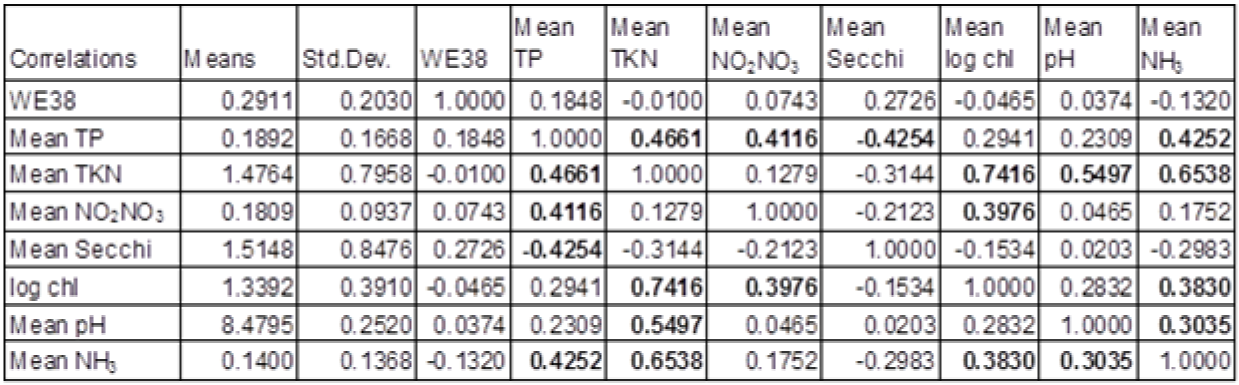
Figure 6. Boxplot of fish tissue mercury vs waterbody type. (t=-0.5760, p=0.5667) (F=1.7354, p=0.4149).

3.4.6.3 Chemical Attributes

McCutcheon (2009) found that correlations exist between water quality characteristics and fish tissue mercury and phosphorus predicts high fish mercury under a specific scenario (northern pike in impoundments). Greenfield (2001) found that pH was the best predictor of yellow perch tissue mercury in Wisconsin. As SDDENR found that there is no meaningful difference between impoundments and natural lakes, analysis was performed on all lake types with a dataset that had expanded greatly since the time of McCutcheon's report (2009).

Pearson correlations were calculated to quantify relationships between water quality parameters and fish tissue mercury. Pearson correlations are the covariance of a pair of (x,y) variables divided by the standard deviation and are used to examine correlation unbiased by the units of the variables (Quinn and Keough 2002). Correlations between water quality variables and fish tissue mercury are shown in Table 13 with bolded values representing significant correlations of p<.05.

Table 13. Pearson correlation coefficients between water quality variables and WE38 (walleye fish tissue mercury). Bolded correlations are significant, p<.05.



Correlations	Means	Std.Dev.	WE38	Mean TP	Mean TKN	Mean NO_2NO_3	Mean Secchi	Mean log chl	Mean pH	Mean NH_3
WE38	0.2911	0.2030	1.0000	0.1848	-0.0100	0.0743	0.2726	-0.0465	0.0374	-0.1320
Mean TP	0.1892	0.1668	0.1848	1.0000	**0.4661**	**0.4116**	**-0.4254**	0.2941	0.2309	**0.4252**
Mean TKN	1.4764	0.7958	-0.0100	**0.4661**	1.0000	0.1279	-0.3144	**0.7416**	**0.5497**	**0.6538**
Mean NO_2NO_3	0.1809	0.0937	0.0743	**0.4116**	0.1279	1.0000	-0.2123	**0.3976**	0.0465	0.1752
Mean Secchi	1.5148	0.8476	0.2726	**-0.4254**	-0.3144	-0.2123	1.0000	-0.1534	0.0203	-0.2983
log chl	1.3392	0.3910	-0.0465	0.2941	**0.7416**	**0.3976**	-0.1534	1.0000	0.2832	**0.3830**
Mean pH	8.4795	0.2520	0.0374	0.2309	**0.5497**	0.0465	0.0203	0.2832	1.0000	**0.3035**
Mean NH_3	0.1400	0.1368	-0.1320	**0.4252**	**0.6538**	0.1752	-0.2983	**0.3830**	**0.3035**	1.0000

Pearson correlation coefficients indicate which predictor variables are correlated. WE38 tissue mercury is not significantly correlated with any water quality variable. Water quality variables exhibit quite a bit of correlation with each other (Table 13). The partial correlations in the multiple regression result show the correlation the variable has with fish tissue mercury after controlling for the number of terms in the equation (Table 14).

Though there were no water quality variables significantly correlated with fish tissue mercury, a multiple regression equation was built which described the relationship between all those water quality variables and fish tissue mercury. A multiple regression line was constructed using seven most highly correlated water quality parameters to predict walleye fish tissue mercury (Table 14). Overall the line had an adjusted R^2 of 0.0681 (adjusted R^2 is preferable as it accounts for the numbers of variables in the model) and a p value of 0.2584.

Table 14. Multiple regression water quality parameters vs. walleye fish tissue mercury. Partial R shows the correlation between parameter and walleye fish tissue mercury controlling for other variables.

Water Quality Variables on Walleye Fish Tissue Mercury Regression Summary						
	Slope	Standard Error	P value	Partial Correlation	R^2	n
Mean TP	0.3561	0.2194	0.1159	0.2931	0.4471	43
Mean TKN	0.4966	0.4329	0.2611	0.2119	0.8579	43
Mean NO_2NO_3	0.1162	0.2231	0.4625	0.1394	0.465	43
Mean Secchi	**0.4686**	**0.1938**	**0.0223**	**0.4156**	**0.2914**	**38**
log Chl	-0.3517	0.3219	0.2839	-0.2022	0.743	36
Mean pH	-0.1382	0.2148	0.5254	-0.1207	0.423	43
Mean NH_3	-0.3207	0.2304	0.2748	-0.2544	0.4982	43
Model Adjusted R^2 =0.0681, F(7,28)=1.3653, p=0.2584, SE=0.1972						

Increasing mean Secchi depth (clearer water) predicted an increase in fish tissue mercury (Figure 7: slope = 0.4686, p=0.0223) which was not expected if eutrophication increased fish tissue methylmercury. Secchi depth is a surrogate measure of eutrophication and is related to the nutrient status of lakes. Lakes with large Secchi measurements are typically clearer and less affected by nutrients than those with smaller Secchi measurements. None of the other variables: Mean TP, TKN, NO_2NO_3, log chlorophyll *a*, NH_3 and pH were significant predictors. Mean TP was a strong contender but did not have a significant relationship with WE38 when examined alone (p=0.2354) or in the multiple regression (p=0.1159). Water quality chemistry is complex and there were relatively weak and contradictory links between correlated water quality variables and fish tissue mercury. Mean Secchi depth, a trophic state indicator, actually predicts higher fish mercury in clearer water. Potential explanations for this may be that it is possibly an artifact related to the depth of the lake or that fish in less eutrophic lakes tend to have slower growth rates which result in higher concentrations of mercury in fish of similar lengths.

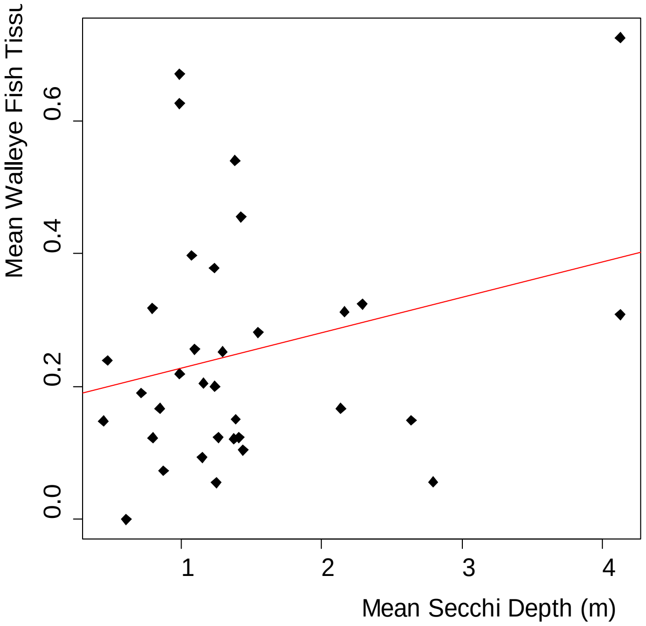


Figure 7. Mean Secchi Depth vs. mean walleye fish tissue weighted by lake-year (p=0.0223, R2=0.2914).

3.4.6.4 Physical Attributes: Habitat and Watershed Factors

Hayer (2011) found that habitat data such as % detritus, % silt and maximum depth were good predictors of fish tissue mercury. Watershed level predictors included surface area change, slope, percent agricultural land and watershed to surface area ratio. Once again, to develop a statewide approach, DENR examined a larger dataset (84 lakes vs. Hayer's 17 lakes) with four additional years of data. Twenty-five lakes had annual lake surface elevations that could be used to quantify lake level fluctuations, seventy nine lakes had at least some habitat and watershed land use data and eighty four lakes had watershed land use data.

Watershed-level land use variables are a measure of the land use type found in each 12-digit HUC in which the lake occurs. Land cover variables include percent open water cover [transwater], percent development [transdev], percent forests [transforest], percent wetlands [transwet], percent herbaceous non-ag cover [transherb], percent cultivated crops [transcult] and percent hay [transhay]. Land cover variables were arc-sin square root transformed to maintain normality. This is a common transformation for percent cover variables and needed if normality is to be maintained (Greenfield et al. 2001; Quinn and Keough 2002). Other watershed-level variables include watershed area (transformed to inverse log of watershed area [logwatershed]) and lake area to watershed ratio (log surface area to watershed ratio [logSaw]).

Habitat variables include lake area (inverse log of lake area[inverselogsa]), shoreline perimeter (log of shoreline perimeter[logshoreline]), maximum lake depth [log max depth], arc-sin square root transformed wetland cover within 500m of the lake [newwetland500trans], and lake fluctuations (standard deviation of the previous eight years of lake elevation data [8yearsstddev]). The standard deviation of lake depth of the previous eight years was chosen based on analysis which is explained later in this section. The lake area to watershed ratio and maximum lake depth were discarded due to large standard deviations and negligible correlation to fish tissue mercury.

To test the continuous response of fish tissue mercury (SLP_Hg) to watershed and habitat characteristics, regression was used rather than t-tests or nonparametric tests. Variables were transformed to maintain normality, put into a correlation table to select likely predictors (Table 15).

Table 15. Pearson correlations between fish tissue mercury (SLP_Hg) and watershed and habitat variables. Bolded correlations are significant, p<.05.

	Correlations (finalnewoldlanduse)Marked correlations are significant at p < .05000													
Variable	Means	Std.Dev.	SLP_Hg	transwater	transdev	transforest	transwet	transherb	transhay	transcult	newwetland500trans	inverselogsa	log shoreline	8yearstd.dev
SLP_Hg	0.337120	0.214425	1.000000	-0.063066	-0.157706	-0.157931	-0.348948	0.093778	-0.064723	0.143940	-0.076853	0.327011	-0.265135	0.544260
transwater	0.382363	0.200417	-0.063066	1.000000	0.068850	-0.196914	0.134626	-0.079826	-0.144422	-0.121785	0.624879	-0.511984	0.240819	0.096300
transdev	0.182558	0.048850	-0.157706	0.068850	1.000000	-0.363735	0.436052	-0.310496	0.330963	0.613311	0.195345	-0.120193	-0.099433	-0.263576
transforest	0.122229	0.228624	-0.157931	-0.196914	-0.363735	1.000000	-0.313008	-0.296286	-0.282184	-0.576467	-0.305559	-0.082801	0.169347	-0.250168
transwet	0.126968	0.061645	-0.348948	0.134626	0.436052	-0.313008	1.000000	-0.141480	0.333412	0.335206	0.343697	-0.261030	0.088314	-0.040882
transherb	0.556515	0.271440	0.093778	-0.079826	-0.310496	-0.296286	-0.141480	1.000000	-0.524147	-0.403895	-0.228784	0.165626	-0.041013	-0.001043
transhay	0.214418	0.184287	-0.064723	-0.144422	0.330963	-0.282184	0.333412	-0.524147	1.000000	0.431320	0.159134	-0.097719	0.078417	-0.336383
transcult	0.597395	0.247340	0.143940	-0.121785	0.613311	-0.576467	0.335206	-0.403895	0.431320	1.000000	0.225049	0.179102	-0.371069	0.185200
newwetlan	0.391191	0.211375	-0.076853	0.624879	0.195345	-0.305559	0.343697	-0.228784	0.159134	0.225049	1.000000	-0.294440	0.060818	0.349659
inverselogs	0.392645	0.102654	0.327011	-0.511984	-0.120193	-0.082801	-0.261030	0.165626	-0.097719	0.179102	-0.294440	1.000000	-0.790767	0.365262
log shoreli	0.844204	0.376980	-0.265135	0.240819	-0.099433	0.169347	0.088314	-0.041013	0.078417	-0.371069	0.060818	-0.790767	1.000000	-0.261738
8yearstd.d	1.437715	0.861717	0.544260	0.096300	-0.263576	-0.250168	-0.040882	-0.001043	-0.336383	0.185200	0.349659	0.365262	-0.261738	1.000000

The most highly correlated predictors, lake level fluctuation [8 yearsstddev] and watershed-scale wetland area [transwet] were then put into a multiple linear regression equation (Table 16). In a separate analysis, the other significant correlates, inverse log of surface area and log of shoreline were included. Fish tissue mercury also tended to increase in smaller lakes and smaller watershed areas, but they were not significant predictors. The regression model improved when these terms were dropped (Adjusted R^2=0.3534, vs. Adjusted R^2=0.2992), Table 16 shows the predictors based on the better regression model.

Table 16. Regression results watershed parameters on fish tissue mercury

Results	Parameter	N	Adjusted R^2	Correlation coefficient	Partial Correlation	Regression Slope	F (df)	F	P Value
All fish	weighted by lake-years		**0.3534**				**2,24**	**8.1048**	**0.0020**
	transwet	**92**		**0.0017**	**-0.3898**	**-0.3272**			**0.0490**
	8year_sd_lakelevel	**27**		**0.0017**	**0.5660**	**0.5309**			**0.0026**
Walleye	**weighted by species**		**0.32364317**				**2,18**	**5.785095**	**0.01148**
	transwet	54		0.00570209	-0.26458384	-0.21467123			0.25961
	8year_sd_lakelevel	**21**		**0.00570209**	**0.58985742**	**0.571546357**			**0.00619**
Northern Pike	weighted by species		N/A too few samples						
	transwet	27							
	8year_sd_lakelevel	6							
Largemouth Bass	weighted by species		N/A: too few samples						
	transwet	11							
	8year_sd_lakelevel	0							

Wetland cover (p=0.0490) and lake level fluctuations (p=0.0026) were significant predictors of fish tissue mercury when all fish species were included. While lake level fluctuations were a significant predictor for walleye, none of the other species had enough samples to conduct multiple regression. This regression line explains 35% of the variation of fish tissue mercury. While the correlation is significant, the majority of the variation remains unexplained. Large scale landscape processes (represented by land cover) operate over a large multiyear timescale affecting lakes across the state creating uncertainty both in time and space. These large scale factors exert control over processes that are local in scale which cannot be directly measured, the methylation of mercury and bioaccumulation, which ultimately control fish tissue mercury. The goal of this analysis was to explore the possible water quality, land use, and habitat characteristics which influence methylation rates and so influence fish tissue mercury indirectly. The end goal is not a coarse prediction of fish mercury in a specific lake based on that lake's predictor variables, but rather to identify factors which best predict the pattern of fish mercury observed across lakes during this timeframe.

The variable most highly correlated with fish tissue methylmercury was the eight year standard deviation of lake level [8yearsstd.dev]. Lake levels were determined from elevations stored in the DENR Water Rights database. Correlations were weakest when considering only the previous two to four years of lake elevations. Correlations were strongest when comparing methylmercury concentrations to water fluctuations in the previous six to ten years (Figure 8). Considering most standard length fish are likely to be approximately three years of age, the six to ten year time frame may be indicative of the amount of time it takes for methylmercury to bioaccumulate through the food chain and into the fish.

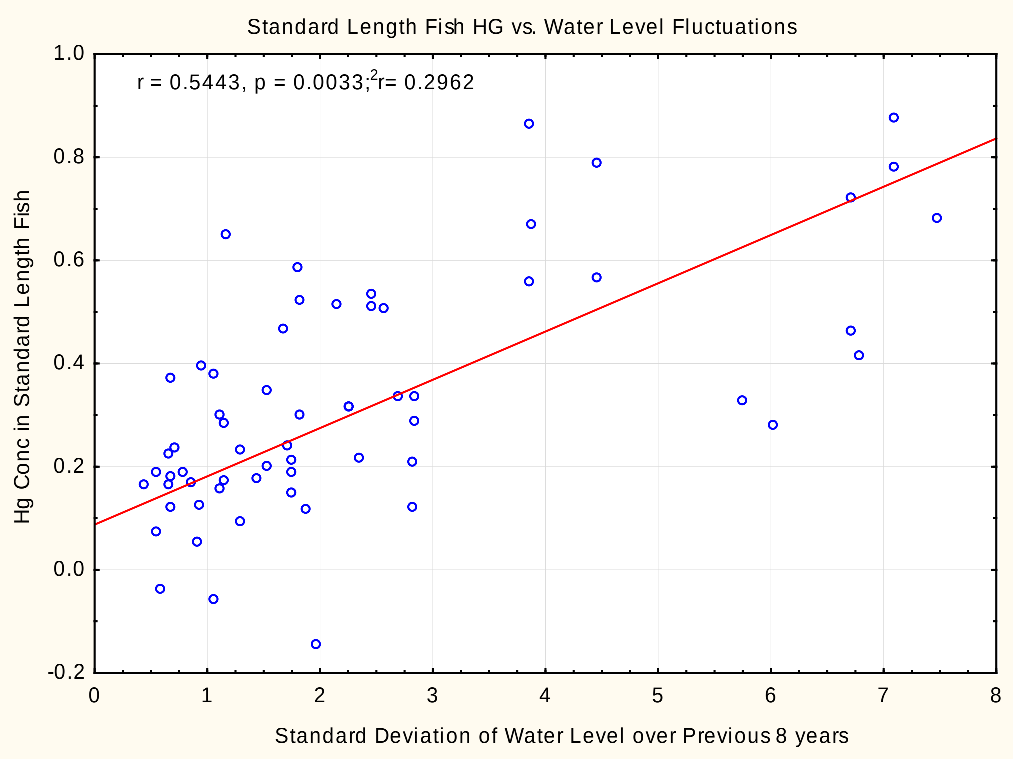


Figure 8. Standard length fish methylmercury (mg/Kg) compared to water level fluctuations (feet).

Selch's hypothesis that lakes that expanded in recent years may have internally adjusted methylation rates and thus are showing lower concentrations in the fish is evident in Bitter Lake (Figure 9). Lake levels rose dramatically (approximately twenty feet) in the closed basin through the 1990's. Fish tissue samples collected in 2000 from Bitter Lake were among the highest ever recorded in the state. Regional drought conditions from 2000 through 2007 saw stable to decreasing water levels and the resulting concentrations of mercury in the fish also decreased.

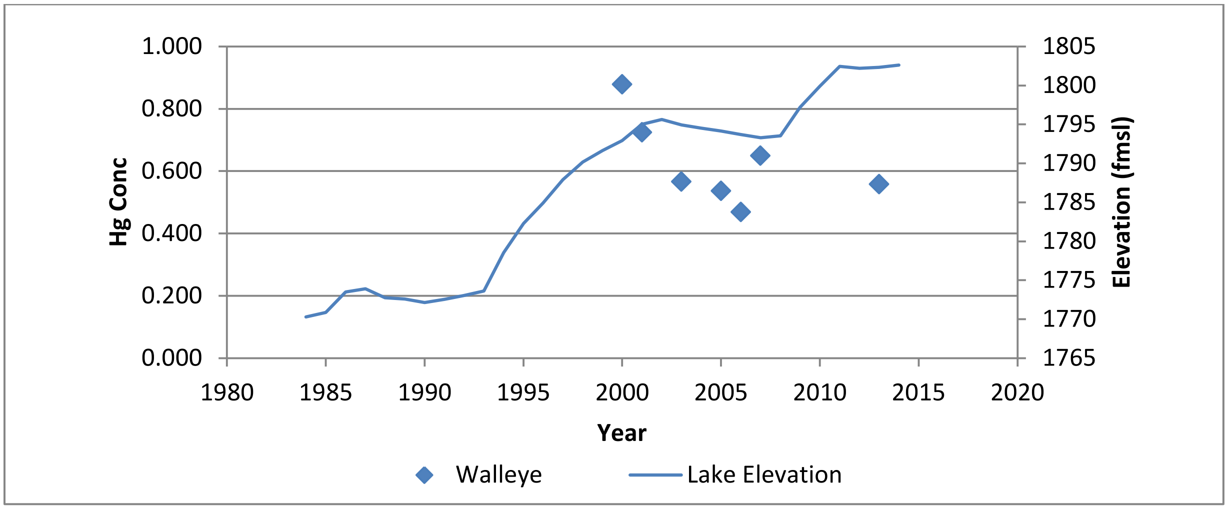


Figure 9. WE38 fish tissue mercury concentrations in Bitter Lake plotted against lake elevation.

To further test Selch's hypothesis, Bitter Lake levels were used as a surrogate for regional hydrologic conditions. The levels on Bitter Lake represent similar conditions exhibited in most lakes found in northeastern SD (Clark, Codington, Day, Deuel, Grant, Marshall, and Roberts Counties). Fish tissue samples collected from these counties were plotted against Bitter Lake Levels to verify the trend shown in Figure 9. Note that the fish tissue methylmercury samples collected from Bitter Lake were omitted from the comparison shown in Figure 10. Both figures indicate a relationship between lake level and fish tissue methylmercury concentrations. While atmospheric mercury deposition is widely accepted to have decreased during this time period, regionally, changing water levels appear to be strongly linked to resultant methylmercury concentrations in fish.

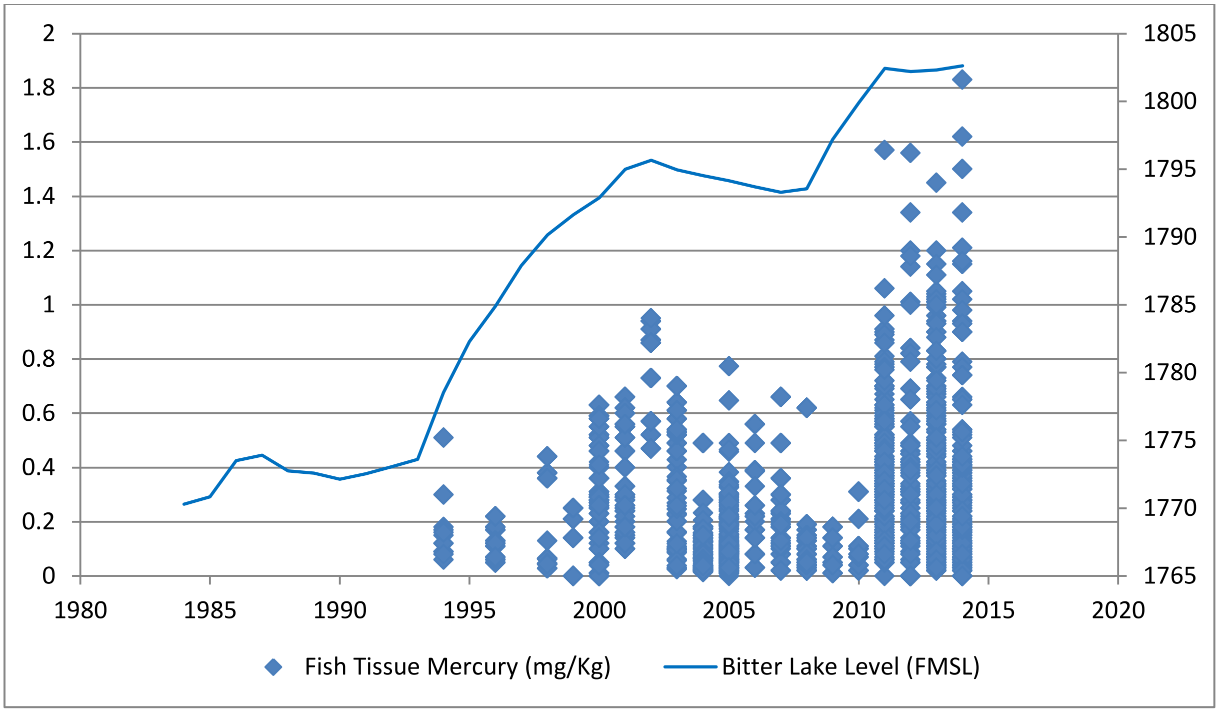


Figure 10. Individual fish tissue concentrations from Northeast South Dakota (excluding Bitter Lake) and Bitter Lake water surface elevations.

Greenfield (2001) examined wetland cover within 500 meters of each lake and found that lakes with more than 6% wetland cover in their watershed had increased fish tissue mercury. DENR's analysis shows that at the much larger HUC 12 scale, higher wetland cover correlates with lower fish tissue mercury (Figure 11). Increases in wetland coverage within the HUC resulted in lower mercury concentrations in fish (p=0.0004, R^2=0.1808). At the habitat scale, wetland cover within 500 meters of the lakes did not exhibit a significant relationship with fish tissue mercury (Figure 12, p=0.4767, R^2=0.05). In contrast, Hayer found that detritus and silt, which are present in large quantities in wetlands, predict higher fish mercury (Table 10).

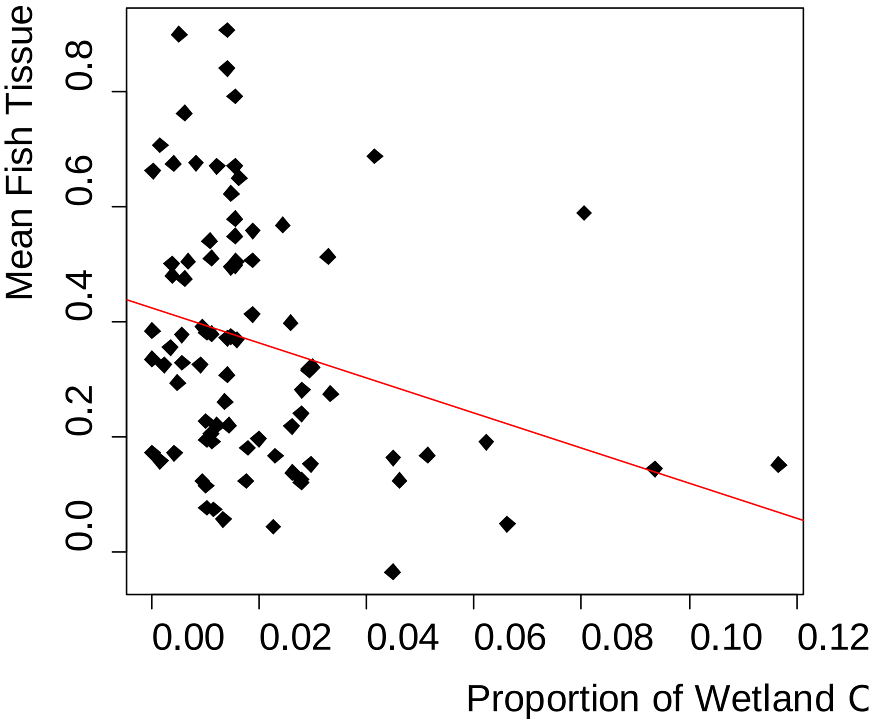


Figure 11. Wetland cover vs. fish tissue mercury p=0.0004, R2=0.1808.

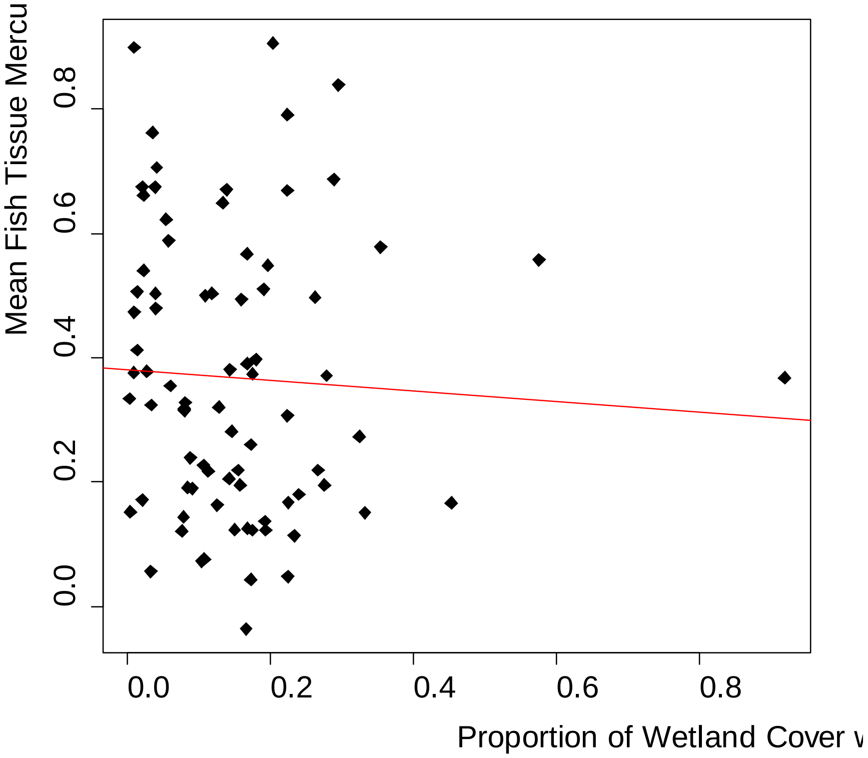


Figure 12. Wetlands within 500m buffer of lakes compared to fish tissue mercury. Regression analysis arc sin square-root transformed wetland cover percentage vs. fish tissue mercury weighted by lake-year (p=0.4767,R2=0.05)

3.4.6.5 Methylation Rate Analysis Conclusions

With the greatly expanded dataset of eighty four lakes, four main conclusions were drawn regarding water quality, habitat, and land cover characteristics' influence on fish tissue mercury. Some of the results SDDENR found differ from previous research when using water quality, habitat and watershed properties to predict fish tissue mercury.

- No major difference existed between lakes and impoundments on the basis of water quality or fish tissue.
- Chemical attributes were poor predictors of fish tissue mercury.
- Increased watershed-level wetland cover predicted lower fish mercury. However, local wetland cover appeared to have no direct effect on fish mercury.
- Water level fluctuations were a major driver in the fish tissue methylmercury concentrations.

The absence of a significant difference between water body types is important in the context of the TMDLs application to all surface waters. The effectiveness of the TMDL should be similar in all water body types.

Linking specific water quality parameters to methylmercury accumulation in fish provided few significant findings. Literature reviews yield conflicting conclusions ranging from suggestions that eutrophic lakes should result in fish with higher concentrations to findings that suggest cleaner lakes are more susceptible to elevated levels (Pickhardt et al. 2002). Data analysis in South Dakota may best be referenced as inconclusive in either case.

The conclusion that watershed-scale wetlands coverage is negatively correlated to fish mercury levels in lakes and reservoirs contradicts some studies (Greenfield et al. 2001) but occurs at very different spatial scales. In Greenfield's study, the average watershed-level wetland cover for study lakes was 17% in a watershed area that averaged 539 hectares while South Dakota's average watershed wetland cover for lakes was 1.7% in an area averaging 10,519 hectares. Wetlands may facilitate methylation by providing an ideal habitat (low dissolved oxygen, high organic matter) for microbes (Wentz et al. 2014). Some studies have suggested that wetlands in the watershed trap sediment with a high mercury load that would otherwise wash into the lake (Engstrom et al. 1999; Betemariam 2010) leading to a reduction in fish mercury.

The strong correlation between the fish tissue mercury and water level fluctuations reinforces Selch's (2008) findings that water level fluctuations are a primary component influencing methylation rates for South Dakota Lakes. Wentz (2014) also suggests that water level fluctuations can increase methylation rates. Future considerations of TMDL progress and attainment should consider the elevation variability of the water bodies evaluated. Increasing water levels in the northeastern part of South Dakota have created numerous issues ranging from lost tax revenue and farm income to flooded roads and public access. Stabilization of the water levels, although desirable on many fronts, is not currently a feasible option for addressing mercury. Reducing mercury inputs is the only feasible option for addressing elevated fish tissue concentrations.

4.0 Source Assessment – Point Sources

Point sources of water pollution were grouped into three primary categories: mining, traditional point sources, National Pollutions Discharge Elimination System (NPDES) permitted facilities, and Municipal Separate Storm Sewer Systems (MS4s).

4.1 Mining

Mercury mining and the use of mercury for the extraction of gold are potential point sources of inorganic mercury. Although mercury mining ceased in the United States in 1992 and mercury amalgamation for the extraction of gold has been replaced by cyanide leaching (Wentz et al. 2014), deposits from these processes remain a localized concern in portions of the country. South Dakota has no record of mercury mining occurring within the state, but does have a history of gold mining in the Black Hills that continues to this day.

Mining has the potential to release mercury into the environment through two separate mechanisms. Air emissions from gold mining may release mercury during the ore extraction process. This fraction is addressed in the air emissions reductions of the TMDL. The other mechanism through which mercury may enter the environment from mining is leaching and direct runoff from tailing sites either from historic mine tailings or existing operations (Wharf Resources USA, Inc.). All of the major mining sites in the Black Hills have individual NPDES permits and are accounted for in section 4.3. Mine tailings may contain elevated mercury concentrations, however this does not always result in elevated fish tissue concentrations. Methylation processes in concert with a source of mercury followed by bioaccumulation are required to elevate fish tissue methylmercury levels. Waters in the Black Hills region of South Dakota are the only ones with potential to be impacted by historic mining. Fish tissue methylmercury sampling from known mining areas (including Whitewood Creek, Spearfish Creek, Rapid Creek, and Bear Butte Creek) have shown no impairments as a result of mercury. These coldwater streams may lack many of the methylation pathways necessary for bioaccumulation to occur. In addition, tailings or mining discharges, if present, may not have contained sufficient levels of mercury to result in subsequent impairments.

Historically, the tailings from the Homestake Gold Mine had been linked to elevated fish tissue methylmercury concentrations in the Cheyenne arm of Lake Oahe, which is located several hundred kilometers downstream of the mine. The following excerpt from the USGS provides some perspective on this history.

> *"From the original discovery of gold at Deadwood, SD in 1875 until the late 1970's, huge volumes of mining and milling wastes were discharged into Whitewood Creek and its tributaries at Lead and Deadwood, South Dakota. The wastes were transported down Whitewood Creek to the Belle Fourche River, then to the Cheyenne River, and then to the Missouri River."* (Goddard 1989)

In the 1970's, fish tissue samples collected from the Cheyenne arm of Lake Oahe had methylmercury concentrations above a then FDA guideline of 0.5 mg/Kg (USEPA 1971). As a result, consumption advisories were issued for this area. Additional fish samples from other areas of western South Dakota and at various locations in Lake Oahe led to two conclusions at that time: First, methylmercury was found in fish tissue throughout western South Dakota suggesting to the investigators it may be naturally occurring. Secondly, the Cheyenne arm had higher concentrations than other parts of Lake Oahe, leading the investigators to the conclusion that Homestake tailings were contributing to the impairment (USEPA 1973).

Since this original investigation in the early 1970's, Homestake mine constructed the Grizzly Gulch Tailings Dam which then began receiving all of the mine tailings by December of 1977. This was followed by a wastewater treatment plant for additional removal of mercury and other pollutants. Homestake mine eventually ceased operation in 2002, and has since been converted to a Deep Underground Science and Engineering Lab. While the mine no longer produces discharges through operation, historically discharged tailings can be found along Whitewood Creek, which is why the state continues to actively monitor water quality and fish tissue from this stream.

The Cheyenne River drains over 24,000 square miles of South Dakota, Wyoming, and Nebraska. Through its sheer size, it naturally carries large volumes of sediment, which are deposited in Lake Oahe. Since the construction of the tailings dam, the river has continued to move sediments downstream which ultimately accumulated in Oahe Reservoir. Near the mouth of the Cheyenne, the delta has visibly extended for nearly 15 miles since the construction of Oahe. This accumulation has entombed most of the tailings which had moved down the Cheyenne River.

Current (1994-2014) fish tissue data from Lake Oahe (Appendix D) is collected from several locations. The samples identified as "Minneconjou Bay" were collected from the Cheyenne Arm (confluence of the Cheyenne River and Lake Oahe). Recent data for Lake Oahe shows that throughout the reservoir fish tissue concentrations are similar. Current data are also similar to concentrations measured outside of the Cheyenne River arm in the 1970's. Although insufficient for statistical analysis, a trend appears to be emerging in which tissue concentrations rise and fall following major reservoir elevation shifts due to wet and dry hydrologic cycles.

It is probable that tailings from the Homestake mine were indeed a contributing cause of elevated mercury levels in fish sampled in the 1970's. The following facts suggest that the current primary cause of elevated mercury levels is atmospheric deposition:

- Most of the mine tailings are entombed in cleaner sediments limiting their access to the current food web.
- When mine tailings were exposed, fish tissue concentrations were greater in the Cheyenne arm then the rest of Lake Oahe.
- Current fish tissue concentrations of mercury are consistent throughout the reservoir.

Continued monitoring is planned statewide, and though it is presently unexpected, a possibility remains that a stream segment may be found with impairments resulting from mine tailings. In the event impairments are found in waters receiving discharge from a mine site, application of this TMDL would be deferred until such time as adequate data shows the cause of the impairment is not related to the mine or a site specific mercury TMDL is developed.

4.2 Municipal Separate Storm Sewer Systems

The requirements of MS4 permits are to control anthropogenic loads in storm water discharges. They are considered a point source under the clean water act and are typically included as a part of the WLA within the TMDL calculation. Factoring out atmospheric deposition, which is accounted for separately in the TMDL source assessment, and illicit discharges, which are already regulated, there should be no anthropogenic sources of mercury found in their runoff. Thus, the only source of mercury in MS4 loads is atmospheric deposition. The MS4 permit areas are included in the measured and modeled deposition results, and as such are fully accounted for by the load allocation (LA) of this TMDL. In previously approved regional and statewide mercury TMDLs, EPA allowed for the MS4 loads to be accounted for in the LA. Based on comments received from EPA during the public notice period of this TMDL, MS4 loads must be termed a portion of the WLA in the final TMDL calculation. It should be emphasized though, that these mercury loads originate entirely from nonpoint sources via atmospheric deposition. Section 5.0 clearly outlines these sources and the processes affecting the distribution of mercury throughout SD. They cannot be mitigated through BMPs identified within MS4 permits.

To calculate this load, the sum of the MS4 acreages (Table 17) was first calculated at 778 km^2. This area was then divided by the area of the state (199,742.5 km^2) which results in 0.39% of the TMDL to be allocated to the MS4s. The remaining 99.61% was allocated to the remainder of the state outside of permitted MS4 boundaries. These percentages will be used to apportion the loads between the MS4's and nonpoint sources.

Reductions associated with the LA will result in equivalent reductions in the MS4 loads, therefore, no additional reductions are necessary as part of the existing permits, nor is it appropriate to calculate a duplicate WLA for loads that are fully represented in the LA component of the TMDL. All of the minimum measures required by MS4 permits (Stormwater Phase II Final Rule Fact Sheet) are designed to reduce storm water volume and sediment loading. Any measure which reduces the volume of water (addresses wet deposition mercury) and sediments (addresses dry deposition mercury) will reduce the amount of mercury delivered to receiving water bodies. The intent of the MS4 WLA will be achieved by the BMPs outlined as part of the existing permit conditions and, therefore, changes to the permit resulting from this TMDL are not necessary.

Table 17. MS4 permits and acreages in South Dakota.

