Appendix A
Constructed Project Components

Appendix A
Constructed Project Components

Introduction

This appendix documents Project components that have been completed with the Court's permission and the impacts seen as a result of that construction. A summary of the National Environmental Policy Act (NEPA) analyses completed for these components, as well as the environmental commitments and mitigation implemented as part of Project construction as it was conceived at the time can be found in the Final Environmental Assessment (SWC et al. 2001) and Finding of No Significant Impact (Reclamation, 2001).

Project construction began in 2002 when the North Dakota State Water Commission issued the first construction contract for a segment of the main water transmission pipeline between Lake Sakakawea and Minot, North Dakota. Figure A.1 shows the pipeline segments that have been constructed, and Table A.1 identifies their general location. The 45-mile main transmission pipeline from Lake Sakakawea to Minot has been completed except for a segment near Max where the proposed Biota Water Treatment Plant would be located, and a small interruption near the proposed location of the South Prairie storage reservoir. This pipeline is currently idle, but would be used if a Missouri River alternative is ultimately selected for implementation.

Table A.1 Northwest Area Water Supply Project Constructed Pipeline Segments.

Pipeline Segment	General Location	Length (miles)
2-1 A	Minot Water Treatment Plant to Hwy 83 four miles south of Minot	7.4
2-1 B	Four miles south of Minot to eleven miles north of Max	11.8
2-1 C	Eleven miles north of Max to Max	11.3
2-1 D	Max to Lake Sakakawea	14.9
2-2 A	Minot Area	4.2
2-2 B	Minot to Berthold	20.2
2-2 C	Berthold to nine miles north of Kenmare	52.6
2-2 D	Nine miles north of Kenmare to Sherwood and Antler	63.9
2-2 E	Burlington	1.7
2-3 A	North Minot to Minot Air Force Base	12.1
2-3 B	Minot Air Force Base to Glenburn	18.8
2008-1	Bottineau to Gardena	9.3

Improvements to the existing Minot water treatment plant include upgrading their filtration system capacity and the construction of a High Service Pump Station and associated reservoir in the immediate vicinity of the Minot WTP. The pump station was constructed on city property and resulted in an impact of less than 1 acre of developed land.

Several components associated with the bulk water distribution system which would deliver water to communities and rural water systems were constructed following approval by the District Court for the District of Columbia in the late 2000s. Approximately 183 miles (63 percent) of the bulk distribution system from Minot to participating communities and rural water systems have been completed. All Project pipelines are buried, and no permanent impacts associated with their construction have been identified. Three storage reservoirs and four pump stations have been constructed to date. The footprint for these above-ground structures totals approximately 3 acres.

To aid in implementing the environmental commitments, an Impact Mitigation Assessment (IMA) team was formed in 2002, prior to initiation of Project construction, to monitor the final design, construction, mitigation and operation of the Project. The IMA team includes representatives from Reclamation, the North Dakota State Water Commission, the U.S. Fish and Wildlife Service (Service), the North Dakota Game and Fish Department, and the Garrison Diversion Conservancy District. When construction took place on lands administered by other agencies or on Tribal or private lands, other specialists and/or landowners were invited to become members of the team for that part of the construction affecting them.

As of April 2013, the IMA team had met 15 times. Each year, the IMA team reviewed Project work plans and, if necessary, recommended specific modifications or other measures to avoid, reduce, or eliminate construction impacts which would have otherwise occurred. After each construction season was completed, a review of newly-constructed facilities was undertaken by the IMA team to determine if any permanent impacts occurred that required mitigation in accordance with the Project's authorizing legislation.

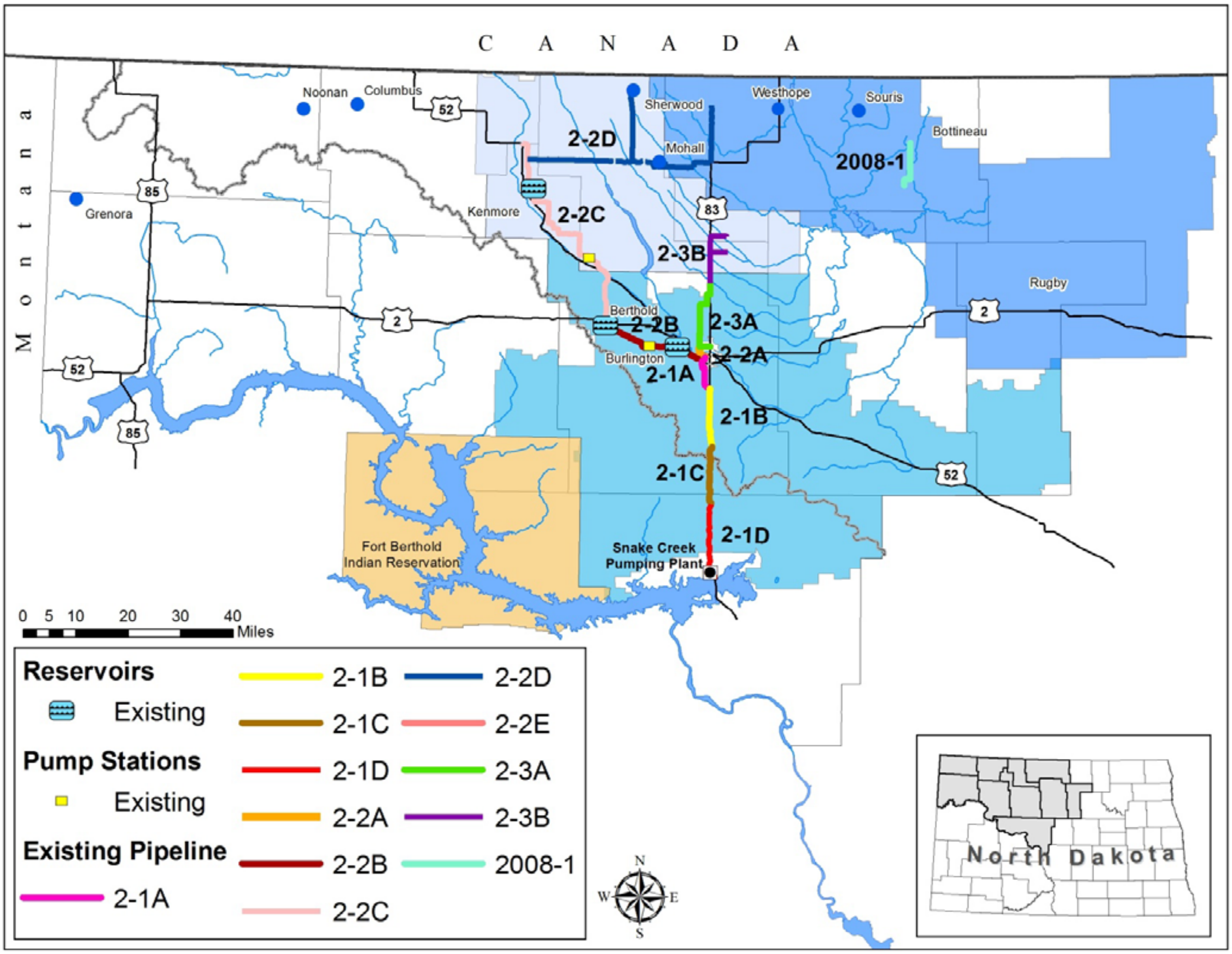


Figure A.1 Northwest Area Water Supply Project Constructed Components

Impacts of Constructed Components

Approximately 228 miles of buried pipelines have been completed. Approximately 3,043 acres of land were within the area temporarily impacted by pipeline construction, based on the assumption of a 110-foot wide right-of-way for each pipeline segment. In most cases, only a portion of the area within the right-of-way is impacted during pipeline construction. Hence, the actual acreage temporarily impacted by pipeline construction is less than 3,043 acres.

Permanent impacts associated with completed above-ground facilities (pump stations and storage reservoirs) total less than 3 acres. All above-ground facilities constructed to date are located on previously disturbed land.

Estimated impacts to-date are described below for resources within the Project Area. Best management practices (BMPs) and mitigation measures implemented to minimize or offset impacts are also identified for each resource.

Geology, Topography, and Soils

Effects of pipeline construction were temporary, and include minor soil disturbance and displacement during construction activities, short-term soil erosion and reduction in soil productivity, and temporary effects to prime farmland. All contracted construction activities were performed under a Stormwater Pollution Prevention Plan and require Notice of Intent to Obtain Coverage under NDPDES General Permit for Storm Water Discharges Associated with Construction Activity under the North Dakota Department of Health Division of Water Quality.

Temporary impacts associated with pipeline construction have been avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the constructed elements:

- Pipelines were generally constructed adjacent to existing highways and roadways.
- Topsoil was stripped and respread on pipeline corridors, pump station sites, and all rights-of-way, except when the pipeline is installed by a trencher or plow. Where topsoil depth exceeds 12 inches, the top 12 inches were salvaged. Gravel was placed around the edge of pump stations and storage reservoirs to control weeds, as needed.
- Compacted areas were chisel plowed and large rocks are removed to develop a good seed bed.
- Trench backfills were compacted to prevent settlement for mainline segments. The lines were inspected after one year to check for subsidence and correct subsidence problems where they occurred.
- Soil was mounded over the trench of small diameter pipelines (approximately six inches or less). One year was allowed for settlement, following which the trench was graded to match existing topography.
- To the extent possible, all excavated material from intermittent streams or wetlands was placed above the high water mark when water was present. Where not possible, the placement of soil materials in intermittent streams or wetlands was minimized.
- Erosion control measures were employed where necessary to reduce wind and water erosion.

- Pipeline segments requiring special reclamation efforts were identified during final design utilizing soils maps and field survey data.
- The placement of permanent facilities on prime (important) farmland was avoided.
- Construction areas were wetted during dry conditions to control dust.

Water Resources

Effects of previously constructed components on water resources included temporary construction impacts where pipelines cross streams, and increased demands on the Minot and Sundre aquifers. Withdrawals from these aquifers to meet existing water demands from the city of Minot and other Project participants currently served by the bulk distribution system exceed natural recharge. Lowering of the water table in these aquifers may increase the hydraulic gradient away from the Souris River, potentially limiting the extent to which base flows in the Souris River are supplemented by the groundwater system. Additionally, lower water tables in the Minot and Sundre aquifers resulting from ongoing withdrawals may adversely affect riparian areas and wetlands adjacent to the Souris River. It should be noted that these aquifers have been declining since the 1960s, more than 30 years before Project construction was initiated. Furthermore, about 90 percent of the current withdrawal from these aquifers is for the City of Minot, with the remaining 10 percent serving other Project participants through existing portions of the Project's bulk distribution system. Thus, only a small portion of the ongoing impacts associated with declining groundwater levels is attributable to the distribution of water through constructed distribution facilities.

Existing pipelines crossed the Souris River at three locations and the Des Lacs River at one location. At each of these crossings, the pipeline was buried below the river bed, and construction impacts were minor and temporary. Existing pipelines also crossed intermittent streams at 51 locations. Impacts to perennial and intermittent streams were avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the constructed elements:

- Directional bore techniques were used at three of four locations where the pipeline crosses perennial streams. Contractors were required to make at least two boring attempts before using an alternative crossing method. At one location on the Souris River in Minot, two attempts at directional boring were unsuccessful, and an open cut technique was used. At intermittent streams, directional boring was used whenever practical. Where it was not practical to bore, open cut construction was used to cross intermittent streams. Construction was initiated when the streams were dry whenever practical. Standard reclamation practices were used to reclaim vegetation and minimize erosion.
- Silt barriers or fabric mats were placed on slopes where necessary to reduce movement of sediments into stream channels.
- No fill material was discharged at stream crossings, in accordance with provisions of Section 404 of the Clean Water Act.
- Contamination of water at construction sites from fuel spillage, lubricants, and chemicals was prevented by following safe storage and handling procedures and North Dakota Department of Health guidelines.

- No structures were placed in any flood plain where such structures would interfere with the movement of flood water.

Vegetation

Effects of constructed Project components include the temporary loss of a variety of vegetative types during project construction, and the permanent loss of vegetation where pumping stations and storage reservoirs were constructed. A total of approximately 2,883 acres of upland vegetation have been temporarily affected by construction of the Project. Permanent vegetation losses associated with storage reservoirs and pump stations involve less than 3 acres. All constructed storage reservoirs and pump stations were located on previously disturbed land (cropland, planted herbaceous cover, or developed land).

Table A.2 shows estimated temporary impacts to vegetation by cover type. Estimates for cover types were derived by overlaying a 110-foot right-of-way for previously constructed pipelines on a GIS database of North Dakota land cover (North Dakota GAP Analysis Project, Strong et al. 2005). The GIS dataset is derived from satellite imagery and has a relatively coarse resolution (30 x 30 m; 0.22 acre). Thus, the estimates in Table A.2 are useful for comparing the proportions of different cover types intersected by the pipeline right-of-way, but should not be considered precise acreage measurements.

About 79 percent of the upland vegetation crossed by constructed Project pipelines is cropland and planted herbaceous cover. Native prairie, sometimes interspersed with low shrubs, comprises about 16 percent of the affected upland vegetation. About 4 percent is developed land (residential, commercial, and industrial), and less than 1 percent is woodland, which includes native woodlands, tree rows, and farmstead shelterbelts. Impacts to woodland habitats were avoided wherever practicable by re-routing pipelines. Reclamation estimates the impact of the 228 miles of pipeline constructed resulted in approximately 12 acres of woodland impacts, or approximately 0.05 acres per mile. Woodland impacts were avoided by re-routing pipelines during final design wherever practicable.

To date, less than 0.1 acres of trees have been removed during pipeline construction. These losses were mitigated by planting two trees for each lost tree. All other vegetation impacts associated with pipeline construction were temporary. Excavated topsoil was salvaged and replaced after construction. Native prairies and planted herbaceous cover were reseeded with an approved seed mixture. Croplands were returned to production in the year following construction.

Table A.2 Estimated Acreage of Vegetation Temporarily Impacted by Pipeline Construction.

Pipeline segment	Acreage of Temporary Impacts by Cover Type				
	Cropland and Planted Herbaceous Cover	Prairie and Shrubland	Woodland	Developed Land	Total
2-1A	62	12	3	17	**94**
2-1B	124	25	0	4	**153**
2-1C	95	31	0	9	**135**

Pipeline segment	Acreage of Temporary Impacts by Cover Type				
	Cropland and Planted Herbaceous Cover	Prairie and Shrubland	Woodland	Developed Land	Total
2-1D	123	32	0	18	**173**
2-2A	17	14	1	20	**52**
2-2B	163	68	1	31	**263**
2-2C	553	95	4	8	**660**
2-2D	682	123	2	9	**816**
2-2E	4	15	0	4	**23**
2-3A	128	26	0	1	**155**
2-3B	223	15	1	3	**242**
2008-1	108	7	0	2	**118**
Total	**2282**	**463**	**12**	**126**	**2883**

Impacts to vegetation resources were avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the constructed elements:

- Topsoil was stockpiled and re-spread on all project areas. Topsoil was recovered to the fullest extent possible.
- Trenches were backfilled after pipe installation.
- Re-topsoiled areas were treated with a disc or chisel plow to reduce compaction created by heavy equipment and to prepare the seedbed.
- Disturbed native grasslands were reseeded with an approved blend of native cool-season and warm-season species. Planted grasslands were reseeded with a seed mixture appropriate for the site.
- Noxious weeds were controlled, as specified under State law, within pipeline corridors during and following construction.
- Herbicides, when needed, were applied in accordance with label instructions and State, Federal and local regulations.
- Landowners were encouraged to defer grazing on newly seeded areas for a minimum of two years.
- Where shelterbelts, riparian woodlands, or woodland vegetation could not be avoided, trees were replaced and replanted off-site at a ratio of two trees planted for each tree lost.
- Weed growth in tree plantings was controlled for three years.
- Tree plantings were monitored for three years and grass plantings for one year. The IMA team reviewed all plantings, and where plantings did not adequately catch, they were replanted with appropriate species.

Wildlife

The principal effect of constructed Project components has been localized, temporary disturbance of wildlife and wildlife habitat resulting from project construction. To date, no wildlife habitat (i.e., grasslands, wetlands, and woodlands) has been permanently lost from the construction of permanent facilities.

Impacts to wildlife resources have been avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the constructed elements:

- Native and tame grasslands have been restored as noted in the preceding section.
- Native woodlands and shelterbelts were replanted as noted in the previous section.
- Construction avoided sharp-tailed grouse dancing grounds during the breeding season (April to mid-May).
- Electrical power lines to Project facilities were buried to the extent practicable. Where power lines could not be buried, they were constructed according to "Suggested Practices for Raptor Protection on Power Lines - The State of the Art in 1981" (Olendorf et al. 1981) to the extent practicable.

Fisheries

Construction impacts at stream crossings have been minor and short-term; therefore any impacts to the fisheries and aquatic communities were also minor and short-term. Silt barriers and other appropriate erosion control measures were used at all crossings to minimize potential sedimentation in stream channels during and after construction. The entire pipeline system is monitored with a computerized data acquisition system to enable quick detection of any loss of pressure due to a pipeline leak and minimize the amount of water released.

Potential effects on fisheries were avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the Project:

- Construction across streams was avoided during periods of high flow and aquatic spawning.
- In-stream flows were maintained where possible during construction through stream crossings.

Threatened and Endangered Species

No listed species (resident or migratory) have been encountered during construction of Project facilities. No Project facilities were located on or adjacent to designated critical habitat for any threatened or endangered species.

Potential effects to listed species were avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the constructed elements:

- The IMA team reviewed the final locations of all pipelines and other facilities to determine if additional field surveys were needed to document the potential occurrence of listed species.
- After reviewing the final designs, the IMA team determined that none of the proposed construction would affect listed species. The Service, which participates as a member of the IMA team, concurred and additional consultation was not required.
- Known locations of piping plover habitat and saline lakes were avoided.

- No threatened or endangered species were encountered during construction. Had any listed species been encountered, all ground disturbing activities in the immediate area would have been stopped immediately until Reclamation could consult with the Service to determine appropriate steps to avoid any effects to these species.

Based on these considerations, no adverse effects to threatened or endangered species have resulted from construction, operation, or maintenance of existing Project facilities.

Wetlands

Wetland impacts were estimated by overlaying the 110-foot pipeline right-of-way on the National Wetlands Inventory digital database (http://www.fws.gov/wetlands/) and calculating the intersection area of wetlands and pipeline right-of-way. Figure A.2 illustrates this methodology. In the figure, wetlands labeled 1 through 5 intersect the pipeline right-of-way, and the green shaded area of each wetland was assumed to be temporarily impacted. Approximately 83 acres of wetland habitat lie within the right-of-way of the 228 miles of pipeline constructed, which is approximately 0.36 acres per mile. This is illustrated in Figure A.3 which shows a small portion of pipeline 2-2C before, during, and after construction. These impacts are likely overestimated because the actual construction footprint was narrower than the right-of-way. Table A.3 shows the estimated temporary impacts by pipeline segment.

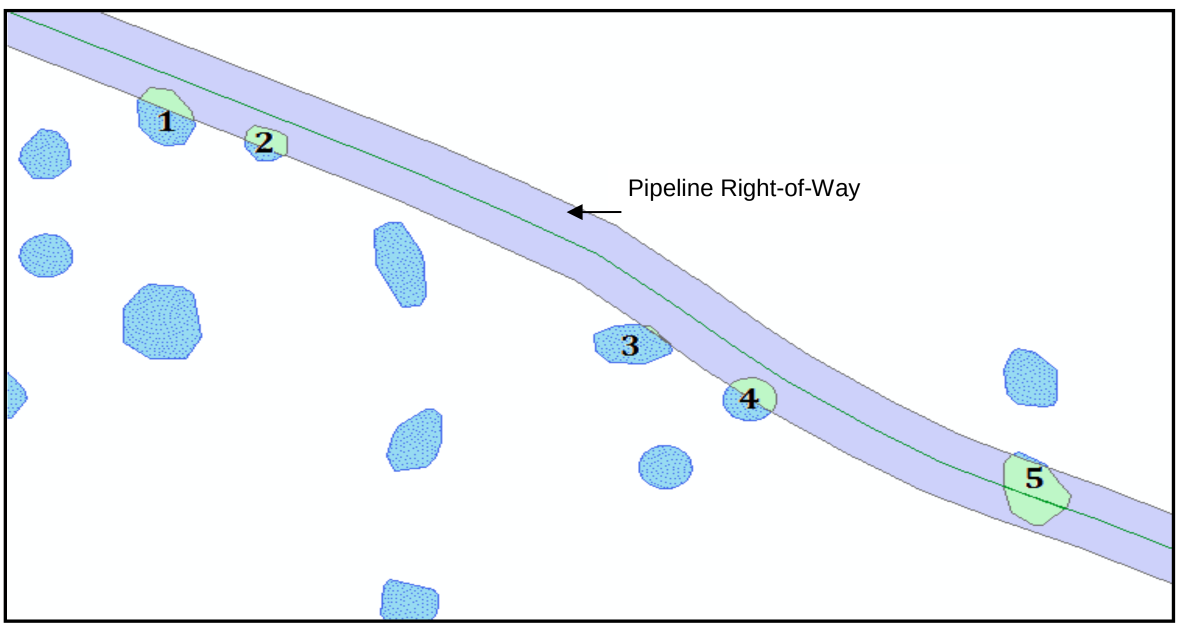


Figure A.2 Illustration of Methodology for Estimating Temporary Wetland Impacts. Figure Shows the 110-foot Pipeline Right-of-Way Overlaid on National Wetlands Inventory Data.

Table A.3 Acreage of Temporary Wetland Impacts for Constructed Project Pipelines.

Pipeline segment	Total Acreage by Wetland Classification[1]					
	Palustrine temporary	Palustrine seasonal	Palustrine semipermanent	Lacustrine	Riverine	Total
2-1 A	1.4	1.5	0.0	0.0	0.0	**2.8**
2-1 B	0.4	0.7	0.1	0.0	0.0	**1.1**
2-1 C	2.3	2.7	0.3	0.0	0.0	**5.3**
2-1 D	2.6	7.8	0.9	0.4	0.0	**11.7**
2-2 A	0.7	0.1	0.3	0.0	0.4	**1.4**
2-2 B	2.2	0.9	0.0	0.0	0.0	**3.1**
2-2 C	7.7	11.5	0.7	0.0	0.0	**19.9**
2-2 D	5.7	14.0	4.9	0.0	0.6	**25.2**
2-2 E	0.0	0.0	0.0	0.0	0.0	**0.0**
2-3 A	0.5	2.2	1.3	0.0	0.0	**4.0**
2-3 B	2.3	1.9	0.2	0.0	0.0	**4.4**
2008-1	0.6	0.6	2.6	0.0	0.0	**3.9**
Total	**26.2**	**43.8**	**11.4**	**0.4**	**1.0**	**82.8**

[1] Acreage values are estimates

Figure A.3 Illustration of pipeline routed around wetlands.

Top panel, dated 2006:
pre-construction, showing preliminary alignment. Middle panel, dated 2009: during construction, showing vegetation removed in right-of-way. Bottom panel, dated 2010: one year post-construction with wetlands intact.

Wetland impacts were avoided or reduced to less than significant through BMPs and mitigation measures incorporated into the constructed elements, including the following:

- Seasonal, semipermanent and permanent wetlands were avoided where practical. Where they could not be avoided, construction through seasonal, semipermanent, or permanent wetlands was avoided until after July 15 where practical.
- Where large wetlands abut the road right-of-way, pipelines were placed in rights-of-way where possible to reduce impacts.
- Backfill was placed in pipeline trenches to restore the impermeable layer below wetlands where necessary.
- Diaphragms or cutoff collars were used where soils and engineering evaluations indicated they were needed to prevent wetland drainage.
- When wetlands were wet, the placement of trench spoil material within the wetland boundaries was avoided wherever possible.
- Wetland basin contours were reestablished after pipeline installation where necessary.
- The Service was consulted on pipeline alignments during the design process wherever pipeline routes cross Service wetland easements.

The IMA team performed field reviews on all pipeline segments after construction. To date, all wetlands affected by Project construction have been restored, and no permanent wetland impacts have been recorded.

Historic Properties

When National Historic Preservation Act compliance for the Project was initiated by Reclamation in 1993, the proposed project was divided into 14 reaches to be constructed over a period of several years. Most reaches were in preliminary engineering design and lacked sufficient detail for identification of historic properties, so a programmatic approach under an existing state-wide programmatic agreement was taken (*Programmatic Agreement Between the Bureau of Reclamation, The Advisory Council on Historic Preservation, and the North Dakota State Historic Preservation Officer for the Implementation of Reclamation Undertakings in North Dakota*.)

In the 2001 Final EA, a two-mile wide corridor was evaluated for each proposed pipeline segment to develop baseline information and to estimate potential effects on cultural resources. A Class I literature review was completed, but some proposed facility locations had not been surveyed at a Class III level (intensive, pedestrian inventory). Reclamation conducted additional inventory and analysis, and consulted with the North Dakota State Historic Preservation Officer and Tribes prior to construction of all Project components after final designs for each component were completed and pipeline centerlines were known. Attachment 1 documents correspondence between consulting parties for this federal undertaking, and lists all cultural resource reports prepared to document the results of the surveys conducted.

Upon determining pipeline alignments for each phase of construction, Reclamation used the Class I file search to consult with the State Historic Preservation Office (SHPO) per 36 CFR Part

800.4 to determine which areas required further Class III, pedestrian cultural resource inventories in the high and medium site potential zones. These inventories were conducted by a qualified professional archaeologist and were completed prior to construction. In addition, Reclamation invited the appropriate tribal groups to participate in the consultation process, and consulted with the appropriate Native American Tribes regarding the locations of and potential impacts to properties of traditional religious and cultural importance to Native Americans. To date, all cultural resource inventories completed for the Project have resulted in a determination of *no historical properties affected*, and the North Dakota State Historic Preservation Officer has concurred in all such determinations.

Paleontological Resources

A literature and database search was completed to determine the general types of paleontological resources present within the Project area. All of the constructed Project components are located within the Drift Plains and Missouri Coteau physiographic regions where the surface geology is comprised of glacial sediments. Such sediments have produced abundant fossils in parts of North Dakota, including tree and other plant pollen, fish, aquatic snail and clam shells, land snails, insects, ostracods, and bones from beaver, caribou, elk, mammoth, and bison (Bluemle 1991). Based upon literature/file searches and field surveys conducted by the North Dakota Geological Survey, no significant fossil sites have been impacted by constructed Project components.

Social and Economic Conditions

As discussed in chapter two, some Project members are receiving an interim water supply from the City of Minot. This water is being delivered through the constructed portions of the bulk distribution system. The effects of constructed Project facilities on social and economic conditions in the Project area include availability of higher quality water for some of the Project participants; improved economic opportunities and increased employment; and a general increase in the attractiveness and quality of life. Because the current withdrawal rate from the Minot and Sundre aquifers is not sustainable, it is assumed that these interim contracts would not be renewed when they expire in 2018, and the social and economic benefits associated with this interim water supply would cease.

Land Use and Ownership

Approximately 95 percent of the lands affected by constructed elements are privately owned and consist of farmland and rangeland. Other land uses in the area include oil and gas production, power, telephone, and other communications transmission, and general public use of public lands.

The main impact to land use on private lands has been a temporary loss of production on cropland, rangeland, and hayland during construction, lasting until reclamation was completed. Landowners were compensated for losses through easement payments and reimbursements for crop damages and hay/pasture losses provided by the Project sponsor. Impacts to other land ownerships and uses have been minor, temporary, and localized. Farming operations have not been interrupted following completion of construction. Pipeline installation has not resulted in any permanent change of land use. Permanent land use changes associated with construction of storage reservoirs and pump stations totals less than 3 acres. Where valves are located in cultivated areas, driveways, roads, or other high traffic areas, the valve box has been buried below the plow depth, or at a depth to clear road grader maintenance.

Impacts have been avoided or reduced to less than significant through the following BMPs and mitigation measures incorporated into the constructed elements:

- Land ownership maps were provided to all agencies, project sponsors and cooperators to use in identifying potential impacts during the final design phase.
- Landowners to be affected by the construction of pipelines or other facilities were contacted as early as possible during the development of final designs.
- Existing utilities were located prior to completion of the final design and each utility operator was notified.
- Gas and petroleum lines were located and owners were consulted about specific design precautions to be taken when crossing them.
- Companies and agencies were consulted about crossing land underlain by mineable mineral deposits such as coal or gravel.
- Agencies, municipalities and private land owners were consulted to ensure the locations of facilities did not conflict with current or future land use plans.
- EPA was consulted to accurately delineate the locations of hazardous waste sites.
- Landowners and agencies were consulted about specific recommendations for restoration of their lands following construction.
- Fences were repaired after construction, unless otherwise agreed to by the landowner.
- State and county highway departments were consulted regarding the use of roadway rights-of-way as pipeline corridors and the type of crossings to be installed.
- The U.S. Air Force was consulted to determine the locations of underground missile communication systems.
- Sewer crossings were constructed in accordance with the North Dakota State Health Department requirements.

Indian Trust Assets

Indian trust assets are defined as legal interests in property held in trust by the United States for Indian Tribes or individuals. No completed pipelines or facilities were located on trust lands, and no other trust assets have been affected.

Aesthetics

Visual and noise impacts were limited to the construction phase and were therefore temporary and localized.

Other aesthetic impacts have been avoided or reduced to less than significant through the following BMPs and mitigation measures:

- Surface disturbance from construction activities have been reclaimed (recontoured and revegetated) to minimize long-term scars on the land.

- Pipeline rights-of-way crossing native prairie were reseeded with native species to reduce contrast between the rights-of-way and undisturbed native prairie.
- Facilities were built in conformance with local or county zoning and/or building requirements or restrictions. Above ground storage reservoirs were painted to blend in with the locale.
- Noise from pump station operations has been contained, as all pumping equipment is housed within buildings.

Summary

Construction of buried pipelines has resulted in temporary impacts to approximately 3,040 acres, primarily on cropland and planted herbaceous cover, with associated temporary impacts to other resources. Following reclamation of lands disturbed by pipeline construction, no permanent impacts have been documented.

Permanent impacts associated with construction of above-ground storage reservoirs and pump stations total less than three acres. All above-ground components are located on cropland or developed land.

Current withdrawals from the Minot and Sundre aquifers are not sustainable. As a result, groundwater levels in these aquifers are declining, which may be adversely affecting Souris River flows, and riparian areas and wetlands adjacent to the river. Only a small portion of the ongoing impacts associated with declining groundwater levels is attributable to the distribution of water through constructed distribution facilities.

Literature Cited

Bluemle, J.P. 1991. The Face of North Dakota- Revised Edition. Educational Series 21, North Dakota Geological Survey, Bismarck, North Dakota.

Bureau of Reclamation. 2001. *Finding of No Significant Impact for the Northwest Area Water Supply Project in North Dakota*. Dakotas Area Office. Bureau of Reclamation.

Bureau of Reclamation. 2001. Northwest Area Water Supply Project Final Environmental Assessment. Dakotas Area Office. Bureau of Reclamation.

Olendorf, P.R., A.D. Miller and R.N. Lehman. 1981. Suggested Practices for Raptor Protection on Power Lines - The State of the Art in 1981. Rap tor Research Report No. 4, Raptor Research Foundation, Inc. University of Minnesota, St. Paul, Minnesota.

Strong, L.L., T.H. Sklebar, and K.E. Kermes. 2005. A Gap Analysis of North Dakota. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND.

U. S. Fish and Wildlife Service. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Available online at: http://www.fws.gov/wetlands/.

Attachment 1 — Cultural Resources Reports and Correspondence Documenting Consultations

Table A1-1 Cultural Resources reports prepared for the Northwest Area Water Supply Project.

Date	Author	Title
1996	Olson, Byron L.	Northwest Area Water Supply Project, Bottineau, Burke, Divide, McLean, Mountrail, Renville, Ward, and Williams Counties, North Dakota: A Class I Cultural Resources Inventory.
1998	Olson, Byron L.	Northwest Area Water Supply Project, Bottineau, Burke, Divide, McLean, Mountrail, Renville, Ward, and Williams Counties, North Dakota: A Class I Class I Cultural Resources Inventory.
1999	Olson, Byron L. and Mark Sullivan	Cultural Resource Management Report NAWS Reach 1 Minot to Highway 83 Ward County ND Class III Cultural Resources Inventory.
1999	Olson, Byron L. and Gordon C. Tucker	Addendum to NAWS Reach 1 Minot to Highway 83 Ward County ND Class III Cultural Resource Inventory.
2002	Morrison, John G.	Phase 2-1B: Northwest Area Water Supply Pipeline: A Class II and III Cultural Resource Inventory, Ward County, North Dakota.
2003		Eleven Mile Survey for the NAWS Water Pipeline and 32 Acre Pump Station in McLean and Ward Counties, North Dakota: A Class III Cultural Resources Inventory.
2004		Addendum to Eleven Mile Survey for the NAWS Water Pipeline and 32 Acre Pump Station in McLean and Ward Counties, North Dakota: A Class III Inventory.
2005	Bluemle, William J.	Eleven Mile Survey for the NAWS Water Pipeline and 32 Acre Pump Station in McLean and Ward Counties, North Dakota: A Class III Cultural Resource Inventory.
2005	Bluemle, William J.	Fourteen Mile Survey for the NAWS Water Pipeline and Two Reroutes in McLean and Ward Counties, North Dakota: A Class III Cultural Resources Inventory.
2006	Hiemstra, Damita.	Northwest Area Water Supply Treated Water Pipeline for Minot: A Cultural Resources Inventory in Ward County, North Dakota.
2007	Jackson, Michael A.	Final Report for the NAWS Berthold Segment Water Pipeline Class I, II, and III Cultural Resources Inventories Ward County, North Dakota.
2007	Jackson, Michael A. Final Class III Report	Addendum on the NAWS Berthold Segment Water Pipeline Class I, II, and III Cultural Resources Inventories Ward County, North Dakota.
2007	Metcalf Archaeological Consultants, Inc.	Northwest Area Water Supply Proposed 2007 Kenmare/Upper Souris Segment Class I Cultural Resources Inventory.
2008	Burns, Christina Grimsrud.	Class I Cultural Resources Inventory for the Kenmore/Upper Souris Water Transmission Pipeline NAWS Project in Ward, Renville, and Burke Counties, North Dakota.
2008	Burns, Wade.	Class II and Class III Cultural Resources Inventory for the Kenmore/Upper Souri Water Transmission Pipeline NAWS Project in Ward, Renville, and Burke Counties, North Dakota.
2008	Pollman, Jennifer and Wade Burns.	Addendum to Class II and Class III Cultural Resource Inventory for the Kenmare/Upper Souris Water Transmission Pipeline NAWS project in Ward, Renville and Burke Counties, North Dakota.
2009	Burns, Christina Grimsrud.	Class II and Class III Cultural Resources Inventory for the Northwest Area Water Supply (NAWS) Burlington Alignment 2-2E Project in Ward, County, North Dakota.

Table A1-2 Correspondence Documenting Consultation under Section 106 of the National Historic Preservation Act for the NAWS Project

Date	Author	Recipient	Subject
02/10/1993	Reclamation	ND SHPO	Letter: Officially initiated consultation under the National Historic Preservation Act for the NAWS Project as a federal undertaking (SHPO Reference 89-13)
10/24/1994	Engineering Consultant	ND Deputy SHPO	Letter: Results of the Class I of pipeline corridors within the NAWS Project Area
06/5/1997	Reclamation	ND SHPO	Letter: Transmittal of Draft Class I Report for the Proposed NAWS Project
06/23/1997	ND SHPO	Reclamation	Letter: Comments on the Draft Class I Cultural Resources Inventory
02/27/2002	Reclamation	Indian Affairs Commission	Letter: Invitation to participate as an interested party in consultation under the NHPA for NAWS Project. Transmittal of the Class III Intensive Pedestrian Survey of Part of Reach 1 of a Seven and one-half Mile Segment of the Proposed NAWS Pipeline.
02/27/2002	Reclamation	ND SHPO	Letter: Consultation under the NHPA for 1) the Class I Inventory in Preparation for the Implementation of the NAWS Pipeline and 2) the Class III Intensive Pedestrian Survey of Part of Reach 1 of a Seven and on-half Mile Segment of the Proposed NAWS Pipeline.
03/01/2002	ND SHPO	Reclamation	Letter: NDSHPO Ref 89-0013 response finding report acceptable
12/15/2004	Reclamation	ND SHPO	Letter: Consultation under the NHPA no historical properties affected determination for a Class III Intensive Pedestrian Survey of 11 Miles along Highway 83 for the NAWS Project and 32-Acre Pump Station in McLean and Ward Counties.
12/21/2004	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected for 11 miles and pump station
? 12/15/04	Reclamation	ND SHPO	Letter: Consultation under NHPA concurrence with 12/15/04 no historic properties affected determination for Reach 1
12/22/2004	ND SHPO	Reclamation	Letter: State Historical Society of North Dakota concurrence with 12/15/04 no historic properties affected determination for Reach 1
01/18/2005	Reclamation	ND SHPO	Letter: Addendum to class III cultural resources survey of 11 Miles Along Highway 83 for the NAWS Project and 43-acre pump station in McLean and Ward counties no historic properties affected determination
02/02/2005	ND SHPO	Reclamation	Letter: Concurrence with 1/18/05 determination of no historic properties affected
02/04/2005	Reclamation	ND SHPO and Corps of Engineers	Letter: Revision of Class III cultural resources survey of 14 miles and 2 reroutes along Highway 83 – title and other minor changes in report
02/09/2005	ND SHPO	Reclamation	Letter: Finds the report acceptable
04/11/2006	Reclamation	Three Affiliated Tribes and Standing Rock Sioux Tribe	Letter: Invitation to participate in EIS as cooperating agencies
04/24/2006	ND SHPO	Reclamation	Letter: Looks forward to further consultation on the EIS
05/05/2006	Three Affiliated Tribes	Reclamation	Letter: Agree to be cooperating agency and request reconsideration of impacts to sacred and cultural resources in government-to-government consultation
05/22/2006	Reclamation	Three Affiliated Tribes	Telephone consultation – TAT requests Reclamation develop a programmatic agreement similar to the Corps'
05/31/2006	Reclamation	Three Affiliated Tribes and Standing Rock	Letters requesting meetings to discuss NAWS EIS

Date	Author	Recipient	Subject
		Sioux Tribe	
08/08/2006	Reclamation	Three Affiliated Tribes and Standing Rock Sioux Tribe	Letter: Invitations to cooperating agency meeting
08/29/2006	Reclamation	Three Affiliated Tribes and Standing Rock Sioux Tribe	Letter: Cooperating agency meeting packets transmitted
09/19/2006	Reclamation	Three Affiliated Tribes and Standing Rock Sioux Tribe	Letter: Cooperating agency meeting minutes transmitted and second invitation to participate as cooperating agencies
10/06/2006	Reclamation	Three Affiliated Tribes and	Letter: Transmittal of cooperating agency MOA
10/19/2006	Reclamation	Standing Rock Sioux THPO	Letter: Confirmation of meeting scheduled between EIS Team Leader and THPO and tribal archaeologist
10/24/2006	Reclamation	Three Affiliated Tribes	Letter: Discussed cooperating agency MOA and future consultation process through THPO
11/26/2006	Reclamation	ND SHPO, Indian Affairs Commission, and Three Affiliated Tribes	Letter: Proposed scope of work for Class I/II/III inventory of Minot to Berthold
11/09/2006	ND SHPO	Reclamation	Letter: Concurrence with letter of 11/26/2006
02/21/2009	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination based on Class III Intensive Pedestrian Survey of Minot to Berthold
02/28/1007	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Class III Intensive Pedestrian Survey of Minot to Berthold and accept report
03/08/2007	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination based on Class II/III Intensive Pedestrian Survey of 4 Miles along the north side of the Souris River and west of the Hwy 83 bypass
03/15/2007	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Class II/III Intensive Pedestrian and accept report
03/22/2007	Reclamation	ND SHPO	Letter: Transmittal of two final reports
03/28/2007	Reclamation	Three Affiliated Tribes THPO	Telephone call to again invite the Three Affiliated Tribes to be a cooperating agency
03/29/2007	Reclamation	Three Affiliated Tribes THPO	Email transmitting past correspondence and draft MOA to new THPO
04/09/2007	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for a high service pump based on Class I survey.
04/12/2007	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Class I
05/04/2007	Reclamation	Three Affiliated Tribes THPO	Letter: Request meeting with Tribal Chairman and members of the Tribal Council to discuss cooperating agency invitation
05/22/2007	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for an addendum to Class III survey report.
05/24/2007	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Class III Intensive Pedestrian survey of Minot to Berthold and accept report addendum
05/24/2007	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Transmittal of final addendum report for Class III survey of Minot to Berthold pipeline

Date	Author	Recipient	Subject
05/31/2007	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Class III Intensive Pedestrian survey of Minot to Berthold and accept final report addendum
06/11/2007 through 06/22/2007	Reclamation	Three Affiliated Tribes THPO	Five phone calls and an e-mail regarding invitation to be a cooperating agency
06/27/2007	Reclamation	Three Affiliated Tribes THPO	E-mail notification of transmittal of Draft EIS chapters and appendixes for review
07/06/2007 through 07/17/2007	Reclamation	Three Affiliated Tribes THPO	Phone messages asking if materials were received and if the Tribal Council would like to meet
07/17/2007	Reclamation	Three Affiliated Tribes THPO	E-mail response to voicemail from THPO suggesting possible meeting dates and invitation to cooperating agency meeting
07/27/2007	Reclamation	Three Affiliated Tribes THPO	E-mail summary of cooperating agency meeting
09/17/2007	ND SHPO	Reclamation	Letter requesting a lead federal agency consultation on a cofferdam on Souris River
06/25/2008	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for Berthold to Beyond Kenmare Class III survey report.
06/27/2008	ND SHPO	Reclamation	Letter: Concurrence with survey route for Berthold to Beyond Kenmare Class II/III survey route and request final report
09/17/2008	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for Reroute of Berthold to Kenmare Class III survey report.
09/22/2008	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Kenmare/Upper Souris survey
10/17/2008	ND SHPO	Reclamation	Letter: Concur with Class III inventory of Kenmare new tank location and Class II for the remainder of the route
10/28/2008	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for Kenmare to Mohall Class III survey report
10/31/2008	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Kenmare to Mohall Class III survey
01/12/2009	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for an addendum Kenmare/Upper Souris Class III survey report.
01/15/2009	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on addendum to Kenmare/Upper Souris Class III survey
10/01/2009	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for the Burlington Alignment Class III survey report.
10/02/2009	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Burlington Alignment report.
10/29/2010	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for pipeline Minot to the Air Force Base (AFB) and from the AFB to Glenburn and Reservoir 4 based Class I, II, and III survey reports..
11/4/2010	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Minot to the Air Force Base (AFB) and from the AFB to Glenburn and Reservoir 4 report.
8/5/2011	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for pipeline Renville 16.2 miles to east Class I survey report.

Date	Author	Recipient	Subject
8/8/2011	ND SHPO	Reclamation	Concurrence with no historic properties affected determination based on Renville 16.2 miles to east report.
8/5/2011	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA recommending Class II/Class III inventory on NAWS Project contract 2-4A Class I survey report
8/9/2011	ND SHPO	Reclamation	Letter: Concurrence to conduct Class II/Class III inventory on NAWS Project contract 2-4A, based on Class I survey.
6/8/12	Reclamation	ND SHPO, Indian Affairs Commission	Letter: Consultation under the NHPA no historical properties affected determination for pipeline Renville 16.2 miles to east Class II and III survey reports.
6/12/2012	ND SHPO	Reclamation	Letter: Concurrence with no historic properties affected determination based on Renville 16.2 miles to east report.

Appendix B
Community/Water Systems Data

Appendix B
Community/Water Systems Data

Introduction

A water needs assessment was conducted to evaluate the future water needs for the communities and rural systems that would be served by the Northwest Area Water Supply Project (Project) (Reclamation 2012b). The results of the water needs assessment are summarized in the following tables, which describe the following for each of the communities and rural systems that are Project members:

- Current and projected (2060) water needs in million gallons per day (mgd).
- Maximum planning period water demands (mgd) (up to 2060).
- Current water sources.
- Potential for ongoing water availability from these sources.
- Future water sources should the Project not be implemented.
- Treatment capability or capacity or withdrawal capacity limitations of this future water source. For the purposes of this section, treatment capabilities are defined as the ability to treat the water to primary standards. Treatment capacity refers to the daily volume of raw water that each entity's treatment infrastructure can process.
- Potential water deficit (if future water needs cannot be met due to treatment or withdrawal capacity limitations).
- Whether or not primary and secondary drinking water standards would be met by the future water sources.
- Water contaminants in the future water sources.
- Issues that each community or rural system would face in the absence of the Project.

All Seasons Water Users District

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.250	0.749	0.955[a]	Antler Creek aquifer, Shell Valley aquifers, unnamed aquifer	Unknown (may be fully allocated)	Same as current	0.252	0.703[b]	Yes	No	TDS, elevated iron, manganese, sodium, color	The District likely would face water shortages throughout its service area. The projected shortage is estimated to be 0.703 mgd if the aquifers are fully allocated. Five secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Notes:
TDS = Total Dissolved Solids
a Maximum planning period demand occurs in 2020.
b Deficit is due to treatment, pipeline, and withdrawal limitations.

City of Berthold

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.030	0.035	0.035	City of Minot	No	Fort Union aquifer	Unknown[a]	0.035[b]	Yes	No	TDS, sodium	Water would not continue to be available from the City of Minot. Berthold would have to return to its previous water source, which does not meet secondary water quality standards and was previously found to be unsuitable as a water supply by the City (Reclamation 2012b). Alternatively, Berthold could try to purchase water from the North Central Rural Water Consortium, but the latter may not have the capacity to extend service to additional communities. If groundwater were used, three secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Notes:

[a] Berthold's treatment plant and withdrawal facilities are not currently in use because Berthold currently receives water from Minot; thus, their limitations have not been quantified.

[b] Deficit is due to treatment limitations. The city's water supply previously has not been found suitable due to water quality issues (Reclamation 2012b).

City of Bottineau

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.030	0.085	0.259[a]	Willow Creek aquifer	Unlikely	Same as current	0.220[b]	0.259[c]	Yes[d]	No	TDS, sodium, uranium, and sulfate	Bottineau would face water shortages throughout its service area, estimated to be 0.22 mgd. Three secondary water quality standards would be exceeded given use of Willow Creek aquifer water without additional treatment capability (Reclamation 2012a).

Notes:
[a] Maximum planning period water need occurs in 2020.
[b] Treatment capacity is 0.220 mgd, but treatment processes may not be sufficient to treat the water to applicable standards.
[c] Deficit due to treatment capacity limitations is 0.039, but the City has indicated that it may not have adequate infrastructure in place to meet future needs. Additionally, the city's water supply has historically not met water quality standards (uranium) and cannot meet needs without treatment upgrades (AEES, 2001).
[d] The city has had periodic issues with high concentrations of uranium in its water supply, which could be exacerbated if withdrawals are increased.

City of Burlington

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.030	0.085	0.085	City of Minot (annual daily average demand) Burlington aquifer (peak demand)	No Yes	Burlington aquifer	0.300	None	Yes	No	Sulfate, TDS, manganese	Water would not continue to be available from the City of Minot. Burlington would have to rely exclusively on water from its aquifer. Burlington has sufficient capacity in its existing wellfield (Schuh 2010) and treatment plant to meet projected demands. Three secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

City of Deering

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.010	0.009	0.01	City of Minot Unnamed aquifer	No Yes	Unnamed aquifer	Unknown	None	Yes	No	Sulfate, TDS, manganese, sodium	Water would not continue to be available from the City of Minot. Deering would have to rely on water from its unnamed aquifer. Water demand is projected to decline by 0.001 mgd, and adequate water is available in this aquifer, but four secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

City of Des Lacs

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.002	0.003	0.003	North Central Rural Water Consortium Permit for unnamed aquifer but unused	Yes, but may not fully meet projected need Unlikely	Same as current	0.002[a]	0.001	Yes	No	TDS, iron, manganese, sodium, sulfate; data unavailable for unused aquifer	Des Lacs would face water shortages throughout its service area, estimated to be 0.001 mgd. The potential to produce additional quantities from the local aquifer is poor (Schuh 2010). Water received from the Consortium would continue to exceed five secondary water quality standards without additional treatment capability (Reclamation 2012a).

Note:
[a] Volume of water available is potentially limited by withdrawal capacity and source limitations.

City of Grenora

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.02	0.012	0.013[a]	Grenora aquifer	Yes	Same as current	Unknown	None	Yes	No	TDS, iron, manganese, sodium	Adequate water to meet projected needs is available from the Grenora aquifer (Schuh 2010), although four secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Note:
[a] Maximum planning period water need occurs in 2020.

City of Kenmare

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.030	0.070	0.076[a]	City of Minot	No	Columbus aquifer	Unknown	0.076[b]	No	No	**Elevated arsenic**[c], TDS, sodium	Water would not continue to be available from the City of Minot. Kenmare may have to rely on water from the Columbia aquifer. One primary and two secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a). Kenmare may seek additional quantities from the Upper Souris Water Users District, which appears to have the capability to supply additional quantities of water through 2060.

Note:
[a] Maximum planning period water need occurs in 2020.
[b] Deficit is due to treatment limitations. The city's water supply has historically not met water quality standards and cannot meet needs without treatment upgrades.
[c] Kenmare's groundwater exceeds the primary standard for arsenic.

City of Maxbass

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.01	0.009	0.010	Unnamed aquifer	Unknown	Same as current	Unknown	None	Yes	No	TDS, iron, manganese, sodium	The potential yield of the aquifer is unknown, but water use is projected to decline; therefore, additional water would not be required. Four secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

City of Minot

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
5.280	7.009	7.009	Minot and Sundre aquifers	No	Same as current	14	Not known	Yes	No	TDS, iron, manganese	Minot's current groundwater withdrawal rates are resulting in unsustainable drawdowns in the Minot and Sundre aquifers. The City is currently permitted to withdraw up to 10 mgd (SWC 2013), which would be sufficient to meet 2060 water needs; however, given the rate of decline, it is not anticipated that this amount of water would be available for withdrawal in the future. Three secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

City of Mohall

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.080	0.126	0.138[a]	City of Minot (annual daily average demand) Mohall (Cut Back Creek) aquifer (peak demand)	No Unlikely	Mohall (Cut Back Creek) aquifer	0.080	0.058[b]	Yes	Yes	None	Water would not continue to be available from the City of Minot. Mohall would need to investigate whether the Mohall aquifer could sustain additional withdrawals, but the probability is low (Schuh 2010). Alternatively, Mohall could seek additional quantities of water from the Upper Souris Water Users District, which appears to have the capability to supply additional quantities of water through 2060. The current water treatment process appears to be sufficient to meet water quality standards, although well and treatment capacities are not sufficient to meet projected needs (Reclamation 2012a).

Notes:

[a] Maximum planning period water need occurs in 2020.

[b] Deficit is due to treatment and wellfield capacity limitations.

North Central Rural Water Consortium[a]

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
1.450	1.587	1.587	City of Minot Voltaire aquifer (North Prairie Rural Water Association[a])	No Possible	Voltaire aquifer	1.1	0.487[b]	Yes	No	TDS, iron, manganese, sodium, sulfates	Water would not continue to be available from the City of Minot. The potential to develop additional quantities of groundwater from the Voltaire aquifer is low, and the aquifer is considered fully allocated, but there is a potential to develop 1,000 to 1,900 acre-feet per year from a portion of the aquifer located 3 to 5 miles east of the City of Minot's Sundre aquifer wellfield (Schuh 2010). Four secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Notes:

[a] For the purposes of population and water demand projections, the Consortium's service area includes the North Prairie Rural Water District (per the North Central Rural Water Consortium's water user survey, included in Reclamation 2012c). Additionally, the West River Water and Sewer District was included in the Consortium's service area for planning purposes, due to a lack of specific information regarding their infrastructure, water needs, and potential limitations. .

[b] Deficit is due to treatment capacity limitations. Source limitations may also occur if supplies are no longer available from North Prairie Rural Water District.

City of Rugby

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.210	0.266	0.272[a]	Pleasant Lake aquifer	Unknown	Same as current	0.272	None	Yes	Yes	None	Infrastructure needs already have been met. No additional needs are anticipated.

Note:

[a] Maximum planning period water need occurs in 2020.

City of Sherwood

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.010	0.012	0.014[a]	City of Minot Unnamed aquifer	No Unlikely	Unnamed aquifer	Unknown	None	Yes	No	TDS, manganese, sodium	Water would not continue to be available from the City of Minot. There is a low probability of obtaining additional water from the local aquifer (Schuh 2010). Three secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Note:
[a] Maximum planning period water need occurs in 2020.

City of Souris

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.010	0.005	0.010	Unnamed aquifer	Yes	Same as current	Unknown	None	Yes	No	TDS, iron, manganese, sulfate	Water use is projected to decline; therefore, additional water would not be required. Four secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

City of Upham

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.010	0.009	0.010	All Seasons Water Users District	Yes[a]	Same as current	Unknown	None	Yes	No	TDS, elevated iron, manganese, sodium, color	Water use is projected to decline; therefore, additional water would not be required. Five secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Note:
[a] As discussed above under All Seasons Water Users District, however, the District is expected to face shortages throughout its entire service area due to increases in water needs at some locations.

Upper Souris Water Users District

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.130	0.119	0.159[a]	Columbus aquifer Glenburn aquifer	Likely Yes	Same as current	0.37	None	Yes	No	TDS, iron, salinity, arsenic, lead, copper, manganese	Water use is projected to decline; therefore, additional water would not be required. Seven secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Note:
[a] Maximum planning period water need occurs in 2020.

City of Westhope

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.060	0.010	0.06	Souris Valley aquifer[a]	Unlikely	Same as current	Unknown	None	Yes	No	TDS, manganese, sodium	Water use is projected to decline; therefore, additional water would not be required. Three secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Note:
[a] Emergency water service is provided by the All Seasons Water Users District.

City of Willow City

2010 Water Use (mgd)	2060 Water Needs (mgd)	Maximum Planning Period Demand (mgd)	Current Water Source	Ongoing Water Availability from this Source	Future Water Source (without Project)	Treatment or Withdrawal Capacity Limits (mgd)	Deficit (mgd)	Meets Water Quality Standards		Water Quality Issues	Future Issues without Project
								Primary	Secondary		
0.030	0.022	0.03	All Seasons Water Users District	Yes	Same as current	Unknown	None	Yes	No	TDS, elevated iron, manganese, sodium, color	Water use is projected to decline; therefore, additional water would not be required. Five secondary water quality standards would be exceeded without additional treatment capability (Reclamation 2012a).

Note:
[a] As discussed above under All Seasons Water Users District, however, the District is expected to face shortages throughout its entire service area due to increases in water needs at some locations.

References

AEES (Advanced Engineering and Environmental Services, Inc.). 2001. Water Supply and Treatment Facility Plan Report. A report prepared for the City of Bottineau and the All Seasons Water Users Association. February.

Bureau of Reclamation (Reclamation). 2012a. Community Discussion Log from SWC 8-27-2012.xls. A spreadsheet describing the utility planning process for several of the NAWS members, provided to Reclamation by the North Dakota State Water Commission. August.

Bureau of Reclamation (Reclamation). 2012b. Water Needs Assessment Technical Report, Northwest Area Water Supply Project. North Dakota. Dakotas Area Office, Great Plains Region.

North Dakota State Water Commission (SWC). 2013. Water Permit Data Query Web Interface. Retrieved June 16, 2013, from: http://www.swc.state.nd.us/4dlink7/4dcgi/permitsearchform/Permits.

Schuh, W.M. 2010. Water Appropriation Requirements, Current Water Use, & Water Availability for Energy Industries in North Dakota: A 2010 Summary –North Dakota State Water Commission Water Resources Investigation No.49. Prepared for the 61st Legislative Assembly of North Dakota in Response to House Bill 1322, Section 2.

Appendix C
Alternatives Formulation

Northwest Area Water Supply Project
Supplemental Environmental Impact Statement

Acronyms and Abbreviations

AR	artificial aquifer recharge
ASR	aquifer storage and recovery
EA	Environmental Assessment
CFR	Code of Federal Regulations
EIS	Environmental Impact Statement
GIS	geographic information system
mgd	million gallons per day
MR&I	municipal, rural, and industrial
NEPA	National Environmental Policy Act
Reclamation	Bureau of Reclamation
SEIS	Supplemental Environmental Impact Statement
UV	ultraviolet
WTP	water treatment plant

Appendix C-1 Alternatives Development Process

Introduction

The National Environmental Policy Act (NEPA) requires that an Environmental Impact Statement (EIS) analyze the impacts of alternative ways of implementing a project. NEPA's requirements for an alternatives analysis are found in the Council on Environmental Quality's NEPA Regulations (40 Code of Federal Regulations [CFR] 1502.14). Under NEPA, the range of alternatives required to be evaluated by an EIS is governed by the rule of reason, which requires an EIS to set forth only those alternatives necessary to permit a reasoned choice. An EIS must rigorously explore and objectively evaluate a reasonable range of alternatives as defined by the specific facts and circumstances of the proposed action. Alternatives must be feasible and consistent with the statement of purpose and need. Feasible alternatives are those that can be carried out based on technical, economic, and environmental factors, as well as common sense (40 CFR 1502.14; Forty Most Asked Questions Concerning the Council on Environmental Quality NEPA Regulations No. 2a [Federal Register 18026, March 23, 1981; as amended, 51 Federal Register 15618, April 25, 1986]). If alternatives have been eliminated from detailed study, the EIS must briefly discuss the reasons for their elimination.

This appendix describes the process used to develop the action alternatives evaluated in the Supplemental Environmental Impact Statement (SEIS) for the Northwest Area Water Supply Project (Project), and also describes alternative water sources and components that were considered but not carried forward for detailed analysis. The SEIS draws on the work performed for earlier studies, such as the Environmental Assessment (EA) and Finding of No Significant Impact completed for the Project in 2001 (North Dakota State Water Commission et al. 2001, Bureau of Reclamation [Reclamation] 2001) and the Northwest Area Water Supply Project Final EIS on Water Treatment (Reclamation 2008), which evaluated different water treatment methods to reduce the risk of transferring potentially invasive species from Lake Sakakawea. It also takes a fresh, hard look at new ways of implementing the Project. The Cooperating Agencies were active participants in each step of the alternatives development process, which occurred in a systematic, incremental manner involving the following:

- Definition of the Project's purpose and need.
- Identification of possible water sources and various ways of implementing the Project using these water sources.
- Elimination of those options that were not considered technically feasible or cost effective.
- Development of action alternatives based on the water sources that were considered feasible.
- Increasingly refined engineering design, drawing on past studies, in order to provide sufficient detail to allow a thorough evaluation of impacts and costs of each alternative in the SEIS.

The determination of whether the water sources and optional ways of implementing the Project were technically feasible or cost effective was based on the following factors:

- **Current and Future Demand.** The ability to produce water in quantities sufficient to meet a portion of the current and future demand of all Project member municipalities and rural water districts with a high degree of reliability.
- **Water Quality**. The ability to produce water that meets all primary drinking water standards and meets secondary drinking water standards to the extent practicable.
- **Invasive Species**. If an interbasin water transfer within North Dakota was involved, the ability to remove/inactivate select invasive species groups (e.g., fungi, bacteria, protozoa) to levels comparable to those aquatic species (*Giardia*, *Cryptosporidium*, viruses) with known removal and inactivation treatment efficiencies.
- **Implementation Timeframe.** The ability to be implemented within a schedule that meets the Project participant requirements.
- **Socioeconomic Impacts.** The ability to avoid unacceptable adverse socioeconomic impacts on the regional economy or regional quality of life.
- **Regulatory Requirements**. Consistency and compatibility with all aspects of state, federal, and local law, including North Dakota water law; international water compacts (e.g., the Boundary Waters Treaty of 1909 and its amendments, particularly the Canada-United States Agreement for Water Supply and Flood Control in the Souris River Basin [1989]); and regulatory requirements for the protection of environmental resources such as threatened or endangered species or their habitat, wetlands, groundwater and surface water quality and quantity, and cultural resources.
- **Technical Feasibility**. Use of existing technology successfully incorporated in water supply projects of similar scope and scale in the region.
- **Siting**. No substantial conflicts with areas designated as sensitive or in need of special recognition or protection by federal, state, or local law.
- **Risk Management**. No unacceptable risks to the Project and its operation from natural occurrences such as flood hazards, earthquakes, etc.
- **Cost and Affordability**. Design, permitting, capital and operating costs comparable to those of water supply projects of similar scope and scale in the region.
- **Integration with the Existing Facilities**. The ability to effectively use and integrate with existing, designed, or planned infrastructure.

The following sections describe the process that was undertaken to develop the action alternatives evaluated in the SEIS in greater detail.

Project Purpose and Need

To clearly define the purpose and need, a water user survey was developed and circulated to each Project member to solicit data regarding their water systems, including present-day water quality and quantity and projected municipal, rural, and industrial (MR&I) water needs. (Details are included in Water Needs Assessment Technical Report [Reclamation 2012], which is a supporting document to this SEIS[1], as well as Appendix B of this SEIS.) This assessment was based on expected population growth and water use habits and showed that MR&I needs are expected to increase by approximately 2.49 million gallons per day (mgd) by 2060. Much of the projected increase is due to the following factors:

- It is anticipated that substantial rural populations that are currently not connected to a public water system would connect to the Project by 2020.
- Significant growth is expected in the cities of Minot, Kenmare, and Rugby; Ward County; in the All Seasons Water Users District service area; and in several service areas of the North Central Rural Water Consortium.
- The cities of Minot and Mohall, along with the All Seasons Water Users District and North Central Rural Water Consortium plan to extend water service to new areas and new developments requiring substantial amounts of water between 2010 and 2020, which will result in increased demands beyond those associated with growth in the existing service areas.

The survey showed that although some communities would have sufficient supplies to meet projected needs until 2060, at least 6, and possibly 7, communities or rural water systems likely would not. Additionally, 20 of the Project members would have water that did not meet the secondary drinking water standards without additional treatment. Most of the drinking water would exceed the secondary standards for total dissolved solids and sodium, and a number of other secondary standards would be exceeded throughout the Project Area, including manganese, sulfate, and iron, among others. Additionally, the City of Kenmare’s water supply would not meet the primary (legally enforceable) standard for arsenic.

As such, it was determined that the purpose of the Project is to provide a reliable source of high quality, treated water to communities and rural water systems in northwestern North Dakota for MR&I uses that would be able to serve projected population growth up to the year 2060. The treated water provided by the Project would meet the primary drinking water standards established by the Safe Drinking Water Act, as well as secondary standards where feasible.

Water Sources Considered

Once the purpose and need for the Project was established, a wide range of potential sources was identified by Reclamation and discussed with Cooperating Agencies, these sources include; groundwater, artificial aquifer recharge (AR) and aquifer storage and recovery (ASR), treated municipal wastewater, water conservation, Souris River water, and water from Lake Sakakawea. Based on a review of available information and professional judgment, the availability and quality of potential water supplies for the Project were identified. Each of the sources that was considered is described below, along with the reasons for its elimination or retention.

[1] This assessment included projections for Grenora and Rugby to account for their potential water needs, although they are currently served by their own water systems.

Groundwater

Groundwater in the Project Area occurs in two major types of aquifers: glaciofluvial and bedrock. For many Project members, obtaining a significant amount of additional water from glaciofluvial aquifers is not possible. In addition, the City of Minot's principal water supply aquifers (Minot and Sundre) cannot sustain withdrawals at historic levels or support additional withdrawals. However, with supplemental recharge from the Souris River during periods of high flow, the Minot and Sundre aquifers could be an important component of a conjunctive use water supply option. Therefore, glaciofluvial aquifers were included in the list of water supply options to be evaluated further for inclusion in the SEIS. The use of bedrock aquifers was eliminated as a water source for a variety of reasons, including excessive depth, potential impacts on nearby wells, and insufficient quantity. In addition, water quality is generally poor and may not be suitable for human consumption due to its high mineral content. As noted above, Project members currently relying on groundwater generally do not have water that meets the secondary drinking water standards for a number of contaminants.

Aquifer Recharge and Aquifer Storage and Recovery

The potential for AR and ASR to be viable storage mechanisms was considered. Artificial AR was carried forward as a potentially viable storage option because it appeared to be technically feasible in both the Minot and Sundre aquifers and could enable the City of Minot to expand groundwater withdrawals. ASR is a less viable storage option for water supply alternatives for the Project because it is not a proven technology for glaciofluvial and bedrock aquifers in North Dakota. Extensive investigations would be required to determine feasibility, technical considerations, and costs. Thus, ASR was not carried forward for further analysis.

Treated Municipal Wastewater

Reusing the City of Minot's treated wastewater to offset a portion of the Project's potable water demand, and thus reduce the overall demand on the system, was evaluated but not considered feasible. This was due to a combination of factors, including the high cost of treatment facility upgrades and developing a distribution system, low rates of outdoor water use, and a customer base that could not use appreciable quantities of the available reuse water. The potential to reuse treated wastewater from other communities and rural water systems within the Project area was not evaluated due to their relatively small size and limited quantity of wastewater.

Water Conservation

The potential water savings that could be achieved by 2060 through the implementation of additional water conservation measures was considered. However, water conservation opportunities are limited in the Project Area because water use is already low, and it is not feasible to conserve enough water to accommodate the projected demand in 2060. Moreover, conservation would not resolve the water quality issues facing the Project members.

Souris River

The feasibility of using Souris River water focused on the Minot area because most of the population in the Project Area is located here, as is the existing water treatment and conveyance infrastructure for the Project. Historic flow data recorded for the Souris River at Minot (i.e., data from 1903 to 2011) were used to estimate the future availability of water in the Souris River for water supply. The analysis showed that the quantity of water necessary to meet the peak and average Project demands of 26.3 mgd and 10.1 mgd, respectively, would frequently be unavailable. Therefore, surface water diversions from the Souris River cannot be relied upon as a consistent source for a water supply option. However, water supplies from the Souris River can support certain conjunctive use options, such as local AR or blending with Missouri River water. The water quality of the Souris River at Minot is of sufficient quality that it can be treated to meet drinking water standards but may require advanced water treatment, such as Reverse Osmosis. The use of the Souris River water was carried forward for further analysis.

Missouri River

The analysis of the quantity and quality of Missouri River flows focused on the impounded portion of the Missouri River watershed above Garrison Dam at Lake Sakakawea because of its proximity to population centers in the Project Area and the existing water conveyance infrastructure such as the Snake Creek Pumping Plant . Monthly mean discharge records from 1969 to 2009 were examined to determine release trends and average flows. Based on mean flow conditions over this 40-year period as measured at the dam, suffecient quantities would be avaiable for the proposed peak Project demand (approximately 26 mgd). Water quality data also were evaluated, and it was determined that water quality does not exceed primary or secondary drinking water standards. Thus, this planning-level analysis concluded that ample quantities of water are available at the Garrison Dam to meet the peak water needs of the Project and that this water is of sufficient quality that it can feasibly be treated to meet drinking water standards. Therefore, this water source was carried forward for further analysis in the SEIS.

Optional Ways of Implementing the Project

While evaluating the water sources described above, 14 optional ways of implementing the Project were developed based on these water sources. Each of these is described along with the reasons they were either eliminated or carried forward.

Option 1: Enhancement of Existing Surface Water Systems

Existing water systems that use the Souris River would be upgraded to achieve compliance with all drinking water standards. Existing Project pipelines and distribution systems of Project members would continue to be used, but additional planned Project distribution pipelines would not be constructed. This option was eliminated because seasonal low flows in the Souris River and its tributaries make it infeasible for the river or its tributaries to supply enough water to meet current and future demands. Very few Project members have existing surface water systems, so very little municipal water is currently derived from this source. The largest historic user of surface water is the City of Minot, but the City has not used the Souris River as a source in many years.

Option 2: Centralized Surface Water System

Souris River water would be harvested at the City of Minot and conveyed through the system to Project members following treatment at the Minot Water Treatment Plant (WTP). This option was eliminated as a stand-alone option because seasonal low flows in the Souris River would not be sufficient to meet current and future demands. The Souris River was carried forward for evaluation as a component of a conjunctive use alternative.

Option 2A: Centralized Surface Water System with Off-Stream Reservoir Storage

Souris River water would be harvested at Minot when available and conveyed through the distribution pipelines to Project members following treatment. Additional raw water would be stored in an off-stream reservoir for later treatment and distribution when flows in the river became too low to utilize. The required capacity of the reservoir would be very large. This option was eliminated because Souris River flows are highly variable from year to year; thus, the reliability of this option would be low during an extended drought because the river could not provide sufficient quantities of water for storage in an off-stream reservoir. Moreover, the capital cost of such a reservoir would be higher than other storage alternatives such as AR or ASR.

Option 2B Centralized Surface Water System with Aquifer Storage and Recovery

Souris River water would be harvested when available and conveyed through the system to Project members following treatment. Additional raw water would be treated to drinking water standards and stored in one or more ASR wellfields and recovered when needed. Treatment would be provided at the Minot WTP, where upgrades may be necessary due to high turbidity levels.. This option was eliminated because extensive hydrogeologic investigations, groundwater modeling, and pilot testing would be needed to determine the feasibility of ASR for the Project. In addition to the costs and lengthy timeline associated with pilot testing and preliminary investigations, the permitting process and requirements for ASR projects in North Dakota are uncertain because ASR projects have not been permitted in North Dakota to date.

Option 2C: Centralized Surface Water System with In-Stream Reservoir Storage

Souris River water would be stored in an in-stream reservoir near the City of Minot. Treatment would be provided at the city’s facility, and water would be conveyed through the system to Project members following treatment. This option was eliminated because compared to the other options being considered, the modeling and permitting of an in-stream reservoir and its operations would be a highly complex process, and likely would be longer, less certain of a positive outcome, and costlier than the permitting process for other options. Additional considerations, including potential impacts on upstream and downstream riparian and aquatic ecosystems, also would need to be addressed prior to developing an instream reservoir, including impacts on the threatened piping plover, which may forage along beaches in the rivers in this region.

Option 2D: Centralized Surface Water System with Off-Stream Reservoir Storage and Aquifer Storage and Recovery

Option 2D combines the storage elements of Options 2A and 2B. Using ASR could reduce the size of the off-stream reservoir, which could significantly reduce costs. Treatment would be provided at the City of Minot’s facility and water would be conveyed through the system to

Project members following treatment. This option was eliminated for the reasons described for Options 2A and 2B.

Option 3: Enhancement of Existing Groundwater Systems

Existing water treatment systems would be upgraded to achieve compliance with all drinking water standards, which would require the use of reverse osmosis treatment technology for most systems. Existing Project pipelines and distribution systems of water suppliers would continue to be used, but additional planned Project distribution pipelines would not be constructed. This was eliminated as a stand-alone option because large declines in groundwater levels of the City of Minot's principal water supply aquifers from the city's withdrawals indicate they cannot sustain withdrawals of the magnitude necessary to meet current and future demands of the City and other Project members. A number of other Project members do not have access to shallow glaciofluvial aquifers that could supply sufficient quantities of water to meet their future demands. The use of groundwater in the Minot area was carried forward as a component of a conjunctive use alternative.

Option 4: Groundwater Wellfields in Ward County in Glaciofluvial Aquifers

A small number of large wellfields would be developed in shallow glaciofluvial aquifers in Ward County near population centers. The City of Minot's facility would provide treatment. Existing water quality data indicate that reverse osmosis treatment may be necessary to meet all standards. Water would be conveyed through the system to Project members following treatment. This option was eliminated because large declines in groundwater levels of the City of Minot's principal water supply aquifers from the city's withdrawals indicate that similar glaciofluvial aquifers in Ward County could not sustain withdrawals of the magnitude necessary to meet current and future demands of Project members.