MS4	Permit	Phase	Area (acres)	Km2	Estimation Description
City of Sioux Falls	SDS00001	I	48,429	196	Provided by permittee
City of Vermillion	SDR41A001	II	2,410	10	The permittee provided the area within city limits, which is covered by the MS4.
City of Pierre	SDR41A002	II	8,340	34	Provided by permittee
City of Brookings	SDR41A003	II	7,450	30	The area within Brookings, minus the SDSU campus, was provided by the permittee.
Pennington County	SDR41A004	II	27,320	111	Provided by permittee using GIS mapping
City of Mitchell	SDR41A005	II	7,256	29	The area within Mitchell, minus Lake Mitchell, was provided by the permittee.
City of Sturgis	SDR41A006	II	3,100	13	The permittee provided the area within city limits, which is covered by the MS4.
City of Rapid City	SDR41A007	II	35,200	142	Provided by permittee
City of Aberdeen	SDR41A008	II	8,960	36	Provided by permittee
SD DOT	SDR41A009	II	0	0	Already Included[1]
City of Watertown	SDR41A010	II	16,596	67	Provided by permittee
City of North Sioux City	SDR41A011	II	1,693	7	Provided by permittee
City of Huron	SDR41A012	II	6,400	26	Provided by permittee
City of Yankton	SDR41A013	II	5,278	21	Provided by permittee
City of Spearfish	SDR41A014	II	10,250	41	Provided by permittee
Meade County	SDR41A015	II	3,670	15	Provided by permittee

1- The SDDOT MS4 area consists of all state highways, interstate systems, and SDDOT maintenance shops within other MS4 permitted entities. As such, the areas covered by this permit are already incorporated into the area calculations of the other permits listed.

In the event that new data becomes available showing that a portion of the municipal storm water load includes non-atmospheric mercury sources, the permit will be subject to control practices necessary to reduce the mercury load from the MS4(s).

4.3 Non Storm Water NPDES Permitted Sources

South Dakota has required water quality sampling for mercury in NPDES permits if mercury is expected to be present in the discharge and places water quality-based mercury limits in those permits when there is reasonable potential mercury could cause a violation of the surface water quality standards. Seven of the state's largest POTWs have implemented pretreatment programs. The approved programs must look at the loading to their treatment plants and develop local limits for pollutants of concern, including mercury. The pollutants investigated usually dictate whether or not the wastewater effluent will meet permit requirements or if the sludge will be disposed of properly. The cities of Brookings, Mitchell, Rapid City, and Watertown have developed a local limit for mercury to ensure that the influent into the plant will not cause elevated mercury levels in the sludge or effluent. The other municipalities (Aberdeen, Huron, and Sioux Falls) have determined that a local limit for mercury is not necessary at this time.

SDDENR retrieved data from the EPA Integrated Compliance Information System (ICIS) to characterize the mercury concentration of effluent in South Dakota. Statewide, samples from POTWs above the detection limit have historically been uncommon with the most recent period (2008-2014 accounting for 126 samples) having no samples in excess of the detection limit. Expanding this dataset to include all NPDES data from 1997-2015, increases the amount of information significantly, with 2,039 measurements. With the expanded dataset, the percentage of effluent samples with detectable levels of mercury remained low at 1%, however, many samples in these datasets were not collected using ultra-low level methods (EPA 1631 revision E or EPA 245.7) that report detection limits low enough to compare against the human health water column criterion (0.05 µg/L). Due to the low percentage of quantifiable concentrations and concerns about the representativeness of using insufficient detection limits in calculations to characterize effluent in South Dakota, it was necessary to use a surrogate source of data to calculate the wasteload allocation.

The Minnesota Mercury TMDL found similarities between data collected by the Association of Metropolitan Sewerage Agencies (AMSA) and monitoring completed by the Minnesota Pollution Control Agency (MPCA) on thirty seven NPDES facilities (POTWs and Industry). The MPCA data indicated that central tendencies fell in line with the AMSA study which used clean sampling and analytical techniques in monitoring twenty four POTWs throughout six states (Nellor 1999). The central tendency of the data in both studies fell at or near 0.005 µg/L. The AMSA study included a range of concentrations from 0.0007 µg/L to 0.0699 with arithmetic mean of 0.00725 µg/L and a 90th percentile of 0.01536 µg/L. It is reasonable to expect that South Dakota NPDES permitted facilities would be similar to the ranges found in these studies. While the MPCA study included POTWs and Industry, the AMSA study looked only at POTWs. To fully account for uncertainties in NPDES contributions, including both POTW and industrial sources, the TMDL will use the 90th percentile of the AMSA study (0.01536 µg/L) to approximate concentrations of mercury in the effluent of South Dakota's point source dischargers.

South Dakota has 247 NPDES permits (Appendix E) which include industry, mines, municipalities and fish hatcheries. Many of the smaller municipalities do not continuously discharge and typically release effluent for a few weeks each year. Average daily flow for 2014 was 119 million gallons with an average annual flow volume of 43 billion gallons. Using the annual flow volume with the 0.01536 µg/L mercury concentration yields a load of 2.53 kg/yr.

The final TMDL calculation is not discussed until later in this document (section 10). However, it is important to present the final TMDL load of 595.32 kg/yr in order to gain perspective on the small percentage (0.43%) attributable to the state's non-stormwater point sources.

Previously approved TMDLs where sources of mercury are predominately from air deposition have taken varying approaches to address the large differences in required reductions from the LA in comparison to the WLA. These approaches range from providing individual WLAs for individual sources such as in the Ochlockonee TMDL (USEPA 2002) to assigning a single WLA for all sources within the region such as the Minnesota TMDL (MPCA 2007). A commonality amongst them is the low percentage (approximately 1%) of mercury allocated to the WLA.

The Minnesota and Northeast Regional Mercury TMDLs used the legal term *de minimis* when referencing the small contributions represented by the NPDES discharges. As defined in those TMDLs, *de minimis* **-** insignificant; a Latin expression "*de minimis non curat lex*: "The law does not concern itself with trifles;" the effect is too small to be of consequence. For the mercury TMDL, wastewater point sources were considered *de minimis* if they represented less than one percent of the TMDL of mercury to the region and reductions to the WLA component of the TMDL were not calculated. The *de minimis* definition is clearly applicable to the contributions of the WLAs in South Dakota. The final TMDL calculation will preserve the current load of 2.53 kg/yr for the WLA component. This approach is consistent with approved mercury TMDLs referenced in this document. Although the WLA contribution is determined to be *de minimis*, it is not an allowance for increased discharges of mercury, nor does it provide exemption from further efforts to reduce mercury from these sources.

5.0 Source Assessment - Nonpoint

Nonpoint sources of mercury pollution are numerous and diffuse throughout the world in the form of emissions from power plants, gold mining, and other human activities. Although diffuse in origin, they coalesce in the atmosphere and are delivered to waterbodies through both wet and dry atmospheric deposition.

This section will first discuss a project conducted by Dr. Stone of the South Dakota School of Mines and Technology (SDSM&T). The intent of this project was to measure wet and dry atmospheric mercury deposition through the deployment of passive bulk mercury deposition monitors at six locations throughout the state. This statewide project improved the resolution of the existing Mercury Deposition Network (MDN) which is a national monitoring network set up to monitor the trends of atmospheric mercury deposition. The data collected from this statewide effort included with existing MDN data refined the measured mercury deposition rates specifically within South Dakota.

The Regional Modeling System for Aerosols and Deposition (REMSAD) is a national modeling effort designed to estimate the sources, rates, and patterns of both wet and dry atmospheric mercury deposition effected by regional meteorologic conditions.

Dr. Stones project was used to establish the atmospheric depositional rates for the baseline year of 2009. The REMSAD model results were used to appropriate the relative percentages of the load to a set of sources which were selected by EPA. A baseline year is used as a loading or occurrence reference point to which future mercury loading will be compared for mercury TMDL attainment and implementation.

5.1 Atmospheric Mercury Deposition Monitoring

5.1.1 Atmospheric Mercury Deposition Monitoring Methods

Figure 13. Typical construction of a passive bulk mercury atmospheric sampler

Bulk mercury samplers constructed and deployed by South Dakota School of Mines and Technology (SDSM&T) were designed using sampling principles utilized from the MDN samplers, Swedish IVL bulk samplers (Chazin et al. 1995), and Wisconsin air samplers (Morrison et al. 1995). The passive samplers consist of insulated steel boxes containing heating and cooling components and rain, moisture, and particulate collection glassware. The glassware components housed within each sampler include a funnel, a thistle tube, and a 1.89 liter bottle; all pre-cleaned to ensure no residual mercury exists prior to deployment. The glassware is kept in place using a system of springs, a strap, and an adjustable platform. The samplers have a thermostatcontrolled climate system used to keep the temperature inside of the sampler at moderate temperatures (i.e., above freezing and below ~ 90°F). Main components associated with the passive samplers constructed and deployed are shown in Figure 13. The system was heated during the winter to facilitate the melting of any accumulated snow (which would be expected to contain mercury) and transported to the sample bottle through the thistle tube. Also, sample freezing within the thistle tube would be problematic, not allowing sample to be transported into the sample bottle. If, during the summer, the sample gets too hot, the probability of evaporative losses would increase, resulting in either volatilizing the accumulated mercury out of the sample bottle, or concentrating the collected mass of mercury within the remaining aqueous solution. The samplers were placed at distances of approximately 3-5 times the height of the nearest object or greater to minimize wind disturbances. Each sampler deployment site was equipped with a sampling kit that included the following items: powder-free nitrile gloves, a notebook and pen for tracking sampling dates, bottle numbers, and important information, pre-labeled shipping tags, two rolls of packing tape, and laminated sampling instructions (Appendix A).

A designated onsite person was responsible for monthly sample collection during the period 2008 through 2010. Samplers at most sites were held in place using a guy wire system anchored into the ground using mobile-home trailer stakes. If the samplers were deployed during the winter when the ground was frozen, the guy wires were temporarily held in place using cement blocks and sand bags. This arrangement was replaced with guy wire system once ground thaw occurred.

Figure 14 shows a sampler deployed near Beresford, SD at the South Dakota State University SE Research Farm. Samplers were installed at ten locations throughout South Dakota and surrounding states. Locations include Theodore Roosevelt National Park, Devil’s Tower National Park, Wind Cave National Park, Scott’s Bluff National Park, Badlands National Park, Buffalo SD, Eagle Butte SD, South Shore SD, Beresford SD, and Huron SD (Figure 15).

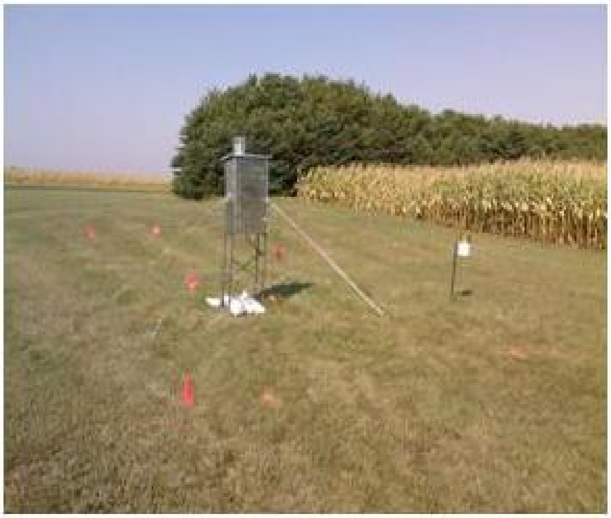


Figure 14. Mercury sampler located near Beresford, SD at South Dakota State University SE research farm.

Figure 15. Atmospheric bulk sampler locations. Sites shown with red stars were funded by NPS, while sites shown with orange stars were funded by South Dakota DENR and EPA.

Procedures have been developed to minimize sample contamination during sample collection. Samples are collected at each site approximately once per month. Dates of collection are recorded. Mercury-free nitrile gloves are used during the handling of each sample bottle, and mercury-free rinse water, supplied by the sample analyzing company, is used to rinse the funnel and thistle tube prior to sample bottle collection. Samples were shipped to Frontier Geosciences (Seattle WA, phone 206-622-6960) for analysis on a monthly basis. Results provided by Frontier Geosciences were provided in total nanograms of mercury in each bottle, and micrograms per square meter per day are calculated using this number along with the collection days of each sample and the funnel area (0.0108 m^2). Micrograms per square meter per year is then found by dividing the total micrograms of mercury from all samples by the number of months sampled, and this number is multiplied by twelve. To find the concentration of mercury in ng/L, total rainfall for the area is required. The total mercury in each bottle [ng] is divided by the total rainfall times the area of the funnel (0.0108 m^2). The atmospheric mercury deposition [ng] per square meter per month was then graphed with daily precipitation and dates to show relations between precipitation and mercury deposition. Raw data results provided by Frontier Geosciences include aliquot volume [mL], mercury in aliquot [ng], mercury concentration [ng/L], and sample volume [mL]. For most sites, precipitation data was obtained using the SDSU climatology website (SDSU 2014), and the precipitation from each atmospheric sampler's corresponding rain gauge is used. Precipitation data sources are shown in Table 18. The samples are exchanged at each site approximately once per month and dates of sample exchange are recorded and used in obtaining the correct volume of precipitation during each sampling period.

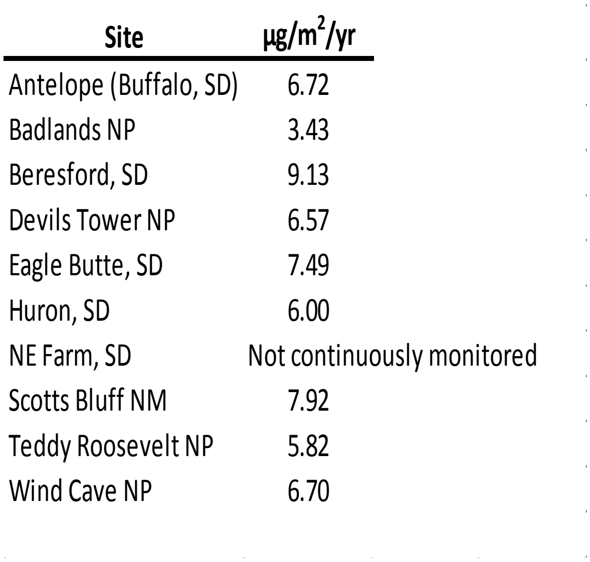
Table 18. List of websites used to acquire precipitation data used with atmospheric samplers.

Station (abbreviation)	Data Website
Beresford (SEF)	http://climate.sdstate.edu/climate_site/archive_data.htm
Huron (HUR)	http://climate.sdstate.edu/climate_site/archive_data.htm
Buffalo (ANT)	http://climate.sdstate.edu/climate_site/archive_data.htm
Wind Cave (WCNP)	http://climate.sdstate.edu/climate_site/archive_data.htm
Badlands (BADNP)	http://climate.sdstate.edu/climate_site/archive_data.htm
Theodore Roosevelt (TRNP)	http://www.ncdc.noaa.gov/oa/climate/uscrn/
South Shore or NortheastFarm (NEF)	http://climate.sdstate.edu/climate_site/archive_data.htm
Devils Tower (DTNP)	http://climate.sdstate.edu/climate_site/archive_data.htm
Eagle Butte (EB)	http://climate.sdstate.edu/climate_site/archive_data.htm
Scotts Bluff (SBNM)	http://raws.wrh.noaa.gov/cgi-bin/roman/meso_base.cgi?stn=TR471&unit=0&time=LOCAL

5.1.2 Atmospheric Mercury Deposition Results

A summary of the bulk mercury sampler results through 2010 are shown in Figure 25 through Figure 34 (Appendix B) and summarized in Table 19. The left y-axis shows mercury wet deposition over the sample time in micrograms per square meter per day (normalized to the funnel surface area), the right y-axis shows the precipitation per day (mm), and the x-axis shows the time periods over which this deposition occurred. The mass of mercury contained within the volume of water for each sample event is normalized to site precipitation data to ascertain contributions of wet and dry mercury deposition. In general, it appears that seasonal precipitation events occurring during the spring and summer result in higher bulk atmospheric mercury deposition; mercury deposition peaks occur during these high precipitation seasons.

Table 19. Mean deposition rates for all atmospheric deposition sites 2008-2010.



Site	µg/m^2/yr
Antelope (Buffalo, SD)	6.72
Badlands NP	3.43
Beresford, SD	9.13
Devils Tower NP	6.57
Eagle Butte, SD	7.49
Huron, SD	6.00
NE Farm, SD	Not continuously monitored
Scotts Bluff NM	7.92
Teddy Roosevelt NP	5.82
Wind Cave NP	6.70

An isopleth map was created for all sampling locations combined using the ArcGIS Spatial Analyst Tool's inverse distance weighted option for interpolation. Values used in the isopleth map are mean values for each location normalized to one year of data. This data was then entered into GIS to create a summary of mercury atmospheric deposition rates from 2008 through 2010 presented as an isopleth map in Figure 16 and for the determination of mean mercury deposition for South Dakota. A mean mercury deposition rate of 6.64 µg/m^2/year was determined for South Dakota. In general, the mercury deposition rates range from 9.13 µg/m^2/year near Beresford, SD to 3.43 µg/m^2/year at Badlands National Park. The high deposition rate at the Beresford site is unknown, however the pattern is consistent with regional 2009 mercury deposition MDN estimates as seen in Figure 3. Since mercury is quite mobile and can travel great distances within the atmosphere, winds aloft could be a contributing factor to the patterns of mercury deposition found within South Dakota. Another possible source could be the George Neal Power Plant (Sioux City, IA) located 55 miles southeast of Beresford, SD.

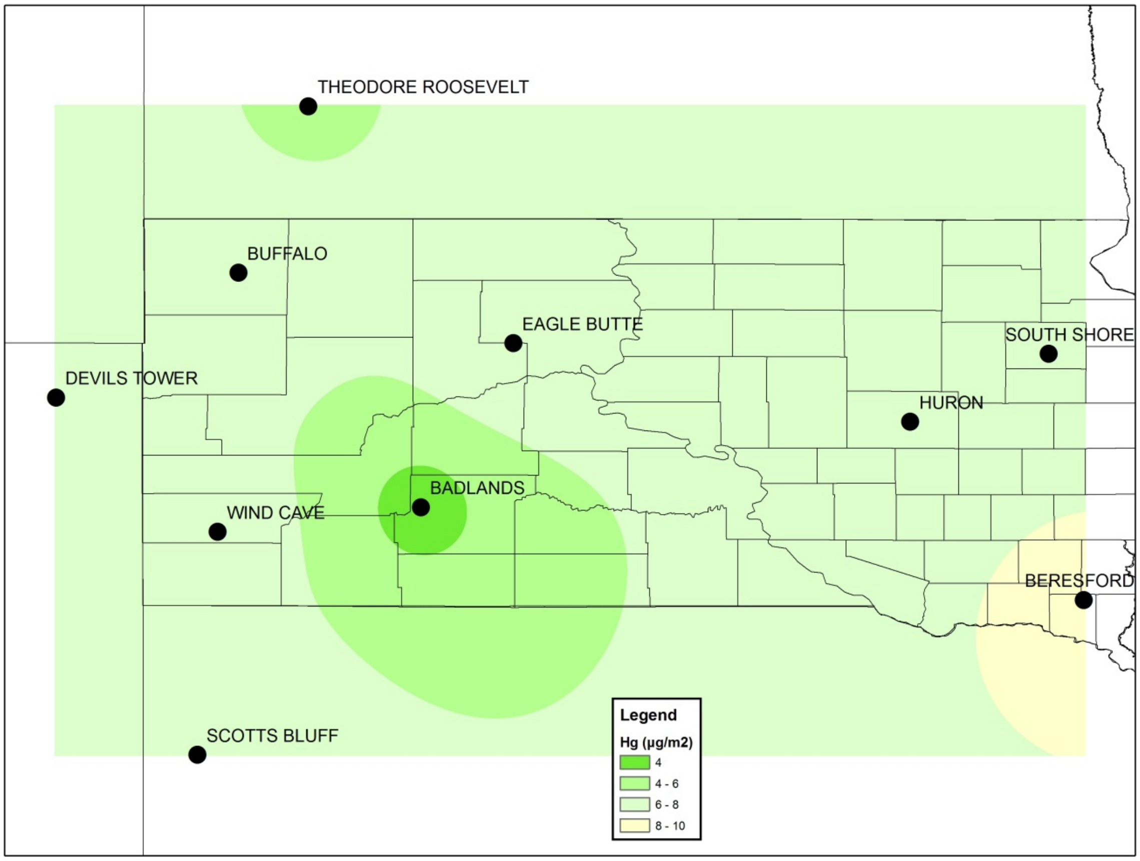


Figure 16. Isopleth map for the 10 atmospheric mercury monitoring sites for 2008 through 2010. Mean bulk atmospheric mercury deposition displayed in units of [µg/m2/yr].

A comparison between the MDN isopleth map (Figure 3) and the South Dakota isopleth map (Figure 16) shows some similarities. In the eastern half of South Dakota, both studies exhibit higher deposition rates in the extreme southeastern part of the state. However, Dr. Stone's data used in Figure 16 shows differences from the MDN data in the western half of SD. This difference is likely attributable to the higher resolution monitoring network created by the data collected at the temporary monitoring sites used for the project. Isopleth deposition values for northeastern South Dakota were similar, ranging from six to eight µg/m^2/year (6-8 g/Km^2/year) in Figure 16 and four to six µg/m^2/year in Figure 3. Similarly, southeastern South Dakota deposition ranged from six to ten µg/m^2/year (8-10 g/Km^2/year).

5.1.3 Atmospheric Mercury Deposition Correlations

A regression analysis showing significant positive correlation ($p < 0.05$) was completed comparing precipitation during sample period versus atmospheric mercury deposition at all locations (Figure 17). This suggests that mercury deposition for South Dakota conditions is primarily correlated to rain and snow precipitation instead of dry matter particulate deposition that is common in the western U.S. This conclusion is consistent with EPA REMSAD modeling which is further discussed later in this document.

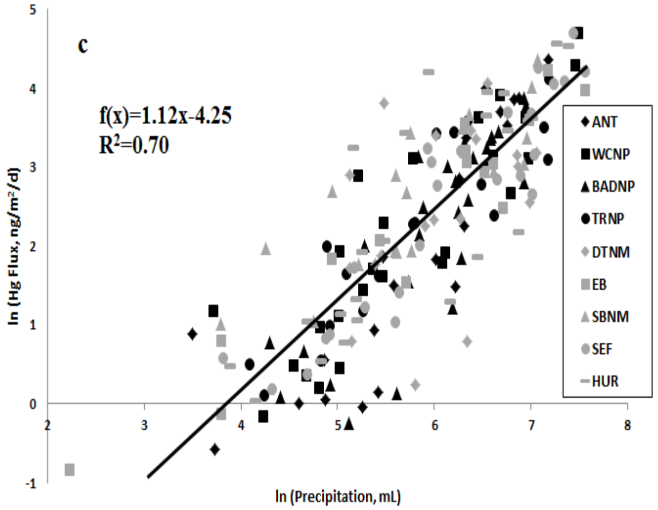


Figure 17. Natural log of daily Hg deposition compared to natural log of precipitation all stations except NEF. (Lupo and Stone 2013)

A regression analysis was completed comparing the mercury concentration within the top ten cm of sediment collected from the ten lakes sampled (as a part of Dr. Stones study) to atmospheric deposition rates. The estimated mercury deposition for each lake was determined using an isopleths map. The results of this analysis, a significant positive correlation between mercury concentration in ten cm and atmospheric deposition, are shown in Figure 18. This trend was expected as the atmospheric mercury deposition that is deposited in a specific watershed would eventually travel into lake sediments, although the specific mechanisms of transport would vary widely depending on topography, geochemistry, and fluvial characteristics. These results suggest that a reduction in atmospheric mercury deposition would eventually lead to a decrease in the loading or occurrence of mercury within lake sediments.

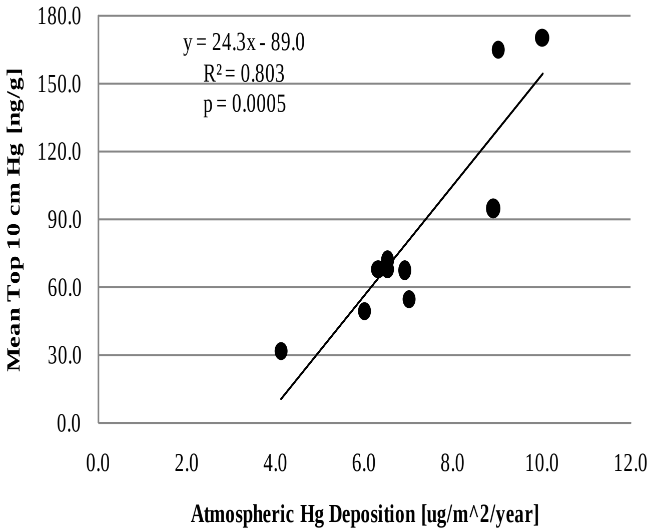


Figure 18. South Dakota atmospheric mercury deposition versus the mean mercury concentration top 10 cm of sediment.

5.2 REMSAD Modeling Results

In August, 2008 EPA released the document "*Model-Based Analysis and Tracking of Airborne Mercury Emissions to Assist in Watershed Planning*". The purpose of this document is to support an analysis of the sources of airborne mercury and their contribution to water quality impairment and fish contamination throughout the continental U.S. The document summarizes results of the Regional Modeling System for Aerosols and Deposition (REMSAD). REMSAD is a three-dimensional grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical process in the atmosphere that affect pollutant concentrations (USEPA 2008). The model simulates both wet and dry deposition of mercury. Included in the report are result summaries for the forty eight conterminous states and the District of Columbia.

Officials from EPA Region 8 expressed concerns over the age of data utilized in the REMSAD report. Although the model data from the REMSAD report in 2008 is based on 2001 emissions data, the model is relatively close to the baseline year of 2009 used for this TMDL. Further, examination of the REMSAD depositional results (Figure 19) show similar distribution patterns between 2001 modeled deposition rates (7.2-25.7 g/Km^2) to the 2008-2010 measured data (Figure 16) (6-10 g/Km^2). The deposition ranges listed in Figure 19 overlap the measured data, but are higher. The states total deposition (Figure 22) of 2,450,501 grams equates to a mean deposition rate of 12.3 µg/m^2 (mass/area of SD), which is 1.8 times the measured mean deposition rate for 2008 through 2010 of 6.64 µg/m^2. The difference between the 12.3 µg/m^2 (calculated from 2001) and 6.64 µg/m^2 (measured during 2008-10) may be partially attributed to emission reductions that occurred during this time period. Although global emissions between the two time frames are considered to have remained relatively constant (UNEP 2013), the distribution of sources has changed with increases in Asia offsetting North American and European sources (UNEP 2013). Considering the similarities in spatial patterns between the model and measured data, it is appropriate to utilize the existing REMSAD data to develop source allocations for this TMDL.

The REMSAD model utilizes a twelve km grid based approach through which annual deposition as well as the source of the deposition may be determined. Utilizing the Particle and Precursor Tagging Methodology (PPTM), the model results include the primary sources of deposition for each grid cell. The sources are identified through the model inputs (tagging). Approximately five tags were assigned within each state following the general procedure of the three largest emitters of divalent gaseous mercury, and then the largest total emitter not already tagged, with the final tag addressing all remaining sources. States with minimal numbers of sources received fewer than five tags while states with numerous large sources received additional tagging. The sources tagged in South Dakota as well as their mercury emissions by speciation are presented in Table 20. The mercury species included in REMSAD and Table 20 are HG0 (elemental mercury vapor), HG2 (divalent mercury compounds in gas phase), and HGP (divalent mercury compounds in particulate phase).

Table 20. REMSAD PPTM results: mercury deposition contribution analysis (mercury emissions in tons per year) (USEPA 2008).

Source	Source Type	HGO	HG2	HGP
Otter Tail Power (Big Stone)	Coal Fired Utility	0.03700	0.01800	0.00024
Health Services	Health services	0.00600	0.00000	0.00000
Collective Sources (remaining sources in State)		0.00700	0.00300	0.00200

Published state summaries included analysis of the point within each state where simulated in-state contributions constituted the greatest percentage of total deposition. This point in South Dakota is located in Butte County and presented in Figure 19. While not representative of the state as a whole, it represents the maximum amount of impact that instate reductions may have. Comparing the point of highest contribution to the state averages provides a more thorough understanding of the impacts that reductions will have on the entire state.

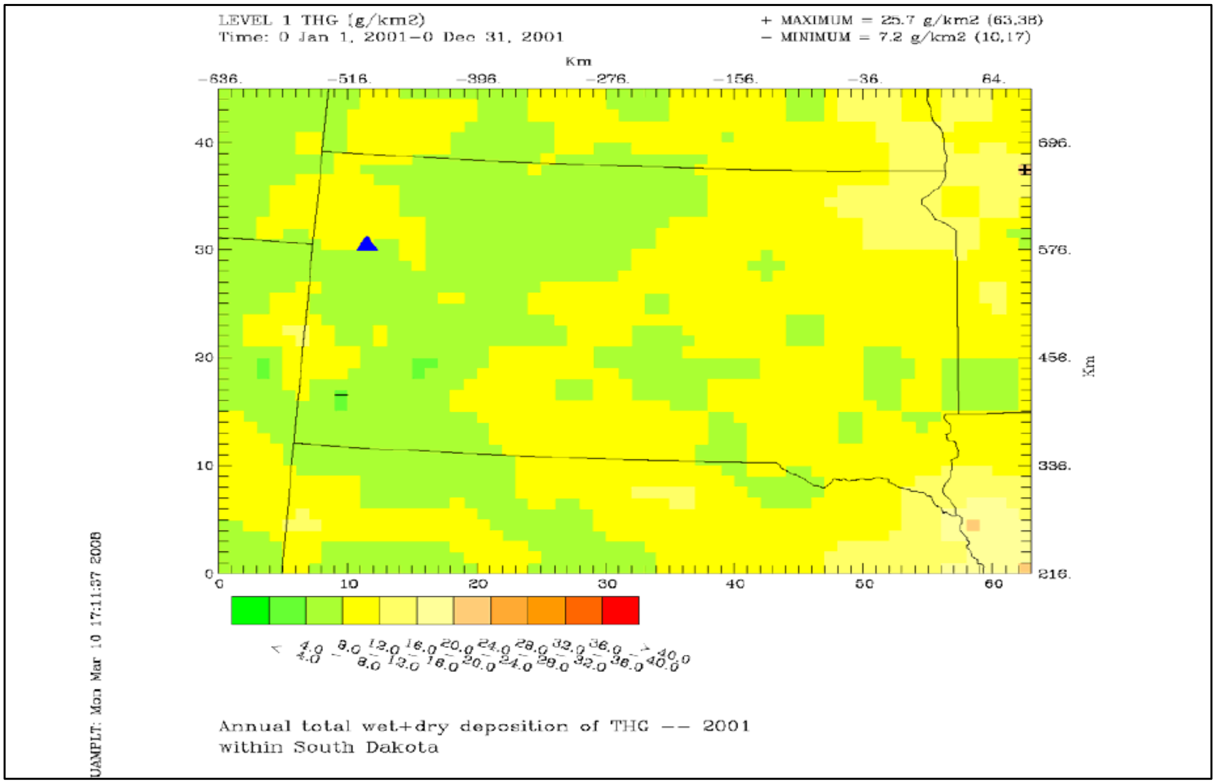
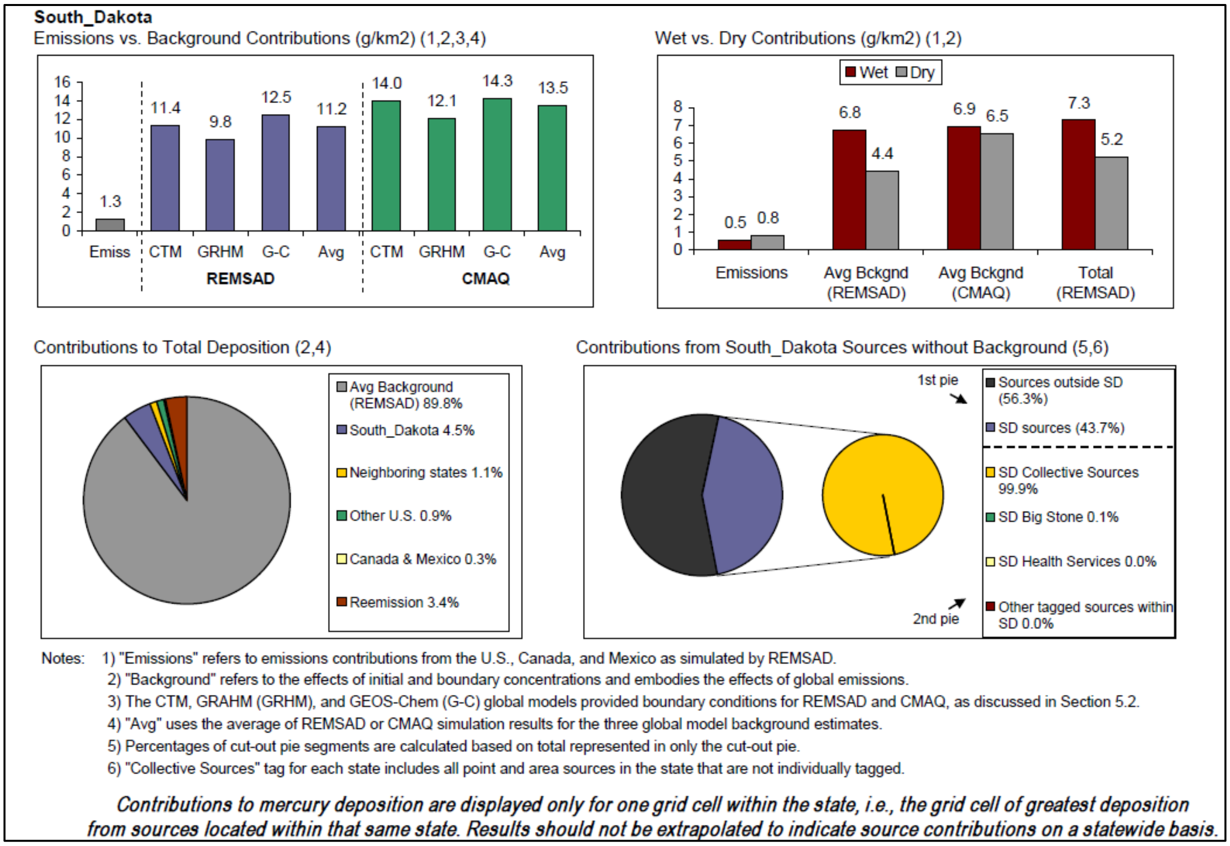


Figure 19. REMSAD-simulated Total (Wet and Dry) annual mercury deposition (g km2) for South Dakota (USEPA 2008)

The deposition summary for the point in Butte County is presented in

Figure 20. Deposition is broken down in several ways. Bar charts in the upper left of the figure present a comparison of the REMSAD and Community Multi-Scale Air Quality (CMAQ) models while the bar chart in the upper right compares both wet and dry deposition. The chart indicates that wet deposition rates are larger than dry deposition. This is in agreement Stone's monitored data from 2008-2010, which indicated that wet deposition is more strongly correlated to accumulations than dry deposition.



Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.

Figure 20. South Dakota deposition analysis for the Single grid cell (Blue Triangle in Figure 19) where in-state sources contributed the most to simulated annual total mercury deposition for 2001 (12.5 g/km^2) (USEPA 2008)

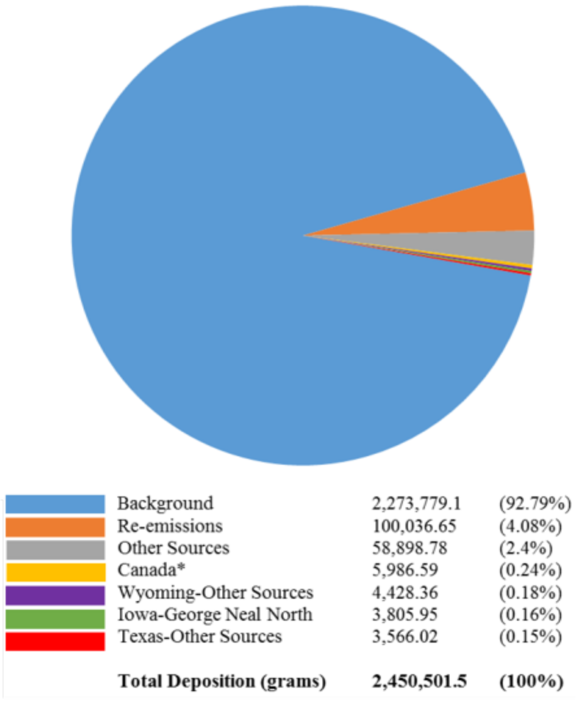
The pie charts break out emissions sources in detail. The chart at the lower left indicates that 4.5% of deposition to this grid cell was from sources located within South Dakota. It is important to note that this is the highest in-state percentage simulated by the model and that the statewide average is significantly lower. The pie charts in the lower right portion of the figure utilize the same data, but progressively remove a component in each step. The first pie represents the proportion of sources when background emissions (grey portion of first pie) are removed. Background, defined by REMSAD as the model's boundary conditions, represents sources (both natural and anthropogenic) originating outside of the REMSAD modeling domain, consisting of the continental United States plus parts of Canada and Mexico, and emissions originating within but transported outside of the modeling domain that become part of the global pool.The final pie breaks down only those sources located within the state. The collective sources tag represents all other sources not individually tagged. Since the three largest emitters of divalent gaseous mercury within the state combined to account for only 0.01% of the total deposition, the data clearly indicates that there are no single sources of mercury within the state that are contributing significantly to the deposition in South Dakota.

Understanding the maximum impacts that in-state reductions will have may be gained through analysis of the Butte County grid cell. However, it is not appropriate to use for source allocations on a statewide basis. To address the statewide depositional rates, EPA utilized the AggreGATOR tool developed by ESRI for EPA. The tool calculates mass loading to a polygon of interest, in the case of this TMDL it was applied to the entire state. The functional outputs of the process are a summary of the REMSAD modeling results for the entire state.

The contribution of state scale sources follows a similar distribution to Butte County, the point of highest in-state source contribution. The data in Figure 21 and Figure 22 present potential sources in two separate methods. In each chart the two largest sources remain static: background and re-emission at 92% and 4%, respectively. The remaining sources accounted for less than 4% of all deposition in the state. Figure 21 includes the South Dakota portion within the ‘Other Sources’ tag and breaks down primary sources in North America. These include Canada, Wyoming, Iowa, and Texas. In combination, these sources account for 0.73% of deposition in the state.

The data in Figure 22 aggregates the North American sources into the other sources tag and separates out three individual sources from within South Dakota. These include Health Services, Otter Tail Power Company (Big Stone), and all other South Dakota Sources. The contribution from each of these is too small to be visible in the pie chart and collectively the three account for 0.12% of the deposition occurring in the state.

The percentage contributions presented in Figure 21 and Figure 22 are applicable to the area addressed by this TMDL. These values were used to establish the source allocations in the final TMDL calculations.



*Excluding Ontario sources and the Burnaby Refuse Incinerator near Vancouver, British Columbia

Figure 21. South Dakota mercury deposition with North American sources summarized (Atkinson 2014)

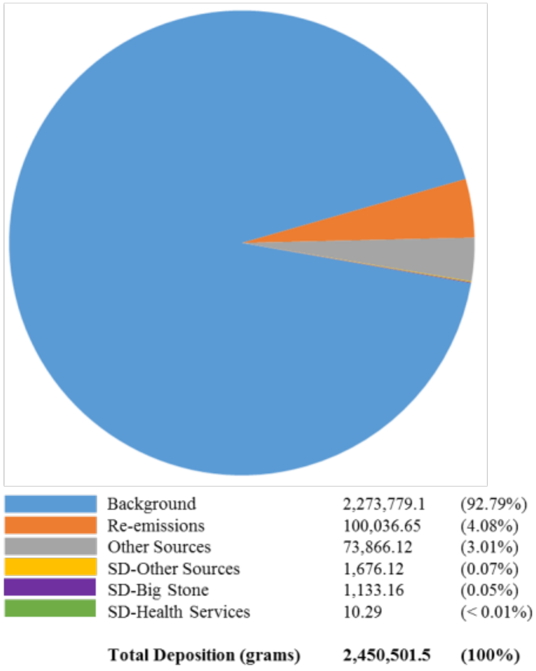


Figure 22. South Dakota mercury deposition with South Dakota sources summarized (Atkinson 2014).

The REMSAD emissions files do not include natural emissions of mercury (e.g., volcanic emissions) within the modeling domain (roughly North America). Natural emissions are included in the inventories used for the global simulations that provide boundary concentrations for both the REMSAD and CMAQ simulations (USEPA 2008). This load is included with other global anthropogenic sources as a portion of the "background" load in the simulation results. Calculating the non-anthropogenic portion of the load is essential in the final TMDL calculation and resulting source allocations. Existing TMDLs have reached similar conclusions as to the percent of deposition which may be attributed to natural or non-anthropogenic sources. The MN and Florida TMDLs each concluded that 30% of the load may be considered natural in origin. The NJ TMDL found that 25% could be allocated to natural sources. Each of these studies looked at a variety of factors and literature to reach similar, if not identical conclusions. Considering the MN TMDL to be geographically closest, it is a reasonable assumption that the conclusions drawn for that assessment are valid for South Dakota as well. The final TMDL calculations will incorporate the assumption that 30% of the mercury load is non-anthropogenic in origin and not subject to reductions.

5.3 Emissions Sources

Emission sources of mercury in South Dakota were provided by EPA. Additionally, SDDENR noted a source of mercury was missing from the EPA's original list of emission sources, Pete Lien & Sons, Inc. This is a quarry operation with a coal fired kiln that emits mercury. Mercury emissions were added to the list based on coal consumption estimates for the kiln. Although this source was omitted from the EPA REMSAD and CMAQ models, it likely did not have a significant impact on the results considering the small amount of coal used in the manufacturing process.

Table 21. 2011 emissions sources in South Dakota (USEPA 2014).

Facility	Facility Type	2011 Mercury EPA (lbs per Year)
Otter Tail Power Company (Big Stone)	Coal Fired Power	153.34
Wharf Resources (U S A) Inc.	Gold Mine	47.4
Black Hills Power & Light Company (Ben French)	Coal Fired Power	17.72
South Dakota State University (SDSU)	Heating	1.38
GCC Dacotah	Cement	0.75
Pete Lien & Sons, Inc.	Quarry (Kiln)	0.72
Rushmore Forest Products Inc	Timber	0.58
POET Biorefining - Great Plains Ethanol	Ethanol	0.22
Spearfish Forest Products	Timber	0.19
Countertops Inc	Industry	3.42E-02
Rapid City Landfill	Landfill	3.40E-02
Sioux Falls Regional Sanitary Landfill (SFRSL)	Landfill	3.18E-02

When considering specific loads from the facilities listed, it is important to note that loads are variable from year to year. Power generation facilities, although listing a particular load, may produce higher or lower loads in any given year as power demands from these facilities are balanced with regional alternative power supplies such as wind and hydroelectric. The reductions in this TMDL will focus more closely on percentages than reported loads from a given year.

The largest source in South Dakota is the Otter Tail Power Company (Big Stone), located in the northeast corner of the state, which utilizes coal for the generation of power. EPA emission reduction mandates through MATS are scheduled to take effect on this plant during the 2015-2016 calendar years. EPA has claimed that *"The final rule establishes power plant emission standards for mercury, acid gases, and non-mercury metallic toxic pollutants which will result in: preventing about 90 percent of the mercury in coal burned in power plants being emitted to the air; reducing 88 percent of acid gas emissions from power plants; and reducing 41 percent of sulfur dioxide emissions from power plants beyond the reductions expected from the Cross State Air Pollution Rule."* (USEPA 2015)

Two additional facilities have made adjustments to their operations that further reduce mercury emissions in the state. Black Hills Power & Light Company shut down its coal fired power plant at its Ben French facility in Rapid City in 2014. SDSU is still permitted to burn coal for the generation of heat in its physical plant; however, the facility has chosen not to in recent years. Although there is some capacity to burn coal remaining, in most years very little if any coal is burned, resulting in reductions approaching 100%.

Including the reductions from Otter Tail Power Company (Big Stone Power Plant) and the decommissioned Black Hills Power & Light Company Power Facility (Ben French) South Dakota will be able to achieve a 70% decrease in mercury emissions (i.e., cumulative emissions from Table 21 [222.4 lbs/yr] minus expected reduction from Otter Tail Power Company [153.34 x 0.9 = 138.006 lbs/yr] minus expected reductions from Black Hills Power & Light Company [17.72 lbs/yr] equates to a predicted future in-state emissions total of 66.674 lbs/yr, which is a 70% reduction from the 2011 estimate of 222.4 lbs/yr). SDSU was not included in the estimated reductions as the facility is still permitted to burn coal. However, the resulting lack of use will help achieve an additional level of reduction.

5.4 Baseline Year

The basis of mercury deposition estimates for South Dakota commenced in 2009 when the expanded air deposition monitors were installed through Dr. Stone's project through SDSM&T. The year 2009 was used as a loading or occurrence reference point (baseline) to which future mercury loading will be compared for mercury TMDL attainment. The year 2009 also works with the fish tissue data, which was primarily collected from 2010 to 2014. The more recent fish tissue data should incorporate some bioaccumulation of the methylmercury that resulted from 2009 emissions. It can be assumed that once the TMDL has been approved and implemented, future fish tissue mercury concentrations would be expected to decrease due to reductions in mercury loading.

According to the Minnesota TMDL (2007), patterns in the predicted time required for a decrease in fish tissue mercury should remain fairly consistent for all locations throughout the United States. An example of mercury loading reduction and subsequent fish tissue behavior is provided in Figure 23 (Atkeson et al. 2002), which was created using an E-MCM model for conditions found in the Florida Everglades. According to the Atkeson study, fish mercury concentrations will be significantly reduced throughout the first twenty years following a reduction in atmospheric deposition, and the concentration decrease will taper off at approximately the twentieth year.

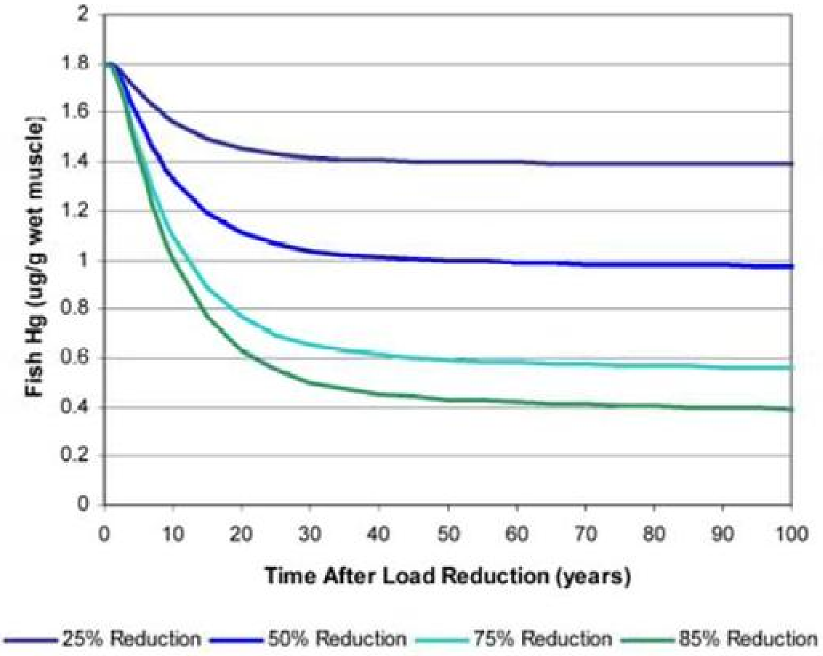


Figure 23. Predicted response times for fish tissue mercury concentrations once a reduction is made for mercury atmospheric deposition (Atkeson et al. 2002).

Sediment cores were collected in 2009 from ten South Dakota lakes to provide better estimates of recent and historical mercury deposition. The intent was to provide a general guidance for estimating future mercury sediment loading for most South Dakota lakes and impoundments. Bulk atmospheric deposition for 2009 was also collected at sampling sites throughout the state, providing an estimate of current atmospheric loading rates. The most recent mercury sediment occurrences for the top ten cm of sediment core data ranged from 7.61 to 310.77 ng/g for 2009, while the atmospheric deposition rates ranged from 3.43 to 9.13 g/Km^2/year for sites across South Dakota. Atmospheric deposition was fairly consistent across the state while the mercury found in the upper sediments of the lakes was highly variable. A number of factors may have influenced this variance including watershed characteristics and changes in lake levels which might be mobilizing mercury from newly flooded shorelines. As a result, the sediment core data was not utilized to modify either the loading rates, or to infer changes in mercury loadings for recent years in this TMDL.

6.0 Wasteload Allocation (WLA)

The TMDL wasteload allocation accounts for point source contributions of mercury and much of their contributions are described in greater detail throughout section 4.0 Source Assessment – Point Sources.

Presently, all mine sites that are known to have a reasonable potential to result in water quality impairments of any kind have NPDES permits which limit mercury discharges. Historically discharged tailings discussed in section 4.1 do not appear to be a contributing factor to the states elevated fish tissue methylmercury concentrations measured since the late 1990's.

MS4 loads are typically addressed as individual WLA's; however, the modeling and atmospheric measurements fully accounted for their contributions within the LA, as discussed in section 4.2. Although the source of mercury to MS4's is atmospheric, EPA has dictated that they must be included in WLA component of this TMDL.

There are 247 NPDES facilities (Appendix E) permitted to discharge effluent to South Dakota surface waters. These permits cover industries such as ethanol and railcar repair facilities as well as municipalities, mines, and fish hatcheries. Total aggregate annual flow from NPDES facilities equaled 43 billion gallons. A concentration of 0.01536 µg/L was applied to this water load based on rationale discussed in section 4.3. The sum of mercury loads from these facilities equaled 2.53 kg/yr and was used for the WLA in the final TMDL. In aggregate, they account for less than 0.2% of the total source load and 0.43% of the final TMDL. Although the WLA contribution was determined to be *de minimis* (Section 4.3) and thus not subject to reductions, it is not an allowance for increased discharges of mercury, nor does it provide exemption from further efforts to reduce mercury from these sources.

7.0 Load Allocations (LA)

The majority of this TMDL is accounted for in the Load Allocation component. The major source of mercury for waters in South Dakota is air deposition (>99%) and this component is subject to all the reductions required for TMDL attainment. REMSAD modeled contributions used for the baseline year (percentage from source) from all nonpoint sources are presented in Table 22. Measured loads calculated in Section 5.0 did not include point source discharges of mercury. To accurately calculate the allocations for the nonpoint sources, point source loads were factored into the total source load (TSL) (see section 10 Table 24). The resulting reduction necessary for the LA was 79% which was applied evenly to all anthropogenic sources. It is important to reiterate that the background portion (92.79%) includes both natural and global anthropogenic sources of mercury. As identified in section 5.2, 30% of this portion of the load is assumed to originate from non-anthropogenic (natural) sources and is therefore not subject to load reductions.

Table 22. REMSAD modeled sources of mercury.

Modeled Air Deposition	
All Sources	100.00%
Background	92.79%
Reemission	4.08%
Other Sources	2.29%
Other US States	0.48%
Canada	0.24%
South Dakota	0.12%

The source allocations for the LA component of the TMDL contribute an area weighted proportion to the MS4s and the rural areas of the state. The MS4s account for 0.39% of the state area while the remaining 99.61% of the state is considered rural. Although a part of the load allocation, the MS4 portion of this load was sub calculated to identify the specific portion of the TMDL attributable to deposition occurring in urban areas. To obtain these loads, the LA was multiplied by the percentage from each category, the resulting split is calculated in section 10 Table 24 with the MS4 portion being then redefined as a WLA, even though it is calculated and tied directly to the LA.

8.0 Margin of Safety (MOS)

According to 40 C.F.R. 130.7, TMDLs must include a margin of safety to account for any lack of knowledge concerning the relationship between effluent limits and water quality. A MOS may be implicit through the use of conservative estimates within the calculations or explicitly stated reserving a portion of load allocation to account for uncertainty. The following conservative assumptions were incorporated into the implicit MOS for South Dakotas Mercury TMDL:

- In the calculation of the standard length fish concentration (WE38=0.669 mg/Kg), fish tissue sampling utilized a process where waterbodies with fish consumption advisories were targeted for additional sampling, i.e. fish flesh MeHg concentrations exceeded 1.0 mg/Kg. As a result, the concentration of 0.669 mg/Kg is biased towards those waterbodies considered impaired three times beyond the recommended EPA criterion of 0.3 mg/Kg. Removing the bias would result in a lower, but less protective, concentration of 0.586 mg/Kg for all waters of the state. Using the higher concentration of 0.669 mg/Kg for TMDL calculations provides a substantial implicit margin of safety that was incorporated into the TMDL calculation.
- Reductions for this TMDL are based on reductions in total fish tissue mercury while the EPA criterion is for methylmercury. Additional implicit MOS is incorporated into the TMDL through the assumption that not all of the mercury measured is methylmercury. Approximately 83% of fish tissue measurements are in the form of methylmercury (Driscoll et al. 2007; Kannan et al. 1998) adding to the potential for an increased MOS.
- Walleye typically contain the highest levels of methylmercury in comparison to other species due to the species top predator status. Reductions adequate to achieve the TMDL goal for walleye will result in proportional reductions in other species. These proportional reductions will result in other species attaining the TMDL sooner as well as

reducing concentrations in these species to well below the TMDL goal when it is achieved for walleye.

- As a regional TMDL, reductions were biased towards the most severely impaired waters in the state. The primary source of the pollutant (mercury) is atmospheric deposition, and it is expected that as emissions are curbed, reductions statewide will be proportional. Although a reduction of 79% is called for in the TMDL, lesser reductions would fully attain the TMDL goal for many of the waters, thus further incorporating an implicit margin of safety for a majority of the waters in the state.
- Approved TMDLs from Minnesota, the Northeast, and New Jersey all included reductions in sulfur emissions as an added margin of safety. A great deal of research (Branfireun et al. 1999; Gilmour and Henry 1991; Gilmour et al. 1992; Jeremiason et al. 2006; Jeremiason et al. 2003) has been conducted linking increased sulfates to a more efficient methylation process. Sulfate-reducing bacteria (SRB) convert inorganic mercury into methylmercury using sulfur rather than oxygen as part of their metabolic processes. Reductions in sulfur emissions as a result of the 1990 Clean Air Act are expected to reduce SRB activity lowering the amount methylated mercury available for bioaccumulation.

9.0 Critical Conditions and Seasonality

As required by 40 CFR 130.7(c)(1), TMDLs need to be established at levels that attain and maintain applicable water quality standards with seasonal variations. TMDLs must also consider critical conditions for stream flow, loading, and water quality. These requirements were incorporated in the final TMDL through:

- The primary seasonal condition considered for this TMDL relates to precipitation patterns. Wet deposition of mercury increases during seasons with increased rainfall. Seasonal rainfall may also result in river and stream connectivity to adjacent wetland areas that have higher methylation rates. These factors affect the overall concentration of mercury; however, fish tissue mercury concentrations are the product of bioaccumulation throughout the lifespan of the fish. The concentration of mercury in the fish at the time of sample collection includes aspects of seasonality since it is a product of the aforementioned conditions.
- To account for the depositional variability that results from seasonal precipitation, the TMDL was initially calculated as an annual load prior to conversion to a daily load. Basing the initial calculation on annual deposition rates fully incorporates the seasonality requirement of the TMDL, which is ultimately reflected in the final daily calculation.
- Numerous critical conditions have been linked to methylation rates throughout the country. Conditions that are frequently mentioned in publications include presence of wetlands, sulfates, depleted oxygen levels, pH, and trophic status. The conditions which were determined to be the most influential factors in determining methylation rates (section 3.0 Data Analysis) for South Dakota waters include presence of wetlands and Secchi depth (both of which were negative correlations) and highly variable lake levels. These conditions are correlated to the waters with the highest mercury concentrations. The development of the reduction targets included the critical conditions described in Section 5.0. Through calculation of the TMDL on a regional level requiring reductions

adequate to meet the conditions of the most severely impaired waters, these factors are accounted for within the final calculation.

10.0 Final TMDL Calculations

The primary components in defining the South Dakota TMDL calculation include estimating the existing atmospheric load (non-point source load), selecting the target atmospheric load, and calculating the atmospheric load reduction required to meet the target load. The Total Source Load (TSL) is the total atmospheric deposition in Kg/yr plus the point source load discussed in sections 4 and 5, respectively.

Table 23 presents the sources of mercury, calculates the Total Source Load (TSL), and applies the Reduction Factor (RF) to calculate the TMDL. The point sources described in section 4.3 are represented as derivative A. The nonpoint source or atmospheric load is based on instate deposition monitoring. South Dakota's average atmospheric mercury deposition is approximately 0.00664 kg/km2/yr (6.64 µg/m^2/yr). The state's area is 199,742.5 km2. Thus, the product of the two is 1,326.3 kg/yr (derivative B). Derivative B is then sub allocated amongst the six REMSAD source categories based on the modeled percentages (derivatives b_1-b_6). The TSL sums the atmospheric deposition and the point source loads, which were considered separate from the atmospheric modeling or the deposition sampler estimates. The sum of these loads (TSL) is represented as derivative C. The RF from section 3.3 (derivative D) is then used to calculate the TMDL from the TSL.

Table 23. TMDL calculations

Sources	Derivation	Load (kg/yr)
Point Sources (NPDES) - Section 4.3	A	2.53
Nonpoint Sources or Atmospheric - Section 5.1.2	B	1326.30
Global Background - 92.79%	b_1	1230.67
Reemission - 4.08%	b_2	54.11
Other Sources - 2.29%	b_3	30.37
Other US States - 0.48%	b_4	6.37
Canada - 0.24%	b_5	3.18
South Dakota - 0.12%	b_6	1.59
Total Source Load (TSL)	C=A+B	1328.83
Reduction Factor (RF) - Section 3.3	D	55.2%
TMDL	E = C*(1-D)	595.32

Table 24 shows 30% of the REMSAD modeled loadings were considered to be from non-anthropogenic background, i.e. natural sources, and were removed from the overall load subject to reductions (derivative F). Removing the background load and the point sources (which were not subject to reductions as described in section 4.3) from the TMDL, the balance of the load (derivative H) is divided into the following components: 1) the municipal areas regulated through MS4s (derivative h_1); and 2) the remaining area of the State that falls outside of those MS4s permits (derivative h_2). Derivative I is the percent reduction required from anthropogenic non-point sources necessary to achieve the TMDL target. The final allocation of the LA, WLA, and MOS are then shown.

Table 24. TMDL allocations

TMDL Calculations	Derivation	Load kg/yr
Point Sources (NPDES) - Section 4.3	A	2.53
Non-Anthropogenic Background (*cannot be reduced*)	F=0.3*B	397.89
Anthropogenic Nonpoint Sources or Atmospheric	G= E-A-F	194.90
Atmospheric Total	H=G+F	592.79
MS4 fraction - 0.39%	h1=H*0.0039	2.31
Non MS4 Fraction - 99.61%	h2=H*0.9961	590.47
Percent Reduction for Anthropogenic Atmospheric Sources	I=(((B-F)-G)/(B-F))*100	79.01%
Load Allocation (LA)	LA = H-h1	590.48
Wasteload Allocation (WLA)	WLA = A+h1	4.84
Margin of Safety (MOS)	MOS = Implicit	0.00
Final TMDL	**TMDL = LA+WLA+MOS**	**595.32**

The annual loads are significantly more important for expressing loading limits and reduction goals due to the chronic nature of mercury impairments and their long term bioaccumulation rates in fish. The conventional equation for a TMDL is: MOS + WLA + LA = TMDL. For this TMDL, the MOS is implicit. The WLA and LA components are described in sections 6.0 Wasteload Allocation (WLA) and 7.0 Load Allocations (LA), respectively.

Table 25. TMDL annual calculation

Annual Calculation		
TMDL(595.32 Kg/yr)	=	WLA (4.84 Kg/yr) + LA(590.48 Kg/yr) + MOS (implicit)

Compliance with the TMDL calculations is based on the annual loads. However, in order to comply with EPA guidance, the TMDL needs to be expressed as a daily load. To identify a maximum daily limit, a method from EPA's "*Technical Support Document For Water Quality-Based Toxics Control*," referred to as the TSD method (USEPA 1991), was used. This method, which is based on a long-term average load that considers variation in a dataset, is a recommended method in EPA's technical guidance "*Options for Expressing Daily Loads in TMDLs*" (USEPA 2007).

The TSD method is represented by the following equation:

$$\text{MDL} = \text{LTA} + Zp^{*}\sigma$$

where,

MDL = maximum daily limit in kg/day
LTA = long-term average=μ, 595.32 kg/yr converted to 1.63 kg/day
Zp= z statistic of the probability of occurrence= 1.645
σ =CV/μ
CV = coefficient of variation

The daily load expression is identified as a static maximum daily limit (MDL). A higher value for the MDL is produced for the same long term average (LTA) as the CV increases, in order to allow for fluctuations about the mean. Assuming a probability of occurrence of 95% and a CV of 1.569 (based on Eagle Butte Hg deposition data), the MDL corresponding with an LTA of 595.32 kg/yr is 3.21 kg/day.

11.0 Reasonable Assurance and Implementation

Reasonable assurance that a TMDL will be attained is required when reductions in the LA are used to balance less stringent reductions in the WLA. This is necessary due to the nature of South Dakota as a primarily rural state and the transport mechanisms of mercury, over 99% of mercury loading enters the waterways from nonpoint sources. As a result, this TMDL requires all reductions to occur through the LA. The amount of mercury which can be attributed to point sources (WLA) is small enough that reductions in any form or amount would not yield a measureable effect on fish tissue samples.

South Dakota has a limited quantity of reductions which may be achieved in the state. South Dakota emissions data has consistently ranked as the third lowest emitter of mercury in the nation (USEPA 2008). Federal mandates are in line to account for the majority of the necessary 79% reduction from within the state.

The single largest source of mercury in South Dakota is the Otter Tail Power Company (Big Stone) located in the northeast corner of the state which uses coal for the generation of power. EPA emissions mandates (MATS) are set to take effect on this plant during the 2015-2016 calendar years. EPA has predicted that the impacts of MATS rule will result in approximately 90% cleaner emissions (USEPA 2015) from this facility.

Two additional facilities have made adjustments to their operations that further reduce mercury emissions in the state. Black Hills Power & Light Company permanently shut down its coal fired power plant at its Ben French facility in Rapid City in 2014. SDSU is still permitted to burn coal for the generation of heat in its physical plant; however, the facility has chosen not to in recent years. Although there is some capacity to burn coal remaining, in most years very little if any coal is burned, resulting in reductions approaching 100%.

The majority of sources exist outside of the state, thus nonpoint source reductions in South Dakota will primarily result from existing and proposed federal rules, e.g. the Mercury Air and Toxics Standards (MATS) rule, which can be found on the following EPA websites (http://www.epa.gov/mercury/regs.htm and http://www.epa.gov/mats/powerplants.html).

On February 16, 2012, the Mercury Air and Toxics Standards (MATS) rule was promulgated in 77 FR 9464. The intent of the rule is to limit power plant emissions of toxic air pollutants such as mercury, arsenic, and metals. The establishment and subsequent revisions of these rules will provide an ongoing reduction effort at the national level which will result in progress towards the attainment of this TMDL. Please note that the recent U.S. Supreme Court decision (*Michigan v. US EPA*) adds uncertainty to MATS rule, however, this TMDL assumes its continued and full implementation; indeed many of the affected power plants (including Otter Tail Power Company - Big Stone) throughout the country are already in the process of installing the necessary controls needed to cut mercury and other emissions.

An outline of these rules, as available from EPA, follows:

- *These rules finalize standards to reduce air pollution from coal and oil-fired power plants under sections 111 (new source performance standards) and 112 (toxics program) of the 1990 Clean Air Act amendments.*
- *Emissions standards set under the toxics program are federal air pollution limits that individual facilities must meet by a set date. EPA must set emission standards for existing*

sources in the category that are at least as stringent as the emission reductions achieved by the average of the top 12 percent best controlled sources.

- *These rules set technology-based emissions limitation standards for mercury and other toxic air pollutants, reflecting levels achieved by the best-performing sources currently in operation.*
- *The final rule sets standards for all hazardous air pollutants (HAPs) emitted by coal- and oil-fired electric generating units (EGUs) with a capacity of 25 megawatts or greater.*
- *All regulated EGUs are considered major under the final rule. EPA did not identify any size, design or engineering distinction between major and area sources.*
- *Existing sources generally will have up to 4 years if they need it to comply with MATS.*
    - *This includes the 3 years provided to all sources by the Clean Air Act. EPAs analysis continues to demonstrate that this will be sufficient time for most, if not all, sources to comply.*
    - *Under the Clean Air Act, state permitting authorities can also grant an additional year as needed for technology installation. EPA expects this option to be broadly available.* (USEPA 2014).

In addition further reductions will follow with the participation of the United States in international agreements designed to curtail mercury pollution. In November 2013, the United States signed the Minamata Convention on Mercury. This multilateral environmental agreement addresses human activities contributing to the global problem of mercury pollution. EPA worked with the State Department and other federal agencies in negotiating a set of approaches that strengthen the global action on mercury (UNEP 2013). These sets of federal rules and international instruments will result in the largest reductions for South Dakota. They target larger industry and coal fired power plants which, unlike the larger population centers on the eastern and western parts of the United States, do not exist in South Dakota in any significant fashion as shown in Figure 22. In the 2012 Compendium of States Mercury Activities it was reported that for period of 1990 to 2008 reductions in atmospheric mercury sources reached up to 70% nationally and in some states 90% (ECOS, 2012). .

The measures South Dakota can implement are limited because of the global nature of mercury. Section 5.0 (Source Assessment) outlines ad nauseum the mercury sources derived instate via MS4, NPDES permits, and nonpoint sources which are derived through atmospheric generators. This section shows the order of magnitude difference between instate sources versus atmospheric sources (globally). Although energy efficiency and renewable energy projects such as wind power are aiding in the reduction of atmospheric mercury sources, the best efforts for South Dakota implementation will focus across two additional areas outside of the already discussed air emissions; point sources and solid waste.

11.1 Point Sources

11.1.1 Dental

The Federal Register (FR) cites an American Dental Association study which estimated that 50% of mercury entering POTWs was contributed by dental offices (page 63260). On October, 22, 2014, EPA proposed Effluent Limitations Guidelines and Standards for the Dental Category (79 FR 63258). This proposed rule states that wastewater from dental offices that use and/or remove amalgam containing mercury shall remove 99% of the mercury entering the sanitary sewer system. Once the rule is finalized, the state of South Dakota will be required to implement this regulation for all municipalities that do not have an approved pretreatment program. Cities with approved pretreatment programs will be required to implement these regulations as part of their pretreatment program. Under the proposed rule, dental offices will be required to submit yearly certifications if they are using amalgam separators that remove 99% of solids. If dental offices do not provide the yearly certification, they will be considered a significant industrial user and will need to submit wastewater monitoring data showing that they meet the 99% mercury removal. As this rule is still in the proposal phase, it is unclear at this point the amount of impact that will result if implemented.

11.1.2 POTWs and NPDES Permitted Sources

South Dakota has required that certain NPDES permittees monitor for mercury in their effluent. Effluent sampling for mercury is only required if the industrial and manufacturing community discharging to the POTW has the potential to be a source of mercury based on their manufacturing process. Currently, the seven of the largest POTWs within the State have implemented pretreatment programs. The approved programs look at the loading to their plants and develop local limits for pollutants of concern, including mercury. These cities will continue to evaluate the wastewater entering their system and will do periodic reviews to determine if new or more stringent mercury local limits are necessary.

11.1.3 MS4s

The six minimum measures that operators of regulated small MS4s must implement are outlined below. Each of these measures contributes to the reduction of water and sediment runoff from within the facilities. Although the MS4 area in South Dakota accounts for only 0.39% of the state's area, any measure which reduces the delivery of either wet or dry deposited mercury to the surface waters of the state can be deemed beneficial towards reaching the TMDL goal.

- Public Education and Outreach
- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping

11.2 Solid Waste

Spent standard fluorescent bulbs, high intensity discharge lamps, batteries, thermostats, pesticides, and switches may contain enough mercury to cause them to be regulated under state and federal hazardous waste requirements. To promote the collection and recycling of these commonly used mercury-containing products, EPA allowed these items to be classified as universal waste when it came time to dispose of them (40 CFR 273). Recycling under the federal Universal Waste rules, adopted by reference in this state, became a more viable management option for many small businesses. The Universal Waste Rule provides a regulatory incentive for businesses that opt to recycle mercury containing wastes and helps keep the mercury from being disposed of in solid waste municipal landfills and thus reduce releases of mercury to the environment. State inspectors have noted an increase in the number of small businesses who have opted to recycle their mercury-containing wastes rather than legally disposing them in municipal solid waste facilities. State inspectors also encourage companies to switch light bulbs to low or no mercury-containing bulbs. Further information on mercury-containing wastes recycling options within the state of South Dakota may be obtained at the SDDENR Hazardous Waste Program webpage.

12.0 Monitoring

Continued monitoring is an essential component of any TMDL. It is needed to determine TMDL applicability and evaluate attainment for South Dakota waterbodies. Monitoring efforts evaluating fish tissue concentrations, air deposition, and water column concentrations all contribute to this evaluation. Global reductions in mercury are expected to occur in an incremental fashion. Monitoring air deposition will provide information on progress towards these reductions and captures data gaps in sources (UNEP 2013). In addition to identifying impairment status of a waterbody, continued fish tissue monitoring will contribute towards a better understanding of methylation processes. Improved water column monitoring at NPDES facilities is necessary to better characterize their contributions to the total mercury load in the state.

12.1 Depositional Monitoring

Since the initial phases of development of this TMDL, the Mercury Deposition Network (MDN) has grown its number of monitoring sites. As of 2015, South Dakota had a permanent site in Eagle Butte, SD, and a site located on the border of Nebraska at Santee, established in 2013. These sites in addition to those located in other neighboring states will provide for continued monitoring of progress towards reductions in deposition.

12.2 Fish Tissue

Fish tissue monitoring in South Dakota is a collaborative effort between the Department of Health, the Department of Game, Fish, and Parks, and the Department of Environment and Natural Resources. Waterbodies are selected for monitoring based on fishing pressure and fishery management objectives. Waterbodies are initially sampled for specific pesticides, PCBs, and some metals including mercury. South Dakotas standard protocol is for each fish length to be measured and either a whole fish or a biopsy plug of muscle tissue to be submitted for individual analysis. After the initial screening is complete, additional testing for specific pollutants is conducted. In the case of mercury, five fish are collected and individually tested for mercury concentrations. Individual fish analysis is an adjustment to the assessment methodology which was adopted in 2010. Previously, five fish composite samples were collected which did not provide variability in the data. This adjustment filled a significant data gap and continued use of this method will be necessary for evaluating TMDL progress and attainment.

Waterbodies found to have maximum fish tissue mercury concentrations greater than 0.5 mg/Kg or those with fish consumption advisories are resampled at five year intervals. Waterbodies with maximum fish tissue mercury concentrations below 0.5 mg/Kg are resampled at ten to fifteen year intervals. The use of the 0.5 mg/Kg or consumption advisory triggers is not to be confused with the 0.3 mg/Kg EPA criteria. These triggers are simply a planning tool to help allocate limited funding to waters that have fish with the highest levels of methylmercury. A list of waters with fish tissue mercury data is kept current on SDDENRs web site: http://denr.sd.gov/des/sw/fish.aspx.

12.3 Water Column Monitoring

Monitoring data for NPDES facilities presented challenges to calculating an accurate load.

Much of the existing data was analyzed using methods that were insufficiently accurate to detect the low levels of mercury originating from these sources. This gap in knowledge has been addressed by EPA when it issued the sufficiently Sensitive Test Methods for Permit Applications and Reporting Rule in August of 2014. The rule states:

> *"The U.S. Environmental Protection Agency (EPA) has finalized minor amendments to its Clean Water Act (CWA) regulations to codify that under the National Pollutant Discharge Elimination System (NPDES) program, where EPA has promulgated or otherwise approved analytical methods under 40 CFR Part 136, or 40 CFR Chapter I, subchapters N and O, permit applicants must use "sufficiently sensitive" analytical test methods when completing an NPDES permit application. Also, the Director (head of the permit-issuing authority) must prescribe that only "sufficiently sensitive" methods be used for analyses of pollutants or pollutant parameters under an NPDES permit."* (USEPA 2014)

Promulgation of this rule will result in facilities testing mercury concentrations with methods that are accurate enough to detect the low levels of mercury found in their effluent. The complete text of this rule is available at EPA NPDES Sufficiently Sensitive Test Methods.

13.0 Public Participation

This section will highlight the components of the public notice period once it is complete.

Prior to the public notice of the mercury TMDL the state was, and continues to be, active in informing the public about health concerns related to the presence of fish with elevated mercury levels.

The South Dakota Departments of Health, Game Fish and Parks, and Environment and Natural Resources use a collaborative approach to monitoring, issuing advisories, and educating the public about mercury. Each agency maintains information regarding consumption advisories on its website (listed below) with links to the cooperating agencies information. In addition to traditional websites, the use of social media for public information is a developing avenue for agencies to inform the public about mercury issues.

SDDOH – https://doh.sd.gov/food/mercury.aspx?

SDGFP – http://gfp.sd.gov/fishing-boating/fish-consumption-advisoiries.aspx

SDDENR – http://denr.sd.gov/des/sw/fish.aspx

South Dakota Game Fish and Parks includes the most current list of fish consumption advisories in its annual fishing regulations publications. Individual lakes with consumption advisories are posted at public access points. Figure 24 shows a typical sign posted at public access points where a fish consumption advisory has been issued.

CAUTION

FISH CONSUMPTION ADVISORY

Elevated Mercury Levels In Fish Tissue

Lynn Lake, Day Co. Walleye 18 inches & longer
Middle Lynn, Day Co. Walleye 18 inches & longer

ADULTS
NO MORE THAN ONE 7 OZ. MEAL PER WEEK

WOMEN WHO PLAN TO BECOME PREGNANT
ARE PREGNANT OR BREAST FEEDING
NO MORE THAN ONE 7 OZ. MEAL PER MONTH

CHILDREN UNDER AGE 7
NO MORE THAN ONE 4 OZ. MEAL PER MONTH

For more information regarding this notice,
contact the SD Dept. of Health in Pierre at:
http://doh.sd.gov/fish/default.aspx or (605) 773-3361.

Updated November 2014

Figure 24. Example fish Consumption advisory posting.

The public notice period for this TMDL resulted in no public comments beyond what EPA provided through both formal and informal reviews.

This TMDL was noticed in the following newspapers in September of 2015:

- Sioux Falls Argus Leader
- Rapid City Journal
- Aberdeen American News
- Pierre Capital Journal
- Native Sun News

In addition to advertising in the aforementioned news sites, the following groups and agencies were also notified directly.

Federal Agencies

- Environmental Protection Agency
- U.S. Dept. Agriculture – NRCS
- U.S. Forest Service
- U.S. Geological Survey
- U.S. Fish & Wildlife Service
- Bureau of Land Management (PN only, by mail)
- U.S. Army Corps of engineers
- Bureau of Reclamation

State Agencies

- SD Dept. Agriculture
- SD Dept. Game Fish & Parks
- SD Dept. of Health
- MN Minnesota Pollution Control Agency
- MN Dept. Natural Resources

Water Development Districts

- East Dakota Water Development District
- James River Water Development District
- West Dakota Water Development District
- West River Water Development District
- Central Plains Water Development District
- South Central Water Development District
- Vermillion Water Development District

Other Groups

- SD Assoc. Conservation Districts
- Trout Unlimited
- Nature Conservancy
- SD Wildlife Federation

MS4 Facilities

- City of Sioux Falls
- City of Vermillion
- City of Pierre
- City of Brookings
- Pennington County
- City of Mitchell
- City of Sturgis
- City of Rapid City

- City of Aberdeen
- City of Watertown
- SD Dept. of Transportation
- City of North Sioux City
- City of Huron
- City of Yankton
- City of Spearfish
- Meade County

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Appendices

Appendix A. SDSM&T Mercury Sampling Procedure

- All operations involving contact with a sample bottle should be performed wearing clean, non-talc laboratory gloves, and these gloves should be changed whenever anything not known to be "trace-metal clean" is touched.
- Sampling dates, times, and notes should be documented in the sampler notebook

1. Sampling Instructions:
2. Unlock sampler and open door.
3. Turn power off using light switch (note power indicator light).
4. Put on clean laboratory gloves.
5. Rinse the funnel with provided rinse water (~ 100mL), using enough water to sufficiently wet the funnel and inside of thistle tube (located below the funnel)
6. Unstrap the sample bottle with black Velcro strap.
7. Remove sample bottle by first softly lifting upwards on the thistle tube and then lift the sample bottle out.
8. Cap the sample bottle using the original cap from the previous month stored in its plastic bag.
9. Place the sample bottle in the previous month's plastic bag, seal, and place in empty cooler for shipping.
10. Find the clean, empty, bagged bottle from the new cooler and open the bag, minimizing direct contact with the bottle.
11. Put on a new pair of laboratory gloves.
12. Be careful not to touch anything but sample bottle and its cap.
13. Remove sample bottle from plastic bag and place beneath the thistle tube by softly lifting up the tube and placing bulb in the bottleneck.
14. Do not place the bottle-cap on any surface while it is removed from the bottle.
15. Place the new bottle-cap in its plastic bag and seal. Place bagged cap in cooler and save for next month's sampling event.
16. Strap the new sample bottle in with black Velcro strap.
17. Gently raise the glass tube and place the bulb into the mouth of the new bottle
18. Make sure the bulb is a gentle but tight fit into the bottle mouth by gently wiggling the glass tube. If the bulb is loose then undo the three platform wing nuts and the bottom nuts until the bottle just makes firm contact with the bulb end of the tube. Retighten wing nuts and bottom nuts.
19. Turn power on using light switch (note power indicator light).
20. Close and lock the sampler by inserting the outside rod into the bottom catch then raise it to the top catch and secure it with the padlock through the top catch.
21. Ship the sample (in cooler provided) to Frontier Geosciences Laboratory using prepaid FedEx shipping labels provided. Contact FedEx for pickup at 1-800-463-3339.

Contact Info:
James Stone
Phone: 605-394-2443
Email: james.stone@sdsmt.edu
Frontier Geosciences:
Shipping Address:
Frontier Geosciences Inc.
414 Pontius Ave. North
Seattle, WA 98109
Phone: 206-622-6960
Fax: 206-622-6960

Email: info@frontiergeosciences.com

Appendix B. Mercury Deposition Results

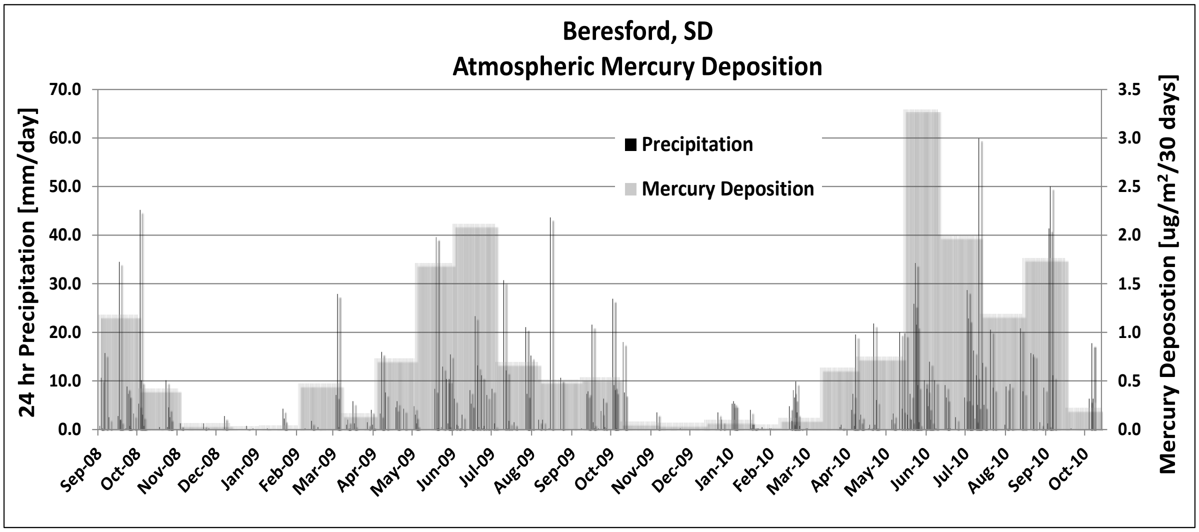

Figure 25. Atmospheric mercury deposition for Beresford, SD from September 2008 to October 2010.