Option 4A: Groundwater Wellfields in Ward County in Glaciofluvial Aquifers with Aquifer Recharge

A small number of large wellfields would be developed in Ward County near population centers. Water would be harvested from the Souris River during high-flow periods and discharged to infiltration basins to recharge aquifers. The City of Minot's facility would provide treatment. Reverse osmosis treatment may be necessary to meet drinking water standards. The use of radial collector wells would be investigated to determine whether treatment costs could be reduced. Water would be conveyed through the system to Project members following treatment. This was eliminated as a stand-alone option because there are not enough unallocated glaciofluvial aquifers in Ward County to provide sufficient quantities of water to meet the demands of all Project members. Recharging these aquifers with Souris River water is possible, but less feasible than recharging the City of Minot's aquifers that supply existing wellfields, which is Option 5. Option 4A would cost tens of millions of dollars more than Option 5 because it would require the purchase of large tracts of land, the permitting of large quantities of new groundwater withdrawals, construction of numerous production and monitor wells, pumping facilities and pipelines, all of which are already in place as part of Option 5. This option was carried forward as a component of a conjunctive use alternative.

Option 5: Enhance Yields and Recover Aquifer Levels of Minot's Existing Wellfields Using Aquifer Recharge

Water would be harvested from the Souris River during high-flow periods and discharged to infiltration basins to recharge Minot's existing wellfields in the Minot and Sundre aquifers. Wellfields could be expanded as necessary to meet the 2060 demand. Water would be treated at the Minot WTP. Existing and planned Project pipelines would convey water through the system to distribute to Project members. Additional pipelines would convey raw water from river to recharge basins. Storage would be achieved by recharging the aquifer with river water through infiltration basins. This option was carried forward for detailed analysis in the SEIS.

Option 6: Groundwater Wellfields in Outlying Counties in Glaciofluvial Aquifers

A small number of large wellfields would be developed in shallow glaciofluvial aquifers in outlying counties where aquifers are not over-allocated. Water treatment facilities would be constructed in the vicinity of the wellfields. A pipeline would connect the treatment facility to the Project system, and water would be distributed to Project members following treatment. This option was eliminated because large declines in groundwater levels of the City of Minot's principal water supply aquifers from the city's withdrawals indicate that a small number of large wellfields in glaciofluvial aquifers cannot sustain withdrawals of sufficient magnitude to meet current and future demands of the city and other Project members without supplemental recharge. This option is less favorable than Option 5, which involves the continued use and recharge of the City of Minot's existing wellfields. Option 6 would cost tens of millions of dollars more than Option 5 because it would require the purchase of large tracts of land, the permitting of large quantities of new groundwater withdrawals, construction of numerous production and monitoring wells, pumping and treatment facilities, and pipelines, all of which are already in place as part of Option 5.

Option 7: Groundwater Wellfields in Ward County in Bedrock Aquifers

A small number of large wellfields would be developed in bedrock aquifers in Ward County near population centers. The City of Minot's facility would provide treatment, and water would be conveyed through the system to Project members following treatment. This option was eliminated because data currently available suggest that the quantities of water necessary to meet current and future demands of the City of Minot and other Project members could not be developed from bedrock aquifers without adverse effects on existing users.

Option 8: Conjunctive Use of Souris River Water and Groundwater

Souris River water would be used when available. The system would transition to groundwater or blend river and groundwater when river flows were too low to meet demand. Treatment would be provided at the City of Minot's facility where upgrades may be requried. This was eliminated as a stand-alone option because it could not produce sufficient quantities of water to reliably meet demand over the long term without an aquifer recharge component or an additional source. This option was carried forward as a component of a conjunctive use alternative.

Option 8A: Conjunctive Use of Souris River Water and Groundwater with Aquifer Recharge to Enhance Groundwater Levels and Yields

Souris River water would be used when available for direct supply and AR of Minot's wellfields. The system would transition to groundwater or blend river water and groundwater when flows were too low to meet demand. Water would be treated at the Minot WTP. Radial collector wells would be investigated to determine whether they could reduce treatment costs. Existing and planned Project pipelines would convey water through the system to distribute to Project members. Storage would be achieved by recharging aquifers with river water through infiltration basins. This option was carried forward for detailed analysis in the SEIS.

Options 9 and 14: Combine any of the Options with Demand Management

This option combines any of the proposed options with water conservation measures and reuse of treated wastewater. This could lengthen the interval that the Project could meet the needs of Project members. The water conservation component of this option was carried forward for further evaluation, but reuse of the City of Minot's treated wastewater component of this option was eliminated due to insufficient quality, need for a distribution system, and insufficient customer base.

Option 10: Missouri River Water/In Basin Groundwater Blending

Missouri River water would be conveyed to Minot and blended with groundwater from aquifers in the Minot vicinity. Blending would occur at the Minot WTP. Existing and planned Project pipelines would convey water from the Missouri River to Minot and from Minot through the system to distribute to Project members. This option was carried forward for detailed analysis in the SEIS.

Option 11: Missouri River Water/Souris River Water Blending

Missouri River water would be conveyed to Minot and blended with Souris River water. Blending would occur at the Minot WTPExisting and planned Project pipelines would convey water from Missouri River to Minot and from Minot through the system to distribute to Project members. This option was carried forward for detailed analysis in the SEIS.

Option 12: Missouri River Water to Supply Minot and Existing Connections

Missouri River water would be conveyed to the City of Minot to meet the city's demands. Remaining water suppliers in the Project Area would continue to use groundwater and upgrade treatment systems if necessary. The 26 mgd capacity of the Project pipeline and availability of water in Missouri River would ensure that future demands in Minot would be met. Relatively small future demands of outlying suppliers could be met by expanding existing groundwater systems. The existing Project pipeline would convey water from the Missouri River to the City of Minot. This was eliminated as a stand-alone option because a number of Project members that plan to receive water through the Project system, but are not currently connected to the system, do not have access to shallow glaciofluvial aquifers that could supply sufficient quantities of water to meet their future demands. This option was carried forward as a component of a conjunctive use alternative.

Option 13: Missouri River to Supply all Project Members

Missouri River water would be conveyed to the Minot WTP and distributed to members via the Project pipelines. The 26 mgd capacity of the Project pipeline and availability of water in Missouri River would ensure that future demands in the Project Area would be met. Additional pipelines would need to be constructed to extend service from portions of the existing Project system to outlying Project members. Although large-scale storage would not be constructed as part of this option, ample storage capacity exists in Lake Sakakawea to meet future demands. This option was eliminated for several reasons. The City of Minot has expressed interest in continuing to use its existing groundwater supply system to meet a portion of the Project demand and as an emergency backup water supply for the system. In addition, a small number of municipalities within the Project area (Grenora and Rugby) rely on their groundwater sources to meet their needs but do not have the capability of receiving Missouri River water through the bulk distribution pipeline; therefore, this option would not serve the purpose and need of the Project for these communities. Rugby has already completed upgrades to its treatment facilities, in part using federal funds from the Project. Additionally, meeting the Project needs with 100 percent Missouri River water would be a potentially less reliable option than a conjunctive use option (using both groundwater and surface water) because it would not offer the flexibility to change water sources in the event of an extreme drought, chemical spill, or natural disaster.

Results of the Water Sources/Options Analysis and Next Steps

The evaluations described above concluded that the Souris River, Minot and Sundre aquifers, and Missouri River were potentially viable water sources when used conjunctively (in combination). The next step was to develop conceptual alternatives at a 10 percent design level using different combinations of these water sources, along with the types of infrastructure that would be required to capture, treat, and distribute the water to the Project members. Four conceptual alternatives were identified using the water sources which include:

- **Concept Alternative 1**. The main supply would be provided by existing well fields at Minot, supplemented by a total of four new wells within the Minot and Sundre aquifers. Souris River water would be used to recharge the aquifers to ensure that the additional Project demand could be met.
- **Concept Alternative 2.** The main supply would be provided by existing well fields at Minot, supplemented by a total of four new wells within the Minot and Sundre aquifers. Souris River water would be provided directly to the Minot WTP and also would be used to recharge the Minot and Sundre aquifers.
- **Concept Alternative 3.** Missouri River would be the main water source and would be conveyed to Minot where it would be blended with groundwater from the existing well fields in the Minot and Sundre aquifers and with Souris River water.
- **Concept Alternative 4.** Missouri River would be the main water supply source, providing the majority the total demand, supplemented by groundwater from the existing well fields near Minot.

The design of each of these conceptual alternatives was further refined during the development of the Appraisal-Level Design Engineering Report (Appendix J), which provides additional detail regarding Project components and their costs, sufficient to allow a thorough evaluation of the comparative impacts, costs, and benefits of each of the alternatives in the SEIS. The appraisal-level design was based on additional studies, including a groundwater supply alternatives assessment for the inbasin alternatives; i.e., those that do not require the use of Missouri River water (Appendix J). This assessment included (1) a siting analysis that used a geographic information systems (GIS)-based analysis to identify potential aquifer recharge facility sites; (2) an analysis of the hydrogeology of the Minot and Sundre aquifers with respect to aquifer recharge feasibility; (3) an analysis of the availability of water in the Souris River; (4)

the development of a water balance model; (5) groundwater flow modeling simulations designed to determine whether the aquifer recharge/wellfield systems are sustainable; and (6) preparation of recharge and withdrawal facility locations, design specifications, seasonal operations, and cost estimates.

The relationship between the concept alternatives and the alternatives described in the SEIS is shown in Table C-1.

Table C-1 Relationship between Concept Alternatives and SEIS Alternatives

Concept Alternative	SEIS Alternative
Concept Alternative 1	Groundwater with Recharge
Concept Alternative 2	Groundwater with Recharge and the Souris River
Concept Alternative 3	Missouri River and Conjunctive Use
Concept Alternative 4	Missouri River and Groundwater

Components Considered and Eliminated or Added to the Design

Alternative ways of implementing the Project previously were considered in the EA and Finding of No Significant Impact that were completed in 2001 (North Dakota State Water Commission et al. 2001; Reclamation 2001) and in the Final EIS on Water Treatment (Reclamation 2008) and Record of Decision (Reclamation 2009). As the Project design has proceeded, certain components identified in these reports were considered but eliminated, and others were retained or enhanced. Other components also were considered but eliminated during the engineering design process for the Project due to a variety of factors, such as cost, schedule implications, and potential for increased environmental impacts. The following discusses key components that were eliminated or added to the Project design.

Intakes and Associated Infrastructure

Alternative ways of implementing the Project previously were considered in the EA and Finding of No Significant Impact that were completed in 2001 (North Dakota State Water Commission et al. 2001; Reclamation 2001). Intake options at both Lake Sakakawea and Audubon Lake were considered in the EA, but a decision on the intake location was deferred pending additional engineering and water quality investigations. Audubon Lake is a sub-impoundment of Lake Sakakawea that was formed by construction of the Snake Creek embankment. The contributing watershed of Audubon Lake is very small, and water levels are controlled almost entirely by operation of the Snake Creek Pumping Plant, which delivers water from Lake Sakakawea to Audubon Lake. Thus, Missouri River depletions would be the same using Audubon Lake or Lake Sakakawea as a water source for the Project. Due to evaporation and limited outflow, concentrations of most water quality constituents are higher in Audubon Lake than in Lake Sakakawea. As a result, higher treatment costs and slightly higher potential to form disinfection by-products would be expected with Audubon Lake water than with water from Lake Sakakawea. Therefore, an intake in Audubon Lake for the alternatives that would use Missouri River water was considered but ultimately eliminated.

Several components of the alternatives using Missouri River water that were considered during the 10 percent design were not carried forward into the appraisal-level design, including an intake and pump station located on Lake Sakakawea northwest of Fort Berthold and east of New Town and a 73-mile transmission line from Lake Sakakawea northwest of Fort Berthold to Minot, of which 59 miles represent a new extension to the intake site that branches off the existing transmission line. These were eliminated because of the cost of the long transmission line extension to the intake site. Additionally, implementing these components would require moving the the Biota WTP (needed to reduce the risk of transfer of invasive species from the Missouri River basin to the Hudson Bay basin), requiring the evaluation and acquisition of a new site.

Although included in the Appraisal-Level Design Report, the optional intake intake located on the South Shore of Lake Sakakawea considered for the alternatives using Missouri River water was not carried forward for analysis in the SEIS due to the need to evaluate and acquire a new site and evaluate and construct a costly and lengthy extension of the transmission pipeline. This option would have required running the pipeline across either Lake Sakakawea or Lake Audubon because the Corps indicated that construction of a buried, pressurized pipeline would not be allowed in the causeway between the two lakes. Costs would be greater for this option than for other intake options, it could have schedule implications, and potentially could result in greater environmental impacts.

Water Treatment

The use of reverse osmosis at the Minot WTP was eliminated following the 10 percent design because the costs were high and the cost-benefit ratio for using this technology was very low.

Biota Treatment

The following five alternative methods of treating the water from the Missouri River basin to reduce the risk of transferring invasive species to the Hudson Bay basin for the Project were evaluated in the Final EIS on Water Treatment (Reclamation 2008) and Record of Decision (Reclamation 2009):

- **No Action**. This was the preferred treatment alternative identified in the Final EA (North Dakota State Water Commission et al. 2001) and selected in the Finding of No Significant Impact (Reclamation 2001) prepared for the Project. This alternative included chemical disinfection of raw Missouri River water prior to being delivered into the Hudson Bay basin. Ultraviolet (UV) disinfection, along with softening and filtration, would be provided at the Minot WTP.
- **Preferred Alternative**. The Preferred Alternative added UV disinfection at the Biota WTP to the No Action Alternative.
- **Basic Treatment Alternative**. This treatment alternative would include a pretreatment (coagulation, flocculation, sedimentation) process followed by chemical and UV disinfection prior to the water crossing the basin divide. The purpose of the pretreatment process would be to reduce raw water turbidity, which can influence the effectiveness of the disinfection processes. Softening and filtration would be provided at the existing Minot WTP.
- **Conventional Treatment Alternative**. This treatment process would include a pretreatment process of dissolved air flotation followed by media filtration and disinfection using UV and

chemicals within the Missouri River basin. Softening and filtration would be provided at the Minot WTP.

- **Microfiltration Alternative**. This treatment alternative would include pretreatment, coagulation, and pin floc) followed by membrane filtration and chemical and UV disinfection processes prior to the water crossing the drainage divide. Softening and filtration would be provided at the existing Minot WTP. (Coagulation and pin floc are the addition of chemicals and mixing similar to that described in the Basic Treatment Alternative. The pin-floc formed is smaller and readily removed by the membranes, therefore no settling step is required.)

The Conventional Treatment and Microfiltration Treatment alternatives were carried forward for analysis in this SEIS, where they are referred to as treatment options, but the Basic Treatment Alternative was not. When filtration was added as part of the conceptual design process, the resulting anticipated water quality and costs were very similar to the Conventional Treatment Alternative. The Chlorination option evaluated in this SEIS is to the same tretment process as the No Action Alternative evaluated in the 2008 Final EIS, and the Chlorination/UV Inactivation option is the same treatment process to the Preferred Alternative in the 2008 Final EIS.

Additionally, the Enhanced Chlorination/UV Inactivation option was developed in the Appraisal-Level Design Report in order to ensure that biota treatment measures considered would protect against a variety of species including unknown and emerging organisms of concern. This option, which was suggested by the State of North Dakota and uses a physical barrier (i.e., filtration), was added after the 10 percent design in order to allow a full evaluation of a range of treatment options and respond to concerns expressed on the previous EIS. The Enhanced Chlorination/UV Inactivation provides an increased level of treatment compared to the Chlorination/UV Inactivation option due to the physical barrier, but less treatment than the Conventional Treatment option.

References

Bureau of Reclamation (Reclamation). 2001. Finding of No Significant Impact for the Northwest Area Water Supply Project in North Dakota. Bureau of Reclamation, Great Plains Regional Office, Bismark, ND. FONSI No. DK-600-97-03. September 10, 2001.

Bureau of Reclamation (Reclamation). 2008. Executive Summary. Northwest Area Water Supply Project Final Environmental Impact Statement on Water Treatment. Bismarck, ND. 22 p.

Bureau of Reclamation (Reclamation). 2009. Record of Decision for the Northwest Area Water Supply Project Final Environmental Impact Statement on Water Treatment.

Bureau of Reclamation (Reclamation). 2012. Water Needs Assessment Technical Report. Northwest Area Water Supply (NAWS) Project, North Dakota. Dakotas Area Office, Great Plains Region. September.

North Dakota State Water Commission, North Dakota Garrison Diversion Conservancy District, Bureau of Reclamation. 2001. Northwest Area Water Supply Project Final Environmental Assessment. Prepared by Houston Engineering, Inc., American Engineering P.C., Montgomery Watson, and Bluestem Incorporated.

Appendix C-2
Rationale for Identification of the Preferred Alternative

To identify a preferred alternative for the Northwest Area Water Supply Project (Project), Reclamation chose a matrix evaluation method that has been established to evaluate several factors (i.e., cost, reliability, and potential impacts) and compare the alternatives to determine the best recommendation for the Project. The process includes four basic steps, which include:

1) Decision Factors – Developing the decision factors that influence the decision.
2) Weight Decision Factors – Comparing the decision factors to each other to determine their relative weight in the decision.
3) Alternative Ranking – Giving each of the alternatives a score for each of the decision factors.
4) Alternative Total Score – Multiplying the decision factor weight by the alternative ranking, resulting in a total score for each alternative. The alternative with the highest score is identified as preferred.

Information presented in this appendix describes the consideration given to each factor in the matrix evaluation process of identifying a preferred alternative. The following alternatives, as described in Chapter 2, were considered for this Project:

- No Action
- Inbasin alternatives:
  - Groundwater with Recharge
  - Groundwater with Recharge and the Souris River
- Missouri River alternatives:
  - Missouri River and Conjunctive Use
  - Missouri River and Groundwater

Permanent Environmental Impacts due to Alternative Construction

Permanent environmental impacts associated with the alternatives due to construction of components would be relatively small for all alternatives. The inbasin alternatives would have slightly more impact than the Missouri River alternatives due mainly to construction of the artificial recharge basins. Because the permanent construction impacts would be relatively small and would be similar for all action alternatives, this factor had a minimal influence on the identification of a preferred alternative.

Risk of Project-Related Transfer of Aquatic Invasive Species

The risk associated with Project-related transfer and establishment of aquatic invasive species is discussed in detail in Chapter 4. For the Missouri River alternatives, the risk of Project-related transfer and establishment is comparatively much smaller than the risk of transfer and establishment through existing non-Project pathways. The risk of transfer for the inbasin alternatives is the same as if there were no Project. There is no increased risk as a result of Project construction or operation. The two Missouri River alternatives slightly increase the overall transfer risk. However, the Project-related risk would be further reduced and mitigated with treatment at the Biota Water Treatment Plant (WTP) that would be included whether either of the Missouri River alternatives is selected. Because of the similar levels of risk involved with each action alternative as well as the no action alternative, this factor was not the controlling factor in choosing a preferred alternative, and each alternative would be equally appropriate. The identification of a preferred Biota WTP option is included in the Missouri River Alternative Options section below.

Source Water Quantity Reliability

Water quantity reliability (the amount of water available on a consistent basis) is a controlling factor in the planning of water supply projects and was a major consideration in the identification of a preferred alternative. As described in Chapter 3, flows in the Souris River are highly variable seasonally and from year to year. The 100+ years of historic flow records show that at times flow rates in the Souris River would fully support needed Project withdrawals; however at other times, flows in the Souris River are extremely low (near-zero) for extended periods. Under the inbasin alternatives, the Project would at times need to withdraw 100 percent of the Souris River flow at Minot. The amount of Souris River water that would be available for withdrawal for the Project for either direct delivery to the Minot WTP or for aquifer recharge for the inbasin alternatives may not be sufficient to reliably meet future water needs in all years, particularly during drought years and during extended droughts like those that have occurred in the past.

Current withdrawals from the Minot and Sundre aquifers have been shown to be unsustainable. Furthermore, the amount of water that could be artificially recharged to the aquifers from the Souris River and subsequently withdrawn from these aquifers is uncertain. Therefore, the inbasin alternatives could be unreliable based on the lack of consistency in meeting future Project water demands.

In contrast to the Souris River, the Missouri River Mainstem Reservoir System (Missouri River System) contains a much larger volume of water, and storage capacity within Lake Sakakawea makes it much more reliable as a source for a water supply project. As described in Chapter 3, throughout the entire period of record, the Missouri River and Lake Sakakawea have always had sufficient water to meet future Project water demands. Based on historic data, the minimum storage in Lake Sakakawea was more than 750 times greater than the estimated annual Project water demand. The amount of water available in Lake Sakakawea would always be much greater than any other water sources identified for the Project, and either of the Missouri River alternatives would provide a more reliable water supply.

When considering future Project operations and water deliver, the two Missouri River alternatives are preferable to the inbasin alternatives because of the reliability of the Missouri River as a water source as compared to the Souris River.

Finished Water Quality

Because the primary purpose of the Project is to provide high quality water for municipal purposes, water quality was a major factor in the process of identifying a preferred alternative. The finished water quality that would be provided to the Project members differs between the inbasin alternatives and the Missouri River alternatives. Although all of the alternatives would provide a level of drinking water quality which would meet all of Environmental Protection Agency's Safe Drinking Water Act primary standards, the two inbasin alternatives would not meet all Safe Drinking Water Act secondary standards. If the secondary standards are not met, the Project Area would continue to experience odor, color, and other aesthetic water quality issues under either of the inbasin alternatives. The finished water quality provided to the Project members would be considerably improved under the Missouri River alternatives, meeting all primary and secondary standards. Therefore, the Missouri River alternatives are preferable to the inbasin alternatives.

Impacts to Missouri River Resources

The two inbasin alternatives would not use water from the Missouri River, and therefore would have no impacts on the Missouri River and associated resources. The Missouri River alternatives would use water from the river as a main water supply source to the Project. The amount of water proposed for use in these alternatives on an annual basis is very small in comparison to the volume of water in the Missouri River System. As discussed in Chapter 4, impacts to the Missouri River and related resources under the two Missouri River alternatives would be minimal. This factor had a minor influence in the identification of a preferred alternative.

Impacts to Souris River Resources

The issue of impacts on the Souris River had a significant influence during the identification process. Both inbasin alternatives include withdrawal of water from the Souris River to recharge the aquifers and/or to be used as a direct water supply for the Project. The analysis described in Chapter 4 discloses the adverse effects this proposed water use would have on the flows in the river and other water-dependent resources associated with it. Operating either of the inbasin alternatives would decrease Souris River flows downstream of Minot and would significantly increase the number of near-zero flow days (Chapter 4).

In using water from the Souris River, the inbasin alternatives would also affect downstream resources including the J. Clark Salyer National Wildlife Refuge, which would be adversely impacted by the reduced flows.

Under the inbasin alternatives, flows below 20 cubic feet per second (cfs) downstream of Minot would occur more frequently. This could impair the ability to maintain the 20-cfs minimum flows at the international border in compliance with the *Agreement between the Governments of Canada and the United States for Water Supply and Flood Control in the Souris River Basin* (ISRB 2000).

The Missouri River and Groundwater Alternative would not withdraw any water from the Souris River and therefore would have no effect on the Souris River or related resources. The Missouri River and Conjunctive Use Alternative would withdraw water from the Souris River for direct delivery to the Minot WTP when the flows are at least twice the demand. Adverse impacts to the J. Clark Salyer National Wildlife Refuge and wildlife would be greatest under the inbasin alternatives but could occur to a lesser extent under the Missouri River and Conjunctive Use Alternative as well.

Alternative Uncertainty

As discussed throughout this SEIS, three of the alternatives for the Project would require additional new withdrawals from the Souris River and several assumptions were made in developing the appraisal level designs of the inbasin alternatives (discussed in Chapter 2 and Appendix J). Due to the number of existing Souris River water permits, it is uncertain whether the Project would be able to obtain a water permit to withdraw enough water to supply the Project as designed. If an additional permit could not be obtained, the inbasin alternatives would not be able to supply enough water to recharge the aquifers sufficiently, and the Missouri River and Conjunctive Use Alternative might not provide enough Souris River water to meet a portion of the future water needs.

The appraisal level designs of the inbasin alternatives were developed based on the best information available; however, there is a high level of uncertainty associated with the construction and operation of an aquifer recharge system as discussed in Appendix J. Detailed engineering studies would need to be conducted in order to determine the feasibility of an aquifer recharge system in the Project Area. The additional studies could include demonstration pilot studies, soil testing, water quality monitoring, and modeling of the system. These types of studies would take years to complete and be costly based on current estimates (Appendix J). The uncertainty associated with the alternatives played a major role during the identification process and therefore a Missouri River alternative, which has more certainty associated with it, has been selected as the preferred alternative.

Missouri River Alternative Options

The Missouri River alternatives included two options for the intake and pump station at Lake Sakakawea as well as five options for the Biota WTP located near Max, North Dakota. To complete the identification of a preferred alternative, Reclamation identified the preferred intake and Biota WTP options to be included in the preferred alternative.

Intake

Two intake options were evaluated in this SEIS: (1) modifications to the Snake Creek Pumping Plant (SCPP) and (2) constructing an intake adjacent to the SCPP. Factors considered in the identification of the preferred intake option were costs (construction and operation/maintenance/repair [OM&R]), environmental impacts, coordination requirements, and uncertainty associated with the options.

The modification to the SCPP intake option has a lower construction cost, lower Project OM&R cost, and also has the potential for Reclamation to reduce existing federal OM&R costs at the SCPP. However there are constructability unknowns associated with modifying the existing SCPP.

Analysis of the two intake options showed they have similar construction footprints, and adverse impacts on any resources associated with the Missouri River System would be negligible for both options.

Considering all these factors, Reclamation identified the Modifications to the SCPP as the preferred intake option.

Biota WTP

Five Biota WTP options were evaluated as described in Chapter 2. Factors Reclamation considered to identify the preferred Biota WTP option were costs (construction and OM&R), environmental impacts associated with construction, level of risk reduction for a Project-related transfer of aquatic invasive species, and ability of the options to target aquatic invasive species of concern in the most cost effective manner.

The five Biota WTP options increase the level of treatment with each option and would provide a corresponding higher level of risk reduction. However, the construction and OM&R cost would also increase with each option. The footprint of the Biota WTP would be the same for each of the options; therefore, the construction impacts would be the same. As discussed in Chapter 4, the construction-related environmental impacts would be minor.

Reclamation's analysis of risks and consequences associated with aquatic invasive species (Chapter 4) concludes that the Project-related risk of transfer of aquatic invasive species associated with the Missouri River alternatives is very small in relation to risks associated with existing and future non-Project pathways. It is also acknowledged that there are no treatment regulations regarding control of aquatic invasive species. Therefore, Reclamation proposes to construct the Biota WTP option that would effectively inactivate the identified aquatic invasive species of concern at the lowest cost. The aquatic invasive species of concern include seven major taxonomic groups exhibiting a range of sizes and susceptibilities to disinfection, and cover a broad range of life histories to protect against a variety of species, including unknown and emerging organisms. The preferred option identified that would achieve that goal is the Chlorination and UV Inactivation Biota WTP option.

Appendix D

Missouri River Basin Depletions

Appendix D
Missouri River Basin Depletions

Introduction

This appendix briefly describes the process including a summary of methods and analysis used by the Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (Corps) to evaluate the potential effects of water withdrawal for the Northwest Area Water Supply project (NAWS). This evaluation includes the process to quantify the historic, present level, and future Missouri River Basin depletions (Reclamation 2012) and process used by the Corps' Missouri River Water Management Division a part of the Northwestern Division to evaluate the cumulative impacts to the Missouri River (Corps 2013) for use in the NAWS Supplemental Environmental Impact Statement (SEIS). It contains a summary of information on methods and analyses used in the NAWS SEIS chapters. This appendix shows the step by step process followed by Reclamation and the Corps for the NAWS SEIS analysis of depletion impacts. For a detailed description of the modeling data and results, see Reclamation's report, Missouri River Basin Depletions Database (2012). For many years Reclamation has been the lead federal agency in providing depletion estimates for Missouri River Basin studies. These estimates are used in modeling studies that assist other agencies like the Corps for hydrologic modeling studies and in making operational decisions on the Missouri River. Reclamation's point of contact for depletion studies is the Hydrology Group in the Great Plains Regional Office in Billings, Montana. The Corps operates the Missouri River Mainstem System with experts from their Missouri River Water Management Division, a part of the Northwestern Division, coordinating flows, reservoir levels, and dam releases. The Omaha and Kansas City Districts are responsible for management and maintenance of Missouri River Projects with the Omaha District providing management and maintenance for the Missouri River dams.

Missouri River flow data are maintained by the U.S. Geological Survey (USGS), with daily data going back to 1930. Based on the flow data at each gaging location, the historic inflows into each reach of the Missouri River can be computed. A requirement for conducting time series analyses using the historic inflow data requires that the inflows for each reach be adjusted to make the data for each year equivalent to the "current" year in the hydrologic analysis being conducted. In the case of the NAWS SEIS the "current" year is 2010. This adjustment requires a historic depletion file and a present level depletion file for each year in the period of analysis for the time series analysis, in this case 1930-2010. Finally, estimates of future depletions of inflows into the Missouri River or water from the Missouri River are required to allow the analysis of future impacts, in this case, 2060 impacts.

> ***Historic Level Depletions*** – Estimated amount of water depleted from the system each year from 1930 to 2010, given in acre-feet by month.
>
> ***Present Level Depletions*** – Estimated amount of water that would be depleted in 2010 based on the current level of development, given in thousands of acre-feet.
>
> ***Net Depletions –*** Difference between the historic and present level depletions, which are used to convert historic inflows to "current "inflows to allow a time series analysis of Missouri River reservoir and river hydrologic data.

Reclamation has developed depletion estimates for historic water use, present level water use, and future water use. Depletions were estimated for five different water use categories: 1) irrigated agriculture, 2) public surface water supply systems, 3) industrial water users, 4) storage in Reclamation reservoirs, and 5) trans-basin diversions. This report summarizes the development of each of these three depletion files for all of the reaches of the Missouri River from above Fort Peck, Montana to Hermann, Missouri, which is located 100 miles above the confluence of the Missouri River and the Mississippi River near St. Louis, Missouri.

Depletions

Irrigated agriculture – are the portion of the diversion that is consumptively used by crops and unavailable for return flows. Based on Agricultural Census data

Public surface water supply system –diversions by existing public surface water supply systems based on future population projections.

Industrial water users – diversions for industrial purposes.

Storage in Reclamation reservoirs – the net effects of storage changes in Missouri River Basin tributary reservoirs due to evaporation, precipitation, and reservoir seepage.

Transbasin diversions – Diversion that provide a source of water from outside the Missouri River basin.

Finally, this appendix summarizes the use of Reclamation's depletion files by the Corps to conduct an analysis of using the present level depletion conditions in 2010 as a baseline for incrementally adding 1) the effects of continuing sedimentation in the Missouri River main stem reservoirs, 2) forecasted non-Project (NAWS) depletions, 3) No Action (future in 2060) and 4) a range of depletions based on two options for depletions associated with the NAWS Project. This analysis of the cumulative effects of the sedimentation and depletions affecting the operation of the Missouri River system of dams addresses the hydrologic and economic effects of changes to these factors out to the year 2060.

The following discussion will take the reader through the step-wise process from determining system and future depletions to the analysis of how NAWS Project depletions may impact Missouri River resources using and analysis of hydrologic and economic factors. This process was used for analysis for the NAWS Supplemental Environmental Impact Statement.

Missouri River Basin Depletions Database

The first step in the process is determining and updating the Missouri River depletion database. Reclamation has maintained a Missouri River depletions database for node basins for all of the tributaries within the Missouri River Basin (Depletions Database). This database was built upon a study completed in 1982 in coordination with the Missouri River Basin Commission, later known as the Missouri Basin States Association (MBSA)[1].

The Depletions Database calculates historic depletions from 1930 through 2007 for irrigated agriculture and contains calculated depletions from public surface water supply systems. Historic depletions are the estimates of the amount of water actually depleted from the surface water in the Missouri River Basin. Historic depletions are added to historic inflow data to calculate "natural flows." The natural flow is the inflow that would have been expected if there were no depletions from the surface water.

The Depletions Database also calculates present-level depletions for 2007. The year 2007 is the year of the last agricultural census and the best available information. The agricultural census is updated every 5 years with 2007 being the most recent data. The agricultural census is the largest

[1] U.S. Army Corps of Engineers. *Big Dam Era*. 1993. Page 186.

and most complete data source available for irrigated acres and is used because the vast majority of water diversions in the Missouri River Basin are from irrigation. Present-level depletions are defined as the impact that current development would have had for any past water year. Present-level irrigated agriculture depletions are calculated the same way as historical depletions, except that the number of acres irrigated in 2007 is used for all years from 1930 through 2010 (*Note-2010 was used as the "current" year as described above)*. Similarly, public surface water supply present-level depletions use the 2010 depletions for each year from 1930 through 2010 (2010 census data is used in these calculations). Calculating depletions in this manner allows us to see how current water uses or depletions would have impacted past or historical water years. Public Surface water supply data is added to the Depletions Database and is discussed later in this report.

Prior to development of the current Depletions Database, Reclamation last updated estimated Missouri River historic and present level depletions in 2005 for the Red River Valley Water Supply Project EIS. An associated report was prepared by Reclamation in 2005 titled, *A Study to Determine the Historic and Present-Level Streamflow Depletions in the Missouri River Basin for the Period 1929 to 2002*.

The results from the current Depletions Database for the irrigated agriculture and public surface water supply systems are summarized in the following sections of this appendix. Also included for the historic, present level, and future depletion analyses are data for the industrial water users, storage in Reclamation reservoirs, and trans-basin diversions.

Historic Depletions

The estimated 1930 historic depletions for all five categories are presented in Table D.1. This year was selected to show the noticeable difference between the historic depletions early in the period and the present level depletions at the end of the 80-year period of analysis of 1930-2010. Descriptions of the derivation of the data follow Table D.1. Data for irrigated agriculture and public surface supply in the table come from the Deletions Database for which detailed information is provided in a report titled, *Missouri River Depletions Database* (Reclamation 2012), which is a supporting document to the NAWS SEIS. Reclamation computed the industrial supply values as a variable percent of the public supply values. Reclamation storage represents the "holdouts" (includes water stored or released, evaporation, seepage from, and precipitation into) in the Reclamation reservoirs located on the tributaries to the Missouri River. Finally, transbasin diversions represent the estimated water added to the Missouri River Basin through a Reclamation project taking water from the St. Mary River Basin for irrigation in the Fort Peck to Garrison reach and for water transferred from the Colorado River Basin to the Missouri River Basin that eventually entered the Missouri River in the Omaha to Nebraska City reach. These transbasin numbers are negative depletions as they added water to the Missouri River Basin.

The estimated historic depletions for 2010 are summarized in Table D.2. These depletions represent the reductions in Missouri River inflows and flows that result from the use of water in the Missouri River Basin in 2010 (2007 for irrigated agriculture as this was the year of the Agricultural

Missouri River Basin States Association – An organization formed in 1981 as a nonprofit corporation by the Missouri River Basin governors as a successor organization to the Missouri River Basin Commission. This group was to "conduct, encourage, and participate in activities which promote interstate coordination of water resources management in the Missouri River basin" (Corps 1993:186).

Census, which is prepared every 5 years). Comparison of the depletions in Tables D.1 and D.2 shows that total Missouri River depletions have grown from just over 8 million acre-feet to 13.6 million acre-feet between 1930 and 2010.

Table D.1 1930 Historic Missouri River Depletions by Reach (thousand acre-feet)

Missouri River Reaches	Agriculture[1]	Public Supply[2]	Industrial Supply[3]	Reclamation Storage[4]	Transbasin Diversions[5]	Total Present Level[6]
Above Fort Peck	2,179.3	6.9	0.2	0.6	0.0	2,187.1
Ft Peck to Garrison	2,648.6	9.9	3.8	-49.6	-89.6	2,523.2
Garrison to Oahe	155.2	9.1	2.6	0.0	0.0	166.9
Oahe to Big Bend	1.3	0.4	0.0	0.0	0.0	1.7
Big Bend to Ft Randall	22.6	1.1	0.0	0.0	0.0	23.7
Ft Randall to Gavins Point	25.5	1.4	0.0	0.0	0.0	26.9
Gavins Point to Sioux City	0.2	5.9	0.9	0.0	0.0	6.9
Sioux City to Omaha	0.1	4.1	0.0	0.0	0.0	4.2
Omaha to Nebraska City	3,120.3	46.1	2.8	-162.1	-13.7	2,993.3
Nebraska City to St Joe	1.1	2.0	0.2	0.0	0.0	3.2
St Joe to Kansas City	83.6	26.0	0.1	0.0	0.0	109.6
Kansas City to Boonville	0.1	34.1	0.2	0.0	0.0	34.4
Boonville to Hermann	0.1	10.8	0.2	0.0	0.0	11.2
Total	8,238.0	157.9	10.9	-211.2	-103.3	8,092.3

Notes: [1]Based on irrigated acres collected using Agricultural census data from 2007
[2]Based on USGS data and U.S. Census data
[3]Based on a variable percentage of the public supply values
[4] Based on water stored/released, evaporation, seepage from, and precipitation into Reclamation reservoirs on the Missouri River
[5]Diversions from basins outside to the Missouri River basin
[6]This column may not exactly total across columns due to rounding.

Table D.2 2010 Historic Missouri River Depletions by Reach (thousand acre-feet)

Missouri River Reaches	Agriculture	Public Supply	Industrial Supply	Reclamation Storage	Transbasin Diversions	Total Present Level
Above Fort Peck	2,389.8	16.4	0.6	38.0	0.0	2,444.8
Ft Peck to Garrison	3,602.1	19.7	7.6	1.4	-110.2	3,520.5
Garrison to Oahe	322.8	10.5	2.9	67.2	0.0	403.4
Oahe to Big Bend	12.0	0.3	0.0	0.0	0.0	12.3
Big Bend to Ft Randall	131.2	1.0	0.0	0.0	0.0	132.1
Ft Randall to Gavins Point	978.2	1.0	0.0	16.0	0.0	995.3
Gavins Point to Sioux City	329.9	5.3	0.8	73.8	0.0	409.9
Sioux City to Omaha	178.4	8.0	0.0	0.0	0.0	186.4
Omaha to Nebraska City	3,706.2	277.8	16.7	580.5	-351.9	4,229.2
Nebraska City to St Joe	68.5	1.9	0.2	0.0	0.0	70.5
St Joe to Kansas City	1,020.7	44.8	0.1	50.9	0.0	1,116.5
Kansas City to Boonville	26.6	55.6	0.3	0.0	0.0	82.4
Boonville to Hermann	70.8	18.3	0.3	0.0	0.0	89.3
Total	12,837.1	460.5	29.4	827.8	-462.1	13,692.6

Present Level Depletions

The average annual present level depletions in Table D.3 were generated using the same methodology followed for the historic depletions except for some changes that represent current conditions. The Depletions Database also computed the depletions that would have resulted in each year of the 81-year period of analysis used for the NAWS Project SEIS analysis of Missouri River effects with the present level of water use development in the basin. These computations are required to convert inflows that occurred historically to those that would have occurred with the present level of water use development. Present level depletion values for agriculture in particular would vary from year to year because the amount of water used on 2010 acres would vary depending on the climatic conditions that occurred historically. Table D.4 presents the present level depletion data for 1930 from the Depletions Database. The estimated total present level depletions for 1930 are 12,929 thousand acre-feet, which is 256 thousand acre-feet more than average annual due to the different climatic conditions in 1930.

Table D.3 Average Annual Present Level Missouri River Depletions by Reach (thousand acre-feet) for 2010 Development Levels

Missouri River Reaches	Agriculture	Public Supply	Industrial Supply	Reclamation Storage	Transbasin Diversions	Total Present Level
Above Fort Peck	2,126.8	16.4	0.6	65.2	0.0	2,209
Ft Peck to Garrison	3,431.1	19.7	7.6	76.2	-182.7	3,351.9
Garrison to Oahe	297.7	10.5	2.9	21.7	0.0	332.8
Oahe to Big Bend	12.5	0.3	0.0	0.0	0.0	12.8
Big Bend to Ft Randall	122.3	1.0	0.0	0.0	0.0	123.3
Ft Randall to Gavins Point	882	1.0	0.0	8.8	0.0	891.8
Gavins Point to Sioux City	311.5	5.3	0.8	47.2	0.0	364.8
Sioux City to Omaha	243.3	8.0	0.0	0.0	0.0	251.3
Omaha to Nebraska City	3,602.6	277.8	16.7	215.5	-392.8	3719.8
Nebraska City to St Joe	69.5	1.9	0.2	0.0	0.0	71.6
St Joe to Kansas City	1,084.8	44.8	0.1	49.5	0.0	1,179.2
Kansas City to Boonville	23.2	55.6	0.3	0.0	0.0	79.1
Boonville to Hermann	67.1	18.3	0.3	0.0	0.0	85.7
Total	12,274.4	460.5	29.5	484.1	-575.5	12,673.1

Table D.4 1930 Present Level Missouri River Depletions by Reach (thousand acre-feet)

Missouri River Reaches	Agriculture	Public Supply	Industrial Supply	Reclamation Storage	Transbasin Diversions	Total Present Level
Above Fort Peck	2,397.5	16.4	0.6	41.7	0.0	2,456.1
Ft Peck to Garrison	3,601.0	19.7	7.6	63.8	-182.7	3,509.4
Garrison to Oahe	308.5	10.5	2.9	-14.7	0.0	307.2
Oahe to Big Bend	12.8	0.3	0.0	0.0	0.0	13.1
Big Bend to Ft Randall	128.9	1.0	0.0	0.0	0.0	129.8
Ft Randall to Gavins Point	900.3	1.0	0.0	6.6	0.0	907.9
Gavins Point to Sioux City	366.6	5.3	0.8	39.2	0.0	411.9
Sioux City to Omaha	394.3	8.0	0.0	0.0	0.0	402.3
Omaha to Nebraska City	3,420.7	277.8	16.7	-6.0	-392.8	3,316.3
Nebraska City to St Joe	83.9	1.9	0.2	0.0	0.0	85.9
St Joe to Kansas City	1,137.6	44.8	0.1	22.7	0.0	1,205.1
Kansas City to Boonville	30.2	55.6	0.3	0.0	0.0	86.1
Boonville to Hermann	79.0	18.3	0.3	0.0	0.0	97.6
Total	12,861.3	460.5	29.4	153.1	-575.5	12,928.8

Net Depletions

Net depletion values are needed for each reach to allow the conversion of the historic inflow data to present level of development inflow data. This provides the Corps the capability to simulate each year in the period of analysis of 1930-2010 as if each year were under 2010 water use conditions. By adding the historic depletions to the inflows, natural inflows are computed. Subtraction of the present level depletions then results in the reduced inflows under present level water use development. The Corps' Daily Routing Model (DRM) for the Missouri River mainstem has an input file of the historic inflows and these inflows are modified within the DRM with a net depletions file, which is equivalent to the historic depletion values for each year minus the present level depletion values. Historic and present level depletions are provided as monthly values by the Depletions Database. The net depletions are summarized for 1930 in Table D.5. This table indicates that 4,836 thousand acre-feet of inflows must be removed from the historic inflows in 1930 by the DRM. A similar process must be accomplished for each year in the 1930-2010 period of analysis. Because the DRM is a daily time-step model, the monthly values provided for each year by Reclamation from the Depletions Database much be divided by the number of days in each month (a file with almost 30,000 values for the 81-year period of analysis for each of the 13 DRM reaches).

Table D.5 – 1930 Net Missouri River Depletions by Reach

Missouri River Reaches	Agriculture	Public Supply	Industrial Supply	Reclamation Storage	Transbasin Diversions	Total Present Level
Above Fort Peck	218.1	9.5	0.3	41.1	0.0	269.1
Ft Peck to Garrison	952.4	9.8	3.8	113.4	-93.1	986.2
Garrison to Oahe	153.3	1.4	0.4	-14.7	0.0	140.3
Oahe to Big Bend	11.5	-0.1	0.0	0.0	0.0	11.4
Big Bend to Ft Randall	106.3	-0.2	0.0	0.0	0.0	106.1
Ft Randall to Gavins Point	874.8	-0.4	0.0	6.6	0.0	880.9
Gavins Point to Sioux City	366.5	-0.6	-0.1	39.2	0.0	405.0
Sioux City to Omaha	394.2	3.9	0.0	0.0	0.0	398.1
Omaha to Nebraska City	300.4	231.7	13.9	156.1	-379.1	322.9
Nebraska City to St Joe	82.8	-0.1	0.0	0.0	0.0	82.7
St Joe to Kansas City	1,054.0	18.8	0.0	22.7	0.0	1,095.5
Kansas City to Boonville	30.1	21.5	0.1	0.0	0.0	51.7
Boonville to Hermann	78.9	7.4	0.1	0.0	0.0	86.5
Total	4,623.2	302.6	18.6	364.3	-472.2	4,836.5

Future Water Project Depletions

Reclamation's next step in the analyses was to look at potential future water project depletions for a cumulative effects analysis. Reclamation collected information on reasonably foreseeable new depletions by specific projects within the Missouri River Basin that may occur between 2011 and 2060. 2060 is planning horizon for the NAWS Project. This section identifies specific future water project depletions (reasonably foreseeable actions) from the Missouri River Basin to be addressed in the NAWS SEIS. Reasonably foreseeable actions are those water withdrawals that meet the criteria identified below. Because these are actions that could potentially occur between 2010 and 2060 they are also identified as resulting in potentially cumulative effects when combined with the effects of the proposed NAWS Project. These actions are expected to occur regardless of which alternative is selected, including the No Action Alternative. For the cumulative effects analysis of Missouri River resources, a list of reasonably foreseeable actions was developed (Table D.6). The following criteria (must meet all criteria) were used to define reasonably foreseeable actions:

- Water withdrawal identified could reasonably be implemented between now and 2060.
- Water withdrawal identified could contribute measurably to cumulative effects in the geographic area and on the Missouri River resources that would be affected by the NAWS SEIS alternatives.
- Water withdrawal identified has sufficient specifics about the amount of water proposed for withdrawal and other information available to define the activity and conduct a meaningful analysis.
- Water withdrawal has been identified in some type of planning document.

Reclamation created a future Missouri River water withdrawal spreadsheet and populated the spreadsheet with information on potential new depletions within or from the Missouri River Basin between 2011 and 2060. These potential projects were identified by canvassing Reclamation offices throughout the Missouri River Basin and contacting the Bureau of Indian Affairs to document future tribal projects. Large-scale projects involving future withdrawals for irrigation and water supply (tribal and state projects) typically need to secure federal funding to assist in development. Historically, sponsors of large-scale water projects have relied on federal assistance for the development of their projects and this is not likely to change based on the economic situation faced by states and tribes. When information was readily available, state or local projects were also included as potential projects if the projects were authorized and funded. Using these data, it was possible to estimate the total anticipated withdrawals through the year 2060 for each Missouri River Basin reach included in the Corps' DRM.

A previous survey of Missouri River Basin States and intake permit holders was conducted to identify current and future water withdrawals. However, that survey was unsuccessful in obtaining comprehensive water withdrawal information (Corps 2004). It was thought that many permittees would not reveal this type of information unless required by law. The time and cost of doing a comprehensive survey, as was done in the Master Manual, is not reasonable nor is it likely that obtaining all necessary data is feasible for this SEIS. Therefore, no attempt was made to survey states and water permit holders.

Furthermore, there is disparity in water use data available from state water permitting agencies (Committee on USGS Water Resources Research, National Research Council 2002). The availability of water use data varies by state, and states within the Missouri River basin do not collect similar types of information. For example, Iowa has a water use permit program, except for agricultural or irrigation water withdrawals from the Mississippi and Missouri Rivers, which do not require a permit. Kansas requires permits for all water withdrawals. Some states record permitted water withdrawals, but do not require users to report the amount of actual withdrawals. Reclamation has used the best available information to document present and future water withdrawals as documented in the *Missouri River Basin Depletions Database* (Reclamation 2012).

Reasonably foreseeable future projects are shown in Table D.6 All of these projects are dependent upon government funding and may be subject to compact agreements and or authorizations. Therefore, some of these projects may not be constructed. The information presented here is based on the best available information and represents a conservative approach that may overestimate future depletions. Any identified non-federal water supply projects for which authorization and/or funding have been obtained (e.g. Western Area Water Supply Project in North Dakota) were added to the list of reasonably foreseeable actions.

Twenty-seven tribes are located in the Missouri River basin, 13 of which have reservations located directly on the Missouri River. Several of these tribes are in various stages of quantifying their water rights. Tribal projects were considered in Table D.6, but until water rights have been adjudicated or specific projects identified, they will not be included in a futures analysis of depletions for the NAWS SEIS.

It should be noted that there is uncertainty when trying to predict the future. Reasonably foreseeable adverse impacts must be identified within the "rule of reason" standard. The criteria noted above were used to document reasonably foreseeable projects. Many of the projects identified as reasonably foreseeable are dependent on federal funding and permitting that has yet to be obtained. However, plans are in place for these projects and needs identified such that if funding did become available projects could move forward. Additionally, some of the projects, e.g., oil and gas development would be temporary in nature and thus limited but the timing of those projects would occur prior to 2060 and a determination was made to include these as reasonably foreseeable during the life of the project. All potential future withdrawals have been identified with the best available information and reasoned managerial decisions and will be applied equally across the alternatives.

The data in Table D.6 were designated to Missouri River Basin reaches and separated according to water use type (public surface water supply, irrigated agriculture, and other projects). Using these data, it was possible to estimate the total anticipated diversions by year 2060 for each Missouri River Basin reach. Estimated future diversions by reach are reported in Table D.7.

Table D.6 – Missouri River Withdrawals for Future Public Surface Water Supply, Irrigated Agriculture, and Other Projects

Project	Withdrawals – Maximum Use to 2060 (acre-feet per year)	River Reach
Public Surface Water Supply Projects		
Rock Boys RWS	8,802	Above Fort Peck
City of Helena	14,284	Above Fort Peck
Blackfeet MR&I	9,248	Above Fort Peck
Crow MR&I	7,482	Fort Peck to Garrison
Ft Peck RWS	6,200	Fort Peck to Garrison
Dry Redwater RWS	0 [1]	Fort Peck to Garrison
Four Bears WTP	808	Fort Peck to Garrison
Mandaree WTP	606	Fort Peck to Garrison
Twin Buttes WTP	403	Fort Peck to Garrison
Southwest Pipeline Project	4,000	Fort Peck to Garrison
Western Area Water Supply System	33,046	Fort Peck to Garrison
Perkins RWS	645	Fort Peck to Garrison
Red River Valley Water Supply Project[2]	80,239	Fort Peck to Garrison
South Central Regional Water Dist	1,400	Garrison to Oahe
Standing Rock RWS	5,600	Garrison to Oahe
Mni Waste Water	5,155	Garrison to Oahe
Dewey and Ziebach	5,084	Garrison to Oahe
Mid-Dakota RWS	9,999	Garrison to Oahe
Mni Wiconi RWS	8,591	Oahe to Big Bend
Crow Creek MR&I	675	Oahe to Big Bend
Santee MR&I	760	Ft Randall to Gavins Point
Lewis and Clark RWS	35,700	Gavins Point to Sioux City
Omaha Indian Reservation	2,369	Sioux City to Omaha
Winnebago MR&I	848	Sioux City to Omaha
Kickapoo Tribe, Prairie Band of Potawatomi Nation, Sac and Fox Nation RWS	999	St Joseph to Kansas City

Project	Withdrawals – Maximum Use to 2060 (acre-feet per year)	River Reach
Irrigated Agriculture Projects		
Canyon Ferry Temporary Irrigation	400	Above Fort Peck
Chester Irrigation Project	40,000	Above Fort Peck
Tiber Irrigation Contracts	44,000	Above Fort Peck
Crow Irrigation	0 [1]	Fort Peck to Garrison
Northern Cheyenne	30,000	Fort Peck to Garrison
Ft Belknap Settlement	60,000	Fort Peck to Garrison
Turtle Lake	27,400	Fort Peck to Garrison
McClusky Canal	20,000	Fort Peck to Garrison
Standing Rock Irrigation	1,800	Garrison to Oahe
Lake Andes Wagner Irrigation	1,000	Big Bend to Ft Randall
Other Future Projects[3]		
Missouri River estimated surplus water demand	630	Above Fort Peck
Missouri River Oil and Gas Development	27,000	Fort Peck to Garrison
Missouri River estimated surplus water demand	5,211	Garrison to Oahe
Missouri River estimated surplus water demand	5,661	Oahe to Big Bend
Hyperion Energy Center	13,440	Gavins Point to Sioux City

[1] Projects identified with "0" cannot be meaningfully considered since there are no estimated withdrawal numbers available at this time.

[2] This project is a complete diversion with no return flows but is planned only to be used during droughts.

[3] Surplus demand numbers and oil and gas numbers are complete diversions that are temporary for drilling needs only and will cease when all wells are completed.

Table D.7 Future Project Withdrawals by Reach in the Missouri River Basin

Missouri River Reaches	Public Surface Water Supply (Acre-Feet per Year)	Irrigated Agriculture (Acre-Feet per Year)	Other (Acre-Feet per Year)
Above Fort Peck	32,334	84,400	630
Fort Peck to Garrison	133,429	137,400	27,000
Garrison to Oahe	27,238	1,800	5,211
Oahe to Big Bend	9,266		5,661
Big Bend to Fort Randall		1,000	
Fort Randall to Gavins Point	760		
Gavins Point to Sioux City	35,700		13,440
Sioux City to Omaha	3,217		
Omaha to Nebraska City			
Nebraska City to St. Joseph			
St. Joseph to Kansas City	999		
Kansas City to Boonville			
Boonville to Hermann			
Total	242,943	224,600	51,942

Depletions by Future Public Surface Water Supply Projects

A portion of the public surface water supply that is withdrawn is generally returned to the river. *Depletion* is defined as the net water loss (i.e., amount withdrawn minus amount returned). The monthly distribution of public surface water supply diversions and monthly depletion rates used in the Depletions Database are shown in Table D.8. The monthly distribution of diversions was used in the MBSA study (Missouri Basin States Association 1982)The distribution demonstrates that water use is higher during the summer months than the winter months. The depletion rate used is taken from a USGS study (2004) of water use in Montana (USGS in Cooperation with the Montana Department of Natural Resources and Conservation. *Estimated Water Use in Montana in 2000*. Page 39). A majority, 63 percent, of the water diverted is returned to the stream for potential reuse downstream.

Table D.8 Public Surface Water Supply Diversion and Depletion Rates

Month	Monthly Diversion Rate %	Depletion Rate %
January	3	37
February	3	37
March	6	37
April	7	37
May	10	37
June	13	37
July	18	37
August	15	37
September	11	37
October	8	37
November	3	37
December	3	37

These values were used for each reach in the basin to determine the depletions by reach of future public surface water supply projects. The depletions were calculated by month using the following equation:

$$\begin{aligned} &Future\ Monthly\ Depletion \\ &\qquad = AF\ Withdrawl\ per\ Year\ \times\ Monthly\ Diversion\ Rate \times Monthly\ Depletion\ Rate \end{aligned}$$

Depletions by Irrigated Agriculture Projects

Future irrigated agriculture depletions are estimated by calculating the difference between the diversion requirements and the return flows for each project. A diversion requirement is the amount of water that needs to be diverted at the main canal to supply irrigation water to the crop, in lieu of natural rainfall, so the crop can grow to maturity.

Return flows are the portion of the irrigation withdrawals that return to the natural streams and become available for reuse within the Missouri River Basin. Return flows include excess withdrawals, operational waste, and a portion of the canal seepage and deep percolation.

Irrigated agriculture depletions are the portion of the diversion that is consumptively used by crops and non-beneficial consumptive uses such as vegetation along the canal. Irrigated agriculture depletions also include the portion of the canal seepage and deep percolation unavailable for return flows to the natural stream in the Missouri River Basin.

Diversion requirements, return flows, and irrigated agriculture depletions, by month, are calculated for all HUCs within the Missouri River Basin in the established Depletions Database. Future irrigated agriculture projects were identified in four reaches of the Missouri River Basin, Above Fort Peck, Fort Peck to Garrison, Garrison to Oahe, and Big Bend to Ft. Randall. Average monthly diversion rates were calculated for each reach by averaging the diversion rates from the Depletions Database for each in HUC in the reach. These diversion rates are shown in TableD.9.

Table D.9 Monthly Diversion Requirement Rates (%)

Month	Above Fort Peck	Fort peck to Garrison	Garrison to Oahe	Big Bend to Fort Randall
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	1	4	1	1
May	7	24	16	9
June	22	22	20	19
July	34	24	28	32
August	24	17	23	27
September	11	8	11	12
October	1	1	1	1
November	0	0	0	0
December	0	0	0	0
Total	100	100	100	100

Irrigation conveyance system and on-farm efficiencies were used to calculate the amount of water available for return flow. The efficiencies used from the Depletions Database are for surface water sprinkler irrigation systems. These efficiencies are slightly higher than furrow irrigation system efficiencies resulting in less potential return flow which in turn means the return flow estimates of the future irrigated agriculture projects are conservative. The conveyance system and on-farm efficiencies used are shown in Table D.10.

HUC – a hydrologic unit code is used in a system developed by USGS, designating an area or region of water like a river, lake, or drainage basin.

Table D.10 Conveyance System and On-Farm Efficiencies

Month	Conveyance System Efficiency	On-Farm Efficiency
January	0	0
February	0	0
March	30	0
April	30	65
May	30	65
June	35	65
July	70	65

Month	Conveyance System Efficiency	On-Farm Efficiency
August	80	65
September	60	65
October	50	65
November	0	0
December	0	0

Non-beneficial consumptive use is a loss that occurs within the irrigation system. These losses are primarily caused by weeds, trees, and other vegetation growing along canals and ditches that use water which would normally return to the river. The available return flow is adjusted for these losses. Accurate figures are very difficult to measure and no studies on these water losses have been completed for the Missouri River Basin. Values between 15 percent and 20 percent have been commonly used in past studies. In the Depletions Database and for this analysis of future irrigated agriculture projects, a non-beneficial consumptive use value of 20 percent is used.

The return flow that is not lost to non-beneficial consumptive use is returned to the river system and used again downstream. However, the return flows are not instantaneous in many cases, and may require several months to return to the river. Sixty percent of the return flow occurs during the month of the diversion. The values shown in Table D.11were used to distribute the remaining return flow. The 60 percent and the values shown in Table D.11 represent a common return flow distribution used in the Depletions Database. To recap, irrigated agriculture depletions equal the amount of water diverted from the river system minus the amount returned to the river system.

Table D.11 Return Flow Distribution

	Percent of Return Flow Returned to River System
Month one following diversion	50
Month two following diversion	15
Month three following diversion	13
Month four following diversion	8
Month five following diversion	4
Month six following diversion	3
Month seven following diversion	2
Month eight following diversion	1
Month nine following diversion	1
Month ten following diversion	1
Month eleven following diversion	1
Month twelve following diversion	1

Other Future Water Use Projects

The water projects listed as other projects (table D.6) were determined to have zero return flow. Therefore, the withdrawal equals the depletion. The Red River Water Supply Project also has zero return flow because the water is being transferred to another basin.

Summary of Future Water Use Project Depletions

The depletions calculated using the methods described above for public surface water supply depletions, irrigated agriculture and other projects are shown in Table D.12.

Table D.12 Future Project Depletions by Reach in the Missouri River Basin

Missouri River Reaches	Public Surface Water Supply (Acre-Feet per Year)	Irrigated Agriculture (Acre-Feet per Year)	Other (Acre-Feet per Year)	Total (Acre-Feet per Year)
Above Fort Peck	12,000	43,400	600	56,000
Fort Peck to Garrison	99,900	64,600	27,000	191,500
Garrison to Oahe	10,100	900	5,200	16,200
Oahe to Big Bend	3,400	0	5,700	9,100
Big Bend to Fort Randall	0	500	0	500
Fort Randall to Gavins Point	300	0	0	300
Gavins Point to Sioux City	13,200	0	13,400	26,600
Sioux City to Omaha	1,200	0	0	1,200
Omaha to Nebraska City	0	0	0	0
Nebraska City to St. Joseph	0	0	0	0
St. Joseph to Kansas City	400	0	0	400
Kansas City to Boonville	0	0	0	0
Boonville to Hermann	0	0	0	0
Total	140,500	109,400	51,900	301,800

These are the anticipated depletions by future project to the year 2060. The total Missouri River Basin depletion for future public surface water supply, irrigated agriculture, and other projects is 301,800 acre-feet per year.

Projected Missouri River Basin Public Surface Water Supply Depletions 2010-2060

Although future projects projected to directly withdrawal water from the Missouri River account have been considered. Reclamation also determined to address water withdrawal throughout the entire Missouri River Basin. Although many of these withdrawals may not be direct to the Missouri River they do affect the amount of water that comes into the Missouri River and a determination was made to include these data. This section describes the analysis used to estimate future 2060 water depletions for the entire Missouri River Basin for existing public surface water supply systems based on population projections. The process is based on the primary assumption that public supply water usage parallels population growth. The depletions estimated in this section are in addition to the specific future water project depletions estimated in the previous section. These projections go from 2010 through 2060.

Some of the specific future public surface water supply projects listed in the previous section will provide water for future demands that are also included in this section. Thus this is a conservative approach that may overestimate future water demands.

Projected Public Surface Water Supply Diversions

The method used to project future public surface water supply system use is the same as the method used in the Depletions Database as documented in the report, *Missouri River Basin Depletions Database* (Reclamation 2012). Unified data covering the Missouri River Basin are published in USGS water use reports. The USGS publishes these reports every 5 years, with more comprehensive reports starting in 1985.

The 1985, 1990, and 1995 USGS water use reports were used as the basis for estimating public supply consumption. These same reports are used in the Depletions Database because the data are provided by HUC. More recent USGS reports do not have the data by HUC. The specific data extracted from these reports for estimating depletions were the percent of the population in each HUC served by a public supply from surface water sources, and the per capita consumption. The per capita consumption was multiplied by the estimated number of people served by a public water supply in each HUC to calculate the total public supply diversion.

Ratios of population served by public supply surface water system to total HUC population were developed from the 1985, 1990, and 1995 USGS water use data. The ratios were combined into an average value for each HUC. The USGS water use data also provides a per capita use rate by HUC. The per capita use rate for 1985, 1990, and 1995 were also combined into an average value per HUC.

Public Surface Water Supply Depletions

Because the Depletions Database operates on a monthly time step, the annual public supply depletions needed to be converted to monthly values. The monthly distribution of municipal water use used in the MBSA study was used to distribute the annual data (see table D.8). The estimated depletion rate (37 percent) is based on a USGS (2004) study of water use in the Missouri River Basin.

Future Population Data

The U.S. Census Bureau has published state-level population projections through 2030 for all states in the Missouri River Basin. County-level population projections through 2030 are available for all states except North Dakota and South Dakota, where county-level projections are only available through 2020.

Population was projected on a state level through 2060 by linear extrapolation using the average annual rate of change from 2010 to 2030. The state-level projections were distributed to counties by using the county to state population ratio from the 2010 census. Table D.13 shows the state-level projections.

Table D.13 Population Projections from Census Bureau Data

	2010*	2015**	2020**	2025**	2030**	Annual Change (2010-2030)	2060***
Montana	989,415	999,489	1,022,735	1,037,387	1,044,898	2,774	1,128,123
South Dakota	814,180	796,954	801,939	801,845	800,462***	-686	779,885
North Dakota	672,591	635,133	630,112	620,777	606,566***	-3,301	507,529
Wyoming	563,626	528,005	530,948	529,031	522,979	-2,032	462,009
Colorado	5,029,196	5,049,493	5,278,867	5,522,803	5,792,357	38,158	6,937,099
Nebraska	1,826,341	1,788,508	1,802,678	1,812,787	1,820,247	-305	1,811,106
Kansas	2,853,118	2,852,690	2,890,566	2,919,002	2,940,084	4,348	3,070,533
Iowa	3,046,355	3,026,380	3,020,496	2,993,222	2,955,172	-4,559	2,818,398
Missouri	5,988,927	6,069,556	6,199,882	6,315,366	6,430,173	22,062	7,092,042

*2010 Census
** U.S. Census Bureau and state projections
*** Reclamation projection

The population ratios between counties and HUCs developed for the Depletions Database were used for the projected public surface water supply system demand analysis. The method for developing these ratios is documented in Reclamation's report on the Depletions Database which is a supporting document to the NAWS SEIS. The county ratios are multiplied by the projected county-level census data to estimate the population in each HUC.

Table D.14 shows the changes in Missouri River Basin public water system depletions from 2010 to 2060 by river reach. The total Missouri River Basin increase in water depletions of 205,700 acre-feet is based on the population increase and the per capita water use data.

Table D.14 – Missouri River Basin Public Surface Water Supply Depletion Projections: 2010-2060

Missouri River Reaches	Estimated Depletions in 2010 (acre-feet)	Projected Depletions 2060 (acre-feet)	Change (acre-feet)
Above Fort Peck	16,400	21,400	5,000
Fort Peck to Garrison	19,700	21,700	2,000
Garrison to Oahe	10,500	8,900	-1,600
Oahe to Big Bend	300	300	0
Big Bend to Fort Randall	1,000	900	-100
Fort Randall to Gavins Point	1,000	1,000	0
Gavins Point to Sioux City	5,300	5,100	-200
Sioux City to Omaha	8,000	9,100	1,100
Omaha to Nebraska City	277,800	443,000	165,200
Nebraska City to St. Joseph	1,900	2,100	200
St. Joseph to Kansas City	44,800	56,600	11,800
Kansas City to Boonville	55,600	72,700	17,100
Boonville to Hermann	1830	23,500	5,200
Total	460,600	666,300	205,700

Depletions Due to Industrial Water Use in the Missouri River Basin

Industrial water use includes all diversions for industrial purposes that are not supplied by public surface water supply systems. Depletions from industrial water use are not included in the Depletions Database. For the NAWS Project analysis, USGS water use reports were used to estimate future industrial water use depletions. Industrial depletions were calculated as a percent of public surface water supply depletions, based on the assumption that industrial water use is greater where the population is greater.

Ratios of industrial water diversions to public surface water supply diversions were developed from the 1985, 1990, 1995 USGS water use reports. The ratios were combined into an average value for each Missouri River Basin reach. The percentages calculated are shown in Table D.15.

Table D.15 Industrial Water Withdrawals as a Percent of Public Surface Water Supply Withdrawals

Missouri River Reaches	1985 Water Use Report	1990 Water Use Report	1995 Water Use Report	Average Percent
Above Fort Peck	3.0	3.8	3.8	3.5
Fort Peck to Garrison	31.4	43.7	40.4	38.5
Garrison to Oahe	11.8	54.0	18.7	28.2
Oahe to Big Bend	0.0	0.0	0.0	0.0
Big Bend to Fort Randall	0.0	0.0	0.0	0.0
Fort Randall to Gavins Point	0.0	0.8	0.0	0.3
Gavins Point to Sioux City	22.7	16.6	5.7	15.0
Sioux City to Omaha	0.0	0.0	0.0	0.0
Omaha to Nebraska City	9.1	4.2	4.7	6.0
Nebraska City to St. Joseph	22.1	0.0	3.0	8.4

Missouri River Reaches	1985 Water Use Report	1990 Water Use Report	1995 Water Use Report	Average Percent
St. Joseph to Kansas City	0.4	0.1	0.1	0.2
Kansas City to Boonville	0.7	0.7	0.1	0.5
Boonville to Hermann	4.8	0.4	0.0	1.7

Although the percentage of industrial water withdrawals that is consumptively used (i.e., the depletion) is generally lower than public surface water supply system depletions, for this analysis the same depletion rate (37 percent) was used as documented in the USGS report noted above. Future industrial water use depletions were calculated by multiplying the total public surface water supply diversions by Missouri River Basin reach by the average percentage calculated for each reach from Table D.16, and then multiplying that number by 0.37, just as they were for the historic and present level depletions presented in Tables D.1 and D.2. The projected industrial water use depletions for 2010 and 2060 are shown in Table D.16.

Table D.16 Industrial Depletions

Missouri River Reaches	Estimated Depletions in 2010 (acre-feet)	Projected Depletions 2060 (acre-feet)	Change (acre-feet)
Above Fort Peck	600	700	100
Fort Peck to Garrison	7,600	8,400	800
Garrison to Oahe	2,900	2,500	-400
Oahe to Big Bend	0	0	0
Big Bend to Fort Randall	0	0	0
Fort Randall to Gavins Point	0	0	0
Gavins Point to Sioux City	800	800	0
Sioux City to Omaha	0	0	0
Omaha to Nebraska City	16,700	26,600	9,900
Nebraska City to St. Joseph	200	200	0
St. Joseph to Kansas City	100	100	0
Kansas City to Boonville	300	400	100
Boonville to Hermann	300	400	100
Total	29,500	40,100	10,600

Trans-Basin Diversions

There are several existing trans-basin diversions in the Missouri River Basin. There are significant diversions into the Missouri River Basin that add to the amount of water available and thus are considered in this analysis. The trans-basin diversions provide a source of water for irrigated agriculture and public surface water supplies. Trans-basin diversions into a Missouri River Basin reach are counted as a negative depletion for that reach. There are a couple of trans-basin diversions within the Missouri River Basin that were looked at but determined to not affect depletion analysis outcomes since they occurred within the same Missouri River Basin reach, Omaha to Nebraska City. Both diversions are from the North Platte to the South Platte River Basin. The following is a list of the major trans-basin diversions into the Missouri River Basin.

Colorado River Basin into South Platte Basin (Omaha to Nebraska City):
- Adams Tunnel
- Roberts Tunnel
- Moffat Tunnel
- Grand River Ditch
- Berthoud Pass Ditch

Diversions from North Platte River Basin into South Platte Basin (Omaha to Nebraska City):
- Laramie-Poudre Tunnel
- Michigan Ditch

Diversions from Arkansas River Basin into South Platte Basin (Omaha to Nebraska City):
- Aurora Homestake Pipeline

Hudson Bay Basin to Milk River Basin (Fort Peck to Garrison):
- St. Mary Canal

Tran-basin diversions by Missouri River Basin reach were estimated for historic, present-level, and future depletions. Historic trans-basin diversions are the actual trans-basin diversion that occurred. Median diversions for the past 30 years (1981-2010) were used to estimate present-level trans-basin diversions. One anticipated future trans-basin diversion out of the Missouri River Basin (Red River Valley Water Supply Project) was discussed in the future projects section of this appendix. The Red River Valley Water Supply Project diversion was included as a future depletion, and the NAWS Project was addressed as alternatives for the NAWS SEIS.

Reservoir Holdouts

Using data from Reclamation's HydroMET database, monthly operational holdouts (depletions) for all Reclamation reservoirs in the Missouri River basin were developed. Potential evaporation data from EPA's BASINS program was also used to calculate reservoir evaporation. The reservoir holdouts include the net effects of storage changes, precipitation, and reservoir seepage. Holdouts are calculated as the monthly total change in storage plus reservoir evaporation. Table D.17 is a list of reservoirs included by Missouri River Basin reach.

Table D.17 Missouri River Basin Reclamation Reservoirs

Missouri River Basin Reach	Reclamation Reservoirs
Above Fort Peck	Clark Canyon, Canyon Ferry, Gibson, Pishkun, Willow Creek, Lake Elwell
Fort Peck to Garrison	Buffalo Bill, Bull Lake, Boysen, Bighorn, Fresno, Nelson
Garrison to Oahe	EA Patterson, Lake Tschida, Shadehill, Belle Fourche, Keyhole, Pactola, Deerfield, Angostura
Oahe to Big Bend	None
Big Bend to Fort Randall	None
Fort Randall to Gavins Point	Box Butte, Merritt
Gavins Point to Sioux City	Jamestown

Missouri River Basin Reach	Reclamation Reservoirs
Sioux City to Omaha	None
Omaha to Nebraska City	Seminoe, Pathfinder, Alcova, Glendo, Guernsey, Horsetooth, Calmus, Davis Creek
Nebraska City to St. Joseph	None
St. Joseph to Kansas City	Bonny, Enders, Trenton, Hugh Butler, Harry Strunk, Keith Sebelius, Kirwin, Webster, Waconda, Cedar Bluff, Lovewell
Kansas City to Boonville	None
Boonville to Hermann	None

Present-level holdouts were assumed to equal to historic holdouts except that median monthly historic holdouts were used for years prior to the reservoir initially filling. There are no current plans by Reclamation to construct any new reservoirs in the Missouri River Basin, so no additional holdouts were estimated for future depletions.