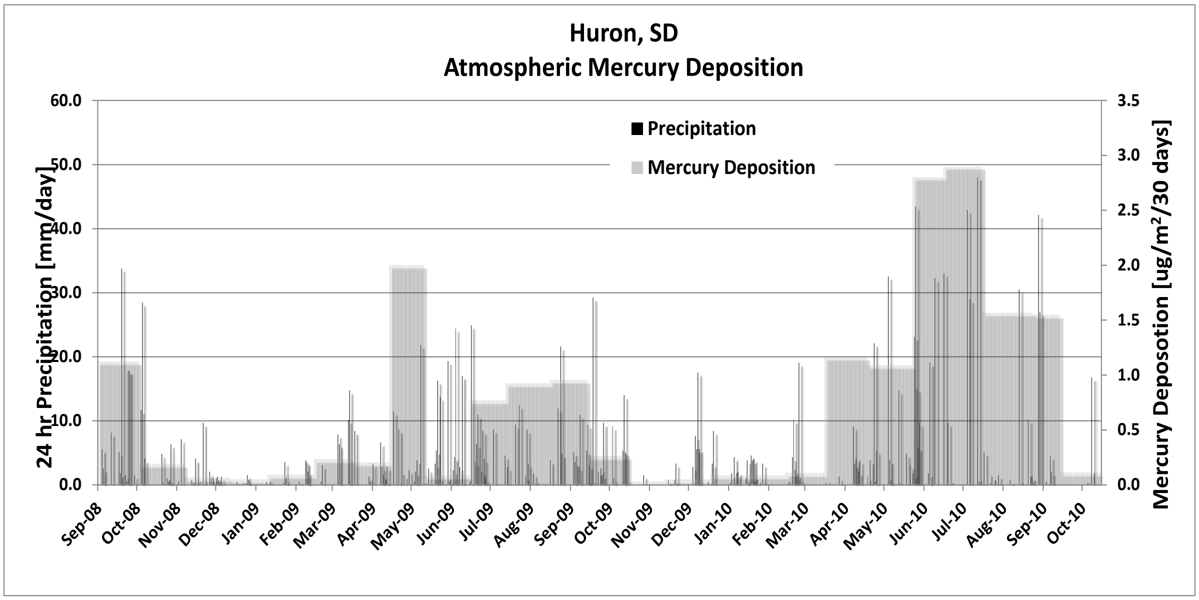

Figure 26. Atmospheric mercury deposition for Huron, SD from September 2008 to October 2010.

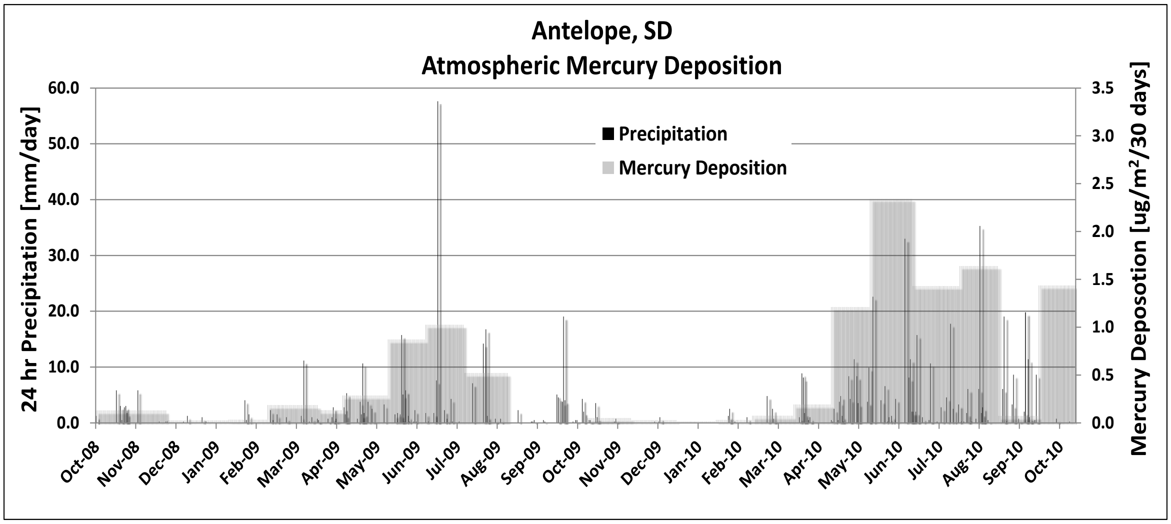

Figure 27. Atmospheric mercury deposition for Antelope Field Station, SD from October 2008 to October 2010.

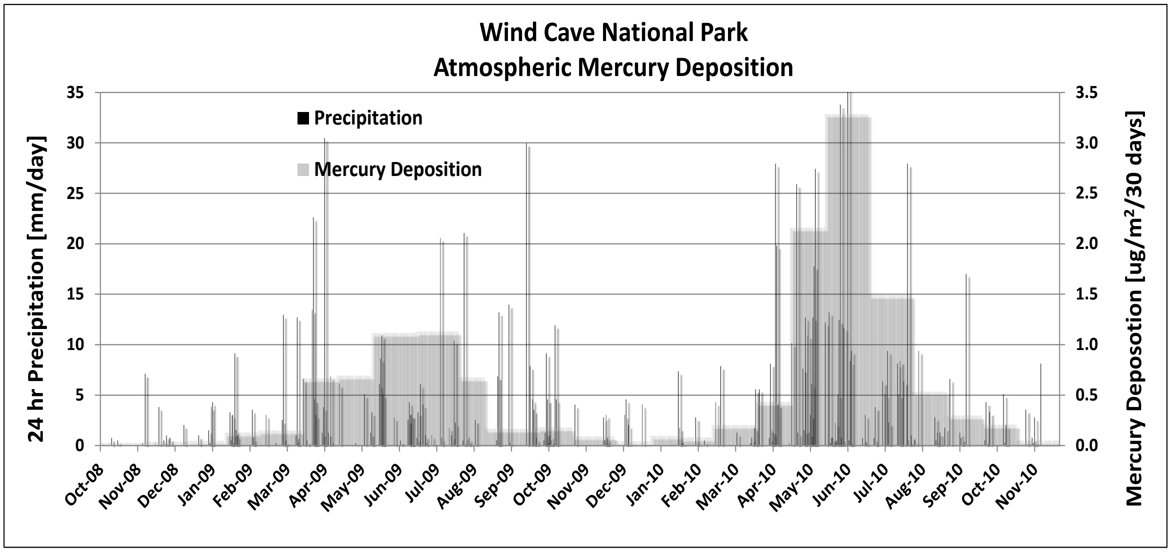

Figure 28. Atmospheric mercury deposition for Wind Cave National Park, SD from October 2008 to November 2010.

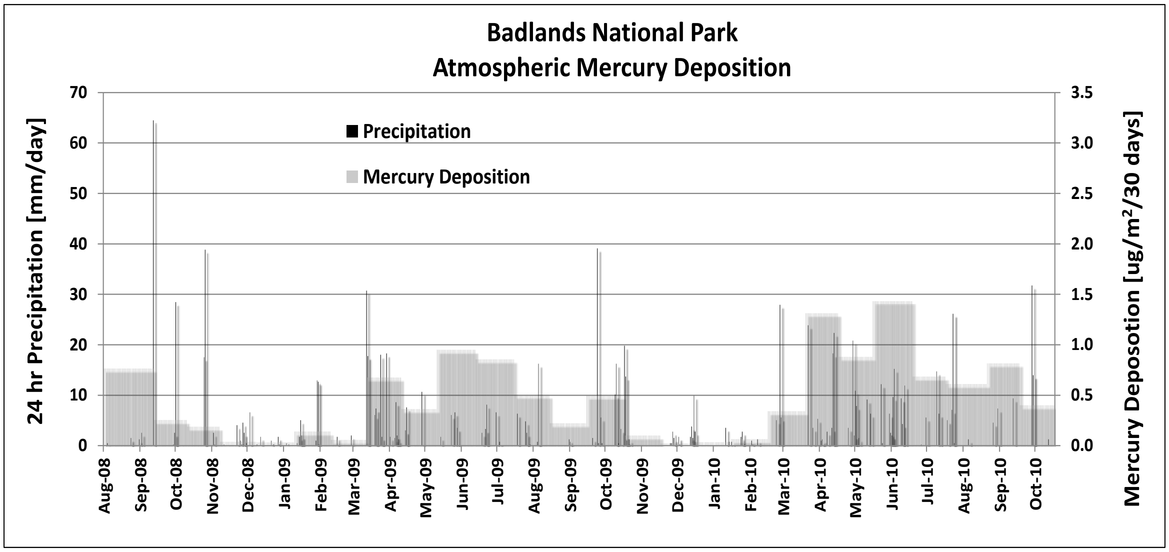

Figure 29. Atmospheric mercury deposition for Badlands National Park, SD from August 2008 to October 2010.

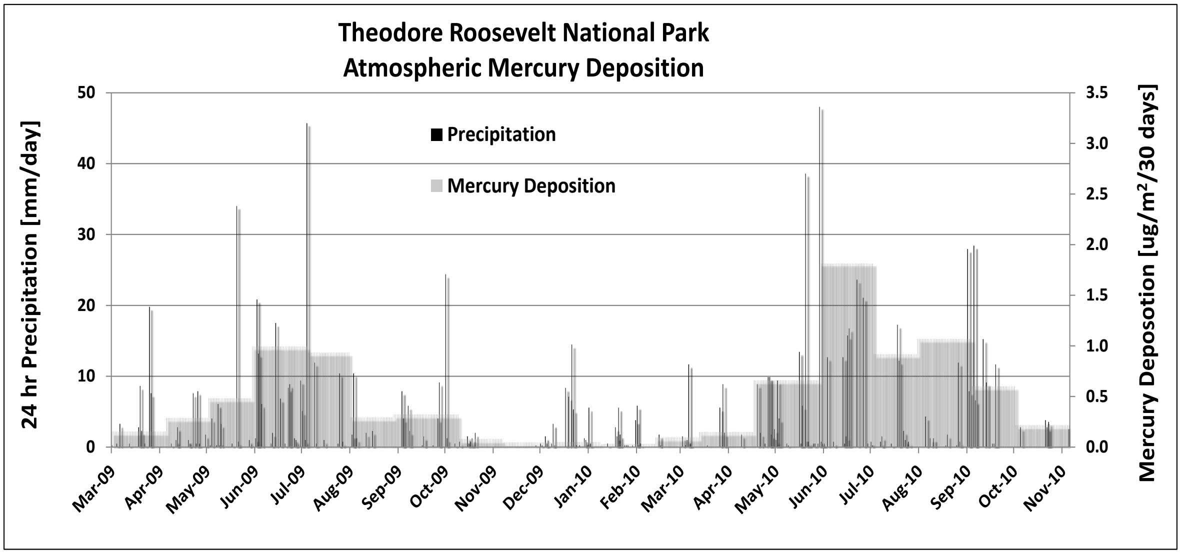

Figure 30. Atmospheric mercury deposition for Theodore Roosevelt National Park, ND from March 2009 to November 2010.

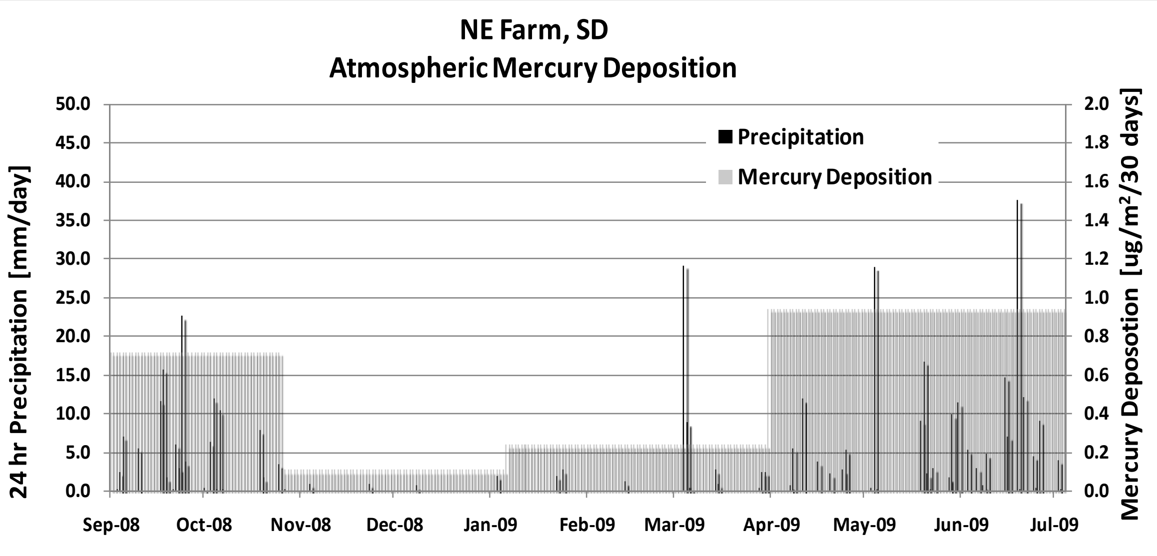

Figure 31. Atmospheric mercury deposition for NE Farm, SD from September 2008 to July 2009. No data collected after July 2009

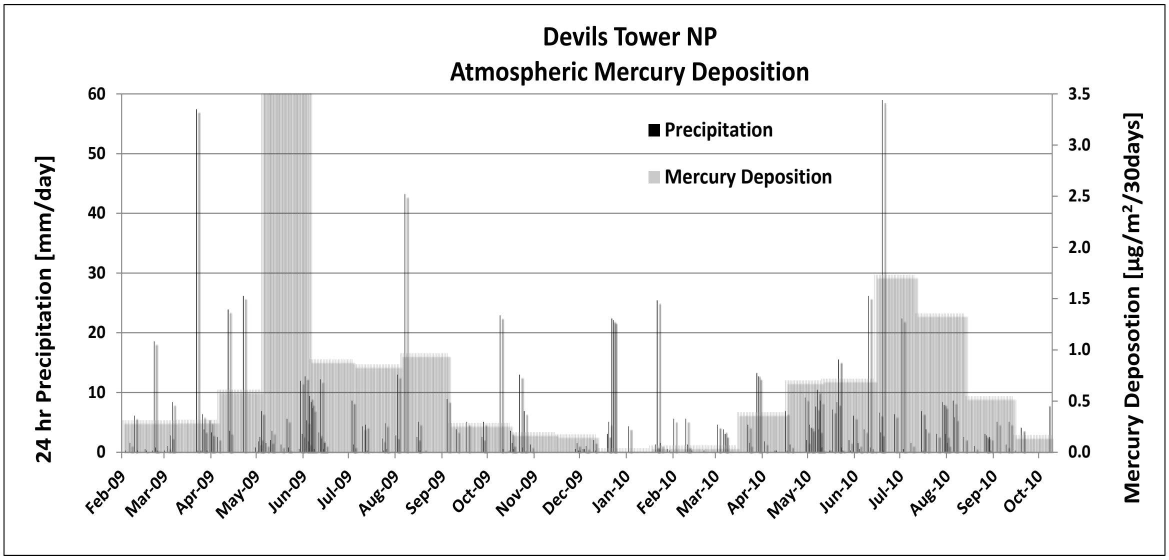

Figure 32. Atmospheric mercury deposition for Devils Tower National Park, WY from February 2009 to October 2010.

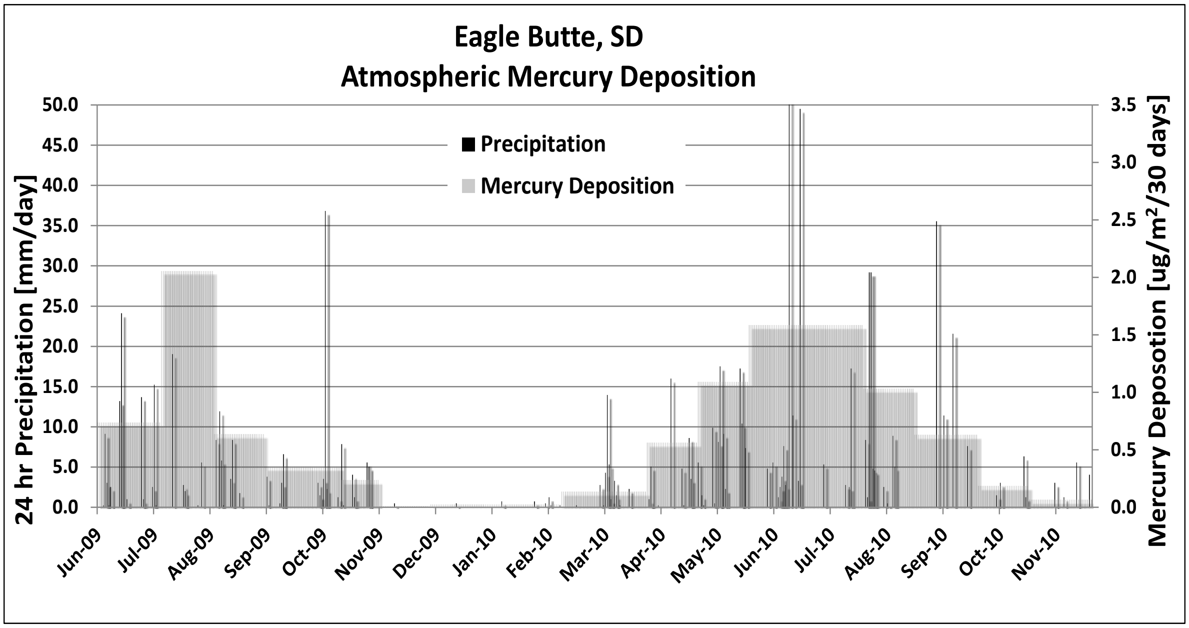

Figure 33. Atmospheric mercury deposition for Eagle Butte, SD from June 2009 to November 2010.

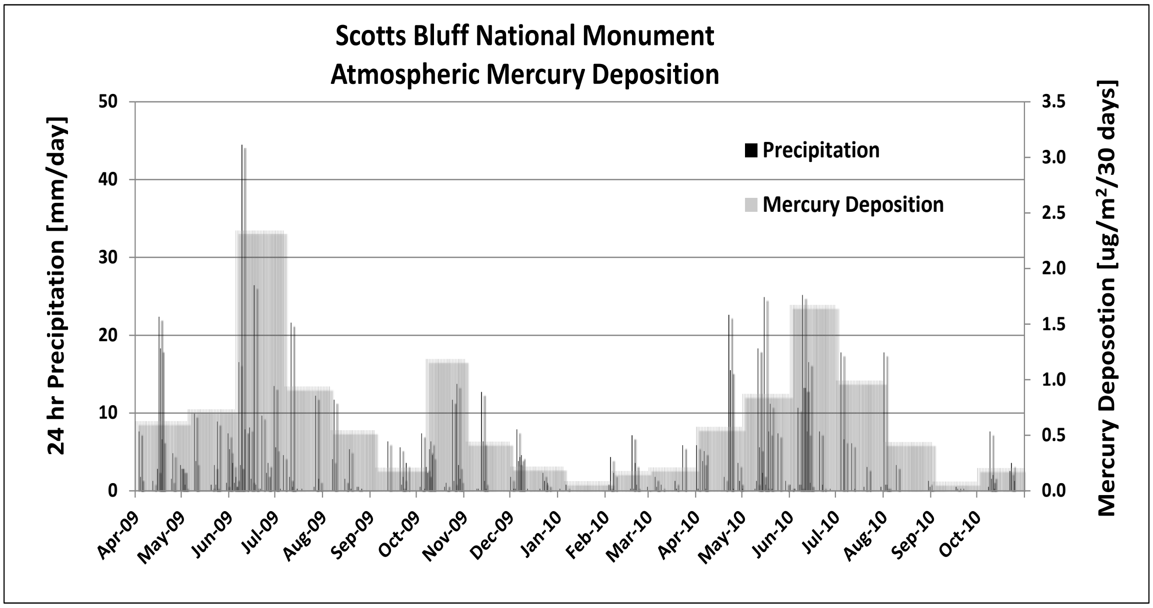

Figure 34. Atmospheric mercury deposition for Scotts Bluff National Monument, NE from April 2009 to November 2010.

Appendix C. Regression Equations for Walleye/Sauger

Equations based off of fish measured in mm and concentrations of total mercury reported as mg/Kg.

Site	Year	Species	equation	Statistics	Total Hg mg/Kg
Amsden Dam-Day	2011	Walleye/Sauger	y= -0.2901 + 0.0016*x	r = 0.8569, p = 0.0015; r2 = 0.7343	0.3243
Angostura Reservoir-Fall River	2014	Walleye/Sauger	y= -0.0588 + 0.0003*x	r = 0.6635, p = 0.0365; r2 = 0.4402	0.0564
Belle Fourche Reservoir-Butte	2006	Walleye/Sauger	y= -0.0011 + 0.0001*x	r = 0.8582, p = 0.0627; r2 = 0.7366	0.0373
Belle Fourche Reservoir-Butte	2011	Walleye/Sauger	y= -0.0588 + 0.0007*x	r = 0.4785, p = 0.1618; r2 = 0.2290	0.21
Big Sioux River-Moody	2012	Walleye/Sauger	y= -0.4347 + 0.0024*x	r = 0.8716, p = 0.1284; r2 = 0.7596	0.4869
Bitter Lake-Day	2000	Walleye/Sauger	y= -0.2358 + 0.0029*x	r = 0.8274, p = 0.0000; r2 = 0.6846	0.8778
Bitter Lake-Day	2001	Walleye/Sauger	y= -0.6972 + 0.0037*x	r = 0.8267, p = 0.00000; r2 = 0.6834	0.7236
Bitter Lake-Day	2003	Walleye/Sauger	y= -0.8929 + 0.0038*x	r = 0.8751, p = 0.0000; r2 = 0.7658	0.5663
Bitter Lake-Day	2005	Walleye/Sauger	y= -0.2317 + 0.002*x	r = 0.7675, p = 0.0000;r2 = 0.5891	0.5363
Bitter Lake-Day	2006	Walleye/Sauger	y= -0.5677 + 0.0027*x	r = 0.7964, p = 0.00000; r2 = 0.6342	0.4691
Bitter Lake-Day	2007	Walleye/Sauger	y= 0.4189 + 0.0006*x	r = 0.2885, p = 0.0030; r2 = 0.0833	0.6493
Bitter Lake-Day	2013	Walleye/Sauger	y= -1.2468 + 0.0047*x	r = 0.8906, p = 0.0005; r2 = 0.7932	0.558
Blue Dog Lake-Day	2011	Walleye/Sauger	y= 0.0328 + 0.0003*x	r = 0.4855, p = 0.1549; r2 = 0.2357	0.148
Bonham #2-Bon Homme	2003	Walleye/Sauger	y= 0.3222 + 0.0002*x	r = 0.0172, p = 0.9578; r2 = 0.0003	0.399
Bonham #4-Bon Homme	2003	Walleye/Sauger	y= -0.0263 + 0.0007*x	r = 0.5225, p = 0.0814; r2 = 0.2730	0.2425
Brant Lake-Lake	2012	Walleye/Sauger	y= -0.0322 + 0.0004*x	r = 0.7556, p = 0.1396; r2 = 0.5709	0.1214
Brush Lake-Brookings	2011	Walleye/Sauger	y= 0.294 + 0.0002*x	r = 0.1101, p = 0.8601; r2 = 0.0121	0.3708
Buffalo Lake, South-Marshall	2011	Walleye/Sauger	y= -0.1404 + 0.0014*x	r = 0.9285, p = 0.0001; r2 = 0.8622	0.3972
Cattail/Kettle Lake-Marshall	2006	Walleye/Sauger	y= -0.6421 + 0.002*x	r = 0.9302, p = 0.2393; r2 = 0.8653	0.1259
Cattail/Kettle Lake-Marshall	2012	Walleye/Sauger	y= -0.1732 + 0.0009*x	r = 0.8570, p = 0.0008; r2 = 0.7344	0.1724
Clear Lake-Deuel	2013	Walleye/Sauger	y= -0.2167 + 0.001*x	r = 0.8984, p = 0.00001; r2 = 0.8072	0.1673
Clear Lake-Hamlin	2014	Walleye/Sauger	y= -0.1926 + 0.001*x	r = 0.9649, p = 0.0000;r2 = 0.9311	0.1914
Cottonwood Lake-Spink	2013	Walleye/Sauger	y= -0.5874 + 0.0021*x	r = 0.9088, p = 0.00000; r2 = 0.8259	0.219
Cottonwood Lake-Sully	2012	Walleye/Sauger	y= 0.5166 + 0.0004*x	r = 0.2141, p = 0.5525; r2 = 0.0458	0.6702
Diamond Lake-Minnehaha	2008	Walleye/Sauger	y= -0.4735 + 0.0018*x	r = 0.9216, p = 0.00000; r2 = 0.8493	0.2177
Dry Lake # 2-Clark	2011	Walleye/Sauger	y= 0.2261 + 0.0012*x	r = 0.2340, p = 0.5153; r2 = 0.0547	0.6869
Dry Lake-Codington	2013	Walleye/Sauger	y= -0.2228 + 0.0009*x	r = 0.7867, p = 0.0069; r2 = 0.6190	0.1228
Elm Lake-Brown	2012	Walleye/Sauger	y= -0.3434 + 0.0023*x	r = 0.9793, p = 0.00000; r2 = 0.9590	0.5398
Enemy Swim Lake-Day	2005	Walleye/Sauger	y= -0.0253 + 0.0005*x	r = 0.3671, p = 0.0422; r2 = 0.1348	0.1667
Fourche lake-Butte	2004	Walleye/Sauger	y= 0.0282 + 9.8922E-5*x	r = 0.2508, p = 0.4846; r2 = 0.0629	0.06619
Goldsmith Lake-Brookings	2013	Walleye/Sauger	y= -0.04 + 0.0006*x	r = 0.3212, p = 0.1174;r2 = 0.1032	0.1904
Goose Lake-Codington	2013	Walleye/Sauger	y= -0.4418 + 0.0026*x	r = 0.7722, p = 0.0002; r2 = 0.5963	0.5566
Gross Lake-McCook	2004	Walleye/Sauger	y= 0.0439 - 1.2841E-6*x	r = -0.0132, p = 0.9660; r2 = 0.0002	0.04341
Hazeldon Lake-Day	2014	Walleye/Sauger	y= -0.8112 + 0.0034*x	r = 0.9493, p = 0.00000; r2 = 0.9011	0.4944
Horseshoe Lake-Marshall	2004	Walleye/Sauger	y= 0.0994 + 0.0002*x	r = 0.2555, p = 0.3779; r2 = 0.0653	0.1762
Horseshoe Lake-Marshall	2011	Walleye/Sauger	y= -0.0667 + 0.0017*x	r = 0.8409, p = 0.0023; r2 = 0.7071	0.5861

Island Lake-Minnehaha	2005	Walleye/Sauger	y= -0.6545 + 0.0028*x	r = 0.8095, p = 0.0969; r2 = 0.6553	0.4207
Island Lake-Minnehaha	2006	Walleye/Sauger	y= 0.2132 + 0.0013*x	r = 0.4502, p = 0.1062; r2 = 0.2027	0.7124
Island Lake-Minnehaha	2012	Walleye/Sauger	y= -0.377 + 0.0023*x	r = 0.5002, p = 0.1409; r2 = 0.2502	0.5062
James River-Beadle	2013	Walleye/Sauger	y= 0.0687 + 0.0012*x	r = 0.3427, p = 0.3324;r2 = 0.1174	0.5295
Lake Albert-Kingsbury	2014	Walleye/Sauger	y= -0.2581 + 0.0015*x	r = 0.8048, p = 0.0009; r2 = 0.6477	0.3179
Lake Alice-Deuel	2013	Walleye/Sauger	y= -0.8291 + 0.0024*x	r = 0.9527, p = 0.00002; r2 = 0.9077	0.0925
Lake Byron-Beadle	2005	Walleye/Sauger	y= 0.1989 - 2.3155E-5*	r = -0.0741, p = 0.4354; r2 = 0.0055	0.19001
Lake Byron-Beadle	2011	Walleye/Sauger	y= 0.0591 - 1.0721E-5*x	r = -0.0327, p = 0.9285; r2 = 0.0011	0.05498
Lake Henry-Kingsbury	2014	Walleye/Sauger	y= -0.4531 + 0.0017*x	r = 0.8921, p = 0.00001; r2 = 0.7958	0.1997
Lake Kampeska-Codington	2005	Walleye/Sauger	y= -0.0593 + 0.0006*x	r = 0.8696, p = 0.00000; r2 = 0.7561	0.1711
Lake Kampeska-Codington	2014	Walleye/Sauger	y= -0.2988 + 0.0014*x	r = 0.9592, p = 0.00001; r2 = 0.9200	0.2388
Lake Minnewasta-Day	2012	Walleye/Sauger	y= -3.7539 + 0.0094*x	r = 0.6373, p = 0.2475; r2 = 0.4061	-0.1443
Lake Minnewasta-Day	2013	Walleye/Sauger	y= -0.2751 + 0.0015*x	r = 0.7967, p = 0.0102; r2 = 0.6348	0.3009
Lake Oahe (Grand River Embayment)-Corson	2001	Walleye/Sauger	y= -0.2818 + 0.0013*x	r = 0.7763, p = 0.0000; r2 = 0.6027	0.2174
Lake Oahe (Grand River Embayment)-Corson	2010	Walleye/Sauger	y= 0.215 + 0.0004*x	r = 0.4089, p = 0.1302; r2 = 0.1672	0.3686
Lake Oahe (Minneconjou Bay)-Stanley	2001	Walleye/Sauger	y= -0.614 + 0.0024*x	r = 0.8785, p = 0.0000; r2 = 0.7718	0.3076
Lake Oahe (Minneconjou Bay)-Stanley	2002	Walleye/Sauger	y= -1.6303 + 0.0042*x	r = 0.8244, p = 0.0860; r2 = 0.6797	-0.0175
Lake Oahe (Minneconjou Bay)-Stanley	2007	Walleye/Sauger	y= -0.0513 + 0.0004*x	r = 0.9937, p = 0.0006; r2 = 0.9873	0.1023
Lake Oahe (Minneconjou Bay)-Stanley	2010	Walleye/Sauger	y= 0.176 + 0.0003*x	r = 0.3739, p = 0.1698; r2 = 0.1398	0.2912
Lake Oahe (Moreau River Embayment)-Dewey	2001	Walleye/Sauger	y= -0.0157 + 0.0007*x	r = 0.5704, p = 0.00004; r2 = 0.3253	0.2531
Lake Oahe (Moreau River Embayment)-Dewey	2011	Walleye/Sauger	y= -0.1757 + 0.0012*x	r = 0.8357, p = 0.0026; r2 = 0.6984	0.2851
Lake Oahe (West Whitlock)-Potter	2002	Walleye/Sauger	y= -0.911 + 0.0025*x	r = 0.9637, p = 0.0020; r2 = 0.9287	0.049
Lake Oahe (West Whitlock)-Potter	2007	Walleye/Sauger	y= -0.0694 + 0.0004*x	r = 0.9567, p = 0.00001; r2 = 0.9153	0.0842
Lake Oahe (West Whitlock)-Potter	2010	Walleye/Sauger	y= 0.3053 + 7.1704E-5*x	r = 0.0623, p = 0.8255; r2 = 0.0039	0.33283
Lake Oakwood-Brookings	2013	Walleye/Sauger	y= -0.3433 + 0.0008*x	r = 0.8780, p = 0.0041; r2 = 0.7709	-0.0361
Lake Poinsett-Hamlin	2011	Walleye/Sauger	y= -0.0176 + 0.0008*x	r = 0.2675, p = 0.4550; r2 = 0.0716	0.2896
Lake Poinsett-Hamlin	2014	Walleye/Sauger	y= -0.1263 + 0.0012*x	r = 0.7244, p = 0.0178; r2 = 0.5247	0.3345
Lake Sharpe (Joe Creek Area)-Hughes/Lyman	1999	Walleye/Sauger	y= -0.4268 + 0.0012*x	r = 0.6255, p = 0.0531; r2 = 0.3913	0.034
Lake Sinai-Brookings	2012	Walleye/Sauger	y= -0.4874 + 0.002*x	r = 0.8225, p = 0.0035; r2 = 0.6766	0.2806
Lake Thompson-Kingsbury	2012	Walleye/Sauger	y= 0.0259 + 0.0006*x	r = 0.5901, p = 0.0725; r2 = 0.3483	0.2563
Lardy Lake-Day	2013	Walleye/Sauger	y= -0.6018 + 0.0024*x	r = 0.9256, p = 0.00000; r2 = 0.8568	0.3198
Lily GPA-Day	2012	Walleye/Sauger	y= 0.0607 + 0.0008*x	r = 0.2159, p = 0.7272; r2 = 0.0466	0.3679
Lindroth Lake-Day	2004	Walleye/Sauger	y= -0.014 + 0.0003*x	r = 0.7097, p = 0.0097; r2 = 0.5037	0.1012
Long Lake-Codington	2013	Walleye/Sauger	y= -0.7772 + 0.0035*x	r = 0.9044, p = 0.00000; r2 = 0.8179	0.5668
Lynn Lake-Day	2002	Walleye/Sauger	y= -0.1619 + 0.0022*x	r = 0.8852, p = 0.0000; r2 = 0.7836	0.6829
Lynn Lake-Day	2003	Walleye/Sauger	y= 0.1691 + 0.0009*x	r = 0.5445, p = 0.0001; r2 = 0.2965	0.5147
Lynn Lake-Day	2005	Walleye/Sauger	y= -0.4486 + 0.0019*x	r = 0.9064, p = 0.00000; r2 = 0.8215	0.281
Lynn Lake-Day	2014	Walleye/Sauger	y= -0.8362 + 0.0035*x	r = 0.8864, p = 0.0006; r2 = 0.7856	0.5078
Lyons Lake-McCook	2003	Walleye/Sauger	y= 0.0303 + 4.5759E-5*x	r = 0.1495, p = 0.6428; r2 = 0.0224	0.04787
Middle Lynn Lake-Day	2012	Walleye/Sauger	y= -0.4242 + 0.0025*x	r = 0.8219, p = 0.0878; r2 = 0.6756	0.5358

Middle Lynn Lake-Day	2013	Walleye/Sauger	y= -0.4552 + 0.0028*x	r = 0.9230, p = 0.0001; r2 = 0.8520	0.62
Newell Lake-Butte	2004	Walleye/Sauger	y= -1.8882 + 0.0061*x	r = 0.7666, p = 0.0265; r2 = 0.5877	0.4542
North Twin Lake-Minnehaha	2008	Walleye/Sauger	y= -0.5915 + 0.0036*x	r = 0.8388, p = 0.00009; r2 = 0.7036	0.7909
Opitz Lake-Day	2011	Walleye/Sauger	y= 0.3706 + 0.0002*x	r = 0.1223, p = 0.7364; r2 = 0.0150	0.4474
Pelican Lake-Codington	2005	Walleye/Sauger	y= -0.0809 + 0.0004*x	r = 0.5847, p = 0.0000; r2 = 0.3419	0.0727
Reid Lake-Clark	2011	Walleye/Sauger	y= -0.296 + 0.0021*x	r = 0.7962, p = 0.0059; r2 = 0.6339	0.5104
Roy Lake-Marshall	2005	Walleye/Sauger	y= 0.0788 + 6.4988E-5*x	r = 0.1869, p = 0.4050; r2 = 0.0349	0.10376
Rush Lake-Day	2011	Walleye/Sauger	y= -0.7311 + 0.0022*x	r = 0.8733, p = 0.0010; r2 = 0.7626	0.1137
Simonson/Traunter-Day	2004	Walleye/Sauger	y= 0.0126 + 0.0003*x	r = 0.5210, p = 0.0824; r2 = 0.2715	0.1278
South Red Iron Lake-Marshall	2005	Walleye/Sauger	y= -0.3291 + 0.001*x	r = 0.9122, p = 0.0308; r2 = 0.8321	0.0549
South Twin Lake-Minnehaha	2008	Walleye/Sauger	y= -0.3294 + 0.0026*x	r = 0.8745, p = 0.00002; r2 = 0.7647	0.669
Stink Lake-Marshall	2004	Walleye/Sauger	y= 0.0688 + 1.8719E-5*x	r = 0.0791, p = 0.7881; r2 = 0.0063	0.07599
Summit Lake-Grant	2006	Walleye/Sauger	y= -1.0928 + 0.0027*x	r = 0.8985, p = 0.0382; r2 = 0.8072	-0.056
Summit Lake-Grant	2014	Walleye/Sauger	y= -0.3187 + 0.0013*x	r = 0.9787, p = 0.0000; r2 = 0.9579	0.1805
Swan Lake-Clark	2013	Walleye/Sauger	y= -0.8783 + 0.0033*x	r = 0.8873, p = 0.0006; r2 = 0.7873	0.3889
Twin Lakes/Hwy 81-Kingsbury	2011	Walleye/Sauger	y= -0.691 + 0.0026*x	r = 0.9338, p = 0.00000; r2 = 0.8720	0.3074
Vermillion Lake-McCook	2012	Walleye/Sauger	y= -0.1216 + 0.0013*x	r = 0.4243, p = 0.0552; r2 = 0.1801	0.3776
W 81/Twin Lakes-Kingsbury	2003	Walleye/Sauger	y= -0.5026 + 0.0032*x	r = 0.8823, p = 0.0000; r2 = 0.7785	0.7262
W 81/Twin Lakes-Kingsbury	2005	Walleye/Sauger	y= -0.7742 + 0.0039*x	r = 0.7604, p = 0.0000; r2 = 0.5782	0.7234
Waubay Lake-Day	2000	Walleye/Sauger	y= -0.0071 + 0.0011*x	r = 0.6606, p = 0.00000; r2 = 0.4364	0.4153
Waubay Lake-Day	2001	Walleye/Sauger	y= -0.1694 + 0.0013*x	r = 0.8958, p = 0.0000; r2 = 0.8025	0.3298
Waubay Lake-Day	2008	Walleye/Sauger	y= -0.0736 + 0.0006*x	r = 0.8713, p = 0.00002; r2 = 0.7591	0.1568
Waubay Lake-Day	2011	Walleye/Sauger	y= 0.0032 + 0.0003*x	r = 0.3211, p = 0.3656; r2 = 0.1031	0.1184
Waubay Lake-Day	2014	Walleye/Sauger	y= -0.5275 + 0.002*x	r = 0.8247, p = 0.0002; r2 = 0.6802	0.2405
Whitewood Lake-Kingsbury	2011	Walleye/Sauger	y= -0.0679 + 0.0008*x	r = 0.5936, p = 0.2913; r2 = 0.3523	0.2393