Depletion Data Use

The collective depletions data developed by Reclamation are used by the Corps in its Daily Routing Model (DRM) to simulate operations of the Missouri River Mainstem System. These simulations can then be used to look at potential effects of depletions. However, depletion data has to be adapted to allow potential simulations and evaluations. Historic depletions can be added to the total historic flows to get “natural” flows of the Missouri River. Historic depletions included in this analysis include irrigated agriculture depletions, public surface water supply depletions, industrial depletions, Reclamation reservoir holdouts, and trans-basin diversions.

Present-level depletions can be subtracted from the natural flows to get present-level depleted streamflows. Present-level depletions include all the same categories as historic depletions. Because the Corps’ DRM hydrologic model depletion input file requires net depletions, the present level depletion file was subtracted from the historic depletion file to derive the net depletion file for each of the 13 DRM reaches.

To estimate streamflow conditions in 2060, estimated depletions for future irrigated agriculture, public surface water supply, and other future projects must also be subtracted. Additionally, depletions by public surface water supply systems and industrial water use that were estimated by looking at population projections must also be subtracted.

Analysis of Missouri River Effects

Missouri River Impact Model Review

Prior to using depletion data in the Corps Daily Routing Model a determination on how to evaluate the effects of water withdrawal needed to be evaluated. As part of the NEPA analysis for the NAWS Project, Reclamation took a look at the tools available to evaluate the potential effects of water withdrawal on the Missouri River and its resources. During the Corps’ Master Manual Review and Update Study EIS (2004), models were developed and used to look at different operational scenarios and their effects on Missouri River resources. Reclamation used these same models on a previous EIS for a water withdrawal for the Red River Valley Water

Supply Project. The Western Area Power Administration as well as the Corps have used these models to make relative comparison of alternatives for several subsequent documents prepared for NEPA.

To insure that the use of these models were still appropriate, Reclamation initiated an independent consultant's review of the Corps 'Master Manual Review and Update Study EIS models for use in the NAWS SEIS (Reclamation 2012). This evaluation and report was completed by Cardno ENTRIX and evaluated the Corps' Daily Routing Model (DRM) and the Economic and Environmental Resource models (Reclamation 2012). Cardno ENTRIX found the DRM remains the model currently in use by the Corps Northwestern Division and its Omaha and Kansas City Districts and is the only readily available source of hydrologic outputs for the Missouri River System. The Corps' has successfully used the DRM for operational decisions on the Missouri River mainstem system and in NEPA evaluations. Reclamation determined that it is appropriate to use the DRM to conduct the Missouri River depletion analysis for the NAWS SEIS.

Additionally, after review of the Cardno ENTRIX report (Reclamation 2012) and the best available information, Reclamation decided to use the Corps' economic impact models to simulate the potential economic effects of water withdrawals on changes to streamflows and reservoir levels. The economic impact models are the best available tools, designed specifically for the Missouri River System, for use in the impact analysis. These models have been approved for limited use through the Corp's internal model review process and used in other NEPA analyses successfully to provide a relative comparison of alternatives. However, the Corps' has identified the process of updating the actual cost data for these models as very costly and time consuming (Corps 2013).

Upon review of the Cardno ENTRIX report (Reclamation 2012) and the best available information, Reclamation decided not to use the Corps' Missouri River environmental resource models. These models were developed in the 1990s, and changes have occurred in these natural resource areas that are not all adequately reflected in the data/assumptions within the models. The environmental resource models have not been reviewed or certified under the Corps' planning model review process. Impacts to environmental resources will be evaluated by Reclamation by working collaboratively with the Corps to qualitatively describe the potential impacts to environmental resources within the Missouri River System using hydrologic outputs from the DRM and the best available scientific information on the environmental resources. Furthermore, the Corps' has identified the process of revising these models as very costly and time consuming (Corps 2013).

Corps Analysis of Depletion Effects on Missouri River Resources

Reclamation initiated a study with the Missouri River Basin Water Management Division of the Corps' Northwestern Division to identify the relative impacts of the withdrawal of water from Lake Sakakawea for the NAWS Project. This study, the *Report on the Cumulative Impacts to the Missouri River for the Bureau of Reclamation Northwest Area Water Supply Project* (Corps 2013), assessed the effects of NAWS Project depletions on Missouri River uses and resources for the SEIS. For this study, the Corps evaluated 1) continuing sedimentation in the System, 2) the effect of anticipated future depletions on inflows from throughout the Missouri River Basin, and 3) the depletion of Missouri River inflows and 4) flows associated with the NAWS Project. Analysis of impacts of this withdrawal of water was accomplished using the best available information the Corps has regarding hydrologic and economic impacts affected by the use of water stored in the System – models developed for the Missouri River Master Water Control Manual (Master Manual) Review and Update Study EIS (Corps 2004).

Methodology

> **Daily Routing Model** – This term generally describes the hydrologic model developed and used by the Corps to simulate future hydrologic, hydropower, and navigation data for the Missouri River. As with previous modeling studies, the Daily Routing Model output data were used in the hydrologic analysis and economic impacts models developed for the previous Corps Missouri River Master Water Control and Update Study (Corps 2004).

The Corps' process for analysis was basically a two-step process. Using historic, present level, and future depletions provided by Reclamation, Corps staff simulated two changes affecting System regulation, continuing sedimentation in the System reservoirs and the depletion of Missouri River inflows and flows using its DRM. The DRM provides hydrologic, navigation, and hydropower data that are then used in impacts models to provide the data for the delineation of the relative differences between and among the simulations. The DRM was developed during the Corps' Master Manual Study to provide daily time-step output data required for several of the Master Manual Study impacts models. The DRM also provides the necessary consolidated monthly files that are required for other models relying on monthly-time step data.

An 81-year period of record was available to use for this analysis of changes affecting System regulation, including the depletions associated with the NAWS Project. These historic flows, however, have to be modified to make every year in the modeling period to be set on the same basis as the last year in the modeling period, in this case 2010, which, with the exception of 2011, was the last year of complete data. In its current form, the DRM cannot simulate the extremely large inflows that occurred in 2011. Therefore, changes in depletions to those historic inflows for the simulation period of 1930 through 2010 were required.

The Corps used Reclamation inflow historic and present level depletion data (Reclamation 2012) that were updated to 2010. These data were revised by Reclamation for the NAWS Project's Missouri River analyses based on the best available and most current data (Reclamation 2012). The Corps' DRM adjusts the amount of inflow coming into the Mainstem Reservoir System based on the adjusted depletion values.

The Corps' report also addresses sedimentation in the Missouri River mainstem system. As sediments accumulate in each reservoir, the amount of storage available at a given water surface elevation diminishes. Thus, the water surface elevation versus storage volume files (capacity files) must be updated following the sediment survey of each reservoir. Total system storage capacity is affected by sedimentation. For example, estimated system storage in 2010 totals 72.3 million acre-feet (MAF), and the total System storage is reduced to 69.4 MAF by 2060. This is illustrated in Table 1 of the Corps report (2013). Simulating the change in System storage over the 50 years without any changes in depletions with the DRM identifies the associated changes in hydrology, navigation service, and hydropower production.

This would allow the identification of relative impacts of sedimentation alone between 2010 and 2060, creating a new baseline for identifying the relative impacts of the second factor that would change between 2010 and 2060, additional non-Project depletions to System inflows without the additional depletions of the NAWS Project. Therefore, cumulative depletion effects are addressed in the Corps analysis. This is accomplished through the identification and consideration of potential future depletions as discussed in the previous section of this Appendix. Reclamation estimated future depletions (Table D.18) accumulated from various sources by identifying potential projects throughout the Missouri River Basin in various stages of planning for potential implementation by 2060. Additional irrigated crop acreage is likely to occur and water use associated with population growth will result in the growth of depletions in the future. Public supply and industrial supply are forecasted to increase. Finally, the "other" category, which includes energy development in North Dakota, includes about 26 percent of the forecasted growth in depletions in the entire Missouri River Basin.

Table D.18 Additional Missouri River Basin depletions, 2010 to 2060 (kAF)

Reach	Public Supply[1]	Industrial Supply[2]	Agriculture	Municipal[3]	Other[4]	Total
Above Fort Peck Dam	4.9	0.2	43.4	11.5	0.6	60.6
Fort Peck Dam to Garrison Dam	2.0	0.8	64.6	18.9	107.2	193.6
Garrison Dam to Oahe Dam	-1.5	-0.4	0.9	9.7	5.2	13.8
Oahe Dam to Big Bend Dam	0.0	0.0	0.0	3.3	5.7	8.9
Big Bend Dam to Fort Randall Dam	0.0	0.0	0.5	0.0	0.0	0.5
Fort Randall Dam to Gavins Point Dam	-0.1	0.0	0.0	0.3	0.0	0.2
Gavins Point Dam to Sioux City, IA	-0.3	0.0	0.0	12.7	13.4	25.8
Sioux City, IA to Omaha, NE	1.1	0.0	0.0	1.1	0.0	2.3
Omaha, NE to Nebraska City, NE	165.2	9.9	0.0	0.0	0.0	175.2
Nebraska City, NE to St. Joseph, MO	0.3	0.0	0.0	0.0	0.0	0.3
St. Joseph, MO to Kansas City, MO	11.8	0.0	0.0	0.4	0.0	12.2
Kansas City, MO to Boonville, MO	17.2	0.1	0.0	0.0	0.0	17.2
Boonville, MO to Hermann, MO	5.2	0.1	0.0	0.0	0.0	5.3
2010 to 2060 Total	205.8	10.6	109.4	57.8	132.2	515.8

[1] This column includes identified potential future water supply projects

[2] This column includes industrial supply, as represented as a percent of municipal.

[3] This column includes future municipal supply based on population projections from census data

[4] This column includes other depletions with zero return flow, e.g., the Red River Valley Water Supply Project

Simulation of the combination of the future depletions presented in Table D.18 and the sedimentation that could occur between 2010 and 2060 using the DRM results in what could be the System's hydrologic values, navigation service, and hydropower generation under 2060 conditions without the NAWS Project – the No Action alternative. Adding in the anticipated depletions of the NAWS Project to a simulation run would identify the hydrologic, navigation service, and hydropower generation values for the total cumulative depletions anticipated by 2060.

The Corps' analysis uses the DRM to simulate an 81-year historic record, adjusts for depletions and sedimentation to demonstrate how the System's hydrologic, navigation service, and hydropower generation values are affected by the NAWS Project depletions. Five simulations of the changes that affect system regulation were analyzed. These simulations include:

- **Existing conditions** – necessary for evaluating the consequences of the No Action alternative and for use in section 7 consultation under the Endangered Species Act,
- **Sedimentation 2060 –** to separate out the effects of sedimentation and the depletions.

- **No Action –** future conditions (2060) with both sedimentation and non-Project depletions but without the NAWS Project used to compare against NAWS Project action alternatives for NEPA.
- **NAWS 13.6 –** action option/simulation that represents the forecasted average monthly water use of the NAWS Project totaling 13,600 acre-feet (ac-ft) per year, or 13.6 thousand ac-ft (kAF) per year.
- **NAWS 29.1 –** action option/simulation that represents the maximum[2] amount of water that could move through the distribution system of the NAWS Project, i.e., 29,100 ac-ft per year or 29.1 kAF per year.

With these simulations, two kinds of impact analyses were conducted. The first was the analysis of the hydrologic effects of the differences among the five simulations, which looked at the impacts incrementally as the sedimentation and depletion values are incorporated incrementally into the Existing Conditions simulation. This information was used to look at impacts to Missouri River environmental resources (water quantity and quality, fisheries and aquatic ecology, federally listed species, wetlands and riparian areas, and historic properties including state and tribal cultural resources) in Chapter 4 of the NAWS SEIS. The second was the economic analyses of the five simulations, which can also be examined for the changes incorporated incrementally into the Existing Conditions simulation. This information was then used to look at impacts in Chapter 4 of the NAWS SEIS to other Missouri River economic resources (flood control, navigation, hydropower, water supply, and recreation).

Summary of Missouri River Analysis Results (Corps 2013)

The volume of water stored in the System varies with changes in annual inflows into the Missouri River mainstem and the amount of water released from the System to meet its authorized purposes. Daily decisions for the operation of the System depend on the amount of water stored in the System and the distribution of the water among the upper three, larger reservoirs. To maintain the desired levels in the individual reservoirs and to meet the flow requirements of the authorized purposes on the lower Missouri River downstream from the System, releases are set from each System project. These flow requirements include downstream flow targets for flood control, navigation, water supply, water quality, hydropower requirements, recreation, fish and wildlife, and intrasystem balancing for all authorized purposes. The main stem projects are operated as a hydrologically and electrically integrated system in order to achieve the multipurpose benefits for which they were authorized. Regulation of the main stem reservoir system follows a repetitive annual cycle that is described in detail in the Missouri River Mainstem Master Manual (Corps 2004).

Thus the focus of this analysis is on looking at the hydrologic variables in view of integrated system operations and its impacts on water resources. The Corps' hydrologic analysis looked at the impacts to the volume of water stored in the System, the water surface elevations of the four larger System reservoirs, and the releases from Gavins Point Dam and the upper three, larger reservoirs (Fort Peck, Garrison, and Oahe).

Hydrologic Impacts: The Corps' analysis concluded that continuing deposition of sediments into the System reservoirs will reduce the storage capacity of primarily the Carryover and

[2] Maximum capacity of the pipe was evaluated however; the system could not physically operate at this maximum capacity 24 hours a day, 7 days a week for 365 days. However, it is an appropriate consideration for this SEIS.

Multiple Use Zone and the Permanent Pool of the each reservoir (See Figure D.1 below). This will, in turn, reduce the storage capacity of the total System. Increased sedimentation out to 2060 is estimated to reduce System storage by 2.8 MAF (Corps 2013). Because the amount of water stored in the two flood control zones will remain relatively constant, the amount of water stored in the System reservoirs will be diminished annually by the sedimentation. The amount of storage in each reservoir will be lower, so the net effect of sedimentation will be higher reservoir levels. In order to understand sedimentation effects out to 2060 one needs to visualize what would happen to a water bucket when soil is placed into the bucket. The water surface would rise due to the displacement of the water by the sediments. So on Missouri River reservoirs sedimentation will cause the water surface elevation of the reservoirs to rise while the sediments would occupy storage space causing the loss of the space for water storage. Sedimentation will have essentially no impact on releases from the System reservoirs.

Non-Project future depletions that would reduce inflows to the System reservoirs and the lower Missouri River are forecasted to reach 516 kAF by 2060 (Table D.18). These depletions to inflows will reduce the amount of water in System storage, especially during extended droughts. This reduction in System storage will carry over to the water surface elevations, or levels of water, in each of the three, larger System reservoirs (Fort Peck, Garrison, and Oahe), as levels will drop in increasing amounts in the droughts as the depletions continue to accumulate each year. Releases from the System reservoirs will drop with the increasing non-Project depletions, with the amount of release reductions being nearly equivalent to the amount of the cumulative depletions above each reservoir.

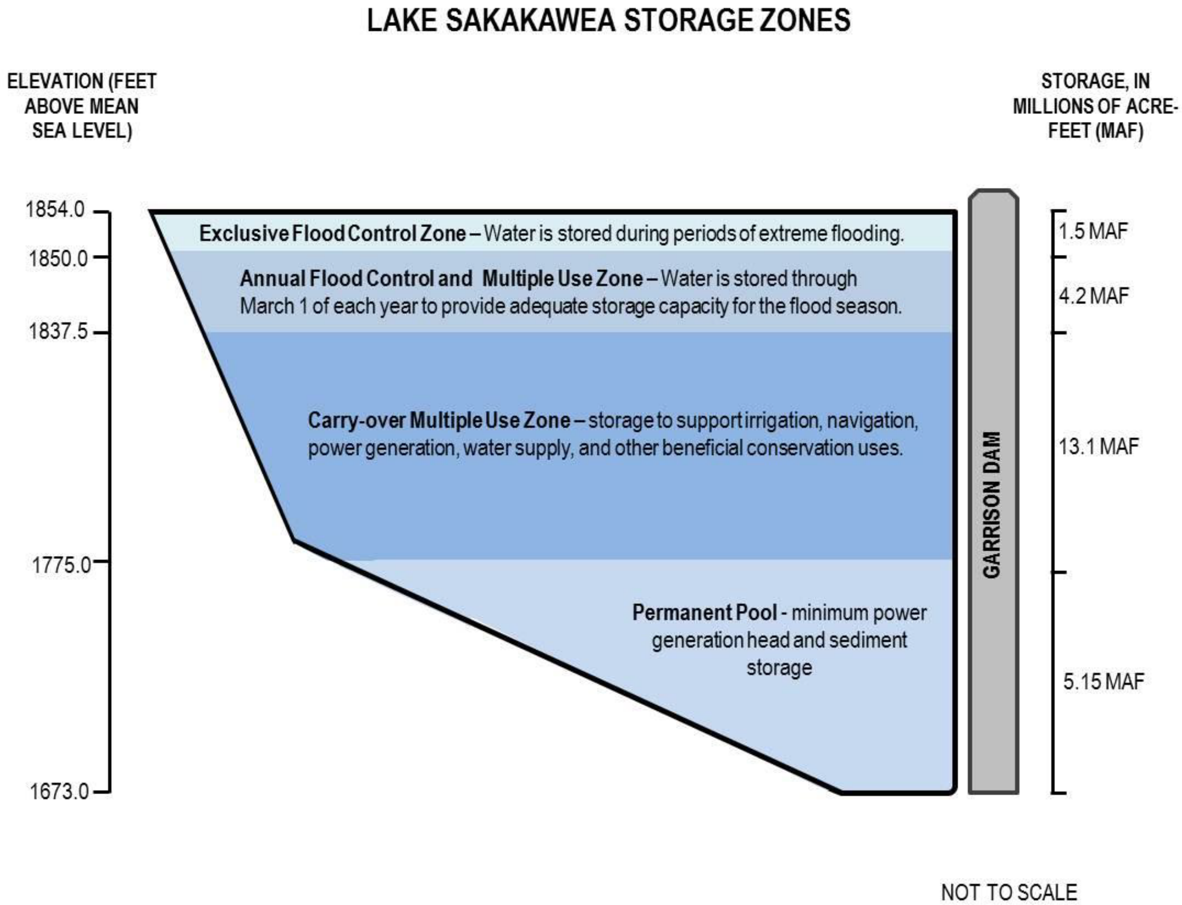


Figure D.1 Lake Sakakawea Storage zones.

NAWS Project depletions will have similar relative effects as the non-Project depletions. However, the amount of the NAWS Project depletion is relatively much smaller (13.6 and 29.1 kAF are 2.6 and 5.6 percent, respectively) compared to 516 kAF of non-Project depletions.

The amount of NAWS Project depletion, whether 13.6 kAF, 29.1 kAF, or some other value below, within, or above that range would have a relatively smaller effect on the water surface elevations of the upper three, larger System reservoirs when compared to future depletions. Because the NAWS Project would remove water from Lake Sakakawea (Garrison Reservoir) and convey it out of the Missouri River basin the amount of water in the System would be reduced. However, these depletions from the Missouri River that could potentially lower the water surface elevations of the upper three reservoirs may not be noticed because of System operations that balance the upper 3 reservoirs combined with offsetting higher water levels resulting from continuing sedimentation. The one exception may be drought but even during drought conditions water conservation measures and reduced navigation flows could help offset or minimize water level changes in the upper three reservoirs. More information on Reservoir Level Impacts and System release Impacts are explained below.

Reservoir Level Impacts: Potential system reservoir impacts are evaluated by looking at reservoir storage and reservoir elevations. Decisions on releases from the System are based on the amount of water in System storage. During extended droughts, the amount of water in System storage drops well below the base of flood control storage throughout the year. In the non-drought periods, the goal on March 1 of each year is to have the volume of water in System storage at the base of flood control storage, which is assumed to be 53.1 MAF by 2060. As the water entering the Missouri River is reduced due to factors that deplete that water, the System storage is likely to be further reduced, especially in drought periods.

Sorted water surface elevation differences for the two NAWS Project simulations from those of the No Action simulations for the 1930-2010 period of analysis are shown in Figure D-2. These results show that for the NAWS 13.6 option, the Garrison reservoir would be at a plus or minus 1-foot difference 95% of the time. When you look at Figure D-2 it clearly shows that for almost 70% of the time the elevation difference is less than a foot. Similar findings were shown for Fort Peck and Oahe reservoirs. For a plus or minus 1-foot difference, Fort Peck and Garrison would be within this range 95 percent of the time, and Oahe would have water levels within this range 92 percent of the time when compared to the water levels of the No Action simulation.

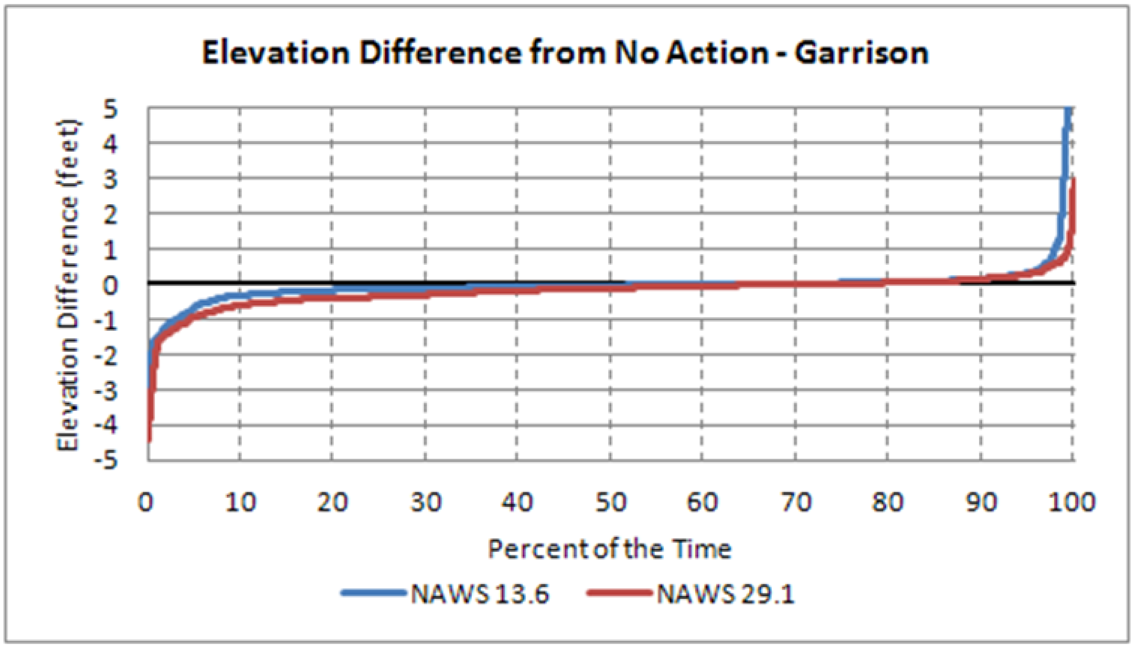


Figure D-2 Garrison Reservoir sorted daily water surface elevation differences for the two NAWS Project simulations from those for No Action for the 1930-2010 period of analysis.

Annual minimum system storage levels in 1933-1943 for the No Action, NAWS 13.6, and NAWS 29.1 simulations are shown in Figure D-3. The annual minimum Garrison Reservoir elevations for the 1933-1943 period for the No Action and the two NAWS simulations shows the values for the annual minimum Garrison elevation are very similar among these three simulations.

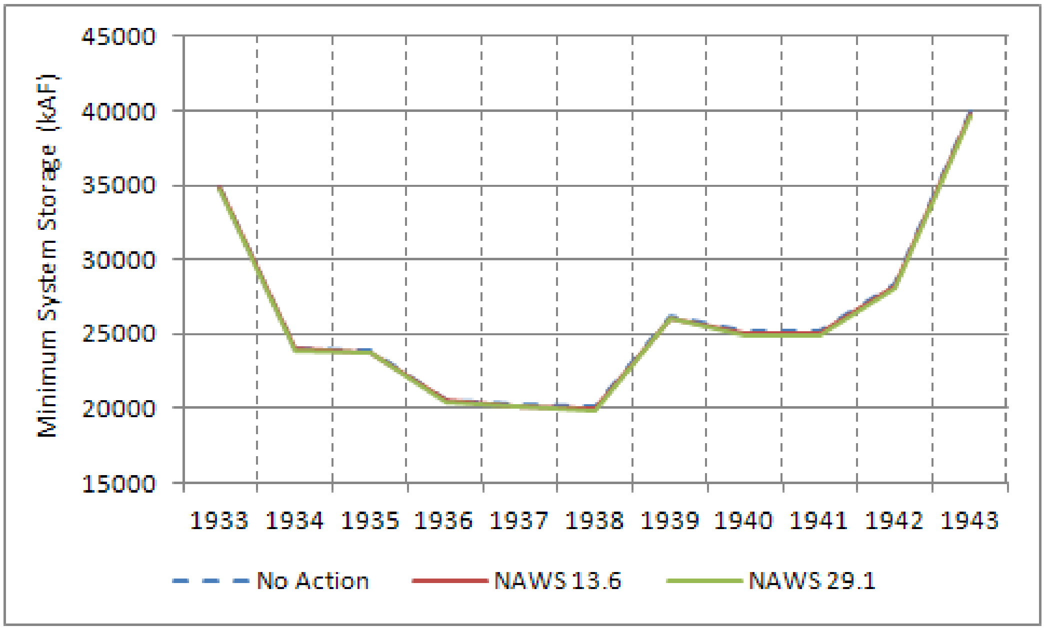


Figure D-3 Annual minimum System storage in 1933-1943 for the No Action, NAWS 13.6, and NAWS 29.1 simulations

The sedimentation and depletions during four extended droughts resulted in System storage changes among the five simulations evaluated for this analysis and report. The minimum System storage values also varied among the simulations. The minimum System storage changes among the simulations showed decreasing values as the sedimentation to 2060 was the first added change followed by the non-Project depletions to 2060 and, finally, the depletions options associated with the NAWS Project. The changes for the NAWS Project options were the lowest, and generally 0.1 MAF or less for NAWS 13.6 and between 0.1 and 0.2 MAF for NAWS 29.1; whereas, the changes for the sedimentation and the larger depletions between existing conditions and 2060 were somewhat larger, as high as about 2.0 MAF. Figure D-4 shows the minimum storage levels in the four droughts for the five simulations. Again, it is readily apparent that there is relatively little change in the minimum storage levels of the NAWS Project simulations compared to the other three simulations.

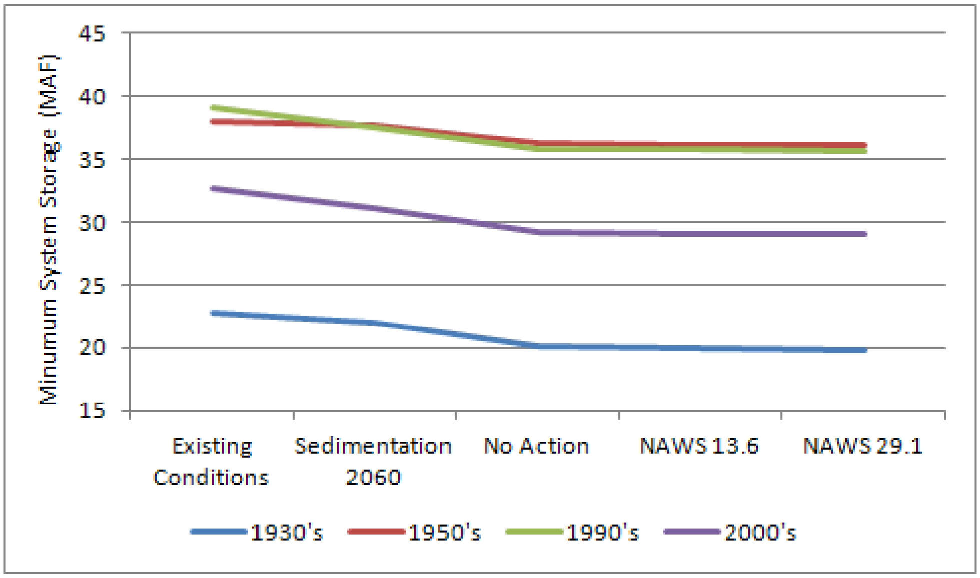


Figure D.4 Minimum storage for the five simulations in the four extended droughts in the 80-year period of analysis of 1930-2010.

The differences among the No Action and two NAWS Project simulations during the 1930s drought were 0.2 feet, 0.0 foot, and 0.8 feet for Fort Peck, Garrison, and Oahe, respectively. The differences among the No Action and two NAWS Project simulations during the 2000s drought were 0.3 feet, 0.5 feet, and 0.2 feet for Fort Peck, Garrison, and Oahe, respectively. Figure D-5 shows the annual minimum Garrison Reservoir levels in 1933-1943 for the No Action, NAWS 13.6, and NAWS 29.1 simulations. The values for the annual minimum Garrison elevation are very similar among these three simulations.

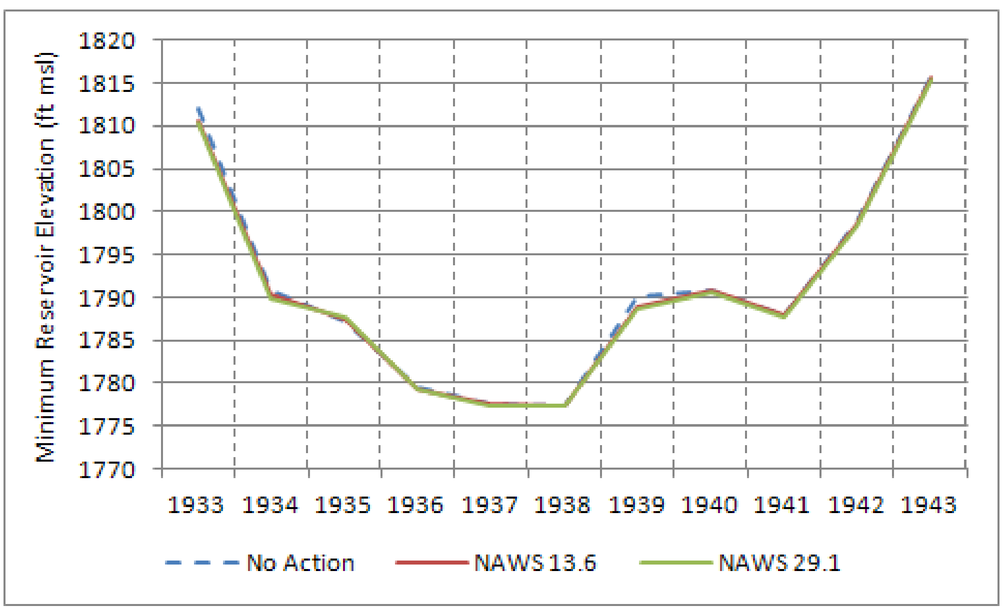


Figure D-5 Annual minimum Garrison Reservoir levels in 1933-1943 for the No Action, NAWS 13.6, and NAWS 29.1 simulations.

System Releases Impacts: The Corps' (2013) analysis also looked at dam releases. Releases from the 6 System dams are affected by cumulative and continuing growth of deposited sediment and System depletions and lower Missouri inflows. Releases from the upper three reservoirs are based on the need to balance the effects of depletions, sedimentation and flood storage evacuation while ensuring that the water required for meeting the Gavins Point release (to meet downstream navigation) is in Gavins Point Reservoir. The Gavins Point releases are made to meet lower Missouri River navigation and flood control requirements and to meet flood storage evacuation requirements from the System reservoirs as well as lower River flow requirements in non-navigation years.

Gavins Point releases vary from month to month as the System release requirements are met. For example, the navigation releases are affected by the inflows from the downstream tributaries, and these inflows are generally higher in the spring and lower during the summer. The summer releases are affected by the need to run as flat a release as possible to limit adverse impacts to downstream terns and plovers nesting on the islands and sandbars. During droughts, the service level can change on July 1 from that met in the months of April through June. Finally fall releases are sometimes higher than those in the summer (restricted in many years by terns and plovers) to evacuate as much of the water as needed to ensure that the volume of water in the System is at the base of flood control storage by the following March 1. This variability is shown in Table D. 19, which presents the average monthly Gavins Point release in thousands of cubic feet per second (kcfs) over the 81-year period of analysis of 1930-2010 for No Action, NAWS 13.6 and NAWS 29.1 simulations. However, you will note from the numbers in table D.19 there are very small differences between the No Action, NAWS 13.6 and NAWS 29.1 simulations. The Corps (2013) analysis shows a graph of this table for comparison but incrementally, the depletions associated with the NAWS Project are barely detectable on the figure so it is not reproduced here. Therefore when comparing No Action to NAWS 13.6 and NAWS 21.9 simulations this alternative would have a relatively small effect on the Gavins Point releases.

Table D.19 Monthly average Gavins Point release 1930-2010 (kcfs)

	No Action	NAWS 13.6	NAWS 29.1
Jan	14.48	14.47	14.48
Feb	14.73	14.73	14.74
Mar	17.74	17.73	17.73
Apr	22.26	22.23	22.22
May	27.21	27.18	27.16
Jun	28.71	28.67	28.68
Jul	30.75	30.70	30.70
Aug	33.01	32.97	32.95
Sep	33.45	33.40	33.36
Oct	30.55	30.53	30.48
Nov	23.56	23.64	23.55
Dec	14.69	14.69	14.69
Ann Ave (kcfs)	24.262	24.245	24.228
Ann Ave (ac-ft)	17565	17553	17541
Actual Depletions (ac-ft)	277.6	13.6	29.1

The Corps' analysis (2013) also found that relatively small differences in annual releases occur on a monthly basis when comparing the No Action releases at the upper 3 dams (Ft. Peck, Garrison, and Oahe) to NAWS13.6 and NAWS 29.1 simulations. Because of these small differences in annual releases the data was sorted across the 81-year period of record to help provide a graphic presentation of differences. Figure D.6 shows 81-year plots of the sorted differences in the average annual releases for Garrison releases since the Missouri River alternatives would withdraw water from Lake Sakakawea (Garrison Reservoir). This plot shows more negative than positive values; however, the negative values are just slightly negative. The net difference is relatively small (<6kcfs) for the addition of these alternatives as last-added to the No Action simulation. The net difference is relatively small for the addition of these alternatives as last-added to No Action for Ft. Peck and Oahe as well.

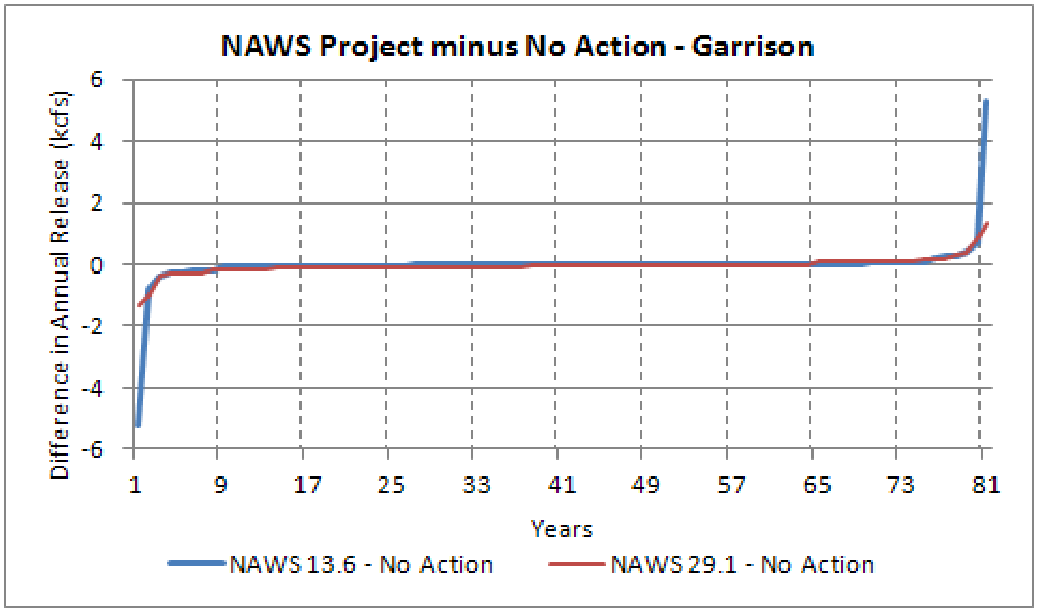


Figure D.6 Sorted differences in the annual average Garrison releases between the two NAWS Project simulations and those of No Action for the 81-year period of analysis of 1930-2010.

Economic Impacts: The Corps analysis used the economic models reviewed by Reclamation (see above discussion under *"Missouri River Impact Model Review"*). These economic models were developed by the Corps for use in evaluating operational changes in the Missouri River system for their Master Manual Study and have been used in subsequent NEPA analysis by the Corps, Reclamation, and the Western Area Power Administration. These analyses focus on the relative differences, or percentage change, among the simulations presented.

Existing Conditions was simulated using the DRM and the Economics Impacts Models to provide some perspective of how the hydrology and the associated economic effects will change due to the two primary factors that will cause change, the continuing deposition of sediments in the System reservoirs and the continuing growth of the depletion of water that enters the Missouri River main stem, with the NAWS Project being one of the projects that deplete this water. The relative effects of the NAWS Project in 2060 due to the Project's removal of water from Lake Sakakawea (Garrison Reservoir) added to the effects of the continuing accumulation of the depletion of Missouri River inflows.

Table D-20 presents the relative differences from the *Existing Conditions* simulation, which can be viewed as the cumulative impacts of the continuing sedimentation and depletions to inflows to the Missouri River. The greatest difference from Existing Conditions (essentially 2010 conditions) in the future will be to navigation, primarily because of the continuing sedimentation in the reservoirs and that factor's effect on System releases (as long as navigation guide curves remain as they are current set in the Master Manual). The loss of navigation benefits from sedimentation will be in the range of 13 to almost 16 percent (see Corps 2013 report for details). The next greatest difference will be to recreation, and the impact will be positive due to the effect of continuing sedimentation on higher water surface elevations in the upper three, larger reservoirs. Energy revenues will be the third greatest difference due to the lower releases resulting primarily from future depletion of inflows into the Missouri River upstream of the System. All of the other economic use categories have cumulative impacts that are less than 1 percent when compared to the economic benefits under Existing Conditions.

Table D-20 Relative differences of the economic benefits of the other alternatives from the *Existing Conditions* alternative (percent)

	Flood Control	Navigation	Hydropower	Water Supply	Recreation	Total	Energy Revenues
Sed 2060	-0.13	-13.05	0.62	0.01	1.94	0.24	0.10
No Action	0.02	-15.48	-0.43	-0.28	1.50	-0.24	-1.54
NAWS 13.6	0.02	-15.42	-0.49	-1.08	1.22	-0.56	-1.63
NAWS 29.1	0.02	-15.60	-0.55	-1.08	0.72	-0.61	-1.72

Table D-21 lists the impacts of the *NAWS Project* as a last-added depletion to the System. The relative impacts in terms of percent changes from the *No Action simulation* are all less than 1 percent. With the exception of water supply and recreation, the impacts are less than 0.2 percent. The impacts resulting from additional depletions were as expected, with the impacts being negative for all of the economic uses except for flood control, the use that requires additional storage space that would be provided by the additional depletion effect of the NAWS Project. Flood control effects of the NAWS 13.6 simulation were -0.01 percent; however, the flood control impacts of depletions should be considered to be zero.

Table D-21 Relative differences of the economic benefits of the NAWS Project alternatives from the No Action alternative (percent)

	Flood Control	Navigation	Hydropower	Water Supply	Recreation	Total	Energy Revenues
NAWS 13.6	-0.01	0.07	-0.06	-0.80	-0.28	-0.32	-0.09
NAWS 29.1	0.00	-0.14	-0.12	-0.81	-0.77	-0.37	-0.19

Literature Cited

Committee on USGS Water Resources Research, National Research Council. 2002. Estimating Water Use in the United States: A New Paradigm for the National Water-Use Information Program. 190 pages.

U.S. Army Corps of Engineers (Corps). 1993. Big Dam Era: A Legislative and Institutional History of the Pick-Sloan Missouri Basin Program. Missouri River Division. 228pp.

U.S. Army Corps of Engineers (Corps). 2004. Missouri River Master Water Control Manual March Review and Update FEIS. U. S. Army Corps of Engineers. Northwestern Division - Missouri River Basin. Omaha, Nebraska. 9 Volumes.

U.S. Army Corps of Engineers (Corps). 2013. Report on the Cumulative Impacts to the Missouri River for the Bureau of Reclamation's Northwest Area Water Supply Project. Missouri River Basin Water Management, Northwestern Division. 131pp.

Missouri Basin States Association. 1982. Technical Paper Municipal, Industrial, Energy, and Rural Domestic Water Use. Page 3.

Reclamation. 2012. Missouri River Basin Depletions Database. Great Plains Region. 13pp.

U.S. Geological Survey (USGS). 2004. Estimating Water use in Montana in 2000. Scientific Investigations Report 2004-5223. Helena, MT.

Appendix E

Transbasin Effects Analysis Technical Report

Northwest Area Water Supply Project
Supplemental Environmental Impact Statement

Contents

Page
Executive Summary ES-1
Introduction and Background 1
Previous Risk Studies 2
Comparative Risk Analysis 2
TetrES Technical Report 3
Review of the Proposed Pre-Treatment Process 3
Analysis of Risks of Interbasin Biota Transfers Potentially Linked to System Failures in the Project 4
Additional Relevant Risk Studies 5
Missouri River and Red River Basin Risk and Consequence Analysis 5
Devils Lake – Red River Basin Qualitative Risk Assessment 6
Current Risk Study 7
Life History Characteristics and Distribution 11
Viruses 11
Channel Catfish Virus 11
Infectious Hematopoietic Necrosis Virus 12
Infectious Pancreatic Necrosis Virus 12
Infectious Salmon Anemia Virus 13
Spring Viremia of Carp Virus 14
Viral Hemorrhagic Septicemia Virus 14
Bacteria 15
Bacterial Kidney Disease 15
Columnaris Disease 16
Edwardsiella spp. 17
Enteric Redmouth Disease 17
Furunculosis 18
Streptococcus spp. 19
Escherichia coli 19
Legionella spp. 20
Mycobacterium spp. 20
Pseudomonas spp. 21
Salmonella spp. 21
Vibrio (Cholera) 21
Mollusks 22
New Zealand Mudsnail 22
Zebra Mussel 23
Quagga Mussel 24
Parasitic Animals 25

Whirling Disease....25
Polypodium hydriforme....27
Parasitic Copepods....28
Helminths....28
Protozoa....29
Cryptosporidium parvum....29
Giardia lamblia....29
Entamoeba histolytica....30
Ichthyophthirius multifiliis....31
Ichthyophonus hoferi....32
Fungi....32
Saprolegnia spp.....32
Branchiomyces spp.....32
Phoma herbarum....33
Exophiala spp.....33
Cyanobacteria....34
Anabaena flos-aquae....34
Aphanizomenon flos-aquae....34
Microcystis aeruginosa....35
Biota Transfer....36
Conceptual Risk Model....36
Biota Transfer Pathways....39
Interbasin Connections and Water Diversions....39
Intrabasin Connections....41
Dispersal of Invasive Species via Aquatic Pathways....43
Animal Transport....46
Weather-related Phenomena....48
Climate Change....48
Fate and Transport....49
Ecological Receptors of Concern....51
Candidate Assessment Endpoints....53
Uncertainty....54
Biota Treatment Associated with Water Supply Alternatives....57
Chlorination....63
Chlorination/UV Inactivation....63
Enhanced Chlorination/UV Inactivation....65
Conventional Treatment....66
Microfiltration....67
Risk Assessment....68
Risk Posed by Potential Biota Transfer Pathways....68
Risk of Biota Transfer from the Project....69
Risk of Biota Transfer from Non-Project Pathways....72
Risk Posed by Aquatic Invasive Species of Concern....74

Viruses 74
Bacteria 75
Mollusks..76
Parasitic Animals 76
Protozoa 77
Fungi 77
Cyanobacteria 77
Consequence Analysis.. 79
Conditions that Support Establishment of Aquatic Invasive Species of Concern 79
Invasive Fish Pathogens and Parasites..79
Effects of Aquatic Invasive Species of Concern in Other Systems...........80
Non-pathogenic Invasive Organisms..85
Potential Environmental Consequences in the Hudson Bay Basin............89
Economic Consequences 93
Baseline Conditions of Potentially-Affected Sectors in Receiving Area ..94
Economic Impact Analysis 111
Conclusions.. 117
References.. 129

Tables

Table ES1 Aquatic Invasive Species of Concern ES-4
Table 1 Aquatic Invasive Species of Concern 9
Table 2 Potential Ecological Receptors of Concern in the Hudson Bay Basin 52
Table 3 Aquatic Invasive Species Summary Table 58
Table 4 Chlorination Log-inactivation[a] 63
Table 5 Chlorination/UV Log-inactivation.. 64
Table 6 Enhanced Chlorination/UV Log-inactivation or Removal 66
Table 7 Conventional Treatment Log-inactivation or Removal 66
Table 8 Microfiltration Log-inactivation or Removal 67
Table 9 Population Characteristics 96
Table 10 Contribution to Manitoba GDP by Industry 97
Table 11 Employment by Winnipeg Sector... 98
Table 12 First Nations Communities at Lake Winnipeg, 2006 Statistics 99
Table 13 2010 Recreational Angler Expenditures 100
Table 14 2010 Recreational Angler Effort.. 101
Table 15 2010 Recreational Catch by Species (number of fish)..................... 101
Table 16 Manitoba Businesses Supported by Recreation-Related Spending .. 103
Table 17 Lake Winnipeg Commercial Landings: Weight in MT and Value of Delivered Weight, 2007 – 2010.. 105
Table 18 Manitoba Commercial Landings: Weight (MT), Landed Value and Market Value 2006/2007 106
Table 19 Lake Winnipeg and Manitoba Direct Commercial Fishing Employment: Licensed Fishers, Hired Helpers, and Income 2003 – 2009 108
Table 20 Manitoba Harvesters by Landed Value, 2006/2007 108

Table 21 Manitoba Small Business Statistics, 2008 109
Table 22 Commercial Trout Aquaculture 2007 - 2009.................................... 110
Table 23 Number of Fish stocked in Manitoba, 2005 – 2009.......................... 111
Table 24 Economically Important Fisheries in Lake Winnipeg and Susceptibility to AIS.. 113
Table 25 Aquatic Invasive Species Potential Consequences Summary Table 118

Figures

Figure ES1 Project Area ES-2
Figure ES2 Example Distribution Map.. ES-5
Figure ES3 Hudson Bay Basin and Adjacent Drainage Basins................... ES-6
Figure ES4 Relative Sizes of Aquatic Invasive Species of Concern and Major Life History Categories.. ES-7
Figure 1 Project Area 2
Figure 2 Relative Sizes of Aquatic Invasive Species and Major Life History Categories 8
Figure 3 Hudson Bay Basin and Adjacent Drainage Basins 37
Figure 4 Conceptual Risk Diagram 38
Figure 5 Devils Lake Subbasin 42
Figure 6 Raw Turbidity at the Snake Creek Pumping Plant 64
Figure 7 Monthly Reservoir Inflow and Raw Water Turbidity for the Southwest Pipeline Project (intake at Renner Bay, Lake Sakakawea)....................... 65
Figure 8 Contributing and Non-contributing Drainages 71
Figure 9 Winnipeg CMA.. 95
Figure 10 Lake Winnipeg Community Licensing Areas.................................. 107

Attachments

Attachment 1 Biota Distribution Maps

Acronyms and abbreviations

AIS	Aquatic Invasive Species of concern
BKD	Bacterial kidney disease
°C	Degrees Celsius
CAD	Canadian Dollars
CCV	Channel catfish virus
CMA	Census Metropolitan Area
CRA	Comparative Risk Assessment
DAF	Dissolved air flotation
DFO	Department of Fisheries and Oceans Canada (1979 - 2008); Fisheries and Oceans Canada (2008 – present)
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERM	Enteric Redmouth Disease
FFMC	Canada Freshwater Fish Marketing Corporation
FONSI	Finding of No Significant Impact
GDP	Gross Domestic Product

GDU	Garrison Diversion Unit
HBB	Hudson Bay basin
HUC	USGS hydrological unit code
IHNV	Infectious hematopoietic necrosis virus
IPNV	Infectious Pancreatic Necrosis Virus
ISAV	Infectious salmon anemia virus
ISU	Iowa State University
km	Kilometer
LSWG	Lake Superior Working Group
mm	Millimeters
MnDNR	Minnesota Department of Natural Resources
mJ/cm^2	Millijoules per square centimeter
MR&I	Municipal, rural and industrial
MRB	Missouri River basin
MT	Metric Tons
NA	Not Applicable
NAICS	North American Industry Classification System
NAS	Non-indigenous Aquatic Species
NAWS	Northwest Area Water Supply
nm	Nanometers
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric turbidity units
Reclamation	U.S. Bureau of Reclamation
RRVWSP	Red River Valley Water Supply Project
RV	Recreational Vehicle
SDWA	Safe Water Drinking Act
Service	U.S. Fish and Wildlife Service
spp.	More than one species
Strep	Streptococcal infections
SVCV	Spring viremia of carp virus
TAM	Triactinomyxon actinospore
USCG	U.S. Coast Guard
USD	U.S. Dollars
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	Ultraviolet
UV-C	See UVGI
UVGI	UV germicidal irradiation (also UV-C)
µm	Micrometers
VHSV	Viral hemorrhagic septicemia virus
WAWS	Western Area Water Supply project
NWFHSDb	National Wild Fish Health Survey Database
WHO	World Health Organization
WTP	Water Treatment Plant

Executive Summary

The U.S. Congress authorized the Municipal, Rural, and Industrial Water Supply (MR&I) program through the Garrison Diversion Unit Reformulation Act of 1986. The Northwest Area Water Supply Project (NAWS, the Project) was initiated the following year with the intent to provide a reliable system to convey water to local communities and rural water systems in 10 counties in northwestern North Dakota faced with low quality/quantity surface water and groundwater supplies (Figure ES1).

A Supplemental Environmental Impact Statement (Supplemental EIS) being prepared evaluates four water supply alternatives to meet the estimated future water needs of the Project Area. Two of the alternatives being evaluated would use in-basin (Hudson Bay basin; HBB) source water (groundwater and surface water), and therefore no biota treatment is proposed. The other two alternatives were designed to use the Missouri River as the main water supply source, combined with in-basin water sources. In the Missouri River alternatives, the Project would deliver Missouri River water from Lake Sakakawea through a buried pipeline to Minot, North Dakota within the Souris River basin of the greater HBB. The interbasin water transfer would withdraw 13,600 acre-feet annually to meet 97 percent of the projected water supply demand of the Project Area. The maximum conveyance rate (for meeting peak day demands) would be 26 million gallons per day.

The potential for transfer of invasive species to the HBB associated with a treatment interruption and main transmission pipeline failure has been a concern identified and studied since the Project's inception. This *Transbasin Effects Analysis* builds upon previous studies and is being conducted in support of the Supplemental EIS for the Project. The objective is to provide a thorough evaluation of the risks and consequences of transferring invasive species from both Project and non-Project pathways to the HBB, including Canada. This analysis addresses concerns regarding potential impacts to valuable fisheries (recreational and commercial) in Canada, such as those in Lake Winnipeg in the Province of Manitoba. This report considers the potential risks and consequences from the Project associated with Missouri River alternatives due to the proposed use of water from outside of the HBB. The potential risks and consequences from other potential sources (e.g., non-Project pathways) and drainage basins are also evaluated.

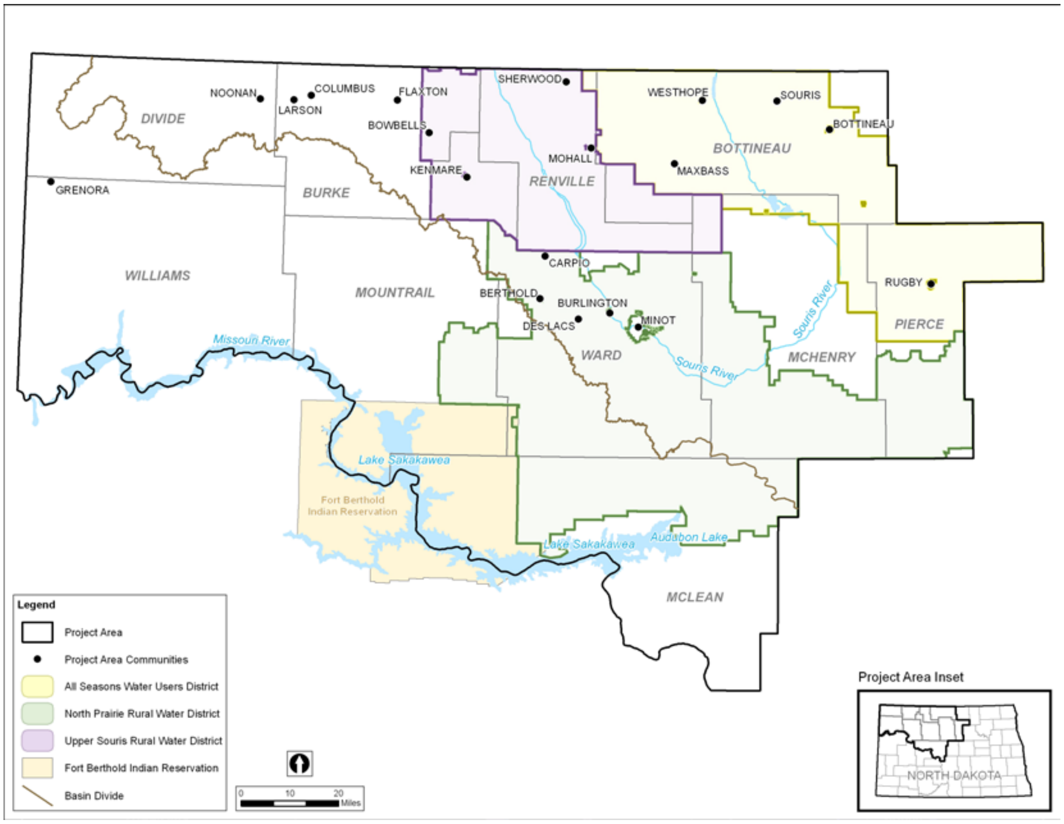


Figure ES1 Project Area

The list of species for the current analysis has been developed and refined over the past ten years. Initially, invasive species were identified during a risk and consequence analysis conducted for the Red River Valley Water Supply Project (RRVWSP; USGS 2005a). That project is similar to NAWS and would also involve a water transfer from the Missouri River basin (MRB) to the HBB to meet municipal, rural, and industrial water needs. The list of species for that project was developed by an interagency technical team that included representatives from the United States Geological Survey (USGS), U.S. Bureau of Reclamation (Reclamation), U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (Service), North Dakota Game and Fish Department, Minnesota Department of Natural Resources (MnDNR), Environment Canada, Canada Department of Fisheries and Oceans (DFO), and Manitoba Conservation. The species evaluated for the RRVWSP (USGS 2005a, b) included both microscopic (viruses, bacteria, protozoa, myxozoa, and cyanobacteria) and macroscopic (vascular plants, mollusks, crustaceans, and fishes) organisms.

As part of the previous EIS for the Project (Reclamation 2008), Reclamation worked collaboratively with the USGS to conduct a biota transfer risk analysis (USGS 2007a). Invasive species for that analysis were the high priority species identified in the risk and consequence analysis conducted for the RRVWSP (USGS 2005a). Because the analysis conducted for the RRVWSP concluded that the risk of transferring macroscopic organisms through a system like the Project was practically zero (USGS 2005a), no further analysis of macroscopic transfer risk was performed during this *Transbasin Effects Analysis*.

In their comments on the Draft EIS for the Project (Reclamation 2008), Manitoba Water Stewardship (2007) identified additional fish pathogens and parasites, which they suggested should have been evaluated. In addition, three mollusk species (juvenile or larval forms) including quagga mussels, zebra mussels, and New Zealand mudsnails were added to the evaluation during the *Transbasin Effects Analysis* Plan of Study process. The species evaluated for the RRVWSP study (USGS 2005a) and the Project Final EIS (USGS 2007a; Reclamation 2008), the additional fish pathogens and parasites identified by Manitoba Water Stewardship (2007), and the three mollusk species are analyzed as aquatic invasive species of concern (herein referred to as AIS) in this *Transbasin Effects Analysis* and are presented in Table ES1. Ultimately, a broad range of life histories are considered to ensure that biota treatment measures considered in the Supplemental EIS would protect against a variety of species including unknown and emerging organisms.

Table ES1 Aquatic Invasive Species of Concern

Taxonomic Group		Latin Name	Common Name
Virus		*Aquabirnavirus* spp.	Infectious pancreatic necrosis virus
		Novirhabdovirus spp.	Infectious hematopoietic necrosis virus
		Novirhabdovirus spp.	Viral hemorrhagic septicemia
		Ictalurid Herpesvirus 1	Channel catfish virus
		Rhabdovirus carpio	Spring viremia of carp virus
		Isavirus spp.	Infectious salmon anemia virus
Bacteria		*Renibacterium salmoninarum*	Bacterial kidney disease
		Aeromonas salmonicida	Furunculosis
		Streptococcus faecalis	Strep
		Flavobacterium columnare	Columnaris disease
		Pseudomonas aeruginosa	NA
		Vibrio cholera	Cholera
		Edwardsiella spp.	NA
		Mycobacterium spp.	e.g., tuberculosis or leprosy
		Yersinia ruckeri	Enteric redmouth disease
		Escherichia coli	E. coli
		Legionella spp.	e.g., Legionnaire's disease
		Salmonella spp.	Salmonella
Animalia	Mollusks	*Dreissena polymorpha*	Zebra mussel
		Dreissena rostriformis bugensis	Quagga mussel
		Potamopyrgus antipodarum	New Zealand mudsnail
	Parasites	*Polypodium hydriforme*	Intracellular parasitic Cnidarian
		Myxobolus cerebralis	Whirling disease
		Actheres pimelodi	Parasitic copepod
		Ergasilus spp.	Parasitic copepod
		Icelanonchohaptor microcotyle	Parasitic flatworm
		Corallotaenia minutia	Parasitic tapeworm
Protozoa		*Giardia lamblia*	Backpacker's diarrhea
		Entamoeba histolytica	NA
		Cryptosporidium parvum	Crypto
		Ichthyophthirius multifiliis	Ich or White spot disease
		Ichthyophonus hoferi	Ichthyophonosis
Fungi		*Branchiomyces* spp.	Branchiomycosis
		Saprolegnia spp.	Saprolegniosis or Winter fungus disease
		Exophiala spp.	Black yeast
		Phoma herbarum	NA

Taxonomic Group	Latin Name	Common Name
Cyanobacteria	*Anabaena flos-aquae*	Blue-green algae
	Microcystis aeruginosa	Blue-green algae
	Aphanizomenon flos-aquae	Blue-green algae

Note: NA – not applicable; no common name

The current study is designed to provide additional perspective on the risks posed by both Project and non-Project biota transfer pathways; risks posed by AIS to potential ecological receptors of concern in the HBB; and potential environmental and economic consequences associated with AIS transfer and establishment in the HBB. The current North American distributions of AIS, especially within the MRB, HBB, and adjacent drainage basins (see example distribution map presented below in Figure ES2) were investigated to support the risk and consequence analyses. Expanded life histories were developed to support the evaluation of effective biota treatment measures for the Project and to assist with the effort to estimate potential impacts in the HBB.

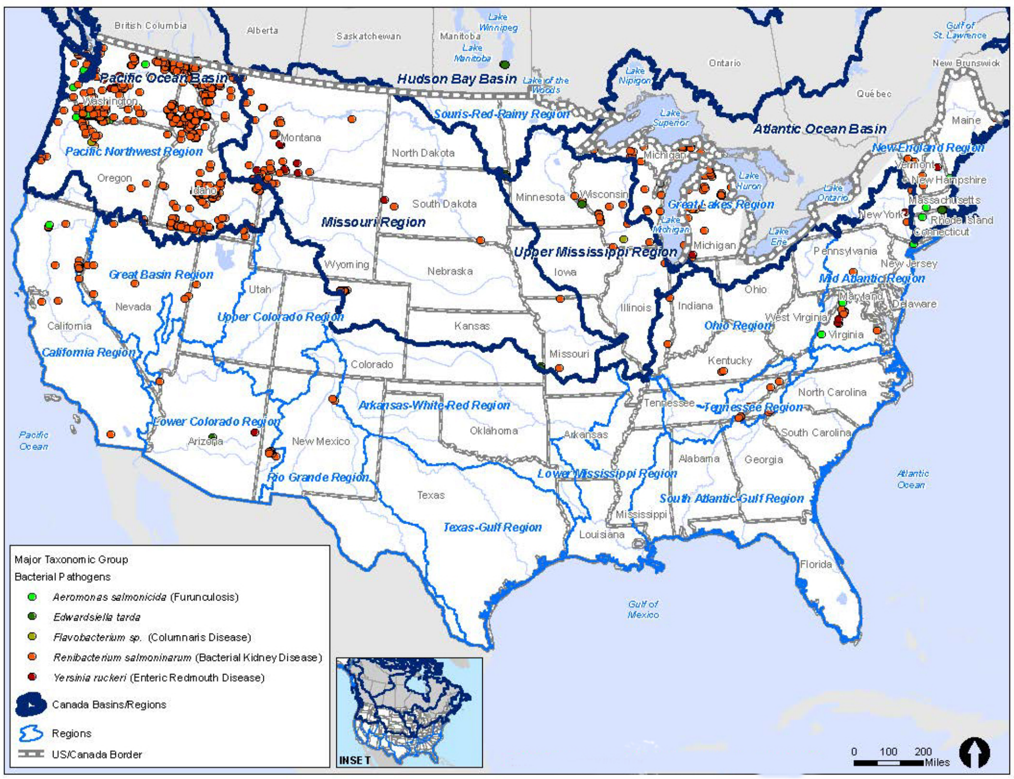


Figure ES2 Example Distribution Map

AIS may be introduced to the HBB via a variety of biota transfer pathways from adjacent and neighboring drainage basins, including the MRB, Atlantic Ocean basin (contains the Great Lakes), Upper Mississippi River basin, and Pacific Ocean basin (contains the Columbia River and tributaries) (Figure ES3). Potential biota transfer pathways linking these drainage basins with the HBB are diverse and include anthropogenic sources (ballast water, bait buckets, intentional introductions, aquaculture, interbasin water transfers, etc.), natural basin-to-basin connections, animal transport mechanisms (birds, fish, mammals), and weather-related phenomena.

Figure ES3 Hudson Bay Basin and Adjacent Drainage Basins

As stated above, four water supply alternatives have been identified for evaluation in the Supplemental EIS, of which two include the use of Missouri River water as the main supply source (Alternatives 3 and 4) and would include biota treatment to further reduce the risk of a Project-related biological invasion from the MRB to the HBB. For both alternatives, Missouri River water would be pre-treated at a Biota water treatment plant (WTP) located on the main transmission line near the town of Max, North Dakota (within the MRB). The pre-treated water would be conveyed via an underground pipeline to the existing Minot WTP where it would be blended with surface water and/or groundwater and treated again to meet Safe Drinking Water Act standards prior to being distributed to water users throughout the Project Area.

To evaluate potential biota treatment options for the two Missouri River-based alternatives, a variety of life history characteristics for each AIS were evaluated, including size (Figure ES4) and susceptibilities to treatment options. Potential biota treatment options being considered for the Project include:

- Chlorine Disinfection
- Chlorine Disinfection and UV Inactivation
- Enhanced Chlorine Disinfection and UV Inactivation
- Conventional Treatment
- Microfiltration

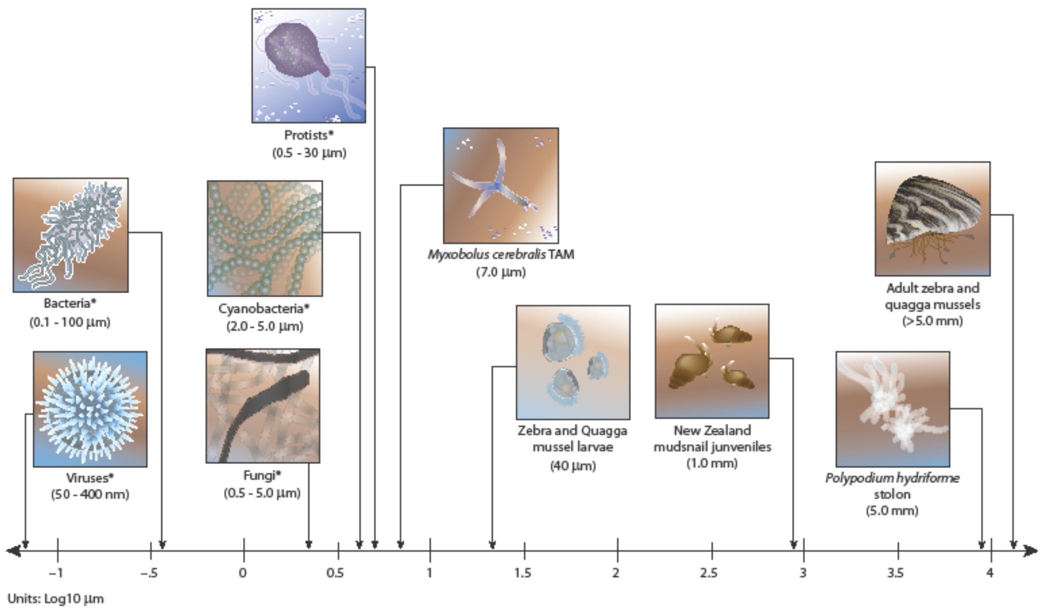


Figure ES4 Relative Sizes of Aquatic Invasive Species of Concern and Major Life History Categories

Based on previous study findings, the Project was designed with a robust set of engineering and operational considerations, and sophisticated failure response systems including alarms, automatic shutdown procedural mechanisms, and motor-operated pipeline isolation valves (USGS 2007a; Reclamation 2008). Reclamation's environmental commitments, engineering controls, and mitigation measures were described in the Final EIS (Reclamation 2008) and are readdressed in the Supplemental EIS.

Most AIS are exceptionally small; therefore thousands of cells (or organisms since the majority of AIS are single-celled microorganisms) could potentially be contained in a single drop of untreated water or waste products from birds, fish, and mammals. Concentrations of AIS vary substantially between different potential sources. For example, fish pathogens are often found in exceptionally low numbers in surface waters (often making detection difficult), whereas piscivorous (fish-eating) birds may potentially contain millions of microorganisms following the consumption of infected fish. The viability of individual transfer pathways also varies, as does the potential for AIS introduction to result in successful establishment. This variability limits the ability to directly compare the volumes of transferred water or materials and assess transfer risk. Volume is, however, less important than other factors considered in the analysis given the Project's configuration, which includes biota treatment designed specifically for AIS and transmission through a buried pipeline.

Nonetheless, the probability of a Project-related transfer and subsequent establishment of AIS in the HBB would be extremely low as such an episode would require a cascade of highly unlikely events, including but not limited to a water treatment interruption coupled with a concomitant pipeline failure within a contributing drainage area, and the release of AIS-containing water. Furthermore, an organism introduced to a subsurface soil (e.g., from a ruptured buried water transmission pipeline that is automatically isolated due to pressure loss) would have to travel through the soil and then through a contributing drainage area (within the HBB) to a surface waterbody in the HBB, find an appropriate host organism, and successfully establish itself in the receiving waters.

Non-Project pathways exhibit risk for transferring AIS from adjacent drainage basins to the HBB. Many of the AIS evaluated in this analysis are widespread and ubiquitous in aquatic systems in North America and may be present and abundant in the HBB, even though they have not been previously reported in the literature or publically-accessible databases. The lack of extensive biological sampling and monitoring (in the HBB and adjacent and neighboring drainage basins) is limiting. However, a comprehensive and accurate characterization of a large drainage system, including the elucidation of microbial distribution and abundance, is infeasible even with the most extensive of biological surveys.

The presence of AIS in mulitple adjacent drainage basins indicates a greater likelihood for non-Project pathways to result in introductions to the HBB. Bait buckets, aquaculture, ballast water discharge, fish stocking, animal transport, and other pathways represent mechanisms with inherent risk for facilitating AIS spread between basins. These pathways are generally not equipped with controls or other measures to prevent AIS transfers and could lead to direct transport of AIS-laden water or material into HBB waterbodies. Conversely, a failure of the Project transmission pipeline could lead to a spill of treated MRB water to subsurface soil. This released water, potentially containing AIS, would subsequently have to move through the subsurface and intercept an HBB waterbody to facilitate an introduction. Transfers to the HBB likely have occurred in the past and are likely to continue in the future via existing transfer pathways from adjacent and neighboring hydrologic basins with or without the Project.

The virulence and invasion potential of pathogens and parasites are unique and variable among species and species strains (Cipriano et al. 2011; Gomez-Casado et al. 2011). Life cycles of some parasites require multiple hosts, which can represent a challenge for the survival of some pathogens, especially in newly encountered environments (Lafferty and Kuris 2002). The impacts of fish pathogens and parasites on individuals and populations are highly dependent on both environmental and biological factors (Hedrick 1998; Lafferty and Kuris 1999). However, there is uncertainty regarding the relationships among abiotic and biotic variables and how they collectively influence infection (Hedrick 1998; Peeler and Feist 2011). Furthermore, an appropriate combination of host abundance and environmental conditions is required to facilitate the establishment and maintenance of a pathogen or parasite in a newly encountered system (Peeler and Taylor 2011).

The potential consequences of an establishment in the HBB are independent of the transfer mechanism and would likely only vary by the species introduced and the location of the introduction. The spread of some pathogens, including viruses, depends upon a suite of criteria including host density, abiotic habitat features, virulence, and other factors (Arkoosh et al. 1998). Transfer of infection among bacteria and viruses is often facilitated by crowding; susceptibility appears to increase with stress, which is why hatchery fish and aquaculture facilities appear most affected by outbreaks.

It should not always be assumed that an aquatic system would necessarily be negatively impacted by introduced AIS; adverse impacts are not always highly deleterious. In some cases, the introduction of novel species may even drive an ecosystem to higher production and diversity (Rosenzweig 2001; Sax and Gaines 2003; Rand and Louda 2012). Although this may sometimes be the case, the *Transbasin Effects Analysis* employs a conservative approach by assuming that AIS establishment would more likely result in negative impacts.

For many of the AIS considered in this analysis, the potential environmental impacts of an introduction (or additional transfer) would likely be minimal due to the lack of potential of some species to cause direct mortality (e.g., channel catfish virus [CCV]); their ubiquity in the environment (*Escherischia coli*, *Pseudomonas aeruginosa*, *Vibrio cholera*, *Mycobacterium* spp.); the general lack of susceptible hosts in the HBB (*Myxobolus cerebralis*); the lack of potential to cause population-level effects (i.e., *P. hydriforme*); and their documented presence in the HBB (*P. hydriforme*, *Renibacterium salmoninarum*, *Flavobacterium* spp., *Edwardsiella* spp., *Yersinia ruckeri*, etc.). In addition, infection may be generally realized under crowded conditions that often occur in habitats such as aquaculture facilities (pathogenic viruses, bacteria, and fungi), and therefore impacts would most likely be limited to these facilities rather than within wild populations.

More substantial impacts are, however, possible from quagga mussels, zebra mussels, and New Zealand mudsnails due to their broad environmental tolerance, rapid spread, and potential to cause metapopulation disruptions (Benson et al. 2012b; Proctor et al. 2007; DFO 2011b). Impacts would likely be site-dependent and highly variable, and therefore largely unpredictable. In the unlikely event that population-level effects occurred from AIS introductions via Project or non-Project pathways, adverse impacts to recreational and commercial fisheries, non-fishing recreational activities, and aquaculture operations, all sectors of the Manitoba economy, are possible. Established and dispersed biota may cause direct and adverse impacts to one or more of these sectors, the effects of which could differ substantially. For commercial and recreational fisheries, AIS could cause population declines and reduced catch rates with subsequent economic effects. For commercial fisheries, the resulting economic impacts could be reduced catch rate valued at then-current market value per unit. For recreational fishing, the resulting reduced catch rate for the affected fish species may be offset partially by increased fishing effort for unaffected species. For non-fishing recreation, the primary impact of AIS (no matter what the source and volume of transferred water/material) would likely be an increase in beach closure days. The resulting economic impacts could be in reduced outlays for recreation-related goods and services, including transportation, food, lodging, and equipment.

Significant uncertainty prevented an explicit prediction and quantification of the environmental and economic impacts in the HBB. The geographic ranges of species can provide some insight into the potential for movement into neighboring areas, including aquatic systems within drainage basins. However, for this study, data and information regarding the distribution of AIS in the HBB and surrounding basins are largely lacking. There have been few systematic surveys for the majority of these aquatic species, with few exceptions including the risk investigation of Devils Lake by Bensley et al. (2011). Most of the available data on presence/absence and distribution in public databases and the literature is largely anecdotal. This general lack of comprehensive species distribution information represents uncertainty in the context of reduced ability to: characterize the risks of individual transfer mechanisms; identify the sources of introduction; and predict the potential associated impacts of AIS establishment.

The technical report describes uncertainties associated with certain components of the analysis including:

- Identification of introduction sources and pathways
- Prediction of both introduction and establishment location
- Relationship of abiotic and biotic factors influencing infection at the individual level and how that could be translated to the population level
- Prediction of impacts caused by AIS establishment
- General lack of documented impacts related to historical invasions
- General lack of systematic surveys for AIS in the HBB and surrounding drainage basins

Even with inherent uncertainty, sufficient information was obtained to support a sound scientific analysis. The lack of existing data, including comprehensive AIS distribution information, is a major source of uncertainty for the current study. However, the available information supported a thorough analysis of the risks of AIS introduction and the potential impacts of establishment in the HBB.

Introduction and Background

The U.S. Congress enacted the Garrison Diversion Unit (GDU) Reformulation Act of 1986, which authorized the Municipal, Rural, and Industrial Water Supply (MR&I) program. In 1987, the Northwest Area Water Supply Project (NAWS; the Project) was initiated with the intent to serve as a reliable system to convey water to local communities and rural water systems in 10 counties in northwestern North Dakota faced with low quality/quantity surface water and groundwater supplies (Figure 1). The Supplemental EIS evaluates four water supply alternatvies to meet the future water needs of the Project Area. Two of the alternatives being evaluated would use in-basin (Hudson Bay basin; HBB) source water (groundwater and surface water), and therefore no biota treatment is proposed. The other two alternatives were designed to use the Missouri River as the main water supply source, combined with in-basin water sources. These two alternatives would transfer Missouri River water stored in the reservoir at Lake Sakakawea through a closed and buried pipeline to Minot, North Dakota within the Souris River basin of the greater Hudson Bay basin (HBB). The interbasin water transfer would withdraw 13,600 acre-feet annually to meet 97 percent of the projected water supply demand of the Project Area. The maximum conveyance rate (for meeting peak day demands) would be 26 million gallons per day.

Prior to passage of the GDU Reformulation Act in 1986, the water supply was planned as part of a large open canal diversion. Canada expressed concern that this interbasin diversion could transfer undesirable fish species, fish larvae, fish eggs, fish diseases, and other biota. With the changes in the Project design to a closed pipeline, the primary concern has shifted to the potential transfer of microorganisms, including fish diseases and parasites.

The objective of this *Transbasin Effects Analysis* is to provide a thorough evaluation of the risks and consequences of transferring invasive species from both Project and non-Project pathways to the HBB, including Canada. This analysis addresses concerns regarding potential impacts to valuable fisheries (recreational and commercial) in Canada, such as those in Lake Winnipeg in the Province of Manitoba. This analysis is being conducted in support of the Supplemental EIS which evaluates the Project alternatives.

The risk posed by the Project as a source for the introduction of invasive species was evaluated in terms of its contribution to the total risk exhibited by a range of possible transfer pathways. The potential environmental and economic consequences resulting from the establishment of invasive species in the receiving basin were also analyzed.

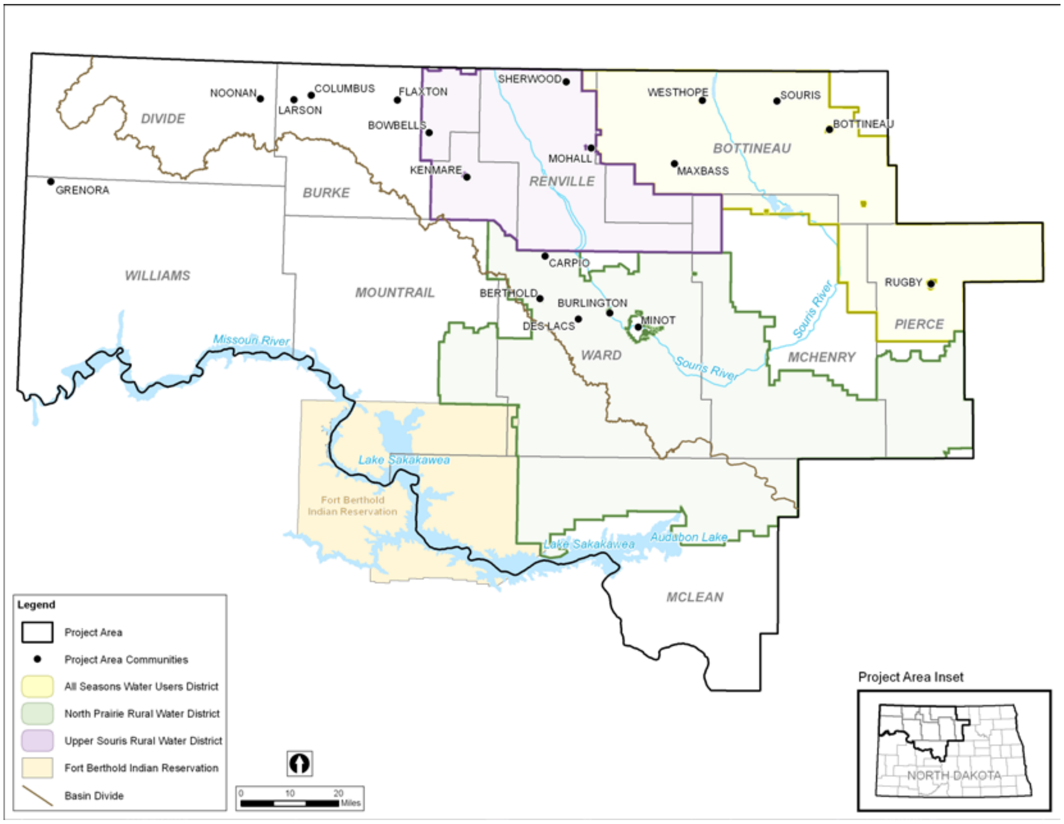


Figure 1 Project Area

Previous Risk Studies

Several previous invasive species risk analyses have been conducted for the Project. These studies were reviewed in preparation for the current analysis and are briefly described below, followed by a focused summary of this *Transbasin Effects Analysis*.

Comparative Risk Analysis

Using mathematical and statistical methods, the U.S. Bureau of Reclamation (Reclamation) and Decision Support (2000) sought to quantitatively analyze and define the low level of risk of biota transfer from the Project as determined by a joint U.S.-Canada Engineering Biology Task Group in 1994. Monte Carlo simulations were conducted in support of uncertainty and sensitivity analysis. The objective of the Comparative Risk Assessment (CRA) was to compare the risk of transferring *Giardia*, viruses, and whirling disease (*Myxobolus cerebralis*) by Project and non-Project pathways, including known, historical, and potential future transfers.

The CRA concluded that the preferred alternative proposed in the NAWS Final Environmental Assessment (Final EA; Houston Engineering et al. 2001), which included pretreatment with either ozone or chlorine/chloramines within the Missouri River basin (MRB) and conveyance to the Minot water treatment plant (WTP) through a buried pipeline would prevent the transfer of macrobiota (e.g., arthropods, amphibians, fish, and associated eggs). The CRA also concluded that the preferred alternative in the Final EA would not contribute significantly to the transfer of microorganisms from the MRB to the HBB. According to CRA estimates, non-Project pathways would transfer 170 times as many *Giardia*-like biota, 100 trillion times as many viruses, and two million times as many whirling disease spore-like organisms as the preferred Project alternative. Birds and hydraulic connections were estimated to pose the greatest risk of biota transfer to the HBB.

The CRA concluded that the likelihood of a pipeline segment failure would be less than one in 10 million per year. If, however, a failure occurred with 100 percent likelihood at the most sensitive locations in the HBB (no time for emergency response to prevent travel of spilled water to the Souris River), the Project would transfer about: one millionth as many *Giardia*-like organisms; one six hundred millionth as many viruses; and one ten millionth as many whirling disease spore-like organisms as non-Project biota transfer pathways.

The CRA provided a quantitative risk assessment of biota transfer but did not speculate on the viability of transferred organisms or the potential environmental and economic consequences of invasive species establishment in the HBB.

TetrES Technical Report

The TetrES Technical Report (2001) was prepared at the request of Manitoba Water Stewardship in support of their litigation against the Project. TetrES reviewed and evaluated the analyses of invasive species transfer and risk potential in the NAWS Final EA and the NAWS Finding of No Significant Impact (FONSI; Reclamation 2001). Pathogen-transfer estimates were recalculated based on an alternative biota concentration assumption (i.e., transfer rate of one organism per gallon of source water).

TetrES concluded that: 1) the 14 commitments outlined in the FONSI intended to collectively provide for a very low risk of biota transfer were inadequate; and 2) the potential consequences of invasive species establishment in the Canadian portion of the HBB were not addressed in the EA, FONSI, or CRA. The authors also claimed that non-Project transfer risk was overestimated while Project-related transfer risk was significantly underestimated. TetrES claimed that the CRA overestimated: the historic risk of hydraulic transfer or organisms from the MRB to the HBB by 100,000; the number of bait-bucket organisms potentially transferred from the MRB to the HBB by 10,000 times; and the risk of biota transfer by boats, trailers, and tackle by at least three orders of magnitude. They estimated that birds would be responsible for two orders of magnitude fewer organism transfers per year. Furthermore, TetrES claimed that the CRA overestimated the contribution of non-Project biota transfers by 100,000 times (TetrES estimated less than 1,000 organisms by non-Project pathways).

It should be noted that the TetrES analysis was based on biota treatment options proposed in the NAWS Final EA and the FONSI, which were subsequently updated in the Final Environmental Impact Statement (EIS) (Reclamation 2008). Furthermore, the updated treatment alternatives are currently being reevaluated in this Supplemental EIS.

Review of the Proposed Pre-Treatment Process

Manitoba Water Stewardship subsequently contracted TetrES again (Earth Tech and TetrES 2005), to evaluate the proposed Project pre-treatment process. The report provided a review of the water quality characteristics and organisms of concern in the MRB that could affect the HBB if transferred via pathways such as pipeline leaks and wastewater disposal.

TetrES concluded that the proposed pre-treatment process would be unlikely to meet the water treatment goals recommended by Earth Tech and TetrES (2005) including protection against disinfection-resistant organisms such as *Myxobolus cerebralis*, *Giardia*, and *Cryptosporidium*. They suggested an enhancement of the pre-treatment process to achieve their recommended water treatment goals that includes:

- A multi-stage barrier approach for the removal of biota of concern
- An improved clarification process that includes dissolved air floatation (DAF)
- Filtration within the MRB
- Disposal of filtration wastes within the MRB.

It should be noted that Earth Tech and TetrES reviewed and provided recommendations on biological treatments originally proposed in the NAWS Final EA over 10 years ago. These treatment options were updated in the Final EIS. In addition, the organisms of concern identified by Earth Tech and TetrES are being addressed in this *Transbasin Effects Analysis* study. Treatment options, including physical and chemical processes that inactivate and remove these organisms are being further evaluated in the Supplemental EIS.

Analysis of Risks of Interbasin Biota Transfers Potentially Linked to System Failures in the Project

As part of the previous NAWS EIS (Reclamation 2008), Reclamation worked collaboratively with the U.S. Geological Society (USGS) to conduct a biota transfer risk analysis (USGS 2007a). The assessment focused on: 1) evaluating the potential for Project control system failures (water treatment/containment); and 2) conducting a preliminary analysis of the risks and consequences of invasive species transfers potentially linked to a system failure. The USGS employed similar approaches and tools as those previously developed for other Reclamation projects including the Red River Valley Water Supply Project (RRVWSP) (see Missouri River and Red River Basin Risk and Consequence Analysis below; USGS 2005a, b, 2006). That project is similar to NAWS, and would also involve a water transfer from the MRB to the HBB to meet municipal, rural, and industrial water needs. The RRVWSP and the Project were characterized with parallel concerns of invasive species establishment and ecosystem shifts resulting from water diversion system failures. Biota identified as high-priority species for the RRVWSP were carried forward into the USGS risk and consequence analysis for the Project (USGS 2007a).

Species were characterized according to their life history attributes that could contribute to or influence invasiveness, and then assigned rank scores in eight categories including:

- Trophic status
- Parental investment (fishes and aquatic invertebrates only)
- Maximum adult size (fishes only)
- Size of native range
- Physiological tolerance
- Distance from nearest native source
- Prior invasion success
- Propagule pressure

Organisms that have not been documented to occur in the HBB were considered species of concern in the analysis. Species with the highest rankings were those that exhibit characteristics that make them particularly invasive and would, therefore likely spread to the HBB with or without the Project.

Biota transfer risk related to treatment and pipeline failure was evaluated with a particular emphasis on risk reduction measures established by Reclamation. To assist with addressing uncertainties related to engineering failures and the biota transfer process, risk reduction measures including water treatment options were designed to control species of particular concern for the Project. Water treatment control system components including chemical and physical methods were described in detail in the report (USGS 2007a). System failure analysis was conducted for major Project infrastructure components including the main transmission pipeline and water treatment systems. Environmental conditions potentially influencing failure (soil corrosivity, earth movements, soil heave, etc.) that could compromise the buried pipeline were also considered.

USGS concluded that conveyance-related risk of biota transfer would be low across all water treatment alternatives (based on pipe materials and built-in pipeline failure prevention measures [e.g., cathodic protection]), but each alternative exhibited unique levels of risk reduction potential, primarily based upon water treatment components. The analysis suggested that the risk of biota transfer through water diversion could be reduced via a control system that incorporates pre-treatment followed by chemical disinfection and physical processes. Microfiltration, ultraviolet (UV), chlorination-chloramination, and treatment to Safe Drinking Water Standards at the Minot WTP was determined to have the lowest risk of treatment failure (USGS 2007a).

Project interbasin water transfer was evaluated as a competitive pathway to a variety of non-Project introduction pathways from the MRB to the HBB. USGS determined that the risk of non-Project pathway transfer is variable and dependent upon several factors, which makes it difficult to quantify risk. Competing pathways were analyzed using a simple model derived from fault-probability trees and failure analyses conducted for the RRVWSP (USGS 2005a and USGS 2006, respectively). Like the Project, the RRVWSP also includes a proposed transfer of treated water from the MRB to the HBB in North Dakota, with similar competing transfer pathways.

The risk of interbasin biota transfer via the Project was characterized as low to very low and dependent upon the implementation of sufficient risk reduction control strategies including a multiple-step water treatment system.

Additional Relevant Risk Studies

Missouri River and Red River Basin Risk and Consequence Analysis

USGS (USGS 2005a, b, 2006) conducted a risk analysis addressing the potential issues of biota transfer associated with interbasin water diversion (RRVWSP) between the MRB and the Red River basin, which lies within the greater HBB. USGS concluded that interbasin transfers of treated water through a controlled and contained conveyance would exhibit the lowest potential risks of biological invasion compared to alternative pathways. USGS also determined that interbasin biota transfers have occurred independent of any engineered transbasin water diversions and that these events will continue to occur as a consequence of existing pathways and extreme events. This study set the stage for the USGS risk and consequence analysis for the Project (USGS 2007a) in terms of analyses employed and representative species to address.

Devils Lake – Red River Basin Qualitative Risk Assessment

The Devils Lake watershed is a 3,810-square mile closed subbasin within the Red River basin in northeast North Dakota. The Devils Lake subbasin's surface runoff drains through many small coulees (streams) and lakes and is ultimately collected by Devils Lake and Stump Lake (which is now part of Devils Lake due to flooding). Water is lost via evaporation, infiltration to underlying groundwater, or natural overflows into the Red River via Stump Lake and the Sheyenne River.

Decades of increasing water levels in Devils Lake and potential flood concerns led to the construction of an engineered outlet in 2005. By 2010, the outlet was operating at near capacity (250 cubic feet per second) throughout most of the open water period from April to November. A coarse mesh screen was included to prevent large organisms including fish from passing through the inlet. A gravel and rock filter was included where the pipeline first transitioned to the open channel of the outlet. These control measures were not designed to inactivate or retain aquatic microorganisms or fish pathogens.

The International Joint Commission requested that a risk assessment be conducted to evaluate the risk of transferring invasive species, including fish pathogens and parasites, through the outlet into the Red River basin and Lake Winnipeg. In 2006, Canadian and U.S. biologists initiated a 3-year study of Devils Lake (Bensley et al. 2011). Seven fish species (1,616 individuals) were collected from Devils Lake, and 21 fish species (4,272 individuals) were collected downstream from the Red River basin including in the Red River Delta and Lake Winnipeg in Canada. A significantly greater number and diversity of pathogens and lesions were detected in fish species within the Red River basin compared to those found in fish species of Devils Lake.

A qualitative risk assessment was conducted for an individual parasite specimen (a gryporhynchid larval tapeworm), three bacterial species (*Pseudomonas mendocina, Yokenella regensburgei*, *Brevundimonas diminuta*), and 17 tissue-specific lesions detected in fish from Devils Lake but not downstream in the Red River basin and Lake Winnipeg. A variety of transfer pathways were identified, including transport by piscivorous birds, release through the outlet's rock and gravel filter, a natural water connection in the northeastern portion of the watershed, movement through Tolna Coulee (the natural outlet of Devils Lake), and both intentional and unintentional transport by humans.

An international group of fish pathologists (four each from the U.S. and Canada) concluded that the risk to downstream fish and fisheries from the Devils Lake microorganisms is low and the likelihood of disease is negligible. The groups' conclusions were supported by the wide distribution of the non-targeted organisms beyond Devils Lake, the life cycles of the organisms that require multiple hosts, and existence of a variety of pathways to transport them to the HBB. Recommendations included monitoring select pathogens and particularly vulnerable fish species in the Red River basin.

Current Risk Study

The current *Transbasin Effects Analysis* builds from previous work conducted for the Project, described above. The USGS (2007a) conducted a risk analysis of interbasin biota transfer in support of the Project EIS (Reclamation 2008), which included a failure analysis for components of long-term operation and maintenance associated with the main transmission pipeline infrastructure and water treatment systems. That analysis indicated that system failures leading to an introduction of invasive biota to the receiving basin would be very unlikely, due to operation and maintenance protocols built into the water supply alternatives, including continuous monitoring of the Biota WTP, and regular maintenance and replacement of system components. The risk of biota transfer associated with an interruption in the Biota WTP, and a simultaneous breach of the transmission pipeline would be further reduced by developing a framework for evaluating water treatment system components and a long-term monitoring plan as part of the operation and maintenance procedures.

USGS (2007a) evaluated potential biota transfer mechanisms (between the MRB and HBB) as competing pathways. This *Transbasin Effects Analysis* evaluates transfer pathways as both competitive and additive, meaning that there is a total risk exhibited by a variety of pathways, part of which may be minimally contributed to by the Project. The current analysis also considers transfer risk from adjacent and neighboring basins in addition to the MRB.

Information from the USGS study (2007a) is considered valuable and contemporary, providing a foundation for the current study. The list of organisms for the Project has been developed and refined over the past ten years. Initially, invasive species were identified as part of a risk and consequence analysis for the RRVWSP (USGS 2005a, b). The list of species for that project was developed by an interagency technical team that included representatives from the USGS, Reclamation, the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (Service), North Dakota Game and Fish Department, Minnesota Department of Natural Resources (MnDNR), Environment Canada, Canada Department of Fisheries and Oceans (DFO), and Manitoba Conservation. The invasive species evaluated for the RRVWSP (USGS 2005a, b) included both microscopic (viruses, bacteria, protozoa, myxozoa, and cyanobacteria) and macroscopic (vascular plants, mollusks, crustaceans, and fishes) organisms.

Invasive species identified for the USGS study in support of the previous Project EIS (USGS 2007a; Reclamation 2008) were the high priority species identified in the risk and consequence analysis conducted for the RRVWSP (USGS 2005a). Because the analysis conducted for the RRVWSP concluded that the risk of transferring macroscopic organisms through a system like the Project was practically zero (USGS 2005a), no further analysis of macroscopic transfer risk was performed during this *Transbasin Effects Analysis*.

In their comments on the Draft EIS for the Project (Reclamation 2008), Manitoba Water Stewardship (2007) identified additional fish pathogens and parasites which they recommended for inclusion in the risk and consequences analysis (Reclamation 2008). In addition, three mollusk species (juvenile and larval forms) including quagga mussels, zebra mussels, and New Zealand mudsnails were added to the evaluation during the *Transbasin Effects Analysis* Plan of Study process. The species evaluated for the RRVWSP (USGS 2005a) and the Project Final EIS (USGS 2007a; Reclamation 2008), the additional fish pathogens and parasites identified by Manitoba Water Stewardship (2007); and the three mollusk species were carried forward as aquatic invasive species of concern (herein referred to as AIS) for this *Transbasin Effects Analysis* (Table 1). Ultimately, a broad range of life histories are evaluated to ensure that biota treatment measures considered in this Supplemental EIS would protect against a variety of species including unknown and emerging organisms.

AIS were evaluated as major life history categories, characterized by a variety of sizes (Figure 2), including:

- Viruses
- Bacteria
- Mollusks
- Animal parasites
- Protozoa
- Fungi
- Cyanobacteria

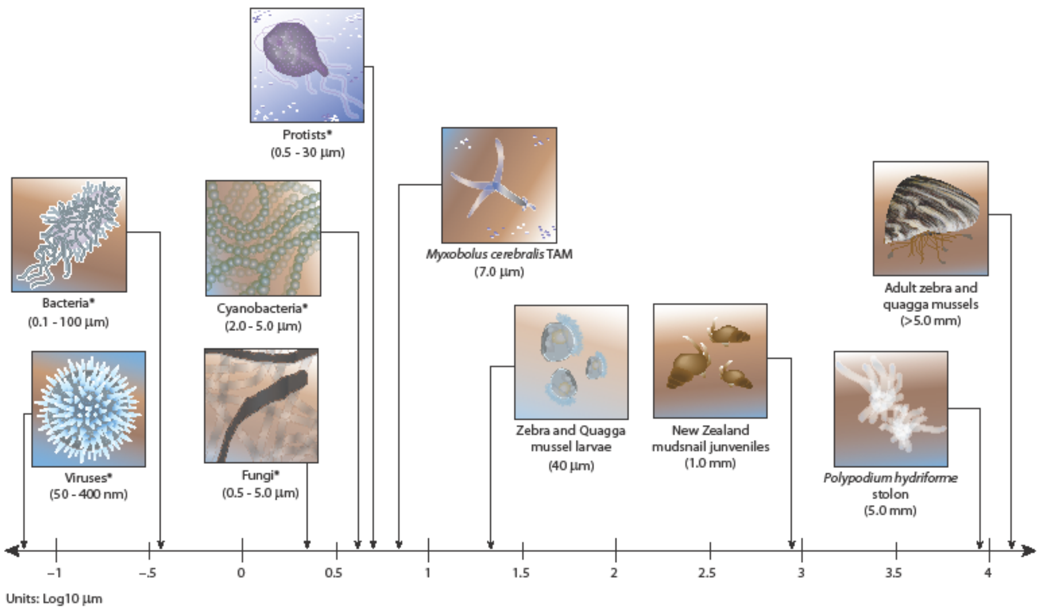


Figure 2 Relative Sizes of Aquatic Invasive Species and Major Life History Categories

Table 1 Aquatic Invasive Species of Concern

Taxonomic Group		Latin Name	Common Name
Virus		*Aquabirnavirus* spp.	Infectious pancreatic necrosis virus
		Novirhabdovirus spp.	Infectious hematopoietic necrosis virus
		Novirhabdovirus spp.	Viral hemorrhagic septicemia
		Ictalurid Herpesvirus 1	Channel catfish virus
		Rhabdovirus carpio	Spring viremia of carp virus
		Isavirus spp.	Infectious salmon anemia virus
Bacteria		*Renibacterium salmoninarum*	Bacterial kidney disease
		Aeromonas salmonicida	Furunculosis
		Streptococcus faecalis	Strep
		Flavobacterium columnare	Columnaris disease
		Pseudomonas aeruginosa	NA
		Vibrio cholera	Cholera
		Edwardsiella spp.	NA
		Mycobacterium spp.	e.g., tuberculosis or leprosy
		Yersinia ruckeri	Enteric redmouth disease
		Escherichia coli	E. coli
		Legionella spp.	e.g., Legionnaire's disease
		Salmonella spp.	Salmonella
Animalia	Mollusks	*Dreissena polymorpha*	Zebra mussel
		Dreissena rostriformis bugensis	Quagga mussel
		Potamopyrgus antipodarum	New Zealand mudsnail
	Parasites	*Polypodium hydriforme*	Intracellular parasitic cnidarian
		Myxobolus cerebralis	Whirling disease
		Actheres pimelodi	Parasitic copepod
		Ergasilus spp.	Parasitic copepod
		Icelanonchohaptor microcotyle	Parasitic flatworm
		Corallotaenia minutia	Parasitic tapeworm
Protozoa		*Giardia lamblia*	Backpacker's diarrhea
		Entamoeba histolytica	NA
		Cryptosporidium parvum	Crypto
		Ichthyophthirius multifiliis	Ich or white spot disease
		Ichthyophonus hoferi	Ichthyophonosis
Fungi		*Branchiomyces* spp.	Branchiomycosis
		Saprolegnia spp.	Saprolegniosis or winter fungus disease
		Exophiala spp.	Black yeast
		Phoma herbarum	NA

Taxonomic Group	Latin Name	Common Name
Cyanobacteria	*Anabaena flos-aquae*	Blue-green algae
	Microcystis aeruginosa	Blue-green algae
	Aphanizomenon flos-aquae	Blue-green algae

Note: NA – not applicable; no common name

Source: Section: Life History Characteristics and Distribution

The current known North American distribution of these AIS (MRB, HBB, and adjacent and neighboring drainage basins) was further documented and is an important component of the current risk analysis. Attachment 1 contains AIS distribution maps that are referenced throughout the technical report. These hydrologic basins are extremely large "open" systems and even the most extensive sampling programs would not deliver finite presence/absence and concentration information for AIS. In addition, the abundance of microorganisms in surface water may fluctuate seasonally and in response to environmental changes. Ultimately, these are not static or constant measurements. Definitive concentrations of AIS in drainage basins adjacent to the HBB are not available, which would be vital input parameters for a quantitative analysis.

Qualitative and quantitative risk assessment methodologies, available information, and data gaps were reviewed, and a qualitative assessment was selected as the best approach to evaluate the risk and consequences of AIS transfer (Section: Uncertainty). The life history descriptions of AIS were also expanded from previous work (USGS 2007a) to assist in evaluating the risk to potential ecological receptors in the HBB if an introduction was realized through any pathway, including Project and non-Project sources. The current analysis also investigated invasions of AIS in other aquatic systems, including documented environmental and economic impacts. Potential consequences associated with AIS establishment in the HBB were evaluated for both the U.S. and Canada, including Lake Winnipeg.

Life History Characteristics and Distribution

This section describes the life history characteristics and geographic distributions of AIS. Life history information was gathered from the published literature. The distribution of select AIS that are tracked and monitored in the U.S. was used to develop Geographic Information System maps (Attachment 1). Recorded observations of AIS came from multiple sources. The Service's National Wild Fish Health Survey Database (NWFHSDb; Service 2011a) regularly updates detection data for a variety of fish pathogens and parasites in the continental U.S. including several, but not all, AIS evaluated in this study. The USGS hosts the Non-indigenous Aquatic Species database (NAS), which monitors observations of North American macrobiotic invaders, including New Zealand mudsnails, quagga mussels, and zebra mussels. Additional observational locations for some AIS were gathered during extensive literature searches.

Viruses

High density populations of fish such as those present in aquaculture settings are particularly vulnerable to viruses, promoting rapid spread of viral diseases. Serious infections lead to mortality in many cases; however, fish that survive a viral challenge may then serve as asymptomatic reservoirs capable of infecting other individuals. This dynamic is particularly important because many commercially valuable fisheries are supplemented with hatchery-raised stock. In most cases, viruses are spread horizontally from fish to fish via contaminated urine, feces, other bodily fluids, or direct contact. Six viruses included within the AIS are described below.

Channel Catfish Virus

Channel catfish virus (CCV), also known as *Ictalurid Herpesvirus* 1, causes a severe hemorrhagic disease frequently associated with high mortality of channel catfish (*Ictalurus punctatus*) fry and fingerlings (Arnizaut and Hanson 2011). Negatively stained enveloped virions have a diameter of 175-200 nanometers (nm; 10^{-6} millimeters [mm]) (Kucuktas and Brady 1999). This species-specific virus can be spread either vertically from brood stock to offspring or horizontally via fish-to-fish contact (Camas 2004). Vertical transmission was demonstrated in a survey of major catfish hatcheries in Mississippi, where latent CCV infection was prevalent. Thompson et al. (2005) found that the latent infections were likely due to vertical transmission, since no virus could be cultured from the fish populations. In addition, fish that survive the initial infection may act as reservoirs, horizontally infecting any new fish they contact.

The virus can generally survive in pond water for two days at approximately 25 degrees Celsius (°C) but may persist up to 28 days at 4°C (Camas 2004). The virus is highly susceptible to UV radiation and drying; therefore leaving netting or other equipment in the sunlight to dry may be an effective way to inactivate the virus. Some evidence suggests that thorough drying of infected ponds may also be sufficient to eliminate the virus (Camas 2004).

Catfish cultivation is the leading aquaculture industry in the U.S. with commercial catfish growing being most important to the southern states including Alabama, Arkansas, Louisiana, and Mississippi (MSU 2011). CCV, first identified in 1971, is currently prevalent in this particular region of the U.S. (Camas 2004). In field studies, population prevalence of CCV increased over time but caused low incidence of mortality (Thompson et al. 2005). In Manitoba, catfish are an important recreational fish, with annual catfish tournaments held each year (Manitoba Catfish Invitational in Selkirk, Manitoba [2012]).

Distribution

Over much of the U.S, many species of wild fish have been tested for CCV. As of December 7, 2011, CCV had not been detected in any of the wild sampled fish (Service 2011a). In addition, CCV was not identified in any fish collected during the recent Devils Lake study (see Section: Devils Lake – Red River Basin Qualitative Risk Assessment) conducted in North Dakota (3,072 fish) and Manitoba (1,641 fish) waters (Bensley et al. 2011).

Infectious Hematopoietic Necrosis Virus

Infectious hematopoietic necrosis virus (IHNV; *Novirhabdovirus* spp.) is a negative sense, single-stranded RNA virus of the Rhabdoviridae family that affects both captive and wild fish (Peñaranda et al. 2009). The virion is bullet-shaped measuring approximately 170 nm long with a diameter of 80 nm (Hill et al. 1975; Gomez-Casado et al. 2011). The symptoms of IHNV infection include abdominal distension, exopthalmia, darkened skin pigment, and pale gills. Fish typically exhibit bouts of lethargy alternating with frenzy, as well as hemorrhaging of the skin around their fins, anus, head, and mouth. The virus is transmitted horizontally (fish-to-fish) through urine, feces, mucus excretions, and contact. Infected fry are generally less symptomatic than adults but have higher rates of mortality. Fish that survive the infection often develop scoliosis (ISU 2007a).

IHNV is known to affect rainbow trout (*Onchorhynchus mykiss*), brown trout (*Salmo trutta*), cutthroat trout (*S. clarki*), Atlantic salmon (*S. salar*), and Pacific salmon including Chinook (*O. tshawytcha*), sockeye/kokanee (*O. nerka*), chum (*O. keta*), masou/yamame (*O. masou*), amago (*O. rhodurus*), and coho (*O. kisutch*) (ISU 2005). The virus is inactivated by many common disinfectants, including iodine-based iodophors and chlorine. IHNV is sensitive to heating and drying and becomes unviable at 60°C (ISU 2007a).

Distribution

IHNV is endemic in fish hatcheries and wild fish in the Pacific Northwest region of North America (ISU 2007a) (Figures A1-1 and A1-5). The virus has been identified in fish from British Columbia, Canada and several U.S. states including Alaska, Washington, Oregon, California, Idaho, Colorado, South Dakota, Minnesota, and West Virginia. The disease has also spread to other parts of the world and has now been noted in Korea, Iran, and parts of China (ISU 2007a). IHNV was not identified in any fish collected during the Devils Lake pathogen study (Bensley et al. 2011). There are no recorded detections of this virus in fish from states in the MRB (Figure A1-3), HBB (Figure A1-2), Great Lakes region (Figure A1-4), or Upper Mississippi River basin (Figure A1-6) in the WFHSDb (Service 2011a).

Infectious Pancreatic Necrosis Virus

Infectious pancreatic necrosis virus (IPNV) is a severe viral disease affecting salmonid fry and post-smolts (Skjesol et al. 2011). The main symptoms are abnormal swimming, distended abdomen, and darkened pigmentation (Marjara et al. 2011). Mortality rates differ depending on the virulence of the strain and environmental factors. Marjara et al. (2011) reported mortality rates of 81 percent for Atlantic salmon exposed to IPNV. The virus is an aquatic member of the *Birnaviridae* family. The virion has a hexagonal profile measuring 57 - 74 nm (Dobos and

Roberts 1983). It primarily replicates in pancreatic and kidney tissues and is spread horizontally (Skjesol et al. 2011) between primary hosts that include Atlantic salmon, lake trout (*Salvelinus namaycush*), arctic char (*Salvelinus alpinus*), and juvenile rainbow trout (Shankar and Yamamoto 1994; Mladineo et al. 2011; Marjara et al. 2011). Fish that survive infection do not exhibit clinical symptoms, but may become carriers of the virus (Marjara et al. 2011).

The virus is extremely sensitive to UV-C, also referred to as UVGI (UV germicidal irradiation), which can achieve a 3-log reduction in freshwater (Øye and Rimstad 2001).

Distribution

IPNV was first identified in a Canadian hatchery in 1940 but eluded isolation in pure culture until 1960 (Wolf et al. 1960). The virus has a global distribution infecting a wide range of salmonid species (Gomez-Casado et al. 2011). IPNV is believed to be indigenous to Cornwall Lake, in Alberta, Canada (Shankar and Yamamoto 1994). Arctic char in the Mackenzie River delta of the Northwest Territories of Canada have also been infected (Souter et al. 1986). Various salmonid species have been infected in Quebec, Newfoundland, New Brunswick, Nova Scotia, and Prince Edward Island (Tarrab et al. 1996) (Figures A1-1 and A1-4). According to the NWFHSDb, IPNV has been detected in five U.S. states: Idaho, New Mexico, South Carolina, Virginia, and Pennsylvania (Service 2011a) (Figure A1-1). IPNV was not detected in North Dakota or Manitoba during the Devils Lake study (Bensley et al. 2011) (Figure A1-2).

Infectious Salmon Anemia Virus

Infectious salmon anemia virus (ISAV), also known as Hemorrhagic Kidney Syndrome and Icterus Syndrome (coho salmon) is an important viral pathogen that causes severe anemia, gross lesions, organ damage, and occasional mortality of marine-farmed Atlantic salmon (MacWilliams et al. 2007). The spherical virus is 100 nm in diameter and generally infects endothelial cells lining the inside of blood vessels and occasionally in white blood cells (Koren and Nylund 1997). The virus is transmitted horizontally fish-to-fish when the virus is shed in the epidermal mucus, urine, feces, or gonadal fluids of infected fish.

Host species include farmed or wild Atlantic salmon, coho salmon, and rainbow trout; however, the full suite of potential reservoir hosts for ISAV is unknown (ISU 2010). In experiments, isolates that are virulent to Atlantic salmon usually infect other fish asymptomatically (ISU 2010). Subclinical infections have been reported in brown trout, rainbow trout, chum salmon, Chinook salmon, coho salmon, Arctic char, and some non-salmonids such as Atlantic herring (*Clupea harengus*), Atlantic cod *(Gadus morhua*), and pollock (*Pollachius virens*) (ISU 2010).

ISAV is inactivated (3-log) in freshwater after exposure to UV-C radiation (Øye and Rimstad 2001). In addition, it can be inactivated by a variety of chemicals including sodium hydroxide, sodium hypochlorite, chloramine-T, chlorine dioxide, iodophors, formic acid, formaldehyde, and potassium peroxymonosulfate (Øye and Rimstad 2001). Because the virus is inactivated at 37-40°C, it is very unlikely that it can survive in an avian or mammalian host (ISU 2010).

Distribution

ISAV was first identified in Norway in 1984 and has since become problematic in Scotland, the Faroe Islands, Chile, New Brunswick (Bay of Fundy), the Northeastern U.S. (Cobscook Bay, Maine) and the Passamaquoddy Bay on the U.S.- Canada border (ISU 2010). The virus has not been documented in either the MRB or HBB (Figures A1-2 and A1-3).

Spring Viremia of Carp Virus

Spring viremia of carp virus (SVCV; *Rhabdovirus carpio*) is primarily a disease of carp species (*Cyprinus* spp.), most frequently causing kidney, spleen, and liver tissue destruction in farmed carp. The resulting hemorrhaging, loss of water-salt balance, and impairment of immune response can lead to mortality (Ahne et al. 2002). The virion measures approximately 80-180 nm long and 60-90 nm wide. It is generally transmitted horizontally in the feces, although evidence suggests the potential for spread by external parasites, such as leeches (Ahne et al. 2002).

SVCV is believed to have existed in European pond cultures since the Middle Ages (5^{th} through 15^{th} century A.D.) when it was referred to by various names including dropsy, rubella, and red contagious disease (Ahne et al. 2002). The virus was isolated from an infected carp individual in 1971 by Fijan et al. (Ahne et al. 2002). Natural infections have been found in several species of European carp (Svetlana et al. 2006; ISU 2007b). An outbreak of SVCV in farmed rainbow trout in Serbia occurred in 2005 (Svetlana et al. 2006). Under experimental conditions, non-carp species including Northern pike (*Esox lucius*), pumpkinseed (*Lepomis gibbosus*), and golden shiners (*Notemigonus crysoleucas*) have also exhibited susceptibility to SVCV (USDA 2003). Fish that survive infection can become asymptomatic reservoir hosts capable of spreading the disease.

The virus can remain viable in water or sediment for several weeks (Ahne et al. 2002), making it important to treat potentially contaminated water. Virus infectivity is destroyed at pH 3 and 12 by lipid solvents and heat (56°C). In addition, the virus is inactivated within 10 minutes with formalin (3%), chlorine (500 parts per million), iodine (0.01%), NaOH (2%), UV (254 nm wavelength), and gamma irradiation (103 krads [a unit of measurement for absorbed radiation dose]) (Ahne et al. 2002).

Distribution

The first incidence of SVCV in the U.S. was recorded in 2002 in koi farms in North Carolina and Virginia (Shivappa et al. 2008) (Figure A1-1). The disease has since been reported in Wisconsin, Illinois, Missouri, West Virginia, Washington, and Ontario, Canada (ISU 2007b). SVCV can have significant economic impacts on pond carp aquaculture (Ahne et al. 2002).

Viral Hemorrhagic Septicemia Virus

Viral hemorrhagic septicemia virus (VHSV; *Novirhabdovirus* spp.) is a serious viral pathogen that can infect a wide variety of freshwater and marine fish species. There are currently 28 species of freshwater fish found in the Great Lakes Basin that are regulated by the VHSV Federal Order (USDA 2009). However, there are far more species of fish that are susceptible to infection with this pathogen. It has been associated with freshwater fish kills in the Great Lakes and is thus of interest to both U.S. and Canadian fisheries. The primary symptoms of VHSV are hemorrhages of the skin and internal organs, which cause fish to become lethargic and swim in circles; organ failure is generally the ultimate cause of mortality (Whelan 2009). The virus is transmitted horizontally in released body fluids, and surviving fish act as asymptomatic reservoirs. The virion is bullet-shaped measuring approximately 170-189 nm in length and 60-70 nm in diameter (Whelan 2009). While there are four major genotypes of VHSV on a worldwide basis, there is currently one genotype of VHSV (VHSV Genotype IVb) found in the Great Lakes region. However, recent studies have found isolates of VHSV with slight genetic variations (Thompson et al. 2011; Cornwell et al. 2012).

A variety of fish species are susceptible to VHSV (MnDNR 2012). Large-scale mortality of black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), common carp, freshwater drum (*Aplodinotus grunniens*), American gizzard shad (*Dorosoma cepedianum*), muskellunge (*Esox masquinongy*), round goby (*Neogobius melanostomus*), white bass (*Morone chrysops*), and yellow perch (*Perca flavescens*) have occurred as a result of VHSV in the Great Lakes region (MnDNR 2011). Species known to act as reservoirs for VHSV include burbot (*Lota lota*), channel catfish, Chinook salmon, lake trout, northern pike, rock bass (*Ambloplites rupestris*), and several species of suckers, shiners, and redhorse (MnDNR 2011). VHSV is inactivated by chlorine, UV (280-200 nm wavelength) irradiation, desiccation, and heat (highly thermolabile) (ISU 2007c).

Distribution

VHSV was first detected in the Great Lakes basin in a sample collected in 2003. While it is not known when the virus entered the Great Lakes ecosystem, it is likely that it was present for several years before that initial isolation. Measurable mortalities began in 2005 with large declines of freshwater drum and round goby (Kipp and Ricciardi 2012). As of 2009, VHSV appeared to be restricted to the Great Lakes region from Wisconsin to New York State (USDA 2009) (Figures A1-1 and A1-4). The virus was first detected in Lake Superior in early 2010. To date, VHSV has not been detected in the MRB or HBB (Bensley et al. 2011; Service 2011a) (Figures A1-2 and A1-3).

Bacteria

Bacterial pathogens spread easily among fish, and their presence in wild populations may go unnoticed until the survival of many hosts becomes impacted. Some bacterial fish diseases can cause low-level sustained mortality resulting in potentially significant losses over time. Such diseases can affect the ecology and economics of fisheries. The bacterial pathogens evaluated as AIS are described below.

Bacterial Kidney Disease

Bacterial kidney disease (BKD) is caused by the small Gram-positive bacterium, *Renibacterium salmoninarum* that measures 1.0-1.5 micrometers (µm; 10^{-3} mm) long by 0.3-1.0 µm wide (Sanders and Fryer 1980). *Renibacterium salmoninarum* primarily affects salmonid fishes, which may exhibit numerous small ulcers or even large, weeping boils on their skin, frequently followed by systemic infection. The kidneys become swollen, lumpy, and riddled with bacterial-laden cysts. The liver and spleen are also susceptible to infection.

Transmission can occur horizontally (Mitchum and Sherman 1981) or vertically (Warren 1983a). BKD has only been detected in salmon, trout, and char of the sub-family Sakoninae (Sanders and Fryer 1980). Some fish, such as lake trout and lake whitefish (*Coregonus clupeaformis*) are slightly susceptible and may act as asymptomatic reservoirs for this bacterium (Mitchum and Sherman 1981; Kipp 2007b).

Renibacterium salmoninarum is difficult to eliminate once it becomes established in a fish population. It is highly sensitive to chemical disinfection such as chlorine (Pascho et al. 1995). Based on the size of this bacterium, particle filtration and microfiltration may be effective means for physical exclusion (Figure 2).

Distribution

BKD was first described in 1930 in Scotland as “Dee disease” during an outbreak in Atlantic salmon (Sanders and Fryer 1980). The disease was concurrently reported in brook trout (*Salveninus fontinalis*) and brown trout from a hatchery in Massachusetts (Belding and Merrill 1935). BKD is now common in hatcheries along the west coast of North America, in the Great Lakes region, and through the Appalachians north into the Canadian Maritime provinces (Figure A1-7). There appears to be a correlation between clinical BKD and locations where soft water conditions are common. In addition, BKD has been reported in Japan, the United Kingdom , Iceland, and several mainland European countries (Warren 1983a). One case of BKD was reported in the NWFHSDb (Service 2011a) from a common carp in Lake Traverse, South Dakota in the HBB (Figure A1-8). Additional infections have been reported for a variety of fish from the MRB in Montana, Wyoming, Colorado, Nebraska, and Missouri (Figure A1-9).

Columnaris Disease

Columnaris disease is a fish infection caused by *Flavobacterium columnare* (Bullock et al. 1986; Durborow et al. 1998b). *Flavobacterium columnare* is a ubiquitous soil and water-borne bacterium and natural epizootics are common worldwide (Schachte 1983a). Cells are long, thin rods measuring approximately 7-10 µm long. Columnaris disease may result in acute or chronic infections in both warmwater and coldwater fishes. All freshwater fish are likely susceptible to the disease under environmental conditions favorable to the bacterium and stressful to the fish. Outbreaks are most common when water temperatures are greater than 15°C and when fish are crowded (Wakabayashi 1991). Ictalurids including channel catfish are scaleless, which may increase their susceptibility to *F. columnare* infection (Service 2012a). For these reasons, columnaris disease is particularly destructive to commercial catfish operations in the Southern United States (Durborow et al. 1998b).

External lesions form on the skin of the infected fish. The bacteria then spreads and destroys the skin, muscle, and gill tissue of the fish, resulting in death in as little as 48 hours following infection (Schachte 1983a; Wakabayashi 1991). Both feral and wild fish can be affected by columnaris disease. In April and May of 2012, columnaris was listed as the primary factor causing mortality of bluegill and other panfish in several lakes and ponds in Wisconsin (WiDNR 2012).

Columnaris is exacerbated by low oxygen, high ammonia, high nitrate, and other stressful environmental conditions common in hatchery populations (Durborow et al. 1998b). However, epizootics of columnaris frequently occur in natural populations and high losses of fish have been observed (Schachte 1983a). Columnaris frequently occurs as a co-infection with other pathogens including *Saprolegnia*, the causative agent of “winter fungus” (Durborow et al. 1998b). Columnaris is generally not problematic in salmon cultures at temperatures as low as 10-15° C (Bullock et al. 1986). In contrast, it is a major problem among cultured warmwater fishes. Treatment of water with ozone significantly reduces the numbers of columnaris cells. Low pH, soft waters, and low organic content reduce the viability of columnaris cells (Bullock et al. 1986). Particle filtration and microfiltration may be effective methods for preventing the transfer of this pathogen in water (Figure 2).

Distribution

The NWFHSDb (Service 2011a) reports *F. columnare* detections in Chinook salmon, mountain whitefish (*Prosopium williamsoni*), and American shad (*Alosa sapidissma*) from several western states (Figures A1-7), and a black crappie (*Pomoxis nigromaculatus*) from Wisconsin (Figure A1-12). An unidentified species of *Flavobacterium* was detected in a fish sample collected from Manitoba waters (Bensley et al. 2011) (Figure A1-8). This occurrence was included in the dataset used to generate biota distribution maps for the technical report (Attachment 1); however, it is unknown whether this particular strain was pathogenic.

In addition, *F. columnare* appears to have been implicated in two catfish mortality events in the HBB, including reports of infected channel catfish in the Red River near Grand Forks, North Dakota in September 2007 (Huberty 2008); and infected black bullhead (*Ameiurus melas*) in the Souris River in March 2012 (Service 2012a; see Section: Environmental Consequences). These events provide evidence for the existence of *F. columnare* in the HBB.

Edwardsiella spp.

The genus *Edwardsiella* encompasses a group of facultatively anaerobic (respire in the presence or absence of molecular oxygen) enteric bacteria within the family Enterobacteriaceae that are sometimes pathogenic to fish and other animals (Bullock and Herman 1985). Documented hosts of the AIS *E. ictaluri* and *E. tarda* include species of catfish, carp, salmon, bullhead, eel, mullet, tilapia, flounder, and several others (Bullock and Herman 1985). *Edwardsiella ictaluri* appears more host-specific than other species within the genus and has been most frequently noted in catfish. Both species are Gram-negative motile rods that are oxidase negative (lack cytochrome oxidase enzyme) and ferment glucose with the production of acid and gas (Bullock and Herman 1985). Cells are approximately 2.0 – 3.0 µm long by 1.0 µm wide (Whitman 2004).

The symptoms of *Edwardsiella* infections include lethargy, abnormal swimming, and gross external lesions, which vary with host species. Some fish may develop small, cutaneous ulcerations while others may develop lesions on internal organs that perforate the body wall (Bullock and Herman 1985). *Edwardsiella ictaluri* is only known to infect fishes; however, *E. tarda* causes disease in some reptiles, birds, and mammals (Clarridge et al. 1980).

Fish that survive infection serve as carriers of bacteria. *Edwardsiella tarda* has been shown to survive 76 days in pond water or mud without the presence of susceptible hosts (Minagawa et al. 1983). Based on the size of this bacterium, particle filtration and microfiltration may be effective methods for removal from water (Figure 2).

Distribution

Edwardsiella tarda is distributed worldwide while *E. ictaluri* is currently confined to specific areas of the U.S. where catfish are reared. *Edwardsiella tarda* has been detected in fish collected from Lake Traverse (South Dakota) and Manitoba waters in the HBB (Bensley et al. 2011) (Figure A1-8). The NWFHSDb (Service 2011a) reports *E. tarda* in fish from Rhode Island, Minnesota (Upper Mississippi River Region), South Dakota (HBB), Kansas (MRB), and Arizona (Figures A1-7 and A1-9).

Enteric Redmouth Disease

Enteric redmouth disease (ERM) is a systemic bacterial infection of fish caused by the pathogenic bacterium, *Yersinia ruckeri*. The symptoms of ERM are lethargy and hemorrhages around the mouth, oral cavity, and base of the fins and rays. Hemorrhagic spots occur on the surface of the liver, pancreas, pyloric caeca (specialized segment of the intestine), swim bladder, and in the lateral musculature (Bullock 1984). The spleen becomes enlarged, the gonads hemorrhage, and the intestines become inflamed, producing thick yellowish or whitish fluids. Hemorrhaging around the ocular cavity commonly leads to rupturing of the eye (Bullock 1984). *Y. ruckeri* is a Gram-negative motile rod-shaped bacterium that measures 1.5-2.0 µm long by approximately 0.5 µm wide (Bullock et al. 1978). The disease is rapidly spread horizontally between fish in water and via physical contact (Warren 1983b). Fish that survive the initial infection can become carriers and continue to spread the disease.

ERM primarily affects salmonids, including rainbow trout, sockeye salmon, Atlantic salmon, Chinook salmon, and brown trout. ERM is often associated with hatcheries; therefore several treatment options exist to treat sick fish or carriers. The *Y. ruckeri* bacterium is susceptible to chlorination and a 3-log inactivation has been achieved with the application of 0.05 parts per million (milligrams per liter) of ozone (Colberg and Lingg 1978). Particle and microfiltration may be effective for preventing the transfer of this pathogen in water (Figure 2).

Distribution

The disease was first reported in Idaho rainbow trout by Rucker in the 1950s (Bullock and Cipriano 1990). Since then, ERM has been reported from hatcheries in Australia, the United Kingdom, mainland Europe, South Africa, and Canada (Bruno 1990). In Canada, the disease has been detected in British Columbia, Saskatchewan, Ontario, and Nova Scotia (Bullock et al. 1978). *Yersinia ruckeri* was identified in a black crappie collected from Lake Traverse, near the border of South Dakota within the HBB (Bensley et al. 2011) (Figure A1-8). The NWFHSDb (Service 2011a) identified *Y. ruckeri* in several non-salmonid species, including channel catfish, rainbow smelt (*Osmerus mordax*), mountain whitefish (*Prosopium williamsoni*), walleye (*Sander vitreus*), blacknose dace (*Rhinichthys atratulus*), and speckled dace (*Rhinichthys osculus*). The current U.S. distribution includes Alaska, Washington, Montana, Idaho, California, Arizona, South Dakota, Minnesota, Wisconsin, Michigan, Virginia, and New York (Figures A1-7, A1-9, A1-10, A1-11, and A1-12).

Furunculosis

Furunculosis is a fish disease cause by *Aeromona salmonicida*, a Gram-negative, bacillus shaped, facultatively anaerobic bacterium (1.0-3.0 µm long by 0.3-1.0 µm wide). Species within the genus are ubiquitous in aquatic environments. The disease manifests as furuncle-like swelling (boils), and later as ulcerative lesions. It affects a wide range of salmonid fishes including lake whitefish, a commercially valuable fish in Manitoba and the Great Lakes (Markwardt et al. 1989; Loch and Faisal 2010; Kipp 2007a). Although almost all salmonids are susceptible to the disease, it has had a much larger impact on native salmonids (e.g., brook trout, Atlantic salmon) in the U.S. than on introduced salmonids (Kipp 2007a). Furunculosis has also been reported in other fish including yellow perch, northern pike, minnows (family Cyprinidae), tiger muskellunge (*E. lucius* x *E. masquinongy* hybrid), and catfish (family Ictaluridae) (Schachte 1983b; Loch and Faisal 2010; Kipp 2007a). The NWFHSDb (Service 2011a) reports infections in burbot and smallmouth bass (*Micropterus dolomieu*), as well as in several salmonids.

Aeromona salmonicida is susceptible to ozone, UV, and slightly susceptible to chlorination (Hoffman 1974). Particle filtration and microfiltration may be effective for preventing the transfer of this pathogen in water (Figure 2). Fish in hatchery settings can be treated with antibacterial agents; however, some strains of the bacteria exhibit antibiotic resistance (Kipp 2007a).

The bacterium is transmitted horizontally to new host fish by infected fish. Fish that survive the initial infection may become reservoirs for the pathogen. In the Great Lakes and neighboring waterways, *A. salmonicida* has had a much larger impact on native salmonids than on stocked salmonids (Kipp 2007a).

Distribution

The pathogenic nature of *A. salmonicida* was first observed in Germany, but its geographic origin remains unknown (Mills et al. 1993). The NWFHSDb (Service 2011a) reports *A. salmonicida* from several western and eastern U.S. states (Figures A1-7, A1-10, and A1-11) none of which are located within the HBB (Figure A1-8) or MRB (Figure A1-9). However, it appears that pathogenic *Aeromonas* spp. were implicated in a catfish mortality event reported in the Red River near Grand Forks, North Dakota in September 2007 (Huberty 2008) (see Section:Environmental Consequences for further details). Therefore, pathogenic species of *Aeromonas* may be present in the HBB.

Streptococcus spp.

Streptococcal infections (Strep) in fish are uncommon, but some species within the genera *Streptococcus*, *Lactococcus*, *Enterococcus*, and *Vagococcus* may cause high mortalities, particularly in aquaculture settings. *Streptococcus* spp. are spherical, Gram-positive bacteria (0.5 – 1.0 µm in diameter; Wood and Holzapfel 1995) that are horizontally transmitted. The symptoms of Strep infections include abnormal swimming, loss of buoyancy, lethargy, pop-eye, corneal opacity, bloating, and hemorrhages around the gills, fins, or vent (Yuasa et al. 2005; Yanong and Francis-Floyd 2006). Fish that survive Strep infection can become asymptomatic reservoirs.

Many species of fish are susceptible to Strep, including salmon, striped mullet (*Mugil cephalus*), shiners (family Cyprinidae), rainbow trout, hardhead catfish (*Arius felis*), Atlantic croaker (*Micropogon undulates*), green sunfish (*Lepomis cyanellus*), bluegills, pinfish (*Lagodon rhomboides*), tilapia (*Oreochromis niloticus*), sturgeon, and striped bass (*Morone saxatilis*) (Bullock 1981; Yanong and Francis-Floyd 2006). Infections are frequently associated with stressful conditions or poor water quality, although some pathogenic strains may be present in unimpaired aquatic systems at low levels. Chlorine, particle filtration, and microfiltration may be effective for preventing the transfer of this pathogen in water (Katz et al. 1994; Figure 2).

Distribution

Outbreaks have been reported in cultured freshwater fish in the U.S., Japan, Thailand, Indonesia, and South Africa. Some outbreaks in saltwater fish have also been recorded in the U.S. and Japan (Bullock 1981). In addition, there have been recorded instances of humans acquiring Strep infections from handling diseased fish (Weinstein et al. 1997).

Escherichia coli

Escherichia coli is a Gram-negative, facultatively anaerobic bacterium. Cells are rod-shaped measuring approximately 1.0 – 3.0 µm long by 0.5 µm wide (Welch 2006). The majority of E. coli strains are harmless, but some cause food poisoning in humans (EPA 1986). Occasional food-borne outbreaks of E. coli result in diarrhea and hospitalization of humans. The route of transmission is fecal-oral, and contaminated water may be a source of infection in humans. Microfiltration or chlorination are effective methods for preventing the transfer of this pathogen in water.

Distribution

These bacteria have a cosmopolitan distribution and less virulent strains are part of a healthy human gut flora (Hudault et al. 2001). Beaches along Lake Winnipeg are routinely monitored for water quality. Densities of E. coli frequently exceeded the Manitoba Water Quality Objective for recreation from 2004 to 2009 (Environment Canada 2011b).

Legionella spp.

Legionellosis is a collection of infections that are caused by *Legionella pneumophila* and other *Legionella* species. *Legionella* spp. are Gram-negative facultative intracellular pathogens that measure 0.3 – 0.9 µm in width and 2.0 - 20 µm in length (Bitar et al. 2004; Diederen 2008). Diseases caused by these bacteria were first reported in the second half of the 20th century. Pontiac Fever is a mild form of the disease while Legionnaire's disease is a potentially fatal form of pneumonia (WHO 2007). The bacteria are acquired via inhalation of contaminated aerosol; particles less than 5µm can be deeply inhaled (Fitzgeorge et al. 1983). *Legionella* infections have been associated with sources located more than three kilometers (1.8 miles) away (Addiss et al. 1989). *Legionella* can be effectively controlled in water systems in several ways, including application of chlorine dioxide, monochloramine, sodium hypochlorite (bleach), or UV (WHO 2007). Particle filtration and microfiltration may also be effective for preventing the transfer of *Legionella* in water due to their particle size.

Distribution

Water is the major natural reservoir for the bacteria, which are ubiquitous in natural and artificial waters worldwide including cooling towers, hotel water systems, homes, ships, factories, respiratory therapy equipment, fountains, misting devices, and spas (WHO 2007). Pneumonia caused by *Legionella* is a common nosocomial (hospital-derived) infection, particularly in immuno-compromised patients.

Mycobacterium spp.

The genus *Mycobacterium* contains a wide range of species, some of which are pathogenic to humans and other animals. Tuberculosis (*M. tuberculosis*), leprosy (*M. leprae*), and Crohn's disease (*M. avium paratuberculosis*) are examples of obligate or opportunistic human pathogens. Cells measure 1.0 – 10.0 µm long by 0.2 - 0.6 µm wide and have a unique and hardy cell wall that is neither Gram-positive or Gram-negative. They are often resistant to chlorine and are found in potable water from municipal sources, in soil, dust, and aerosols (Falkinham 2003; Lee et al. 2010). UV is effective at inactivating *Mycobacterium*, but each species exhibits different susceptibility. *Mycobacterium* spp. are 2-10 times more resistant to UV than E. coli for 3-log inactivation (Lee et al. 2010). UV sensitivity of mycobacteria is species specific. Greater than 3-log of *M. aviaum*, *M. intracellulare*, and *M. lentiflavum* inactivation could be achieved at 20 millijoules per square cm (mJ/cm^2); the highly resistant *M. fortuitum* required a dose greater than 50 mJ/cm^2 for the same log inactivation (Lee et al. 2010). Particle filtration and microfiltration may be effective removing this organism from water (Figure 2).

Distribution

Mycobacteria are ubiquitous in the environment.

Pseudomonas spp.

Pseudomonas aeruginosa is a common bacterium found in soil, water, skin flora, and most man-made environments throughout the world. It is a Gram-negative, aerobic (oxygen- respiring), rod-shaped bacterium that measures 1.5 - 3.0 µm long and 0.5 - 0.8 µm wide (Todar 2011). This opportunistic pathogen may cause symptoms ranging from skin irritation (e.g., hot tub foliculitus) to major infections in the lungs, urinary tract, or kidneys (e.g., endocarditis, septicemia). Infections are particularly harmful for immunocompromised people and transmission can occur via contact or ingestion of contaminated food or drink (Todar 2011).

UV irradiation can achieve 4-log inactivation of *P. fluorescens* (Bullock and Stuckey 1977). In addition, ozone can achieve 3-log inactivation (Colberg and Lingg 1978). Particle filtration and microfiltration may be effective for preventing the transfer of this organism in water (Figure 2).

Distribution

Pseudomonas aeruginosa has a cosmopolitan distribution and is found commonly in nature. In 2005 and 2006, *P. aeruginosa* was isolated from sand and bathing water from West Grand and Gimli beaches on Lake Winnipeg (Environment Canada 2011b).

Salmonella spp.

The genus *Salmonella* contains widely recognized enteric pathogens known to cause illnesses including typhoid fever, paratyphoid fever, and food poisoning (EPA 1986). These bacteria are rod-shaped, Gram-negative, motile, facultative anaerobes measuring 2.0 – 5.0 µm long by 0.7 - 1.5µm wide (Bergey and Holt 2000). Salmonella can infect humans and many species of animals, including livestock, birds, and reptiles (The Merck Veterinary Manual 2011). The transmission route is fecal-oral and contaminated food or water represent sources of infection. Salmonella are susceptible to chlorine disinfection. Particle filtration and microfiltration may be effective methods for physical exclusion (Figure 2).

Distribution

Salmonella are widely distributed in aquatic systems. Stomach illnesses contracted by swimmers in Manitoba are typically caused by Salmonella (Manitoba Water Stewardship 2012a). In 2006 Salmonella were isolated from sand and bathing water at West Grand Beach on Lake Winnipeg (Environment Canada 2011b).

Vibrio (Cholera)

Vibrio cholerae, the agent of Cholera, are Gram-negative, curved-rod-shaped (‘vibrio’ cell morphology) bacteria that infect the human small intestine, producing diarrhea and vomiting. Cholera vibrios are 1.5-2.0 µm long and 0.3-0.5 µm wide (Thaker et al. 2011). The transmission route is generally fecal-oral and contaminated food or water are usually the sources of infection. Some strains of *V. cholerae* are normal inhabitants of surface waters and survive and multiply in association with plankton, never coming in contact with humans (Colwell et al. 1977; Nair et al. 1988; Huq et al. 1983; Islam et al. 1990). Cholera has only been identified in humans, shellfish, and plankton (Sack et al. 2004). Most strains of *V. cholerae* are inactivated by exposure to chlorine; however, a resistant strain was isolated during a Cholera epidemic in South America during the early 1990s (Morris et al. 1996). Chlorine, ozone, and UV are effective treatments for *Vibrio* spp. (Liltved et al. 1995; Bullock and Stuckey 1977).

Distribution

Cholera outbreaks have achieved pandemic status several times in recorded history. *Vibrio cholerae* is endemic to south Asia, Peru, and other warm regions of the globe; however, outbreaks have also occurred in the United Kingdom, U.S., and Russia, where the disease is not endemic (Sack et al. 2004).

Mollusks

Invasive mollusks present unique and formidable challenges for water managers. Exotic snails and mussels can cause ecosystem changes by effectively competing with native species and affecting water quality by filter-feeding (e.g., zebra mussels). In addition, the sheer mass of colonized mussels can clog pipes and impair water flow associated with hydrologic infrastructure. The three mollusk AIS described in this section reproduce rapidly and adapt to novel habitats easily, making them of particular concern in the HBB.

New Zealand Mudsnail

The New Zealand mudsnail (*Potamopyrgus antipodarum*) is a small freshwater snail endemic to New Zealand that has become naturalized and often invasive over much of the globe, including the U.S. and Canada. In New Zealand, female snails reproduce either by sexual pairings or by parthenogenesis (asexual reproduction which occurs without fertilization). All of the mudsnail populations in North America and Europe are strictly clonal and males are very rare (Dybdahl and Kane 2005). Female snails reach maturity at six to nine months of age and bear live, “crawl-away” stage young (Winterbourn 1970). Juvenile mudsnails are minute (less than 1 mm in length) (Levri and Lively 1996). Adult snails range in size from four to six mm in North America, but can grow up to 12 mm within their native range (Benson and Kipp 2011).

The New Zealand mudsnail is tolerant of a wide range of environments and has been documented in almost all western states of the U.S. (not documented in North Dakota), the Great Lakes, and more recently in British Columbia, Canada (Proctor et al. 2007; DFO 2011a). Once established, the mudsnail can typically be found at densities of 10,000 to 40,000 snails per meter (Richards et al. 2004). New Zealand mudsnails frequently threaten ecosystems by outcompeting and overcrowding native mollusk species (Kerans et al. 2005; Riley et al. 2008). In addition, the voracious and indiscriminant feeding can lead to overgrazing of algae populations, thereby changing energy flows; increasing nitrogen availability through excretion; and disturbing food webs (Brown et al. 2008; Arango et al. 2009). In Lake Winnipeg, the native snail *Physa winnipegensis* (Lake Winnipeg physa snail) could potentially be threatened by a mudsnail invasion. The Lake Winnipeg physa snail is currently considered endangered by the Committee on the Status of Endangered Wildlife in Canada (DFO 2012a).

The New Zealand mudsnail is easily spread by passive means. Their tiny size allows them to become trapped and transported passively on vegetation or sediment affixed to waders, fishing tackle, boat trailers, or even birds and other wildlife (Proctor et al. 2007). Additionally, some evidence suggests that the snails are robust enough to survive the digestive processes of predatory fish (Bruce et al. 2009; Bruce and Moffitt 2010). Although survival of the snails in the digestive tract of fish may be as low as five percent (Oplinger et al. 2009), the possible spread of mudsnails via aquaculture should not be overlooked.

Currently, New Zealand mudsnails are managed by minimizing accidental transport of live snails. Disinfecting field gear such as waders and fishing equipment with solutions of benzethonium chloride, chlorine bleach, Commercial Solutions Formula 409®, Cleaner Degreaser Disinfectant, Pine-Sol®, ammonia, or copper sulfate effectively kill snails (Hosea and Finlayson 2005). Snail populations that have become established in a water body are more difficult to eliminate; however, a one percent solution containing the algaecide GreenClean® PRO has been shown to kill 100 percent of mudsnails under laboratory conditions (Garretson 2005). Other molluscicide or biocide applications will also effectively eliminate the snails, but the risk to native mollusks must also be considered. Chemical methods are used to eliminate mudsnails where feasible (e.g., in hatcheries, water canals, hydrologically-isolated ponds, etc.) include Bayluscide (Bayer 73); copper sulfate, and 4-nitro-3-trifluoromethylphenol sodium salt (Francis-Floyd et al. 1997; Proctor et al. 2007). These strategies are most effective in an aquaculture setting where water supply and flow can be manipulated. Physical exclusion can be achieved via particle filtration or microfiltration (Figure 2).

Distribution

According to the NAS, New Zealand mudsnails have not been detected in the HBB or the Upper Mississippi Region (Figures A1-14 and A1-18, respectively). In contrast, 111 documented occurrences have been recorded in the MRB (USGS 2011b) (Figure A1-15). The snails are locally abundant in western U.S. rivers from six disparate invasion foci ranging from Oregon to Montana to Arizona (Figure A1-17) (Dybdahl and Kane 2005) and are less common in the eastern U.S. (Figures A1-13 and A1-16). To date, New Zealand mudsnails have not been detected in North Dakota.

The demonstrated ability of this species to colonize novel water bodies makes it of primary concern for managers. The USGS (2005a) used genetic algorithm for rule-set prediction to project the future distribution of New Zealand mudsnails in North America and the HBB. The analysis suggested that the Red River basin within the HBB contains appropriate physical habitat to support the dispersal and spread of this snail. USGS also noted that the potential projected distribution of this species is not dependent on interbasin water diversion; the experimental outcomes show that many biota transfer pathways could be responsible for introduction to the Red River basin.

Zebra Mussel

Zebra mussels (*Dreissena polymorpha*) are small (less than 50 mm) freshwater bivalves native to Eurasia. They are highly adaptable to a wide range of environments, which they colonize rapidly. Once established, colonies can reach densities of tens of thousands of individuals per meter (Bossenbroek et al. 2007). Zebra mussel larvae (veligers) are planktonic and disperse passively in the water column. The larval stage lasts a few days to a month, after which they settle on the bottom and begin crawling in search of a suitable substratum upon which to settle by means of byssal threads (Benson et al. 2012a). Externally-fertilized zebra mussel gametes (40 - 96 µm) are released into the water column. Several developmental stages occur prior to settling larvae, which measure between 160 and 350 µm (Ackerman et al. 1994).

Zebra mussels can cause significant ecological and economic damage. Ecosystems may be altered as populations of zebra mussels filter large volumes of water, removing phytoplankton thus disrupting food webs. In addition, adult zebra mussels attach to any suitable surface which may include the inner walls of pipes, leading to water works function impairment (Higgins and Vander Zanden 2010; Benson et al. 2012a).

Recent modeling efforts suggest that commercial navigation has been the most important determinant of the early invasion into the Missouri and Mississippi rivers; and that recreational boating has contributed to the continued penetration of the species into smaller water bodies (Mari et al. 2011). Although zebra mussels are susceptible to several control methods including molluscicides, desiccation, thermal extremes, electrical currents, sonic vibrations, UV, ozone, chlorine, peracetic acid, and hypoxia (Benson 2012b), they continue to successfully invade major water bodies in much of North America (Figure A1-25). Particle filtration and microfiltration can provide an effective barrier to transfer of all life stages of the zebra mussel (Figure 2). The product Zequanox®, composed of dead cells of the bacterium *Pseudomonas fluorescens*, was recently approved for the control of zebra mussels within enclosed systems and infrastructures by the EPA (Marrone Bio Innovations 2012).

Distribution

Zebra mussels were introduced to North America in 1988 in the ballast water of a transatlantic vessel. Within 10 years, the mussels had spread throughout the Great Lakes region (Figures A1-25 and A1-28) and are now common throughout the Upper Mississippi region (Figure A1-30). Zebra mussels have not yet invaded the Pacific Ocean basin (Figure A1-29). The NAS database reports 164 records of zebra mussels in the MRB (Figure A1-27) and four records in the HBB (USGS 2011b) (Figure A1-26). In the U.S. portion of the HBB, zebra mussels have been found in the Red River near Wahpeton, North Dakota, and in (Big) Pelican Lake, Minnesota (Manitoba Water Stewardship 2012c).

Quagga Mussel

The quagga mussel (*Dreissena rostriformis bugensis*) is a bivalve indigenous to the Dneiper River drainage of Ukraine and the Ponto-Caspian Sea (Benson et al. 2012b). Adults can grow up to 4 cm in length, which is significantly larger than the otherwise morphologically similar zebra mussel. Like zebra mussels, quagga mussels are thought to have arrived in North America in ship ballast water. The planktonic larvae (veligers) range in size from less than 40 µm to greater than 400 µm, depending on age (Corps 2012).

Quagga mussels are ecologically and economically destructive due to their high capacity to filter phytoplankton and suspended particulates from large volumes of water. This impacts the food web by reducing feeding options for zooplankton (Benson et al. 2012b). Quagga mussels are also well-known bio-fouling organisms due to their production and release of pseudofeces, a filter-feeding byproduct (Claxton et al. 1998). As pseudofeces decompose, dissolved oxygen is depleted increasing water pH in the process.

Quagga mussel control can be achieved with chlorination and potassium permanganate; however, these treatment methods are not ideal for lake-wide application due to the potential toxicity to sensitive native species (Benson et al. 2012b; Grime 1995). While quagga mussels are susceptible to similar control methods as zebra mussels including molluscicides, desiccation, thermal extremes, electrical currents, sonic vibrations, UV, ozone, chlorine, peracetic acid, and hypoxia (Benson et al. 2012b; Craft and Myrick 2011). they do appear to be hardier and more resistant to treatment options compared to zebra mussels. Zequanox® was also recently approved for the control of quagga mussels within enclosed systems and infrastructures by the EPA

(Marrone Bio Innovations 2012). Particle filtration and microfiltration can provide an effective barrier to transfer of all life stages of the quagga mussel (Figure 2).