Appendix D. Individual Fish Mercury Data Summary

AUID	Species	Year	Valid N	Mean	Minimum	Maximum	80th Percentile
SD-BF-L-ORMAN_01	Channel Catfish	1994	1	0.180	0.180	0.180	0.180
SD-BF-L-ORMAN_01	Walleye	1994	1	0.200	0.200	0.200	0.200
SD-BF-L-ORMAN_01	White Bass	1994	1	0.230	0.230	0.230	0.230
SD-BF-L-ORMAN_01	Yellow Perch	1994	1	0.110	0.110	0.110	0.110
SD-BS-L-KAMPESKA_01	Black Crappie	1994	1	0.090	0.090	0.090	0.090
SD-BS-L-KAMPESKA_01	Walleye	1994	1	0.300	0.300	0.300	0.300
SD-BS-L-KAMPESKA_01	White Bass	1994	1	0.510	0.510	0.510	0.510
SD-BS-L-KAMPESKA_01	White Sucker	1994	1	0.090	0.090	0.090	0.090
SD-BS-L-MADISON_01	Bigmouth Buffalo	1994	1	0.070	0.070	0.070	0.070
SD-BS-L-MADISON_01	Common Carp	1994	1	0.050	0.050	0.050	0.050
SD-BS-L-MADISON_01	Northern Pike	1994	1	0.220	0.220	0.220	0.220
SD-BS-L-MADISON_01	Walleye	1994	1	0.200	0.200	0.200	0.200
SD-BS-L-PICKEREL_01	Rock Bass	1994	1	0.180	0.180	0.180	0.180
SD-BS-L-PICKEREL_01	Walleye	1994	1	0.170	0.170	0.170	0.170
SD-BS-L-PICKEREL_01	White Sucker	1994	1	0.120	0.120	0.120	0.120
SD-BS-L-PICKEREL_01	Yellow Perch	1994	1	0.160	0.160	0.160	0.160
SD-CH-L-ANGOSTURA_01	Black Crappie	1994	1	0.090	0.090	0.090	0.090
SD-CH-L-ANGOSTURA_01	Channel Catfish	1994	1	0.160	0.160	0.160	0.160
SD-CH-L-ANGOSTURA_01	Common Carp	1994	1	0.090	0.090	0.090	0.090
SD-CH-L-ANGOSTURA_01	Walleye	1994	1	0.160	0.160	0.160	0.160
SD-CH-L-PACTOLA_01	Brown Trout	1994	1	0.110	0.110	0.110	0.110
SD-CH-L-PACTOLA_01	Largemouth Bass	1994	1	0.140	0.140	0.140	0.140
SD-CH-L-PACTOLA_01	Rainbow Trout	1994	1	0.070	0.070	0.070	0.070
SD-CH-L-PACTOLA_01	Rock Bass	1994	1	0.130	0.130	0.130	0.130
SD-CH-L-PACTOLA_01	White Sucker	1994	1	0.060	0.060	0.060	0.060
SD-GR-L-SHADEHILL_01	Channel Catfish	1994	1	0.130	0.130	0.130	0.130
SD-GR-L-SHADEHILL_01	Common Carp	1994	1	0.250	0.250	0.250	0.250
SD-GR-L-SHADEHILL_01	Walleye	1994	1	0.290	0.290	0.290	0.290
SD-GR-L-SHADEHILL_01	Yellow Perch	1994	1	0.130	0.130	0.130	0.130
SD-JA-L-CLEAR_M_01	Northern Pike	1994	1	0.120	0.120	0.120	0.120
SD-JA-L-CLEAR_M_01	Walleye	1994	1	0.150	0.150	0.150	0.150
SD-JA-L-CLEAR_M_01	White Sucker	1994	1	0.060	0.060	0.060	0.060
SD-JA-L-CLEAR_M_01	Yellow Perch	1994	1	0.080	0.080	0.080	0.080
SD-JA-L-MITCHELL_01	Black Crappie	1994	1	0.090	0.090	0.090	0.090
SD-JA-L-MITCHELL_01	Bluegill	1994	1	0.190	0.190	0.190	0.190
SD-JA-L-MITCHELL_01	Common Carp	1994	1	0.120	0.120	0.120	0.120
SD-JA-L-MITCHELL_01	Walleye	1994	1	0.180	0.180	0.180	0.180
SD-VM-L-THOMPSON_01	Black Crappie	1994	1	0.300	0.300	0.300	0.300
SD-VM-L-THOMPSON_01	Common Carp	1994	1	0.100	0.100	0.100	0.100
SD-VM-L-THOMPSON_01	Walleye	1994	1	0.420	0.420	0.420	0.420
SD-BF-R-SPEARFISH_05	Brook Trout	1996	5	0.050	0.050	0.050	0.050
SD-BF-R-SPEARFISH_05	Brown Trout	1996	5	0.080	0.080	0.080	0.080
SD-BS-L-BLUE_DOG_01	Northern Pike	1996	5	0.180	0.180	0.180	0.180
SD-BS-L-BLUE_DOG_01	Walleye	1996	10	0.115	0.110	0.120	0.120
SD-BS-L-BLUE_DOG_01	White Bass	1996	5	0.070	0.070	0.070	0.070
SD-BS-L-BLUE_DOG_01	White Sucker	1996	5	0.220	0.220	0.220	0.220
SD-BS-L-ENEMY_SWIM_01	Black Bullhead	1996	5	0.170	0.170	0.170	0.170
SD-BS-L-ENEMY_SWIM_01	Black Crappie	1996	5	0.050	0.050	0.050	0.050
SD-BS-L-ENEMY_SWIM_01	Bluegill	1996	6	0.062	0.060	0.070	0.060
SD-BS-L-ENEMY_SWIM_01	Rock Bass	1996	5	0.130	0.130	0.130	0.130
SD-BS-L-HERMAN_01	Black Bullhead	1996	5	0.080	0.080	0.080	0.080
SD-BS-L-HERMAN_01	Black Crappie	1996	5	0.070	0.070	0.070	0.070
SD-BS-L-HERMAN_01	Northern Pike	1996	5	0.100	0.100	0.100	0.100

SD-BS-L-HERMAN_01	Yellow Perch	1996	5	0.060	0.060	0.060	0.060
SD-BS-L-SINAI_01	Black Bullhead	1996	5	0.230	0.230	0.230	0.230
SD-BS-L-SINAI_01	Common Carp	1996	4	0.090	0.090	0.090	0.090
SD-BS-L-SINAI_01	Walleye	1996	10	0.425	0.420	0.430	0.430
SD-BS-L-SINAI_01	Yellow Perch	1996	5	0.210	0.210	0.210	0.210
SD-JA-L-ELM_01	Black Bullhead	1996	4	0.180	0.180	0.180	0.180
SD-JA-L-ELM_01	Black Crappie	1996	8	0.180	0.180	0.180	0.180
SD-JA-L-ELM_01	Walleye	1996	4	0.280	0.280	0.280	0.280
SD-JA-L-ELM_01	Yellow Perch	1996	4	0.150	0.150	0.150	0.150
SD-MI-R-FRANCIS_CASE_01	Channel Catfish	1996	15	0.070	0.060	0.080	0.080
SD-MI-R-FRANCIS_CASE_01	Common Carp	1996	15	0.147	0.130	0.180	0.180
SD-MI-R-FRANCIS_CASE_01	Smallmouth Bass	1996	15	0.087	0.060	0.100	0.100
SD-MI-R-FRANCIS_CASE_01	Walleye	1996	30	0.090	0.070	0.110	0.100
SD-VM-L-E_VERMILLION_01	Black Bullhead	1996	5	0.120	0.120	0.120	0.120
SD-VM-L-E_VERMILLION_01	Black Crappie	1996	5	0.110	0.110	0.110	0.110
SD-VM-L-E_VERMILLION_01	Bluegill	1996	5	0.130	0.130	0.130	0.130
SD-VM-L-E_VERMILLION_01	Northern Pike	1996	5	0.380	0.380	0.380	0.380
NoAUID-FFWhitewoodCr-SDDOH	Brown Trout	1997	15	0.067	0.060	0.070	0.070
NoAUID-FFWhitewoodCr-SDDOH	Mountain Sucker	1997	5	0.030	0.030	0.030	0.030
SD-BF-R-BEAR_BUTTE_01	Brook Trout	1997	10	0.045	0.040	0.050	0.050
SD-BF-R-BEAR_BUTTE_01	Longnose Dace	1997	5	0.060	0.060	0.060	0.060
SD-BF-R-BEAR_BUTTE_01	Mountain Sucker	1997	5	0.030	0.030	0.030	0.030
SD-BF-R-BEAR_BUTTE_01	White Sucker	1997	5	0.030	0.030	0.030	0.030
SD-BF-R-BELLE_FOURCHE_03	Common Carp	1997	5	0.200	0.200	0.200	0.200
SD-BF-R-BELLE_FOURCHE_03	Largemouth Bass	1997	10	0.285	0.270	0.300	0.300
SD-BF-R-BELLE_FOURCHE_03	Shorthead Redhorse	1997	5	0.100	0.100	0.100	0.100
SD-BF-R-BELLE_FOURCHE_03	White Sucker	1997	5	0.150	0.150	0.150	0.150
SD-BS-L-POINSETT_01	Black Bullhead	1997	5	0.080	0.080	0.080	0.080
SD-BS-L-POINSETT_01	Northern Pike	1997	1	0.200	0.200	0.200	0.200
SD-BS-L-POINSETT_01	Smallmouth Bass	1997	5	0.150	0.150	0.150	0.150
SD-BS-L-POINSETT_01	Walleye	1997	10	0.095	0.090	0.100	0.100
SD-BS-L-POINSETT_01	Yellow Perch	1997	5	0.040	0.040	0.040	0.040
SD-BS-R-BIG_SIOUX_08	Channel Catfish	1997	5	0.150	0.150	0.150	0.150
SD-BS-R-BIG_SIOUX_08	Common Carp	1997	10	0.155	0.150	0.160	0.160
SD-BS-R-BIG_SIOUX_08	River Carpsucker	1997	5	0.270	0.270	0.270	0.270
SD-BS-R-BIG_SIOUX_08	Walleye	1997	4	0.250	0.250	0.250	0.250
SD-CH-R-CHEYENNE_02	Channel Catfish	1997	10	0.180	0.160	0.200	0.200
SD-CH-R-CHEYENNE_02	River Carpsucker	1997	5	0.130	0.130	0.130	0.130
SD-JA-R-JAMES_08	Black Bullhead	1997	5	0.170	0.170	0.170	0.170
SD-JA-R-JAMES_08	Channel Catfish	1997	5	0.140	0.140	0.140	0.140
SD-MI-R-OAHE_01	Channel Catfish	1997	20	0.198	0.140	0.320	0.225
SD-MI-R-OAHE_01	Common Carp	1997	10	0.220	0.220	0.220	0.220
SD-MI-R-OAHE_01	Goldeye	1997	5	0.096	0.080	0.110	0.105
SD-MI-R-OAHE_01	Walleye	1997	15	0.239	0.150	0.370	0.370
SD-MI-R-OAHE_01	White Bass	1997	15	0.268	0.100	0.630	0.380
SD-MI-R-OAHE_01	Yellow Perch	1997	10	0.075	0.070	0.080	0.080
SD-BS-L-BRANT_01	Black Bullhead	1998	2	0.075	0.030	0.120	0.120
SD-BS-L-BRANT_01	Black Crappie	1998	1	0.067	0.067	0.067	0.067
SD-BS-L-BRANT_01	Walleye	1998	1	0.180	0.180	0.180	0.180
SD-BS-L-BRANT_01	Yellow Perch	1998	1	0.069	0.069	0.069	0.069
SD-BS-L-E_OAKWOOD_01	Black Bullhead	1998	2	0.056	0.054	0.057	0.057
SD-BS-L-E_OAKWOOD_01	Common Carp	1998	1	0.019	0.019	0.019	0.019
SD-BS-L-E_OAKWOOD_01	Walleye	1998	1	0.069	0.069	0.069	0.069
SD-BS-L-E_OAKWOOD_01	Yellow Perch	1998	5	0.029	0.029	0.029	0.029
SD-BS-L-PELICAN_01	Northern Pike	1998	5	0.065	0.065	0.065	0.065
SD-BS-L-PELICAN_01	Walleye	1998	10	0.053	0.043	0.063	0.063

SD-BS-L-PELICAN_01	White Sucker	1998	5	0.028	0.028	0.028	0.028
SD-BS-L-PELICAN_01	Yellow Perch	1998	5	0.046	0.046	0.046	0.046
SD-BS-L-WALL_01	Black Bullhead	1998	2	0.090	0.079	0.100	0.100
SD-BS-L-WALL_01	Black Crappie	1998	1	0.130	0.130	0.130	0.130
SD-BS-L-WALL_01	White Sucker	1998	1	0.084	0.084	0.084	0.084
SD-BS-L-WALL_01	Yellow Perch	1998	1	0.190	0.190	0.190	0.190
SD-BS-L-WAUBAY_01	Northern Pike	1998	5	0.380	0.380	0.380	0.380
SD-BS-L-WAUBAY_01	Walleye	1998	10	0.400	0.360	0.440	0.440
SD-BS-L-WAUBAY_01	White Sucker	1998	1	0.130	0.130	0.130	0.130
SD-BS-L-WAUBAY_01	Yellow Perch	1998	5	0.043	0.043	0.043	0.043
SD-CH-L-DEERFIELD_01	Rainbow Trout	1998	10	0.068	0.068	0.068	0.068
SD-CH-L-DEERFIELD_01	Rock Bass	1998	5	0.061	0.061	0.061	0.061
SD-CH-L-DEERFIELD_01	Splake Trout	1998	5	0.057	0.057	0.057	0.057
SD-CH-L-DEERFIELD_01	White Sucker	1998	5	0.030	0.030	0.030	0.030
SD-CH-L-STOCKADE_01	Largemouth Bass	1998	5	0.140	0.140	0.140	0.140
SD-CH-L-STOCKADE_01	Northern Pike	1998	5	0.039	0.039	0.039	0.039
SD-CH-L-STOCKADE_01	White Sucker	1998	10	0.170	0.170	0.170	0.170
SD-CH-L-STOCKADE_01	Yellow Perch	1998	5	0.150	0.150	0.150	0.150
SD-JA-L-MINA_01	Black Bullhead	1998	1	0.100	0.100	0.100	0.100
SD-JA-L-MINA_01	Black Crappie	1998	10	0.200	0.190	0.210	0.210
SD-JA-L-MINA_01	Bluegill	1998	5	0.180	0.180	0.180	0.180
SD-JA-L-MINA_01	Yellow Perch	1998	5	0.120	0.120	0.120	0.120
SD-MI-L-BRAKKE_01	Black Bullhead	1998	1	0.058	0.058	0.058	0.058
SD-MI-L-BRAKKE_01	Bluegill	1998	5	0.210	0.210	0.210	0.210
SD-MI-L-BRAKKE_01	Walleye	1998	1	0.100	0.100	0.100	0.100
SD-MI-L-BRAKKE_01	Yellow Perch	1998	10	0.225	0.210	0.240	0.240
SD-MU-L-LITTLE_MOREAU_NO1_01	Black Bullhead	1998	1	0.170	0.170	0.170	0.170
SD-MU-L-LITTLE_MOREAU_NO1_01	Black Crappie	1998	5	0.270	0.270	0.270	0.270
SD-MU-L-LITTLE_MOREAU_NO1_01	Bluegill	1998	5	0.076	0.076	0.076	0.076
SD-MU-L-LITTLE_MOREAU_NO1_01	Yellow Perch	1998	10	0.053	0.053	0.053	0.053
SD-BS-L-ALVIN_01	Black Bullhead	1999	5	0.020	0.020	0.020	0.020
SD-BS-L-ALVIN_01	Bluegill	1999	5	0.000	0.000	0.000	0.000
SD-BS-L-ALVIN_01	White Crappie	1999	5	0.000	0.000	0.000	0.000
SD-BS-L-ALVIN_01	White Sucker	1999	5	0.000	0.000	0.000	0.000
SD-BS-L-BITTER_01	Northern Pike	1999	2	0.700	0.700	0.700	0.700
SD-BS-L-BITTER_01	Walleye	1999	5	1.100	1.100	1.100	1.100
SD-BS-L-BITTER_01	Yellow Perch	1999	5	0.520	0.520	0.520	0.520
SD-BS-L-WAUBAY_01	Black Crappie	1999	5	0.140	0.140	0.140	0.140
SD-BS-L-WAUBAY_01	Walleye	1999	5	0.210	0.210	0.210	0.210
SD-BS-L-WAUBAY_01	White Sucker	1999	5	0.000	0.000	0.000	0.000
SD-BS-L-WAUBAY_01	Yellow Perch	1999	5	0.250	0.250	0.250	0.250
SD-GR-L-ISABEL_01	Black Bullhead	1999	5	0.360	0.360	0.360	0.360
SD-GR-L-ISABEL_01	Black Crappie	1999	5	0.250	0.250	0.250	0.250
SD-GR-L-ISABEL_01	Bluegill	1999	6	0.368	0.360	0.410	0.360
SD-GR-L-ISABEL_01	Yellow Perch	1999	5	0.150	0.150	0.150	0.150
SD-JA-L-BYRON_01	Black Bullhead	1999	5	0.040	0.040	0.040	0.040
SD-JA-L-BYRON_01	Black Crappie	1999	5	0.080	0.080	0.080	0.080
SD-JA-L-BYRON_01	Northern Pike	1999	5	0.080	0.080	0.080	0.080
SD-JA-L-BYRON_01	White Sucker	1999	5	0.000	0.000	0.000	0.000
SD-JA-L-FAULKTON_01	Black Bullhead	1999	5	0.030	0.030	0.030	0.030
SD-JA-L-FAULKTON_01	Bluegill	1999	5	0.080	0.080	0.080	0.080
SD-JA-L-FAULKTON_01	Northern Pike	1999	5	0.340	0.340	0.340	0.340
SD-JA-L-FAULKTON_01	Yellow Perch	1999	5	0.190	0.190	0.190	0.190
SD-MI-L-COTTONWOOD_01	Black Bullhead	1999	5	0.110	0.110	0.110	0.110

SD-MI-L-COTTONWOOD_01	Black Crappie	1999	5	0.210	0.210	0.210	0.210
SD-MI-L-COTTONWOOD_01	Common Carp	1999	5	0.000	0.000	0.000	0.000
SD-MI-L-COTTONWOOD_01	Walleye	1999	6	0.330	0.080	0.380	0.380
SD-MI-R-SHARPE_01	Channel Catfish	1999	15	0.040	0.010	0.070	0.070
SD-MI-R-SHARPE_01	Common Carp	1999	10	0.075	0.050	0.100	0.100
SD-MI-R-SHARPE_01	River Carpsucker	1999	5	0.050	0.050	0.050	0.050
SD-MI-R-SHARPE_01	Sauger	1999	6	0.090	0.090	0.090	0.090
SD-MI-R-SHARPE_01	Smallmouth Bass	1999	5	0.020	0.020	0.020	0.020
SD-MI-R-SHARPE_01	Walleye	1999	21	0.058	0.000	0.220	0.110
SD-MI-R-SHARPE_01	White Bass	1999	5	0.070	0.070	0.070	0.070
SD-BS-L-ANTELOPE_01	Northern Pike	2000	5	0.400	0.400	0.400	0.400
SD-BS-L-ANTELOPE_01	Walleye	2000	2	0.415	0.410	0.420	0.420
SD-BS-L-ANTELOPE_01	Yellow Perch	2000	5	0.230	0.230	0.230	0.230
SD-BS-L-BITTER_01	Northern Pike	2000	35	0.794	0.540	1.130	0.980
SD-BS-L-BITTER_01	Walleye	2000	40	0.814	0.490	1.100	1.040
SD-BS-L-BITTER_01	Yellow Perch	2000	20	0.563	0.410	0.700	0.700
SD-BS-L-BLUE_DOG_01	Northern Pike	2000	5	0.260	0.260	0.260	0.260
SD-BS-L-BLUE_DOG_01	Walleye	2000	6	0.282	0.280	0.290	0.280
SD-BS-L-BLUE_DOG_01	White Bass	2000	5	0.200	0.200	0.200	0.200
SD-BS-L-BLUE_DOG_01	White Sucker	2000	5	0.100	0.100	0.100	0.100
SD-BS-L-CAMPBELL_01	Black Bullhead	2000	5	0.000	0.000	0.000	0.000
SD-BS-L-CAMPBELL_01	White Crappie	2000	5	0.000	0.000	0.000	0.000
SD-BS-L-CAMPBELL_01	White Sucker	2000	5	0.000	0.000	0.000	0.000
SD-BS-L-CAMPBELL_01	Yellow Perch	2000	5	0.040	0.040	0.040	0.040
SD-BS-L-DRY_01	Black Bullhead	2000	5	0.000	0.000	0.000	0.000
SD-BS-L-DRY_01	Northern Pike	2000	5	0.200	0.200	0.200	0.200
SD-BS-L-DRY_01	Walleye	2000	5	0.290	0.290	0.290	0.290
SD-BS-L-DRY_01	White Sucker	2000	5	0.000	0.000	0.000	0.000
SD-BS-L-DRY_01	Yellow Perch	2000	5	0.040	0.040	0.040	0.040
SD-BS-L-LONG_DAY_01	Northern Pike	2000	5	0.270	0.270	0.270	0.270
SD-BS-L-LONG_DAY_01	Walleye	2000	5	0.520	0.520	0.520	0.520
SD-BS-L-LONG_DAY_01	Yellow Perch	2000	5	0.260	0.260	0.260	0.260
SD-BS-L-RUSH_01	Black Bullhead	2000	5	0.050	0.050	0.050	0.050
SD-BS-L-RUSH_01	Northern Pike	2000	5	0.290	0.290	0.290	0.290
SD-BS-L-RUSH_01	Walleye	2000	5	0.280	0.280	0.280	0.280
SD-BS-L-RUSH_01	White Sucker	2000	5	0.050	0.050	0.050	0.050
SD-BS-L-RUSH_01	Yellow Perch	2000	5	0.160	0.160	0.160	0.160
SD-BS-L-SWAN_01	Black Bullhead	2000	5	0.010	0.010	0.010	0.010
SD-BS-L-SWAN_01	Walleye	2000	5	0.160	0.160	0.160	0.160
SD-BS-L-SWAN_01	Yellow Perch	2000	5	0.140	0.140	0.140	0.140
SD-BS-L-WAUBAY_01	Black Crappie	2000	5	0.120	0.120	0.120	0.120
SD-BS-L-WAUBAY_01	Northern Pike	2000	5	0.310	0.310	0.310	0.310
SD-BS-L-WAUBAY_01	Walleye	2000	55	0.484	0.270	0.630	0.590
SD-BS-L-WAUBAY_01	White Sucker	2000	5	0.000	0.000	0.000	0.000
SD-BS-L-WAUBAY_01	Yellow Perch	2000	5	0.260	0.260	0.260	0.260
SD-JA-L-CATTAIL_01	Northern Pike	2000	5	0.300	0.300	0.300	0.300
SD-JA-L-CATTAIL_01	Walleye	2000	5	0.250	0.250	0.250	0.250
SD-JA-L-CAVOUR_01	Black Bullhead	2000	5	0.030	0.030	0.030	0.030
SD-JA-L-CAVOUR_01	Black Crappie	2000	5	0.060	0.060	0.060	0.060
SD-JA-L-CAVOUR_01	Northern Pike	2000	5	0.320	0.320	0.320	0.320
SD-JA-L-CAVOUR_01	Yellow Perch	2000	5	0.180	0.180	0.180	0.180
NoAUID-FFMankeyS-SDDOH	Black Bullhead	2001	5	0.100	0.100	0.100	0.100
NoAUID-FFMankeyS-SDDOH	Yellow Perch	2001	5	0.180	0.180	0.180	0.180
SD-BS-L-BITTER_01	Northern Pike	2001	30	0.428	0.260	0.540	0.500
SD-BS-L-BITTER_01	Walleye	2001	30	0.787	0.490	1.040	1.020
SD-BS-L-BITTER_01	Yellow Perch	2001	10	0.695	0.660	0.730	0.730

SD-BS-L-DRY_#2_01	Black Bullhead	2001	5	0.120	0.120	0.120	0.120
SD-BS-L-DRY_#2_01	Northern Pike	2001	5	0.250	0.250	0.250	0.250
SD-BS-L-DRY_#2_01	Walleye	2001	5	0.240	0.240	0.240	0.240
SD-BS-L-KAMPESKA_01	White Bass	2001	20	0.423	0.220	0.560	0.560
SD-BS-L-REID_01	Black Bullhead	2001	5	0.140	0.140	0.140	0.140
SD-BS-L-REID_01	Walleye	2001	5	0.460	0.460	0.460	0.460
SD-BS-L-REID_01	Yellow Perch	2001	5	0.300	0.300	0.300	0.300
SD-BS-L-WAUBAY_01	Walleye	2001	45	0.347	0.160	0.620	0.600
SD-CH-R-CHEYENNE_02	Black Bullhead	2001	5	0.120	0.120	0.120	0.120
SD-CH-R-CHEYENNE_02	Bluegill	2001	5	0.030	0.030	0.030	0.030
SD-CH-R-CHEYENNE_02	River Carpsucker	2001	5	0.080	0.080	0.080	0.080
SD-CH-R-CHEYENNE_02	Smallmouth Bass	2001	5	0.050	0.050	0.050	0.050
SD-CH-R-CHEYENNE_04	Channel Catfish	2001	5	0.080	0.080	0.080	0.080
SD-CH-R-CHEYENNE_04	Goldeye	2001	5	0.190	0.190	0.190	0.190
SD-CH-R-CHEYENNE_04	Shorthead Redhorse	2001	5	0.180	0.180	0.180	0.180
SD-CH-R-RAPID_05	Channel Catfish	2001	5	0.140	0.140	0.140	0.140
SD-CH-R-RAPID_05	Goldeye	2001	5	0.180	0.180	0.180	0.180
SD-CH-R-RAPID_05	Shorthead Redhorse	2001	5	0.100	0.100	0.100	0.100
SD-JA-L-CARTHAGE_01	Black Bullhead	2001	5	0.030	0.030	0.030	0.030
SD-JA-L-CARTHAGE_01	Black Crappie	2001	5	0.090	0.090	0.090	0.090
SD-JA-L-CARTHAGE_01	Bluegill	2001	5	0.070	0.070	0.070	0.070
SD-JA-L-CARTHAGE_01	Largemouth Bass	2001	5	0.300	0.300	0.300	0.300
SD-JA-L-LYNN_01	Black Crappie	2001	5	0.330	0.330	0.330	0.330
SD-JA-L-LYNN_01	Bluegill	2001	5	0.150	0.150	0.150	0.150
SD-JA-L-LYNN_01	Saugeye	2001	5	0.660	0.660	0.660	0.660
SD-JA-L-REETZ_01	White Sucker	2001	5	0.120	0.120	0.120	0.120
SD-JA-L-REETZ_01	Yellow Perch	2001	5	0.260	0.260	0.260	0.260
SD-MI-R-LEWIS_AND_CLARK_01	Paddlefish	2001	1	0.000	0.000	0.000	0.000
SD-MI-R-OAHE_01	Channel Catfish	2001	127	0.192	0.070	0.420	0.270
SD-MI-R-OAHE_01	Walleye	2001	140	0.268	0.100	0.960	0.290
SD-MI-R-OAHE_01	White Bass	2001	35	0.350	0.240	0.460	0.440
NoAUID-FFLDimock-SDDOH	Black Bullhead	2002	5	0.070	0.070	0.070	0.070
NoAUID-FFLDimock-SDDOH	Black Crappie	2002	5	0.120	0.120	0.120	0.120
NoAUID-FFLDimock-SDDOH	Common Carp	2002	5	0.160	0.160	0.160	0.160
NoAUID-FFLDimock-SDDOH	White Crappie	2002	5	0.100	0.100	0.100	0.100
NoAUID-FFLDimock-SDDOH	Yellow Perch	2002	5	0.120	0.120	0.120	0.120
NoAUID-FFMcNenny-SDDOH	Brown Trout	2002	6	0.000	0.000	0.000	0.000
NoAUID-FFMcNenny-SDDOH	Rainbow Trout	2002	8	0.000	0.000	0.000	0.000
SD-BF-L-NEWELL_01	Bluegill	2002	5	0.330	0.330	0.330	0.330
SD-BF-L-NEWELL_01	Rudd	2002	5	0.050	0.050	0.050	0.050
SD-BF-L-NEWELL_01	Walleye	2002	5	0.360	0.360	0.360	0.360
SD-BF-L-NEWELL_01	White Sucker	2002	5	0.380	0.380	0.380	0.380
SD-BF-L-NEWELL_01	Yellow Perch	2002	5	0.560	0.560	0.560	0.560
SD-BS-L-TWIN_01	Black Bullhead	2002	5	0.300	0.300	0.300	0.300
SD-BS-L-TWIN_01	Northern Pike	2002	3	1.080	1.080	1.080	1.080
SD-BS-L-TWIN_01	Walleye	2002	5	0.540	0.540	0.540	0.540
SD-BS-L-TWIN_01	Yellow Bullhead	2002	5	0.190	0.190	0.190	0.190
SD-BS-L-TWIN_01	Yellow Perch	2002	5	0.300	0.300	0.300	0.300
SD-GR-L-ISABEL_01	Largemouth Bass	2002	20	0.765	0.600	1.120	1.120
SD-GR-L-ISABEL_01	Northern Pike	2002	9	0.872	0.600	1.190	1.190
SD-JA-L-LYNN_01	Walleye	2002	20	0.573	0.470	0.730	0.730
SD-JA-L-LYNN_01	Walleye/Saugeye	2002	21	0.898	0.860	0.950	0.940
SD-LM-R-LITTLE_MISSOURI_01	Sauger	2002	2	0.480	0.480	0.480	0.480
SD-MI-L-HURLEY_01	Black Crappie	2002	10	0.280	0.220	0.340	0.340
SD-MI-L-HURLEY_01	Bluegill	2002	5	0.300	0.300	0.300	0.300

SD-MI-L-HURLEY_01	Northern Pike	2002	10	0.630	0.620	0.640	0.640
SD-MI-L-HURLEY_01	Yellow Perch	2002	5	0.150	0.150	0.150	0.150
SD-MI-L-ROOSEVELT_01	Black Bullhead	2002	10	0.105	0.100	0.110	0.110
SD-MI-L-ROOSEVELT_01	Bluegill	2002	10	0.190	0.160	0.220	0.220
SD-MI-L-ROOSEVELT_01	Northern Pike	2002	5	0.660	0.660	0.660	0.660
SD-MI-L-TWIN_01	Bluegill	2002	9	0.120	0.080	0.170	0.170
SD-MI-L-TWIN_01	Yellow Perch	2002	10	0.125	0.120	0.130	0.130
SD-MI-R-OAHE_01	Channel Catfish	2002	13	0.274	0.160	0.700	0.340
SD-MI-R-OAHE_01	Freshwater Drum	2002	2	0.195	0.160	0.230	0.230
SD-MI-R-OAHE_01	Northern Pike	2002	2	0.355	0.220	0.490	0.490
SD-MI-R-OAHE_01	Walleye	2002	11	0.323	0.110	0.980	0.470
SD-MI-R-OAHE_01	White Bass	2002	7	0.381	0.240	0.450	0.430
SD-MU-L-LITTLE_MOREAU_NO1_01	Northern Pike	2002	15	0.700	0.580	0.940	0.940
NoAUID-Bonham#1-SDSU	Walleye	2003	12	0.171	0.031	0.401	0.225
NoAUID-FFBonham#2-SDSU	Walleye	2003	12	0.348	0.247	0.519	0.428
NoAUID-FFBonham#4-SDSU	Walleye	2003	12	0.080	0.025	0.119	0.103
NoAUID-FFCleghornSp-SDDOH	Rainbow Trout	2003	5	0.000	0.000	0.000	0.000
NoAUID-FFLyonsL-SDSU	Walleye	2003	12	0.040	0.036	0.046	0.043
SD-BS-L-BITTER_01	Northern Pike	2003	41	0.805	0.500	1.140	1.120
SD-BS-L-BITTER_01	Walleye	2003	46	0.486	0.120	0.860	0.780
SD-BS-L-TWIN_01	Northern Pike	2003	94	1.020	0.810	1.310	1.120
SD-BS-L-TWIN_01	Walleye	2003	44	0.912	0.510	1.260	1.200
SD-CH-L-ANGOSTURA_01	Black Crappie	2003	5	0.000	0.000	0.000	0.000
SD-CH-L-ANGOSTURA_01	Bluegill	2003	5	0.000	0.000	0.000	0.000
SD-CH-L-ANGOSTURA_01	Channel Catfish	2003	5	0.000	0.000	0.000	0.000
SD-CH-L-ANGOSTURA_01	River Carpsucker	2003	5	0.000	0.000	0.000	0.000
SD-CH-L-ANGOSTURA_01	Walleye	2003	10	0.006	0.000	0.060	0.000
SD-CH-L-SHERIDAN_01	Black Bullhead	2003	5	0.120	0.120	0.120	0.120
SD-CH-L-SHERIDAN_01	Largemouth Bass	2003	5	0.300	0.300	0.300	0.300
SD-CH-L-SHERIDAN_01	Northern Pike	2003	5	0.100	0.100	0.100	0.100
SD-CH-L-SHERIDAN_01	Rock Bass	2003	5	0.190	0.190	0.190	0.190
SD-CH-L-SHERIDAN_01	Yellow Perch	2003	5	0.180	0.180	0.180	0.180
SD-GR-L-ISABEL_01	Largemouth Bass	2003	26	0.631	0.210	1.200	1.160
SD-GR-L-ISABEL_01	Northern Pike	2003	20	0.890	0.520	1.100	1.100
SD-JA-L-LOUISE_01	Black Bullhead	2003	5	0.060	0.060	0.060	0.060
SD-JA-L-LOUISE_01	Bluegill	2003	5	0.180	0.180	0.180	0.180
SD-JA-L-LOUISE_01	Largemouth Bass	2003	5	0.480	0.480	0.480	0.480
SD-JA-L-LOUISE_01	Yellow Perch	2003	5	0.140	0.140	0.140	0.140
SD-JA-L-LYNN_01	Walleye	2003	45	0.563	0.460	0.700	0.640
SD-JA-L-WILMARTH_01	Black Bullhead	2003	5	0.000	0.000	0.000	0.000
SD-JA-L-WILMARTH_01	Bluegill	2003	5	0.100	0.100	0.100	0.100
SD-JA-L-WILMARTH_01	Largemouth Bass	2003	5	0.540	0.540	0.540	0.540
SD-MI-L-HURLEY_01	Largemouth Bass	2003	26	0.836	0.630	1.060	0.900
SD-MI-L-HURLEY_01	Northern Pike	2003	11	0.681	0.580	0.790	0.790
SD-MI-L-POTTS_01	Black Bullhead	2003	5	0.080	0.080	0.080	0.080
SD-MI-L-POTTS_01	Black Crappie	2003	5	0.350	0.350	0.350	0.350
SD-MI-L-POTTS_01	Bluegill	2003	5	0.220	0.220	0.220	0.220
SD-MI-L-POTTS_01	Largemouth Bass	2003	4	0.760	0.760	0.760	0.760
SD-MI-L-POTTS_01	Yellow Perch	2003	5	0.210	0.210	0.210	0.210
SD-MI-L-ROOSEVELT_01	Largemouth Bass	2003	21	0.563	0.280	1.070	1.070
SD-MI-L-ROOSEVELT_01	Northern Pike	2003	16	0.397	0.360	0.420	0.420
SD-MU-L-COAL_SPRINGS_01	Black Bullhead	2003	5	0.240	0.240	0.240	0.240
SD-MU-L-COAL_SPRINGS_01	Northern Pike	2003	1	0.320	0.320	0.320	0.320
SD-MU-L-COAL_SPRINGS_01	Walleye	2003	7	0.280	0.280	0.280	0.280
SD-MU-L-LITTLE_MOREAU_NO1_01	Largemouth Bass	2003	26	0.414	0.150	0.680	0.660

SD-MU-L-LITTLE_MOREAU_NO1_01	Northern Pike	2003	12	0.460	0.300	0.860	0.740
SD-VM-L-MARINDAHL_01	Black Crappie	2003	5	0.070	0.070	0.070	0.070
SD-VM-L-MARINDAHL_01	Bluegill	2003	5	0.040	0.040	0.040	0.040
SD-VM-L-MARINDAHL_01	Channel Catfish	2003	5	0.040	0.040	0.040	0.040
NoAUID-FFGrossL-SDSU	Walleye	2004	13	0.044	0.033	0.062	0.047
NoAUID-FFLindrothL-SDSU	Walleye	2004	12	0.025	0.017	0.039	0.036
NoAUID-FFStinkL-SDSU	Walleye	2004	14	0.072	0.040	0.111	0.101
NoAUID-FFWhitewoodCr-SDDOH	Brown Trout	2004	5	0.000	0.000	0.000	0.000
NoAUID-FourcheLake-SDSU	Walleye	2004	19	0.068	0.037	0.133	0.094
NoAUID-Fransen-SDSU	Walleye	2004	16	0.142	0.089	0.232	0.173
NoAUID-Simonson/Taunter-SDSU	Walleye	2004	12	0.061	0.035	0.089	0.080
SD-BA-L-WAGGONER_01	Black Bullhead	2004	5	0.000	0.000	0.000	0.000
SD-BA-L-WAGGONER_01	Bluegill	2004	5	0.060	0.060	0.060	0.060
SD-BA-L-WAGGONER_01	Northern Pike	2004	5	0.140	0.140	0.140	0.140
SD-BA-L-WAGGONER_01	White Sucker	2004	5	0.000	0.000	0.000	0.000
SD-BF-L-NEWELL_01	Largemouth Bass	2004	19	0.319	0.190	0.630	0.630
SD-BF-L-NEWELL_01	Walleye	2004	8	0.694	0.400	0.870	0.870
SD-BF-L-NEWELL_01	Yellow Perch	2004	1	0.250	0.250	0.250	0.250
SD-BS-L-BRUSH_01	Walleye	2004	6	0.045	0.040	0.054	0.048
SD-BS-L-DIAMOND_01	Black Bullhead	2004	5	0.060	0.060	0.060	0.060
SD-BS-L-DIAMOND_01	Walleye	2004	5	0.370	0.370	0.370	0.370
SD-BS-L-DIAMOND_01	Yellow Perch	2004	5	0.060	0.060	0.060	0.060
SD-GR-L-SHADEHILL_01	Channel Catfish	2004	5	0.120	0.120	0.120	0.120
SD-GR-L-SHADEHILL_01	Northern Pike	2004	2	0.210	0.210	0.210	0.210
SD-GR-L-SHADEHILL_01	Walleye	2004	5	0.250	0.250	0.250	0.250
SD-GR-L-SHADEHILL_01	White Bass	2004	5	0.160	0.160	0.160	0.160
SD-GR-L-SHADEHILL_01	Yellow Perch	2004	5	0.140	0.140	0.140	0.140
SD-JA-L-AMSDEN_01	Black Bullhead	2004	5	0.280	0.280	0.280	0.280
SD-JA-L-AMSDEN_01	Black Crappie	2004	5	0.180	0.180	0.180	0.180
SD-JA-L-AMSDEN_01	Walleye	2004	5	0.490	0.490	0.490	0.490
SD-JA-L-AMSDEN_01	Yellow Perch	2004	5	0.150	0.150	0.150	0.150
SD-JA-L-HORSESHOE_01	Walleye	2004	14	0.132	0.062	0.183	0.175
SD-JA-L-RICHMOND_01	Black Bullhead	2004	5	0.130	0.130	0.130	0.130
SD-JA-L-RICHMOND_01	Black Crappie	2004	5	0.190	0.190	0.190	0.190
SD-JA-L-RICHMOND_01	Bluegill	2004	5	0.130	0.130	0.130	0.130
SD-JA-L-RICHMOND_01	Walleye	2004	5	0.220	0.220	0.220	0.220
SD-JA-L-RICHMOND_01	White Bass	2004	5	0.190	0.190	0.190	0.190
SD-JA-L-TWIN_01	Black Crappie	2004	5	0.120	0.120	0.120	0.120
SD-JA-L-TWIN_01	Bluegill	2004	5	0.000	0.000	0.000	0.000
SD-JA-L-TWIN_01	Northern Pike	2004	5	0.000	0.000	0.000	0.000
SD-JA-L-TWIN_01	Walleye	2004	5	0.000	0.000	0.000	0.000
SD-MI-L-HIDDENWOOD_01	Black Bullhead	2004	5	0.000	0.000	0.000	0.000
SD-MI-L-HIDDENWOOD_01	Black Crappie	2004	5	0.140	0.140	0.140	0.140
SD-MI-L-HIDDENWOOD_01	Largemouth Bass	2004	5	0.200	0.200	0.200	0.200
SD-MI-L-HIDDENWOOD_01	White Sucker	2004	5	0.060	0.060	0.060	0.060
SD-MI-L-HIDDENWOOD_01	Yellow Perch	2004	5	0.110	0.110	0.110	0.110
SD-MI-L-POTTS_01	Largemouth Bass	2004	20	0.690	0.660	0.810	0.690
SD-MI-L-SIMON_01	Black Bullhead	2004	5	0.180	0.180	0.180	0.180
SD-MI-L-SIMON_01	Bluegill	2004	5	0.240	0.240	0.240	0.240
SD-MI-L-SIMON_01	Northern Pike	2004	5	0.750	0.750	0.750	0.750
SD-MI-L-SIMON_01	Yellow Perch	2004	5	0.260	0.260	0.260	0.260
SD-MN-L-TURTLE_FOOT_01	Walleye	2004	12	0.027	0.014	0.038	0.031
SD-BS-L-BITTER_01	Northern Pike	2005	8	0.608	0.262	0.878	0.784
SD-BS-L-BITTER_01	Walleye	2005	232	0.402	0.040	1.750	0.601
SD-BS-L-BITTER_01	Yellow Perch	2005	23	0.379	0.125	0.674	0.507
SD-BS-L-ENEMY_SWIM_01	Northern Pike	2005	6	0.237	0.152	0.383	0.249