Distribution

Quagga mussels are well established in the lower Great Lakes (Figure A1-19 and A1-22) and may exhibit a preference for deeper, cooler water as compared to zebra mussels (Mills et al. 1996). Their current range in North America is rapidly expanding and has recently been observed in the Upper Mississippi region (Figure A1-24). Both zebra and quagga mussels are thoroughly established in the Great Lakes. In Lake Erie, there is a gradient of dreissenid distribution. Quagga mussels dominate the western portion of the lake and zebra mussels dominate the eastern portion (Benson et al. 2012b). Quagga mussels appear to be displacing zebra mussels in some areas, including southern Lake Ontario, and may become the dominant dreissenid species (Benson et al. 2012b). The NAS database documents two quagga mussel detections in the MRB; Jumbo Lake and the Tarryall Reservoir, both in Colorado (Figure A1-21); and none in the HBB (Figure A1-20) (USGS 2011b) or the Pacific Ocean basin (USGS 2012) (Figure A1-23).

Parasitic Animals

Internal and external parasites are ubiquitous in nature, many of which are pathogenic to freshwater fishes. Some damage tissues directly while others cause imbalances in bodily functions indirectly harming the health of the host. Six AIS parasites were evaluated in the HBB and are described below.

Whirling Disease

Whirling disease is typically a disease of juvenile salmonids and may impact some coldwater fisheries in North America (Elwell et al. 2009; Alexander 2010). Symptoms of infection include mandibular (lower jaw) malformations, mouth gaping, a “humpback” appearance, sinking, and circular swimming. Susceptibility differs among host fish species (Nehring 2006).

The causative agent of whirling disease, *Myxobolus cerebralis*, was recently reclassified within the kingdom Animalia (Phylum Cnidaria) ending its tenure as a Protist (Ferguson et al. 2008). *Myxobolus cerebralis* has a complicated life cycle which involves free-living and parasitic stages and requires an oligochaete worm intermediate host and a fish final host. Infected fish contain one larval stage of the parasite that is released into the water column once the fish has died and its tissue begins to decay. The parasite transforms into the next larval stage called a myxospore. The myxospore stage measures 7-9 µm long by 7-10 µm wide (Ferguson et al. 2008; Crosier et al. nd) and is highly robust in the environment. Previous authors have suggested that myxospores retain their viability anywhere from three to 30 years (Halliday 1976). Although myxospores may be viable for long periods under some environmental conditions, they are not able to withstand temperatures below -20°C, over 22°C, or desiccation (Hedrick et al. 2008).

Myxospores are ingested with soil by the first-intermediate host, the oligochaete worm *Tubifex tubifex*. There are several lineages of *T. tubifex* in North America. Currently, the lineage 3 *T. tubifex* (3 Tt) is the only lineage that is known to host *M. cerebralis*. Inside *T. tubifex*, *M. cerebralis* myxospores transform into the next larval stage, the triactinomyxon actinospore (TAM). Upon maturation, the TAMs exit the worm host in search of a susceptible fish host. Compared to the myxospores, the waterborne TAM stage of *M. cerebralis* is fragile and relatively short-lived (Gilbert and Granath 2003). TAMs are shaped like a grappling hook and are generally 125 µm long, but their style and processes are only 10 µm wide (Arndt and Wagner 2003). When water temperatures are favorable (<15°C), TAMs have been shown to remain viable from two to 15 days (El-Matbouli et al. 1999; Gilbert and Granath 2003).

The TAM enters the fish via penetration of the epidermis. It then proceeds through a developmental cycle involving multiplication and migration from skin to nerves and then to cartilage (Hedrick et al. 1999). Once the parasites have successfully penetrated the fish host, most migrate to the central nervous system tissue, and then to the associated cartilage (e.g., spinal column, skull). In the cartilage the parasite asexually produces myxospores, which are later released into the water upon the death of the fish (Gilbert and Granath 2003).

Different species of host salmonids appear to have unique susceptibilities to *M. cerebralis.* Rainbow trout, huchen (*Hucho hucho*), and sockeye salmon are highly susceptible. The susceptibility of fish can be measured using several metrics including: 1) quantification of cranial myxospores five or more months post exposure; 2) chronic mortality resulting from exposure to the parasite; and 3) histological techniques to assess the relative amount of tissue and skeletal damage caused by the parasite 80-90 days post-exposure (Nehring 2006). Rainbow trout are considered highly susceptible, because they support the production of the highest number of *M. cerebralis* myxospores per dose of parasite (metric 1). In contrast, if mortality (metric 2) is applied, cutthroat trout suffer significantly higher fatality rates than rainbow trout following continuous exposure to the parasite (Nehring 2006). Bull trout (*Salvelinus confluentus*) and rainbow trout exposed to specific doses of the parasite both have similar prevalence of infection with rainbow trout producing a greater abundance of myxospores (Nehring 2006). Chinook salmon, brook trout, and Atlantic salmon are considered to have intermediate susceptibility. Brown trout and coho salmon appear to have low susceptibility (Markiw 1992; Nehring 2006).

Studies focusing on the susceptibility of other salmonids and non-salmonid species have been largely inconclusive. Some wild mountain whitefish have exhibited clinical signs of the disease (Pierce et al. 2011). Studies of the susceptibilities of lake trout, lake whitefish, and Arctic grayling (*Thymallus thymallus*) have been both contradictory and inconclusive (Hedrick et al. 1999).

Selection for resistance may occur in naturally reproducing populations in *M. cerebralis* endemic areas. Preliminary research on wild rainbow trout of the Madison River, Montana suggests that rainbow trout that survived the severe outbreak in the 1990s may have passed along genetic resistance to their offspring and subsequent generations (Vincent 2006).

There are several pathways for introduction of *M. cerebralis* into novel systems. The myxospores have been documented surviving the digestive tract of birds, and therefore may be deposited by migrating water birds that consume infected fish (Koel et al. 2010). Myxospores are also easily transferred by adherence to mud carried on felt wader boots (Gates et al. 2008). Still living infected fish will transmit the parasites upon death; therefore, hatchery-raised fish must be monitored closely before being stocked to new water bodies. Once the *M. cerebralis* parasite becomes enzootic within a drainage basin, it generally spreads both upstream and downstream quite rapidly. Passive drift of TAMs can spread the parasite downstream and active movement of infected fish can spread the parasite upstream and downstream rapidly, assuming there are no barriers to trout migration.

Whirling disease may induce high mortalities in wild populations once the parasite becomes established in an aquatic system. Sediment habitats supportive of Tubifex worms are important for the establishment of whirling disease (Nehring 2006). Without the worm host, *M. cerebralis* cannot complete its life cycle; therefore, decreasing or eliminating suitable *Tubifex* habitat is an effective method for reducing the spread of whirling disease, particularly where salmonids are purposely housed. Individual *M. cerebralis* can be eliminated using UV radiation, desiccation, or by filtering water using a 20-µm mesh filter (Hedrick et al. 2007, 2008). Studies of the infectivity of myxospores to *Tubifex* worms has demonstrated that myxospores have a selective resistance to various physical and chemical treatments, consistent with conditions that they are likely to encounter in nature including UV and variable temperature (Hedrick et al. 2008). TAMs were inactivated using a wide range of UV doses (40-160 mJ/cm^2) and were uninfective to fish (Hedrick et al. 2007). Particle filtration and microfiltration can also be effective for excluding *M. cerebralis* life stages (Figure 2).

Distribution

Myxobolus cerebralis has been found in the upper MRB including Montana and Wyoming, but has yet to be detected in North Dakota or Canada (Figures A1-31, A1-32, and A1-33). *Myxobolus cerebralis* has also been observed in the Great Lakes (Figure A1-34) and the Pacific Ocean basin (Figure A1-35) but not in the Upper Mississippi region (Figure A1-36). With the exception of rainbow trout, which are continually stocked into Manitoba waters (Manitoba 2012), susceptible fish species, such as salmonids, are absent or less common in the Souris River, a subbasin of the HBB. Several species that are resistant to infection by *M. cerebralis* or that are of unknown susceptibility are present in the HBB, including lake trout, lake whitefish, shortjaw cisco, brown trout, and brook trout (Table 3). Additionally, a large swath of warm, turbid waterways lies between the naturally infected populations of salmonids in western Montana and the stocked populations in the upper MRB in eastern Montana and North Dakota (Holm, pers. comm., 2011).

Polypodium hydriforme

Polypodium hydriforme is a highly specialized, intracellular freshwater cnidarian that infects the eggs of sturgeon and paddlefish (Acipenseriformes). This organism has both a parasitic and a free-living stage, with a life cycle that can last several years (Raikova 2008). *Polypodium. hydriforme* is released from host cells during spawning in freshwater. The initial free-living stage consists of a mass of tentacled individuals called a stolon. The size of the stolon depends on the number of aggregated individuals each measuring approximately 5 mm (Raikova 2008). Eventually, individuals separate from the stolon and asexually reproduce gametophores capable of infecting host fish. Free-living *P. hydriforme* have been observed depositing gametophores onto the skin of prelarval starry sturgeon (*Acipenser stellatus*) (Smolyanov and Raikova 1961). It is currently unknown how the gametophores enter the oocyte of host fish. Free-living *P. hydriforme* could likely be removed from the water column by particle filtration or microfiltration (Figure 2).

Distribution

The current documented range of *P. hydriforme* in North America is fairly wide, including the HBB (Figure A1-32), MRB (Figure A1-33), and Great Lakes (Figure A1-34). *Polypodium hydriforme* has not been observed in the Upper Mississippi region (Figure A1-36) or the Pacific Ocean basin (Figure A1-35). In the U.S., the parasite has been found in the Black and the St.

Clair Rivers, Michigan; the Wabash River, Indiana; the Davis River, California; and the Osage River, Missouri (Hoffman et al. 1974; Suppes and Meyer 1975; Raikova et al. 1979; Raikova 1994; Thomas and Muzzall 2009; Sepúlveda et al. 2010). In Canada, *P. hydriforme* has been identified in the Nelson River, the St. John River, the Saskatchewan River, and the Winnipeg River (Figures A1-31 and A1-32) (Dadswell et al. 1984; Choudhury and Dick 1993; Dick et al. 2001).

Parasitic Copepods

Actheres pimelodi (previously *Achtheres ambloplitis*) and *Ergasilus* spp. are parasitic copepods that attach to the mouth cavity, tongue, or gills of host fish. In North America, *Achtheres pimelodi* is distributed east of the Rocky Mountains, wherever sunfish and catfish are found. Mature copepods range from 1.6 to 3.0 mm in length (USGS 2011a). These copepods are likely susceptible to chemical treatments such as organophosphates, pyrethroids, and hydrogen peroxide, which are currently used to treat infected marine aquaculture fish infected with pathogenic copepods ("sea lice," genus *Lepeophtherius* and *Caligus*; Burridge et al. 2010). Particle filtration or microfiltration would be effective for physically excluding copepods from water (Figure 2).

Distribution

Roberts (1970) identified *E. cyprinaceus* taken from Alabama, North Dakota, and Florida. Many other species of *Ergasilus* were also identified in that study, and a taxonomic key was created to aid in species identification. Other species in the *Ergasilus* genus are distributed throughout North America, including *E. arthrosis, E. caeruleus, E. megaceros,* and *E. nerkae. Ergasilus* spp. tend to be somewhat smaller (adult females are approximately 1 mm long) than *Actheres pimelodi* (USGS 2011a).

Both *Actheres pimelodi* and *Ergasilus* spp. are thought to have widespread distribution throughout North America and are likely a normal component of fish parisitofauna (Dick et al. 2001). A recent survey of fish from Manitoba and North Dakota waters found *A. pimelodi* and *Ergasilus* spp. present in fish from both areas including the Red River basin (Bensley et al. 2011).

Helminths

Icelanonchohaptor microcotyle (class Trematoda; parasitic flatworms) and *Corallotaenia minutia* (class Cestoda; parasitic tapeworms) are two parasitic worms (helminths) evaluated for their potential risk to fish in the HBB. Like other members of the taxonomic subfamily Corallobothriinae, *C. minutia* requires a copepod intermediate host in which to develop before it enters the viscera of its fish host, typically a catfish (Befus and Freeman 1972; Rosas-Valdez et al. 2004). Based on the size of these organisms, particle filtration or microfiltration would be effective methods for physical exclusion (Figure 2).

Distribution

Both species were found in fish from North Dakota collected by Sutherland and Holloway (1979). Dick et al. (2001) noted the presence of *C. minutia* in the Wild Rice River, a tributary of the Red River. *Corallotaenia minutia* was also more recently detected in a black bullhead collected from the La Salle River in Manitoba, also in the HBB (Rosas-Valdez et al. 2004). *Icelanonchohaptor microcotyle* has only been found in the Missouri River (within the MRB)

(Dick et al. 2001), and further information regarding its distribution and life history are absent from the literature.

Protozoa

Of the various life history categories evaluated in this *Transbasin Effects Analysis*, protozoan cysts or oocysts (infective stage) have generally proven to be the most resistant to chemical disinfection. For example, chlorination, a common method of disinfection for a variety of organisms, is ineffective against many protozoans. There are four protozoans described as AIS, which may be pathogenic to humans or fish.

Cryptosporidium parvum

Cryptosporidium parvum is a parasitic protozoan that infects mammalian hosts causing gastrointestinal distress (Cryptosporidiosis). *Cryptosporidium parvum* has a cosmopolitan distribution and is common in aquatic systems (Karanis et al. 2007). Hosts include humans, ruminants, swine, dogs, cats, and various wildlife species. The protozoan is transmitted via a fecal-oral route and can be present in contaminated water or food sources. Children and newborn animals generally exhibit more severe symptoms than adults. Community outbreaks of *C. parvum* have resulted from failure or overloading of public water utilities or contamination of swimming pools (Reclamation 2008). Additionally, surface waters receiving runoff from livestock operations may become contaminated and spread the protozoan.

Oocysts of *C. parvum* are present in the feces of infected hosts. The oocysts are introduced to water bodies when the water is contaminated with feces; hosts become infected after consuming contaminated water. Oocysts are approximately five µm in diameter and have a thick cell wall, which makes them highly resistant to environmental stressors, as well as traditional water treatment technologies such as chlorination (Venczel et al. 1997). They are susceptible to UV disinfection, ozonation, and filtration (Venczel et al. 1997; Morita et al. 2002; Hsu and Yeh 2003).

Distribution

Outbreaks of cryptosporidiosis have occurred in both the MRB and the HBB. An outbreak occurred in 1997 in Shoal Lake, which supplies drinking water to the city of Winnipeg, Manitoba. Shortly thereafter, a new WTP was constructed and brought on-line. Shoal Lake and Deacon Reservoir have been monitored for *C. parvum* since 2001. Samples of drinking water have occasionally tested positive for the pathogen (Winnipeg Water and Waste 2011), at a low incidence rate (e.g., one in 15 samples of Shoal Lake from 2003 and one in 42 samples of Deacon Reservoir in 2001). Additional outbreaks occurred in Dauphin, Manitoba (Macey et al. 2002), and a 2003 treatment failure in Lake Michigan resulted in the largest outbreak of cryptosporidiosis in the U.S., occurring in Milwaukee, Wisconsin (MacKenzie et al. 1994). Outbreaks occasionally occur throughout Canada and the U.S. (Karanis et al. 2007), including North Dakota (Hlavsa et al. 2005).

Giardia lamblia

Giardia lamblia (also known as *G. duodenalis* and *G. intestinalis*) is a common protozoan parasite of the small intestine and represents one of the leading causes of diarrheal disease worldwide in humans and other mammals (Savioli et al. 2006; Geurden et al. 2010). The cysts of this cosmopolitan species are transmitted via consumption of contaminated food or water or through a direct fecal-oral route (Cotton et al. 2011). *Giardia* is frequently found in lakes and streams and commonly affects backpackers who fail to appropriately treat drinking water, earning it the name “backpacker’s diarrhea.” Symptoms of giardiasis vary among individuals and may include nausea, weight loss, bloating, abdominal pain, and diarrhea. Giardiasis commonly occurs throughout the U.S. (Lengerich et al. 1994) and Canada (Isaac-Renton et al. 1994; Odoi et al. 2004). In remote areas, the life cycle may be carried out by a variety of mammalian hosts including beaver, deer, prairie dogs, groundhogs, and free-range livestock, such as cattle and sheep (Appelbee et al. 2005).

The life cycle of *Giardia* is composed of two stages: the active, feeding stage (trophozoite) and the restive stage (cyst). The cysts (11 - 14 µm by 7 - 10 µm) are highly resistant to environmental extremes, surviving in water for several months until ingested by an appropriate host (Wolfe 1992). The cysts are the infectious stage of *Giardia* and transform into trophozoites (excyst) in the first section of the small intestine (duodenum) of their host. Each excysted *Giardia* individual produces two trophozoites (10 - 20 µm by 5 - 15 µm). Trophozoites replicate in the crypts of the small intestine and reproduce by binary fission (cell division; Ortega and Adam 1997). Some trophozoites form cysts (encyst) in the last portion of the small intestine (ileum) and are passed from the body with feces. Infections may result from the ingestion of 10 or fewer cysts (Rendtorff and Holt 1954); therefore, it is very important that cysts be removed from water or rendered non-viable. 2-log (99%) inactivation can be achieved at UV doses of 3 mJ/cm^2 (Mofida et al. 2002). Ozonation of water prior to filtration can destroy Giardia cysts (Hsu and Yeh 2003).

Distribution

Giardia is common throughout North America, including in the MRB and HBB. One notable outbreak in the HBB stemmed from a contaminated pool water slide in Winnipeg, Manitoba in 1986 (Greensmith et al. 1988). Shoal Lake and Deacon Reservoir, which supply water to the city of Winnipeg, are tested annually for *Giardia*, resulting in few positive samples over the years (Winnipeg Water and Waste 2011).

Entamoeba histolytica

Entamoeba histolytica is an obligate parasitic protozoan (requiring a specific host to complete life cycle) of the human digestive tract (Public Health Agency of Canada 2012). Humans can acquire *E. histolytica* from contaminated water. Symptoms include diarrhea, abdominal cramps, liver abscesses, and fever (Public Health Agency of Canada 2012). This amoeba has a cosmopolitan distribution with recorded outbreaks in the U.S., Sweden, Taiwan, Georgia, and Thailand. *Entamoeba histolytica* can also be transmitted through sexual contact, as was the case during a 2007 cluster of infections in Canada (specific locations not provided to maintain patient confidentiality) (Salit et al. 2009). Most outbreaks have been associated with contaminated fresh water, community water, and private tap water (Karanis et al. 2007).

Infected hosts pass *E. histolytica* cysts (10 – 15 µm) into water with their feces, infecting new hosts upon ingestion. Once inside the new host, *E. histolytica* excysts form a trophozoite (12 - 50 µm), which reproduces by binary fission (Public Health Agency of Canada 2012). Some trophozoites will encyst and pass out with feces, continuing the life cycle (Sodeman 1996). Minor infections with *E. histolytica* usually result in diarrhea and abdominal cramping, but more serious infections can lead to amoebic dysentery. In some cases, trophozoites may invade nonintestinal tissue and become established in the liver, brain or lungs, causing serious damage to the host.

Effective water treatment options include the physical removal, or chemical inactivation, of cysts (LeChevallier and Au 2004). Free chlorine tends to be a more effective disinfectant than chloramines for cyst inactivation (Chang and Fair 1941; Chang 1982; Stringer and Kruse 1970). Particle filtration or microfiltration would also be effective for excluding this protozoan in water (Figure 2).

Distribution

While *Entamoeba histolytica* is widely distributed, significant outbreaks have become less common in the U.S. and other industrialized countries (EPA 1999; Salit et al. 2009).

Ichthyophthirius multifiliis

Ichthyophthirius multifiliis is a highly pathogenic ciliate external parasite (ectoparasite) of freshwater fishes. This protozoan causes the common disease “Ich” or “white spot,” which manifests as white nodules on the skin of infected fish. *Ichthyophthirius multifiilis* most commonly infect captive fish kept in stressful conditions or where water quality is poor; however, it can also infect wild fish in natural unpolluted systems. The parasite has been documented in sockeye salmon, rainbow trout, brown trout, channel catfish, blue catfish, and many species of ornamental fish, however, most freshwater fish are susceptible (Durborow et al. 1998a; Traxler et al. 1998; Ogut et al. 2005; Xu et al. 2005; Dickerson 2006; Xu et al. 2011). Infected fish exhibit behaviors such as scratching, rubbing, and flashing, which could subsequently lead to lethargy, loss of appetite, and death. An outbreak of *I. multifiliis* caused high mortalities of pre-spawning adult sockeye salmon in 1994-1995 at various spawning sites in British Columbia (Traxler et al. 1998). This outbreak was the first recorded epizootic of *I. multifiliis* in wild or feral salmonids.

Infected fish shed the adult *I. multifiliis* stage (tomont) into the water where it forms a cyst wall. Cysts are viable for several days in water (Traxler et al. 1998). Within the cyst, the tomont divides several times, forming up to 2,000 small tomites. The tomites are eventually released from the cysts and become theronts. Theronts actively travel seeking a fish host. Once a suitable host has been located, the theronts will penetrate the epithelium (skin) of the fish, burrowing in and feeding on tissues (Durborow et al. 1998a). Once the theront has successfully entered a host, it is called a trophont.

Only the theront (30 – 40 µm) and tomont stages are susceptible to water treatments, as they are the only stages that occur, albeit for a short time, outside their fish hosts. These stages can be treated with a range of methods, including chlorination and the application of chemicals such as chlorine, salt, copper sulfate, potassium permanganate, or formalin (Francis-Floyd and Reed 1997). *Ichthyophthirius multifiliis* tomonts are viable for several days in water but must locate a host once the tomites emerge from the cyst. Without fish hosts present, *I. multifiliis* cannot complete its life cycle and will expire. Particle filtration or microfiltration would be effective for physical exclusion of this organism (Figure 2).

Distribution

This protozoan has a worldwide distribution and is particularly common in aquaculture settings.

Ichthyophonus hoferi

Ichythyophonus hoferi is a fungus-like protozoan that causes chronic, progressive internal infection in wild and cultured fish, amphibians, and crustaceans (Kramer-Schadt et al. 2010). It causes lesions on the heart, liver, spleen, kidneys, skin, and muscles and has proven particularly lethal to herring (Kramer-Schadt et al. 2010). Nodules on internal organs can range from 0.5 to 230 µm, depending on the organ affected (Rahimian 1998). *Ichthyophonus* spores are transmitted when contaminated tissues are ingested (Gavryuseva 2007). Reared salmon (in hatcheries) may become infected when fed diets containing infected herring (Zubchenko and Karaseva 2002). In water, spores can be inactivated using chlorine and iodine solutions (Hershberger et al. 2008). Particle filtration and microfiltration may also be effective methods for physical exclusion of this species (Figure 2).

Distribution

This protozoan has a worldwide distribution. Large epizootics of *Ichthyophonus* have occurred in Europe, the U.S., and Japan (Gavryuseva 2007).

Fungi

Many fungi are opportunistic or primary pathogens of fish. Fungal infections are usually facilitated by stressful environmental conditions such as over-crowding or poor water quality and are therefore, more common in cultured fish than in wild populations. Most fungal infections are caused by water molds of the family Saprolegniaceae. *Saprolegnia*, *Achyla*, and *Branchiomyces* are the most common genera causing disease (Durborow et al. 2003). Four genera of pathogenic fungi are described as AIS.

Saprolegnia spp.

Saprolegnia spp. cause “winter fungus disease” in cultured channel catfish. It is characterized by brownish patches of cottony fungal growth on the skin and gills, dry skin, and sunken eyes (Durborow et al. 2003). The hyphae of *Saprolegnia* are 0.5 – 1.0 mm long (Thoen et al. 2011). The lesions caused by *Saprolegnia* infection are frequently colonized by other pathogens (secondary infections), including protozoan parasites. *Saprolegnia* is ubiquitous in freshwater ecosystems worldwide infecting catfish, salmon, and other fish species (Mayer 2000). Outbreaks in fish farms have been documented in the U.S., Norway, Chile, Japan, and Scotland (Thoen et al. 2011). *Achyla* spp. cause symptoms similar to those of *Saprolegnia* (Srivastava 1980) but remain less understood.

Saprolegnia has a wide range of temperature tolerances and is difficult to prevent and treat, particularly among stressed or crowded fish. Based on their size, *Saprolegnia* spp. can be physically excluded via particle filtration and microfiltration (Figure 2). Some chemical treatments, including formalin, hydrogen peroxide, and sodium chloride are effective against *Saprolegnia* infections (Mayer 2000; Durborow et al. 2003).

Branchiomyces spp.

Branchiomyces spp. cause branchiomycosis, an infection that affects a variety of cultured fish worldwide. The fungus primarily infects the blood vessels of the gills causing hypoxia due to the destruction of gill tissue. The primary agents of branchiomycosis in fish are *B. demigrans* and *B. sanguinis*. The fungi appear to be endemic to Eastern Europe, but have recently become problematic in the U.S. (The Merck Veterinary Manual 2011). *Branchiomyces sanguinis* hyphae (vegetative growth of fungi) collected from catfish gill tissue range from 10 to 35 µm long; spores measure between 8 and 15µm in diameter. The hyphae and spores of *B. demigrans* are slightly larger (Khoo et al. 1998). Based on their size, *Branchiomyces* spp. can be physically excluded via particle filtration and microfiltration (Figure 2). Some chemical treatments including formalin and chlorine are effective against this fungus (Durborow et al. 2003).

Phoma herbarum

Phoma herbarum is a weakly-infectious, facultative pathogen of fish and other animals, including humans (Aveskamp et al. 2008). The fungus is normally a pathogen of plants but may also cause systemic infections in salmonids. *Phoma herbarum* invades the air bladder, digestive tract, and other organs causing hemorrhaging, gut obstruction, peritonitis, and necrosis (Meyers et al. 2008). It invades its fish host when the conidia (fungal spores) or hyphae (5-8 µm in diameter) enter the air bladder via the pneumatic duct connecting the esophagus or by entering with food into the gastrointestinal tract. Pycnidia (fungal fruiting body) contain conidia, which measure 50-200 µm in diameter (Faisal et al. 2007). The disease has been found in cultured fry and fingerling coho, Chinook, and sockeye salmon; lake trout; rainbow trout; and Arctic grayling (Burton et al. 2004; Meyers et al. 2008). While the disease is more common in hatchery settings, natural infections may occur with an often low mortality (less than 5%) (Meyers et al. 2008). Based on their size, *P. herbarum* could be physically excluded via particle filtration and microfiltration (Figure 2).

Distribution

Phoma herbarum has a cosmopolitan distribution and has been isolated from soil, water, foods, and fish tissues (Burton et al. 2004). Outbreaks in fish have been recorded along the West Coast of North America from Oregon to Alaska and in the Great Lakes region (Faisal et al. 2007; Meyers et al. 2008).

Exophiala spp.

The genus *Exophiala* contains pathogenic fungal species, commonly referred to as “black yeasts,” that cause superficial and systemic infections in a wide variety of warm- and cold-blooded animals (Gjessing et al. 2011). The species is an opportunistic pathogen and may be found in soil, sediment, wood, plant material, human hair and nails, and drinking water (Gjessing et al. 2011). The conidia are 3.0-5.0 µm long by 1.5-2.0 µm wide; and hyphae measure 1.8-3.0 µm in diameter (Munchan et al. 2009). There are many species of *Exophiala*, which are distributed worldwide (De Hoog et al. 2006; Li et al. 2011). Infections occur when conidia are inhaled, the fungus is accidentally introduced into an open wound, or introduced mechanically through such things as a catheter in a hospital setting (Nucci et al. 2002).

In fish, *Exophiala* infection causes cranial ulcers, skin ulcers, nodules on skin and internal organs, and erratic swimming. *Exophiala* infection has been documented in cutthroat trout, lake trout, channel catfish, Atlantic salmon, Atlantic cod, smooth dogfish (*Mustelus canis*), King George whiting (*Sillaginodes punctata*), and others (Munchan et al. 2009). Fatal infections have also been documented in humans; symptoms include vomiting, meningeal irritation, fever, lesions on the brain, nodular lesions on the skin, and osteolysis (Li et al. 2011). *Exophiala* infections can also be mild, and a recent nosocomial outbreak has brought the pathogen more attention (Nucci et al. 2002). Strains of *Exophiala* have been isolated from bathroom floors, dialysis fluid, and dental unit waterlines (De Hoog et al. 2006). Free-living amoebae are known to act as reservoirs for *Exophiala* in drinking water and cooling towers (Cateau et al. 2009).

Exophiala spp. are capable of surviving hot, moist conditions, and some strains are resistant to acidic conditions, UV, and even the extreme temperatures and alkalinity of modern dishwashers (Zalar et al. 2011). *Exophiala dermatitidis*, a human pathogen, was isolated from dishwashers in the U.S., South Africa, Japan, Italy, Israel, Germany, Denmark, Brazil, Belgium, Austria, Australia, and Slovenia (Zalar et al. 2011). Based on their size, *Exophiala* spp. can be physically excluded via particle filtration and microfiltration (Figure 2).

Distribution
Exophiala spp. are distributed worldwide. Most species are opportunistic pathogens and present in nature in many habitats.

Cyanobacteria

The cyanobacteria, or "blue-green algae," encompass a group of photosynthetic single-celled organisms common in freshwater (e.g., lakes and ponds) and marine environments. Some species are found in filamentous strands of cells. Eutrophication is often associated with overpopulation, or "blooms," of cyanobacteria. Cyanobacterial cells contain cyanotoxins, a diverse group of natural toxins which can be harmful to terrestrial vertebrates, including humans, pets, and livestock when ingested (WHO 1999).

Anabaena flos-aquae
Anabaena flos-aquae grows in filamentous clumps consisting of multi-cellular chains. Blooms of this species are often referred to as blue-green algae. Each *Anabaena* cell is cylindrical, and the species is notable for the presence of large, specialized nitrogen-fixing (convert atmospheric nitrogen to ammonia) cells called heterocysts. *Anabaena* cells vary in size depending upon their location within the chain (4 – 50 µm). Anatoxins or microcystins may be released from ruptured or deteriorated *Anabaena* cells. Anatoxins are potent neurotoxins that act by either inhibiting or mimicking the acetocholine system, a key component of proper nervous system function. Microcystins are highly hepatotoxic (toxic to the liver) and actively inhibit phosphatases, enzymes important for many signal transduction pathways, and therefore play a crucial role in many biological processes (WHO 1999).

Over 100 *Anabaena* species have been found to exist in North America, including benthic and planktonic varieties (UC Santa Cruz 2011). The most common anatoxin is anatoxin-a, which has been reported in Canada (Devlin et al. 1977), the U.S. (Stevens and Krieger 1991), Scotland (Bumke-Vogt et al. 1999), and Kenya (Ballot et al. 2005). Acute effects of anatoxin-a toxicity include rapid paralysis, loss of coordination, twitching, respiratory failure, convulsions, and death (Osswald et al. 2007).

Aphanizomenon flos-aquae
Aphanizomenon flos-aquae is another filamentous cyanobacterium capable of releasing cyanotoxins. The filaments may form colonies resembling grass clippings or float freely in water. Individual cells are cylindrical measuring 5 – 7 µm in length, although size may vary depending on the type of cell and its position in the chain. *Aphanizomenon* are often found in eutrophic lakes, reservoirs, agricultural ponds, and fish ponds (UC Santa Cruz 2011). Toxic

blooms of *Aphanizomenon* are potentially harmful to wildlife, pets, livestock, and humans that may accidentally ingest the cyanotoxins (primarily anatoxins) in water (WHO 1999).

Microcystis aeruginosa

Microcystis aeruginosa is a colonial cyanobacterium that floats near the surface in fresh or low-salinity waters. Colonies are encased in a fine, colorless mucus. Cells are 2 -3 µm in size and primarily produce highly hepatotoxic microcystins (UC Santa Cruz 2011; WHO 1999).

Cyanobacteria blooms can generally be prevented by limiting the potential for eutrophication. Cells can be physically removed using barriers and filters. Chlorination has been shown to damage cell membranes resulting in the release of intracellular toxins, potassium, and chlorophyll (Ma et al. 2012). The release and degradation of the toxins during chlorination is dependent on pH, chlorine dose, and contact time (Ma et al. 2012). Toxins in water are much more difficult to remove than whole cells. Slow-sand filtration may cause some biosorption and biotransformation of toxins and is also effective for the removal of whole cells. Based on their size, these cyanobacterial species could be physically removed via particle filtration and microfiltration (Figure 2). Extracellular toxins are most effectively removed from water by ozonation; however, total dissolved organic carbon must be considered to achieve effective removal, making ozonation a more complicated treatment option (WHO 1999).

Distribution

These cyanobacterial species have a cosmopolitan distribution and are ubiquitous in aquatic systems. The three cyanobacterial species described are widespread in North America and their presence has been documented in the HBB, including Lake Winnipeg (Zhang and Rao 2012).

Biota Transfer

Microbial AIS may be introduced to the HBB via a variety of biota transfer pathways from adjacent or neighboring drainage basins. The potential sources of AIS introduction are not limited to the MRB. Other drainage basins bordering the HBB including the Atlantic Ocean basin (contains the Great Lakes and associated watersheds), the Pacific Ocean basin (contains the Columbia River and its watersheds), and the Upper Mississippi River basin also represent potential sources of AIS (Figure 3). This section provides: 1) a conceptual risk model that describes the relationships of AIS sources and transfer pathways; 2) descriptions of potential biota transfer pathways; 3) a summary regarding microorganism fate and transport processes in the environment; and 4) a list of potential ecological receptors that may be at risk for adverse effects from AIS introduction in the receiving basin.

Conceptual Risk Model

Conceptual models generally reveal an initial understanding of the links between sources and effects in systems being evaluated during risk assessments (Suter 2007). A conceptual model figure is a powerful tool for investigating and communicating risk by providing a visual representation of predicted relationships between environmental stressors and potentially exposed ecological receptors (EPA 1998). A conceptual risk diagram (Figure 4) was developed for this *Transbasin Effects Analysis* that graphically presents the linkages between potential AIS sources, candidate transfer pathways, and potentially vulnerable ecological receptors in the HBB.

Primary AIS sources include other hydrologic basins and are linked to potential pathways (e.g., interbasin outlets/diversions, direct discharges, animal transport, and weather-related phenomena) for transfer to environmental media in the receiving basin. Primary and secondary pathways have the potential to transfer AIS to the HBB. Organisms could be introduced via primary pathways (e.g., bait buckets, live wells, aquaculture, and migrating animals) directly to surface water or initially introduced to a primary medium (e.g., surface or subsurface soil) and subsequently transferred to the receiving waters via secondary pathways such as runoff or infiltration. Potential routes of exposure to ecological receptors including ingestion, contact, and interspecies competition are also presented in Figure 4. Biota transfer pathways and their contribution to risk of AIS introduction are described below.

Figure 3 Hudson Bay Basin and Adjacent Drainage Basins

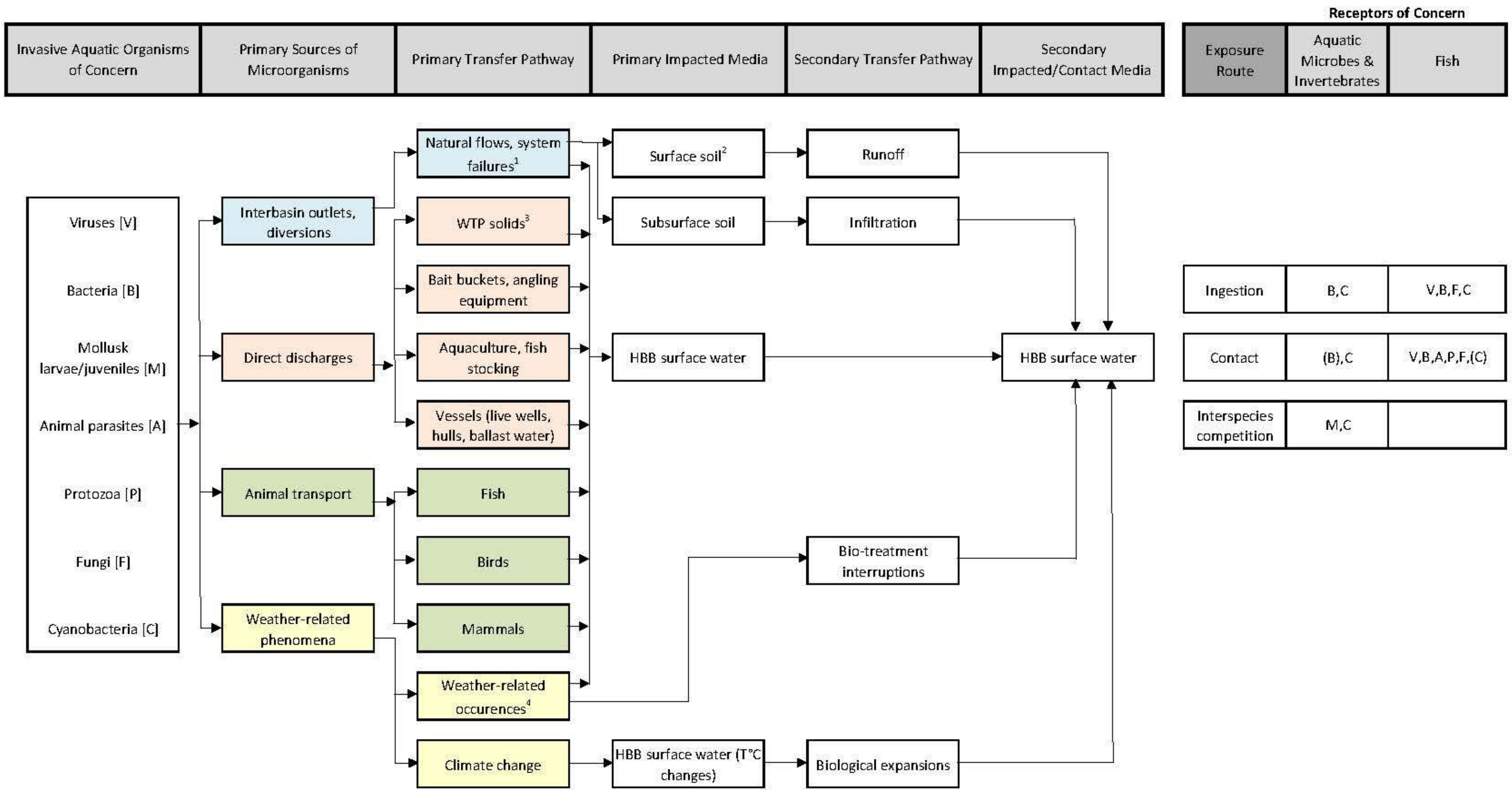


Figure 4 Conceptual Risk Diagram

Notes:

Sources of organisms could include neighboring hydrologic basins.

[1] failures associated with biota treatment, pipelines, outlet flows with limited or no biological transfer control mechanisms

[2] Surface soils would not be contacted/impacted by a Project release. The entire pipeline from Lake Sakakawea to Minot is buried below the soil surface (beneath the frost zone).

[3] e.g., improper sludge disposal from WTP

[4] Examples include floods, tornadoes that could temporarily link basins

(B) - inconclusive whether bacteria cause adverse effects to receptor via this exposure route

(C) - inconclusive whether cyanobacteria (toxins) cause adverse effects to receptor via this exposure route

Biota Transfer Pathways

There are numerous potential non-Project AIS sources and pathways represented by a variety of natural mechanisms such as basin-basin connections (e.g., outlet overflows as a result of flooding) and weather events; biotic mechanisms such as birds, mammals, and fish; and abiotic mechanisms including engineered interbasin water diversions and ballast water discharge. Transfer pathways have uniquely inherent levels of AIS introduction risk potential and the sum of their individual contributions represents a cumulative and total risk. The risk contributions associated with each pathway are dynamic and change over time and space and should be considered as both: additive, meaning to contribute collectively to a “total” risk; and competitive, even though there is a total transfer risk, one of the pathways will be the first to transfer AIS at a concentration sufficient to result in establishment in the HBB. Ultimately, there is a level of risk associated with biota transfer to the HBB, in the presence or absence of the Project. The major pathway categories that represent potential links between neighboring and adjacent drainage basins and the HBB are described below with an emphasis on those that have been well characterized in the literature.

Interbasin Connections and Water Diversions

Interbasin water diversions have the potential to transport invasive species across drainage basins. Most states, including North Dakota, have laws and regulations prohibiting the transport or introduction of known invasives. However, there are no current or proposed standards for treatment of interbasin water transfers to control invasive species. The EPA has published a final rule in the *Federal Register* (73 FR 33694), which generally exempts interbasin water transfers from regulations under the Nation Pollutant Discharge Elimination System permitting program.

Conveyance risk is unique for different water diversion projects. Large, untreated water diversions with significantly higher flow rates are expected to exhibit greater biota transfer probabilities than those like the Project, which are lower volume and designed and equipped with biota treatment facilities and sophisticated control and response systems (Section: Risk Assessment). There are numerous interbasin water diversions constructed in the U.S. and Canada, many of which are located in the region of the Project. In addition to these constructed interbasin diversions, basin divides may naturally overflow during flood conditions (Davies et al. 1992). Regional interbasin water diversions with the potential to pose AIS transfer risk to the HBB are described below.

Red River Valley Water Supply Project

A Final EIS was issued for the RRVWSP on December 21, 2007 (Reclamation 2007). To date, the project has not received congressional authorization, and a Record of Decision has not been issued. The proposed project would develop and deliver bulk water supply to meet both short- and long-term future water needs of the Red River Valley in North Dakota and Minnesota through 2050. The RRVWSP would include construction of features and facilities needed to develop and deliver sufficient water to existing infrastructure for distribution to MR&I water uses in the service area.

The North Dakota In-Basin and Red River Basin alternatives would not include biota water treatment, since water would not be transferred between basins. The remaining alternatives, GDU Import to Sheyenne River, GDU Import Pipeline, and Missouri River Import to Red River

Valley) would include construction of a Biota WTP. Each of the Missouri River import alternatives would use an in-filter DAF or a comparable, cost effective process to reduce the risk of invasive species transfer from the MRB to the HBB (Reclamation 2007).

The GDU Import to Sheyenne River and GDU Import Pipeline alternatives would include construction of a Biota WTP adjacent to the McClusky Canal, three miles north of McClusky, North Dakota. The Missouri River Import to Red River Valley alternative would have a Biota WTP located beside the Missouri River south of Bismarck, North Dakota. Basic treatment would include coagulation, flocculation, sedimentation, UV disinfection, chlorination, and chloramines. Microfiltration would use coagulation, pin-floc, microfiltration, UV disinfection, chlorination, and chloramines. The in-filter DAF option includes DAF, media filtration, UV disinfection, chlorination, and chloramines (Reclamation 2007).

Western Area Water Supply Project (Northwest Region of North Dakota)

The Western Area Water Supply project (WAWS) is a water project that would utilize Missouri River water to meet the MR&I water needs for all or parts of McKenzie, Williams, Divide, Burke, and Mountrail Counties (including the cities of Williston, Watford City, Ray, Tioga, Stanley, Wildrose, and Crosby). Construction of Phase I and most of Phase II began in 2011; completion of all three phases is estimated to occur by the end of 2014 (WAWS 2011). WAWS would help meet the demand for water needed to supply the oil industry and supply drinking water for estimated 48,000 (peak population) expected in 2032 (WAWS 2011).

WAWS is designed to meet the domestic water needs in that region and would utilize its unused capacity during the growth period to sell water to the oil industry, which is projected to pay for 80 percent of the initial project cost (WAWS 2011). In addition, WAWS would maximize infrastructure already in place and combine efforts of many entities for the good of the region.

WAWS would pump Missouri River water throughout the service area via a buried pipeline network. Part of the WAWS service area lies within the HBB. Project water would be treated to meet Safe Drinking Water Act standards at the Williston WTP. Pipeline construction would begin on the Missouri River southwest of Williston and extend in all directions, serving Ray, Wildrose and Crosby to the northeast, Alexander and Watford City to the south, and if additional funding is available reaching Grenora to the northwest.

Saint Mary's and Milk River Diversion (Montana) – Milk River Project

The Milk River Project in north-central Montana furnishes water for the irrigation of approximately 48,562 hectares (120,000 acres) of land. The water supply for the Milk River Project originates in the St. Mary River watershed, within the HBB, in Glacier National Park in northwest Montana. Runoff is stored in Lake Sherburne for release into the St. Mary River. Untreated water is then diverted into the 34-km (29-mile) long St. Mary Canal and discharged into the north fork of the Milk River within the MRB. The discharged water continues along the Milk River, which originates in the eastern slopes of Montana's Rocky Mountains and flows in a northeast direction into Canada travelling more than 322 km (200 miles) through Alberta before re-entering the U.S. Water then flows into Fresno Reservoir where it is stored until needed for irrigation. There are no measures designed to control the transfer of potentially invasive species between basins; however, drop structures in the diversion canal provide a physical barrier to upstream interbasin macrobiota (e.g., fish) transfer from the MRB to the HBB (Reclamation 1998).

Project features include Lake Sherburne; Nelson and Fresno Storage Dams; Dodson, Vandalia, St. Mary, Paradise, and Swift Current Diversion Dams; Dodson Pumping Plant; 322 km (200 miles) of canals; 352 km (219 miles) of laterals; and 474 km (295 miles) of drains. A water supply is furnished to project lands, which are divided into the Chinook, Malta, and Glasgow Divisions, and the Dodson Pumping Unit. The lands extend about 266 km (165 miles) along the river from near Havre to a point 9.7 km (6 miles) below Nashua, Montana (Reclamation 2011).

The primary benefit derived from the Milk River Project is a reliable irrigation water supply along the lower Milk River. Along with irrigation benefits, the Milk River Project provides many recreational (swimming, boating, and fishing) benefits. In addition, Fresno Reservoir provides limited flood protection along the lower reaches of the Milk River above Fort Peck Reservoir.

Lake Traverse and Big Stone Lake (Minnesota-South Dakota Border)

The Minnesota River originates in Big Stone Lake on the Minnesota-South Dakota border. The Little Minnesota River enters Minnesota at the town of Browns Valley and enters Big Stone Lake, which is drained by the Minnesota River. The area between Lake Traverse and Big Stone Lake is known as the Traverse Gap. There is a natural interbasin flow between Little Minnesota River in the Mississippi River basin and Lake Traverse in the HBB. Flow occurs from the Little Minnesota River though the Browns Valley dike to Lake Traverse (Corps 2000). Anecdotal, observed, and documented connections between the Little Minnesota River and Lake Traverse occurred in 1820, 1916, 1930, 1943, 1993, 1997, and 2001 (SWC 2012). No biota (macrobiota and microbiota) transfer controls have been implemented between these systems (Corps 2000).

Intrabasin Connections

Devils Lake Basin

Devils Lake is a closed subbasin of the Red River basin that began to experience water level increases in the 1940s. By 2010, water levels had increased by more than 15.5 m (50.8 ft), which put water levels close to Tolna Coulee, the natural outlet of Devils Lake. In 2003, the State of North Dakota began construction of an outlet (Figure 5) containing a coarse mesh screen and a rock and gravel filter for control of potentially invasive species of macrobiota. Construction of the outlet was completed in 2005, connecting Devils Lake with an outlet to the Sheyenne River for the first time in recorded history (Bensley et al. 2011).

The Devils Lake Basin Joint Water Resource Board and Red River Joint Water Resource District have established a goal to promote aquatic nuisance species control efforts as it relates to basin waters. To accomplish this goal, these entities work with state, federal, and private agencies, tourism groups, chambers of commerce, and other interested parties to increase awareness on the risks of biota transfer. In addition, they will continue to work towards closing off likely open water hydrologic connections (not including engineered connections) between Devils Lake and other subbasins to prevent transfers of fish or other aquatic nuisance species from the Red River into Devils Lake. Investigations and inventories of potential transfer points will be conducted in all nine basin counties, including Cavalier, Eddy, Nelson, Pierce, Ramsey, Rolette, Towner, and Walsh (DLBJWRB and SWC 2009).

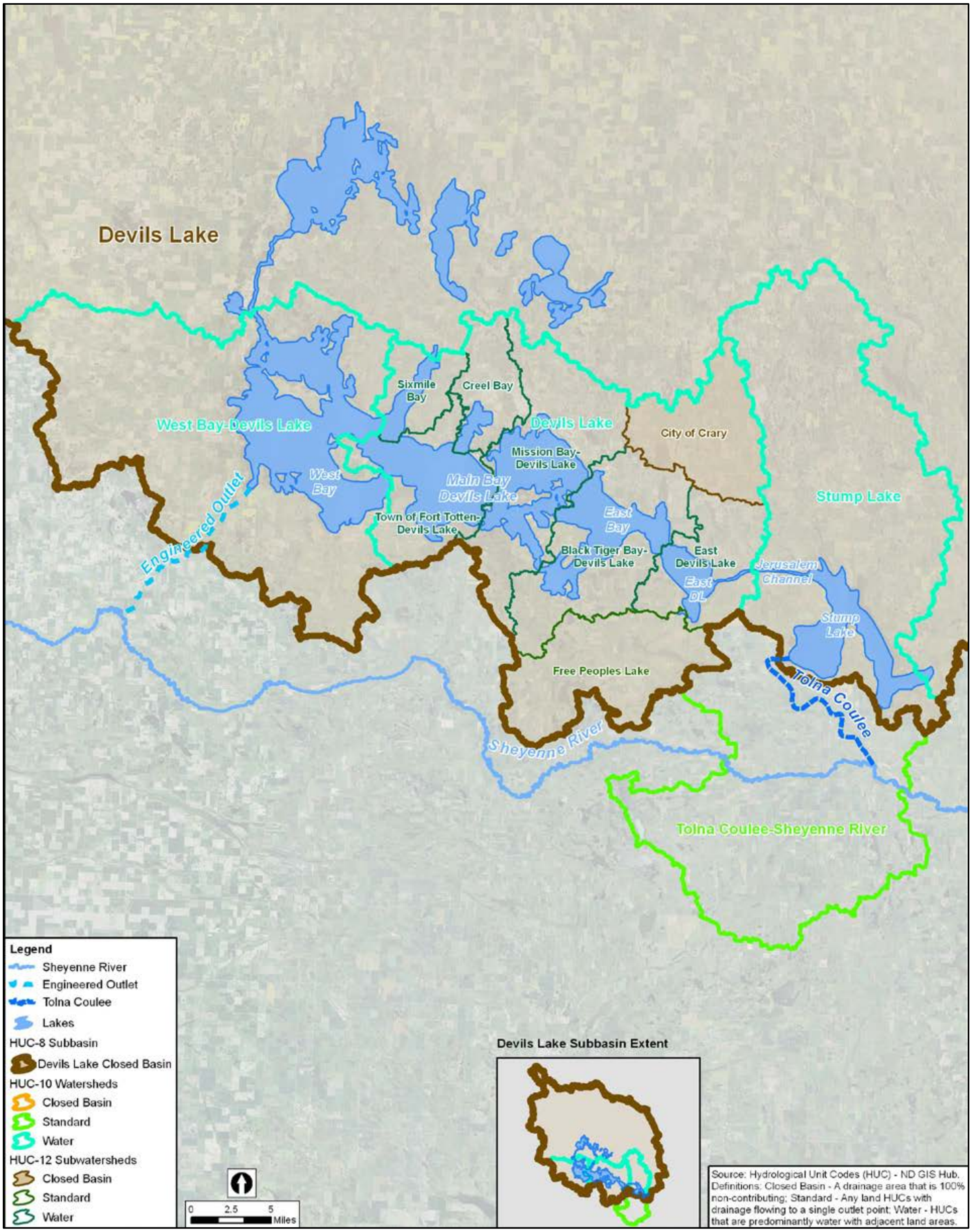


Figure 5 Devils Lake Subbasin

Dispersal of Invasive Species via Aquatic Pathways

Kerr et al. (2005) concluded that the greatest potential risk of invasive aquatic species spread is associated with ballast water, the live food fish industry, and the ornamental pond/aquarium trade. From an ecological perspective, invasive species may cause major disruptions to native fauna due to competition, predation, pathogenecity, or genetic alteration (e.g., hybridization with non-indigenous species; Kerr et al. 2005).

Maritime Commerce

Ballast Water Discharge

The release of invasive species from shipping ballast tanks has been one of the most significant pathways for introducing non-native species into aquatic systems. On average, two million gallons of ballast water are released into U.S. waters every hour (Goldsborough 2003). Ballast water may contain a wide variety of microscopic marine and freshwater life forms including eggs, cysts, larvae, and bacteria (ODEQ 2009), some of which could represent “exotics” due to shipping vessel travel through international waters.

The majority of invasive species introduced to a habitat outside of their native range are unable to gain a foothold and establish reproducing populations (ODEQ 2009). However, some invasive species, when freed from the natural controls of their native range can proliferate in waterways, displace native species, and degrade ecosystem services critical to human economics and health (ODEQ 2009). Management becomes more problematic as an invasive population spreads while other vectors work to rapidly distribute it (Minchin 2007). For example, zebra mussels (*Dreissena polymorpha*) accidentally delivered to the U.S. from Europe in ship ballast water have since spread via other routes (e.g., boat hulls) resulting in adverse effects to native ecosystems and water system infrastructure (Service 2011b; USGS 2007b).

All vessels that hold ballast water pose some level of risk of introducing invasive species. Currently, the U.S. Coast Guard (USCG) oversees a Ballast Water Management Program, which mandates practices for all vessels entering domestic waters. The requirements include avoiding or minimizing ballast uptake in specific areas, discharging minimal amounts of ballast water in coastal and interior areas, maintaining a ballast water management plan, and training vessel personnel on appropriate ballast water management procedures (USCG 2012). The USCG is currently amending the standards for discharging living organisms in ballast water. The final rule published March 23, 2012 in the *Federal Register* (46 CFR Part 162) includes protective thresholds for allowable organisms per milliliter of discharge, as well as mandatory testing and reporting (effective June 21, 2012).

The HBB contains a single major navigable waterway: the Port of Churchill, located on the west coast of Hudson Bay. The Port of Churchill is Canada’s only Arctic seaport (Port of Churchill Hudson Bay Port Company 2012). Therefore, ballast water discharge does not generally represent a direct link between the HBB and adjacent basins. Rather, this pathway has the potential to transfer biota to systems such as the Great Lakes with subsequent transfers to adjacent basins via other pathways.

Hull/Anchor/Superstructure Fouling

Invasive species can be transported from home waters by attaching themselves to hulls, anchors and exterior surfaces, fouling shipping vessels or barges. Once a vessel arrives at a port-of-call, an organism can release its larvae into the non-native waters or attach itself directly to port infrastructure, establishing residence as an invasive aquatic (LSWG 2009). In addition, aquatic organisms attached to exterior surfaces can become dislodged during dry dock operations and be released into non-native waters (LSWG 2009).

Canals and Diversions

Canals and channels for shipping goods and bulk water diversion create artificial connections that allow the free movement of species across physical barriers between (interbasin) and within (intrabasin) watersheds. For example, it is widely believed that white perch (*Morone americana*) and alewife (*Alosa pseudoharengus*) invaded Lake Ontario via the Erie Canal. In addition, the Chicago Sanitary and Ship Canal likely allowed zebra mussels and round gobies (*Meogobius melanstomus*) to gain access to the Mississippi River basin following establishment in the Great Lakes (Kerr et al. 2005).

Organisms in Trade

Trade of aquarium and ornamental species is generally an unregulated industry and may provide a viable mechanism for invasive species introductions (Padilla and Williams 2004).

Pets/Aquariums

The majority of species available in pet stores and nurseries are non-native in the regions of retail sale. Unwanted species are often released into natural habitats rather than handling them properly and safely. In addition, aquarium water is generally disposed of improperly, which can result in the introduction of aquatic species, including viruses and other pathogens (LSWG 2009).

At least 12 species of exotic plants and animals have been introduced into the Great Lakes region as a result of aquarium releases (Kerr et al. 2005). In addition, the aquarium trade is likely responsible for the introduction of several bivalve diseases in the northern hemisphere. Even a small amount of biomass can distribute potential disease agents including viruses, bacteria, and protozoa. However, since many aquarium species are raised at warmer temperatures, the majority of establishments in the wild occur in tropical and sub-tropical zones (Minchin 2007).

Aquatic Plants

Water gardening can result in the introduction of invasive aquatics. Many gardens utilize exotic plants, fish, reptiles, and invertebrates, which can escape into the natural environment. Water gardens that occur in areas prone to flooding pose the greatest risk, as invasives are more likely to be released during flood events. Similar to the pet and aquarium trade, improper disposal of unwanted species into storm sewers, ditches, or waters could result in an introduction (LSWG 2009).

Fishing and Aquaculture

Fishing Equipment

Anglers and commercial fishers could potentially transfer invasive species via boats and equipment. Invasive species can accumulate on nets, waders, lures, anchors, boat hulls and trailers, livewells, bilges, motors, and other equipment. Some invasive species can survive for long periods in boat livewells. The release of livewell and bilge contents can lead to invasive species transfer when boats are transported between waterways (LSWG 2009).

Use and Disposal of Live Bait

An angler awareness study published by Lindgren (2006) found that 25 percent of anglers disposed of unused live bait in the fished waterbody. Improper disposal of baitfish via the “bait bucket” phenomenon could aggravate the spread of invasive species by introducing non-native plants, invertebrates, and pathogens. Improper disposal of live bait infected with pathogens or parasites can adversely affect native fish populations (LSWG 2009).

Aquaculture Facilities

Aquaculture is the practice of farming aquatic organisms such as fish, crustaceans, mollusks, and aquatic plants. Populations of organisms are cultivated under controlled and often crowded conditions in either land-based facilities or cage operations within natural and man-made waterbodies. Cultivated species are not usually native to the area and/or waters where they are bred and raised. Historically, the popularity of raising non-native species increased as transportation became more frequent and reliable (Minchin 2007).

Invasive organisms often displace native species by outcompeting them for space and other resources. Farmed fish may also carry diseases not found naturally in some aquatic habitats. Wild fish and other aquatic organisms may therefore, exhibit vulnerability due to their lack of natural disease resistance (NMFS and Service 2005).

In 2002, approximately 100,000 reared Atlantic salmon escaped from an aquaculture facility in Maine. This accidental release led to a 1,000-fold increase in the local salmon population. The interaction between wild Atlantic salmon and aquaculture escapees may adversely affect wild salmon through both ecological and genetic effects. Escaped farm salmon can interbreed with wild fish leading to disruption of location adaptations, diminished wild stock viability, and decreased recruitment. Aquaculture salmon may also transfer disease and/or parasites to wild salmon (NMFS and Service 2005). Infestation of aquaculture facilities in the western U.S. by the New Zealand mudsnail has disrupted fish stocking and transport activities due to the risk of introducing this hardy gastropod to new waters (Nielson et al. 2011).

Stocking/Hatcheries

Private, public, and tribal agencies stock waterways with hatchery fish in an effort to enhance sport and commercial fishing. Stocking may result in the accidental introduction of invasive species to aquatic ecosystems, but the risk is reduced if preventative measures are implemented. However, certain life history characteristics allow some species to survive and pass into non-native waters even when stocking is managed to prevent transfer.

In some instances, anglers deliberately introduce unauthorized fish into waterbodies. Unauthorized stocking is typically conducted for the purpose of creating a new fishery or to manipulate existing fish stocks (LSGW 2009). Fish pathogens and parasites may also be transferred in infected fish during stocking efforts. For example, in 2005, a private hatchery owner was found guilty of unlawfully introducing fish carrying whirling disease into waters in Colorado, New Mexico, and Utah (WDI 2006). There is strong evidence for a link between stocking whirling disease-infected fish and subsequent elevated TAM spore production (Nehring 2006). Furthermore, the stocking of highly susceptible fish such as rainbow trout into waters where *M. cerebralis* is established can result in significant increases of TAM spore production (Nehring 2006).

Unauthorized stocking has lead to rearrangement of native taxa (Marsden and Hauser 2008), increased competition for food and living space, and decreased biodiversity due to crowding out of native species (LSWG 2009).

Invasive species can also be introduced into non-native waters via contaminated gear, stocking water, or in the stomach of stocked fish. Cysts of the toxin-producing algae *Prorocentrum lima* can survive gut passage in bivalves and become distributed with stock movements of mussels or Pacific oysters. Cysts have been found to germinate from the fecal wastes of polychaetes and other mollusks (Minchin 2007). In addition, New Zealand mudsnails are capable of live passage though some fish species' digestive systems (ANSTF 2006). Stocked fish can also function as carriers of pathogens and parasites. For example, *M. cerebralis*, which can be transmitted by infected fish and fish parts, is thought to have been introduced inadvertently into U.S. waters in the 1950's through the transfer of infected fish or fish product from Europe (Elwell et al. 2009).

Water Recreation

Boating

Water recreation activities involving boats, water skis, wake boards, pull ropes, and personal flotation devices have the potential to transfer non-native hitchhikers, such as larvae or algae if not cleaned or dried properly (LWSG 2009). Recreational boaters represent an important secondary transfer pathway for invasive species. For example, recreational boaters using the Rideau Canal are widely considered the source of zebra mussels from the Great Lakes to the Rideau River (Kerr et al. 2005). Tournament anglers who transport their boats over large geographic distances may pose greater transfer risk than recreational boaters.

Animal Transport

Fish Transport

Diffusive dispersal of invasive species could occur with the often gradual intrabasin downstream or upstream movement of introduced fish. This movement provides a mechanism for transferring harbored pathogens and parasites. Factors that can limit diffusive dispersal include unsuitable habitat, competing species, and physical barriers such as dams and fish screens.

Avian Transport

Small organisms (e.g., insect larvae, plant propagules, parasites) often rely on larger, more mobile species for dispersal. Fish are particularly important vectors for the transmission of pathogenic organisms such the parasite *M. cerebralis*. Birds and mammals have been shown to transport small organisms recently ingested or that have become adhered to skin, fur, or feathers; often called hitchhikers (Charalambidou and Santamaría 2005; Green et al. 2008; Koel et al. 2010; Waterkeyn et al. 2010).

Passive dispersal of invertebrates by nomadic birds has recently been demonstrated (Charalambidou and Santamaría 2005; Green et al. 2008). When the feces of grey teal (*Anas gracilus*), Eurasion coot (*Fulica atra*), and black swans (*Cygnus atratus*) were examined, viable invertebrates, including ciliates, nematodes, ostracods, and rotifers were present (Green et al. 2008). In addition, seeds and spores of 19 plant taxa were recorded, 14 of which were viable and germinated under laboratory conditions. Fecal samples from one Australian pelican (*Pelecanus conspicillatus*) contained more taxa and propagules than any of the other waterbirds suggesting that piscivorous birds may have an important role in the direct dispersal of propagules or other items previously ingested by fish (Green et al. 2008).

The survival of *M. cerebralis* has been demonstrated following ingestion of infected fish by piscivorous birds (Koel et al. 2010). Rainbow trout infected with whirling disease were fed to double-crested cormorants (*Phalocrocorax auritus*), white pelicans (*Pelecanus erythrorhynchos*), and great blue herons (*Ardea herodias*). Living, viable myxospores were produced from the feces of great blue herons up to four days after the infected fish were consumed. Snails have also been documented to survive digestion. New Zealand mudsnails have been observed surviving gut passage through rainbow trout (Oplinger et al. 2009) and similar hydrobiid snails have been known to survive digestion by ducks (Cadée 2011).

Potential long-distance dispersal of invertebrates via birds was reviewed by Green and Figuerola (2005) who combined literature-supported estimates for flight speeds, invertebrate survival during attachment and desiccation, and assessments of bird behavior. Their estimates indicated that maximum dispersal distances of propagules via avian pathways could easily exceed 1,000 km (600 mi).

The receiving waters of the HBB contain important waterbird habitat that support large populations of migrating and resident birds (Environment Canada 2012). Bensley et al. (2011) examined the risk of transferring pathogens and parasites associated with the construction of a water outlet connecting Devils Lake (a closed basin) in North Dakota to the Red River and Lake Winnipeg in the HBB. They concluded that the risk of transfer by piscivorous birds was greater than that posed by the outlet, which is not equipped with treatment mechanisms to prevent the movement of microorganisms. Likewise, the probability of passive dispersal of AIS to the HBB, especially via avian-mediated mechanisms is an important non-Project pathway.

Mammalian Transport

Few studies have addressed the facilitated overland transport of aquatic organisms by non-human mammalian vectors. Despite the paucity of available information, mammal movement and migration represents a viable and important mechanism for transferring aquatic organisms across hydrologic basins.

Bacteria and protozoa are common inhabitants of the gastrointestinal tract of mammals and, therefore may be released in the manure of livestock and wildlife (Pachepsky et al. 2006). Modeling the fate and transport of manure-borne pathogenic microorganisms by wildlife is exceptionally challenging (Ferguson et al. 2003). Pathogens may be transferred directly to new locations in the manure of wildlife or, in the case of some hardy organisms, shed in the feces, partitioned to the water or soil, and then transported with surface or subsurface water (Pachepsky et al. 2006).

Invertebrate animals may also be transported by mammals. Some hardy invertebrates such as gastropods and mussels may be transported on mud fixed to larger animals (e.g., mammals). Vanschoenwinkel et al. (2008) observed the transfer of several species to new water bodies via mud attached to wallowing wild boar (*Sus scrofa*) or in their feces. Seventeen viable invertebrate species were isolated from mud samples; and 10 viable species were isolated from feces. Similar results were obtained in a separate study of the nutria (*Myocastor coypus*), an aquatic rodent native to South America. In that study, more than 800 invertebrates represented by 14 different taxa were retrieved from the fur of only ten individual nutria specimens in southern France

(Waterkeyn et al. 2010). Mammalian transport may represent an important pathway for organism dispersal and interbasin transfer.

Weather-related Phenomena

Storm events, major floods, and high winds can provide natural pathways for dispersal of invasive organisms across basin boundaries. During high water and flood events, interbasin water exchange can occur through wetlands, rivers, and streams. The proximity of infected waters to uninfected waters influences the probability of transfer and establishment of invasive species (Davies et al. 1992; Ferguson et al. 2003).

In the south-central U.S., flooding has facilitated the spread of invasive species that had previously been contained in aquaculture farms or captive breeding facilities. For example, silver and bighead carp (*Hypophthalmichthys molitrix* and *H. nobilis*, respectively) once introduced to maintain aquaculture and wastewater treatment facilities (e.g., phytoplankton control) in the region, escaped into the Mississippi River following major flooding in the early 1980s. These highly adaptable species have since thrived and currently threaten the entire Great Lakes system (Burgiel and Muir 2010). The Chicago Sanitary and Ship Canal represents the only shipping link between the Great Lakes and the Mississippi River system. Asian carp are present in the Mississippi River system and may have invaded waters of the Great Lakes, despite the presence of eco-separation (fencing) efforts (Rasmussen et al. 2011). Jerde et al. (2010) have reported 10 species originating from the Great Lakes that have become invasive in the Mississippi River basin, including two species of fish, five plants, and three crustaceans.

Weather events could indirectly contribute to invasive species expansion by increasing habitat disturbance. This disturbance could allow an opportunity for the establishment and/or spread of existing invasive species (Burgiel and Muir 2010).

Climate Change

Dispersal of invasive species to new aquatic systems may be facilitated by increasing water temperatures associated with climate change (Chu et al. 2005). In Canada, average temperatures have increased by more than 1.3°C since 1948 (Natural Resources Canada 2012). Climate change is expected to cause dramatic changes in North America, including glacial melt and flooding in the western U.S., melting ice caps in the Arctic, rising sea levels in the Atlantic, and increased drought episodes in central regions of the U.S. (Chu et al. 2005; Natural Resources Canada 2012). In particular, water shortages and increased aridity are the key climate change concerns facing the Prairie Provinces of Canada (Natural Resources Canada 2012). Decreased annual runoff will likely prompt the construction of water storage reservoirs and increase the pressure to transport water from areas of abundance to areas where it is scarce (Rahel and Olden 2008). New canals to transport water could represent pathways for invasive species to spread. Reservoirs can become habitat for undesirable species, as well. For example, a 75 percent increase in impounded water in the Powder River basin of Wyoming potentially provides habitat for mosquitoes carrying the West Nile virus, a damaging pathogen of humans and sage grouse (Zou et al. 2006).

Climate change may encourage the establishment of non-native species by affecting abiotic factors such as water temperature and flow rate. Changes to these physical parameters can influence plant community structure and lead to loss of ecosystem diversity (Sandel and Dangremond 2012). Additionally, the current ranges of some native species, such as channel catfish and the pathogens they harbor are expected to expand with increasing air temperatures (Rahel and Olden 2008). Air and water temperature have historically been used as predictors of expanding distributions of invasive species; however, temperature does not appear to be a strong predictor of spread for the zebra mussel (Drake and Bossenbroek 2004).

In some cases, climate change may simply open up niches for invasive species that were previously filled by native species (Kappes and Haase 2012). For instance, the New Zealand mudsnail, zebra mussel, and quagga mussel are known to withstand a wide variety of physical stressors and may persevere in areas where native snails and mussels are eliminated by changing ecosystem compositions. Altered thermal regimes could also cause increased consumption of native prey species by non-native predators, or increased effects of non-native parasites on native species (Rahel and Olden 2008). This can be seen in laboratory experiments where brook trout and brown trout were equally competitive for prey items at cold temperatures, but the latter gained superiority at warmer temperatures (Taniguchi et al. 1998).

In addition to the movement of larger organisms, the effect of climate change on microbial communities must also be considered. Pathogen growth and reproduction are temperature-dependent. Extreme weather events have correlated with outbreaks of pathogens such as *Cryptosporidum* and E. coli in Canada between 1975 and 2001 (Thomas et al. 2006). The life cycle of parasites such as *M. cerebralis* are also highly dependent on temperature. Laboratory studies have shown that water temperatures between 5°C and 15 °C resulted in greater TAM release and increased overall *M. cerebralis* proliferation in the intermediate *Tubifex* worm host (El-Matbouli et al. 1999). Temperatures above 25°C resulted in degeneration of the parasite within the *Tubifex* worms.

Several of the pathogens and potential host receptors inhabit aquatic systems with specific physical conditions (e.g., temperature, turbidity, water flow) that determine their distribution and abundance. Climate change may cause dramatic regional changes including temperature increases and droughts in the Prairie Provinces of Canada (Natural Resources Canada 2012). Therefore, climate change may become a significant source of chronic, non-Project related ecosystem compositional changes in the HBB, the effects of which are difficult to predict.

Fate and Transport

The fate and transport of microorganisms in the environment is affected by many variables. There are both physical and chemical factors involved in the control of microbial transport, which are unique to the different types of environmental media encountered. For the Project, fate and transport processes in soil are important considerations due to the buried depth of the main Project transmission pipeline and the potential for release of AIS to surrounding subsurface soil if there was a system compromise. Non-Project biota transfer pathways involve media other than subsurface soil; therefore this section also addresses movement and retention in surface soil and surface water.

The main factors that govern the transport of microbes in soil include soil type, filtration, pH, presence of cations, presence of organic material, microbial type, flow rate, and hydraulic flow conditions (e.g., saturated versus unsaturated flow) (Bitton 1999). Single-celled microorganisms such as bacteria may be retained in soils due to their small size. This relationship is inversely proportional to the particle size of the encountered soil (Bitton 1999). Bacteria are essentially charged particles that can attach to soil particles such as clay minerals that have small particle sizes and abundant adsorption sites.

Virus transport is also dependent upon soil type with the highest affinity reserved for charged clays (Bitton 1999). Other factors affecting viral survival in soils include the species of virus, ionic strength of porewater, pH, organic matter, and flow rate. In addition, some soil bacteria produce antiviral substances that can further inactivate viruses (Bitton 1999).

There are a number of physical processes that can impede the transport of microbes in soil including inactivation, predation, filtration and attachment, sedimentation, and air-water interface trapping (Buchanan and Flurry 2004). Pathogenic bacteria are subjected to additional factors affecting their survival in soil including temperature, moisture content, sunlight, and antagonistic indigenous bacteria and predatory protozoa. Desiccation is also a significant process controlling pathogen survival in soils (Bitton 1999).

A geotechnical evaluation was conducted in 1997 along the Project main transmission pipeline route (Arman Engineering Testing, Ltd 1997). Seven test borings were completed in the area of the proposed intake structure at Lake Sakakawea and 101 test borings were completed along the proposed pipeline route. Lean clays dominated the subsurface with small amounts of gravel and glacially deposited sands and gravels (Arman Engineering Testing, Ltd 1997). The pipeline is buried below ground surface for the entire route between Lake Sakakawea and the Minot WTP. Therefore, a hypothetical pipeline release of water containing AIS would encounter subsurface soil. Unless a leak was large enough to result in overland flow in a contributing drainage, microbes released into subsurface soils dominated by clays would likely be entrapped and deactivated based on their high affinity for the small charged particles of this soil type (Bitton 1999).

Alternatively, microorganisms released onto surface soil through other pathways could be transported in runoff to waterways hydraulically connected to the HBB. Endospore-forming microbes could encapsulate themselves to protect against desiccation and radiation (Bitton 1999; Madigan et al. 2003) and remain viable for extended periods of time until they are transported to conditions that favor survival and growth. Therefore, an establishment of a microbial species in the HBB could occur well beyond (both spatially and temporally) an initial release/transfer event.

Biota transport to surface water (direct transfer to surface water, or transport from soil to surface water) is dependent upon several variables including initial cell concentration, survival probability of the organism, number of organisms that reach the water-soil interface, degree of removal/deactivation through the soil, and hydraulic gradient (EPA 1986). Chemical factors that influence the survival of microorganisms (especially enteric bacteria such as E. coli and *Salmonella* spp.) in water include temperature, salinity, dissolved oxygen, pH, cell size, predation, and nutrient availability (Metge 2002). Furthermore, inactivation and sedimentation of microbes may occur during initial introduction to the aquatic environment (Ferguson et al. 2003).

The movement of microorganisms in surface water and the ways in which they partition between settled and suspended particles are also important considerations. However, one of the key assumptions of this analysis is that a release of any size could contain viable cells capable of entering the receiving basin and causing adverse effects. That said, transport and survival of each major class of organism must be understood particularly for assessing transfer risk and developing mitigation strategies.

The environmental fate of an organism is also dependent upon niche availability in the receiving basin. There may be specific conditions required by the organism, which may be more adept at exploiting limited resources than the native competition. The examination of biota life histories was an integral process for evaluating the competitiveness of AIS and the potential for exclusion of present species in the HBB.

Ecological Receptors of Concern

Potential ecological receptors represent species that could be adversely affected by infection (host; direct effect) or those that could suffer or benefit from a change in conditions caused by an AIS establishment (e.g., loss of food-source prey for a commercially valuable fish species or newly available niche habitat for a native species to exploit; indirect effect). Potential ecological receptors in the HBB are shown in Table 2. Species in the HBB were identified from published literature and other data sources, and include potentially susceptible host species for fish pathogens and parasites, and species that would likely compete for resources with zebra mussels, quagga mussels, and New Zealand mudsnails. This list does not include all potential ecological receptors that could be indirectly affected by the introduction of an AIS. For example, filter-feeding by zebra mussels can alter aquatic ecosystems, potentially affecting (positively or negatively) all other species present. The geographic distribution and extent of potential host species may influence the potential consequences of an establishment, which would be specific to the transferred AIS.

Table 2 Potential Ecological Receptors of Concern in the Hudson Bay Basin

Common Name	Scientific Name	Criteria[a]		
		Special Status	Recreational/ Commercial Value	Susceptible to AIS Evaluated
Brook Trout	*Salvelinus fontinalis*	No	Yes[CA,U.S.]	BKD, whirling disease[b]
Brown Bullhead	*Ameiurus nebulosus*	No	Yes[CA,U.S.]	*Edwardsiella* infections, VHSV
Brown Trout	*Salmo trutta*	No	Yes[CA,U.S.]	BKD, *Ichthyophopthirius multifiliis*, ERM, furunculosis, IHNV, ISAV, VHSV, whirling disease[b]
Channel catfish	*Ictalurus punctatus*	No	Yes[CA,U.S.]	CCV, columnaris disease, *Edwardsiella* infections, ERM, *Exophiala* spp., *I. multifiliis*, furunculosis, *Saprolegnia* spp., VHSV
Common Carp	*Cyprinus carpio*	No	Yes[CA,U.S.]	BKD, furunculosis, SVCV, VHSV
Chinook Salmon	*Oncorhynchus tshawytscha*	No	Yes[US]	BKD, columnaris disease, ERM, furunculosis, IHNV, ISAV, *Saprolegnia* spp., VHSV, whirling disease[c]
Crappie	*Pomoxis* spp.	No	Yes[CA,U.S.]	Columnaris disease, *Edwardsiella* infections, ERM, VHSV
Fathead Minnow	*Pimephales promelas*	No	Yes[US]	Furunculosis, VHSV
Lake Sturgeon	*Acipenser fulvescens*	E[CA]	Yes[CA,U.S.]	*Polypodium hydriforme*
Lake Trout	*Salvelinus namaycush*	SC	Yes[CA,U.S.]	BKD, *Exophiala* spp., furunculosis, ISAV, IPNV, *Phoma herbarum*, VHSV, whirling disease[d]
Lake Whitefish	*Coregonus clupeaformis*	No	Yes[CA]	Furunculosis, VHSV, whirling disease[d]
Lake Winnipeg Physa Snail	*Physa winnipegensis*	E[CA]	No	Zebra mussel, quagga mussel, New Zealand mudsnail
Largemouth Bass	*Micropterus salmoides*	No	Yes[CA,U.S.]	*Edwardsiella* infections, VHSV
Mapleleaf mussel	*Quadrula quadrula*	E[CA, U.S.]	No	Zebra mussel, quagga mussel, New Zealand mudsnail, any pathogens that impact the mussel's fish host (catfish)
Muskellunge	*Esox masquinongy*	No	Yes[CA,U.S.]	VHSV
Northern Pike	*Esox lucius*	No	Yes[CA,U.S.]	Furunculosis, SVCV, VHSV
Rainbow Trout	*Oncorhynchus mykiss*	No	Yes[CA,U.S.]	Furunculosis, ISAV, VHSV, whirling disease[e]
Sauger	*Sander canadensis*	No	Yes[CA,U.S.]	Furunculosis, columnaris disease, VHSV
Shortjaw Cisco	*Coregonus zenithicus*	T[CA]	No	Zebra mussel, quagga mussel, New Zealand mudsnail, whirling disease[d]
Smallmouth Bass	*Micropterus dolomieu*	No	Yes[CA,U.S.]	Furunculosis, VHSV
Walleye	*Sander vitreus*	No	Yes[CA,U.S.]	ERM, furunculosis, columnaris disease, VHSV
White Bass	*Morone chrysops*	No	Yes[CA,U.S.]	VHSV
White Sucker	*Catastomus commersoni*	No	Yes[CA,U.S.]	VHSV
Yellow Perch	*Perca flavescens*	No	Yes[US]	Columnaris disease, furunculosis, VHSV

Notes:

[a] Criteria pertain only to fisheries and organisms falling within the U.S. portion of the HBB (U.S. HUC-2 Souris-Red-Rainy Region) and the Province of Manitoba.

[b] partial resistance, clinical disease rare or only develops at high parasite doses

[c] susceptible, clinical disease common at high parasite doses but greater resistance is seen at low parasite doses

[d] susceptibility is unknown or unclear at this time due to conflicting reports or insufficient data

[e] highly susceptible; clinical disease common

SC Species of Concern, Montana Department of Fish, Wildlife and Parks

T Threatened Species

E Endangered Species

[CA] Canada (Manitoba)

[U.S.] United States (North Dakota, South Dakota, and Minnesota)

Sources:

Bensley et al. 2011

DFO 2012a

Environment Canada 2011b

Hagen et al. 2005

Katona 2010

Manitoba Water Stewardship 2010, 2012a, b

Merck Animal Health 2012Michigan Department of Natural Resources 2012

MnDNR 2012

Montana Natural Heritage Program 2009

Montana State University 2012

Nico and Fuller 2012

North Dakota Game and Fish Department 2012a, b, c

Ontario Ministry of Natural Resources 2009

Power and Ryckman 1998

Service 2012b

USDOI 2011

Candidate Assessment Endpoints

Assessment endpoints are explicit expressions of the environmental value to be protected (Suter 2007). Candidate assessment endpoints were formulated for the risk and consequence analysis based on the types of relevant impacts that could occur as a result of AIS transfer and establishment, including:

- Population declines of threatened, endangered, and recovering species in the HBB
- Population declines of commercially or recreationally valuable fish species in the HBB
- Community (ecological) structure shifts in the HBB

Assessment endpoints generally represent potential impacts that can be measured or estimated during a risk assessment. The candidate assessment endpoints provide a framework for evaluating environmental consequences from historical aquatic invasions in other systems and assessing the applicability of that information to the receiving waters of the HBB.

Uncertainty

Invasive species are a serious problem in locations where they have caused economic damages to fisheries, maritime infrastructure, water supply systems, and a host of other resources. In addition, invasive species may cause impacts not readily measurable in monetary terms, such as changes in ecosystem dynamics and adverse impacts on biodiversity and habitats (Cardno ENTRIX and Andy Cohen 2011). Invasive species may be introduced into an area by many pathways, both unintentional and intentional. Global flows of goods and services and commercial and recreational activities correlate with economic growth, international trade, and population growth. Prevention of invasive species introduction is extremely complex, and it is difficult to predict which species will become established or will be challenging to control or eradicate (Cardno ENTRIX and Andy Cohen 2011; Herborg et al. 2007).

Early intervention/eradication of invasive species is usually much less costly than later attempts after the species has become established and dispersed (Cardno ENTRIX and Andy Cohen 2011). As a consequence, there is a great deal of interest in predicting the locations where invasive species will successfully establish. Such predictions require detailed knowledge on the species “propagule pressure” (i.e., the number of individuals of that species in a specific area over time), as well as indications of the environmental suitability of the location (Herborg et al. 2007). Some assert that the introduction of a non-native species to a new location and its later establishment require that the species successfully navigate sequential filters commencing with the “introduction effort” (Muirhead and MacIsaac 2005), which includes the number of introduction events and the number of individuals introduced at each event.

While historical accounts of invasive species establishment may assist in predicting future locations of introduction and spread, this approach is not foolproof. There have been instances in which an invasive species with no invasion history has had very large impacts, such as the invasion of San Francisco Bay by the Asian or overbite clam (*Corbula amurensis*), and ensuing large-scale changes in phytoplankton blooms and trophic dynamics (Cardno ENTRIX and Andy Cohen 2011). Conversely, impact predictions made from establishment of a species in one ecosystem may not apply to another ecosystem. For example, predictions made in the 1990s that the green crab (*Carcinus maenas*) would decimate the West Coast shellfish industry, based on its impacts in New England and elsewhere, have not materialized (Cardno ENTRIX and Andy Cohen 2011).

The impact potential of parasites and pathogens are highly uncertain, as well. For example, the impact of the introduction of *M. cerebralis* has varied greatly. Water temperature (seasonal range and variation), host size and availability, turbidity, flow rate, elevation, substrate, and land use all affect the relative success of *M. cerebralis* (Elwell et al. 2009). The wide range of variables involved makes it difficult to predict with certainty where, when, and under what circumstances the impact of whirling disease might be significant and where it might be benign (Nehring 2006).

Because aquatic systems are complex and local conditions are variable, it is usually not feasible to determine the pathway through which an invasion occurs. Further, little empirical information exists on the time lapse between introduction and establishment for a specific invasive species in a particular location. For example, quagga mussels are believed to have been first introduced into the Great Lakes in 1986, although they were not detected until 1988. That time lapse may be affected significantly by local climate conditions, for instance, longer in cold climates and shorter in warm environments. Trends due to climate change may also affect the time between an introduction and establishment of an invasive species.

The geographic ranges of species provide some insight into the potential for movement into neighboring areas, including aquatic systems within adjacent drainage basins. However, data and information regarding the distribution of AIS in the HBB and surrounding basins are lacking. There have been few systematic surveys for the majority of these AIS, with few exceptions including the Devils Lake study (Bensley et al. 2011). Most of the available data on presence/absence and distribution in publicly accessible databases and published literature is largely anecdotal. The lack of comprehensive species distribution information represents an uncertainty that reduces the ability to identify the most likely sources of introduction, characterize the risks of these transfer mechanisms, and predict potential impacts associated with AIS establishment.

In addition, the lack of abundant information for AIS in the MRB and other adjacent drainage basins precluded the development of a sensitivity analysis, which would have relied on biota concentration as an integral input variable. Because comprehensive abundance and distribution data is largely absent, this *Transbasin Effects Analysis* employed a qualitative approach.

The lack of well-documented impacts of AIS, and related or similar organisms in other aquatic systems also represents uncertainty. Relatively few studies have adequately described the incidence of disease at the individual level and how those effects translated to the population level. Population-level studies tend to be cost-prohibitive (Peeler and Taylor 2011). The lack of baseline data regarding the frequency and prevalence of infections and associated diseases hinders the ability to predict cumulative impacts (Hammell et al. 2009). Another issue investigated by ecologists is the uncertainty regarding whether mortality and reduced fertility can lead to recruitment loss and associated declines in populations (Peeler and Taylor 2011).

The USGS (2007a) described uncertainty related to several components of their analysis of the potential for the Project to result in the introduction of invasive species including, but not limited to:

- Control system operation
- Biota treatment and water transmission pipeline
- Infrastructure materials, installation, and system aging
- Preliminary failure analysis and system designs
- Competing interbasin biota transfer pathways
- Potential system failures and associated risks of biota transfer

The USGS concluded that risk of AIS transfer could be reduced by treatment of intake water at the source within the MRB and transmission through a closed conveyance system (buried pipeline) and delivery to the HBB, consistent with the RRVWSP (USGS 2005a). The study also concluded that random or unplanned events leading to an AIS release and establishment in the HBB could compromise any of the alternatives. Therefore, the selection of an alternative should be based on a framework for evaluating system components and developing operation and maintenance protocols that would reduce the risks of biota transfer (USGS 2007a).

Uncertainty associated with random or stochastic events was the primary focus of the USGS analysis due to its relevance to mediate failure of individual elements that could result in a system failure and introduction of AIS to the HBB. System failure analysis is complicated by the relationship of factors linked to the interaction among components, as well as the components themselves (USGS 2007a). Stochastic events that can physically damage or compromise a system, no matter how unlikely (e.g., earthquakes) should be considered in design features and within the context of uncertainty. In addition, it is conservative to assume that a system failure would result in a release of AIS-containing water, a transfer of this AIS-containing water to the HBB, and successful establishment of a sustainable population of an AIS in the HBB. However, the actual likelihood of a system failure is highly unlikely; and the probability of an associated transfer of water containing AIS is even more unlikely. The transfer of AIS to the HBB would not guarantee success of that organism in the receiving waters and potential to infect hosts and cause impacts. Specific spatial and temporal conditions in the HBB may be required for successful AIS establishment, but the precise conditions are not well understood and therefore, contribute additional uncertainty to a consequence analysis.

Biota treatment is integral to the Project water diversion to reduce the risk of AIS transfer to the HBB. Water treatment options including physical removal and disinfection, have been identified for source water from the Missouri River; however each step of the treatment process exhibits levels of uncertainty. In addition, construction materials and the operation and maintenance of transmission and treatment system have characteristic uncertainties related to system failures and associated biota transfers (USGS 2007a). Some pipe materials may be more supportive of microbial growth, influenced by organic matter in a system, or susceptible to corrosion by certain water chemistry variables both internally and externally (USGS 2007a). The long-term operation and maintenance of a water diversion including withdrawal, treatment, and transmission is also characterized with uncertainty, which reduces an accurate estimation of the potential for system failures capable of facilitating biota release and transfer (USGS 2007a).

Thorough research and data acquisition efforts ensured that the available scientific data and relevant studies were captured and used in the analysis. Sufficient information was obtained to support a sound scientific analysis, even without the availability of additional information that could have reduced uncertainty. The lack of existing data (e.g., AIS distribution information) is a major source of uncertainty for the current study; however, the available information supported a thorough analysis and ability to draw informed conclusions regarding the risks of AIS introduction and the evaluation of potential impacts of an establishment in the the HBB. Further details regarding uncertainty in the context of the National Environmental Policy Act are described in the Supplemental EIS.

Biota Treatment Associated with Water Supply Alternatives

Key life history characteristics of AIS including size and susceptibility to both water treatment and physical removal (Table 3) were considered during the evaluation of biota treatment options for the Project. Two of the alternatives being evaluated in the Supplemental EIS would use only in-basin (HBB) source water (groundwater and surface water), and therefore no biota water treatment would be needed. The other two alternatives would use the Missouri River as the main water supply source, combined with in-basin water sources. These alternatives would include biota treatment within the MRB.

The biota treatment options being evaluated in the Supplemental EIS are discussed in this section and further described in the Appraisal-Level Design Engineering Report. The main transmission pipeline from Lake Sakakawea to Minot will include automated pump shutoffs and isolation valves to minimize the amount of water that would be released in the event of a pipeline failure. In addition, biota treatment within the MRB is included in these alternatives to minimize the risk that a Project-related AIS transfer could occur due to a failure in the main transmission pipeline prior to final water treatment at Minot.

The water supply alternatives and associated biota treatment options described below are proposed for the Supplemental EIS. The Supplemental EIS also contains a discussion of the appropriate response plans and monitoring efforts for the water supply alternatives and Biota WTP options.

For both of the Missouri River alternatives, water from Lake Sakakawea (main supply source) would be treated to remove and/or inactivate potential AIS at a Biota WTP located within the MRB near the town of Max, North Dakota. Pretreated water would then be conveyed by buried pipeline to the existing Minot WTP. At the Minot WTP, the pretreated Missouri River water would be blended with in-basin groundwater and/or surface water sources and treated to meet SDWA standards before distribution to water users throughout the Project Area. The Minot WTP would be upgraded to handle the additional water demand.

The Biota WTP would be operated to reduce the risk of a Project-related transfer of AIS. It would not be considered a drinking water treatment facility, and therefore would not be regulated by the EPA or other regulatory agencies. Relevant water quality regulations (Appraisal-Level Design Engineering Report) were used to identify and develop effective treatment approaches for the removal and/or inactivation of AIS. The following five biota water treatment options are evaluated as part of both alternatives that would use Missouri River water:

- Chlorination
- Chlorination/UV Inactivation
- Enhanced Chlorination/UV Inactivation
- Conventional Treatment
- Microfiltration

Table 3 Aquatic Invasive Species Summary Table

Aquatic Invasive Species	Common Name	Classifications	Primary Hosts	Symptoms of Infection	Transmission Modes	Physical size	Water Treatment and Physical Removal Options
Channel Catfish Virus *(Ictaluris Herpesvirus 1)*	CCV	Virus	Juvenile ictalurids	Mortality, hemorrhaging	Vertical and horizontal	Diameter: 170 – 200 nm	Chlorine; UV
Infectious hematopoietic necrosis virus	IHNV	Virus: Rhabdoviridae	Juvenile salmonids	Mortality, abdominal distention, lethargy, hemorrhaging	Horizontal	Width: 80 nm Length: 170 nm	Chlorine
Infectious pancreatic necrosis virus	IPNV	Virus: Birnaviridae	Juvenile salmonids	Mortality, abnormal swimming, abdominal distention, darkened pigmentation	Horizontal	Diameter: 57 – 74 nm	Chlorine; UV
Infectious salmon anemia virus	ISAV	Virus	Salmonids	Mortality, severe anemia, lesions	Horizontal	Diameter: 100 nm	Chlorine; UV
Spring viremia of carp virus *(Rhabdovirus carpio)*	SVCV	Virus	Carp species (especially farmed carp)	Hemorrhaging of kidney, spleen, liver	Horizontal and via passive vectors	Width: 60 -90 nm Length: 80-180 nm	Chlorine
Viral hemorrhagic septicemia	VHS	Virus	Wild fish game fish, non-game fish, and hatchery fish	Mortality, hemorrhages of skin and internal organs, abnormal swimming, lethargy	Horizontal	Width: 60 – 70 nm Length: 170 – 180 nm	Chlorine; UV
Renibacterium salmoninarum	BKD	Bacteria	Salmonids	Mortality, ulcers, boils	Vertical and horizontal	Width: 0.3 – 1.0 µm Length: 1.0 – 1.5 µm	Conventional treatment with media filtration; particle filtration; microfiltration; chlorine
Flavobacterium columnare	Columnaris or myxobacterial infections	Bacteria	Fish (generalist pathogen)	Mortality, gill lesions	Contact and fecal-water contamination	Length: 7.0 – 10.0 µm	Conventional treatment with media filtration; particle filtration; microfiltration
Edwardsiella ictaluri, E. Tarda	None	Bacteria: Enterobacteriaceae	Fish, some reptiles, birds, mammals (including humans)	Lethargy, abnormal swimming, ulcers	Contaminated food or water	Width: 0.9 – 1.0 µm Length: 2.0-3.0 µm	Conventional treatment with media filtration; microfiltration
Yersinia ruckeri	ERM	Bacteria	Salmonids	Bleeding mouth, lethargy, hemorrhages, enlarged organs	Contaminated water, contact	Width: 0.5 µm Length: 1.5 – 2.0 µm	Conventional treatment with media filtration; particle

Aquatic Invasive Species	Common Name	Classifications	Primary Hosts	Symptoms of Infection	Transmission Modes	Physical size	Water Treatment and Physical Removal Options
							filtration; microfiltration; chlorine
Aeromonas salmonicida	Furunculosis	Bacteria	Salmonids	Internal hemorrhaging, boils, ulcers	Horizontal	Width: 0.3 – 1.0 µm Length: 1.0 – 3.0 µm	Conventional treatment with media filtration; microfiltration; chlorine; UV
Streptococcus spp.	Strep infection	Bacteria	Fish	Mortality, distress, hemorrhages, abnormal swimming, lethargy	Contact, oral	Diameter: 0.5 – 1.0 µm	Conventional treatment with media filtration; microfiltration
Escherichia coli	E. coli bacteria	Bacteria	Mammals (including humans), birds	Diarrhea, gastric distress	Contaminated food, water, or air	Width: 0.5 µm Length: 1.0 – 2.0 µm	Conventional treatment with media filtration; microfiltration; chlorine
Legionella spp.	Legionnaire's disease	Bacteria	Humans, amoebae	Gastric distress, pneumonia, nervous system malfunction	Aerosol	Width: 0.3 – 0.9 µm Length: 2.0 – 20.0 µm	Conventional treatment with media filtration; microfiltration; chlorine; monochloramine
Mycobacterium spp.	e.g., tuberculosis, leprosy, Crohn's disease	Bacteria	Mammals, amoebae	Varies widely	Varies	Width: 0.2 – 0.6 µm Length: 1.0 – 10.0 µm	Conventional treatment with media filtration; particle filtration; microfiltration; monochloramine
Pseudomonas spp.	None	Bacteria	Humans, fish, plants	Pneumonia dermatitis, endocarditis (humans), internal hemorrhaging (fish)	Contaminated food or water	Width: 0.5 – 0.8 µm Length: 1.5 – 3.0 µm	Conventional treatment with media filtration; particle filtration; microfiltration; UV
Salmonella spp.	Salmonellosis	Bacteria	Mammals (including humans), fish, reptiles	Gastric distress, diarrhea (humans)	Contaminated food, water, or air	Width: 0.7 – 1.5 µm Length: 2.0 – 5.0 µm	Conventional treatment with media filtration; particle filtration;

Aquatic Invasive Species	Common Name	Classifications	Primary Hosts	Symptoms of Infection	Transmission Modes	Physical size	Water Treatment and Physical Removal Options
							microfiltration; chlorine
Vibrio spp.	e.g., Cholera	Bacteria	Humans, plankton, shellfish	Diarrhea, vomiting (humans)	Contaminated water, fecal-oral	Width: 0.3 - 0.5 µm Length: 1.5 – 2.0 µm	Conventional treatment with media filtration; particle filtration; microfiltration; chlorine; UV
Potamopyrgus antipodarum	New Zealand mudsnail	Animalia: Gastropoda	NA	NA	Water transfer or juveniles and adults	Juveniles: < 1.0 mm Adults: 4.0 – 6.0 cm	Particle filtration; microfiltration; desiccation; parasitic control; molluscicides; algaecides
Dreissena polymorpha (larval)	Zebra mussel	Animalia: Bivalva	NA	NA	Water transfer of adults and larvae	Larvae: 40-350 µm Adults 8-50 mm	Particle filtration; microfiltration; chlorine
Dreissena rostriformis bugensis (larval)	Quagga mussel	Animalia: Bivalva	NA	NA	Water transfer of adults and larvae	Larvae 39-410 uM Adults: ≤ 4 cm	Same as for zebra mussel (see above)
Myxobolus cerebralis	Whirling disease	Animalia: Cnidaria	Salmonids (especially rainbow trout)	Mortality, craniofacial or spinal malformation, circular swimming, sinking, blacktail	Multi-host lifecycle with multiple life stages involving oligochaete intermediate host and fish final host	Myxospore stage: [Width: 7.0 – 10.0 µm Length: 7.0 – 9.0 µm] TAM stage: [Length: 125 µm]	Particle filtration; microfiltration; UV
Polypodium hydriforme	None	Animalia: Cnidaria	Sturgeon and paddlefish	Destruction of fish eggs and reduced reproductive capacity	Water transfer of parasite	Free-living stages: 5.0 mm – 1.0 cm	Particle filtration; microfiltration
Actheres pimelodi	Parasitic copepods, gill lice	Animalia: Copepoda	Ictalurids, centrarchids	Adult female visible when attached to gills or tongue	Parasite actively seeks host in water column	Adult female: 1.6 – 3.0 mm	Particle filtration; microfiltration
Ergasilus spp.	Parasitic copepods, gill lice	Animalia: Copepoda	Ictalurids, centrarchids	Adult female visible. Causes flashing, scratching, lethargy	Parasite actively seeks host in water column	Adult female: 1.0 mm	Particle filtration; microfiltration
Icelanonchophaptor microcotyle	None	Animalia: Trematoda	Ictalurids	Unknown	Unknown	Unknown	Unknown

Aquatic Invasive Species	Common Name	Classifications	Primary Hosts	Symptoms of Infection	Transmission Modes	Physical size	Water Treatment and Physical Removal Options
Corallotaenia minutia	Tapeworm	Animalia: Cestoda	Ictalurids	Unknown	Multi-host life cycle include copepod intermediate host and fish final host	Eggs: 40 – 90 µm	Particle filtration; microfiltration
Cryptosporidium parvum	Cryptosporidiosis	Protozoa: Apicomplexa	Mammals (including humans)	Diarrhea, vomiting	Contaminated water (feces)	Diameter: 5 µm	Particle filtration; microfiltration; UV
Giardia lamblia	Beaver fever, backpacker's diarrhea	Protozoa: Mastigophora	Mammals (including humans)	Diarrhea, vomiting	Contaminated water (feces)	Cysts: [Length: 11.0 – 14.0 µm, Width: 7 – 10 µm]	Chlorine; particle filtration; microfiltration; UV
Entamoeba histolytica	Amoebic dysentery	Protozoa: Rhizopoda	Humans	Diarrhea, liver cysts	Contaminated water (feces)	Trophozoite stage: [Diameter: 12 – 50 µm] Cysts: [Diameter: 10-15 µm]	Particle filtration; microfiltration; chlorine; chloramines
Ichthyophthirius multifiliis	Ich, white spot disease	Protozoa: Ciliophora	Freshwater fish	White skin nodules, cloudy eyes, lethargy, flashing, rapid breathing	Obligate parasite actively seeks fish host	Theront: [Diameter: 30 – 40 µm]	Particle filtration; microfiltration; chlorine
Ichthyophonus hoferi	Ichthyophonosis	"Fungus-like" protozoa	Salmonids, herring, crustaceans, amphibians	Mortality, nodules on organs, behavioral changes	Ingestion	Spores (nodules): 0.5 – 230 µm depending on organ	Microfiltration; chlorine
Saprolegnia spp.	Oomycetosis, winter fungus	Fungi	Salmonids, ictalurids, and some others	Epidermal damage, damage to eggs	Contact	Hyphae: 0.5 – 1.0 mm	Particle filtration; microfiltration
Branchiomyces sanguinis, B. demigrans	Branchiomycosis	Fungi	Farmed fish (salmonids, ictalurids, tilapia, bass, etc.)	Mortality, hemorrhaging of gill tissue	Contact, contaminated water	Hyphae: [Diameter: 5.0 – 8.0 µm] Spores: [Diameter: 8.0 – 15 µm]	Particle filtration; microfiltration; chlorine
Phoma herbarum	Coleomycetosis	Fungi	Salmonids (opportunistic pathogen)	Gut obstruction, peritonitis, visceral necrosis, severe hemorrhaging	Via air bladder/pneumatic duct or gulped into gastrointestinal tract	Hyphae: [Width: 2.3 µm Length: 4.0 – 5.5 µm] Pycnidia: [Diameter: 50 – 200 µm]	Particle filtration; microfiltration

Aquatic Invasive Species	Common Name	Classifications	Primary Hosts	Symptoms of Infection	Transmission Modes	Physical size	Water Treatment and Physical Removal Options
Exophiala spp.	Black yeast	Fungi	Freshwater and marine fishes, including salmonid and non-salmonid species; humans	Subcutaneous dermal infections, some strains cause death	Dermal inoculation	Hyphae: [Diameter: 1.8 – 3.0 µm] Conidia: [Length: 3.0 –5.0 µm, Width: 1.5 – 2.0 µm]	Particle filtration; microfiltration
Anabaena flos-aqua	Blue-green algae	Cyanobacteria	NA	Neurotoxicity, liver toxicity, dermatitis	Ingestion of cells or dermal contact	Diameter: 4.0 – 50 µm	Particle filtration; microfiltration; coagulation; granulated activated carbon filtration (to remove extracellular toxins)
Aphanaizomenon flos-aqua	Blue-green algae	Cyanobacteria	NA	Neurotoxicity, liver toxicity, dermatitis	Ingestion of cells or dermal contact	Length: 5.0 – 7.0 µm	Same as for Anabaena flos-aqua (see above)
Microcystis aeruginosa	Blue-green algae	Cyanobacteria	NA	Liver toxicity, dermatitis	Ingestion of cells or dermal contact	Diameter: 2.0 – 3.0 µm	Same as for Anabaena flos-aqua (see above)

Note**:** NA – not applicable

Source: Section: Life History Characteristics and Distribution

Chlorination

This Biota WTP option includes chlorination of Missouri River water and conversion of the resulting free chlorine residual to chloramines before being pumped to the Minot WTP for final treatment prior to distribution. Within the Biota WTP options, chlorine would be used for disinfection of biota including *Giardia* and viruses.

Chloramine is used as a residual disinfectant in the transmission pipeline for all biota treatment options evaluated. Formed by the addition of ammonia to chlorine in water, it provides a stable disinfectant and reduces the potential for disinfection by-products. Table 4 presents the log-inactivation credits for the chlorination option.

Table 4 Chlorination Log-inactivation[a]

Target Biota	Chlorine	Chloramination (Pipeline)	Total
Giardia	2.7	0.30	3
Cumulative Credit	2.7	3	
Viruses	> 4	0.5	> 4
Cumulative Credit	> 4	> 4	
Cryptosporidium	0	0	0
Cumulative Credit	0	0	
Myxobolus cerebralis[b]	0	0	0
Cumulative Credit	0	0	

Notes:

[a] Log inactivation is a measure of the percent of the biota that are inactivated/removed as a result of a treatment process. For example, 2-log, 3-log, 4-log and 5-log inactivation corresponds to 99%, 99.9%, 99.99%, and 99.999% inactivation/removal, respectively. Inactivation removal credits for drinking water treatment are generally limited to *Giardia*, viruses, and *Cryptosporidium*.

[b] Log inactivation for *Myxobolus cerebralis* based on Hedrick et al. 2008. Inactivation with chlorine was assumed to be zero as chlorine doses employed by Hedrick et al. far exceeded those used in development of this option.

Source: Table IV.B-2. EPA, National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule, 40 Code of Federal Regulations (CFR) Parts 9, 141, and 142, January 5, 2006.

Chlorination/UV Inactivation

This option includes UV irradiation of Missouri River water, followed by chlorine disinfection, and conversion of the free chlorine residual to chloramines. The pretreated water would then be pumped to the Minot WTP for additional treatment. UV is used to inactivate chlorine-resistant protozoa and myxozoa, which is not limited to *Cryptosporidium* and *Giardia*. For example, a UV dose of 40 mJ/cm^2 has been found to completely inactivate *M. cerebralis* (Hedrick et al. 2007, 2008). UV light delivered through water irradiates microorganisms rendering them non-infectious. Table 5 presents the log-inactivation credits for the chlorination/UV inactivation option.

Table 5 Chlorination/UV Log-inactivation

Target Biota	UV Irradiation	Chlorine	Chloramination (Pipeline)	Total
Giardia	3.0	0.63	0.30	> 3
Cumulative Credit	3.0	> 3	>3	
Viruses	0.5	> 4	0.5	> 4
Cumulative Credit	0.5	> 4	> 4	
Cryptosporidium	3.0	0	0	3.0
Cumulative Credit	3.0	3.0	3.0	
Myxobolus cerebralis[a]	> 4	0	0	> 4
Cumulative Credit	> 4	> 4	> 4	

Note: [a] UV log-inactivation for *Myxobolus cerebralis* based on Hedrick et al. 2008. Inactivation with chlorine was assumed to be zero as chlorine doses employed by Hedrick et al. far exceeded those used in development of this option.

Source: Table IV.B-2. EPA, National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule, 40 Code of Federal Regulations (CFR) Parts 9, 141, and 142, January 5, 2006.

High turbidity can reduce the efficacy of chlorination (LeChevallier et al. 1981) and UV disinfection (EPA 2006). For unfiltered water, the UV dose-response is generally not affected when the turbidity is less than 10 nephelometric turbidity units (NTU) (Oppenheimer et al. 2002, Passantino et al. 2004).

In 2006-2007 a pilot study conducted at the Snake Creek Pumping Plant evaluated the potential effectiveness of UV disinfection on unfiltered Lake Sakakawea water (MWH and Houston Engineering, Inc. 2007). Raw water turbidity was monitored continuously (except during system maintenance) during the entire study. Figure 6 shows the raw water turbidity at the Snake Creek Pumping Plant during the pilot study. The turbidity ranged from 3-10 NTU from April to December 2006. After the lake froze in December, the turbidity was below 2 NTU. During the ice-free period, there was no apparent seasonal pattern, suggesting that wind and wave action are the dominant factors affecting turbidity at this location.

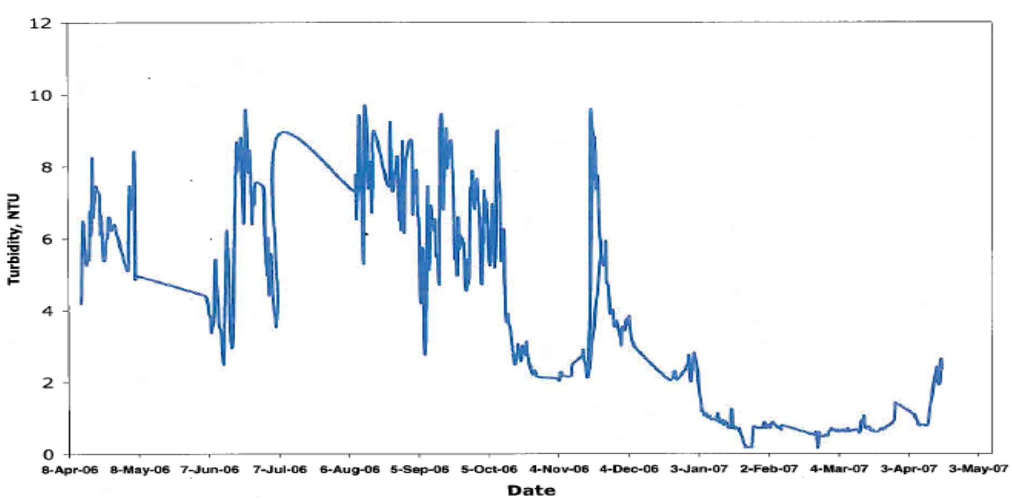


Figure 6 Raw Turbidity at the Snake Creek Pumping Plant

The pilot study was conducted during a drought period with low reservoir levels and inflows that may not be representative of long-term water quality. However, because the Snake Creek Pumping Plant is located more than 100 miles from the reservoir headwaters, it is likely not subject to significant inflow-related changes in turbidity. Figure 7 shows 2006-2011 monthly reservoir inflow and raw water turbidity for a regional water system that withdraws water from Lake Sakakawea approximately 30 miles west (upstream) of the Snake Creek Pumping Plant. This period included near record low inflows and reservoir elevations (2006-2008) and record high inflows and reservoir levels (2011). No relationship between inflow and turbidity is apparent (coefficient of correlation [r]=0.09, probability [p]=0.45). These data and the results of the pilot study suggest that turbidity of source water for the Project should not limit the efficacy of UV disinfection. To provide a further level of control, water parameters including turbidity would be monitored to ensure efficacy of system components including UV.

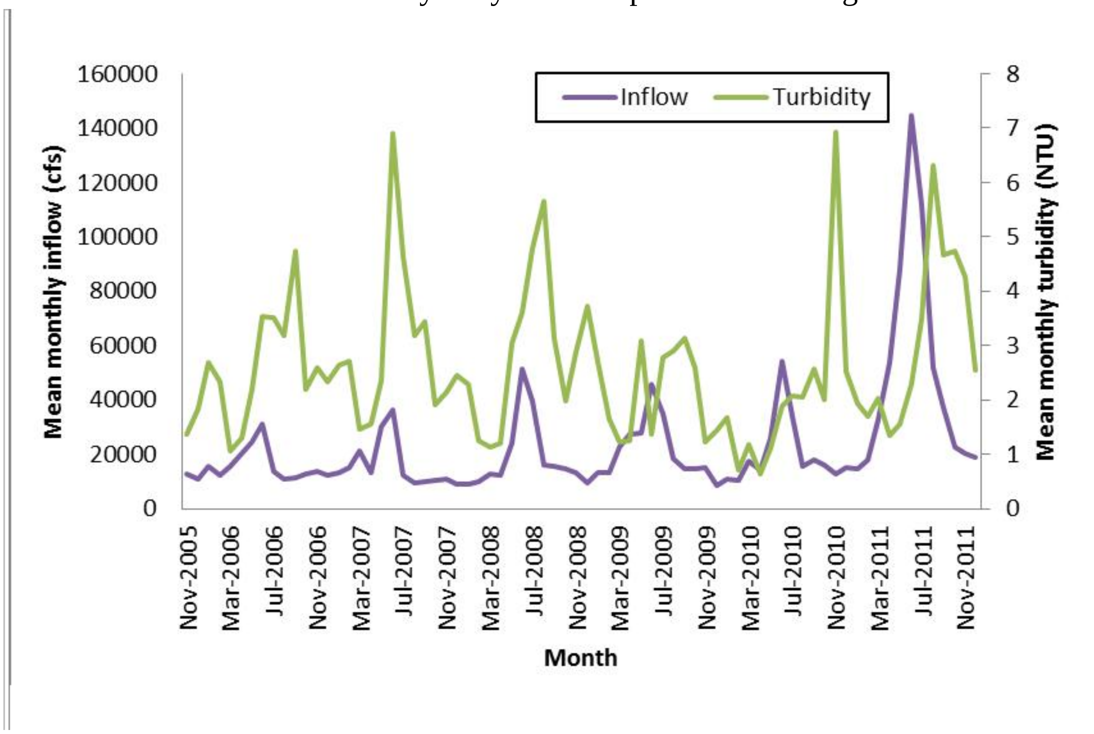


Figure 7 **Monthly Reservoir Inflow and Raw Water Turbidity for the Southwest Pipeline Project (intake at Renner Bay, Lake Sakakawea)**

Enhanced Chlorination/UV Inactivation

This option includes pressure filtration of Missouri River water, followed by UV irradiation, followed by chlorine disinfection, and conversion of the free chlorine residual to chloramines before being pumped to the Minot WTP for treatment. Pressure filtration has been included as an enhancement to the Chlorination/UV Inactivation Biota WTP as it provides a physical barrier by removing particles from the Missouri River water during high turbidity events to ensure the effectiveness of UV inactivation. Table 6 provides a summary of the removal credits and log-inactivation for the enhanced chlorination/UV inactivation option.

Table 6 Enhanced Chlorination/UV Log-inactivation or Removal

Target Biota	Pressure Filtration[a]	UV Irradiation	Chlorine	Chloramination (Pipeline)	Total
Giardia	1[b]	3.0	0.63	0.30	> 3
Cumulative Credit	1	> 3	> 3	> 3	
Viruses	0	0.5	> 4	0.5	> 4
Cumulative Credit	0	0.5	> 4	> 4	
Cryptosporidium	1[b]	3.0	0	0	4.0
Cumulative Credit	1	4.0	4.0	4.0	
Myxobolus cerebralis[c]	1[b]	> 4	0	0	> 4
Cumulative Credit	1	> 4	> 4	> 4	

Notes:

[a] Log-inactivation values from "California Surface Water Treatment Alternative Filtration Technology Demonstration Report, June 2001, and includes a 1-log safety factor from the inactivation values demonstrated from the pilot testing as recommended by the California Department of Health Services.

[b] When the pressure filter is in operation and achieving finished water turbidity comparable to conventional filtration and as documented in a pilot study completed prior to design.

[c] UV log-inactivation for *Myxobolus cerebralis* based on Hedrick et al. 2008. Inactivation with chlorine was assumed to be zero as chlorine doses employed by Hedrick et al. far exceeded those used in development of this option. Pressure filtration log-removal for *Myxobolus cerebralis* based on comparison of particle size with *Cryptosporidium* oocysts.

Source: Table IV.B-2. EPA, National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule, 40 Code of Federal Regulations (CFR) Parts 9, 141, and 142, January 5, 2006.

Conventional Treatment

This Biota WTP option includes coagulation/flocculation, followed by DAF, media filtration, UV irradiation, and chlorine/chloramines disinfection. DAF requires fewer chemicals, smaller spaces, and allows for higher loading rates compared to conventional pretreatment methods. Flocculated particles are mobilized to the water surface after attachment with micro-bubbles. Media filtration provides a practical treatment process for the removal of particles and microorganisms. This reduces the disinfectant demand upon chlorination, thus providing more effective inactivation. Table 7 provides the removal credits for the conventional treatment option.

Table 7 Conventional Treatment Log-inactivation or Removal

Target Biota	DAF and media filtration	UV Irradiation	Chlorine	Chloramination (Pipeline)	Total
Giardia	2.5	3.0	0.63	0.30	> 3
Cumulative Credit	2.5	> 3	> 3	> 3	
Viruses	2.0	0.5	> 4	0.5	> 4
Cumulative Credit	2.0	2.5	> 4	> 4	
Cryptosporidium	2.5	3.0	0	0	> 3
Cumulative Credit	2.5	> 3	> 3	> 3	
Myxobolus cerebralis[a]	2.5	> 4	0	0	> 4
Cumulative Credit	2.5	> 4	0	> 4	

Note: [a] UV log-inactivation for *Myxobolus cerebralis* based on Hedrick et al. 2008. DAF and media filtration log-removal for *Myxobolus cerebralis* based on comparison of particle size with *Cryptosporidium* oocysts. Inactivation with chlorine was assumed to be zero as chlorine doses employed by Hedrick et al. far exceeded those used in development of this option.

Source: Table IV.B-2. EPA, National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule, 40 Code of Federal Regulations (CFR) Parts 9, 141, and 142, January 5, 2006.

Microfiltration

This option includes coagulation and flocculation, followed by microfiltration. Filtered water would be treated with UV irradiation and chemically disinfected with chlorine, followed by conversion of the resulting free chlorine residual to chloramines. Microfiltration, or membrane filtration, is a pressure-driven separation process that provides a transport barrier to particulates including inorganic and organic suspended solids and microorganisms. The types and sizes of matter retained is a function of the membrane pore size and composition. Typical nominal pore sizes range from 0.05 to 0.5 µm, which is capable of removing protozoan cysts (i.e., *Giardia* and *Cryptosporidium*) and most bacteria. Table 8 provides the removal credits for the microfiltration treatment option.

Table 8 Microfiltration Log-inactivation or Removal

Target Biota	Microfiltration	UV Irradiation	Chlorine	Chloramination (Pipeline)	Total
Giardia	4.0	3.0	0.63	0.30	> 3
Cumulative Credit	> 3	> 3	> 3	> 3	
Viruses	0.5	0.5	> 4	0.5	> 4
Cumulative Credit	0.5	1.0	> 4	> 4	
Cryptosporidium	4.0	3.0	0	0	> 3
Cumulative Credit	> 3	> 3	> 3	> 3	
Myxobolus cerebralis[a]	4.0	> 4	0	0	> 4
Cumulative Credit	4.0	> 4	> 4	> 4	

Note: [a] UV log-inactivation for *Myxobolus cerebralis* based on Hedrick et al. 2008. Microfiltration log-removal for *Myxobolus cerebralis* based on comparison of particle size with *Cryptosporidium* oocysts. Inactivation with chlorine was assumed to be zero as chlorine doses employed by Hedrick et al. far exceeded those used in development of this option.

Source: Table IV.B-2. EPA, National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule, 40 Code of Federal Regulations (CFR) Parts 9, 141, and 142, January 5, 2006.

Risk Assessment

For this *Transbasin Effects Analysis*, risk was evaluated in two ways: 1) the contribution of each potential biota transfer pathway, including Project-related, to the overall risk of AIS introduction; and 2) the threat posed by AIS to potential ecological receptors of concern in the HBB (i.e., the potential consequences). These elements are distinct and provide necessary perspective in the context of transbasin AIS risks and consequences. Potential environmental and economic consequences are described in later sections of this technical report.

Risk Posed by Potential Biota Transfer Pathways

The HBB is not a closed system and is therefore connected to other drainage basins by both biotic and abiotic linkages, including interbasin connections and water diversions, aquatic pathways, animal transport, and weather-related phenomena. The potential consequences of an AIS introduction may be the same regardless of the introduction pathway (pathway-independent), but would likely vary by the species transferred (AIS-dependent), as well as the location (within the HBB) of the introduction. For example, impacts could vary spatially if a pathogen or parasite is introduced into a river system such as the Souris River or directly into Lake Winnipeg. Each of these systems within the HBB have unique environmental and ecological characteristics, including water chemistries and the presence and availability of host species, which would affect the success of AIS establishment in the HBB.

Interbasin water diversions have the potential to transport AIS and there are several existing and proposed in the region of the Project. Interbasin water diversions that may pose a risk of AIS introduction to the HBB include the RRVWSP, WAWS Project, Saint Mary's and Milk River Diversion (Milk River Project), the Lake Traverse and Big Stone Lake Project, and the Project alternatives, which include the transfer of Missouri River water. In addition, the constructed outlet at Devil's Lake established a connection between the HBB and the formerly closed Devil's Lake basin.

Dispersal of AIS may occur via aquatic pathways including: ballast water discharge; shipping canals and channels; or attachment of AIS to hulls, anchors, and exterior surfaces of shipping vessels or barges. Aquaculture facilities, in either land-based facilities or cage operations within natural and manmade waterbodies, provide opportunities for AIS introduction, including the accidental release of non-native species. Movement of fishing equipment, use and disposal of live bait, and trade in aquarium and ornamental plant and fish species provide additional mechanisms for invasive species introductions. Private, public, and tribal agencies stock waterways with hatchery fish in an effort to enhance sport and commercial fishing, which could result in the accidental introduction of invasive species. In addition, anglers sometimes deliberately introduce unauthorized fish into waterbodies.

Transport of AIS can occur via animal transport, including fish, birds, and mammals. Storm events, major floods, and high winds can provide pathways for dispersal of invasive organisms across basin boundaries, including interbasin water exchange through wetlands, rivers, and streams. Dispersal of invasive species may also be facilitated by increasing water temperatures associated with climate change.

Risk of Biota Transfer from the Project

The Project is intended to provide reliable high-quality MR&I water to northwestern North Dakota. Because the Missouri River is the main source of out-of-basin water for two of the proposed water supply alternatives, the Project would provide a rigorously engineered system with state-of-the-art biota treatment, operation and maintenance practices, and emergency protocols.

The biota treatment options for the Project would inactivate and/or remove AIS from water transferred to the HBB. Project biota treatment options including chlorine (Ahne et al. 2002; ISU 2007c) and UV irradiation (Øye and Rimstad 2001; Ahne et al. 2002; ISU 2007c) are capable of inactivating viruses (Appraisal-Level Design Engineering Report). Bacteria would be inactivated and/or removed via treatment with chlorine (Pascho et al. 1995; Colberg and Lingg 1978; WHO 2007), UV (Hoffman 1974; WHO 2007; Lee et al. 2010; Bullock and Stuckey 1977), and filtration (WHO 2007; Liltved et al. 1995) (Appraisal-Level Design Engineering Report). New Zealand mudsnails would be eliminated with chlorine (Hosea and Finlayson 2005; Benson and Kipp 2011; Craft and Myrick 2011) and UV (Benson and Kipp 2011). Water filtration (via conventional treatment or microfiltration options), would eliminate protozoans such as *Cryptosporidium* (approximately 5 µm; McCuin and Clancy 2006) and would also exclude juvenile New Zealand mudsnails, which are considerably larger (approximately 1 mm; Levri and Lively 1996). Parasitic animals, such as *M. cerebralis*, would be inactivated and/or removed by UV treatment (Hedrick et al. 2007, 2008) and filtration (Hedrick et al. 2007, 2008) (Appraisal-Level Design Engineering Report). Particle filtration and microfiltration would remove *P. hydriforme* and/or other parasitic copepods. UV and filtration are capable of inactivating and/or removing protozoan AIS (Reclamation 2008). *Cryptosporidium* is resistant to chlorination, but susceptible to UV disinfection, ozonation, and filtration (Venczel et al. 1997; Morita et al. 2002; Hsu and Yeh 2003). *Giardia* is inactivated by UV and ozonation, as well (Mofida et al. 2002; Hsu and Yeh 2003).

Treatment with chlorine (Durborow et al. 2003), UV (Urban et al. 2011), and filtration (Urban et al. 2011) are capable of inactivating and/or removing fungi. A combination of UV irradiation (200 mJ/cm^2) and filtering (1.2 µm nitrocellulose filter disc) has been successfully used to inactivate several species of fungi that are pathogenic to plants (Urban et al. 2011). The spore size of the fungi examined by Urban et al. (2011) ranged in size from 1.5 to 9.0 µm in width. The smallest fungal AIS evaluated are *Exophiala*, which have conidia as small as 1.5 µm in width (Munchan et al. 2009).

Methods such as rapid filtration and DAF are effective methods for the removal of cyanobacterial cells from municipal water sources (WHO 1999). Slow-sand filtration and membrane filtration may be effective for the removal of cyanobacterial toxins (e.g. microcystins, anatoxins; WHO 1999). The Project's average annual water withdrawals would be approximately 13,600 acre-feet per year with a projected peak day withdrawal of 26 million gallons per day which would be sufficient to dilute any cyanotoxins that entered the transmission pipeline intake. Cyanotoxins are chemicals and therefore not capable of self-propagation and spread.

The main transmission pipeline of the Project was designed and constructed with sophisticated failure response systems, including alarms, automatic shutdown procedural mechanisms, and motor-operated pipeline isolation valves (Figure 8). These valves are designed to reduce the volume of pretreated water that could be released during a catastrophic failure in the pretreated water pipeline (Houston Engineering and Montgomery Watson 2001; Houston Engineering et al. 1998). Pressure sensors were installed to continuously monitor the system pressure at each isolation valve location. In the event of a catastrophic failure, a drop in pipeline pressure would be detected by the sensor at the compromised valve location, which would then trigger an alarm. The valves are designed to close automatically if the measured pressure change is constant over a threshold time period (Houston Engineering and Montgomery Watson 2001). A transmission pipeline failure could lead to a release of water to surrounding subsurface soil; an environment characterized by conditions capable of immobilizing and deactivating organisms (Bitton 1999; Buchanan and Flurry 2004).

Following treatment at the Biota WTP near the town of Max, the Project transmission pipeline extends 8.5 miles northward before reaching the basin divide. The pipeline then extends 4.2 miles to the northern boundary of the Nelson Lake subbasin (Figure 8). This is a closed non-contributing HUC-12 (USGS hydrological unit code[1]) subbasin; therefore water released from a pipeline failure in this area would not hydraulically connect with tributaries of the Souris River drainage. The distance between the northern boundary of the Nelson Lake subbasin and the Minot WTP is approximately 17 miles.

1 The USGS HUC system is a nested hierarchy of boundaries within the U.S. ranging from the largest continental units of regions at HUC-2 to the smallest unit of subwatersheds at HUC-12. The HUC classification hierarchy used for the basin divide in the Project Area included HUC-4 subregions, HUC-10 watersheds, and HUC-12 subwatersheds. Each watershed and subwatershed was graphically represented by their drainage classification. The three drainage classifications in this area included closed, standard, and water. Closed basin HUCs are drainage areas that are 100 percent non-contributing and, and therefore over-land flow is contained within the basin boundary. Standard HUCs are drainage areas flowing to a single outlet point, excluding non-contributing areas. Water HUCs are predominantly water with adjacent land areas. The North Dakota Department of Health-Division of Water Quality made revisions to the USGS HUC dataset in 2010 (available at the ND GIS Hub) to incorporate boundaries that extend across the Canadian border and changes made to neighboring states, as well as to correct coding and naming errors and inconsistencies.

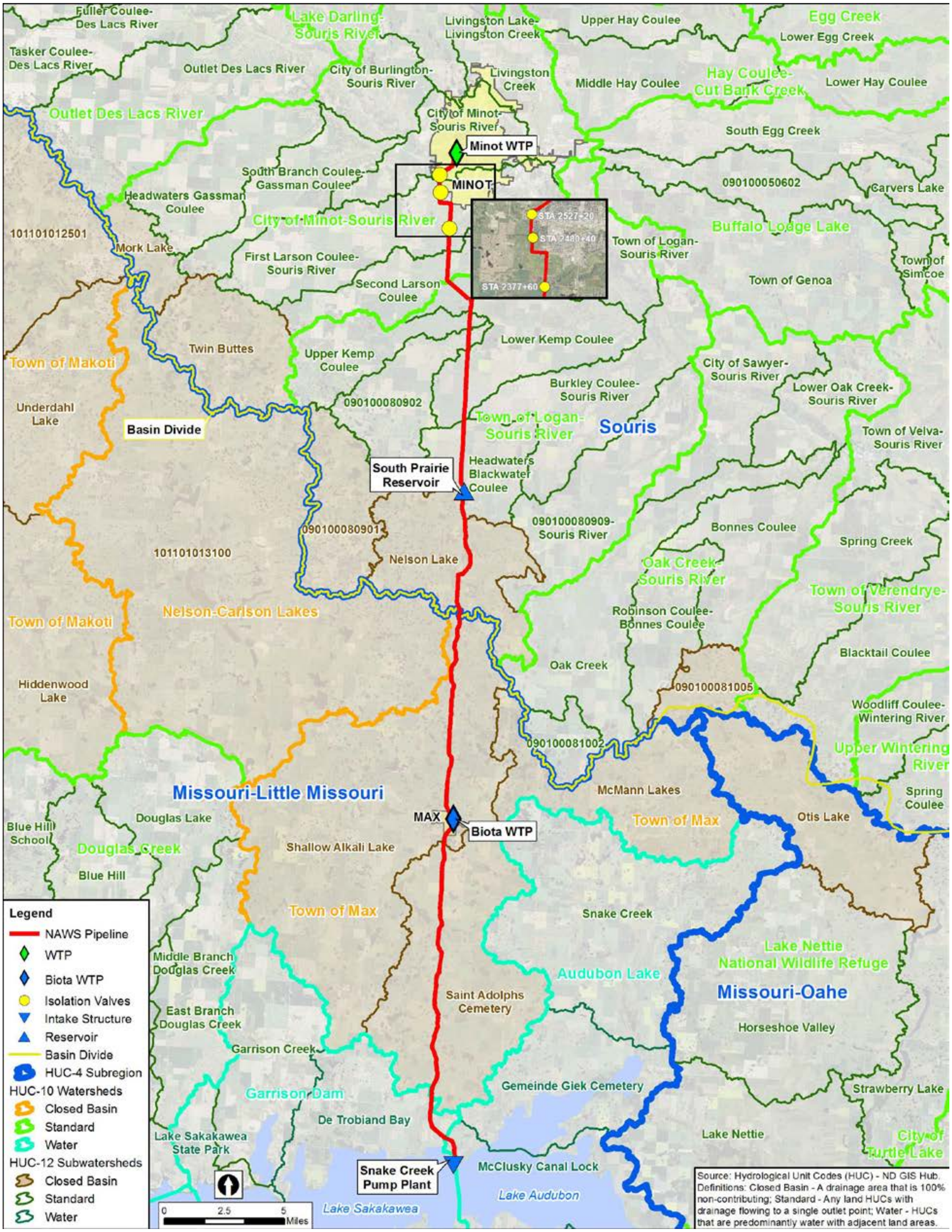


Figure 8 Contributing and Non-contributing Drainages

Source: USGS 2011c

For alternatives using Missouri River water, the Project intake would be located at or adjacent to the Snake Creek Pumping Plant. The deck of the pumping plant is at elevation 1,867 feet mean sea level, which is 8.5 feet above the elevation of Lake Sakakawea corresponding to the design discharge capacity of Garrison Dam (827,000 cubic feet per second). Thus, the risk of flooding the Project intake works is essentially zero. The pipeline does not cross any perennial or intermittent streams between Lake Sakakawea and the proposed biota treatment plant location at Max, North Dakota.

There are numerous isolated wetlands located along the pipeline route. Because the entire transmission pipeline is buried below the maximum frost depth, these wetlands pose a negligible risk to pipeline integrity, even if some wetlands were to inundate the pipeline right-of-way during high water years. The proposed location of the Biota WTP is on an upland site that has never historically been flooded. Thus, the risk of flooding at the Biota WTP would be negligible.

The transmission pipeline crosses underneath three intermittent streams between Max and Minot. The pipeline was directionally bored beneath the bed of these intermittent streams. Therefore, the risk of pipeline failure due to flood events at these locations would be very low. Additionally, automatic pipeline isolation valves are installed at each of these locations to reduce the volume of water that could be released if a catastrophic failure of the transmission pipeline were to occur.

The main transmission pipeline terminates at the Minot WTP, where Project water would be filtered and again disinfected prior to distribution. The Minot WTP lies adjacent to the Souris River, and thus is potentially vulnerable to flooding during extreme events. The City of Minot plans to construct additional levees at the plant to increase flood protection in the wake of the record flood that occurred in 2011.

The geographically-separated components of the proposed water transmission and treatment system would collectively work to reduce risks of interbasin transfer of AIS. Simultaneous failures at the Biota WTP and the main transmission pipeline or Minot WTP would be required for a release of untreated or undertreated water into a contributing drainage in the HBB. Potential failures of these components would likely be independent and uncorrelated. For example, equipment malfunction or power outage at the Biota WTP would not affect the integrity of the transmission pipeline or the operation of the Minot WTP. With multiple independent barriers in the proposed system, risk of release of Missouri River water would be low.

Further, the probability of an organism introduced to a subsurface soil (e.g., from a ruptured transmission pipeline) ‘migrating’ through a contributing region to the HBB, finding an appropriate host organism, successfully establishing itself in an ecosystem, and causing adverse effects to ecological receptors is also extremely low.

Risk of Biota Transfer from Non-Project Pathways

Potential non-Project pathways for transfer of AIS to the HBB include water diversions (without biota treatment), interbasin connections, aquatic pathways, animal transport, weather-related phenomena, and climate change. Some of these pathways do not require any water transfer (e.g., piscivorous birds or mussels attached to boat hulls), while others are entirely dependent on water. Most of the AIS evaluated in this analysis are exceptionally small and, therefore the potential exists for the transfer of thousands of organisms in a single drop of water. Many AIS have life histories that can increase in abundance without the need for locating reproductive partners.

Some require the location of a suitable and susceptible host and conditions that are favorable to the AIS. In some instances, it may take mutiple introductions for an invasive organism to firmly take hold and proliferate in a new environment.

The ability of some organisms to “self-preserve” can confound the evaluation of the timing of an introduction. For example, spore-forming organisms such as bacteria, fungi, and some protozoa can encapsulate themselves and remain viable for extended periods until encountering more favorable conditions (Bitton 1999; Madigan et al. 2003). Endospores can remain dormant and resistant to environmental extremes such as desiccation or radiation for several years with the ability to rapidly convert back to a viable vegetative cell (Madigan et al. 2003). Therefore, establishment could occur well beyond (both spatially and temporally) an initial release/transfer event. The risk of transfer and establishment exists for all of the pathways evaluated, as well as others not yet identified.

Even a small amount of biomass (in a small volume of transfer water) can distribute potential disease agents including viruses, bacteria, and protozoans. Ballast water discharge, animal transport, and fish stocking represent extremely important potential transfer pathways. Ballast water discharge also has the potential to introduce more exotic species compared to other biota transfer pathways (e.g., international vessel transportation). Birds and mammals can mediate transport across large geographic distances. However, some viruses exhibit a low tolerance to heat (ISAV) and would not likely survive the physiological conditions in such animal vectors (ISU 2010).

The risk of transfer from the MRB to the HBB is very low for AIS not currently present in the MRB. However, the presence of those AIS in adjacent drainage basins (Upper Mississippi region, Pacific Ocean basin, the Great Lakes) suggests that non-Project pathways could introduce AIS to the MRB and from there to the HBB. Bait buckets, aquaculture, ballast water discharge, fish stocking, and water recreation represent mechanisms with greater inherent risk for facilitating spread between basins than “natural” pathways, such as animal transport or weather-related phenomena. The successful establishment of invasive organisms via one of these non-Project pathways may have a low probability. However, in the long-term, even low probability events have the potential to eventually occur.

The successful introduction of an AIS in the HBB is much more likely to be caused by a high-probability pathway, such as those that involve relatively large transfers of untreated water or that occur repeatedly (such as the discharge of ballast water or water recreation activities). The risk of AIS transfer from some of these non-Project pathways can be limited by implementation of appropriate control mechanisms. However, the successful implementation of control mechanisms (e.g., boat inspections to control invasive mollusks) typically require widespread and consistent application.

Once a species has been transferred (through any pathway) and becomes established, subsequent introductions may pose little or no additional risk to aquatic ecosystems. In essence, the various pathways are competing to induce a biological invasion, and several non-Project pathways are very likely to introduce AIS to the HBB.

Uncertainty limits the ability to assign unique transfer risk probabilities to any of these biota transfer pathways. However, based on a qualitative assessment of the basin linkages and competing pathways, the risk of AIS transfer by the Project is considered to be extremely low compared to non-Project pathways.

Risk Posed by Aquatic Invasive Species of Concern

The virulence of pathogens and parasites and the invasion potential of AIS are unique and variable among strains and individual species (Cipriano et al. 2011; Gomez-Casado et al. 2011). Hosts may impact the speed at which a pathogen or parasite establishes in an aquatic system (Lafferty and Kuris 1999). Some pathogens can survive outside of their host organisms, while others have an obligate relationship and perish in the absence of that association (Lafferty and Kuris 1999). Life cycles of some parasites require multiple hosts, which can be a significant challenge to survival in a newly encountered ecosystem (Lafferty and Kuris 2002). There is a tremendous amount of uncertainty regarding both the physiological processes at the individual level and the relationship of biotic and abiotic factors in the environment that influence infection (Hedrick 1998; Peeler and Feist 2011).

The potential risk posed by AIS to HBB receptors is described below with an emphasis on invasive distribution and host susceptibility. AIS are considered a potential threat when ‘apparently’ absent from receiving waters, however, lack of detection does not rule out AIS presence. Uncertainty limits our understanding of the effects of additional transfers on expansion rates and ecosystem effects of AIS residents in the HBB. Therefore, the risk evaluation of individual species was primarily based on a presence/absence framework.

Viruses

CCV is present throughout all catfish-growing areas of the U.S. (Camas 2004). Impacts appear to be primarily limited to farmed catfish as CCV has not been detected in wild fish and impacts are likely to remain in regions of intensive catfish aquaculture (southern U.S. states), which does not include the HBB in North Dakota or the Province of Manitoba, for instance. Infection rarely leads to mortality in wild hosts (Thompson et al. 2005). Therefore, this virus does not appear to be of significant concern or risk to HBB catfish.

IHNV has been found in several U.S. states but appears to be most prevalent in the western U.S., specifically the Pacific Ocean basin (Figures A1-1 and A1-5) adjacent to the HBB, primarily affecting raised fish, including salmonids. The virus has also been found in South Dakota and Minnesota (ISU 2007a), although these detections were not recorded in the NWFHSDb (USGS 2011a). Based on its presence in adjacent watersheds, IHNV may pose some risk to susceptible wild and farmed salmonid hosts in the HBB.

IPNV may pose some risk to HBB receptors based on its cosmopolitan distribution and presence in salmonid populations in eastern Canada (Figures A1-1 and A1-4), as well as its potential to cause significant population declines in salmonid hosts. Non-Project pathways would likely be responsible for introduction to the HBB due to the apparent absence of IPNV in the MRB.

ISAV has not been observed in the MRB and is generally limited geographically to the coastal northeastern U.S. and Canada, primarily the Atlantic Ocean basin (Figures A1-1 and A1-4). ISAV does not currently pose a significant threat to receptors in the HBB due to its apparent distance from this drainage basin, as well as its low tolerance for heat, which would likely limit its survival probability in avian or mammalian digestive systems.

SVCV has already been detected in the Great Lakes region (Figures A1-1 and A1-4) and the Upper Mississippi region (Figures A1-1 and A1-6; Wisconsin and Minnesota) (ISU 2007b). The close geographic proximity of these systems to the receiving basin suggests a greater likelihood of non-Project pathway transfers of this organism. SVCV can also survive in water or sediment for several weeks. Farmed carp are the primary hosts, but the virus may also infect other fish species. The virus is usually transmitted horizontally but may also be spread by external parasites (e.g., leeches). Due to its presence in adjacent watersheds (other than the MRB), ability to spread via alternate vectors, and survivability outside of hosts, it is probable that SVCV may pose some risk to carp and other fish species in the HBB.

VHSV appears to be geographically limited to the Great Lakes region in North America (Figures A1-1 and A1-4). Therefore, non-Project pathways that link this area to the HBB could exhibit significant transfer risk. The virus is non-host specific and the presence of appropriate hosts and reservoir vectors in the HBB further increases the potential risk of VHSV establishment and impacts to fish receptors.

Bacteria

Based on the documented existence of BKD (*Renibacterium salmoninarum*), *Edwardsiella* spp., and ERM (*Y. ruckeri*) in the HBB, the threat of impacts related to future introductions (via Project or non-Project pathways) is considered extremely low.

Streptococcal bacteria, E. coli, *Legionella*, mycobacteria, *Pseudomonas aeruginosa*, and *Salmonella* spp. are ubiquitous in aquatic systems and likely already occupy niche habitat in the waterbodies of the HBB. As a result, these bacteria are not monitored as potentially invasive aquatic species in data repositories such as the NWFHSDb (USGS 2011a). In addition, pathogenic (fish) strains of Strep are uncommon. Furthermore, *Vibrio cholera* is significantly more common in warm, tropical regions. Therefore, the risk posed to fish and humans associated with future introduction of these bacteria are considered extremely low.

Flavobacterium spp. are widely distributed and abundant in aquatic systems throughout the world. These bacteria have the ability to infect a broad range of fish species and, therefore may pose some risk to receptors in the HBB. However, there is evidence of *F. columnare* infection associated with a channel catfish mortality event in the Red River within the HBB (Huberty 2008; see Section: Environmental Consequences). In addition, a strain of *Flavobacterium* with unknown pathogenecity was detected in the HBB during the Devils Lake study (Bensley et al. 2011). It is likely that columnaris disease is already present in the HBB.

The presence and documentation of impacts to native salmonids in the Great Lakes region indicate the potential for eventual spread of *Aeromonas salmonicida* to the HBB. It appears that pathogenic *Aeromonas* spp. may already be present in the HBB, based on evidence from a catfish mortality event (co-infection with *F. columnare* reported in the Red River in September 2007). Non-Project pathways including bait buckets, aquaculture, fish stocking, and avian and mammalian transport of various AIS represent mechanisms with greater inherent risk for facilitating spread between the Great Lakes and the HBB. For instance, aquatic invertebrates, propagules may remain viable and infectious in or on birds for distances exceeding 1000 km (600 mi) (Green and Figuerola 2005).

Mollusks

The probability of a New Zealand mudsnail invasion of the HBB through non-Project pathways is considered low to moderate but with high uncertainty by DFO (2011a). This uncertainty is due mostly to the fact that many transport pathways for the mudsnail are human-mediated, and therefore the control of these snails relies on education of the public (DFO 2011a). New Zealand mudsnails are easily spread by passive means when they attach to and are transported on vegetation or sediment affixed to waders, fishing tackle, boat trailers, or even birds and other wildlife (Proctor et al. 2007). Their small size, high fecundity, asexual reproduction, low susceptibility to predation, and relative hardiness have enabled the mudsnail to become an effective invader (DFO 2011a). Ultimately, the spread of this snail is expected to continue, and the species is likely to become established throughout the West, Midwest, and the coastal Northeast U.S. (Loo et al. 2007).

Zebra and quagga mussels are susceptible to several control methods including molluscicides, desiccation, thermal extremes, electrical currents, sonic vibrations, UV irradiation, ozone, chlorine, peracetic acid, and hypoxia (Benson et al. 2012b). The product Zequanox®, composed of dead cells of the microbe *Pseudomonas fluorescens*, was recently approved for the control of zebra mussels within enclosed systems and infrastructures by the EPA (Marrone Bio Innovations 2012). Live zebra mussels have not been reported in the Province of Manitoba to date (Manitoba Water Stewardship 2012c), although their ability to actively disperse as larvae suggests a high likelihood of eventual invasion of Canadian waterbodies via the Red River. Currently, zebra mussels have not been detected in Montana or North Dakota near or in Lake Sakakawea (Figure A1-21; USGS 2011b). Considering their recent success invading regions of North America, their geographic range is likely to expand to other suitable habitats throughout the HBB without facilitated movement by water diversions that lack biota treatment. Zebra mussels are currently present in the Red River basin near Wahpeton, North Dakota, Minnesota, and the Missouri River below Gavins Point Dam in South Dakota (Figures A1-25, A1-26, and A1-27; Manitoba Water Stewardship 2012c).

The quagga mussel is a hardy and adaptable invader that would likely establish itself in any suitable waterbody encountered. Quagga mussels have been detected in Colorado in the MRB (Figure A1-21) and throughout the Great Lakes region (Figure A1-22), but have not yet been found in the HBB (Figure A1-20; USGS 2011b). However, their current range in North America is rapidly expanding (Benson et al. 2012b), and the presence of quagga mussels in Colorado indicates that they may eventually disperse further throughout the MRB and beyond.

Parasitic Animals

The presence of lineage 3 *Tubifex* worms in the receiving waters of the HBB is unknown; however they are common in other regions of western North America. Infected fish are the most probable vehicle for the spread of *M. cerebralis* (Gates et al. 2008). Provided that there are no major barriers to trout migration, infected fish could travel to uninfected sites within and across watershed boundaries. Because *M. cerebralis* TAMs are intolerant of water temperatures above 15°C, the stretch of MRB water between Montana and Lake Sakakawea would not facilitate passive drift of TAMs. Mean July water temperature in the Missouri River near Culbertson, Montana between 2002 and 2004 was 21.5°C (USGS 2012). The general lack of susceptible hosts in the HBB, the biota treatment options designed to prevent AIS transfer (including *M. cerebralis*) at the Biota WTP in Max (Section: Biota Treatment Associated with Water Supply

Alternatives), and the environmental barriers that prevent natural expansion contribute to an extremely low likelihood of introduction and establishment via a Project transbasin water diversion. Of particular concern is the possibility that *M. cerebralis* may be spread via migrating birds and mammals (Gates et al. 2009, Koel et al. 2010). An introduction to the HBB would not necessarily lead to a successful invasion due to the lack of suitable host populations (salmonids), particularly in the Souris River. Susceptibility differs widely among salmonids, and lake whitefish vulnerability remains unknown; however, the species is particularly valuable to Manitoba (commercial and recreational fisheries) (Manitoba Water Stewardship 2010) and should not be overlooked as a potential host for *M. cerebralis* if it were to spread to the HBB.