SD-BS-L-ENEMY_SWIM_01	Walleye	2005	31	0.163	0.065	0.773	0.244
SD-BS-L-ISLAND_N_01	Black Bullhead	2005	5	0.140	0.140	0.140	0.140
SD-BS-L-ISLAND_N_01	Northern Pike	2005	5	0.630	0.310	0.710	0.710
SD-BS-L-ISLAND_N_01	Walleye	2005	5	0.488	0.290	1.040	0.705
SD-BS-L-KAMPESKA_01	Walleye	2005	22	0.113	0.045	0.191	0.140
SD-BS-L-PELICAN_01	Walleye	2005	101	0.081	0.000	0.647	0.108
SD-BS-L-TWIN_01	Northern Pike	2005	4	1.178	0.811	1.580	1.580
SD-BS-L-TWIN_01	Walleye	2005	58	0.867	0.084	2.270	1.540
SD-BS-L-TWIN_01	Yellow Perch	2005	3	0.461	0.454	0.465	0.465
SD-CH-L-CURLEW_01	Black Bullhead	2005	5	0.120	0.120	0.120	0.120
SD-CH-L-CURLEW_01	Black Crappie	2005	5	0.150	0.150	0.150	0.150
SD-CH-L-CURLEW_01	Common Carp	2005	2	0.030	0.030	0.030	0.030
SD-CH-L-CURLEW_01	Largemouth Bass	2005	5	0.110	0.110	0.110	0.110
SD-CH-L-CURLEW_01	Northern Pike	2005	1	0.250	0.250	0.250	0.250
SD-CH-L-CURLEW_01	Walleye	2005	4	0.080	0.080	0.080	0.080
SD-CH-L-PACTOLA_01	Black Crappie	2005	4	0.100	0.100	0.100	0.100
SD-CH-L-PACTOLA_01	Bluegill	2005	5	0.130	0.130	0.130	0.130
SD-CH-L-PACTOLA_01	Largemouth Bass	2005	4	0.145	0.100	0.190	0.190
SD-CH-L-PACTOLA_01	Rock Bass	2005	5	0.260	0.260	0.260	0.260
SD-CH-L-PACTOLA_01	Yellow Perch	2005	5	0.240	0.240	0.240	0.240
SD-GR-L-ISABEL_01	Largemouth Bass	2005	36	0.490	0.033	1.620	0.681
SD-JA-L-BYRON_01	Walleye	2005	113	0.191	0.034	0.265	0.211
SD-JA-L-LYNN_01	Northern Pike	2005	1	0.490	0.490	0.490	0.490
SD-JA-L-LYNN_01	Walleye	2005	20	0.270	0.180	0.465	0.329
SD-JA-L-ROY_01	Black Bullhead	2005	5	0.090	0.090	0.090	0.090
SD-JA-L-ROY_01	Bluegill	2005	5	0.060	0.060	0.060	0.060
SD-JA-L-ROY_01	Northern Pike	2005	7	0.173	0.027	0.300	0.210
SD-JA-L-ROY_01	Walleye	2005	22	0.105	0.036	0.262	0.123
SD-JA-L-ROY_01	White Sucker	2005	5	0.220	0.220	0.220	0.220
SD-JA-L-S_RED_IRON_01	Black Bullhead	2005	5	0.090	0.090	0.090	0.090
SD-JA-L-S_RED_IRON_01	Northern Pike	2005	2	0.170	0.100	0.240	0.240
SD-JA-L-S_RED_IRON_01	Walleye	2005	5	0.084	0.050	0.220	0.135
SD-JA-L-S_RED_IRON_01	White Sucker	2005	5	0.030	0.030	0.030	0.030
SD-JA-L-SOUTH_BUFFALO_01	Black Bullhead	2005	5	0.100	0.100	0.100	0.100
SD-JA-L-SOUTH_BUFFALO_01	Bluegill	2005	5	0.090	0.090	0.090	0.090
SD-JA-L-SOUTH_BUFFALO_01	Walleye	2005	5	0.238	0.190	0.270	0.270
SD-JA-L-SOUTH_BUFFALO_01	White Sucker	2005	5	0.030	0.030	0.030	0.030
SD-JA-L-WILMARTH_01	Largemouth Bass	2005	19	0.387	0.290	0.640	0.640
SD-JA-L-WILMARTH_01	Northern Pike	2005	15	0.440	0.300	0.650	0.650
SD-MI-L-BYRE_01	Black Bullhead	2005	5	0.040	0.040	0.040	0.040
SD-MI-L-BYRE_01	Bluegill	2005	5	0.130	0.130	0.130	0.130
SD-MI-L-BYRE_01	Walleye	2005	5	0.130	0.130	0.130	0.130
SD-MI-L-FATE_01	Black Crappie	2005	5	0.160	0.160	0.160	0.160
SD-MI-L-FATE_01	Walleye	2005	5	0.290	0.290	0.290	0.290
SD-MI-L-HURLEY_01	Largemouth Bass	2005	25	0.822	0.557	1.080	0.926
SD-MI-L-MCCOOK_01	Black Crappie	2005	5	0.200	0.200	0.200	0.200
SD-MI-L-MCCOOK_01	Channel Catfish	2005	5	0.030	0.030	0.030	0.030
SD-MI-L-MCCOOK_01	Largemouth Bass	2005	5	0.188	0.170	0.260	0.215
SD-MI-L-SIMON_01	Largemouth Bass	2005	17	0.889	0.800	0.920	0.920
SD-MI-L-SIMON_01	Northern Pike	2005	15	0.633	0.550	0.690	0.690
NoAUID-FFBeaverL-SDDOH	Black Bullhead	2006	5	0.020	0.020	0.020	0.020
NoAUID-FFBeaverL-SDDOH	Black Crappie	2006	5	0.120	0.120	0.120	0.120
NoAUID-FFEastLemmonL-SDDOH	Black Bullhead	2006	5	0.180	0.180	0.180	0.180
NoAUID-FFEastLemmonL-SDDOH	White Sucker	2006	5	0.190	0.190	0.190	0.190
NoAUID-FFEastLemmonL-SDDOH	Yellow Perch	2006	5	0.150	0.150	0.150	0.150
SD-BA-L-HAYES_01	Black Bullhead	2006	5	0.090	0.090	0.090	0.090

SD-BA-L-HAYES_01	Black Crappie	2006	5	0.260	0.260	0.260	0.260
SD-BA-L-HAYES_01	Bluegill	2006	5	0.170	0.170	0.170	0.170
SD-BA-L-HAYES_01	Northern Pike	2006	7	0.339	0.330	0.350	0.350
SD-BA-L-MURDO_01	Black Bullhead	2006	5	0.130	0.130	0.130	0.130
SD-BA-L-MURDO_01	Black Crappie	2006	5	0.300	0.300	0.300	0.300
SD-BA-L-MURDO_01	Largemouth Bass	2006	5	0.150	0.150	0.150	0.150
SD-BF-L-ORMAN_01	Channel Catfish	2006	4	0.170	0.090	0.250	0.250
SD-BF-L-ORMAN_01	Walleye	2006	5	0.056	0.050	0.060	0.060
SD-BF-L-ORMAN_01	White Bass	2006	2	0.220	0.220	0.220	0.220
SD-BS-L-BITTER_01	Walleye	2006	48	0.256	0.081	0.627	0.366
SD-BS-L-ISLAND_N_01	Northern Pike	2006	10	0.675	0.650	0.700	0.700
SD-BS-L-ISLAND_N_01	Walleye	2006	14	0.912	0.530	1.280	1.280
SD-JA-L-CATTAIL_01	Walleye	2006	3	0.312	0.220	0.386	0.386
SD-JA-L-STAUM_01	Black Bullhead	2006	5	0.110	0.110	0.110	0.110
SD-JA-L-STAUM_01	Largemouth Bass	2006	5	0.658	0.580	0.710	0.710
SD-MI-L-SIMON_01	Northern Pike	2006	5	0.860	0.860	0.860	0.860
SD-MI-R-LEWIS_AND_CLARK_01	Bigmouth Buffalo	2006	1	0.360	0.360	0.360	0.360
SD-MI-R-LEWIS_AND_CLARK_01	Channel Catfish	2006	4	0.030	0.030	0.030	0.030
SD-MI-R-LEWIS_AND_CLARK_01	River Carpsucker	2006	5	0.096	0.060	0.120	0.120
SD-MI-R-LEWIS_AND_CLARK_01	Saugeye	2006	1	0.050	0.050	0.050	0.050
SD-MI-R-LEWIS_AND_CLARK_01	Shorthead Redhorse	2006	5	0.024	0.020	0.040	0.030
SD-MI-R-LEWIS_AND_CLARK_01	Smallmouth Buffalo	2006	5	0.106	0.070	0.250	0.160
SD-MN-L-PUNISHED_WOMAN_01	Black Bullhead	2006	5	0.170	0.170	0.170	0.170
SD-MN-L-PUNISHED_WOMAN_01	Northern Pike	2006	5	0.220	0.200	0.230	0.230
SD-MN-L-PUNISHED_WOMAN_01	White Sucker	2006	5	0.030	0.030	0.030	0.030
SD-MN-L-PUNISHED_WOMAN_01	Yellow Perch	2006	5	0.140	0.140	0.140	0.140
SD-MN-L-SUMMIT_01	Black Bullhead	2006	5	0.080	0.080	0.080	0.080
SD-MN-L-SUMMIT_01	Northern Pike	2006	5	0.384	0.260	0.490	0.440
SD-MN-L-SUMMIT_01	Walleye	2006	5	0.440	0.260	0.560	0.560
SD-MN-L-SUMMIT_01	Yellow Perch	2006	5	0.080	0.080	0.080	0.080
NoAUID-FFNFWhetstoneR-SDDOH	Black Bullhead	2007	4	0.120	0.120	0.120	0.120
NoAUID-FFNFWhetstoneR-SDDOH	Bluegill	2007	2	0.100	0.100	0.100	0.100
NoAUID-FFNFWhetstoneR-SDDOH	Green Sunfish hybrid	2007	5	0.230	0.230	0.230	0.230
NoAUID-FFNFWhetstoneR-SDDOH	White Sucker	2007	1	0.130	0.130	0.130	0.130
NoAUID-FFSoukup-SDDOH	Black Bullhead	2007	5	0.060	0.060	0.060	0.060
NoAUID-FFSoukup-SDDOH	Black Crappie	2007	5	0.170	0.170	0.170	0.170
NoAUID-FFSoukup-SDDOH	Northern Pike	2007	3	0.220	0.220	0.220	0.220
SD-BF-R-BEAR_BUTTE_01	Brown Trout	2007	5	0.030	0.030	0.030	0.030
SD-BF-R-SPEARFISH_05	Brown Trout	2007	5	0.070	0.070	0.070	0.070
SD-BF-R-SPEARFISH_05	Rainbow Trout	2007	5	0.090	0.090	0.090	0.090
SD-BS-L-BITTER_01	Walleye	2007	109	0.627	0.177	0.944	0.720
SD-BS-L-BITTER_01	Yellow Perch	2007	8	0.147	0.052	0.207	0.194
SD-BS-L-BULLHEAD_01	Common Carp	2007	10	0.085	0.050	0.120	0.120
SD-BS-L-BULLHEAD_01	Walleye	2007	5	0.140	0.050	0.200	0.200
SD-BS-L-BULLHEAD_01	Yellow Perch	2007	5	0.020	0.020	0.020	0.020
SD-BS-L-ENEMY_SWIM_01	Bluegill	2007	5	0.080	0.080	0.080	0.080
SD-BS-L-ENEMY_SWIM_01	Rock Bass	2007	5	0.180	0.180	0.180	0.180
SD-BS-L-ENEMY_SWIM_01	Smallmouth Bass	2007	5	0.240	0.240	0.240	0.240
SD-BS-L-ENEMY_SWIM_01	Walleye	2007	5	0.300	0.300	0.300	0.300
SD-BS-L-ENEMY_SWIM_01	White Bass	2007	4	0.490	0.490	0.490	0.490
SD-BS-L-TWIN_02	Black Bullhead	2007	10	0.300	0.230	0.370	0.370
SD-BS-L-TWIN_02	Walleye	2007	10	0.765	0.380	1.150	1.150
SD-BS-L-TWIN_02	Yellow Perch	2007	10	0.145	0.110	0.180	0.180
SD-GR-L-PUDWELL_01	Black Bullhead	2007	5	0.220	0.220	0.220	0.220
SD-GR-L-PUDWELL_01	Black Crappie	2007	5	0.780	0.780	0.780	0.780

SD-GR-L-PUDWELL_01	Walleye	2007	5	0.770	0.770	0.770	0.770
SD-JA-L-HORSESHOE_01	Black Crappie	2007	3	0.210	0.210	0.210	0.210
SD-JA-L-HORSESHOE_01	Bluegill	2007	5	0.120	0.120	0.120	0.120
SD-JA-L-HORSESHOE_01	Smallmouth Bass	2007	4	0.300	0.300	0.300	0.300
SD-JA-L-HORSESHOE_01	Walleye	2007	5	0.660	0.660	0.660	0.660
SD-JA-L-HORSESHOE_01	Yellow Perch	2007	5	0.190	0.190	0.190	0.190
SD-JA-L-ROSEHILL_01	Black Bullhead	2007	5	0.220	0.220	0.220	0.220
SD-JA-L-ROSEHILL_01	Black Crappie	2007	5	0.340	0.340	0.340	0.340
SD-MI-R-OAHE_01	Channel Catfish	2007	5	0.200	0.200	0.200	0.200
SD-MI-R-OAHE_01	Walleye	2007	15	0.133	0.100	0.180	0.180
SD-MI-R-OAHE_01	White Bass	2007	5	0.280	0.280	0.280	0.280
SD-MN-L-ALICE_01	Black Bullhead	2007	5	0.120	0.120	0.120	0.120
SD-MN-L-ALICE_01	Common Carp	2007	5	0.140	0.140	0.140	0.140
SD-MN-L-ALICE_01	European Rudd	2007	4	0.280	0.280	0.280	0.280
SD-MN-L-ALICE_01	Northern Pike	2007	5	0.360	0.360	0.360	0.360
SD-MN-L-ALICE_01	Walleye	2007	5	0.110	0.110	0.110	0.110
SD-VM-L-THOMPSON_01	Black Crappie	2007	5	0.310	0.310	0.310	0.310
SD-VM-L-THOMPSON_01	Walleye	2007	5	0.250	0.250	0.250	0.250
NoAUID-FFBullheadLR-SDDOH	Black Bullhead	2008	15	0.027	0.020	0.040	0.040
NoAUID-FFBullheadLR-SDDOH	Northern Pike	2008	10	0.145	0.100	0.190	0.190
NoAUID-FFBullheadLR-SDDOH	Yellow Perch	2008	5	0.050	0.050	0.050	0.050
NoAUID-FFCrookedL-SDDOH	Black Bullhead	2008	5	0.030	0.030	0.030	0.030
NoAUID-FFCrookedL-SDDOH	Northern Pike	2008	5	0.080	0.080	0.080	0.080
NoAUID-FFCrookedL-SDDOH	Yellow Perch	2008	5	0.040	0.040	0.040	0.040
NoAUID-FFHurricaneL-SDDOH	Black Bullhead	2008	5	0.030	0.030	0.030	0.030
NoAUID-FFHurricaneL-SDDOH	Northern Pike	2008	5	0.080	0.080	0.080	0.080
NoAUID-FFHurricaneL-SDDOH	Yellow Perch	2008	5	0.050	0.050	0.050	0.050
SD-BS-L-DIAMOND_01	Black Bullhead	2008	5	0.040	0.040	0.040	0.040
SD-BS-L-DIAMOND_01	Walleye	2008	15	0.413	0.190	0.650	0.650
SD-BS-L-MADISON_01	Black Bullhead	2008	5	0.030	0.030	0.030	0.030
SD-BS-L-MADISON_01	Black Crappie	2008	5	0.030	0.030	0.030	0.030
SD-BS-L-MADISON_01	Bluegill	2008	5	0.020	0.020	0.020	0.020
SD-BS-L-MADISON_01	Yellow Perch	2008	5	0.020	0.020	0.020	0.020
SD-BS-L-PICKEREL_01	Black Bullhead	2008	5	0.040	0.040	0.040	0.040
SD-BS-L-PICKEREL_01	Bluegill	2008	5	0.060	0.060	0.060	0.060
SD-BS-L-PICKEREL_01	Rock Bass	2008	5	0.100	0.100	0.100	0.100
SD-BS-L-PICKEREL_01	Walleye	2008	5	0.100	0.100	0.100	0.100
SD-BS-L-PICKEREL_01	White Sucker	2008	5	0.020	0.020	0.020	0.020
SD-BS-L-SCHOOL_01	Black Bullhead	2008	5	0.050	0.050	0.050	0.050
SD-BS-L-SCHOOL_01	Northern Pike	2008	5	0.130	0.130	0.130	0.130
SD-BS-L-SCHOOL_01	Yellow Perch	2008	2	0.060	0.060	0.060	0.060
SD-BS-L-TWIN_02	Walleye	2008	30	0.965	0.610	1.620	1.450
SD-BS-L-WAUBAY_01	Northern Pike	2008	10	0.395	0.170	0.620	0.620
SD-BS-L-WAUBAY_01	Walleye	2008	15	0.130	0.110	0.150	0.150
SD-BS-L-WAUBAY_01	Yellow Perch	2008	15	0.093	0.060	0.140	0.140
SD-GR-L-PUDWELL_01	Black Crappie	2008	9	0.691	0.680	0.700	0.700
SD-GR-L-PUDWELL_01	Walleye	2008	11	1.147	1.020	1.230	1.230
SD-JA-L-MITCHELL_01	Black Crappie	2008	5	0.130	0.130	0.130	0.130
SD-JA-L-MITCHELL_01	Bluegill	2008	1	0.110	0.110	0.110	0.110
SD-JA-L-MITCHELL_01	Channel Catfish	2008	5	0.170	0.170	0.170	0.170
SD-JA-L-MITCHELL_01	Walleye	2008	5	0.150	0.150	0.150	0.150
SD-MI-L-HURLEY_01	Largemouth Bass	2008	23	0.793	0.500	0.900	0.900
SD-MI-L-ROOSEVELT_01	Largemouth Bass	2008	15	0.753	0.510	1.110	1.110
NoAUID-FFPiyasL-SDDOH	Walleye	2009	5	0.140	0.140	0.140	0.140
NoAUID-FFPiyasL-SDDOH	Yellow Perch	2009	5	0.040	0.040	0.040	0.040
SD-BS-L-HERMAN_01	Black Bullhead	2009	5	0.050	0.050	0.050	0.050

SD-BS-L-HERMAN_01	Bluegill	2009	5	0.030	0.030	0.030	0.030
SD-BS-L-HERMAN_01	Channel Catfish	2009	5	0.020	0.020	0.020	0.020
SD-BS-L-HERMAN_01	White Bass	2009	5	0.230	0.230	0.230	0.230
SD-BS-L-HERMAN_01	Yellow Perch	2009	5	0.380	0.380	0.380	0.380
SD-BS-L-SINAI_01	Black Crappie	2009	4	0.140	0.140	0.140	0.140
SD-BS-L-SINAI_01	Smallmouth Bass	2009	5	0.180	0.180	0.180	0.180
SD-BS-L-SINAI_01	Walleye	2009	5	0.170	0.170	0.170	0.170
SD-BS-L-SINAI_01	Yellow Perch	2009	5	0.120	0.120	0.120	0.120
SD-JA-L-CLEAR_M_01	Black Bullhead	2009	3	0.050	0.050	0.050	0.050
SD-JA-L-CLEAR_M_01	Bluegill	2009	5	0.010	0.010	0.010	0.010
SD-JA-L-CLEAR_M_01	Northern Pike	2009	5	0.180	0.180	0.180	0.180
SD-JA-L-CLEAR_M_01	Smallmouth Bass	2009	5	0.110	0.110	0.110	0.110
SD-JA-L-CLEAR_M_01	Walleye	2009	4	0.070	0.070	0.070	0.070
SD-JA-L-ELM_01	Black Crappie	2009	5	0.200	0.200	0.200	0.200
SD-JA-L-ELM_01	Northern Pike	2009	5	0.200	0.200	0.200	0.200
SD-JA-L-ELM_01	Walleye	2009	5	0.360	0.360	0.360	0.360
SD-JA-L-ELM_01	White Sucker	2009	5	0.130	0.130	0.130	0.130
SD-MI-R-FRANCIS_CASE_01	Channel Catfish	2009	5	0.060	0.060	0.060	0.060
SD-MI-R-FRANCIS_CASE_01	Common Carp	2009	5	0.140	0.140	0.140	0.140
SD-MI-R-FRANCIS_CASE_01	Smallmouth Bass	2009	5	0.050	0.050	0.050	0.050
SD-MI-R-FRANCIS_CASE_01	Walleye	2009	5	0.120	0.120	0.120	0.120
SD-MI-R-FRANCIS_CASE_01	White Bass	2009	4	0.190	0.190	0.190	0.190
SD-MU-L-LITTLE_MOREAU_NO1_01	Largemouth Bass	2009	4	0.270	0.270	0.270	0.270
SD-MU-L-LITTLE_MOREAU_NO1_01	Northern Pike	2009	11	0.306	0.150	0.440	0.440
SD-VM-L-E_VERMILLION_01	Black Bullhead	2009	5	0.120	0.120	0.120	0.120
SD-VM-L-E_VERMILLION_01	Bluegill	2009	5	0.150	0.150	0.150	0.150
SD-VM-L-E_VERMILLION_01	Walleye	2009	5	0.100	0.100	0.100	0.100
SD-BF-L-NEWELL_01	Largemouth Bass	2010	5	0.580	0.580	0.580	0.580
SD-BF-L-NEWELL_01	Walleye	2010	6	0.875	0.790	0.960	0.960
SD-JA-L-OPITZ_01	Northern Pike	2010	1	0.210	0.210	0.210	0.210
SD-JA-L-OPITZ_01	Walleye	2010	5	0.310	0.310	0.310	0.310
SD-JA-L-OPITZ_01	Yellow Perch	2010	5	0.110	0.110	0.110	0.110
SD-BS-L-POINSETT_01	Black Bullhead	2010	3	0.130	0.130	0.130	0.130
SD-BS-L-POINSETT_01	Common Carp	2010	5	0.060	0.060	0.060	0.060
SD-BS-L-POINSETT_01	Northern Pike	2010	5	0.330	0.330	0.330	0.330
SD-BS-L-POINSETT_01	Smallmouth Bass	2010	5	0.220	0.220	0.220	0.220
SD-BS-L-POINSETT_01	Walleye	2010	5	0.200	0.200	0.200	0.200
SD-BS-L-POINSETT_01	Yellow Perch	2010	5	0.180	0.180	0.180	0.180
SD-CH-L-STOCKADE_01	Black Bullhead	2010	3	0.020	0.020	0.020	0.020
SD-CH-L-STOCKADE_01	Black Crappie	2010	5	0.180	0.180	0.180	0.180
SD-CH-L-STOCKADE_01	White Sucker	2010	4	0.120	0.120	0.120	0.120
SD-CH-L-STOCKADE_01	Yellow Perch	2010	5	0.110	0.110	0.110	0.110
SD-GR-L-ISABEL_01	Largemouth Bass	2010	9	1.030	0.580	1.430	1.430
SD-GR-L-ISABEL_01	Northern Pike	2010	5	1.088	1.040	1.160	1.160
SD-JA-L-FAULKTON_01	Black Bullhead	2010	5	0.270	0.270	0.270	0.270
SD-JA-L-FAULKTON_01	Black Crappie	2010	5	0.490	0.490	0.490	0.490
SD-JA-L-FAULKTON_01	Bluegill	2010	5	0.300	0.300	0.300	0.300
SD-JA-L-FAULKTON_01	Northern Pike	2010	5	0.430	0.430	0.430	0.430
SD-JA-L-FAULKTON_01	Yellow Perch	2010	5	0.210	0.210	0.210	0.210
SD-JA-L-MINA_01	Black Bullhead	2010	5	0.170	0.170	0.170	0.170
SD-JA-L-MINA_01	Bluegill	2010	5	0.170	0.170	0.170	0.170
SD-JA-L-MINA_01	Channel Catfish	2010	5	0.250	0.250	0.250	0.250
SD-JA-L-MINA_01	Northern Pike	2010	5	0.530	0.530	0.530	0.530
SD-JA-L-MINA_01	Yellow Perch	2010	5	0.290	0.290	0.290	0.290
SD-MI-L-BRAKKE_01	Black Crappie	2010	5	0.130	0.130	0.130	0.130

SD-MI-L-BRAKKE_01	Bluegill	2010	5	0.240	0.240	0.240	0.240
SD-MI-L-BRAKKE_01	Northern Pike	2010	4	0.410	0.410	0.410	0.410
SD-MI-L-BRAKKE_01	Walleye	2010	5	0.570	0.570	0.570	0.570
SD-MI-R-OAHE_01	Walleye	2010	45	0.357	0.240	0.700	0.415
SD-MI-R-SHARPE_01	Channel Catfish	2010	14	0.091	0.070	0.120	0.120
SD-MI-R-SHARPE_01	Smallmouth Bass	2010	4	0.130	0.130	0.130	0.130
SD-MI-R-SHARPE_01	Walleye	2010	15	0.173	0.130	0.220	0.220
SD-MI-R-SHARPE_01	White Bass	2010	5	0.210	0.210	0.210	0.210
SD-MN-L-COCHRANE_01	Black Bullhead	2010	5	0.020	0.020	0.020	0.020
SD-MN-L-COCHRANE_01	Bluegill	2010	5	0.040	0.040	0.040	0.040
SD-MN-L-COCHRANE_01	Largemouth Bass	2010	5	0.100	0.100	0.100	0.100
SD-MN-L-COCHRANE_01	Walleye	2010	5	0.070	0.070	0.070	0.070
SD-MN-L-COCHRANE_01	Yellow Perch	2010	5	0.080	0.080	0.080	0.080
SD-BF-L-NEWELL_01	Bluegill	2011	10	0.267	0.030	0.370	0.340
SD-BF-L-NEWELL_01	Northern Pike	2011	7	1.213	0.780	2.470	1.560
SD-BF-L-NEWELL_01	Walleye	2011	2	1.090	0.940	1.240	1.240
SD-BF-L-NEWELL_01	White Sucker	2011	10	0.332	0.160	0.550	0.510
SD-BF-L-NEWELL_01	Yellow Perch	2011	1	0.920	0.920	0.920	0.920
SD-BF-L-ORMAN_01	Channel Catfish	2011	11	0.191	0.080	0.390	0.270
SD-BF-L-ORMAN_01	Walleye	2011	10	0.281	0.210	0.380	0.320
SD-BF-L-ORMAN_01	White Bass	2011	10	0.486	0.160	0.920	0.710
SD-BS-L-ANTELOPE_01	Northern Pike	2011	10	0.402	0.220	0.810	0.545
SD-BS-L-ANTELOPE_01	Yellow Perch	2011	10	0.331	0.190	0.470	0.385
SD-BS-L-BLUE_DOG_01	Northern Pike	2011	10	0.147	0.100	0.240	0.205
SD-BS-L-BLUE_DOG_01	Walleye	2011	10	0.142	0.050	0.280	0.180
SD-BS-L-BRUSH_01	Black Bullhead	2011	5	0.078	0.070	0.100	0.090
SD-BS-L-BRUSH_01	Walleye	2011	5	0.370	0.240	0.550	0.485
SD-BS-L-BRUSH_01	Yellow Perch	2011	5	0.104	0.060	0.190	0.150
SD-BS-L-DRY_#2_01	Northern Pike	2011	10	0.518	0.190	0.670	0.625
SD-BS-L-DRY_#2_01	Walleye	2011	10	0.651	0.460	0.960	0.785
SD-BS-L-ENEMY_SWIM_01	Smallmouth Bass	2011	10	0.270	0.120	0.580	0.330
SD-BS-L-ENEMY_SWIM_01	White Bass	2011	7	0.469	0.060	0.860	0.760
SD-JA-L-OPITZ_01	Northern Pike	2011	4	0.793	0.300	1.570	1.570
SD-JA-L-OPITZ_01	Walleye	2011	10	0.440	0.330	0.610	0.495
SD-BS-L-POINSETT_01	Northern Pike	2011	10	0.335	0.070	0.530	0.465
SD-BS-L-POINSETT_01	Walleye	2011	10	0.258	0.130	0.390	0.315
SD-BS-L-REID_01	Walleye	2011	10	0.633	0.510	1.060	0.710
SD-BS-L-REID_01	Yellow Perch	2011	10	0.279	0.080	0.380	0.340
SD-BS-L-RUSH_01	Northern Pike	2011	10	0.227	0.160	0.350	0.255
SD-BS-L-RUSH_01	Walleye	2011	10	0.388	0.020	0.870	0.605
SD-BS-L-TWIN_01	Northern Pike	2011	19	1.091	0.390	1.550	1.420
SD-BS-L-TWIN_01	Walleye	2011	20	0.439	0.240	1.330	0.560
SD-BS-L-TWIN_01	Yellow Perch	2011	10	0.190	0.120	0.320	0.260
SD-BS-L-TWIN_02	Black Bullhead	2011	10	0.206	0.080	0.390	0.280
SD-BS-L-TWIN_02	Yellow Perch	2011	10	0.457	0.320	0.640	0.555
SD-BS-L-WAUBAY_01	Northern Pike	2011	4	0.408	0.270	0.690	0.690
SD-BS-L-WAUBAY_01	Walleye	2011	10	0.130	0.060	0.180	0.165
SD-BS-L-WAUBAY_01	Yellow Perch	2011	10	0.080	0.050	0.130	0.110
SD-CH-L-CURLEW_01	Common Carp	2011	10	0.094	0.050	0.230	0.110
SD-CH-L-CURLEW_01	Largemouth Bass	2011	5	0.318	0.190	0.570	0.475
SD-CH-L-PACTOLA_01	Northern Pike	2011	10	0.179	0.110	0.320	0.210
SD-GR-L-SHADEHILL_01	Black Crappie	2011	1	0.270	0.270	0.270	0.270
SD-GR-L-SHADEHILL_01	Channel Catfish	2011	10	0.210	0.160	0.260	0.245
SD-GR-L-SHADEHILL_01	Walleye	2011	1	0.400	0.400	0.400	0.400
SD-GR-L-SHADEHILL_01	White Bass	2011	11	0.645	0.480	1.000	0.680
SD-GR-L-SHADEHILL_01	White Crappie	2011	7	0.367	0.250	0.470	0.420

SD-JA-L-AMSDEN_01	Black Bullhead	2011	10	0.135	0.110	0.160	0.150
SD-JA-L-AMSDEN_01	Walleye	2011	10	0.360	0.190	0.770	0.465
SD-JA-L-BYRON_01	Northern Pike	2011	10	0.146	0.060	0.310	0.195
SD-JA-L-BYRON_01	Walleye	2011	10	0.055	0.040	0.070	0.065
SD-JA-L-CAVOUR_01	Black Bullhead	2011	10	0.134	0.020	0.290	0.255
SD-JA-L-CAVOUR_01	Black Crappie	2011	10	0.182	0.090	0.360	0.305
SD-JA-L-HORSESHOE_01	Walleye	2011	10	0.549	0.390	0.890	0.605
SD-JA-L-HORSESHOE_01	Yellow Perch	2011	10	0.396	0.300	0.460	0.435
SD-JA-L-REETZ_01	Black Crappie	2011	10	0.320	0.250	0.370	0.355
SD-JA-L-REETZ_01	Yellow Perch	2011	10	0.197	0.120	0.300	0.260
SD-JA-L-SOUTH_BUFFALO_01	Northern Pike	2011	10	0.352	0.150	0.460	0.420
SD-JA-L-SOUTH_BUFFALO_01	Walleye	2011	10	0.468	0.200	0.910	0.630
SD-JA-L-WILMARTH_01	Largemouth Bass	2011	10	0.476	0.310	0.720	0.625
SD-JA-L-WILMARTH_01	Northern Pike	2011	10	0.572	0.330	0.710	0.675
SD-MI-L-BURKE_01	Black Bullhead	2011	5	0.028	0.020	0.040	0.035
SD-MI-L-BURKE_01	Black Crappie	2011	5	0.132	0.070	0.170	0.165
SD-MI-L-BURKE_01	Bluegill	2011	5	0.126	0.080	0.180	0.180
SD-MI-L-BURKE_01	Largemouth Bass	2011	5	0.140	0.110	0.160	0.155
SD-MI-L-FATE_01	Northern Pike	2011	11	0.359	0.250	0.510	0.390
SD-MI-L-HURLEY_01	Northern Pike	2011	10	0.645	0.570	0.780	0.715
SD-MI-L-ROOSEVELT_01	Bluegill	2011	10	0.464	0.310	0.570	0.515
SD-MI-L-ROOSEVELT_01	Northern Pike	2011	10	0.745	0.520	1.150	0.930
SD-MI-R-OAHE_01	Channel Catfish	2011	30	0.347	0.150	0.820	0.430
SD-MI-R-OAHE_01	Common Carp	2011	10	0.264	0.160	0.410	0.340
SD-MI-R-OAHE_01	Northern Pike	2011	20	0.540	0.190	0.940	0.780
SD-MI-R-OAHE_01	Walleye	2011	10	0.478	0.240	0.720	0.600
SD-MI-R-OAHE_01	White Bass	2011	9	0.813	0.620	0.930	0.900
SD-MU-L-COAL_SPRINGS_01	Black Bullhead	2011	3	0.443	0.370	0.490	0.490
SD-MU-L-COAL_SPRINGS_01	Northern Pike	2011	10	0.790	0.460	1.400	1.235
SD-VM-L-WHITEWOOD_01	Black Bullhead	2011	5	0.110	0.060	0.200	0.165
SD-VM-L-WHITEWOOD_01	Northern Pike	2011	4	0.215	0.150	0.280	0.280
SD-VM-L-WHITEWOOD_01	Walleye	2011	5	0.226	0.110	0.330	0.320
SD-VM-L-WHITEWOOD_01	White Sucker	2011	5	0.164	0.050	0.230	0.225
SD-BA-L-MURDO_01	Black Bullhead	2012	10	0.094	0.060	0.140	0.120
SD-BA-L-MURDO_01	Black Crappie	2012	10	0.276	0.200	0.370	0.340
SD-BS-L-BRANT_01	Black Bullhead	2012	5	0.030	0.020	0.040	0.035
SD-BS-L-BRANT_01	Walleye	2012	5	0.110	0.060	0.140	0.135
SD-BS-L-BRANT_01	White Bass	2012	5	0.126	0.090	0.190	0.160
SD-BS-L-BRANT_01	White Sucker	2012	5	0.042	0.040	0.050	0.045
SD-BS-L-HERMAN_01	Black Bullhead	2012	10	0.072	0.050	0.110	0.090
SD-BS-L-HERMAN_01	Black Crappie	2012	10	0.053	0.030	0.090	0.060
SD-BS-L-ISLAND_N_01	Smallmouth Bass	2012	10	0.548	0.370	1.010	0.655
SD-BS-L-ISLAND_N_01	Walleye	2012	10	0.844	0.390	2.030	1.190
SD-BS-L-MID_LYNN_01	Black Bullhead	2012	5	0.242	0.200	0.310	0.290
SD-BS-L-MID_LYNN_01	Walleye	2012	5	1.074	0.840	1.340	1.260
SD-BS-L-MID_LYNN_01	Yellow Perch	2012	5	0.464	0.420	0.550	0.515
SD-BS-L-MINNEWASTA_01	Black Bullhead	2012	5	0.072	0.050	0.110	0.100
SD-BS-L-MINNEWASTA_01	Black Crappie	2012	5	0.170	0.120	0.190	0.190
SD-BS-L-MINNEWASTA_01	Walleye	2012	5	0.980	0.310	1.560	1.380
SD-BS-L-MINNEWASTA_01	White Bass	2012	5	0.656	0.450	0.820	0.805
SD-BS-L-SINAI_01	Black Crappie	2012	10	0.182	0.100	0.250	0.210
SD-BS-L-SINAI_01	Walleye	2012	10	0.410	0.220	1.220	0.425
SD-BS-L-WALL_01	Black Bullhead	2012	5	0.062	0.030	0.100	0.095
SD-BS-L-WALL_01	Black Crappie	2012	5	0.080	0.070	0.090	0.085
SD-BS-L-WALL_01	Bluegill	2012	5	0.068	0.060	0.090	0.080
SD-BS-L-WALL_01	Channel Catfish	2012	5	0.056	0.040	0.090	0.075

SD-BS-R-BIG_SIOUX_07	Channel Catfish	2012	5	0.254	0.150	0.380	0.340
SD-BS-R-BIG_SIOUX_07	Common Carp	2012	5	0.164	0.050	0.230	0.225
SD-BS-R-BIG_SIOUX_07	Shorthead Redhorse	2012	5	0.252	0.140	0.420	0.360
SD-BS-R-BIG_SIOUX_07	Walleye	2012	4	0.603	0.370	0.740	0.740
SD-CH-L-DEERFIELD_01	Rainbow Trout	2012	5	0.038	0.030	0.050	0.045
SD-CH-L-DEERFIELD_01	Rock Bass	2012	5	0.118	0.100	0.150	0.135
SD-CH-L-DEERFIELD_01	White Sucker	2012	5	0.062	0.040	0.080	0.075
SD-CH-L-DEERFIELD_01	Yellow Perch	2012	5	0.110	0.090	0.150	0.130
SD-CH-L-SHERIDAN_01	Black Bullhead	2012	4	0.070	0.020	0.140	0.140
SD-CH-L-SHERIDAN_01	Black Crappie	2012	8	0.146	0.100	0.180	0.180
SD-CH-L-SHERIDAN_01	green sunfish	2012	2	0.095	0.070	0.120	0.120
SD-CH-L-SHERIDAN_01	Largemouth Bass	2012	10	0.359	0.190	0.470	0.435
SD-CH-L-SHERIDAN_01	Northern Pike	2012	2	0.135	0.110	0.160	0.160
SD-CH-L-SHERIDAN_01	Yellow Perch	2012	14	0.182	0.110	0.380	0.250
SD-CH-R-RAPID_05	Brown Trout	2012	5	0.046	0.040	0.050	0.050
SD-CH-R-RAPID_05	creek chub	2012	4	0.055	0.040	0.080	0.080
SD-CH-R-RAPID_05	White Sucker	2012	5	0.122	0.050	0.200	0.190
SD-JA-L-CATTAIL_01	Northern Pike	2012	10	0.239	0.120	0.490	0.320
SD-JA-L-CATTAIL_01	Walleye	2012	11	0.255	0.080	0.420	0.320
SD-JA-L-ELM_01	Black Crappie	2012	10	0.207	0.150	0.340	0.225
SD-JA-L-ELM_01	Walleye	2012	10	0.496	0.200	1.130	0.805
SD-JA-L-LILY_01	Northern Pike	2012	5	0.442	0.380	0.480	0.480
SD-JA-L-LILY_01	Walleye	2012	5	0.338	0.250	0.430	0.400
SD-JA-L-LILY_01	Yellow Perch	2012	5	0.284	0.200	0.400	0.395
SD-JA-L-STAUM_01	Black Bullhead	2012	11	0.136	0.030	0.340	0.190
SD-JA-L-STAUM_01	Largemouth Bass	2012	10	0.400	0.160	0.670	0.580
SD-LM-R-LITTLE_MISSOURI_01	Channel Catfish	2012	1	0.060	0.060	0.060	0.060
SD-LM-R-LITTLE_MISSOURI_01	Goldeye	2012	5	0.406	0.260	0.530	0.495
SD-LM-R-LITTLE_MISSOURI_01	River Carpsucker	2012	2	0.120	0.060	0.180	0.180
SD-LM-R-LITTLE_MISSOURI_01	Sauger	2012	20	0.470	0.150	1.120	0.645
SD-MI-L-BRAKKE_01	Northern Pike	2012	4	0.623	0.580	0.700	0.700
SD-MI-L-BRAKKE_01	Yellow Perch	2012	4	0.170	0.110	0.270	0.270
SD-MI-L-COTTONWOOD_01	Walleye	2012	10	0.683	0.580	0.970	0.735
SD-MI-L-COTTONWOOD_01	Yellow Perch	2012	10	0.248	0.190	0.350	0.295
SD-MI-L-TWIN_01	Bluegill	2012	5	0.174	0.150	0.210	0.200
SD-MI-L-TWIN_01	White Sucker	2012	3	0.140	0.100	0.220	0.220
SD-MI-L-TWIN_01	Yellow Perch	2012	5	0.202	0.150	0.300	0.265
SD-MI-R-LEWIS_AND_CLARK_01	Channel Catfish	2012	10	0.105	0.070	0.140	0.125
SD-MI-R-LEWIS_AND_CLARK_01	Freshwater Drum	2012	10	0.317	0.130	0.730	0.435
SD-VM-L-E_VERMILLION_01	Northern Pike	2012	10	0.508	0.270	0.690	0.650
SD-VM-L-E_VERMILLION_01	Walleye	2012	21	0.397	0.070	1.050	0.530
SD-VM-L-THOMPSON_01	Black Crappie	2012	10	0.170	0.100	0.320	0.205
SD-VM-L-THOMPSON_01	Northern Pike	2012	10	0.368	0.190	0.640	0.460
SD-VM-L-THOMPSON_01	Walleye	2012	10	0.261	0.130	0.340	0.315
SD-BF-R-BELLE_FOURCHE_04	Channel Catfish	2013	10	0.231	0.150	0.440	0.280
SD-BF-R-BELLE_FOURCHE_04	River Carpsucker	2013	9	0.133	0.060	0.210	0.180
SD-BF-R-BELLE_FOURCHE_05	Channel Catfish	2013	5	0.146	0.070	0.190	0.180
SD-BF-R-BELLE_FOURCHE_05	River Carpsucker	2013	5	0.092	0.060	0.150	0.125
SD-BS-L-ALVIN_01	Black Bullhead	2013	10	0.056	0.040	0.070	0.065
SD-BS-L-ALVIN_01	Black Crappie	2013	10	0.172	0.070	0.240	0.235
SD-BS-L-ALVIN_01	Channel Catfish	2013	10	0.123	0.030	0.210	0.205
SD-BS-L-BITTER_01	Northern Pike	2013	10	0.892	0.740	1.040	0.995
SD-BS-L-BITTER_01	Walleye	2013	10	1.000	0.360	1.780	1.260
SD-BS-L-BITTER_01	Yellow Perch	2013	10	0.242	0.140	0.360	0.315
SD-BS-L-CAMPBELL_01	Channel Catfish	2013	10	0.127	0.050	0.180	0.165
SD-BS-L-CAMPBELL_01	Northern Pike	2013	6	0.138	0.030	0.290	0.230