Polypodium hydriforme is present in both the MRB and the HBB, and is likely a normal component of the freshwater parisitofauna of sturgeon species (Choudhury and Dick 1993). *Polypodium hydriforme* infection is rarely lethal to adult fish. Due to the documented presence of this parasite in the HBB and lack of potential to cause population-level effects, the risk of additional introductions is considered to be extremely low.

Because parasitic copepods are already present in the HBB, the risk of transfer is considered to be extremely low. The current distribution and ecology of *I. microcotyle* is largely unavailable, therefore transfer risk and potential impacts to ecological receptors in the HBB cannot be accurately evaluated. Considering how rare this flatworm appears to be in aquatic systems, the potential risk of transfer and risk posed to HBB receptors is estimated to be extremely low.

Protozoa

The Project is not expected to alter the prevalence or incidence of *Cryptosporidium parvum* in the HBB, as it is already widely distributed and common in HBB. Transfer of *E. histolytica* is not expected to alter the prevalence or incidence of it in the HBB, as the organism is known to have a cosmopolitan distribution. Approximately 10 percent of the world's population is infected with *E. histolytica*. A stool survey in the U.S. indicated that about five percent of the population harbors *E. histolytica* (Public Health Agency of Canada 2012).

Absent unscreened interbasin transfers of water, the risk of transfer of *I. multifiliis* is low due to the low survival rates of theronts and tomonts outside of their fish hosts. Although the parasite already has a worldwide distribution, it is most commonly a serious problem for intensive aquaculture programs (Francis-Floyd and Reed 1997).

Fungi

No risk of increased *Phoma* infections due to the Project is expected due to the vast geographic distribution and common occurrence of this fungus in nature. The risk to HBB receptors posed by these widely distributed and common organisms (*Exophiala* spp., *Saprolegnia* spp., *Achyla* spp., *Branchiomyces* spp., *I. hoferi,* and *P. herbarum*) is low. Most are opportunistic pathogens and are present in nature in a variety of habitats.

Cyanobacteria

Additional introductions of cyanobacteria to the HBB are not considered to be significant since the three AIS are already present. Increased cyanobacterial blooms are partially related to the presence of cyanobacteria and concentration of nutrients such as nitrogen and phosphorous. There is a greater prevalence of blooms in the HBB within waterbodies impaired by high nutrient loading, such as Lake Winnipeg. The risk and potential consequences of interbasin transfer of cyanobacterial AIS and their associated toxins (considered additional transfer since the three species are present in the HBB) would be negligible due to the ubiquity of these organisms in the environment including the receiving basin (e.g., Lake Winnipeg).

Consequence Analysis

This section presents a qualitative analysis of the potential environmental and economic consequences resulting from the establishment of AIS in the HBB. To inform the discussion of the potential consequences, the section provides additional information on AIS occurrence and the conditions that support their spread and also summarizes impacts of historical invasions of AIS and relevant species in other aquatic systems.

Conditions that Support Establishment of Aquatic Invasive Species of Concern

When introduced into a new environment, most organisms fail to become established and many that succeed only have minor effects on the newly encountered ecosystem (Williamson and Fitter 1996). However, some non-indigenous species may become invasive, reproducing and spreading rapidly with significant adverse consequences. Non-indigenous species can alter population, community, and ecosystem structure and function (Mooney and Drake 1986; Vitousek et al. 1996).

Invasive Fish Pathogens and Parasites

The impacts of fish pathogens and parasites on individuals and populations are highly dependent on both environmental and biological factors (Hedrick 1998; Lafferty and Kuris 1999). An appropriate combination of host abundance and environmental conditions is required to facilitate the establishment and maintenance of a pathogen or parasite in a newly encountered system (Peeler and Taylor 2011).

Relatively few published observational studies have adequately described disease incidence and dynamics at the population level. Population-level studies are labor-intensive and cost-prohibitive, which typically prevents them from being funded on non-commercial fish species (Peeler and Taylor 2011). The inclusion of non-commercial species in population studies would be valuable, because they can act as reservoirs for diseases impacting game fish and commercial fish alike (Peeler and Taylor 2011). The lack of baseline data regarding the frequency and prevalence of infections and diseases limits the ability to predict cumulative impacts from invasive species introductions (Hammell et al. 2009).

When examining the occurrence of disease in fish, it is difficult to assess whether impacts on individuals can or should be scaled to the population level (Peeler and Taylor 2011). The health effects caused by abiotic factors and other stressors in aquatic systems are currently not well understood. Another key question in determining the impact of pathogens on wild populations is whether the resulting mortality, reduced fertility, and low recruitment actually culminate in population declines (Peeler and Taylor 2011). Taken together, these uncertainties represent barriers to fully understanding the impacts of diseases and infection on the fitness, abundance, reproduction, distribution, and survival of populations of fish (Hammell et al. 2009).

Environmental factors such as dissolved oxygen, pH, temperature, flow, turbidity, and the presence of toxic contaminants can impact the health of fish populations (Hedrick 1998). Other environmental factors, such as high intensity of infection or stress caused by low dissolved oxygen, high carbon dioxide, high ammonia, elevated temperature, and toxins including pesticides can enhance the probability of a disease outbreak (Hedrick 1998; Lafferty and Kuris 1999). Many pathogens have the greatest effect on individuals in crowded conditions. Such conditions are encountered in fish farms where the infections are exacerbated by poor water quality and stress (Hedrick 1998; Peeler and Taylor 2011). On a population scale, wild fish tend to be less susceptible to these types of diseases, although climate change may cause temperature-induced mortality in wild fish species (e.g. the Arctic grayling) and amplify their susceptibility to pathogens and parasites (Wedekind and Kung 2010).

The virulence of pathogens may differ among strains, serotypes, or biotypes within individual species (Cipriano et al. 2011; Gomez-Casado et al. 2011). Hosts themselves may also impact how quickly a new pathogen or parasite settles into a novel system (Lafferty and Kuris 1999). Some pathogenic organisms are host-specific, while others are capable of infecting many species. The range of host species available, their developmental state, size, nutritional status, and immune defenses all affect their contribution to pathogen and parasite distributions (Iwanowicz 2011). While some pathogens may survive extended periods of time outside of their host during inactive stages, others may require a host during their entire life cycle (Lafferty and Kuris 2002).

Due to the high degree of uncertainty associated with individual impacts from pathogenesis and the nexus with population-scale effects, potential environmental consequences related to invasive species introduction are difficult to predict. This lack of predictive ability warrants the evaluation of historically observed effects of similar organisms in other aquatic systems.

Effects of Aquatic Invasive Species of Concern in Other Systems

AIS can cause detrimental effects to vulnerable ecosystems following successful propagation and establishment. Current and historical scientific literature was examined to gather information regarding observed environmental impacts from documented invasions in other aquatic systems. The literature review did not yield documented impacts for all AIS evaluated during this *Transbasin Effects Analysis*. However, the identified examples provide a basis to qualitatively describe potential environmental consequences in the HBB.

Viruses

Viruses can have ecological impacts on both wild and cultured fisheries. Many viruses have a greater impact on hatchery fishes due to the increased availability of hosts, reservoirs, and frequent poor water quality conditions in these crowded facilities.

Infectious Hematopoietic Necrosis Virus

The presence of IHNV is positively correlated with host density. Other factors associated with high host density include decreased water quality, increased stress, impaired immune function, and increased contact with diseased individuals. Cumulative mortalities of greater than 90 percent have been recorded for infected farmed fish (ISU 2007a). Mortalities from IHNV were first noted in the Pacific Northwest of the U.S. in the 1950s.

Infectious Pancreatic Necrosis Virus

IPNV was first isolated in Canada by Wolf et al. (1960). The virus was later identified in Fisheries Branch tests at a Grand Rapids, Manitoba fish hatchery in 2006. IPNV is a highly contagious aquabirnavirus disease of young fish. Although it is sometimes found in wild fish, IPNV most often affects salmonid species reared in hatcheries (McAllister 1983). The infected Manitoba hatchery responded to the virus by completely eliminating all fish reared at the facility followed by disinfection of all tanks, surfaces, and rearing ponds prior to restocking. IPNV has not been detected at the Grand Rapids hatchery since 2006. Mortality rates vary based on virulence of the IPNV strains; Marjara et al. (2011) reported an 81% decline of infected hatchery Atlantic salmon.

Infectious Salmon Anemia Virus

Mortalities caused by ISAV (*Isavirus* spp.) were first reported in Norway in 1984 (ISU 2010). By 2010, the virus was affecting fish in Chile, the U.S., Canada, and Scotland. The Faroe Islands were particularly impacted by ISAV when its valuable commercial salmon industry was devastated (ISU 2010). The Province of New Brunswick has reported annual losses to their salmon industry purportedly related to ISAV infection (ISU 2010).

Spring Viremia of Carp Virus

SVCV (*Rhabdovirus carpio*) primarily affects farmed carp but can also occur in wild carp and some other fresh water fishes (Ahne et al. 2002). In 1989, carp deaths were attributed to the virus in Wisconsin; and in 2002, an SVCV outbreak in Cedar Lake, Wisconsin led to the death of more than 1,500 carp (Cipriano et al. 2011). Shortly thereafter, mortalities also occurred in North Carolina (Cipriano et al. 2011). By 2007, SVCV was identified in Washington, Ohio, Illinois, Missouri, and Ontario.

Viral Hemorrhagic Septicemia Virus

Expansion of VHSV throughout water bodies is generally slow and dependent upon the movement of infected fish (Warren 1983a). When fish kills occur in spring, large amounts of the virus are released into the water as the dead fish decompose. VHSV affects a wide variety of fish, several of which inhabit the HBB including black crappie, lake whitefish, largemouth bass, muskellunge, rainbow trout, sauger, smallmouth bass, walleye, white bass, and yellow perch (Michigan DNR 2012). The disease had spread throughout the Great Lakes by 2010 (ISU 2012) leading to recorded mortalities of largemouth bass in Budd Lake, Michigan. The mortalities caused by VHSV have exceeded 100 metric tons (MT) of fish in the Great Lakes (Michigan DNR 2009).

Bacteria

Bacterial pathogens spread easily among fish and are often difficult to treat. Their presence in wild populations may go undetected until significant mortalities occur within a population. Diseases such as ERM can cause low-level sustained mortality that can result in significant losses over time.

Bacterial Kidney Disease

Renibacterium salmoninarum is an obligate pathogen of salmonids. Outbreaks usually occur in the spring, spread slowly (Warren 1983a), and are dependent upon water temperature and hardness as well as both the species and densities of hosts present (Warren 1983a). BKD can occur in both farmed and wild salmonids. Harsh environmental conditions can weaken host resistance and facilitate outbreaks of BKD (Warren 1983a).

BKD was first detected in Massachusetts in the 1930s. The occurrence of the disease was associated with Chinook salmon mortalities between 1988 and 1992 (Sanders and Fryer 1980; Kipp 2007b). By 2007, BKD had spread throughout much of the northern hemisphere and south to Chile (Kipp 2007b).

Renibacterium salmoninarum was identified in 12 percent of Chinook salmon collected in Oregon waters (Arkoosh et al. 1998), although not all fish were symptomatic. About 40 percent of wild Pacific salmonids have disappeared from their historical breeding ranges (Wildness Society 1993 as cited by Arkoosh et al. 1998). This decline cannot be definitively associated with BKD due the multitude of other factors potentially at work including aggressive commercial fishing harvest, degradation of spawning habitat, and physical barriers that prevent fish passage such as hydroelectric dams (Arkoosh et al. 1998).

Columnaris Disease

According to the NWFHSDb, *F. columnare* has been reported in various fish species (e.g., Chinook salmon, mountain whitefish, American shad, and black crappie) from several states. An identified species of *Flavobacterium* was also identified in a fish collected from Manitoba waters during the Devils Lake study, however, it is unknown whether the particular strain was pathogenic (Bensley et al. 2011) (Figure A1-8). In addition, this bacterium appears to have been the partial cause of mortality for at least 1,626 channel catfish in the Red River near Grand Forks, ND in September 2007. Internal and external lesions from two moribund (approaching death; about to die) channel catfish examined at the MnDNR pathology laboratory were consistent with bacterial infections including columnaris disease (Huberty 2008). Columnaris disease also appears to have been responsible for mortalities of black bullhead in the Souris River in the Upper Souris River National Wildlife Refuge in North Dakota. Shallow dermal lesions from moribund individuals examined at the Service’s Bozeman Fish Health Center were consistent with columnaris disease (Service 2012a). Other bacteria and parasites were identified, however, lesions appeared to be predominantly colonized by *F. columnare*, which was likely the cause of black bullhead mortality.

Enteric Redmouth Disease

ERM was introduced to France in a shipment of live minnows from the U.S. in 1981 (Peeler et al. 2011). The disease affects salmonids and other fish in fresh and seawater. Since it was first reported, the disease has spread to virtually all trout producing regions of the U.S., Canada, and Europe (Bullock 1984). The causative bacterium, *Yersinia ruckeri* expanded throughout Europe and currently causes significant yearly mortalities and monetary losses (Tobback et al. 2009).

Furunculosis

The pathogenic nature of *A. salmonicida* was first observed in Germany, but its geographic origin remains unknown (Mills et al. 1993). The NWFHSDb (Service 2011a) reports *A. salmonicida* from several western and eastern U.S. states (Figures A1-7, A1-10, and A1-11), none of which are located within the HBB (Figure A1-8) or MRB (Figure A1-9).

However, it appears that pathogenic *Aeromonas* spp. were implicated in a catfish mortality event reported in the Red River near Grand Forks, North Dakota in September 2007 (Huberty 2008).

Internal and external lesions from two diseased channel catfish were consistent with a bacterial co-infection, which included *Aeromonas* spp. and columnaris disease (see above) (Huberty 2008).

Streptococcal Fish Infections

Strep in fish is not common, but can occasionally result in high mortality, particularly in aquaculture settings. Species from the genera *Streptococcus*, *Lactococcus*, *Enterococcus*, and *Vagococcus* can cause streptococcal infections in fish. Many species of fish are susceptible to Strep, including salmon, mullet, shiners, rainbow trout, hardhead catfish, Japanese eel, Atlantic croaker, silver trout, green sunfish, bluegills, pinfish, tilapia, sturgeon, and striped bass (Inglis et al. 1993). Strep bacteria are often opportunistic, and some strains may be present in nature at low levels. Infections are often associated with stressful conditions and poor water quality, such as high ammonia or nitrate levels common in aquaculture settings (Yanong and Francis-Floyd 2006). Infections occur in both fresh and salt water (Bullock 1981). In 2001, a streptococcal outbreak caused a 40-60 percent cumulative mortality of farmed tilapia over a 2-week period in the Mekong River in Thailand (Yuasa et al. 2005).

Parasitic Animals

Internal and external parasites are ubiquitous in nature. Many are obligate parasites of fish, damaging tissues directly or causing imbalances in bodily functions leading to indirect health effects. The presence of the final hosts (and possibly intermediate hosts) is critical for the invasion of many parasites.

Myxobolus cerebralis

Whirling disease is known to cause physical deformities and mortality in juvenile salmonid fishes. Whirling disease presents a serious threat to coldwater fisheries in North America and has been implicated in the decline of sensitive trout populations. The numerous variables involved in the life cycle of *M. cerebralis* and manifestation of whirling disease, which makes prediction of disease spread particularly complex (Duffield et al. 1999). While the affects on individual fish are well established, managers are interested in assessing population-level impacts of the disease (McMahon et al. 2010).

McMahon et al. (2010) found that juvenile rainbow trout (less than nine weeks old and less than 40 mm long) in the Madison River in Montana suffered a 50 percent decline due to whirling disease. In Colorado’s Gunnison River, fry and fingerling trout recruitment was severely impacted by the disease and was followed by a 99 percent decline of trout populations in the river (Elwell et al. 2009). Cutthroat trout suffer the highest mortality rates of all susceptible trout species (Nehring 2006). A 99 percent decline in cutthroat populations occurred following the establishment of whirling disease in the Yellowstone River region (Alexander 2010). In the Madison and Missouri rivers (“blue ribbon reach” in western Montana), a 50-80 percent decline in yearling production of rainbow trout was recorded. During the monitoring period, however, the number of adult trout greater than two years old was stable and normal (Leathe et al. 2002).

There is some concern that whirling disease might lead to possible food chain effects because trout are important prey items for larger carnivores such as bears and eagles (Steinbach et al. 2009). Additional ecological impacts might include changes in community structure of a water body. For example, when rainbow trout populations decline, another species such as the brown trout, which has greater resistance to whirling disease, may increase in numbers (Granath et al. 2007). Such shifts can impact entire food webs.

Trout are important recreational and subsistence fish so the decline in trout fisheries from whirling disease is also of economic concern. Impacts to recreational fishing, private fish culture, government research, and revenue for fishing communities could be impacted by the disease (Steinbach et al. 2009). Despite concerns over wild rainbow trout population declines in Rock Creek, Montana, anglers still report satisfaction despite reduced catch. It is possible that anglers may choose to fish in nearby alternative streams (Steinbach et al. 2009). Some rainbow trout appear to be developing a genetic resistance to whirling disease, and some populations may be more robust than others (Whirling Disease Steering Committee 2009).

Geographic location and water temperature impact the probability of whirling disease occurrence. Water temperature directly affects susceptibility to the parasite as it impacts fry emergence times and growth rates (Elwell et al. 2009). Widely fluctuating temperatures are also known to affect infection rates and variable conditions may weaken the physiological condition of fry (Murcia 2008; McMahon et al. 2010). Additionally, flow rate changes between spring and summer can decrease infection severity by diluting the availability of actinospores in the water column (Vincent 2002; Hallett and Bartholomew 2008).

Polypodium hydriforme

Polypodium hydriforme is present in both the MRB and HBB and is likely a natural component of the parasitofauna of sturgeon species in the region (Choudury and Dick 1993). If a high percentage of sturgeon females were infected and a high percentage of their eggs were parasitized by *P. hydriforme*, it is possible that the reproductive potential of the population could be compromised. Sepúlveda et al. (2010) recorded infection prevalence of 18 percent for female shovelnose sturgeon (*Scaphirhynchus platyrhynchos*) from the Wabash River, Indiana. Thomas and Muzzall (2009) recorded a *P. hydriforme* infection prevalence of 67 percent among sampled female lake sturgeon (*Ascipenser fulvescens*) from Lake St. Clair, Michigan. Lake St. Clair sturgeon, however, have shown consistent recruitment for over 20 years, suggesting that the parasite is not negatively affecting the population size (Thomas and Muzzall 2009).

Parasitic Copepods

Parasitic copepods are common parasites of fish in the wild but usually do not cause significant stress to populations. Sea lice are a common parasite of farmed salmon and have been known to cause declines in wild salmon that inhabit waters near farmed areas (Krkosek et al. 2011). The genera of parasitic copepods (*Actheres* and *Ergasilus*) evaluated during this analysis have never been demonstrated to impact wild fish populations.

Fungi and Fungi-like Infections

Many fungi are opportunistic or primary pathogens of fish. Fungal infections are usually facilitated by stressful environmental conditions such as over-crowding or poor water quality and are more common in cultured than wild fish populations.

Phoma herbarum is a weakly-infectious facultative pathogen of fish and other animals that causes systemic infection in salmonids, although it is normally a pathogen of plants. The fungus invades the air bladder, digestive tract, and other organs causing hemorrhaging, gut obstruction, peritonitis, and necrosis (Meyers et al. 2008). The fungus caused a 65 percent cumulative mortality of fingerling Chinook salmon when experimentally injected with the fungus. However, mortality was not observed via oral or airborne exposure (Burton et al. 2004).

Saprolegnia fungal infections have been known to cause high mortality of farmed fish, including a $40 million USD (U.S. Dollars) economic loss of catfish in the southeastern U.S. (Mayer 2000). In Japan, facilities have observed 50 percent annual mortalities of farmed coho salmon and channel catfish (Mayer 2000).

The *Exophiala* fungus has a cosmopolitan distribution (Nucci et al. 2002). *Exophiala* infections caused mortalities of cultured striped jack in Japan in 2005. During that outbreak, approximately nine percent of farmed fish died per day for an entire month (Munchan et al. 2009). *Exophiala* infection has been documented in cutthroat trout, lake trout, channel catfish, Atlantic salmon, Atlantic cod, smooth dogfish, King George whiting, and others (Munchan et al. 2009). Fatal cases of *Exophiala* have been documented in humans; the fungus is considered an important nosocomial pathogen (Nucci et al. 2002).

Ichthyophonus hoferi is a fungus-like protozoan that causes chronic, progressive internal infection in wild and cultured freshwater, marine, and estuarine fish (Kramer-Schadt et al. 2010). Large epizootics of *Ichthyophonus* have occurred in Europe, the U.S., and Japan (Gavryuseva 2007). It causes lesions on the heart, liver, spleen, kidneys, skin, and muscles and has proven particularly lethal to herring (The Merck Veterinary Manual 2011, Kramer-Schadt et al. 2010). A 1991 outbreak of *I. hoferi* caused a crash in herring populations (Patterson 1996). Herring are particularly susceptible to *I. hoferi* infection and because they are also a intensively harvested food fish, they are more likely to experience population-level impacts from this infectious agent.

Non-pathogenic Invasive Organisms

Mollusks

Mollusks are known for their ability to colonize water supply pipes of hydroelectric and nuclear power plants, public water supply plants, and industrial facilities causing flow constriction and ultimately reduced intake function. Mollusks are able to disperse rapidly throughout the environment via connected waterways and overland travel (boats transported by trailer). Mollusks can have major effects on invaded ecosystems by competing directly with native organisms for food and space, and indirectly by altering parasite communities (Brown et al. 2008).

Mussels

When zebra and quagga mussels are introduced into a previously uncolonized system, they reproduce at a rapid rate and displace other more energy-rich food sources, which leaves fish and other aquatic species with fewer food options (NOAA 2012; USGS nd.). Given these effects, the colonization of zebra mussels is expected to significantly alter the food web compositions in invaded systems (New York State Dept. of Environmental Conservation 2012; USGS nd.). Zebra and quagga mussels primarily consume phytoplankton through filter-feeding but also remove other suspended material from the water column, including bacteria, protozoa, mussel larvae (veligers), microzooplankton, and silt. While zebra and quagga mussels have many similarities, they currently have differing spatial distributions. Both zebra and quagga mussels are thoroughly established in the Great Lakes; however, there is a gradient of dreissenid distribution in Lake Erie. Quagga mussels dominate the western portion of the lake and zebra mussels dominate the eastern portion (Benson et al. 2012b). Quagga mussels appear to be displacing zebra mussels in some areas, including southern Lake Ontario, and quagga mussels may become the dominant dreissenid species (Benson et al. 2012b).

One of the more detrimental impacts of mussel invasion is an increase in the biomass of cyanobacteria. Several factors contribute to this increase, including: zebra mussels' ability to filter-feed large quantities of water; selective filtering which allows rejected species to become dominant to other taxa; and alteration of the concentrations and ratios of plant nutrients that promote cyanobacteria dominance (Dzialowski 2010, Holeck 2008). Increased biomass of cyanobacteria can have implications on the quality of drinking water due to the production of algal toxins by several taxa (Dzialowski 2010).

In the Hudson River of the northeastern U.S., phytoplankton biomass declined 85 percent following a zebra mussel invasion (Benson et al. 2012a). Such a decrease in biomass can result in increased water clarity, allowing sunlight to penetrate deeper into the water column where macrophytes (aquatic plants) can become established in areas they were previously absent (Karatayev et al. 2007). Conversely, macrophytes can be colonized by mussel veligers, which can be detrimental to the plant community, causing a decrease in oxygen, cover for fish, and substrate for aquatic invertebrates. In addition, as phytoplankton is consumed, dissolved organic carbon concentrations may decline (Benson et al. 2012a).

Zooplankton can also be affected by mussel invasion. Zooplankton abundance dropped 55-71 percent following the 1989 invasion of Lake Erie, and 70 percent following the 1992 invasion of the Hudson River (Benson et al. 2012a). These effects are attributed to reduction of available food (e.g., phytoplankton) and direct predation of microzooplankton. Increased competition in the zooplankton community for newly limited food could also likely result from mussel invasion. Effects of invasion could reverberate through the foodweb, eventually affecting higher trophic levels such as fish (Raikow 2004).

Reductions in zooplankton biomass may cause increased competition, decreased survival, and decreased biomass of planktivorous fish. The expansion of zebra and quagga mussels has led to a decline in the amphipod *Diporeia,* the dominant benthic macroinvertebrate in offshore waters of the Great Lakes (NOAA nd). Dreissenid mussels have interrupted the foodweb by filtering out organic material such as diatoms which are the main food source for *Diporeia.* This has affected many Great Lakes fish that rely on *Diporeia* as a food source (NOAA nd). Additional studies have concluded that production and growth of fish is directly impacted by the presence of dreissenid mussels. Larval bluegill reared in the presence of mussels grew 24 percent slower than fish reared in the absence of mussels. The effect was attributed to competition for microzooplankton. Additionally, the zooplankton experienced starvation as zebra mussels consumed most of the available phytoplankton during the experiments (Raikow 2004).

While bivalve grazing appears to reduce plankton abundance, which presumably is the pathway responsible for the largest declines in abundance and growth rates of open-water fish, most studies of zebra mussel invasion have reported small or no effect on the fish community (Strayer et al. 2004). In the presence of zebra mussels in general, planktivorous fish would be negatively affected, littoral zone fish would benefit, and there would be little to no change in the pelagic food web (Strayer et al. 2004 and Idrisi et al. 2001). However, the magnitude of these changes could vary widely across ecosystems. Furthermore, primary production does not seem to be affected by zebra mussels. This lack of affect could be attributed to increased water clarity resulting in deeper sunlight penetration (Idrisi et al. 2001).

Wild lake whitefish may have exhibited adverse effects following the introduction of zebra and quagga mussels. The body condition of lake whitefish in southern Lake Michigan was monitored following zebra mussel invasion. As the proportion of *Diporeia* in the diet decreased, the proportion of mussels in the diet increased. Overall body condition and growth of the fish declined and is assumed to be an effect of consumption of prey with lower energy content, such as dreissenid mussels (NOAA nd). Following the invasion of Lake Ontario, lake whitefish experienced near reproductive failure for five consecutive years (Hoyle et al. 2008). A decrease in juvenile and adult abundance was observed, which was attributed to decreased juvenile survival, significant declines of adult body condition, and reduced production of young of the year fish (Hoyle et al. 1999). This appeared to be a direct result of diet replacement by low nutritional zebra mussels from previous prey items; zebra mussels were present in 90 percent of whitefish stomachs (Hoyle et al. 1999; 2008). Lake whitefish fishery declines resulted in reduced quota for commercial fishermen (Hoyle et al. 2008). Lake Ontario whitefish have begun adopting new life history strategies involving slower maturation and growth, presumably in response to dreissenid invasion (Hoyle et al. 2008). Additionally, habitat changes occur in response to dreissenid filtering, including increased water clarity, resulting in the colonization of new plant species and creating habitat for previously absent fish (e.g., bluegill, crappie) at the expense of lake whitefish.

New Zealand Mudsnails

The New Zealand mudsnail was first detected in the U.S. in 1990 in the Snake River, Idaho (Kerans et al. 2005). By 2005, it had spread throughout waters in much of the western U.S. The presence of New Zealand mudsnails in an ecosystem can alter or impair the food web and affect interactions among native macroinvertebrates (Kerans et al. 2005; Brown et al. 2008; Riley et al. 2008; Arango et al. 2009). These effects can lead to reductions of valuable fisheries in extreme situations such as a food web crash. This snail frequently becomes a major dietary component of many native species in invaded aquatic systems. Unfortunately, they are generally indigestible and therefore yield no nutritional value (Oplinger et al. 2009). Publications have noted New Zealand mudsnails reaching a mass capable of overpowering grazing areas of native invertebrates ultimately leading to reductions of algae in the water column (Kerans et al. 2005).

Cyanobacteria

Several species of photosynthetic cyanobacteria produce toxins that can be harmful to wildlife and humans. These species can form toxic blooms, which can lead to closures of recreational waters and increased water treatment costs. Blooms typically occur in lakes with high chlorophyll concentrations and low water transparency during calm conditions characteristic of the late summer months (Environment Canada 2011b). Toxin production is less predictable than cyanobacterial bloom occurrence (Havens 2008).

Cyanobacteria blooms may cause a wide range of biological effects including: potential toxic effects on other algae, invertebrates and fish; impacts to plants and benthic algae due to shading; and impacts to food web function as large inedible mats produce a bottleneck to carbon and energy flow in the food web (Havens 2008). Accumulation of organic material in sediments and subsequent increased bacterial activity can lead to dissolved oxygen declines in lakes with dense blooms. As cyanobacteria die and decompose, dissolved oxygen is depleted in the process sometimes leading to fish kills (Environment Canada 2011b). Eutrophication of a waterbody can also promote fish disease as cyanobacterial blooms decompose in summer leading to reduced dissolved oxygen concentrations (Environment Canada 2011b). In addition, eutrophic conditions can lead to higher growth rates of intermediate invertebrate hosts and some bacteria (Havens 2008; Environment Canada 2011b).

Dense blooms of cyanobacteria can lead to anoxic conditions caused by the accumulation of organic material in lake sediments and increased bacterial activity; this can alter the structure of benthic macroinvertebrate communities (Havens 2008). Furthermore, diffusive internal nutrient loading and bottom water anoxia may lead to a loss of fish that require a summer deep cold water refuge in temperate lakes (Havens 2008). Ecosystem changes associated with frequent blooms may result in a delayed response of lakes, rivers, and estuaries to external nutrient load reductions.

When cyanobacterial blooms occur, sunlight penetration is reduced in the water column, reducing the growth of other photosynthetic organisms including epiphyton, benthic algae, and rooted vascular plants (Havens 2008). Therefore, lakes with frequent or long–lasting dense blooms may not support a healthy diversity of photosynthetic organisms. In shallow eutrophic lakes, transition from plant to phytoplankton dominance can occur rapidly (Havens 2008). These lakes may cycle their plant/phytoplankton dominance from year to year depending on the early growing season conditions.

Toxins produced by certain species of cyanobacteria, and released upon cell rupture during bloom decomposition can lead to a wide range of biological impacts (Havens 2008) including:

- Suppression of zooplankton grazing, leading to reduced growth and reproductive rates and changes in dominance
- Hepatotoxic (kidney) effects on fish and accumulation of toxins in tissues of invertebrates and fish
- Reduced survival, growth, and fecundity of snails
- Accumulation of toxins in freshwater clams leading to toxicity in muskrat and their predators
- Impacts to waterfowl due to reduced water quality, food abundance and quality, and habitat loss

Gastropods may uptake cyanotoxins by feeding on cyanobacteria directly or absorption from the surrounding water (oral water uptake, trans-tegument penetration, gill or pulmonary breathing) (Lance et al. 2010). Pulmonate snails such as *Physa* spp. (e.g., *Physa winnipegensis*, the Lake Winnipeg physa) are more tolerant of cyanobacterial toxins than prosobranch snails (e.g., New Zealand mudsnail) and are less likely to experience population-level impacts. It is therefore hypothesized that cyanobacterial proliferations may indirectly influence competitive interactions by favoring the most tolerant snails (Lance et al. 2010).

Fish are also susceptible to the toxic effects of cyanobacteria. Toxin susceptibility has been observed in species including salmon, minnows, and sunfish (Ernst et al. 2006). Fish kills may be the result of toxin ingestion, reduced oxygen availability as a result of significant ‘blooming,’ or both (Dodds et al. 2009).

Cyanobacterial blooms may also directly enhance phosphorous loading to surface waters, if cyanobacteria capture this element near the sediment surface and migrate vertically in the water column. Estimates of phosphorous loading by this process range from 2.0 to 3.6 milligrams phosphorous per square meter per day (Havens 2008). Bunting et al. (2010) indicated that potentially-irreversible changes can occur in an ecosystem due to nutrient (phosphorus, nitrogen) loading such as increased frequency of cyanobacterial blooms. A nutrient influx reduction would be required to decrease cyanobacterial blooms in an aquatic system (Bunting et al. 2010).

In addition, cyanobacteria can lead to increased drinking water treatment costs. Boiling alone is insufficient to remove the toxins; activated carbon filtration, UV irradiation, and ozonation are needed for removal and destruction of cyanobacterial toxins (Environment Canada 2011a).

Potential Environmental Consequences in the Hudson Bay Basin

The potential consequences of an AIS becoming established in the HBB are independent of the transfer mechanism and would likely only vary by the species introduced and the location of the introduction. Transfer pathways represent distinct sources of AIS. Invasive organisms may impact an aquatic ecosystem by infecting native species (direct impact) or by causing community shifts (indirect impact). Impacts resulting from spread and establishment of introduced species may be unique based on the mode and severity of infection within preferred hosts and the potential for adverse effects translated to the population level. The potential environmental consequences described in this section are not specific to any one pathway of introduction and are presented separately for each AIS evaluated.

A broad range of life histories were considered to systematically evaluate the potential risk and consequences of AIS transfer to the HBB. It is possible that some of these species could have an impact in a newly encountered aquatic system; however, others likely would not. Uncertainty in the context of predicting potential effects is enormous. Aquatic systems are characterized by unique environmental conditions that are site-specific and highly variable in terms of the interrelationships of abiotic factors and members of biological communities (Peeler and Feist 2011). Few studies have been conducted on the impact of pathogens on free-living fish, and the effects of pathogens on wild fish populations are even more limited (Gozlan et al. 2006). The pathogens that have been studied tend to be those that cause immediate and negative consequences, usually in the form of epidemics, such as whirling disease (Gozlan et al. 2006). Despite whirling disease having been studied more thoroughly than many other fish pathogens, there is still uncertainty about the complex interactions between host, pathogen, and environment, making best management strategies difficult to discern (Gozlan et al. 2006).

It should not be assumed that an aquatic system would necessarily be negatively impacted by introduced AIS. Furthermore, adverse impacts are not always highly deleterious. In some cases, the introduction of novel species may even drive an ecosystem to higher production and diversity (Rosenzweig 2001; Sax and Gaines 2003; Rand and Louda 2012). However, this study employed a conservative approach by assuming that AIS establishment would more likely result in negative impacts in the HBB.

Fish species that are potential hosts for AIS, such as walleye, have wild populations in the MRB including Lake Sakakawea. There is little evidence that robust potential host populations in the HBB should suffer greater detrimental effects from introductions than their conspecifics in the MRB. Epidemiological models predict that the number of hosts available directly determines the transmission potential of parasites. A minimum or threshold number of hosts is required for the establishment of most parasites or pathogens (Bagge et al. 2004). Some AIS examined occur in the MRB but have not yet been identified in the HBB; including the New Zealand mudsnail and *Myxobolus cerebralis* (whirling disease).

There is generally a stepwise process for invasive species establishment in aquatic systems. First, an organism is introduced to a system via a biota transfer pathway. Second, the organism is faced with the challenge to increase in numbers and expand throughout a system. Finally, an effect, which may be either beneficial or adverse, is generally detected or observed (Bartell and Nair 2003). The time elapsed prior to detectable effects may be significant, therefore it is nearly impossible to identify the source and timing of an introduction.

A common effect of aquatic invasions, and disturbances of ecosystems in general, is to alter the relative abundance or rank dominance of species. For example, while populations of rainbow trout have crashed following outbreaks of whirling disease in some Montana streams, the numbers of brown trout have increased (Granath et al. 2007).

Case histories of historical aquatic invasions indicate that it is difficult to predict the impacts of species introductions due to site-specific environmental conditions that directly influence the outcomes (Moyle and Light 1996). Historical information does, however, provide observational evidence for the consequences of AIS transfer. Qualitative suggestions for potential environmental consequences are provided herein based on historical observations described earlier in this section.

Potential Environmental Consequences from Viruses

Fish viruses tend to have the most significant impact on individuals and populations experiencing stress, such as those contained in aquaculture facilities (Gomez-Casado et al. 2011). Detection of viral infections in rearing facilities usually results in the elimination of contained fish and sterilization prior to returning to normal operations. Therefore, a single observed infection (in a facility within the HBB) could have ‘indirect’ population-level impacts (anthropogenic eradication rather than population-level effects directly caused by the infectious agent) when fish are euthanized to eradicate a viral pathogen from a aquaculture facility.

Viruses are not exclusive to infecting farm-raised fish, as IPNV, ISAV, and VHSV have caused significant mortality of wild fish (Shankar and Yamamoto 1994; ISU 2010; MnDNR 2011). VHSV, in particular, has caused severe impacts in the Great Lakes due to its potential to cause mortality to a variety of host species (ISU 2007c). The spread of viruses depends upon a suite of criteria including host density, abiotic habitat features, virulence, etc. (Arkoosh et al. 1998). Most viruses examined herein are transferred either horizontally via feces, urine, or direct contact or vertically from parent to egg/offspring. Transfer is facilitated by crowding and susceptibility appears to increase with stress, which is why hatchery fish appear most affected by viral outbreaks. Because no large aquaculture facilities have been identified in the HBB, the spread of viruses via farmed fish would likely be minimal. In addition, catfish are not intensively farmed in Manitoba, therefore CCV infection, and related impacts, would be unlikely (Statistics Canada 2009).

Potential Environmental Consequences from Bacteria

Large-scale ecological and environmental impacts related to bacterial fish infections are not well characterized in the published literature. Information gathered was limited to bacterial infections already present in the HBB (BKD and ERM) or ubiquitous in aquatic systems (Strep). Stressful environmental conditions characteristic of impaired water bodies with poor water quality may compromise immune systems of host fish and facilitate outbreaks (Meyer et al. 1983). Most bacterial infections of fish are spread horizontally, fish-to-fish, and are therefore more likely to negatively impact aquaculture facilities than wild fish located in the HBB. In aquaculture settings, introduced pathogens could include direct mortality of infected individuals or elimination of reared populations as a consequence of standard management actions. Impacts to wild fish including declines of fish stocks are possible; however, there is uncertainty regarding the influence of infection on reproduction and recruitment and how that translates to effects at the population level.

Several of the bacterial AIS were found to be present in the HBB (*Aeromonas* spp., *R. salmoninarum*, *Flavobacterium* spp., *Edwardsiella* spp., and *Y. ruckeri*) or widely distributed and ubiquitous in aquatic systems of North America (*P. aeruginosa*, *V. cholera*, *Mycobacterium* spp., E. coli, *Legionella* spp., and *Salmonella* spp.), and therefore would not pose a "new" risk to HBB receptors. In addition, concentrations of bacterial pathogens are related to environmental factors (e.g., nutrients, sewage) hence, additional transfers would likely have little influence on concentrations in HBB waterbodies and impacts to humans.

Potential Environmental Consequences from Animal Parasites

The primary barrier to whirling disease risk and success in the HBB is the general lack of susceptible salmonid hosts in these receiving waters. Whirling disease is present in the Rocky Mountain region of the western MRB, which is characterized by cooler, oxygenated water and abundant wild trout populations (rainbow, cutthroat, and brown trout). The potential for whirling disease to spread naturally via infected host fish along waterways connecting the current western populations of *M. cerebralis* to the Project water transfer site is thought to be seriously limited by the lack of susceptible hosts and the sub-optimal habitat that lies between the two regions (Holm, pers. comm., 2011; Nehring, pers. comm., 2011). A more likely scenario would involve the accidental stocking of infected salmonids in or near HBB waters. If infected fish or infected *Tubifex* worms (the intermediate host) are present in the eastern MRB or in the HBB, the potential does exist for whirling disease-related impacts to some wild and farmed trout and char populations in the HBB. Population declines of some of the more vulnerable species (e.g., rainbow trout; primarily a farmed species) could result in subsequent increases of other more resilient species (e.g. brown trout) (Granath et al. 2007). However, it must be reiterated that these types of larger ecosystem-level impacts are not possible to accurately predict.

The lack of evidence for sensitivity of two of the most common salmonids in the HBB, lake whitefish and lake trout suggests a low likelihood for deleterious effects to their wild populations. Ecological receptors of concern that may exhibit at least some vulnerability to whirling disease may include brook trout, brown trout, Chinook salmon, lake trout, lake whitefish, rainbow trout, and shortjaw cisco (Table 2). Lake whitefish are one of the most important commercial fish species in the Province of Manitoba, including Lake Winnipeg. Wild lake trout and hatchery brook and brown trout represent important recreational species in the region (DFO 2012b). Whirling disease has the potential to induce significant mortalities in wild populations; however, the probability of introduction and establishment is extremely low due to the general lack of naturally-reproducing salmonid populations in the HBB, especially the Souris River.

Unlike whirling disease, infection with *P. hydriforme* is rarely lethal to fish hosts (acipenserids such as lake sturgeon) that inhabit the receiving basin (Dick et al. 2001). Furthermore, infection does not appear to manifest into adverse population-level impacts and is already well-established among a variety of fishes in the MRB and HBB and throughout North America (Hoffman et al. 1974; Suppes and Meyer 1975; Raikova et al.1979, 1994; Dadswell et al. 1984; Choudhury and Dick 1993; Dick et al. 2001; Thomas and Muzzall 2009; Sepúlveda et al. 2010). Because this parasite is currently present in the receiving waters, it would not represent a new threat if additional transfers occurred.

Parasitic copepods including *Actheres* spp. and *Ergasilus* spp. are widely distributed in North America, including the HBB (Dick et al. 2001; Bensley et al. 2011). Due to the apparent lack of adverse influence on fish populations, the potential impacts to receptors in the HBB are not expected.

Helminths including *I. microcotyle* and *C. minutia* do not appear to represent parasites of major concern for the receiving basin. *Corallotaenia minutia* requires a copepod intermediate host for development prior to its invasion of host tissue. In addition, this parasite has already been detected in North Dakota (Wild Rice River) and Manitoba (La Salle River) within the HBB (Dick et al. 2001; Rosas-Valdez et al. 2004). *Icelanonchohaptor microcotyle* has only been found in the Missouri River (Dick et al. 2001) and the effects of this parasite have not been observed in the environment. This parasitic flatworm has eluded characterization due to its apparent scarcity (both presence throughout and abundance within hydrologic basins). For these reasons, the potential consequences of an introduction of this organism, no matter what the source of introduction, would not be expected.

Potential Environmental Consequences from Fungi

Fungal infections are more likely to occur under stressful environmental conditions, such as those characteristic of fish-rearing facilities. *Phoma herbarum* and *Saprolegnia* infections could potentially lead to population declines of salmonids such as Chinook salmon and lake trout, as well as channel catfish in the HBB. However, there is significant uncertainty regarding the effects of these fungal pathogens on wild fish individuals and populations, as they are primarily of interest as pathogens of aquacultural facilities (Durborow et al. 2003; Meyers et al. 2008). In addition, effects from *P. herbarum* are difficult to predict since it is considered to be only weakly-infectious. Potential impacts associated with fungal infection would likely be most severe to farmed fish where entire populations could be at risk in these controlled systems. However, large rearing facilities have not been identified in the HBB including Lake Winnipeg.

Potential Environmental Consequences from Mollusks

Native invertebrates such as the mapleleaf mussel (*Quadrula quadrula*) could be adversely affected by direct competition from non-indigenous quagga and zebra mussels. Zebra mussels are already present in the HBB and the distribution of quagga mussels is rapidly expanding (Benson et al. 2012a, b). Dietary replacement of native mussels with less nutritional invasive mussels could have impacts on HBB fish, although this possibility has not been thoroughly addressed in the available literature. The introduction of quagga mussels could have an effect on plankton biomass and diversity in the HBB. Plankton decline can lead to decreased dissolved oxygen and organic carbon potentially affecting higher trophic levels, including vertebrates (Benson et al. 2012a, b). The presence of mussels could also lead to increased abundance of cyanobacteria, which pose unique challenges to the aquatic environment. Zebra mussels selectively reject cyanobacteria while filtering (Benson et al. 2012a). Zebra mussels are one of the most important biological invaders in North America, but quagga mussels have the potential to replace zebra mussels as the dominant dreissenid species due to their broad environmental tolerance and rapid spread (Benson et al. 2012b).

New Zealand mudsnails could cause ecosystem-level disruptions in waterbodies within the greater HBB. Impacts could include direct crowding of, and competition with, native invertebrates such as pulmonate snails (e.g., *Physa* spp.) (Kerans et al. 2005; Riley et al. 2008). More severe consequences could include fish population declines associated with food web structure alterations. The New Zealand mudsnail is tolerant of a wide range of environments and has been documented in almost all western states of the U.S., the Great Lakes, and more recently in British Columbia, Canada (Proctor et al. 2007; DFO 2011a). However, these effects would be site-dependent, highly variable, and unpredictable due to ecological uncertainty. That said, invasive mussels have the greatest chance of all AIS evaluated to result in adverse environmental impacts in the HBB.

Potential Environmental Consequences from Cyanobacteria

All three species of cyanobacteria are already present in the HBB. Thus, the introduction of additional cyanobacterial cells or toxins would be unlikely to result in deleterious consequences to HBB ecosystems. Increased cyanobacterial abundance is partially linked to nutrient influx, which is characteristic of agricultural runoff and waterbodies near populated areas where periodic or frequent sewage discharges occur.

Economic Consequences

This section addresses the potential economic impacts of an unintended introduction of AIS to the HBB from any of the potential transfer pathways (impacts would be pathway-independent and AIS-dependent). The primary focus of the economic analysis is on the potential impacts from these organisms on recreational and commercial fishing and on recreation other than fishing in the HBB. The geographic focus of the economic analysis is mainly on the Canadian region of the HBB, particularly Manitoba and the communities adjacent to Lake Winnipeg.

The economic analysis includes both quantitative and qualitative components, both governed by the availability of pertinent data. The available level of geographic detail and frequency of release varies between data sources and individual statistics. All demographic and population data were sourced from Statistics Canada,[2] while recreational and commercial fishing data were sourced primarily from Canada's Department of Fisheries and Oceans.[3] Data in this report collectively describe existing conditions for the overall Manitoba economy, key industries, population, and the size and impact of both recreational and commercial fishing sectors, as well as other recreational activities. This report also includes available data to describe socioeconomic conditions and fishery statistics specific to Lake Winnipeg. In order to incorporate this analysis into the broader study, all values are expressed in 2011 USD by first adjusting for inflation and then converting from Canadian Dollars (CAD) to USD using the 2011 average monthly exchange rate.

---

[2] See www.statcan.gc.ca.w.statcan.gc.ca.

[3] See www.dfo-mpo.gc.ca.www.dfo-mpo.gc.ca

The remainder of this section is organized into two key parts: Baseline Conditions and Economic Impacts. The discussion of baseline conditions includes general economic conditions in Manitoba and the Winnipeg area, as well as recreational and commercial fishing and, as part of commercial fishing, aquaculture. It also includes recreational activities other than fishing. The economic impact analysis includes a discussion of uncertainty in predicting invasive species spread and associated economic impacts, a review of literature regarding the prediction of impacts, and potential economic impacts in the HBB.

Baseline Conditions of Potentially-Affected Sectors in Receiving Area

General Economic Conditions in Manitoba

In 2010, over half of Manitoba's population of 1.2 million lived in the Census Metropolitan Area (CMA) of Winnipeg. The CMA includes the core city of Winnipeg, as well as neighboring municipalities where at least 50 percent of the labor force works in the core city. Rural municipalities in the Winnipeg CMA include Ritchot, Tache, Springfield, East St. Paul, West St. Paul, Rosser, St. Francois Xavier, Headingley, St. Clements, and Brokenhead First Nation, as shown in Figure 9 (CAO 2007).

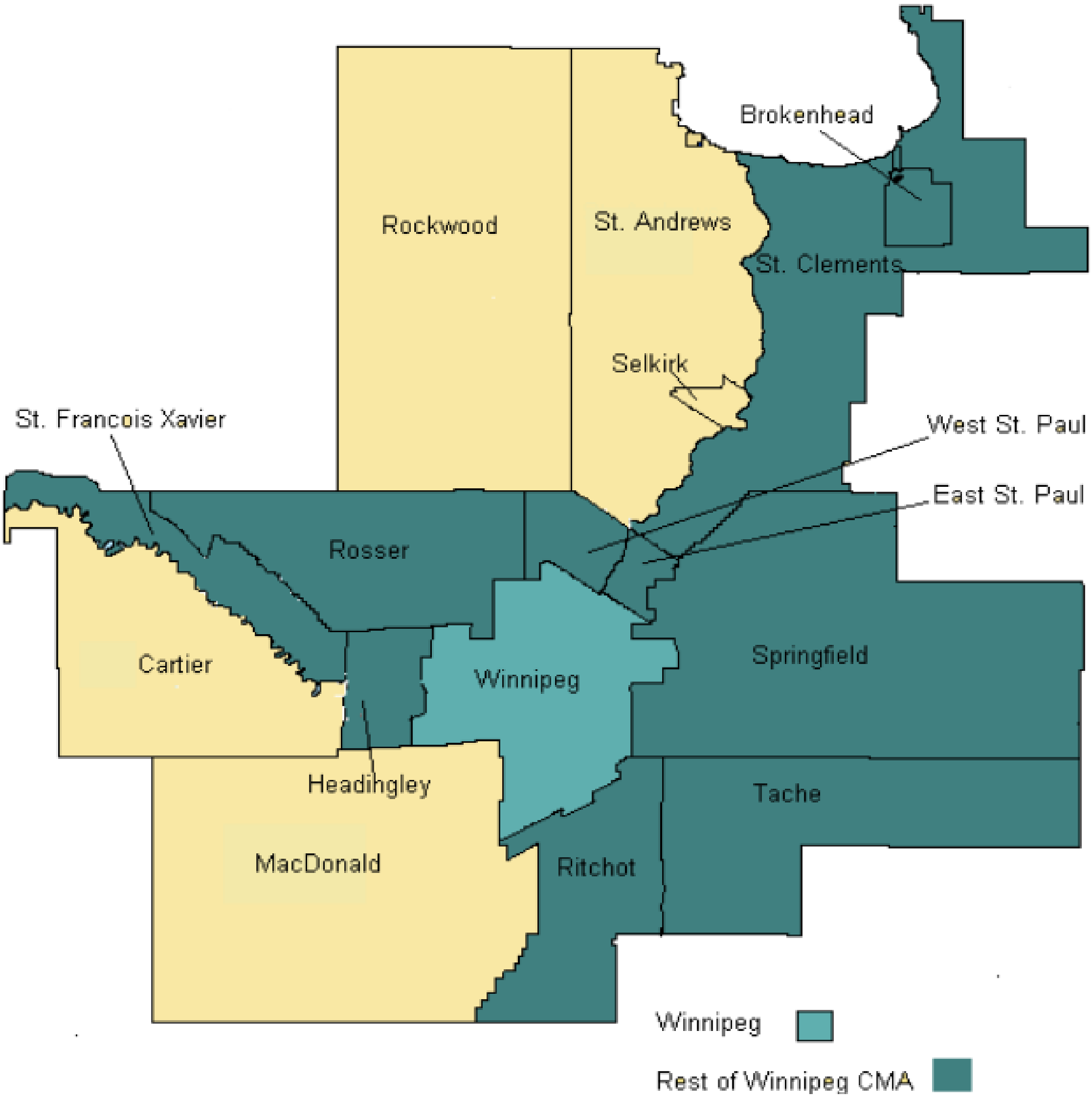


Figure 9 Winnipeg CMA

Source: CAO 2007

Manitoba has a strong, developed service-based economy and a rapidly growing population. In 2010, Manitoba grew by over 16,000 persons (Manitoba Finance 2011). The population of the Winnipeg CMA is expected to grow by 190,000 persons before 2031, a 28 percent increase over the 2010 population (CAO 2007).

Population growth throughout the province is fueled by inter-provincial migration and a strong regional job market. Low wages and a low cost of living help to make the Winnipeg CMA one of the most desirable places to do business in Canada. In 2007, the Winnipeg median hourly wage was approximately 20 percent lower than that in British Columbia, Alberta and Ontario, making Winnipeg one of the lower cost centers for business in North America (City of Winnipeg 2007). The favorable business environment is one factor accounting for higher Gross Domestic Product (GDP) growth in Manitoba than in any other Canadian province between 2005 and 2009. GDP growth was 2.4 percent in 2010.

Winnipeg's 2010 unemployment rate of 5.2 percent lies below the national average of 8.0 percent. As summarized in Table 9, median income and education levels in the Winnipeg CMA are comparable to the Canadian average, but are slightly lower across all of Manitoba, reflecting an urban-rural discrepancy. Median income after tax across Canada and in the city of Winnipeg in 2006 was just over $26,000, compared to approximately $24,400 in Manitoba. Furthermore, 24 percent of persons between the age of 25 and 64 in Winnipeg held some university certificate, diploma or degree in 2010, compared to just 19 percent in Manitoba. Approximately 15 percent of the Manitoba population is Aboriginal people, compared to 10 percent for Winnipeg, and four percent for Canada.

Table 9 Population Characteristics

Indicator	Winnipeg[1,2]	Manitoba[1,3,5]	Canada[3,4,5]
Population (2010 estimate)	684,100	1,235,400	34,482,779
Unemployment rate (2010)	5.2%	5.4%	8.0%
Median income after tax (2006)	$26,246	$24,446	$26,130
Percent of population low income, after tax (2006)	14.6%	12.2%	11.4%
Percent of population Aboriginal people (2006)	10%	15%	4%
Percent of population (age 25 – 64) with university certificate, diploma, or degree (2006)	24%	19%	23%

Sources:

[1]City of Winnipeg 2011

[2] Statistics Canada 2007a

[3] Statistics Canada 2007b

[4] Statistics Canada 2012

[5] Statistics Canada 2013

GDP growth in Manitoba between 2007 and 2011 was led by an expansion of nearly $3.8 billion in the services sector, as well as steady growth in several other sectors. Service-producing industries grew 11 percent from 2007 to 2011, whereas the goods-producing industries recorded two percent growth in this time period.

The economies of Manitoba and Winnipeg are primarily service-based. As Table 10 shows, service-producing industries contributed over $39.1 billion to Manitoba GDP in 2011, accounting for approximately 72 percent of total GDP for all industries. Agriculture, forestry, fishing and hunting is a comparatively small sector, contributing approximately $1.7 billion dollars to Manitoba's 2011 GDP.

Table 10 Contribution to Manitoba GDP by Industry

Industry, Manitoba	Contribution to Manitoba GDP, 2011 (Millions, $'s)	Additional GDP 2007 – 2011 (Millions, $'s)	Percent Growth 2007 - 2011
All Industries Total	$53,885	$4,059	8%
By Industry Type			
Goods Producing Industries	$14,829	$295	2%
Services-producing Industries	$39,056	$3,764	11%
Total	$53,885	$4,059	8%
By Industry			
Agriculture, forestry, fishing and hunting	$1,724	-$74	-4%
Mining, quarrying, and oil and gas extraction	$2,360	-$211	-8%
Utilities	$1,493	-$57	-4%
Construction	$3,745	$820	28%
Manufacturing	$5,507	-$183	-3%
Wholesale trade	$3,007	$37	1%
Retail trade	$2,877	$32	1%
Transportation and warehousing	$3,212	-$62	-2%
Information and cultural industries	$1,670	$26	2%
Finance and insurance	$3,045	$25	1%
Real estate and rental and leasing	$6,811	$1,216	22%
Professional, scientific and technical services	$1,622	$152	10%
Management of companies and enterprises	$339	$36	12%
Administrative and support, waste management and remediation services	$916	$64	8%
Educational services	$3,018	$327	12%
Health care and social assistance	$4,920	$829	20%
Arts, entertainment and recreation	$383	$44	13%
Accommodation and food services	$1,035	$108	12%
Other services (except public administration)	$1,045	$59	6%
Public administration	$5,157	$872	20%
Total	$53,885	$4,059	8%

Source: Statistics Canada 2011

The service sector is also the single largest employer in the Winnipeg CMA. Approximately 332,000 persons were employed in services industries in 2011, accounting for approximately 81 percent of employment. Within goods producing industries, manufacturing is the largest employer, accounting for approximately 41,000 jobs in 2011, or about 10 percent of total Winnipeg employment (Table 11).

Table 11 Employment by Winnipeg Sector

Sector, Winnipeg	Number of Jobs in 2011
Goods Producing Sector	
Primary and Utilities	7,840
Manufacturing	40,930
Construction	27,490
Subtotal	*76,260*
Service Sector	
Transportation & Warehousing	23,710
Information and Cultural Industries	9,080
Wholesale & Retail Trade	62,540
Finance Insurance & Real Estate	27,770
Business Services	34,290
Personal Services	54,200
Non-Commercial Services	94,740
Public Administration & Defense	26,110
Subtotal	*332,440*
Total Employment	408,700

Source: City of Winnipeg 2012

Population in the Lake Winnipeg Area

More than 23,000 permanent residents live in 30 communities along the shores of Lake Winnipeg, not including the Winnipeg CMA. These communities include ten First Nations communities, listed in Table 12, which had a combined population of nearly 17,000 in 2006. The largest two communities that year were Norway House, with a population of 4,071; and Fisher River, with a population of 3,390.

Other sizeable communities around Lake Winnipeg include Winnipeg Beach, which had a permanent population of approximately 1,000 and total taxable assessment of $46 million in 2006; and the municipality of Gimli, which had a permanent population of approximately 5,000 and a taxable assessment of $257 million in 2006. Municipalities such as Gimli, Winnipeg Beach, and others rely heavily on the growing market for retirement properties and lake-side recreation for income. Unlike the commercial fishing populations and First Nations communities that share the shores of Lake Winnipeg, these recreation-oriented communities are among the wealthiest in Manitoba (Lake Winnipeg Stewardship Board 2005).

Some areas and villages, especially First Nations communities, rely heavily on income from commercial fishing at Lake Winnipeg (Environment Canada 2011b). In addition, many of the First Nations communities rely on subsistence fishing as an important source of food and as a central part of their culture. As illustrated by Table 12, the First Nations communities around Lake Winnipeg are low income, averaging approximately $16,000 annually, and have a high unemployment rate, averaging 24 percent. These figures, together with the dependence on fishing for sustenance and income, indicate the vulnerability of First Nations communities to changing fishing conditions in Lake Winnipeg.

Table 12 First Nations Communities at Lake Winnipeg, 2006 Statistics

First Nations Community	Population	Average per Capita Earned Income (persons with income)	Unemployment Rate
Fisher River	3,390	$20,637	20%
Norway House	4,071	$9,902	23%
Berens River	2,971	$11,096	37%
Hollow Water	1,728	$16,792	28%
Brokenhead Ojibway Nation	1,794	$17,927	13%
Grand Rapids First Nation	650	$22,049	33%
Bloodvein	575	$14,530	27%
Little Black River	460	$13,244	24%
Poplar River First Nation	640	$16,516	18%
Kinonjeoshtegon (Jackhead) First Nation	700	$17,688	14%
Total/Average	16,979	$16,037	24%

Note: Does not include income from government transfers, which accounted for up to 45% of total earnings for First Nations communities in 2006.

Source: AADNC 2011

Key Potentially Affected Sectors

The introduction of AIS to the HBB has the potential to affect many sectors, including, but not limited to, those related to commercial fishing, recreational fishing, and non-fishing recreational activities. The potential effects differ by sector and by the specific businesses which operate within those sectors.

Recreation

Recreation and tourism proximate to Lake Winnipeg generate an estimated $111 million in revenue per year (Lake Winnipeg Stewardship Board 2011). Recreation at Lake Winnipeg is concentrated around its beaches and shoreline parks, which provide opportunities for boating, swimming, angling, and wind surfing. According to beach safety staff estimates, Lake Winnipeg’s two biggest beaches, Grand Beach and Winnipeg Beach, recorded a combined visitation of approximately 483,000 in 2002 (Environment Canada 2011b). Recreational visitation to Lake Winnipeg is increasing steadily, and is driven both by the popularity of recreational activities and of lake-side retirement and vacation homes.

According to the 2010 Survey of Recreational Fishing in Canada, Canadian anglers spent an average of $51 in trip expenditures for each day fishing, and an average of $114 in major purchases for each day fishing. This is substantially higher than expenditures for beach recreation. According to the Statistics Canada Travel Survey, in 2006, Canadian tourists spent an average of approximately $11 per day of beach activity.[4] Together, these values provide a useful indication of the economic impact to the local economy of recreation-related spending by tourists at Lake Winnipeg, discussed in more detail below.

Recreational fishing

Recreational fishing data, including angling participation, catch, and expenditures related to recreational fishing, is collected every five years through a mail-in survey conducted by the DFO. The latest survey is the 2010 Survey of Recreational Fishing in Canada. In 2005, Manitoba had the sixth highest number of active anglers among Canadian provinces (resident and non-resident, freshwater and saltwater), the third highest number of total freshwater days fished, and the fourth highest number of total freshwater fish caught. An estimated 170,500 anglers fished in Manitoba in 2010, of which approximately 30,000 (17.6%) were from outside the province. Together, these anglers spent approximately $230 million on fishing related capital purchases and investments, and another $103 million on trip related expenses (Table 13).

Table 13 2010 Recreational Angler Expenditures

		Manitoba			Total Estimated Expenditures at Lake Winnipeg
	Expenditure Category	Total	Expenditure per Angler	Expenditure per Angler Day	
Major Purchases and Investments[a]	Camping Equipment	$27,948,960	$164	$14	$2,199,401
	Boating Equipment (new and used)	$49,676,583	$291	$25	$3,909,223
	Special Vehicles (new and used)	$79,693,567	$467	$39	$6,271,364
	Land-buildings	$57,571,839	$338	$29	$4,530,528
	Total Estimated Major Purchases and Investments	**$229,529,591**	**$1,346**	**$114**	**$18,062,483**
Trip Expenditures	Fishing Packages	$5,648,992	$33	$3	$444,539
	Camp Fees	$19,825,053	$116	$10	$1,560,102
	Food	$6,832,342	$40	$3	$537,661
	Accommodation	$25,771,433	$151	$13	$2,028,044
	Travel Costs	$14,625,107	$86	$7	$1,150,901
	Boat Costs & Rentals	$8,253,516	$48	$4	$649,498
	Fishing Supplies	$3,470,981	$20	$2	$273,144
	License and Access Fees	$1,413	$0	$0	$111
	Total Estimated Trip Expenditures	**$102,595,853**	**$602**	**$51**	**$8,073,625**

Note: [a] includes expenditures reported as wholly or partially attributed to recreational fishing

Within Manitoba's sizeable recreational fishing sector, Lake Winnipeg accounts for a small percentage of total recreational fishing effort. Recreational anglers tend to seek out small lakes and streams that provide an intimate and easily accessible fishing environment, and most

[4] Expenditures for a day of beach activities were calculated by dividing the number of days of participation for beach activities in Canada by total Canadian beach expenditures, as reported by the Statistics Canada Travel Activities and Motivations Survey. The figures are for all of Canada and are likely to vary among the provinces

recreational fishing occurs in Southern Manitoba on the Red River, Buffalo Bay, and in the Whiteshell/Nopiming Region (Brickley, pers. comm., 2012). Lake Winnipeg is not especially well suited as a recreational fishing destination due to its size, rough weather conditions, and its commercial fishing orientation (Brickley, pers. comm., 2012).

In 2010, only 12 percent of Manitoba's active recreational anglers fished on Lake Winnipeg, making up approximately 8 percent of total days fished in Manitoba that year (Table 14). Moreover, anglers on Lake Winnipeg account for no more than 12 percent of catch for any individual fish species in Manitoba (Table 14).

Table 14 2010 Recreational Angler Effort

	Manitoba	Lake Winnipeg	Percent of Effort at Lake Winnipeg
Number of active anglers (resident and non-resident)	170,501	20,331	12%
Number of days fished in freshwater (resident and non-resident)	2,019,443	158,917	7.9%

Source: DFO 2010

Perch dominates recreational catch on Lake Winnipeg, and recreational fishers caught approximately 133,500 perch from the lake in 2010, or 12 percent of all perch caught in Manitoba. Other species caught recreationally on Lake Winnipeg include walleye, northern pike, channel catfish, and smallmouth bass, as shown in Table 15. Although no trout fishing occurs on Lake Winnipeg, trout is widely fished in other parts of the province. About 420,000 lake trout, rainbow trout, brown trout, and brook trout were caught across Manitoba in 2010.

Table 15 2010 Recreational Catch by Species (number of fish)

Species	Total Catch, Manitoba[1]	Percent Change in Fish Catch since 2005[1,2]	Total Catch, Lake Winnipeg[1]	Percent of Manitoba's Fish Catch at Lake Winnipeg in 2010[1]
Walleye	4,672,533	-24%	418,852	9%
Northern Pike	2,027,706	-38%	18,900	1%
Channel catfish	331,967	36%	10,484	3%
Smallmouth bass	313,354	-12%	11,612	4%
Perch	1,102,420	2%	133,538	12%
Lake trout	307,165	21%	--	0%
Rainbow trout	75,613	-19%	--	0%
Brown trout	20,195	184%	--	0%
Brook trout	16,788	-1%	--	0%
Other species	480,157	-18%	80,483	17%
Total fish	9,347,897	-19%	673,868	7%

Sources:

[1] DFO 2010

[2] DFO 2012b

There are two types of economic values associated with fishing recreation at Lake Winnipeg: value to recreationists and value to the local economy of angler spending at local businesses, such as sporting good stores and food and lodging establishments. The net value to an angler of a recreational fishing day at freshwater lakes (equal to the benefits of the recreation experience that exceed the costs) is often estimated at approximately $40, but estimates vary from a few dollars per day to several hundred dollars per day (Ontario Ministry of the Environment 2010).

As summarized above in Table 13, according to the 2010 Survey of Recreational Fishing in Canada, Canadian anglers spent an average of $51 in trip expenditures for each day fishing, and an average of $114 in major purchases for each day fishing. This value includes estimated expenditures for such direct trip expenses as gear and transportation, as well as outlays for lodging, food, and durable vehicle purchases that may be either fully or partially attributed to fishing trips. The average angler is estimated to spend $1,346 annually on purchases and investments related in part to recreational fishing, in addition to $602 on trip expenses such as food, bait, transportation and accommodations. Total annual expenditures by all anglers in Manitoba are estimated at $102.6 million. These estimates, summarized in Table 13, provide an indication of the economic importance of recreational angling in Manitoba to individual business sectors.

Table 16 provides data on the businesses in diverse industries that are linked to recreational fishing in Manitoba. Many of these enterprises are small businesses, defined as having annual revenue between $30,350 and $5,058,450 in 2011 USD.[5] The accommodations and food services sector, North American Industry Classification System (NAICS) 72, is the largest. It contains over 2,000 small businesses in Manitoba, including 44 recreational vehicle (RV) parks and campgrounds, 357 hotels and motels, and 64 hunting and fishing camps in 2008. Data from the 2006 Census of Population show that 15,455 employees worked in food and beverage and travel and accommodation businesses that year. Anglers in Manitoba are estimated to have spent approximately $12.5 million at food and lodging establishments in 2010, according to DFO recreational fishing surveys.[6]

In addition to food and lodging establishments, there were 122 sporting goods stores in Manitoba in 2008, at which recreational anglers spent approximately $96 million, based on recreational angler purchases and investments in fishing, boating, and camping equipment in 2010. There were also 24 truck, utility trailer and RV rental and leasing establishments in Manitoba in 2005, as well as 33 RV dealers. Based on recreational fishing expenditures in transportation and investments in specialty vehicles, recreational anglers are estimated to have spent $80 million at these businesses in 2010.

[5] In 2011 USD; the Canadian Dollar equivalent is from $30,000 to $5,000,000

[6] Because of differences in occupational classifications and small business categories, there may be some mismatch between the types of establishments accounted for in each of these categories.

Table 16 Manitoba Businesses Supported by Recreation-Related Spending

Small Business, Manitoba, 2008[a]	Number of Businesses 2008[1]	Average Total Revenue ($1,000's)[1]	Average Net Profit/Loss ($1,000's)[1]	Estimated Number of Laborers by Small Business[2]	Direct Expenditures by Resident and Out of State Anglers, 2010 ($1,000s)[3]
NAICS 72 - Accommodation and Food Services	2,056	$669	$32	15,455[b]	$12,481[c]
NAICS 721211 - RV Parks and Campgrounds	44	$184	$12		
NAICS 72111 - Hotels (except Casino Hotels) and Motels	357	$1,047	$63		
NAICS 721212 - Hunting and Fishing Camps	64	$463	-$11		NA
NAICS 45111 - Sporting Goods Stores	122	$666	$20	NA	$96,238[d]
NAICS 53212 - Truck, Utility Trailer and RV Rental and Leasing	24	$297	$14	NA	$79,694[e]
NAICS 44121 - Recreational Vehicle Dealers	33	$669	$32	NA	

Notes:

[a] A small business is defined as having annual revenue between $30,000 and $5,000,000 CAD or between $30,350 and $5,058,450 USD.

[b] includes laborers in Food and Beverage Services (census category G5), and Travel and Accommodation, including attendants in recreation and sport (census category G7).

[c] includes direct expenditures in food and accommodations, including campgrounds

[d] includes direct expenditures in food and accommodations, including campgrounds

[e] includes transportation expenditures and purchases and investments in new and used specialty vehicles

NA: not applicable

Sources:

[1] Statistics Canada 2011

[2] Statistics Canada 2006

[3] DFO 2010

Expenditure data is not available for individual water bodies. Therefore, expenditure estimates for Lake Winnipeg are estimated by applying the average expenditures per angling day for Manitoba (presented in Table 13) to the estimated number of recreational fishing days at Lake Winnipeg.

Based on approximately 159,000 angler days on Lake Winnipeg, resident and non-resident anglers are estimated to spend just over $18.1 million on fishing-related purchases and investments in 2010 with an additional $8.1 million on trip-related expenses. Vehicles and lodging are the biggest individual expense categories: in 2010, recreational fishers on Lake Winnipeg may have spent approximately $6.3 million on vehicles for purposes relating to fishing, $4.5 million on vacation houses, and just over $2 million on other accommodations. These estimates assume that anglers at Lake Winnipeg have similar expenditure patterns as anglers elsewhere in Manitoba. As described above, Lake Winnipeg is not especially well suited as a recreational fishing destination due to its size and rough weather conditions, which suggests that there may be relatively few non-residents fishing at the lake. As locals spend less on fishing trips than non-residents (due to lower transportation costs and less need for food, lodging, and other services) expenditures per fishing day at Lake Winnipeg may be significantly lower than average per day expenditures for all of Manitoba. If this is the case, then the estimated expenditures associated with fishing in Lake Winnipeg discussed above and presented in Table are overestimates.

Commercial Fishing in Lake Winnipeg

In 2006/2007, commercial fisheries in Manitoba accounted for 36 percent of total freshwater landings and 39 percent of the total value of landings in Canada. The nearly 11,800 MT of fish were valued at $27.5 million that year.[7] Lake Winnipeg is by far the largest source of commercial freshwater landings in Manitoba. The 2009/2010 harvest in Lake Winnipeg accounts for approximately 46 percent of the total fish weight and 68 percent of total Manitoba landed fish value in 2006/2007. The nearly 5,400 MT of freshwater fish were harvested by 872 licensed commercial fishers and hired helpers on Lake Winnipeg in 2009, at a value of $18.6 million.

Commercially harvested freshwater fish go through two primary financial transactions before entering the fish market. All fish is first sold to the Canada Freshwater Fish Marketing Corporation (FFMC) for a price that is dependent on the quantity of catch as well as the Canadian dollar value and FFMC net earnings for the period. These fish are delivered to one of the 27 FFMC packing stations in Manitoba, where the catch is processed and eventually sold as a value-added fish product to markets and distributors. Both the direct income to fishers (landed value) and the annual sales by FFMC (marketed value, which includes landed value plus value added from other sectors) reflect a direct benefit to Manitoba's economy, and are captured below in Tables 17 and 18. Table 17 provides data specific to Lake Winnipeg commercial catch, while Table 18 is for Manitoba overall. Data availability differs for landed and marketed value data for Manitoba and Lake Winnipeg. Table 17 summarizes species level catch data for Lake Winnipeg, but includes only the available landed value data for walleye, lake whitefish, and sauger. Table 18 summarizes landed value, market value, and catch data for all commercial species in 2006/2007 for Manitoba.