SD-BS-L-CAMPBELL_01	White Bass	2013	10	0.137	0.110	0.230	0.155
SD-BS-L-CLEAR_D_01	Black Bullhead	2013	15	0.040	0.030	0.090	0.040
SD-BS-L-CLEAR_D_01	Walleye	2013	15	0.183	0.080	0.460	0.215
SD-BS-L-CLEAR_D_01	Yellow Perch	2013	15	0.055	0.030	0.090	0.070
SD-BS-L-DRY_01	Northern Pike	2013	10	0.272	0.070	0.380	0.325
SD-BS-L-DRY_01	Walleye	2013	10	0.137	0.070	0.240	0.195
SD-BS-L-DRY_01	Yellow Perch	2013	10	0.037	0.020	0.070	0.060
SD-BS-L-GOLDSMITH_01	Black Bullhead	2013	17	0.053	0.020	0.160	0.060
SD-BS-L-GOLDSMITH_01	Walleye	2013	25	0.189	0.050	0.650	0.300
SD-BS-L-GOLDSMITH_01	White Bass	2013	19	0.441	0.180	0.540	0.500
SD-BS-L-GOOSE_01	Black Bullhead	2013	16	0.122	0.070	0.190	0.160
SD-BS-L-GOOSE_01	Walleye	2013	18	0.452	0.220	0.700	0.620
SD-BS-L-GOOSE_01	Yellow Perch	2013	15	0.147	0.080	0.270	0.175
SD-JA-L-LARDY_01	Northern Pike	2013	15	0.483	0.330	0.960	0.550
SD-JA-L-LARDY_01	Walleye	2013	15	0.587	0.210	1.050	0.800
SD-JA-L-LARDY_01	Yellow Perch	2013	15	0.091	0.050	0.190	0.110
SD-BS-L-LONG_COD_01	Walleye	2013	15	0.713	0.180	1.110	0.970
SD-BS-L-LONG_COD_01	Yellow Perch	2013	15	0.240	0.130	0.390	0.340
SD-JA-L-MID_LYNN_01	Black Bullhead	2013	10	0.060	0.040	0.090	0.080
SD-JA-L-MID_LYNN_01	Walleye	2013	10	0.906	0.660	1.450	1.095
SD-JA-L-MID_LYNN_01	Yellow Perch	2013	10	0.430	0.190	0.720	0.590
SD-BS-L-MINNEWASTA_01	Northern Pike	2013	11	0.418	0.270	0.940	0.410
SD-BS-L-MINNEWASTA_01	Walleye	2013	9	0.312	0.220	0.600	0.320
SD-BS-L-SWAN_01	Northern Pike	2013	10	0.572	0.400	1.040	0.635
SD-BS-L-SWAN_01	Walleye	2013	10	0.711	0.440	1.150	1.010
SD-BS-L-SWAN_01	Yellow Perch	2013	9	0.267	0.150	0.340	0.320
SD-BS-L-W_OAKWOOD_01	Northern Pike	2013	10	0.107	0.030	0.270	0.180
SD-BS-L-W_OAKWOOD_01	Walleye	2013	8	0.088	0.030	0.280	0.100
SD-BS-L-W_OAKWOOD_01	White Sucker	2013	10	0.031	0.020	0.080	0.040
SD-CH-R-CHEYENNE_0?	Bluegill	2013	5	0.038	0.020	0.070	0.055
SD-CH-R-CHEYENNE_0?	Channel Catfish	2013	5	0.078	0.070	0.080	0.080
SD-CH-R-CHEYENNE_0?	Largemouth Bass	2013	5	0.086	0.040	0.130	0.125
SD-CH-R-CHEYENNE_05	Bluegill	2013	10	0.038	0.020	0.060	0.055
SD-CH-R-CHEYENNE_05	Channel Catfish	2013	4	0.193	0.040	0.540	0.540
SD-CH-R-CHEYENNE_05	Largemouth Bass	2013	8	0.063	0.020	0.150	0.130
SD-GR-L-PUDWELL_01	Black Bullhead	2013	1	1.080	1.080	1.080	1.080
SD-GR-L-PUDWELL_01	Black Crappie	2013	9	0.540	0.300	0.990	0.700
SD-GR-L-PUDWELL_01	Largemouth Bass	2013	20	0.666	0.470	0.940	0.775
SD-GR-L-PUDWELL_01	Northern Pike	2013	10	0.511	0.340	0.690	0.610
SD-JA-L-CARTHAGE_01	Black Bullhead	2013	10	0.076	0.060	0.120	0.085
SD-JA-L-CARTHAGE_01	Channel Catfish	2013	10	0.174	0.040	0.530	0.235
SD-JA-L-COTTONWOOD_01	Black Crappie	2013	15	0.200	0.090	0.430	0.275
SD-JA-L-COTTONWOOD_01	Northern Pike	2013	15	0.463	0.300	0.680	0.525
SD-JA-L-COTTONWOOD_01	Walleye	2013	15	0.248	0.120	0.490	0.400
SD-JA-L-HENRY_01	Black Crappie	2013	14	0.169	0.120	0.330	0.180
SD-JA-L-HENRY_01	Common Carp	2013	5	0.082	0.060	0.130	0.105
SD-JA-L-HENRY_01	Largemouth Bass	2013	14	0.324	0.240	0.470	0.410
SD-JA-L-LOUISE_01	Black Bullhead	2013	10	0.258	0.080	0.660	0.570
SD-JA-L-LOUISE_01	Largemouth Bass	2013	20	0.599	0.420	0.800	0.715
SD-JA-L-LOUISE_01	Northern Pike	2013	10	0.350	0.260	0.470	0.420
SD-JA-L-RAVINE_01	Channel Catfish	2013	15	0.466	0.330	0.700	0.540
SD-JA-L-RAVINE_01	Common Carp	2013	15	0.147	0.040	0.300	0.205
SD-JA-L-RAVINE_01	Northern Pike	2013	9	0.310	0.150	0.400	0.400
SD-JA-R-JAMES_08	Channel Catfish	2013	12	0.407	0.150	1.130	0.590
SD-JA-R-JAMES_08	Northern Pike	2013	9	0.579	0.190	0.990	0.900
SD-JA-R-JAMES_08	Walleye	2013	10	0.519	0.140	0.890	0.720

SD-MN-L-ALICE_01	Northern Pike	2013	10	0.250	0.170	0.370	0.295
SD-MN-L-ALICE_01	Walleye	2013	10	0.341	0.240	0.830	0.360
SD-MN-L-ALICE_01	Yellow Perch	2013	10	0.159	0.030	0.250	0.245
SD-MU-L-LITTLE_MOREAU_NO1_01	Bluegill	2013	10	0.184	0.130	0.230	0.225
SD-MU-L-LITTLE_MOREAU_NO1_01	Northern Pike	2013	11	0.578	0.240	0.840	0.780
NoAUID-FFWhitewoodCr-SDDOH	Brown Trout	2014	10	0.077	0.060	0.100	0.085
SD-BA-L-HAYES_01	Black Bullhead	2014	10	0.109	0.020	0.180	0.165
SD-BA-L-HAYES_01	Bluegill	2014	10	0.062	0.030	0.090	0.080
SD-BA-L-HAYES_01	Northern Pike	2014	7	0.273	0.160	0.410	0.370
SD-BA-L-WAGGONER_01	Bluegill	2014	10	0.065	0.020	0.140	0.110
SD-BA-L-WAGGONER_01	Largemouth Bass	2014	10	0.185	0.110	0.400	0.225
SD-BA-L-WAGGONER_01	Northern Pike	2014	4	0.108	0.050	0.190	0.190
SD-BS-L-ALBERT_01	black Bullhead	2014	15	0.099	0.040	0.130	0.125
SD-BS-L-ALBERT_01	Northern Pike	2014	15	0.378	0.170	0.690	0.475
SD-BS-L-ALBERT_01	Walleye	2014	13	0.360	0.130	0.650	0.430
SD-BS-L-CLEAR_H_01	Black Bullhead	2014	15	0.038	0.020	0.060	0.050
SD-BS-L-CLEAR_H_01	Walleye	2014	15	0.211	0.110	0.440	0.355
SD-BS-L-CLEAR_H_01	Yellow Perch	2014	15	0.044	0.030	0.070	0.050
SD-BS-L-KAMPESKA_01	Black Bullhead	2014	10	0.099	0.050	0.180	0.145
SD-BS-L-KAMPESKA_01	Walleye	2014	10	0.187	0.110	0.370	0.275
SD-BS-L-KAMPESKA_01	White Bass	2014	10	0.369	0.190	0.430	0.425
SD-BS-L-POINSETT_01	Black Bullhead	2014	15	0.099	0.030	0.160	0.135
SD-BS-L-POINSETT_01	Smallmouth Bass	2014	15	0.351	0.250	0.510	0.420
SD-BS-L-POINSETT_01	Walleye	2014	15	0.405	0.260	0.700	0.525
SD-BS-L-WAUBAY_01	Northern Pike	2014	15	0.403	0.150	0.740	0.530
SD-BS-L-WAUBAY_01	Walleye	2014	15	0.214	0.060	0.630	0.320
SD-BS-L-WAUBAY_01	Yellow Perch	2014	15	0.036	0.020	0.080	0.060
SD-CH-L-ANGOSTURA_01	Channel Catfish	2014	10	0.105	0.060	0.230	0.130
SD-CH-L-ANGOSTURA_01	Smallmouth Bass	2014	10	0.089	0.070	0.110	0.100
SD-CH-L-ANGOSTURA_01	Walleye	2014	10	0.072	0.040	0.130	0.100
SD-JA-L-HANSON_01	Black Crappie	2014	15	0.243	0.070	0.680	0.370
SD-JA-L-HANSON_01	Common Carp	2014	15	0.123	0.020	0.360	0.195
SD-JA-L-HANSON_01	Largemouth Bass	2014	11	0.446	0.130	0.760	0.650
SD-JA-L-HAZELDON_01	Black Bullhead	2014	20	0.055	0.020	0.190	0.060
SD-JA-L-HAZELDON_01	Walleye	2014	16	0.634	0.130	1.620	1.210
SD-JA-L-HAZELDON_01	Yellow Perch	2014	20	0.123	0.050	0.180	0.165
SD-JA-L-LYNN_01	Northern Pike	2014	5	0.828	0.740	0.940	0.920
SD-JA-L-LYNN_01	Walleye	2014	10	0.920	0.270	1.830	1.155
SD-JA-L-LYNN_01	Yellow Perch	2014	10	0.226	0.170	0.440	0.230
SD-JA-L-RICHMOND_01	Black Crappie	2014	10	0.184	0.100	0.340	0.255
SD-JA-L-RICHMOND_01	Bluegill	2014	10	0.270	0.100	0.400	0.370
SD-JA-L-RICHMOND_01	Walleye	2014	10	0.425	0.190	0.800	0.730
SD-MI-L-HIDDENWOOD_01	Black Bullhead	2014	24	0.085	0.030	0.160	0.120
SD-MI-L-HIDDENWOOD_01	White Sucker	2014	20	0.060	0.030	0.160	0.085
SD-MI-R-OAHE_01	Channel Catfish	2014	19	0.207	0.090	0.480	0.260
SD-MI-R-OAHE_01	Common Carp	2014	20	0.191	0.100	0.360	0.230
SD-MN-L-SUMMIT_01	Northern Pike	2014	20	0.381	0.280	0.540	0.440
SD-MN-L-SUMMIT_01	Walleye	2014	20	0.200	0.090	0.410	0.340
SD-MN-L-SUMMIT_01	Yellow Perch	2014	10	0.075	0.060	0.090	0.090
SD-VM-L-HENRY_01	Black Bullhead	2014	15	0.145	0.070	0.260	0.210
SD-VM-L-HENRY_01	Northern Pike	2014	15	0.435	0.150	0.990	0.645
SD-VM-L-HENRY_01	Walleye	2014	15	0.287	0.130	0.610	0.445

Appendix E. NPDES Permitted Discharge Facilities in South Dakota

Permit	Facility	City	Lat	Long
SD0024007	KEYSTONE, TOWN OF	KEYSTONE	43.891321	-103.391309
SD0021512	BRIDGEWATER - CITY OF	BRIDGEWATER	43.539056	-97.513667
SD0022128	SIOUX FALLS WATER RECLAMATION PLANT	SIOUX FALLS	43.595252	-96.65977
SD0023574	RAPID CITY WATER RECLAMATION FACILITY	RAPID CITY	44.016667	-103.1
SD0024767	EVANS PLUNGE (HOT SPRINGS, CITY OF)	HOT SPRINGS	43.441646	-103.480196
SD0023779	TROUT HAVEN RANCH	BUFFALO GAP	43.526651	-103.362974
SDG860058	SPEARFISH WTP	SPEARFISH	44.489022	-103.860213
SD0000060	SD GFP CLEGHORN FISH HATCHERY	RAPID CITY	44.058905	-103.297687
SD0000191	SD DEPT GF and P - MCNENNY NFH	SPEARFISH	44.560028	-104.008833
SD0023388	BROOKINGS - CITY OF	BROOKINGS	44.244361	-96.806361
SD0022659	MILLER - CITY OF	MILLER	44.517004	-98.989261
SD0023370	WATERTOWN - CITY OF	WATERTOWN	44.900055	-97.111086
SD0020702	ABERDEEN WWT	ABERDEEN	45.46327	-98.4866
SD0023361	MITCHELL - CITY OF - LANDFILL	MITCHELL	43.670444	-97.966139
SD0000043	SD SCIENCE AND TECHNOLOGY AUTHORITY	LEAD	44.355262	-103.754643
SD0000078	JOHN MORRELL and CO	SIOUX FALLS	43.5634	-96.7188
SD0026905	GOLDEN REWARD MINING CO LTD	LEAD	44.325818	-103.800478
SD0026361	US ARMY CORPS OF ENGINEERS BIG BEND POWER PLANT	FORT THOMPSON	44.06	-99.454167
SD0023396	YANKTON - CITY OF	YANKTON	42.866387	-97.381726
SD0020796	LEAD-DEADWOOD SANITARY DISTRICT	DEADWOOD	44.387444	-103.710556
SD0020176	PIERRE WWTP	PIERRE	44.345889	-100.320028
SD0000051	EVERIST, L.G. INC.	SIOUX FALLS	43.819111	-96.691111
SD0025186	BOX ELDER -CITY OF	BOX ELDER	44.105821	-102.995452
SD0020044	SPEARFISH	SPEARFISH	44.48527	-103.85202
SD0026883	LAC MINERALS	LEAD	44.374984	-103.858814
SD0025798	SAINT JOSEPH INDIAN ELEMENTARY SCHOOL	CHAMBERLAIN	43.828111	-99.323833
SD0020061	VERMILLION, CITY OF	VERMILLION	42.762472	-96.918361
SD0000027	GCC DACOTAH	RAPID CITY	44.0896	-103.271663
SD0021024	WILMOT - CITY OF	WILMOT	45.410417	-96.845361
SD0020192	EAGLE BUTTE- CITY OF	EAGLE BUTTE	45.007472	-101.257056
SD0020648	US ARMY CORPS OF ENGINEERS - FORT RANDALL PROJECT	PICKSTOWN	43.064306	-98.553667
SD0000281	US DOD USAF ELLSWORTH AFB	ELLSWORTH AFB	44.14806	-103.0958
SD0023400	BUFFALO- TOWN OF	BUFFALO	45.576028	-103.535139
SD0020371	MILBANK WASTEWATER TRMT PLNT	MILBANK	45.229409	-96.59117
SDG860003	WEB WATER TREATMENT FACILITY	MOBRIDGE	45.436083	-100.227639
SD0022918	HOT SPRINGS, CITY OF	HOT SPRINGS	43.404675	-103.436619
SD0027987	VALLEY QUEEN CHEESE FACTORY	MILBANK	45.221361	-96.637306
SD0025933	HOMESTAKE MINING CO - OPEN CUT	CENTRAL CITY	44.36304	-103.761309
SD0020079	BERESFORD, CITY OF	BERESFORD	43.096357	-96.777966

SD0026816	ABE SOUTH DAKOTA LLC	ABERDEEN	45.459762	-98.550068
SD0023281	CUSTER, CITY OF	CUSTER	43.767749	-103.598918
SD0020028	CITY OF MOBRIDGE WWT PLANT	MOBRIDGE	45.53438	-100.432282
SD0028380	NUGEN ENERGY	MARION	43.432639	-97.26088
SD0027928	HIGMAN SAND and GRAVEL	SPINK	44.74619	-98.29122
SD0023698	CHAMBERLAIN, CITY OF	CHAMBERLAIN	43.796911	-99.344628
SD0027898	VALERO RENEWABLE FUELS LLC	AURORA	44.297222	-96.717222
SD0021784	TEA - CITY OF	TEA	43.44572	-96.836368
SD0000299	USGS - EROS DATA CENTER	SIOUX FALLS	43.737611	-96.620694
SD0021768	LENNOX - CITY OF	LENNOX	43.343314	-96.907828
SDG820869	FRANKFORT - CITY OF	FRANKFORT	44.865268	-98.310878
SD0021539	CLARK, CITY OF	CLARK	44.862583	-97.725333
SD0025852	WHARF RESOURCES	LEAD	44.34444	-103.86166
SD0023582	FT PIERRE - CITY OF	FT PIERRE	44.354911	-100.373868
SD0020567	NORTH SIOUX CITY, CITY OF	NORTH SIOUX CITY	42.5415	-96.530056
SD0027847	DAKOTA ETHANOL LLC	WENTWORTH	43.976389	-96.95333
SD0020184	WAGNER, CITY OF	WAGNER	43.085833	-98.280556
SD0020885	HILL CITY - CITY OF	HILL CITY	43.935444	-103.557278
SD0024279	SD DEPT GF and P - SYLVAN LAKE	CUSTER	43.8375	-103.571944
SD0021920	VOLGA - CITY OF	VOLGA	44.320278	-96.893972
SD0020354	PLATTE, CITY OF	PLATTE	43.385642	-98.878717
SD0028509	ABERDEEN ENERGY LLC	MINA	45.443889	-98.789167
SD0020753	ARLINGTON - CITY OF	ARLINGTON	44.365222	-97.113778
SD0021750	HARTFORD - CITY OF	HARTFORD	43.611005	-96.935377
SD0028193	REDFIELD ENERGY	REDFIELD	44.919167	-98.502222
SD0027758	SUMMERSET, CITY OF	SUMMERSET	44.210278	-103.358028
SD0022535	BRANDON - CITY OF	BRANDON	43.599056	-96.594722
SD0022080	ELK POINT, CITY OF	ELK POINT	42.67447	-96.706148
SD0028614	WATERTOWN - CITY OF	WATERTOWN	44.900055	-97.111086
SD0020311	MARION, CITY OF	MARION	43.440833	-97.238056
SD0020699	CLEAR LAKE, CITY OF	CLEAR LAKE	44.751163	-96.668542
SD0022489	CANTON, CITY OF	CANTON	43.298694	-96.56375
SD0022519	IPSWICH, CITY OF	IPSWICH	45.447472	-99.024854
SD0026794	USCOE - OAHE DAM	PIERRE	44.525971	-100.423788
SD0022551	COLMAN, CITY OF	COLMAN	43.97729	-96.82774
SD0022853	SCOTLAND, CITY OF	SCOTLAND	43.1455	-97.707
SD0022021	PARKSTON - CITY OF	PARKSTON	43.39472	-97.98818
SDG860047	RANDALL COMMUNITY WATER DIST.	LAKE ANDES	43.073028	-98.526611
SD0022900	HERREID - CITY OF	HERREID	45.826167	-100.084583
SD0022705	LANGFORD, TOWN OF	LANGFORD	45.597167	-97.803417
SD0020923	VALLEY SPRINGS - CITY OF	VALLEY SPRINGS	43.583222	-96.481417

SD0022772	KIMBALL - CITY OF	KIMBALL	43.743333	-98.931306
SD0028606	BEEF PRODUCTS, INC.	DAKOTA DUNES	42.508333	-96.476389
SDG860028	AURORA-BRULE RWS INC	KIMBALL	43.746886	-98.960896
SD0020737	OACOMA - TOWN OF	OACOMA	43.799861	-99.376428
SD0027855	RED RIVER ENERGY LLC	ROSHOLT	45.849959	-96.717019
SD0021695	ALCESTER- CITY OF	ALCESTER	43.032917	-96.6575
SD0021466	WHITEWOOD - CITY OF	WHITEWOOD	44.468028	-103.625528
SD0022004	LAKE ANDES - CITY OF	LAKE ANDES	43.134762	-98.553135
SD0020133	TYNDALL - CITY OF	TYNDALL	42.966694	-97.854833
SD0000094	PETE LIEN and SONS INC	RAPID CITY	44.11437	-103.277238
SD0020125	WAUBAY - CITY OF	WAUBAY	45.314861	-97.290833
SD0021571	TORONTO - TOWN OF	TORONTO	44.569056	-96.630028
SD0021610	U.S. NATL PARK SERVICE MOUNT RUSHMORE NMEM	KEYSTONE	43.87971	-103.451858
SD0028011	CLAY RURAL WATER SYSTEM - WYNS	NORTH SIOUX CITY	42.519996	-96.561421
SD0028576	MYRL and ROY'S PAVING, INC.	SIOUX FALLS	43.518786	-96.575789
SD0027588	ARCTIC ICE COMPANY	NORTH SIOUX CITY	42.532028	-96.497361
SD0022799	ONIDA, CITY OF	ONIDA	44.702472	-100.088194
SD0025437	T and R ELECTRIC SUPPLY COMPANY	COLMAN	43.980041	-96.825136
SD0021474	WORTHING - TOWN OF	WORTHING	43.325389	-96.77525
SD0021971	FAULKTON - CITY OF	FAULKTON	45.042361	-99.107111
SD0026310	USGS FIELD RESEARCH STATION	YANKTON	42.869028	-97.478611
SD0022322	COLTON - CITY OF	COLTON	43.786	-96.941639
SD0023434	HURON - CITY OF	HURON	44.35626	-98.235483
SD0025810	DAIRI CONCEPTS	POLLOCK	45.898605	-100.285957
SD0020460	WESSINGTON SPRINGS, CITY OF	WESSINGTON SPRINGS	44.095463	-98.559754
SD0022438	IROQUOIS, CITY OF	IROQUOIS	44.355194	-97.847361
SD0020974	SINAI - CITY OF	SINAI	44.227306	-97.047306
SD0023701	EDGEMONT- CITY OF	EDGEMONT	43.304056	-103.807833
SD0022187	GROTON - CITY OF	GROTON	45.433689	-98.084842
SD0020443	STAR ACADEMY, WEST CAMPUS (BIOSOLIDS)	CUSTER	43.702083	-103.600528
SDG860026	MADISON MUNICIPAL WATER SYSTEM	MADISON	44.005068	-97.114224
SDG860011	CITY OF VERMILLION CODE COMPLIANCE DEPT	VERMILLION	42.779677	-96.93206
SDG860032	PIERRE WATER DEPARTMENT	PIERRE	44.357611	-100.32882
SD0020087	MENNO, CITY OF	MENNO	43.227944	-97.592889
SD0027910	POET BIOREFINING	GROTON	45.453963	-98.137741
SD0020036	ROSCOE, CITY OF	ROSCOE	45.437694	-99.319333
SDG860001	BIG SIOUX COMMUNITY WATER SYSTEM	EGAN	44.059682	-96.969194
SD0025194	ASTORIA- TOWN OF	ASTORIA	44.566611	-96.541306
SD0027464	HURON WATER TREATMENT PLANT	HURON	44.353333	-98.194444
SD0020401	WINNER- CITY OF	WINNER	43.3755	-99.855131

SD0023639	CHANCELLOR - TOWN OF	CHANCELLOR	43.370361	-96.996722
SD0022802	ROSLYN - TOWN OF	ROSLYN	45.49925	-97.502222
SD0028436	MIDWEST RAILCAR REPAIR, INC.	BRANDON	43.625	-96.575278
SD0027871	BLACK HILLS POWER - LCTF	RAPID CITY	44.120278	-103.26
SD0020788	ELKTON, CITY OF	ELKTON	44.225306	-96.504278
SD0025313	SD DOT	ABERDEEN	45.907792	-96.859056
SD0025917	VISHAY-DALE ELECTRONICS	YANKTON	42.876235	-97.37116
SD0020834	USFS - BOXELDER JCCCC	NEMO	44.209167	-103.546472
SD0020605	DOLAND, CITY OF	DOLAND	44.90725	-98.097944
SD0025861	CITATION OIL and GAS CORPORATION	BUFFALO	45.71	-103.421389
SD0024244	SD DEPT GF and P - GAME LODGE	CUSTER	43.744103	-103.364373
SD0023230	COLOME - CITY OF	COLOME	43.254814	-99.704545
SD0021636	WHITE - CITY OF	WHITE	44.427167	-96.665944
SD0022101	DELL RAPIDS, CITY OF	DELL RAPIDS	43.812	-96.735417
SDG860045	WATERTOWN WTP	WATERTOWN	44.89742	-97.13172
SD0027685	RAPID CITY REGIONAL LANDFILL	RAPID CITY	44.031222	-103.196222
SDG860021	SIOUX FALLS WATER PURIFICATION PLANT	SIOUX FALLS	43.5715	-96.73044
SD0021962	CORSICA, CITY OF	CORSICA	43.41055	-98.401699
SD0026662	LABOLT, TOWN OF	LABOLT	45.050988	-96.668563
SD0021491	STICKNEY, TOWN OF	STICKNEY	43.597572	-98.435888
SD0020761	CROOKS - CITY OF	CROOKS	43.653369	-96.833604
SD0026514	LAKE COCHRANE SANITARY DIST	GARY	44.702917	-96.461722
SD0027481	LEAD, CITY OF	LEAD	44.355731	-103.754319
SD0028568	DACOTAH BANK	BROOKINGS	44.311389	-96.781667
SDG589401	WEST BRULE LAGOON (NORTH)	LOWER BRULE	44.075972	-99.6315
SD0022063	WHITE RIVER - CITY OF	WHITE RIVER	43.5735	-100.755694
SD0027251	NW 1/4 OF SECTION 2, T103N,	MITCHELL	43.68415	-97.94563
SD0026832	SOUTH DAKOTA STATE UNIVERSITY	BROOKINGS	44.318639	-96.779028
NDG589301	MCLAUGHLIN, CITY OF	MCLAUGHLIN	45.817778	-100.824444
SD0000141	BLACK HILLS CORP - BEN FRENCH POWER PLANT	RAPID CITY	44.089222	-103.265194
SD0000183	BIRDSALL SAND and GRAVAL CO	RAPID CITY	43.413472	-103.263194
SD0000264	NORTHERN STATES POWER-PATHFIND	SIOUX FALLS	43.596536	-96.644689
SD0020109	NISLAND WWTP	NISLAND	44.671556	-103.547028
SD0020117	PRESHO, CITY OF	PRESHO	43.906889	-100.043778
SD0020168	POLLOCK CITY OF WWTP	POLLOCK	45.904111	-100.298722
SD0020222	ARMOUR, CITY OF	ARMOUR	43.316899	-98.346614
SD0020231	RELIANCE - TOWN OF	RELIANCE	43.881083	-99.591528
SD0020257	WAKONDA , TOWN OF	WAKONDA	43.001889	-97.101778
SD0020303	PHILIP - CITY OF	PHILIP	44.035861	-101.653389
SD0020338	CHESTER SANITARY DISTRICT	CHESTER	43.898888	-96.931389
SD0020346	WALL - CITY OF	WALL	43.996514	-102.227981

SD0020389	WARNER	WARNER	45.320361	-98.500917
SD0020486	MOUNT VERNON - CITY OF	MT. VERNON	43.724382	-98.255885
SD0020494	NEWELL - CITY OF	NEWELL	44.724167	-103.415278
SD0020524	ROSHOLT - TOWN OF	ROSHOLT	45.875193	-96.725848
SD0020575	GETTYSBURG WWT FACILITIES	GETTYSBURG	44.995167	-99.959639
SD0020613	HOWARD, CITY OF	HOWARD	43.998722	-97.521194
SD0020672	MELLETTE , CITY OF	MELLETTE	45.158989	-98.491404
SD0020818	MURDO - CITY OF	MURDO	43.875389	-100.709472
SD0020826	SISSETON CITY OF	SISSETON	45.688015	-96.997859
SD0020851	EUREKA, CITY OF	EUREKA	45.758001	-99.651727
SD0020877	GLENHAM - TOWN OF	GLENHAM	45.53025	-100.275556
SD0020931	NEW EFFINGTON, TOWN OF	NEW EFFINGTON	45.8665	-96.918111
SD0020940	PARKER, CITY OF	PARKER	43.408101	-97.124745
SD0020958	PLANKINTON - CITY OF	PLANKINTON	43.718583	-98.466861
SD0020966	SALEM - CITY OF	SALEM	43.72754	-97.38738
SD0020982	ST. LAWRENCE, TOWN OF	ST. LAWRENCE	44.523083	-98.935389
SD0021016	WHITE LAKE - CITY OF	WHITE LAKE	43.725493	-98.732065
SD0021547	CONDE, TOWN OF	CONDE	45.162194	-98.100389
SD0021555	BRYANT- CITY OF	BRYANT	44.583611	-97.4525
SD0021661	AURORA- CITY OF	AURORA	44.279806	-96.696944
SD0021717	SELBY - CITY OF	SELBY	45.500472	-100.040222
SD0021741	EMERY, CITY OF	EMERY	43.613917	-97.614861
SD0021776	LETCHER - TOWN OF	LETCHER	43.904028	-98.133556
SD0021806	CAVOUR - TOWN OF	CAVOUR	44.367306	-98.0425
SD0021831	FLANDREAU, CITY OF	FLANDREAU	44.032778	-96.615
SD0021989	HIGHMORE, CITY OF	HIGHMORE	44.532361	-99.425472
SD0022047	SPRINGFIELD - CITY OF	SPRINGFIELD	42.854204	-97.892625
SD0022110	FREEMAN - CITY OF	FREEMAN	43.365167	-97.485694
SD0022144	ESTELLINE - CITY OF	ESTELLINE	44.573577	-96.913951
SD0022152	FREDERICK- TOWN OF	FREDERICK	45.828714	-98.508497
SD0022161	GAYVILLE, TOWN OF	GAYVILLE	42.887611	-97.175194
SD0022179	GREGORY- CITY OF___________(E)	GREGORY	43.201472	-99.421028
SD0022209	TABOR - TOWN OF	TABOR	42.954429	-97.653206
SD0022276	ASHTON, CITY OF	ASHTON	44.990028	-98.4825
SD0022284	BALTIC, CITY OF	BALTIC	43.755806	-96.744583
SD0022314	CLAREMONT, TOWN OF	CLAREMONT	45.669722	-98.008333
SD0022349	HERMOSA - TOWN OF	HERMOSA	43.834222	-103.18175
SD0022357	KADOKA - CITY OF	KADOKA	43.848528	-101.518611
SD0022373	LESTERVILLE - TOWN OF	LESTERVILLE	43.037222	-97.6
SD0022403	TRIPP - CITY OF	TRIPP	43.233361	-97.946056
SD0022454	IRENE - CITY OF	IRENE	43.073917	-97.1615

SD0022497	CANISTOTA, CITY OF	CANISTOTA	43.592194	-97.322361
SD0022527	CENTERVILLE- CITY OF	CENTERVILLE	43.118333	-96.969167
SD0022560	GARRETSON - CITY OF	GARRETSON	43.7035	-96.515
SD0022586	PUKWANA - TOWN OF	PUKWANA	43.783979	-99.184868
SD0022624	RAMONA - TOWN OF	RAMONA	44.125028	-97.215889
SD0022641	EDEN - TOWN OF	EDEN	45.609917	-97.420972
SD0022667	LEOLA - CITY OF	LEOLA	45.725694	-98.92225
SD0022730	AVON - CITY OF	AVON	43.012389	-98.068694
SD0022756	PEEVER - TOWN OF	PEEVER	45.544127	-96.948688
SD0022926	COLUMBIA - CITY OF	COLUMBIA	45.614278	-98.315472
SD0024228	SD DEPT. GF and P - BLUE BELL	CUSTER	43.77564	-103.42727
SD0024724	KRANZBURG - TOWN OF	KRANZBURG	44.888361	-96.906472
SD0024759	CAMP CROOK, TOWN OF	CAMP CROOK	45.550694	-103.968417
SD0026344	MINA LAKE SANITARY DISTRICT	MINA	45.461358	-98.734472
SD0026425	PRAIRIEWOOD SAN SEWER DISTRICT	ABERDEEN	45.509083	-98.429667
SD0026611	MISSION HILL, TOWN OF	MISSION HILL	42.915583	-97.295722
SD0026778	WALL LAKE SANITARY DISTRICT	HARTFORD	43.52258	-96.956143
SD0027227	ROCKY MOUNTAIN PIPELINE SYSTEM, LLC	RAPID CITY	44.0971	-103.16391
SD0027367	SOUTH DAKOTA SOYBEAN PROCESSORS	VOLGA	44.324969	-96.905892
SD0027456	COFFEE CUP FUEL STOPS	VERMILLION	42.784944	-96.793028
SD0027901	GREAT PLAINS ETHANOL, LLC	CHANCELLOR	43.371009	-96.961024
SD0027944	POET BIOREFINING - HUDSON	HUDSON	43.096722	-96.477778
SD0028053	NORTHVILLE - TOWN OF	NORTHVILLE	45.161365	-98.575096
SD0028134	SD SCIENCE AND TECHNOLOGY AUTHORITY	LEAD	44.353611	-103.744167
SD0028240	PRAIRIE ETHANOL LLC (DBA POET BIOREFINING) MITCHELL	MITCHELL	43.803409	-98.104912
SD0028274	COLLINS COLONY AQUACULTURE	IROQUOIS	44.545952	-97.703476
SD0028534	SUNSHINE BIBLE ACADEMY	MILLER	44.32867	-98.98414
SD0028611	SOUTH DAKOTA ELLSWORTH DEVELOPMENT AUTHORITY	BOX ELDER	44.10464	-102.99018
SDG589119	CITY OF TIMBER LAKE	TIMBER LAKE	45.431933	-101.061256
SDG589201	BIG BEND LAGOON SYSTEM FACILITY	FORT THOMPSON	44.213972	-99.789722
SDG589202	CROW CREEK LAGOON SYSTEM FACILITY	FORT THOMPSON	43.946133	-99.227989
SDG589203	FORT THOMPSON LAGOON SYSTEM	FORT THOMPSON	44.067407	-99.451774
SDG589205	FORT THOMPSON-EAST	FORT THOMPSON	44.070278	-99.402222
SDG589402	WEST BRULE LAGOON (SOUTH)	LOWER BRULE	44.06725	-99.639528
SDG589519	PRAIRIE WINDS CASINO WWTF	PINE RIDGE	43.18359	-102.988527
SDG589521	LONEMAN DAY SCHOOL	OGLALA	43.200844	-102.765984
SDG589602	BLACK PIPE, COMMUNITY OF	ROSEBUD	43.478556	-101.19475
SDG589603	HORSE CREEK, COMMUNITY OF	ROSEBUD	43.536806	-100.744667
SDG589605	COMMUNITY OF IDEAL WWTF	IDEAL	43.53775	-99.917083
SDG589612	TWO STRIKES	PARMELEE	43.189311	-100.888617
SDG589613	WHITE HORSE COMMUNITY OF	WHITE HORSE	43.297806	-100.605028

SDG589803	LAKE TRAVERSE UTILITY COMMISSION	AGENCY VILLAGE	45.566349	-97.056192
SDG589804	RED IRON HOUSING WWTP	AGENCY VILLAGE	45.683083	-97.335583
SDG589805	VEBLEN FLATS HOUSING WWTP	AGENCY VILLAGE	45.879333	-97.315056
SDG860066	CLARK RURAL WATER-KAMPESKA WTP	CLARK	45.006667	-97.178611

EPA REGION 8 TMDL REVIEW FORM AND DECISION DOCUMENT

TMDL Document Info:

Document Name:	**South Dakota Mercury Total Maximum Daily Load**
Submitted by:	**SD DENR**
Date Received:	**September 18, 2015**
Review Date:	**October 13, 2015**
Reviewer:	**Peter Brumm**
Rough Draft / Public Notice / Final Draft?	**Public Notice Draft**
Notes:	

Reviewers Final Recommendation(s) to EPA Administrator (used for final draft review only):

☐ Approve
☐ Partial Approval
☐ Disapprove
☐ Insufficient Information

Approval Notes to the Administrator:

This document provides a standard format for EPA Region 8 to provide comments to state TMDL programs on TMDL documents submitted to EPA for either formal or informal review. All TMDL documents are evaluated against the TMDL review elements identified in the following 8 sections:

1. Problem Description
    1.1. TMDL Document Submittal
    1.2. Identification of the Waterbody, Impairments, and Study Boundaries
    1.3. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis

4. TMDL Technical Analysis
    4.1. Data Set Description
    4.2. Waste Load Allocations (WLA)
    4.3. Load Allocations (LA)
    4.4. Margin of Safety (MOS)
    4.5. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

Under Section 303(d) of the Clean Water Act, waterbodies that are not attaining one or more water quality standard (WQS) are considered “impaired.” When the cause of the impairment is determined to be a pollutant, a TMDL analysis is required to assess the appropriate maximum allowable pollutant loading rate. A TMDL document consists of a technical analysis conducted to: (1) assess the maximum pollutant loading rate that a waterbody is able to assimilate while maintaining water quality standards; and (2) allocate that assimilative capacity among the known sources of that pollutant**.** A well written TMDL document will describe a path forward that may be used by those who implement the TMDL recommendations to attain and maintain WQS.

Each of the following eight sections describes the factors that EPA Region 8 staff considers when reviewing TMDL documents. Also included in each section is a list of EPA’s review elements relative to that section, a brief summary of the EPA reviewer’s findings, and the reviewer’s comments and/or suggestions. Use of the verb “must” in this review form denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term “should” below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

This review form is intended to ensure compliance with the Clean Water Act and that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Problem Description

A TMDL document needs to provide a clear explanation of the problem it is intended to address. Included in that description should be a definitive portrayal of the physical boundaries to which the TMDL applies, as well as a clear description of the impairments that the TMDL intends to address and the associated pollutant(s) causing those impairments. While the existence of one or more impairment and stressor may be known, it is important that a comprehensive evaluation of the water quality be conducted prior to development of the TMDL to ensure that all water quality problems and associated stressors are identified. Typically, this step is conducted prior to the 303(d) listing of a waterbody through the monitoring and assessment program. The designated uses and water quality criteria for the waterbody should be examined against available data to provide an evaluation of the water quality relative to all applicable water quality standards. If, as part of this exercise, additional WQS problems are discovered and additional stressor pollutants are identified, consideration should be given to concurrently evaluating TMDLs for those additional pollutants. If it is determined that insufficient data is available to make such an evaluation, this should be noted in the TMDL document.

1.1 TMDL Document Submittal

When a TMDL document is submitted to EPA requesting review or approval, the submittal package should include a notification identifying the document being submitted and the purpose of the submission.

Review Elements:

☒ Each TMDL document submitted to EPA should include a notification of the document status (e.g., pre-public notice, public notice, final), and a request for EPA review.

☐ Each TMDL document submitted to EPA for final review and approval should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute**.** The submittal letter should contain such identifying information as the name and location of the waterbody and the pollutant(s) of concern, which matches similar identifying information in the TMDL document for which a review is being requested.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information ☐ N/A

Summary: The draft South Dakota statewide mercury TMDL was submitted to EPA via email on September 18, 2015 with a public notice letter requesting comments on the document by October 23, 2015.

Comments: The draft TMDL meets the requirements of this review element.

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

The TMDL document should provide an unambiguous description of the waterbody to which the TMDL is intended to apply and the impairments the TMDL is intended to address. The document should also clearly delineate the physical boundaries of the waterbody and the geographical extent of the watershed area studied. Any additional information needed to tie the TMDL document back to a current 303(d) listing should also be included.

Review Elements:

☐ The TMDL document should clearly identify the pollutant and waterbody segment(s) for which the TMDL is being established. If the TMDL document is submitted to fulfill a TMDL development requirement for a waterbody on the state's current EPA approved 303(d) list, the TMDL document submittal should clearly identify the waterbody and associated impairment(s) as they appear on the State's/Tribe's current EPA approved 303(d) list, including a full waterbody description, assessment unit/waterbody ID, and the priority ranking of the waterbody. This information is necessary to ensure that the administrative record and the national TMDL tracking database properly link the TMDL document to the 303(d) listed waterbody and impairment(s).

☒ One or more maps should be included in the TMDL document showing the general location of the waterbody and, to the maximum extent practical, any other features necessary and/or relevant to the understanding of the TMDL analysis, including but not limited to: watershed boundaries, locations of major pollutant sources, major tributaries included in the analysis, location of sampling points, location of discharge gauges, land use patterns, and the location of nearby waterbodies used to provide surrogate information or reference conditions. Clear and concise descriptions of all key features and their relationship to the waterbody and water quality data should be provided for all key and/or relevant features not represented on the map

☐ If information is available, the waterbody segment to which the TMDL applies should be identified/geo-referenced using the National Hydrography Dataset (NHD). If the boundaries of the TMDL do not correspond to the Waterbody ID(s) (WBID), Entity_ID information or reach code (RCH_Code) information should be provided. If NHD data is not available for the waterbody, an alternative geographical referencing system that unambiguously identifies the physical boundaries to which the TMDL applies may be substituted.

Recommendation:

☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: The South Dakota statewide mercury TMDL was written to address 16 waterbody segments identified on the 2014 303(d) List as impaired for mercury in fish tissue. Fish consumption advisories developed using the Food and Drug Administration (FDA) action level of 1 mg/kg were the basis for the 16 existing listings and the geographic extent of these listed waters is mapped in Figure 4 of the TMDL document (pg. 21).

South Dakota is in the process of adopting the EPA recommended 304(a) methylmercury criterion of 0.3 mg/kg and does not have a defined or standardized assessment method for listing mercury impairments at this time. The TMDL document identified another 72 waterbody segments in Table 3 of the TMDL document (pg. 23) with at least one fish tissue concentration ≥ 0.3 mg/kg methylmercury, but which the State has not yet determined to be impaired. The document states, "If any of these waters are found to be impaired through the adoption and application of the 0.3 mg/kg methylmercury criterion, this TMDL will be considered applicable." The geographic extent of some of these 72 additional waterbody segments is mapped in Figure 5 (pg. 24).

South Dakota determined that a single statewide TMDL was representative and appropriate for the entire state after finding that atmospheric mercury deposition rates and methylmercury concentrations did not significantly differ between geographic location and waterbody type (i.e., lakes vs. impoundments). A comparison of various water quality and watershed factors to methylmercury concentrations found slight differences but identified reducing inputs through addressing atmospheric mercury emissions as the only viable solution to resolving the State's mercury impairments (see Section 3.4 of the TMDL document).

Because the TMDL investigation found that atmospheric deposition was the most significant contributor of mercury to South Dakota waters, and the loading scenario is occurring across the entire state, South Dakota intends to revise the TMDL document in the future by broadening its scope to include additional waterbody segments if monitoring data becomes available indicating new mercury impairments. An excerpt from Section 1.3 of the TMDL document that outlines this revision approach is provide below:

> *In summary, this TMDL may be applicable to additional waters of the state if:*
>
> - *It falls entirely within state jurisdiction,*
> - *If jurisdiction is shared, it may only be applied to those portions of the water under South Dakotas' jurisdiction,*
> - *The standard length fish tissue methylmercury concentrations does not exceed 0.878 mg/Kg,*
> - *There are no potential impacts from current or historic gold mining processes,*
> - *If it is a river or stream, NPDES discharges do not exceed permitted limits,*
> - *The TMDL will meet the water quality standards in the proposed water, and*
> - *The original TMDL assumptions (e.g., source contributions, loading capacity, etc.) are still valid.*

According to the process outlined in the draft TMDL, if a new waterbody segment meets all seven of the conditions listed above, South Dakota may revise the original statewide mercury TMDL to include the new water provided the State public notices the proposed revision, reviews and addresses public comments, and obtains EPA approval.

Comments: As described above, the TMDL includes a list and a partial map of 72 waterbodies for which the State has some data indicating elevated methylmercury concentrations in fish tissue. The State has neither listed these 72 waters as impaired in its most recent 303(d) list, nor identified these waters as "threatened" for 303(d) purposes. As a result, the purpose of including these 72 unlisted waterbody segments in the TMDL document is unclear. As the draft TMDL document is currently written, these 72 additional waterbody segments would not be part of EPA's TMDL approval action. If these waterbody segments are later identified as impaired through a clearly defined and acceptable assessment method, additional information would be needed before the TMDL could be considered applicable and EPA could make an approval decision. Such necessary information would include, but is not limited to, evidence that there are no mining related impacts to these waters, evidence that the TMDL is appropriate for riverine waterbody types, a plan for how the TMDL would be implemented on shared jurisdictional waters, and documentation of the public participation process followed for the TMDL revision.

SDDENR Response: Section 1.3 has been revised to include a listing methodology to be used in the 2016IR. It also identifies impaired waters through the application of this methodology and which waters the State expects the TMDL to be applicable to.

1.3 Water Quality Standards

TMDL documents should provide a complete description of the water quality standards for the waterbodies addressed, including a listing of the designated uses and an indication of whether the uses are being met, not being met, or not assessed. If a designated use was not assessed as part of the TMDL analysis (or not otherwise recently assessed), the documents should provide a reason for the lack of assessment (e.g., sufficient data was not available at this time to assess whether or not this designated use was being met).

Water quality criteria (WQC) are established as a component of water quality standard at levels considered necessary to protect the designated uses assigned to that waterbody. WQC identify quantifiable targets and/or qualitative water quality goals which, if attained and maintained, are intended to ensure that the designated uses for the waterbody are protected. TMDLs result in maintaining and attaining water quality standards by determining the appropriate maximum pollutant loading rate to meet water quality criteria, either directly, or through a surrogate measurable target. The TMDL document should include a description of all applicable water quality criteria for the impaired designated uses and address whether or not the criteria are being attained, not attained, or not evaluated as part of the analysis. If the criteria were not evaluated as part of the analysis, a reason should be cited (e.g. insufficient data were available to determine if this water quality criterion is being attained).

Review Elements:

☒ The TMDL must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)).

☒ The purpose of a TMDL analysis is to determine the assimilative capacity of the waterbody that corresponds to the existing water quality standards for that waterbody, and to allocate that assimilative capacity between the identified sources. Therefore, all TMDL documents must be written to meet the existing water quality standards for that waterbody (CWA §303(d)(1)(C)). *Note: In some circumstances, the load reductions determined to be necessary by the TMDL analysis may prove to be infeasible and may possibly indicate that the existing water quality standards and/or assessment methodologies may be erroneous. However, the TMDL must still be determined based on existing water quality standards. Adjustments to water quality standards and/or assessment methodologies may be evaluated separately, from the TMDL.*

☒ The TMDL document should describe the relationship between the pollutant of concern and the water quality standard the pollutant load is intended to meet. This information is necessary for EPA to evaluate whether or not attainment of the prescribed pollutant loadings will result in attainment of the water quality standard in question.

☒ If a standard includes multiple criteria for the pollutant of concern, the document should demonstrate that the TMDL value will result in attainment of all related criteria for the pollutant. For example, both acute and chronic values (if present in the WQS) should be addressed in the document, including consideration of magnitude, frequency and duration requirements.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: A discussion of water quality standards, including the topics of beneficial uses and numeric criteria, is contained in Section 2.0 of the TMDL document. State regulations that establish water quality standards in South Dakota are also referenced. Seven of the State's eleven beneficial uses, including various drinking water, stock water, and fish and wildlife propagation use categories, have associated numeric water quality criteria for total mercury that range from 0.05 µg/L to 1.4 µg/L.

Because South Dakota chose to use 0.3 mg/kg methylmercury in fish tissue as the TMDL target, an analysis was necessary to show that meeting the TMDL target would achieve water quality standards and meet applicable water column criteria. This demonstration was performed following EPA's *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion* (2010) and involved two steps. First, South Dakota converted the total methylmercury fish tissue target into a total methylmercury water column concentration using the draft national Bioaccumulation Factor (BAF) for the 4th order tropic level. Then the State converted the total methylmercury water column concentration into a total mercury water column concentration using separate translators for lotic and lentic aquatic systems identified in EPA's *Water Quality Criterion for the Protection of Human Health: Methylmercury* (2001). The resulting concentrations (lotic = 0.008 µg/L; lentic = 0.003 µg/L) indicated that the TMDL target is protective of the most stringent water column criteria (0.050 µg/L) thereby demonstrating that the TMDL was written to meet water quality standards.

The TMDL document includes a discussion of the global mercury cycle, the process of methylation, routes of human exposure, and methylmercury's capacity to bioaccumulate within an individual and biomagnify within a food chain. Collectively, this background information helps support the selection of a fish tissue methylmercury TMDL target intended to meet mercury water quality standards.

Comments: The TMDL document should more clearly link numeric criteria to beneficial uses. **EPA recommends updating the list and table on page 28 of the TMDL document to more clearly link beneficial uses to criteria.** As currently written, the list within a list is hard to follow and the table has no column or row headers. See Table 3 in *The 2014 South Dakota Integrated Report for Surface Water Quality Assessment* for a more understandable presentation of the same material.

The State submitted a water quality standards revision package to EPA on August 11, 2015. In the standards package, South Dakota adopted the EPA recommended 304(a) methylmercury criterion of 0.3 mg/kg. EPA is currently reviewing the revised water quality standards package. South Dakota demonstrated in the TMDL document that meeting the methylmercury TMDL target will simultaneously meet the State's existing water column criteria.

SDDENR Response: The table on page 28 was modified.

2. Water Quality Targets

TMDL analyses establish numeric targets that are used to determine whether water quality standards are being achieved. Quantified water quality targets or endpoints should be provided to evaluate each listed pollutant/waterbody combination addressed by the TMDL, and should represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the water quality target. For pollutants with narrative standards, the narrative standard should be translated into a measurable value. At a minimum, one target is required for each pollutant/waterbody combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include a variety of targets representing water column sediment such as TSS, embeddedness, stream morphology, up-slope conditions and a measure of biota).

Review Elements:

☒ The TMDL should identify a numeric water quality target(s) for each waterbody pollutant combination. The TMDL target is a quantitative value used to measure whether or not the applicable water quality standard is attained. *Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. Occasionally, the pollutant of concern is different from the parameter that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as a numerical dissolved oxygen criterion). In such cases, the TMDL should explain the linkage between the pollutant(s) of concern, and express the quantitative relationship between the TMDL target and pollutant of concern. In all cases, TMDL targets must represent the attainment of current water quality standards.*

☐ When a numeric TMDL target is established to ensure the attainment of a narrative water quality criterion, the numeric target, the methodology used to determine the numeric target, and the link between the pollutant of concern and the narrative water quality criterion should all be described in the TMDL document. Any additional information supporting the numeric target and linkage should also be included in the document.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: As described in Section 1.3 of this review form, South Dakota used 0.3 mg/kg methylmercury in fish tissue as the TMDL target. In order to show that the TMDL was written to meet water quality standards, South Dakota demonstrated that the methylmercury fish tissue target will meet all existing, EPA-approved, numeric water quality criteria through the use of a Bioaccumulation Factor (BAF) translation. The draft TMDL assumes steady-state conditions and relies on the principle of proportionality to determine the reduction factor needed to meet the fish tissue TMDL target. As explained in Section 3.3 of the TMDL document, South Dakota expects that a reduction in mercury emissions will result in a proportional reduction in deposition, mercury loading to waterways, and fish tissue methylmercury concentrations.

Comments: The draft TMDL meets the requirements of this review element.

3. Pollutant Source Analysis

A TMDL analysis is conducted when a pollutant load is known or suspected to be exceeding the loading capacity of the waterbody. Logically then, a TMDL analysis should consider all sources of the pollutant of concern in some manner. The detail provided in the source assessment step drives the rigor of the pollutant load allocation. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each identified source (or source category) when the relative load contribution from each source has been estimated. Therefore, the pollutant load from each identified source (or source category) should be specified and quantified. This may be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach may be appropriate. The approach should be clearly defined in the document.

Review Elements:

☒ The TMDL should include an identification of the point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.

☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.

☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that the anthropogenic sources of the pollutant of concern have been identified, characterized, and quantified.

☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

<u>Summary</u>: South Dakota investigated sources of mercury impairment through two complementary approaches. The first involved partnering with the South Dakota School of Mines and Technology to operate a network of in-state monitoring stations over a two year period. The atmospheric mercury deposition data collected under this monitoring effort helped the State estimate mercury deposition rates and helped inform the overall analysis by highlighting geographical and seasonal patterns of deposition. This effort also addressed a data gap where previous national studies had interpolated South Dakota deposition rates from monitoring stations in neighboring states. Deposition monitoring results are provided in Appendix B of the TMDL document.

As a second step, the State quantified specific sources and source categories contributing to atmospheric mercury deposition by using the Regional Modeling System for Aerosols and Deposition (REMSAD). REMSAD is a widely accepted, peer reviewed model developed by EPA and used in numerous other statewide mercury TMDLs across the nation. Modeling runs were conducted by EPA and provided to South Dakota for this TMDL analysis. The results clearly indicated that statewide, the largest source of mercury (93%) either originates from outside the modeling domain (continental U.S. plus parts of Canada and Mexico) or originates within the modeling domain but is transported outside to become part of the global pool. In-state emission sources were shown to account for only 0.12% of South Dakota's total atmospheric mercury deposition. The contribution of North American sources is presented in Figure 22 of the TMDL document, and the contribution of in-state sources is summarized in Table 21 and Figure 23. The draft TMDL assumes that 30% of the total atmospheric mercury deposition is non-anthropogenic in origin and represents natural background conditions. This characterization is in line with other statewide mercury TMDLs and scientific literature. An analysis of NPDES point sources was also conducted as described in Section 4.2 of this review form.

Comments: The draft TMDL meets the requirements of this review element.

4. TMDL Technical Analysis

TMDL determinations should be supported by an analysis of the available data, discussion of the known deficiencies and/or gaps in the data set, and an appropriate level of technical analysis**.** This applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader.

A TMDL analysis determines the maximum pollutant loading rate that may be allowed to a waterbody without violating water quality standards. The TMDL analysis should demonstrate an understanding of the relationship between the rate of pollutant loading into the waterbody and the resultant water quality impacts. This stressor → response relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and load allocations needs to be clearly articulated and supported by an appropriate level of technical analysis. Every effort should be made to be as detailed as possible, and to base all conclusions on the best available scientific principles.

The pollutant loading allocation is at the heart of the TMDL analysis. TMDLs apportion responsibility for taking actions by allocating the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways, such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or division of responsibility.

The pollutant loading allocation that will result in achievement of the water quality target is expressed in the form of the standard TMDL equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

Where:

TMDL = Total Maximum Daily Load (also called the Loading Capacity)

LAs = Load Allocations

WLAs = Wasteload Allocations

MOS = Margin Of Safety

Review Elements:

☒ A TMDL must identify the loading capacity of a waterbody for the applicable pollutant, taking into consideration temporal variations in that capacity. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

☒ The total loading capacity of the waterbody should be clearly demonstrated to equate back to the pollutant load allocations through a balanced TMDL equation. In instances where numerous LA, WLA and seasonal TMDL capacities make expression in the form of an equation cumbersome, a table may be substituted as long as it is clear that the total TMDL capacity equates to the sum of the allocations.

☒ The TMDL document should describe the methodology and technical analysis used to establish and quantify the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

☒ It is necessary for EPA staff to be aware of any assumptions used in the technical analysis to understand and evaluate the methodology used to derive the TMDL value and associated loading allocations. Therefore, the TMDL document should contain a description of any important assumptions (including the basis for those assumptions) made in developing the TMDL, including but not limited to:

- the spatial extent of the watershed in which the impaired waterbody is located and the spatial extent of the TMDL technical analysis;
- the distribution of land use in the watershed (e.g., urban, forested, agriculture);
- a presentation of relevant information affecting the characterization of the pollutant of concern and its allocation to sources such as population characteristics, wildlife resources, industrial activities etc…;
- present and future growth trends, if taken into consideration in determining the TMDL and preparing the TMDL document (e.g., the TMDL could include the design capacity of an existing or planned wastewater treatment facility);
- an explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

☒ The TMDL document should contain documentation supporting the TMDL analysis, including an inventory of the data set used, a description of the methodology used to analyze the data, a discussion of strengths and weaknesses in the analytical process, and the results from any water quality modeling used. This information is necessary for EPA to review the loading capacity determination, and the associated load, wasteload, and margin of safety allocations.

☒ TMDLs must take critical conditions (e.g., steam flow, loading, and water quality parameters, seasonality, etc…) into account as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe the approach used to determine both point and nonpoint source loadings under such critical conditions. In particular, the document should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

☒ Where both nonpoint sources and NPDES permitted point sources are included in the TMDL loading allocation, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document must include a demonstration that nonpoint source loading reductions needed to implement the load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: Due to the statewide nature of this TMDL, the loading capacity was developed at the statewide scale, however, the TMDL is still written to meet water quality standards in individual waters. The State demonstrated this by relating the loading capacity back to numeric water quality criteria. Conservative decisions made throughout the process, such as selecting the 90th percentile standard length fish tissue concentration for reduction factor purposes, result in a statewide TMDL that may be more protective than necessary to meet water quality standards in some waters.

The TMDL capacity clearly equates to the sum of the allocations and can be simplified as: Implicit MOS (0 kg/yr) + WLA (2.53 kg/yr) + LA (592.79 kg/yr) = TMDL (595.32 kg/yr). This balanced TMDL equation, additional source category breakouts, and derivation steps are included in Section 10.0 of the TMDL document.
Comments: The draft TMDL meets the requirements of this review element.

4.1 Data Set Description

TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis. An inventory of the data used for the TMDL analysis should be provided to document, for the record, the data used in decision making. This also provides the reader with the opportunity to independently review the data. The TMDL analysis should make use of all readily available data for the waterbody under analysis unless the TMDL writer determines that the data are not relevant or appropriate. For relevant data that were known but rejected, an explanation of why the data were not utilized should be provided (e.g., samples exceeded holding times, data collected prior to a specific date were not considered timely, etc…).

Review Elements:

☒ TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and appropriate water quality criteria.

☐ The TMDL document submitted should be accompanied by the data set utilized during the TMDL analysis. If possible, it is preferred that the data set be provided in an electronic format and referenced in the document. If electronic submission of the data is not possible, the data set may be included as an appendix to the document.

Recommendation:

☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: The majority of information used during the TMDL analysis is included as appendices to the TMDL document. Appendix B contains figures displaying mercury deposition results from each of the 10 deposition monitoring stations installed throughout the state. South Dakota relied upon this information to calculate the existing statewide atmospheric mercury deposition load. Appendix C contains regression equations and standard length fish tissue concentrations listed individually for each waterbody and year that data is available. South

Dakota used this standard length fish tissue concentration dataset to derive the TMDL reduction goal. Finally, Appendix D summarizes the individual fish tissue dataset collected from 1994-2014.

Comments: The sites identified in Appendix C and D, and the data associated with those sites, are not easily related back to waterbody segments or assessment units. For example, some sites listed in the appendices do not match waterbody names provided in the 2014 Integrated Report and the appendices do not identify assessment unit IDs (AUIDs). **EPA recommends adding AUIDs to the data tables in Appendix C and D, and using consistent waterbody names between the TMDL document and the Integrated Report.** Additionally, while Appendix D summarizes the fish tissue dataset, the TMDL does not provide the complete dataset of individual fish tissue samples. **EPA recommends the TMDL include the complete dataset of individual fish tissue methylmercury samples.** If the individual fish tissue sample dataset is too large to easily include as an appendix, it should be provided electronically or noted that it is available by request.

SDDENR Response: This TMDL utilized all available fish tissue data from within the state. Some of the data was collected as a part of research projects from small private rearing and hatching ponds as well as fish hatcheries that are not included in the state Integrated Report. The data for these sites was included in the appendix and in lieu of an AUID, those sites state “NOAUID” followed by the site name. Any dataset used in South Dakotas TMDLs can be provided upon request.

4.2 Waste Load Allocations (WLA):

Waste Load Allocations represent point source pollutant loads to the waterbody. Point source loads are typically better understood and more easily monitored and quantified than nonpoint source loads. Whenever practical, each point source should be given a separate waste load allocation. All NPDES permitted dischargers that discharge the pollutant under analysis directly to the waterbody should be identified and given separate waste load allocations. The finalized WLAs are required to be incorporated into future NPDES permit renewals.

Review Elements:

☐ EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to individual existing and future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. If no allocations are to be made to point sources, then the TMDL should include a value of zero for the WLA.

☒ All NPDES permitted dischargers given WLA as part of the TMDL should be identified in the TMDL, including the specific NPDES permit numbers, their geographical locations, and their associated waste load allocations.

Recommendation:

☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

__Summary__: As described in Section 4.3 of the TMDL document, South Dakota characterized the existing, non-stormwater, NPDES-permitted point source load by using the average annual combined flow of all facilities in South Dakota (43 billion gallons) and the 90th percentile effluent mercury concentration (0.01536 µg/L) of an Association of Metropolitan Sewerage Agencies (AMSA) dataset composed of data from six other states. South Dakota chose not use in-state effluent concentration data due to data quality concerns with sampling techniques, reporting errors, and detection level issues. The analysis attributed 2.53 kg of mercury per year to NPDES-permitted point sources, equivalent to 0.43% of the TMDL. Section 6 of the TMDL describes how the load was represented in the WLA component of the TMDL. The State established an aggregate, non-stormwater, NPDES-permitted WLA which caps the statewide load at existing conditions. South Dakota went on to clarify that the WLA "is not an allowance for increased discharges of mercury, nor does it provide exemption from further efforts to reduce mercury from these sources" (pg. 71).

__Comments__: The draft TMDL fails to include NPDES-regulated Municipal Separate Storm Sewer System (MS4) loads under the WLA component of the TMDL. As described in Section 4.2 of the TMDL document, "the only source of mercury in MS4 loads is atmospheric deposition." The MS4 load, calculated based on the percentage of the South Dakota's land surface falling within MS4 boundaries relative to the atmospheric mercury deposition for the entire state, is allocated within the TMDL as a LA. MS4s are regulated point sources under Section 402(p) of the Clean Water Act (33 U.S.C. §1342(p)), and the regulatory definition of WLAs (40 CFR §130.2(h)) clearly specifies that WLAs are "the portion of a receiving water's loading capacity that is allocated to . . . point sources of pollution." **South Dakota must attribute the NPDES-**

permitted MS4 load to the WLA component of this TMDL. This longstanding position has been widely announced in numerous EPA resources[1].

Appendix E of the TMDL document contains a list of all 247 NPDES-permitted facilities in the state with permit number, name and location clearly identified. These facilities were provided a single aggregated WLA in the TMDL. **EPA recommends the TMDL indicate how the aggregated WLA will be implemented in individual permit decisions.**

[1] (EPA 2002) Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs

(EPA 2008a) TMDLs to Stormwater Permits Handbook

(EPA 2008b) Recommended TMDL Elements and Factors to Consider in Developing Mercury TMDLs

(EPA 2010) Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion

(EPA 2014) Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs"

SDDENR Response: During the development of this TMDL, SDDENR initially chose to follow the 2007 MN Mercury TMDL example where MS4s were given an effective load of zero. The basis for that approach is that the areas the MS4 permits cover do not generate mercury. The presence of mercury in the runoff from these areas was entirely attributed to nonpoint sources through mercury deposition. This loading was fully addressed in the LA component of the TMDL. In contrast with the SD TMDL, EPA required SDDENR to identify what portion of the LA fell within the MS4s based simply on the proportional acreage of the state to the MS4. This was followed by an edict that this load must be deemed a portion of the WLA. While SDDENR acknowledges that MS4s are regulated under Section 402(p) of the Clean Water Act and subsequent guidance and lawsuits have removed any latitude with regards to the MS4 allocation, at question is the need to assign any load at all to them.

Although pollutant loads from NPDES facilities are given a WLA, the approval of the MN and NE regional mercury TMDLs without MS4 loads would suggest that despite the strong bolded language in the comments, alternative approaches are acceptable. It is important to reiterate that the entire load associated with the MS4's was originally fully accounted for in the LA component of the TMDL. While the minimum measures for the MS4 are credited with a positive influence on the total loads, attainment of the TMDL is **entirely** dependent on reductions in atmospheric sources that contribute equally to rural and urban areas covered under MS4 permits.

Assigning a load generates the need for creating complicated permit conditions, which will have no bearing on the success of the TMDL. The MS4 assigned loads were based on a fraction of the atmospheric load after successful reductions are eventually achieved. Until those reductions are achieved, it can be expected that deposition within the MS4 areas will be greater than the WLA.

The state disagrees with EPA's assessment that the MS4s should be given any load at all in this particular circumstance. However, to facilitate approval, the TMDL has been adjusted to call the portion of nonpoint source mercury which happens to fall within the boundaries of the MS4s a WLA. The WLA will be implemented in the NPDES permits for these MS4s. The details for implementing the WLA in the TMDL will be addressed during each permit's renewal.

4.3 Load Allocations (LA):

Load allocations include the nonpoint source, natural, and background loads. These types of loads are typically more difficult to quantify than point source loads, and may include a significant degree of uncertainty. Often it is necessary to group these loads into larger categories and estimate the loading rates based on limited monitoring data and/or modeling results. The background load represents a composite of all upstream pollutant loads into the waterbody. In addition to the upstream nonpoint and upstream natural load, the background load often includes upstream point source loads that are not given specific waste load allocations in this particular TMDL analysis. In instances where nonpoint source loading rates are particularly difficult to quantify, a performance-based allocation approach, in which a detailed monitoring plan and adaptive management strategy are employed for the application of BMPs, may be appropriate.

Review Elements:

☐ EPA regulations require that TMDL expressions include LAs which identify the portion of the loading capacity attributed to nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Load allocations may be included for both existing and future nonpoint source loads. Where possible, load allocations should be described separately for natural background and nonpoint sources.

☒ Load allocations assigned to natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g., measured in stream) unless it can be demonstrated that the anthropogenic sources of the pollutant of concern have been identified and given proper load or waste load allocations.

Recommendation:

☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: As described in Section 3 of this review form, South Dakota identified and quantified sources of nonpoint source pollution through in-state atmospheric deposition monitoring and the REMSAD computer model. Using this information, South Dakota estimated it receives 1,326.3 kg of mercury per year from atmospheric, nonpoint sources of pollution statewide (see Section 5.1.2 and Section 10.0 of the TMDL document). After attributing 30% of this load to natural background, the remaining human-derived nonpoint source load requires a 79% reduction to meet the atmospheric deposition LA (592.79 kg/yr) and the final TMDL (595.32 kg/yr). The draft TMDL separated out the MS4 fraction from the non-MS4 fraction of atmospheric deposition loading but considered both under the LA component of the TMDL.

Comments: **South Dakota must attribute the NPDES-permitted MS4 load to the WLA component of this TMDL.** See additional comments on this subject in Section 4.2 of this review form.

4.4 Margin of Safety (MOS):

Natural systems are inherently complex. Any mathematical relationship used to quantify the stressor → response relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty and error. To compensate for this uncertainty and ensure water quality standards will be attained, a margin of safety is required as a component of each TMDL. The MOS may take the form of a explicit load allocation (e.g., 10 lbs/day), or may be implicitly built into the TMDL analysis through the use of conservative assumptions and values for the various factors that determine the TMDL pollutant load → water quality effect relationship. Whether explicit or implicit, the MOS should be supported by an appropriate level of discussion that addresses the level of uncertainty in the various components of the TMDL technical analysis, the assumptions used in that analysis, and the relative effect of those assumptions on the final TMDL. The discussion should demonstrate that the MOS used is sufficient to ensure that the water quality standards would be attained if the TMDL pollutant loading rates are met. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Review Elements:

☒ TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d) (1) (C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

☒ If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS should be identified and described. The document should discuss why the assumptions are considered conservative and the effect of the assumption on the final TMDL value determined.

☐ If the MOS is explicit, the loading set aside for the MOS should be identified. The document should discuss how the explicit MOS chosen is related to the uncertainty and/or potential error in the linkage analysis between the WQS, the TMDL target, and the TMDL loading rate.

☐ If, rather than an explicit or implicit MOS, the TMDL relies upon a phased approach to deal with large and/or unquantifiable uncertainties in the linkage analysis, the document should include a description of the planned phases for the TMDL as well as a monitoring plan and adaptive management strategy.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: South Dakota used an implicit margin of safety for this TMDL. As described in Section 8.0 of the TMDL document, the TMDL incorporated conservative approaches at numerous steps of the TMDL development such as:

- Resampling waters with elevated fish tissue methylmercury concentrations more frequently than other waters. As a result, the fish tissue dataset is biased to egregiously impaired waters and the statewide TMDL's reduction factor is potentially greater than necessary for many waters.
- Focusing target attainment within a top predator species (walleye) where methylmercury concentrations and bioaccumulation rates are highest. This protects all other fish species.
- Selecting the 90th percentile standard length fish concentration to represent existing conditions overestimates the loading reductions needed for many waters.
- Comparing fish tissue analyzed for total mercury concentration directly to the methylmercury TMDL target for listing decisions and TMDL calculations. This affords a level of protection because measurements of total mercury include other forms of mercury in addition to methylmercury.
- Setting allocations without accounting for reductions in sulfur emissions realized under the Clean Air Act which is expected to affect sulfate-reducing bacteria and lower methylation rates.

Comments: The draft TMDL meets the requirements of this review element.

4.5 Seasonality and variations in assimilative capacity:

The TMDL relationship is a factor of both the loading rate of the pollutant to the waterbody and the amount of pollutant the waterbody can assimilate and still attain water quality standards. Water quality standards often vary based on seasonal considerations. Therefore, it is appropriate that the TMDL analysis consider seasonal variations, such as critical flow periods (high flow, low flow), when establishing TMDLs, targets, and allocations.

Review Elements:

☒ The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variability as a factor. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: Critical conditions and seasonal variation are summarized in Section 9.0 of the TMDL document. South Dakota supported a monitoring network of mercury deposition stations across the state for multiple years to explore temporal and geospatial differences in mercury deposition. Results indicated a positive relationship between deposition and precipitation, and an average annual deposition rate of 6.64 µg/m^2 with a range of 3.43 - 9.13 µg/m^2. South Dakota reviewed atmospheric mercury deposition patterns and the fish tissue dataset, and decided that a single statewide TMDL was representative and appropriate for the entire state. The TMDL is presented in both an annual and daily loading expression. The use of a fish tissue concentration for a TMDL target inherently includes a seasonality component because tissue concentrations are the product of bioaccumulation throughout a fish’s lifespan.

South Dakota also investigated various water quality and watershed factors in Section 3.4 of the TMDL document and found that while Secchi depth, wetland abundance, and lake level variability affected methylation rates, the only viable solution to resolving mercury impairments is to control emissions and reduce inputs from atmospheric deposition. Additionally, sediment cores from ten lakes were reviewed for insight into mercury loading trends but no conclusions were drawn. The results indicated that mercury concentrations in upper lakebed sediments was highly variable.

Comments: The draft TMDL meets the requirements of this review element.

5. Public Participation

EPA regulations require that the establishment of TMDLs be conducted in a process open to the public, and that the public be afforded an opportunity to participate. To meaningfully participate in the TMDL process it is necessary that stakeholders, including members of the general public, be able to understand the problem and the proposed solution. TMDL documents should include language that explains the issues to the general public in understandable terms, as well as provides additional detailed technical information for the scientific community. Notifications or solicitations for comments regarding the TMDL should be made available to the general public, widely circulated, and clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for approval, a copy of the comments received by the state and the state responses to those comments should be included with the document.

Review Elements:

☐ The TMDL must include a description of the public participation process used during the development of the TMDL (40 C.F.R. §130.7(c)(1)(ii)).

☐ TMDLs submitted to EPA for review and approval should include a summary of significant comments and the State's/Tribe's responses to those comments.

Recommendation:

☐ Approve ☐ Partial Approval ☐ Disapprove ☒ Insufficient Information

Summary: Section 13.0 of the TMDL document states that the document will be updated to reflect the media outlets used to announce the public comment period and indicates that the final document will include responses to public comments. In the current draft TMDL document, Section 13 highlights resources the general public may use to find more information on fish consumption advisories.

Comments: EPA expects the final TMDL to include a full description of the public participation process such as where the document was public noticed, what time period it was public noticed, and what process was used to submit public comments.

SDDENR Response: This section has been updated to reflect the public outreach conducted by SDDENR. No comments or inquiries were received outside of those provided by EPA.

6. Monitoring Strategy

TMDLs may have significant uncertainty associated with the selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL document to articulate the means by which the TMDL will be evaluated in the field, and to provide for future supplemental data that will address any uncertainties that may exist when the document is prepared.

Review Elements:

☐ When a TMDL involves both NPDES permitted point source(s) and nonpoint source(s) allocations, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring.

☐ Under certain circumstances, a phased TMDL approach may be utilized when limited existing data are relied upon to develop a TMDL, and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load calculation and merit development of a second phase TMDL. EPA recommends that a phased TMDL document or its implementation plan include a monitoring plan and a scheduled timeframe for revision of the TMDL. These elements would not be an intrinsic part of the TMDL and would not be approved by EPA, but may be necessary to support a rationale for approving the TMDL. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf

Recommendation:

☐ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: Section 12.0 of the TMDL document identifies and describes three monitoring categories to address data gaps and evaluate progress towards meeting the TMDL target. The three categories of mercury monitoring are atmospheric deposition, fish tissue, and water column.

Comments: South Dakota chose to use mercury concentrations from a 1999 AMSA study to represent the existing, non-stormwater, NPDES-permitted load instead of using in-state effluent data due to concerns with the South Dakota dataset (see Section 4.2 of this review form). As noted on page 80 of the TMDL document, "Improved water column monitoring at NPDES facilities is necessary to better characterize their contributions to the total mercury load in the state." EPA agrees with this statement and encourages additional monitoring to better characterize the point source load.

SDDENR Response: Of primary concern with the data was the use of testing methods with insufficient resolution to capture the low levels of mercury potentially present. Section 12.3 elaborates in greater detail the changes that will help address this issue.

7. Restoration Strategy

The overall purpose of the TMDL analysis is to determine what actions are necessary to ensure that the pollutant load in a waterbody does not result in water quality impairment. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document. During the TMDL analytical process, information is often gained that may serve to point restoration efforts in the right direction and help ensure that resources are spent in the most efficient manner possible. For example, watershed models used to analyze the linkage between the pollutant loading rates and resultant water quality impacts might also be used to conduct "what if" scenarios to help direct BMP installations to locations that provide the greatest pollutant reductions. Once a TMDL has been written and approved, it is often the responsibility of other water quality programs to see that it is implemented. The level of quality and detail provided in the restoration strategy will greatly influence the future success in achieving the needed pollutant load reductions.

Review Elements:

☐ EPA is not required to and does not approve TMDL implementation plans. However, in cases where a WLA is dependent upon the achievement of a LA, "reasonable assurance" is required to demonstrate the necessary LA called for in the document is practicable). A discussion of the BMPs (or other load reduction measures) that are to be relied upon to achieve the LA(s), and programs and funding sources that will be relied upon to implement the load reductions called for in the document, may be included in the implementation/restoration section of the TMDL document to support a demonstration of "reasonable assurance".

Recommendation:

☐ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: The TMDL loading analysis showed that nonpoint sources outside of South Dakota account for over 99% of the mercury loading to state waterbodies. As a result, the TMDL requires all reductions to occur through the LA and stresses the importance of national and international regulatory controls on mercury emissions such as the U.S. Mercury Air Toxics Standards Rule and the United Nations Minamata Convention Agreement. South Dakota also highlighted recent emission reductions observed at two South Dakota coal power plants (Ben French and SDSU) and in-state efforts to recycle mercury-containing solid waste products and avoid releases of mercury from these products into the environment.

Comments:

8. Daily Loading Expression

The goal of a TMDL analysis is to determine what actions are necessary to attain and maintain WQS. The appropriate averaging period that corresponds to this goal will vary depending on the pollutant and the nature of the waterbody under analysis. When selecting an appropriate averaging period for a TMDL analysis, primary concern should be given to the nature of the pollutant in question and the achievement of the underlying WQS. However, recent federal appeals court decisions have pointed out that the title TMDL implies a “daily” loading rate. While the most appropriate averaging period to be used for developing a TMDL analysis may vary according to the pollutant, a daily loading rate can provide a more practical indication of whether or not the overall needed load reductions are being achieved. When limited monitoring resources are available, a daily loading target that takes into account the natural variability of the system can serve as a useful indicator for whether or not the overall load reductions are likely to be met. Therefore, a daily expression of the required pollutant loading rate is a required element in all TMDLs, in addition to any other load averaging periods that may have been used to conduct the TMDL analysis. The level of effort spent to develop the daily load indicator should be based on the overall utility it can provide as an indicator for the total load reductions needed.

Review Elements:

☒ The document should include an expression of the TMDL in terms of a daily load. However, the TMDL may also be expressed in temporal terms other than daily (e.g., an annual or monthly load). If the document expresses the TMDL in additional “non-daily” terms the document should explain why it is appropriate or advantageous to express the TMDL in the additional unit of measurement chosen.

Recommendation:

☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: South Dakota presented the statewide mercury TMDL as both an annual and a daily loading expression. The document notes that an annual load is most appropriate due to characteristics of the pollutant (i.e., mercury levels in fish represent bioaccumulation over longer period of time, impairments are often long-term and persistent, etc.) and because setting loads at a yearly timescale incorporates the seasonal precipitation patterns that influence atmospheric mercury deposition. South Dakota used the TSD method to derive a total maximum daily load from the annual load.

Comments: The equation on page 75 of the TMDL document used to derive a daily load is incorrect. **EPA recommends South Dakota correct the error in the daily loading calculation.**

SDDENR Response: The equation and results were corrected.