As shown in Table 17, the Lake Winnipeg commercial fishery is dominated by the three quota species walleye, whitefish, and sauger, which together accounted for 95 to 96 percent of total catch weight between 2007/2008 and 2009/2010. The three species also accounted for all of the recorded value of landings.[8]

Among the three quota species, walleye is the most important in terms of both tons caught and total value. Moreover, per unit value for walleye is considerably higher than the respective values for whitefish or sauger, although the relative importance of walleye both in tons and total value declined over the three years shown. In 2007/2008, walleye accounted for 74 percent of tons and 91 percent of total value. By 2009/2010, the relative importance of walleye declined to 59 percent of tons caught and 73 percent of total value. During the same period, whitefish increased from 19 to 27 percent of the total tons caught and the value of the catch rose from seven to 15 percent. Sauger rose from two to 10 percent of the tons caught and from two to 11 percent of total value. Although sauger represents a relatively minor species in terms of tons caught compared to walleye and whitefish, nearly all sauger caught in Canada are caught in Manitoba, and the majority of this catch is from Lake Winnipeg.

---

[7] Weight of landings refers to delivered weight. Value refers to initial payments to fishers from delivered weight.

[8] DFO data on total value of landings covers only the three quota species; thus the values for the other species shown in the table are not known. However, it is likely that the quota species account for nearly all of the value of the commercial catch.

Table 17 Lake Winnipeg Commercial Landings: Weight in MT and Value of Delivered Weight, 2007 – 2010

Species	2007/2008			2008/2009			2009/2010		
	MT	Value ($1000's)	Value/MT	MT	Value ($1000's)	Value/MT	MT	Value ($1000's)	Value/MT
Walleye[a]	3,469	$16,794	$4,850	3,344	$16,331	$4,890	3,176	$13,531	$4,260
Lake Whitefish	872	$1,329	$1,520	1,452	$3,140	$2,160	1,449	$2,843	$1,960
Sauger	105	$422	$4,020	242	$1,067	$4,400	522	$1,981	$3,790
Carp	64	--	--	51	--	--	4	--	--
Perch	23	--	--	22	--	--	36	--	--
Northern Pike	43	--	--	68	--	--	72	--	--
Sucker (Mullet)	38	--	--	76	--	--	76	--	--
Other fish	55	--	--	37	--	--	34	--	--
Total	4,672	$18,545	$3,970	5,280	$20,538	$3,890	5,369	$18,611	$3,460

Notes:

[a] Walleye is commonly misclassified as yellow pickerel in DFO statistics.

Sources:

DFO 2010

Lake Winnipeg Quota Review Task Force 2011

Table 18 includes additional detail on the Manitoba commercial fish catch for 2006/2007. Data at the same level of detail are not available for Lake Winnipeg alone. As shown, total landings that year were 11,758 MT of which walleye accounted for 50 percent, whitefish 17 percent, sucker 13 percent, pike 11 percent, and carp four percent. Landed value summed to $27.5 million, of which walleye was 79 percent, whitefish was nine percent, pike and perch each three percent, and sucker two percent. Markups from landed value to market value differed widely. The smallest markups were for sauger, perch, and walleye, at 144 percent, 150 percent, and 154 percent, respectively. The largest were for whitefish, pike, and sucker at 233 percent, 319 percent, and 374 percent, respectively.[9]

[9] Landed value represents the payments received by fish harvesters for fish sales to the FFMC. The payments are generally recorded free on board lakeside; in some cases, however, payments are free on board at a central delivery point which may be some distance from the lake where fish are harvested. Marketed value reflects the landed quantity of a species and the average market selling price for the year. Because the estimates do not carryover inventory from year to year, market value differs from the FFMC statement of annual fish sales (DFO 2010).

Table 18 Manitoba Commercial Landings: Weight (MT), Landed Value and Market Value 2006/2007

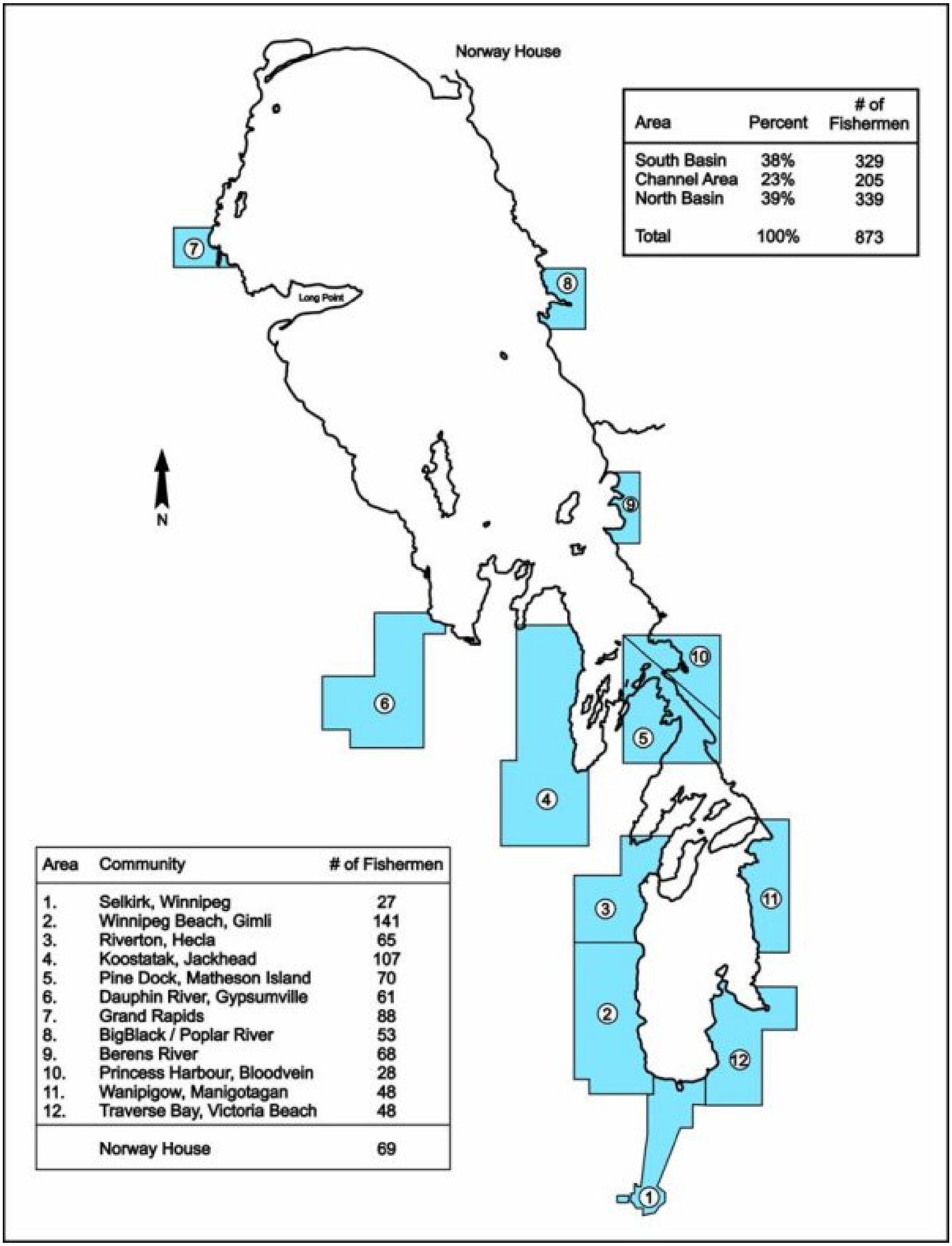
Species	2006/2007					
	MT	Landed Value ($1,000's)	Landed Value/MT	Market Value ($1,000's)	Market Value Value/MT	Market Value as Percent of Landed Value
Walleye[a]	5,918	$21,739	$3,670	$33,562	$5,670	154%
Lake Whitefish	2,049	$2,414	$1.170	$5,625	$2,740	233%
Sauger	165	$512	$3.100	$736	$4,460	144%
Carp	466	$248	$0.530	$501	$1,080	202%
Perch	206	$712	$3.460	$1,065	$5,170	150%
Pike	1,237	$864	$700	$2,753	$2,230	319%
Sucker (mullet)	1,518	$590	$380	$2,148	$1,420	374%
Other fish	98	$340	$3,470	$687	$7,010	202%
Total	11,758	$27,501	$2,340	$47,241	$4,010	172%

Note :[a] Walleye is commonly misclassified as Yellow Pickerel in DFO statistics.

Source: DFO 2010

Most fishing in Lake Winnipeg is in the South Basin, near the convergence of the Red River. As illustrated by Figure 10, Lake Winnipeg is divided into 12 community licensing areas. Areas 1, 2, 3, 11, and 12 make up the South Basin, and in combination represented 38 percent of commercial fishing licenses at Lake Winnipeg in 2002.

The number of licensed fishers at Lake Winnipeg has slowly declined since 2002, with a high of 921 in 2003/2004 and a low of 872 in 2008/2009. Between the 2003/2004 and 2008/2009 seasons, the average number of licensed fishers was 895, while the average for all Manitoba was 2,248 (Table 19). Average numbers of hired helpers over the same period were 179 and 868 for Lake Winnipeg and Manitoba, respectively. Average annual income per fisher between 2003/2004 and 2008/2009 was substantially higher among Lake Winnipeg fishers than among all Manitoba fishers; $23,280 versus $13,372, respectively.



Area	Percent	# of Fishermen
South Basin	38%	329
Channel Area	23%	205
North Basin	39%	339
Total	100%	873

Area	Community	# of Fishermen
1.	Selkirk, Winnipeg	27
2.	Winnipeg Beach, Gimli	141
3.	Riverton, Hecla	65
4.	Koostatak, Jackhead	107
5.	Pine Dock, Matheson Island	70
6.	Dauphin River, Gypsumville	61
7.	Grand Rapids	88
8.	BigBlack / Poplar River	53
9.	Berens River	68
10.	Princess Harbour, Bloodvein	28
11.	Wanipigow, Manigotagan	48
12.	Traverse Bay, Victoria Beach	48
	Norway House	69

Figure 10 Lake Winnipeg Community Licensing Areas

Source: Manitoba Water Stewardship 2011

Table 19 Lake Winnipeg and Manitoba Direct Commercial Fishing Employment: Licensed Fishers, Hired Helpers, and Income 2003 – 2009

Year	Lake Winnipeg				Manitoba			
	Licensed Fishers	Hired Helpers	Total	Income per Licensed Fisher	Licensed Fishers	Hired Helpers	Total	Income per Licensed Fisher
2003/2004	921	184	1,105	$24,318	2,354	986	3,340	$15,000
2004/2005	910	182	1,092	$23,195	2,404	868	3,272	$12,988
2005/2006	897	179	1,076	$22,487	2,310	839	3,149	$12,407
2006/2007	891	178	1,069	$22,984	2,206	804	3,010	$13,620
2007/2008	881	175	1,056	$22,379	2,167	881	3,048	$12,111
2008/2009	872	174	1,046	$24,315	2,048	829	2,877	$14,107
Average	895	179	1,074	$23,280	2,248	868	3,116	$13,372

Source: Manitoba Water Stewardship 2010

Much of the commercial fishing activity in Manitoba is by part-time rather than full-time fish harvesters. Table 20 shows that in 2006/2007, there were 1,714 fish harvesters in the province, 246 of whom are estimated to have worked full-time at the activity.[10] Thus, full-time employment was an average of 14 percent among all harvesters. Within each landed value category presented in Table 20, the average landed value per harvester corresponds with the proportion of harvesters employed full-time in the activity. For example, among those harvesters landing $10,000 or less, 11 percent worked full-time in the activity, whereas among those landing from $20,001 to $30,000, the full-time proportion was 18 percent and among those 97 harvesters landing at least $40,001, 26 percent were full-time.

Table 20 Manitoba Harvesters by Landed Value, 2006/2007

Landed Value, 2006/2007	Number of Licensed Harvesters	Full-Time Equivalent Employment	Deliveries per Harvester	Pounds per Harvester	Payments per Harvester
$0 - $10,000	767	83	14	2,534	$4,227
$10,001 - $20,000	479	68	23	6,207	$15,238
$20,001 - $30,000	248	44	33	10,884	$27,871
$30,001 - $40,000	123	26	37	15,311	$39,777
$40,001+	97	25	48	23,466	$59,685
Total/Average	1,714	246	23	$6,870	$16,415

Source: DFO 2010

Data from Statistics Canada were used to estimate the number of small businesses, defined as having annual revenue between $30,000 and $5,000,000 CAD, as well as the number of

[10] Full-time equivalent employment is estimated by dividing the number of weeks worked during a given year by 52. It is unknown why the number of Licensed Fishers reported by DFO for the 2006/2007 season (1,714) differs from the Manitoba Water Stewardship's estimate for the same season (2,206, Table 19).

employees that could be affected, either directly or indirectly, by changes in commercial fishing activity. Table 21 shows that there were 172 inland fishing establishments in Manitoba in 2008. These establishments had average net profits of approximately $11,000 for the year. Additionally, there were 12 fish and seafood product wholesaler/distributers in the Province that year, with average net profits of $26,000 and total employment of 120.[11]

Detailed demographic or socioeconomic statistics of commercial fishers at Lake Winnipeg are not available. However, approximately 80 percent of commercial fishers are of First Nations Heritage (Lake Winnipeg Implementation Committee 2007). Although economic characteristics of First Nations communities listed in Table 12 provide an indication for the relative vulnerability of this population of fishers, it is unclear what percentage of total fishing effort these fishers constitute.

Table 21 Manitoba Small Business Statistics, 2008

Small Businesses, Manitoba, 2008[a]	Number of Businesses, 2008[1]	Average Total Revenue ($1,000's)[b,1]	Average Net Profit/Loss ($1,000's)[b,1]	Estimated number of Laborers, Full-time & Part-time
NAICS 114114 - Inland Fishing	172	$74	$11	1,714[c,1]
NAICS 41314 - Fish and Seafood Product Wholesaler-Distributors	12	$462	$26	120[d,2]

Notes:

[a] annual revenues between $30,000 and $5,000,000 CAD

[b] revenue and profit/loss numbers expressed in CAD

[c] total number of fish harvesters in Manitoba in 2006/2007

[d] includes fish plant workers (J172) and laborers in fish processing (J318)

Sources:

[1] DFO 2010

[2] Statistics Canada 2006

Aquaculture and Fish Stocking in Manitoba

Aquaculture operations are particularly vulnerable to disease outbreak. Depending on the disease, an outbreak may require all the fish reared at an aquaculture facility to be euthanized with resulting high costs.

Commercial Aquaculture

In Manitoba, government-run hatcheries dominate the aquaculture sector. However, commercial aquaculture is a small industry in Manitoba when compared to other parts of Canada, especially the east and west coasts. Harsh winter temperatures and a limited fish market combine to constrain Manitoba's commercial aquaculture sector to a small number of operations. Currently, there are just four major commercial operations that supply approximately 200,000 trout fingerlings annually to hobby farmers. Two of these are "grow out" operations, and additionally sell about 35 MT of rainbow trout and Arctic char annually. Although the primary uses of Manitoba aquaculture trout are to supply on-site or small-scale private pond fishing, a small

[11] It is assumed that the seafood wholesalers purchased fish from the FFMC.

number of trout grown at commercial facilities help supplement the public stocking efforts described below. Other fish produced at these operations are for recreational fishing or are used for human consumption.

Commercial operations primarily sell rainbow trout, which is resilient and fast growing compared to other trout species (Canadian Aquaculture Alliance, pers. comm., 2012). Other species sold in smaller quantities include Arctic char, brown trout, and brook trout. According to Statistics Canada aquaculture statistics presented in Table 22, the total value of sales by these operations ranged from $31,000 to $95,000 between 2007 and 2009, or an average value of $4,440 per MT (; Statistics Canada 2009). Total production for all of Canada ranged between 5,044 MT and 7,785 MT over the three years, with annual values ranging from $25.9 million in 2007 to $43.2 million in 2008.

Table 22 Commercial Trout Aquaculture 2007 - 2009

Commercial Trout Aquaculture	2007			2008			2009		
	MT	Value ($1,000's)	Value/ MT	MT	Value ($1,000's)	Value/ MT ($1,000's)	MT	Value ($1,000's)	Value/ MT
Manitoba	21	$95	$4,540	20	$87	$4,340	7	$31	$4,430
Canada	5,044	$25,856	$5,120	7,785	$43,233	$5,550	7,000	$33,589	$4,800

Source: Statistics Canada 2009

Fish Stocking

The Manitoba Water Stewardship Fishery Branch runs three major hatcheries in Manitoba which stock lakes and rivers throughout the province. These hatcheries are the Whiteshell Fish Hatchery, the Grand Rapids Fish Hatchery, both of which raise a combination of species; and the Swan Creek Fish Hatchery, which raises walleye exclusively. The purpose of these hatcheries is to supplement wild fish stocks based on commercial and recreational demand, and to maintain fish populations where they are in decline. As shown in Table 23, these hatcheries stocked an average of 53 million fish between 2005 and 2009, of which rainbow trout and walleye account for 98 or 99 percent (depending on the year).

Hatcheries stock numerous water bodies and lakes throughout Manitoba. Lake Manitoba is the largest receiving site, and was stocked with 13.5 million walleye in 2011, more than ten times as many as any other site. Although Lake Winnipeg has historically been stocked, stocking at this site was discontinued several years ago (Whiteshell Fish Hatchery, pers. comm., 2012).

Table 23 Number of Fish stocked in Manitoba, 2005 – 2009

Species	2005	2006	2007	2008	2009
Walleye	69,450,735	22,100,000	62,025,000	78,895,000	30,150,929
Rainbow trout	138,917	166,037	257,234	186,950	424,450
Lake trout	118,200	0	0	182,000	435,205
Brown trout	98,245	47,340	121,250	93,124	66,860
Brook trout	38,433	21,980	83,000	49,640	18,574
Splake	59,000	3,175	0	44,900	4,800
Tiger trout	0	1,005	12,500	18,842	0
Lake sturgeon	0	5	0	9,366	9,424
Arctic char	0	0	0	1,783	0
Brook\Char hybrid	0	0	0	1,750	0
Northern pike	556	188	0	473	0
Yellow perch	0	4,400	600	75	0
Total	**69,904,086**	**22,344,130**	**62,499,584**	**79,483,903**	**31,110,242**

Source: Manitoba Water Stewardship 2009

Other Domestic Fish Harvests of Lake Winnipeg

The ten First Nations aboriginal communities around Lake Winnipeg (see Table 12) rely on commercial fishing for income and subsistence fishing to supplement their diets. Aboriginal subsistence harvests are protected by the Manitoba Water Stewardship, which assigns domestic aboriginal harvests in Manitoba first priority for allocation beyond conservation levels, but which does not require licenses or reporting for subsistence catch. Because data on subsistence harvest levels are not collected in an organized manner, the best information available is from three studies that estimate fish consumption within five aboriginal communities adjacent to Lake Winnipeg: Norway House (Weagle 1973); Berens River, Hollow Water, and Brokenhead (Wagner 1986); and Fisher River (Maclean 2007). Using data from these studies, and the assumption that fish consumption represents approximately 75 percent of total harvests, the Lake Winnipeg Quota Review Task Force estimated in their 2011 report that the 14,350 First Nations residents in Lake Winnipeg communities annually harvest between 140 and 402 MT of fish from Lake Winnipeg. This represents between three and nine percent of the average commercial harvest from 2000 to 2007.

Economic Consequence Analysis

This section provides an assessment of the potential economic consequences from establishment of AIS in the HBB. The discussion includes a review of the many sources of uncertainty regarding the introduction and establishment of potentially harmful non-indigenous waterborne species, and the resultant difficulty in quantifying the economic impacts of AIS.

The economic impact analysis focuses on the potential *incremental* impacts of AIS introduction in the HBB and Lake Winnipeg. There are currently AIS in Lake Winnipeg and elsewhere in the HBB that could lead to economic impacts, including declines in fish stock population or quality, or beach closures. These effects are baseline effects; they would occur even without the Project.

Impacts of the Project are limited to the increased, or incremental, impacts associated with the ‘with Project’ condition compared to the baseline, ‘No Project’ condition.

Review of Literature on Invasive Species and Predicting Their Establishment and Economic Impacts

Published literature on invasive aquatics is available; however, as pointed out by Lovell and Stone, there is relatively limited theoretical and empirical literature on the economic costs of invasive aquatics (Lovell and Stone 2005). They point out that such estimates for the U.S. range from the hundreds of thousands to the tens of millions of dollars for individual species and locations. They also point out that measuring ecosystem services, human health, and other values and costs related to invasive aquatics is difficult at best; and that estimating these economic costs requires assessing the rates of biological propagation, which may depend on many factors.

Invasive aquatics are not limited by national borders. Such species have entered waters in Canada for centuries, and 15 invasive aquatics are established in the country’s coastal or inland waters each decade (Canadian Council of Fisheries and Aquaculture 2004). DFO (2011b) reported that invasive aquatics have been responsible for destruction of several native fish species and fisheries in the country; and that lost revenues and control costs annually sum in the billions of dollars.

Principal pathways for introduction of invasive aquatics in Canada are similar to those for other countries, including shipping, commercial and recreational boating, aquarium and water garden trade, live food fish, use of live bait, intentional introductions, and water diversions. Shipping is considered to be the single most important source of new invasive aquatics introductions in Canada, primarily by the discharge of ballast water taken on in foreign ports (DFO 2011b).

A variety of techniques have been used to predict the establishment and dispersal of invasive aquatics in different environments. Some species in lacustrine environments are reported to follow “stratified diffusion,” in which long-range expansion is accomplished by local and long-distance dispersal (Hengeveld 1989 as cited in Muirhead and MacIsaac 2005). One example cited is the dispersal of zebra mussels in the U.S. Further, boats are a type of “human-mediated dispersal” accounting for the spread of invasive aquatics, particularly when such vessels are moved from invaded to non-invaded lakes (Muirhead and MacIsaac 2005).

Potential Impacts of Aquatic Invasive Species of Concern in the HBB

One of the concerns regarding these transfers is the potential adverse impacts of the AIS on recreational and commercial fisheries, non-fishing recreational activities, and aquaculture operations, all components of the Manitoba economy. Established and dispersed AIS may have direct and adverse impacts on one or more of these sectors, no matter the source of introduction. The impacts of AIS on the four sectors may differ substantially.

For commercial and recreational fisheries, AIS may cause population declines in target fish stocks. If the AIS spread throughout water bodies, the decline of the commercial or recreational fisheries may worsen over time or be offset by increased populations of other species with economic potential. There is significant uncertainty in AIS, and the associated risk for them to incrementally affect economically valuable fish species in the HBB. For example, the impact of whirling disease has varied greatly among introduction sites. As noted in previous sections, the success of *M. cerebralis* is affected by water temperature (seasonal range and variation), host size and availability, turbidity, flow rate, elevation, substrate, and land use (Elwell et al. 2009).

The wide range of variables involved makes it difficult to predict with any certainty where, when, and under what circumstances the impact of whirling disease might be significant and where it might be benign (Nehring 2006).

The fish species accounting for current recreational and commercial fishing value are presented in Table 24 along with their susceptibility to AIS. All reported commercial fishery value is from landings of walleye, whitefish, and sauger, whereas nearly 94 percent of recreational fish caught are walleye, northern pike, channel catfish, smallmouth bass, perch, or lake trout (see Table 15). Any incremental decline in these fish populations due to AIS would likely result in reduced catch rates, with subsequent economic effects (such effects would be mitigated if reductions in any of these fish populations were offset by increased abundance of other economically valuable species). Furthermore, AIS may have effects on fish appearance and fish health, which can affect the value of fish caught both recreationally and commercially.

While the risk of AIS introduction and the degree of susceptibility of economically important HBB fish stocks to AIS is not completely understood, the fact that most, if not all, of these fish species are present and fished in the MRB suggests that there is low probability for incremental impacts in the HBB. For example, the Corps of Engineers manages flows below Fort Peck and water levels on Lake Sakakawea for fisheries based on recommendations from the state agencies responsible for fisheries management including Montana and North Dakota. The North Dakota and Montana state agencies manage the fishery resources for walleye, sauger, and Chinook salmon primarily, with northern pike, trout, and smallmouth bass also managed. Other warm water species present include goldeye, carp, channel catfish, river carpsucker, crappie, and emerald shiner (Reclamation 2007). The coexistence of these managed fisheries and several AIS in the MRB suggests that the vulnerability of the same, economically important fish stocks in the HBB to these pathogens may be low.

Table 24 Economically Important Fisheries in Lake Winnipeg and Susceptibility to AIS

Common Name	Recreation Value	Commercial Value	Susceptibility to AIS Evaluated
Channel catfish	Yes		CCV, columnaris disease, *Edwardsiella,* ERM, *Exophiala* spp., *Ichthyophthirius multifiliis,* furunculosis, *Saprolegnia* spp., VHSV
Lake Whitefish		Yes	Furunculosis, VHSV, whirling disease[a]
Northern Pike	Yes		Furunculosis, SVCV, VHSV
Sauger		Yes	Furunculosis, columnaris disease, VHSV
Smallmouth Bass	Yes		Furunculosis, VHSV
Walleye	Yes	Yes	ERM, furunculosis, columnaris disease, VHSV
Yellow Perch	Yes		Columnaris disease, furunculosis, VHSV
Lake Trout	Yes		BKD, *Exophiala* spp., furunculosis, ISAV, IPNV, *Phoma herbarum*, VHSV, whirling disease[a]

Note: [a] susceptibility is unknown or unclear at this time due to conflicting reports or insufficient data

Commercial fishing

Commercial fishing would be adversely affected if AIS were to result in incremental reduced catch rates or reduced fish quality. The risk of AIS affecting any or all commercial fish species is unknown. The potential for reductions in the population of one or more commercially important fish species to be offset by an associated increase (e.g., due to reduced competition for resources or altered predator-prey dynamics) in another commercially important fish species is also unknown. Therefore, this analysis is limited to a discussion of the types and potential magnitude of possible incremental adverse impacts.

For commercial fisheries, reductions in catch rate can have several impacts. First, if fishing effort is unchanged, then commercial catch would be lower. Lake Winnipeg accounts for a substantial proportion (approximately two-thirds) of commercial landings in Manitoba. Reduced commercial fish catch at Lake Winnipeg, if significant, could have adverse ripple effects on industries processing and marketing fish as demand for their services would drop. Similarly, if Lake Winnipeg commercial catch declines were significant, the price of local fish could rise and the availability could decrease, increasing costs to consumers and potentially reducing food choices for fish consumers. Reduced fish quality and/or appearance would also adversely affect fish consumers unless associated with price reductions that offset the quality reduction.

Reduced catch also means lower revenues and thus lower profits for fishermen. Commercial fishermen may respond to reductions in catch rate by increasing fishing effort (hours fishing) to maintain total catch. In this case, revenue may remain constant, but operating costs (both vessel fuel and labor costs) would increase, resulting in lower profits. Reduced profits translates to lower income for fishermen. If profits are significantly lower, then fishermen may exit from the fishery, reducing fish industry employment and resulting in even lower commerical catch. Lake Winnipeg fishermen currently have much higher profits than commercial fishermen elsewhere in Manitoba ($23,280 per fisher compared to $13,372 elsewhere in the province), suggesting that exit of the fishery due to reduced profits would likely be minimal unless AIS effects were severe. In any case, direct impacts on fishery employment would be limited to some portion of the 1,000 to 1,100 total Lake Winnipeg licensed fishers and hired helpers (Table 19).

If AIS results in reduced quality (due to changes in fish appearance or fish size) of commercially valuable species, then the per unit value of catch would decline, thereby also decreasing fishermen profits and potentially impacting fish industry employment. Fish consumers could also be adversely affected if fish quality declines as a result of AIS.

Aquaculture

AIS capable of infecting fish species reared at an aquaculture operation could cause significant mortalities within a fish stock for that year. However, the economic impacts of any effects of AIS on the aquaculture industry would be minor in the context of the regional economy. The aquaculture industry in Manitoba is a very small piece of the province’s economy, with gross output value of $31,000 to $95,000 (see Table 22). Impacts of AIS would therefore be limited to some portion of this small value. Reduced availability of trout fingerlings from the aquacultural industry could adversely affect aquaculture consumers, primarily hobby farmers.

Recreation and Tourism

Similar to commercial fishing, the risk of AIS incrementally affecting any or all recreationally important fish species is unknown, as is the potential for reductions in the population of one or more recreational fish species to be offset by an associated increase (e.g, due to reduced competition for resources or altered predator-prey dynamics) in another recreationally important fish species. Therefore, this analysis is limited to a discussion of the types and potential magnitude of possible incremental adverse impacts.

AIS can have two potential types of effects on recreation and tourism: effects on the level of enjoyment and value of the experience to the recreators/tourists themselves, and effects on the recreation and tourism economy that may result from changes in the number of visitors and their expenditures. These two types of effects are closely related as the level of visitor enjoyment also affects the number of visitors and their expenditures.

For recreational fishing, any reduction in the health or abundance of fish species targeted by recreational anglers could adversely affect the level of enjoyment of the angling experience. It is well documented that reductions in fish catch rate reduce recreational enjoyment. For example, one study of anglers in the Great Lakes region found that anglers value each one percent change in fish abundance at approximately $0.20 to $0.40 per fishing day (Ontario Ministry of the Environment 2010). Thus, if AIS incrementally reduced catch rates in Lake Winnipeg, even if the number of angler days stayed at the current level of approximately 159,000, there would likely be a reduction in value of each angler day. Using the values from the Great Lakes study of $0.20 to $0.40 and applying this to the 159,000 angler days at Lake Winnipeg, every one percent change in fish abundance could reduce the value of the angler experience in the range of $30,000 to $60,000.

Reduced catch rates or reduced health of fish species could also result in fewer fishing trips to Lake Winnipeg, with resulting reductions in angler expenditures. Reduced angler expenditures would adversely affect area businesses that sell goods and services to anglers, such as those highlighted in Table 16 (food and drink establishments, lodging, sporting good stores, etc.). As estimated above, the 159,000 fishing days at Lake Winnipeg have an associated estimated fishing trip expenditure of approximately $8 million (Table 13). However, impacts to the local economy are limited to changes in tourism (non-local) visitation, and it is not known what proportion of the 159,000 trips are non-local. Changes in the number of fishing trips enjoyed by locals would not be expected to impact the local economy since such locals would likely spend their recreation dollars on other local recreational activities. As Lake Winnipeg is not particularly attractive as a recreational fishing destination (Brickley, pers. comm., 2012), there may be more local than non-local anglers fishing at Lake Winnipeg, which would limit the potential effects of AIS on tourism expenditures.

For non-fishing recreation, the primary impacts of AIS would likely be an increase in beach closure days. Incremental beach closures could result if cyanobacteria or human pathogens such as E. coli or *Salmonella* spp. were transferred and thereby resulted in increased concentrations in Lake Winnipeg. However, as noted in earlier sections, several of the bacterial AIS of human health concern are widely distributed and ubiquitous in aquatic systems of North America (*P. aeruginosa*, *Vibrio* spp., *Mycobacterium* spp., E. coli, *Legionella* spp., and *Salmonella* spp.), and therefore pose a potential risk, but not a “new” risk in Lake Winnipeg. In addition, concentrations of bacterial pathogens and cyanobacteria are predominantly determined by other water quality factors (e.g., nutrients and water temperature). Hence, additional transfers of these AIS would likely have little influence on concentrations in a HBB waterbody such as Lake Winnipeg.

Similar to the effects on recreational fishing, incremental beach closures could cause economic impacts if fewer visitors came to the Lake Winnipeg area to recreate. As Lake Winnipeg has become a recreation and vacation home destination, with beach and shoreline recreation a major draw, AIS impacts on beach access could have measurable effects on the $111 million local recreation economy. If beach closures resulted in fewer visitors, impacts would likely include reduced expenditures at local businesses for recreation-related goods and services such as transportation, food, lodging, and equipment. Furthermore, if shoreline recreational quality significantly declined, the property values and associated tax revenues for lakeside retirement and recreation communities would also potentially decline.

First Nations

First Nations communities rely heavily on Lake Winnipeg fisheries for employment as commercial fishermen, for a subsistence food source, and for cultural value. With such reliance on Lake Winnipeg fisheries, it is expected that First Nations communities would be impacted by AIS effects on fishery resources. A study of the economic value of hunting and fishing for the Mushkegowuk region, Hudson and James Bay Lowlands, highlights that the replacement value of subsistence food resources (cost to replace subsistence foods with store-bought foods) can be equivalent to about one-third of the total cash economy in First Nations communities (Berkes et al. 1994).

Based on the estimated subsistence harvest of 140 to 402 MT of fish (Lake Winnipeg Quota Review Task Force 2011) and an average market value of fish of $4,010 per MT (Table 18), the replacement value of the First Nations subsistence fish harvest may be somewhere in the range of $561,000 to $1.6 million annually. Increased food costs could be a noticeable burden on the First Nations communities around Lake Winnipeg, as these communities are low income and have a high unemployment rate (Table 12). Furthermore, it is important to note that replacement cost does not take into account the cultural and/or social value of subsistence activity. Thus, replacement food costs represent a lower bound estimate of the value of subsistence use.

Conclusions

The probability of a Project-related release of water resulting in the transfer of AIS and subsequent establishment in the HBB would be extremely low. An introduction and establishment would require a cascade of low probability events, including: an interruption of water treatment; a pipeline failure and release of AIS-containing water within a contributing drainage area within the HBB; AIS transport through subsurface soil to a surface water body with appropriate conditions to support growth and survival; AIS location of a suitable host or substrate to colonize (i.e., invasive mussels); AIS infection of susceptible host; and AIS establishment throughout an aquatic system. The analysis initially considered the possibility that these events could be independent, correlated, or dependent. As described previously (Section: Risk Assessment), it was determined that the major system components are independent, as would be any potential events that could occur within each component. For instance, a power failure at the Biota WTP near Max would affect the booster pump station, and hence stop the flow of water through the transmission pipeline. Engineering controls are discussed in the Supplemental EIS.

The numerous and diverse non-Project pathways were determined to exhibit a greater risk (baseline risk) for introducing AIS (present in adjacent drainage basins) to the HBB. Many of the species evaluated are widespread and ubiquitous in aquatic systems and may be both present and abundant in the HBB. Water diversions with minimal or limited biota treatment systems, engineering controls, and mitigation response systems (unlike the Project) were determined to exhibit higher risk for AIS interbasin transfer.

Potential environmental impacts are considered to be low or minimal due to the lack of potential of some AIS to cause direct mortality, their ubiquity in the environment, and the general lack of susceptible hosts in the HBB. More substantial impacts are possible from the introduction of quagga mussels and New Zealand mudsnails and additional transfers of zebra mussels especially due to their broad environmental tolerance, rapid spread, and potential to cause metapopulation disruptions (Benson et al. 2012b; Proctor et al. 2007; DFO 2011b). However, impacts would be site-dependent and highly variable, and therefore largely unpredictable.

Although the potential impacts of AIS introductions, or additional transfers (AIS already present in the HBB) could be minimal, the potential exists for pathogens and parasites to cause mortalities significant enough to result in population-level effects. In these cases, there could be impacts on recreational and commercial fisheries, non-fishing recreational activities, and aquaculture operations, all components of the Manitoba economy. The economic impacts on these four sectors would likely differ substantially based on the AIS and the receptor of concern (e.g., susceptible fish hosts). Potential adverse impacts to recreational fisheries could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential impacts to the commercial fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers could be adversely impacted by increased price or reduced availability/quality of local fish.

Table 2, at the beginning of this report, summarizes potential ecological receptors of concern, their recreational or commercial value, and associated pathogens (AIS). This information was expanded to include the primary economic sectors which might be impacted should the specific

AIS become established in the HBB, no matter what the source of introduction (Table 25). Because of the multiple potential pathways and uncertainties regarding AIS establishment and spread, the economic sectors shown must be viewed as those possible from the specific AIS regardless of pathway(s) and temporal patterns of introduction and establishment.

The sectors shown in the table reflect the specific fish listed as important recreational or commercial species in Canadian publications. Those publications exclude some species, and the economic sectors which might be impacted are therefore not listed. However, the sectors shown are believed to be representative for various recreational and commercial fisheries. The annual recreational expenditures for the sectors are presented in Table 13.

Table 25 Aquatic Invasive Species Potential Consequences Summary Table

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Ictalurid Herpesvirus 1 (channel catfish virus)	Virus can cause high mortality of catfish fry and fingerlings. Spread is vertical and horizontal.	Catfish-rearing regions in southern U.S.	Causes limited mortality among wild fish. Primarily a disease of farmed catfish. Environmental impacts not expected.	Economic impacts not expected (pathogen problematic in southern U.S.). Absence of intensive catfish aquaculture in the HBB.
Novirhabdovirus spp. (infectious hematopoietic necrosis virus)	RNA virus that affects wild and captive fish. Can cause mortality in adults and fry. Surviving adults can develop scoliosis.	Endemic in hatchery and wild fish in Pacific Northwest.	Chinook salmon and brown trout hosts for virus could potentially be affected.	Impacts to Chinook salmon and brown trout (both non-native species) recreational fisheries could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Adverse impacts to the commercial fishing sector (e.g., Chinook salmon) (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Aquabirnavirus spp.(infectious pancreatic necrosis virus)	Severe viral disease can affect salmonid fry and post-smolts. Causes abnormal swimming, distended abdomen, and darkened pigmentation. Spread is horizontal.	Widely distributed and primarily affects salmonids.	Salmonid species could be differentially affected due to variable virulence among viral strains.	Impacts to recreational fisheries of salmonids could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Adverse impacts to the commercial fishing sector (salmonids) (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Isavirus spp. (infectious salmon anemia virus)	Virus causes severe anemia, lesions, organ damage, and mortality of hosts, including Atlantic salmon. Spread is horizontal.	Atlantic coastal areas.	Some species of salmonids and non-salmonids may be susceptible.	Impacts to recreational fisheries could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Adverse impacts to the commercial fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Rhabdovirus carpio (spring viremia of carp virus)	Viral disease of carp causes organ damage, hemorrhaging, and sometimes mortality. Thought to have been common in carp ponds since the 5th Century A.D.	Sporadically distributed throughout the U.S. Common in Europe.	Primarily a disease of carp and carp aquaculture. Carp species are susceptible and mortalities could occur at high infection rates.	Adverse impacts to the commercially-valuable carp fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Novirhabdovirus spp. (viral hemorrhagic septicemia virus)	Viral infection can affect a variety of freshwater fishes. Causes hemorrhages of the skin and internal organs, which can result in mortality. Spread is horizontal.	Throughout the Great Lakes west to Wisconsin and east to New York.	Infection could result in mortalities of valuable game fish, such as crappie or muskellunge.	Impacts to recreational fisheries (e.g., crappie, muskellunge) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors.
Renibacterium salmoninarum (bacterial kidney disease)	Obligate bacterial salmonid pathogen that causes BKD. Symptoms are ulcers and boils often followed by systemic infection. Spread is horizontal and vertical.	Occurs throughout much of the northern hemisphere, including the HBB.	Present in the HBB. BKD infections could result in salmonid species mortalities. Infected individuals could also be largely asymptomatic.	Adverse impacts would be likely more problematic in aquaculture facilities. Commercial aquaculture is a small component of the Manitoba economy; therefore, potential economic losses would likely be minimal. However, potential impacts to salmonid recreational fisheries could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Adverse impacts to the commercial fishing sector (salmonids) (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Flavobacterium columnare (columnaris disease)	Bacterium causes columnaris disease in freshwater and marine fishes. Manifests as lesions on the gills, skin, and fins.	Western and southeastern U.S. and Wisconsin, including the HBB.	Present in the HBB. More common in hatchery conditions (especially in catfish growing regions). Potential to cause mortalities of wild fish, including channel catfish.	Impacts to recreationally-valuable catfish fisheries (e.g., channel catfish) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (e.g., channel catfish) (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Edwardsiella spp.	Enteric bacteria sometimes pathogenic to fish. Symptoms include lethargy, poor swimming, and lesions.	*Edwardsiella tarda* distributed globally, including the HBB. Common in intense catfish rearing areas of the U.S.	Present in the HBB. Common in catfish rearing regions, but *Edwardsiella* spp. can affect catfish (channel catfish, brown bullhead), as well as other wild species (e.g., black crappie, largemouth bass). Large mortalities do not appear frequent so population declines of recreational fisheries would be unlikely or rare.	Economic effects would not be expected due to the low likelihood of population-level effects to recreational fisheries.
Yersinia ruckeri (ERM)	Bacterium that causes ERM, a systemic infection primarily in salmonids. Causes lethargy and hemorrhages. Spread is horizontal.	Global distribution.	Present in the HBB. May affect salmonid and non-salmonid fish species. Based on its history, outbreak could cause large mortalities or fishery declines. Incremental or additive adverse effects to fish not expected as a result of additional transfers (from any adjacent drainage basin).	Impacts to recreational fisheries (salmonids) could result in decreased expenditures by recreational anglers and decreased revenues, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Aeromonas salmonicida (furunculosis)	Bacterium that causes the disease furunculosis. Causes boils and ulcerative lesions. Affects wide range of salmonid fishes. Spread is horizontal. Primarily affects salmonids.	Reported from several western U.S. states and Europe. Present in the HBB	Present in the HBB. May affect several species of salmonids, however, native salmonids such as brook trout could be at a greater risk than introduced salmonid species. Incremental or additive adverse effects to fish not expected as a result of additional transfers.	Impacts to recreational fisheries, including brook trout could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors.
Streptococcus spp.	Bacterial infection commonly called strep. Causes abnormal swimming, lethargy, pop-eye, hemorrhaging, etc.	Global	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Escherichia coli	E. coli bacteria cause gastrointestinal distress in humans. Transmitted via fecal contamination of food or water.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Legionella spp.	Bacteria that cause diseases of humans such as Legionnaire's disease. Occur in water sources such as cooling towers, spas, etc. Pneumonia is common, but symptoms vary widely.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Mycobacterium spp.	A wide range of bacteria, some of which are pathogenic to humans. Cause diseases such as tuberculosis or Crohn's disease.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Pseudomonas spp.	Common bacteria found in soil, water, skin, plants, and most man-made environments worldwide. Can cause dermatitis, septicemia, etc.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Salmonella spp.	Enteric bacteria that cause human illnesses such as typhoid fever and food poisoning.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Vibrio cholera (cholera)	Bacteria causing the human disease cholera, manifested as diarrhea and vomiting.	Global.	Not endemic to the U.S., therefore low chance of introduction and potential associated impacts to HBB.	No adverse economic effects expected from this extremely rare pathogen.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Potamopyrgus antipodarum (New Zealand mudsnail)	The New Zealand mudsnail is invasive in North America. Juveniles are miniscule and adults are small (4-6 mm) and easily dispersed in water.	Abundant in the western U.S., noted in the MRB.	Dense populations of New Zealand mudsnails could threaten (out-compete) native mollusks, overgraze algae, and change energy flows and disrupt food-webs. In extreme situations, fish population declines could occur as a result of food web structure alterations.	Impacts to recreational fisheries (related to population declines in only the most extreme circumstances) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Dreissena polymorpha (zebra mussel)	The zebra mussel is a freshwater bivalve native to Eurasia. Highly adaptable to a wide range of environments and can colonize rapidly. Larvae are planktonic and easily dispersed in water.	Great Lakes region, MRB, HBB, Red River in ND, and Pelican Lake, MN	Present in the HBB. Ecosystems could be impacted as populations of zebra mussels remove (filter) phytoplankton disrupting food webs. In extreme situations, fish population declines could occur as a result of food web structure alterations.	Economic impacts could include declines of commercially valuable fisheries, such as lake whitefish. Fishery declines could result in reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish. Zebra mussels could also cause “fouling” of port infrastructure, which is costly to remediate.
Dreissena rostriformis bugensis (quagga mussel)	The quagga mussel is a freshwater bivalve native to Europe. Highly adaptable to a wide range of environments and colonize rapidly. Larvae are planktonic and easily dispersed in water.	Great Lakes region and Colorado.	Ecosystems could be impacted as populations of quagga mussels remove (filter) phytoplankton disrupting food webs. In extreme situations, fish population declines could occur as a result of food web structure alterations.	Impacts to recreational fisheries (related to population declines in only the most extreme circumstances) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential impacts to commercial fisheries could result in reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Myxobolus cerebralis (whirling disease)	Parasite that causes whirling disease of juvenile salmonids. Symptoms may be severe and include malformations of the head and spine. Complex life cycle of the parasite includes an annelid worm intermediate host. Susceptibility varies among species of salmonids.	Present in most western U.S. states, as well as in New York and Maryland.	The susceptibility of lake whitefish and other native fish (in the HBB) to whirling disease has not been verified. There is a lack of vulnerable salmonid populations in the Souris River and North Dakota region of the HBB. *Myxobolus cerebralis* could be transferred from drainage basins other than the MRB to regions of the HBB (e.g., Canada) supporting populations of susceptible salmonid species, which could potentially be impacted from infection.	Impacts to recreational fisheries (e.g., rainbow trout) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (e.g., rainbow trout) (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Polypodium hydriforme	Parasite that invades the eggs of sturgeon and paddlefish. Multiple life-stages exist, including a free-living stage.	MRB, HBB, Great Lakes region, Missouri, and California. Also found in Canada in the Nelson, St. John, Saskatchewan, and Winnipeg Rivers.	Present in the HBB. Parasite can reduce the number of viable eggs of sturgeon and paddlefish; however, infection does not appear to cause population-level effects. No adverse effects expected as a result of additional transfers.	Economic impacts not expected due to a lack of potential for population-level effects.
Actheres pimelodi	Parasitic copepod that attached to the mouth cavity, tongue, or gills of fish host.	Considered to be widespread throughout North America	Likely a normal component of fish parisitofauna in the HBB. No records regarding the potential for mortalities in wild fish populations. Unknown potential for environmental impacts, including population-level effects of wild fish.	Unknown potential for economic impacts.
Ergasilus spp.	Parasitic copepod that attached to the mouth cavity, tongue, or gills of fish host.	Thought to be widespread throughout North America	Likely a normal component of fish parisitofauna in the HBB. No records regarding the potential for mortalities in wild fish populations. Unknown potential for environmental impacts, including population-level effects of wild fish.	Unknown potential for economic impacts.
Icelanonchohaptor microcotyle	Parasitic trematode that infects fish. Little known about life history characteristics of this rare organism.	Identified in the Missouri River. Further distribution unknown.	Organism is extremely rare. Unknown potential for environmental impacts, including population-level effects of wild fish.	Unknown potential for economic impacts.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Corallotaenia minutia	Parasitic cestode that infects catfish. Requires a copepod intermediate host. Little known about life history characteristics of this rare organism.	Identified in the Missouri River. Further distribution unknown.	Organism is extremely rare. Unknown potential for environmental impacts, including population-level effects of wild fish.	Unknown potential for economic impacts.
Cryptosporidium parvum (crypto)	Parasitic protozoan that causes gastrointestinal distress in mammals. Transmitted by fecal contamination of food or water.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Giardia lamblia (giardia)	Parasitic protozoan that causes gastrointestinal distress in mammals. Transmitted by fecal contamination of food or water.	Global.	Ubiquitous in aquatic systems including the HBB. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Entamoeba histolytica	Parasitic protozoan that causes gastrointestinal distress, liver abscesses, and fever in humans.	Global.	Not common in U.S. and other industrialized countries so low likelihood of transfer to the HBB. Potential to cause human illness through contaminated water (feces).	No adverse economic effects expected from this pathogen that is extremely rare in the U.S.
Ichthyophthirius multifiliis (ich or white spot disease)	A highly pathogenic protozoan ciliate external parasite that causes the disease “ich” in freshwater fishes. Encysts in the skin of hosts forming visible white nodules.	Global.	Could cause mortalities of captive or wild fish, including pre-spawning salmonids.	Impacts to recreational fisheries could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Ichythyophonus hoferi (ichthyophonosis)	A fungus-like protozoan that causes chronic, progressive internal infection in wild and cultured fish. Symptoms include lesions on the internal organs and skin. Transmitted when the tissue of an infected fish is consumed by another fish.	Northern hemisphere	Could cause mortalities of captive or wild fish. Unknown potential for causing population-level impacts to fish hosts.	Impacts to recreational fisheries could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Saprolegnia spp. (saprolegniosis or winter fungus disease)	Causes winter fungus disease of fish. Characterized by brownish patches of cottony fungal growth on the skin and gills.	Global.	Infections are most common in captive fish (e.g., catfish aquaculture), so reared populations could be at risk. Unknown potential for causing population-level impacts to wild fish hosts.	Channel catfish are not raised in aquaculture facilities in Manitoba. Therefore no adverse economic effects are expected in the local economy. In addition, aquaculture is a small component of Manitoba's economy.
Branchiomyces spp. (branchiomycosis)	Fungus that primarily infects the blood vessels of the gills of fish. Causes hypoxia due to tissue obstruction of gills.	Global.	Infections are most common in captive fish (e.g., catfish and salmonid aquaculture), so reared populations could be at risk. Unknown potential for causing population-level impacts to wild fish hosts.	Potential adverse impacts to aquaculture and the commercial fishing sector could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.

AIS	Major Life History Characteristics	Distribution	Potential Environmental Consequences in HBB	Potential Economic Consequences in HBB
Phoma herbarum	A weakly infectious, facultative fungal pathogen of fish. Normally a pathogen of plants but sometimes invades the air bladder or digestive tract of fish. Causes gut obstruction, hemorrhaging, etc.	Global.	Potential to impact salmonids including Chinook salmon based on experimental evidence of fingerling mortality (study results may not be indicative of natural effects of infection).	Impacts to recreational fisheries (e.g., Chinook salmon) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors. Potential adverse impacts to the commercial fishing sector (e.g., Chinook salmon) (including processors, wholesalers, etc.) could include reduced profit, employment, and catch value, while consumers may be adversely impacted by increased price or reduced availability/quality of local fish.
Exophiala spp. (black yeast)	Pathogenic fungal species commonly called "black yeasts." Causes ulcers and nodules in fish.	Global.	Potential to cause mortalities of salmonid (e.g., lake trout) and non-salmonid species (channel catfish) in the HBB. Unknown potential for causing population-level effects in fish hosts.	Impacts to recreational fisheries (e.g., lake trout, channel catfish) could result in decreased expenditures by recreational anglers, decreased value of the recreation experience to recreationists, and decreased revenues in associated economic sectors.
Anabaena flos-aquae (blue-green algae)	Blue-green algae that can release neurotoxic and hepatotoxic compounds, which may be harmful to humans.	Global.	Present in the HBB, including Lake Winnipeg. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Aphanizomenon flos-aquae (blue-green algae)	Blue-green algae that can release neurotoxic and hepatotoxic compounds, which may be harmful to humans.	Global.	Present in the HBB, including Lake Winnipeg. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.
Microcystis aeruginosa (blue-green algae)	Blue-green algae that can release hepatotoxic compounds, which may be harmful to humans.	Global.	Present in the HBB, including Lake Winnipeg. Incremental or additive adverse effects not expected as a result of additional transfers.	No adverse economic effects expected as a result of additional transfers.

The uncertainty revealed during the current analysis precludes the prediction of definitive results in terms of risks and consequences of AIS establishment in the HBB. Actual concentrations of AIS in drainage basins adjacent to the HBB are not available, which would be vital input parameters for a quantitative analysis. However, the available data and information acquired and evaluated provided the necessary means to conduct a qualitative assessment and comparison of biota transfer pathways. Proper execution of Project operation and maintenance activities and mitigation measures would translate to risk reduction of both Project-related and total aggregate risk of AIS introduction to the receiving basin.

References

Aboriginal Affairs and Northern Development Canada (AADNC). 2011. First Nation Details. Website (http://pse5-esd5.ainc-inac.gc.ca/fnp/Main/index.aspx) accessed December 2, 2011.

Ackerman, J.D., B. Sim, S.J. Nichols, and R. Claudi. 1994. A review of the early life history of zebra mussels (*Dreissena polymorpha*): comparisons with marine bivalves. *Canadian Journal of Zoology* 72:1169-1179.

Addiss, D.G., J.P. Davis, M. LaVenture, P.J. Wand, M.A. Hutchinson, and R.M. McKinney. 1989. Community-acquired Legionnaires' disease associated with a cooling tower: evidence for longer-distance transport of *Legionella pneumophila*. *American Journal of Epidemiology* 130:557–568.

Ahne, W., H.V. Bjorklund, S. Essbauer, N. Fijan, G. Kurath, and J.R. Winton. 2002. Spring viremia of carp (SVC*). Diseases of Aquatic Organisms* 52:261-272.

Alexander, J.D. 2010. Dissertation: Influence of environmental features on *Tubifex tubifex* and *Myxobolus cerebralis* infected *Tubifex tubifex* in Yellowstone National Park: Implications for whirling disease risk.

Appelbee, A.J., R.C.A. Thompson, and M.E. Olson. 2005. *Giardia* and *Cryptosporidium* in mammalian wildlife – current status and future needs. Trends in Parasitology 21: 370-376.

Aquatic Nuisance Species Task Force (ANSTF). 2006. National Management and Control Plan for the New Zealand Mudsnail (*Potamopyrgus antipodarum*). Draft. August 2006. Prepared by the New Zealand Mudsnail Management and Control Plan Working Group. 96 pp.

Arango, C.P., L.A. Riley, J.L. Tank, and R.O. Hall, Jr. 2009. Herbivory by an invasive snail increases nitrogen fixation in a nitrogen-limited stream. *Canadian Journal of Fisheries and Aquatic Sciences* 66: 1309-1317.

Arkoosh, M.R., E. Casillas, E. Clemons, A.N. Kagley, R. Olson, P. Reno, and J.E. Stein. 1998. Effects of pollution of fish diseases: potential impacts on salmonid populations. *Journal of Aquatic Animal Health* 10(2)182-190.

Arman Engineering Testing, Ltd. 1997. A geotechnical evaluation report for Houston Engineering, Inc. Proposed Northwest Area Water Supply (NAWS). Bismarck, ND. 244 pp.

Arnizaut, A.B., and L.A. Hanson. 2011. Antibody response of channel catfish after channel catfish virus infection and following dexamethasone treatment. Diseases of Aquatic Organisms 95: 189-201.

Arndt, R.E., and E.J. Wagner. 2003. Filtering *Myxobolus cerebralis* triactinomyxons from contaminated water using rapid sand filtration. Aquacultural Engineering 29:77-91.

Aveskamp, M.M., J. De Gruyter, and P.W. Crouse. 2008. Biology and recent developments in the systematic of *Phoma*, a complex genus of major quarantine significance. Fungal Diversity 31: 1-18.

Bagge, A.M., R. Poulin, and E.T. Valtonen. 2004. Fish population size, and not density, as the determining factor of parasite infection: a case study. Parasitology 128:305-313.

Ballot, A., L. Krienitz, K. Kotut, C. Wiegand, and S. Pflugmacher. 2005. Cyanobacteria and cyanobacterial toxins in the alkaline crater lakes Sonachi and Simbi, Kenya. Harmful Algae 4: 139–150.

Bartell, S.M., and S.K. Nair. 2003. Establishment risks for invasive species. Risk Analysis 24:833-845.

Befus, A.D., and R.S. Freeman. 1972. Life cycles of two corallobothriin cestodes (Proteocephaloidea) from Algonquin Park, Ontario. *Canadian Journal of Zoology* 51: 249-257.

Belding, D.L., and B. Merrill. 1935. A preliminary report upon a hatchery disease of the Salmonidae. Transactions of the American Fisheries Society 65: 76-84.

Bensley, M., T.A. Dick, C. Hudson, J.S. Lumsden, K. Kenneth Peters, B.W. Souter, L. Vannest, D.B. Donald, and R. Nelson. 2011. Devils Lake – Red River basin fish parasite and pathogen project – qualitative risk assessment. Prepared by the Aquatic Ecosystem Committee. Prepared for International Red River Board and International Joint Commission. October. 45 pp.

Benson, A. J., D. Raikow, J. Larson, and A. Fusaro. 2012a. Dreissena polymorpha. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Website (http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=5) Revision Date: February 15, 2012.

Benson, A.J., M.M. Richerson, E. Maynard, J. Larson, and A. Fusaro. 2012b. *Dreissena bugensis*. USGS Nonindigenous Aquatic Species Database. Website (http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=95) Revision Date: March 19, 2012.

Benson, A. J., and R. M. Kipp. 2011. *Potamopyrgus antipodarum*. United States Geological Survey (USGS) Nonindigenous Aquatic Species Database Website (http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1008) accessed January 24, 2012.

Bergey, D.H., and J.G. Holt. 2000. Bergey's Manual of Determinative Bacteriology, 9th Edition. Lippincott Williams & Williams, 530 Walnut St. Philadelphia, PA 19106 USA.

Berkes, Fikret, P. J. George, R. J. Preston, A. Hughes, J. Turner, and B. D. Cummins. 1994. "Wildlife harvesting and sustainable regional native economy in the Hudson and James Bay Lowland, Ontario." Arctic: p. 356.

Bitar, D.M., M. Molmeret, and Y.A. Kwaik. 2004. Molecular and cell biology of Legionella pneumophila. *International Journal of Medical Microbiology* 293: 519-527.

Bitton, G. 1999. Wastewater Microbiology. Second Edition. Eds: R. Mitchell. University of Florida, Gainesville, FL. 578 pp.

Bossenbroek, J. M., L. E. Johnson, B. Peters, and D. M. Lodge. 2007. Forecasting the expansion of zebra mussels in the United States, *Conservation Biology* 21: 800– 810.

Brickley, K. 2012. Department of Fisheries and Oceans Canada (DFO). Personal communication with Deva Shafer, Assistant Staff Scientist, Cardno ENTRIX, January 27.

Brown, K.M., B. Lang, and K.E. Perez. 2008. The conservation ecology of North American pleurocerid and hydrobiid gastropods. *Journal of North American Benthological Society* 27(2):484-495.

Bruce R.L., C.M. Moffitt, and B. Dennis. 2009. Survival and passage of ingested New Zealand mudsnails through the intestinal tract of rainbow trout. *North American Journal of Aquaculture* 71, 287–301.

Bruce, R.L., and C.M. Moffitt. 2010. Quantifying risks of volitional consumption of New Zealand mudsnails by steelhead and rainbow trout. *Aquaculture Research* 41:552-558.

Bruno, D.W. 1990. Enteric redmouth disease. Aquatic Information Series No. 10. Department of Agriculture and Fisheries for Scotland, Marine Laboratory, Aberdeen, Scotland.

Buchanan, G.D., and M. Flurry. 2004. Pathogen transport by water, in *Encyclopedia of Water Science*, B.A. Steward and T.A. Howell (Eds.), Marcel Decker, New York.

Bullock, G.L. 1981. Streptococcal infections of fishes. U.S. Fish and Wildlife Service, Fish Disease Leaflet 63.

Bullock, G.L. 1984. Enteric redmouth disease of salmonids. U.S. Fish and Wildlife, Washington D.C. Fish Disease Leaflet 67. 17pp.

Bullock, G.L., and R.C. Cipriano. 1990. Revision of Fish Disease Leaflet 57 (1979) by G.L. Bullock and S.F. Snieszko and Fish Disease Leaflet 67 by G.L. Bullock. Enteric redmouth disease of salmonids. U.S. Fish & Wildlife Service, Fish Disease Leaflet 82.

Bullock, G.L., and R.L. Herman. 1985. *Edwardsiella* infections of fishes. U.S. Fish and Wildlife Service National Fish Health Research Laboratory, Fish Disease Leaflet 71.

Bullock, G.L., and H.M. Stuckey. 1977. Ultraviolet treatment of water for destruction of five Gram-negative bacteria pathogenic to fish. *Journal of the Fisheries Research Board of Canada* 34:1244-1249.

Bullock, G.L., H.M. Stuckey, and E.B. Shotts, Jr. 1978. Enteric redmouth bacterium: comparison of isolates from different geographic areas. *Journal of Fish Pathology* 1: 351-356.

Bullock, G.L., T.S. Hsu, and E.B. Shotts, Jr. 1986. Columnaris disease of fishes. U.S. Fish & Wildlife Publications Paper 129. Available online (http://digitalcommons.unl.edu/usfwspubs/129).

Bumke-Vogt, C., W. Mailahn, and I. Chorus. 1999. Anatoxin-a and neurotoxic cyanobacteria in German lakes and reservoirs. *Environmental Toxicology* 14: 117–125.

Bunting, L., P.R. Levitt, B. Wissel, K.R. Laird, B.F. Cumming, A. St. Amand, and D.E. Engstom. 2010. Sudden ecosystem state change in Lake Winnipeg, Canada, caused by eutrophication arising from crop and livestock production during the 20th century. Limnology Laboratory, Department of Biology, University of Regina, Regina, Saskatchewan, Canada. 67 pp.

Burgiel, S.W. and A.A. Muir. 2010. Invasive Species, Climate Change and Ecosystem Based Adaption: Addressing Multiple Drivers of Global Change. Global Invasive Species Programme (GISP), Washington DC, U.S., and Nairobi, Kenya.

Burridge, L., J.S. Weis, F. Cabello, J. Pizarro, and K. Bostick. 2010. Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. *Aquaculture* 306:7-23.

Burton, T.O., T.R. Meyers, N.S. Starkey, and J.E. Follett. 2004. Experimental transmission of the fungus *Phoma herbarum* to Chinook salmon. *Journal of Aquatic Animal Health* 16: 251-257.

Cadée, G. 2011. *Hydrobia* as "Jonah in the Whale": shell repair after passing through the digestive tracts of shelducks alive. *PALAIOS* 26: 245-249.

California Department of Public Health (CDPH). 2011. California Surface Water Treatment Alternative Filtration Technology Demonstration Report, Draft June 2001.

Camas, A.C. 2004. Channel catfish virus disease. Southern Regional Aquaculture Center Publication No. 4702. Texas A&M University.

Canadian Aquaculture Alliance. 2012. Personal communication with Deva Shafer, Assistant Staff Scientist, Cardno ENTRIX, March 5.

Canadian Council of Fisheries and Aquaculture Ministers Aquatic Invasive Species Task Group. 2004. A Canadian Action Plan to Address the Threat of Aquatic Invasive Species. Website (www.dfo-mpo.gc.ca) accessed February 2, 2012.

Cardno ENTRIX and Andy Cohen. June 30, 2011. California Aquatic Invasive Species Rapid Response Fund, An Economic Evaluation. Prepared for U.S. Fish and Wildlife Service, Stockton, CA.

Cateau, E., T. Mergey, C. Kauffmann-LaCroix, and M.-H. Rodier. 2009. Relationships between free-living amoebae and *Exophiala dermatitidis*: a preliminary study. *Medical Mycology* 47:115-118.

Chang, S.L. 1982. The safety of water disinfection. *Annual Review of Public Health*, 3:393–418.

Chang, S.L., and G.M. Fair. 1941. Viability and Destruction of the Cysts of *Entamoeba histolytica*. *Journal of the American Water Works Association* 33: 1705.

Charalambidou, I., and L. Santamaría. 2005. Field evidence for the potential of waterbirds as dispersers of aquatic organisms. Wetlands 25: 252-258.

Chief Administrator Officer Secretariat (CAO). 2007. Trends Report: Key Demographic, Economic & City Government Information.

Choudhury, A. and T.A. Dick. 1993. Parasites of the lake sturgeon , *Ascipenser fulvescens* Rafinesque, 1817 (Chondrostei: Ascipenseridae) from Central Canada. *Journal of Fish Biology* 42: 571-584.

Chu, C., N.E. Mandrak, and C.K. Minns. 2005. Potential impacts of climate change on the distributions of several common and rare freshwater fishes in Canada. *Diversity and Distributions* 11: 299-310.

Cipriano R.C., P.R. Bowser, A. Dove, A. Goodwin, and C. Puzach (USGS). 2011. Prominent emerging disease within the United States. U.S. Geological Survey, Leetown Science Center, National Fish Health Research Laboratory. 12pp.

City of Winnipeg. 2007. Trends Report: Key Demographic, Economic & City Government Information. Website (http://www.winnipeg.ca/cao/pdfs/TrendsReportDec2007.pdf) accessed November 29, 2011.

City of Winnipeg. 2011. Population of Winnipeg. May 16, 2011.

City of Winnipeg. 2012 .The Community Trends Report: Selected Demographic and Economic Information. Available at (http://www.winnipeg.ca/cao/pdfs/TheCommunityTrendsReportApril2012). Accessed March 25, 2013.

Clarridge, J.E., D.M. Musher, V. Fainstein, and R.J. Wallace, Jr. 1980. Extraintestinal human infection caused by *Edwardsiella tarda*. *Journal of Clinical Microbiology* 11: 511-514.

Claxton, W. T., A. B. Wilson, G. L. Mackie, and E. G. Boulding. 1998. A genetic and morphological comparison of shallow- and deep-water populations of the introduced dreissenid bivalve *Dreissena bugensis*. *Canadian Journal of Zoology*. 76:1269-1276.

Colberg, P.J., and A.J.Lingg. 1978. Effect of ozonation on microbial fish pathogens, ammonia, nitrate, nitrite, and BOD in simulated reuse hatchery water. *Journal of the Fisheries Research Board of Canada* 35: 1290-1296.

Colwell, R.R., J. Kaper, and S.W Joseph. 1977. *Vibrio cholerae, Vibrio parahaemolyticus*, and other vibrios: occurrence and distribution in Chesapeake Bay. *Science* 198**:** 394–396.

Cornwell, E.R., G.E. Eckerlin, T.M. Thompson, W.N. Batts, R.G. Getchell, G.H. Groocock, G. Kurath, J.R. Winton, R.N. Casey, J.W. Casey, M.B. Bain, and P.R. Bowser. 2012. Predictive factors and viral genetic diversity for viral hemorrhagic septicemia virus infection in Lake Ontario and the St. Lawrence River. *Journal of Great Lakes Research* 38:278-288.

Cotton, J.A., J.K. Beatty, and A.G. Buret. 2011. Host parasite interactions and pathophysiology in *Giardia* infections. International Journal for Parasitology 41: 925-933.

Craft, C.D., and C.A. Myrick. 2011. Evaluation of quagga mussel veliger thermal tolerance. Final Report - January 2011 Research Season. Colorado Division of Wildlife.

Crosier, D.M., D.P. Molloy, and J. Bartholomew. Nd. (http://el.erdc.usace.army.mil/ansrp/myxobolus_cerebralis.pdf) accessed October 4, 2011 .

Dadswell, M., B. D. Taubert, T. S. Squiers, D. Marchette, and I. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* LeSueur, 1818. FAO (Food and Agriculture Organization of the United Nations) Fisheries Synopsis 40:16.

Davies, B.R., M. Thoms, and M. Meador. 1992. An assessment of the ecological impacts of inter-basin water transfers, and their threats to river basin integrity and conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 2: 325-349.

De Hoog, G.S., J.S. Zeng, M.J. Harrak, and D.A. Sutton. 2006. Exophiala xenobiotica sp. nov., an opportunistic black yeast inhabiting environments rich in hydrocarbons. DOI 10.1007/s10482-006-9080-z. 12pp.

Devils Lake Basin Joint Water Resource Board (DLBJWRB) and North Dakota State Water Commission (SWC). 2009. Devils Lake Basin Water Management Plan. 2009 Update. 12 pp.

Devlin, J.P., O.E. Edwards, P.R. Gorham, N.R. Hunter, R.K. Pike, and B. Stavric, B. 1977. Anatoxin-a, a toxic alkaloid from *Anabaena flos-aquae* NRC-44 h. *Canadian Journal of Chemistry* 55: 1367–1371.

Dick, T.A., A. Choudhury, and B. Souter. 2001. Parasites and pathogens of the fishes in the Hudson Bay drainage. In: *Science and Policy: Interbasin water transfer of aquatic biota*, J.A. Leitch and M.J, Tenamoc. Institute for Regional Studies, North Dakota State University. 82-103f.

Dickerson, H.W. 2006. Chapter 4 (pp 116 – 152) Ichthyopthirius multifiliis and Cryptocaryon irritans (Phylum Ciliophora) In: *Fish Diseases and Disorders Volume 1: Protozoan and Metazoan Infections*. 2nd Ed. CABI Publishing, Oxfordshire, UK.

Diederen, B.M.W. 2008. *Legionella* spp. and Legionnaires' disease. *Journal of Infection* 56: 1-12.

Dobos, P., and T.E. Roberts. 1983. The molecular biology of infectious pancreatic necrosis virus: a review. *Canadian Journal of Microbiology* 29: 377-384.

Dodds, W.K., W.W. Bouska, J.L. Eitzmann, T.J. Pilger, K.L. Pitts, A.J. Riley, J.T. Schloesser, and D.J. Thornbrugh. 2009. Eutrophication of U.S. freshwaters: Analysis of potential economic damages. *Environmental Science and Technology* 43: 12-19.

Drake, J.M., and J.M. Bossenbroek. 2004. The potential distribution of zebra mussels in the United States. *Bioscience* 54: 931-941.

Duffield, J.W., D.A. Patterson, C.J. Nether, and J.B. Loomis. 1999. Final report economic consequences of whirling disease in Montana and Colorado trout fisheries. August 1999. 67 pps.

Durborow, R.M., D.J. Wise, and J.S. Terhune. 2003. Saprolegniasis (winter fungus) and branchiomycosis of commercially cultured catfish. Southern Regional Aquaculture Center Publication No. 4700.

Durborow, R.M., A.J. Mitchell, and M.D. Crosby. 1998a. Ich (White Spot Disease). Southern Regional Aquaculture Center (SRAC) Publication No. 476.

Durborow, R.M., R.L. Thune, J.P. Hawke, and A.C. Camas. 1998b. Columnaris disease. A bacterial infection caused by *Flavobacterium columnarae*. Southern Regional Aquaculture Center Publication No. 479.

Dybdahl, M.F. and S.L. Kane. 2005. Adaptation vs. phenotypic plasticity in the success of a clonal invader. *Ecology* 86: 1592-1601.

Dzialowski, A. 2010. How will invasive zebra mussels impact drinking water quality in Kansas reservoirs? The Kansas Lifeline. November 2010: 66-68.

Earth Tech and TetrES. 2005. Report on the review of the proposed pre-treatment process for the Northwest Area Water Supply Project. Prepared for the Water Science and Management Branch of the Manitoba Department of Water Stewardship. Earth Tech, Burnaby, British Columbia, Canada and TetrES Consultants Ltd., Winnipeg, Manitoba, Canada.

El-Matbouli, M., T.S. McDowell, D.B. Antonio, K.B. Andree, and R.P. Hedrick. 1999. Effect of water temperature on the development, release and survival of the triactinomyxon stage of *Myxobolus cerebralis* in its oligochaete host. *International Journal of Parasitology* 29: 627-641.

Elwell, L.C.S., K.E. Stromberg, E.K.N. Ryce, and J.L. Bartholomew. 2009. Whirling Disease in the United States. A summary of progress in research and management.

Environment Canada. 2011a. Canada's conservation plan for seabirds and colonial waterbirds. Website (http://www.ec.gc.ca/mbc-com/default.asp?lang=En&n=B65F9B7E-1) accessed January 17, 2012.

Environment Canada. 2011b. State of Lake Winnipeg: 1999 to 2007. Environmental Canada Manitoba Water Stewardship. June 2011. 222 pp.

Environment Canada. 2012. Migratory birds. Website (http://www.ec.gc.ca/nature/default.asp?lang=En&n=FDF836EF-1) accessed June 5, 2012.

Ernst, B., S.J. Hoeger, E. O'Brien, and D.R. Dietrich. 2006. Oral toxicity of the microcystins-containing cyanobacterium *Planktothrix rubescens* in European whitefish (*Coregonus lavaretus*). *Aquatic Toxicology* 79: 31-40.

Faisal, M., E. Elsayed, S.D. Fitzgerald, V. Silva, and L. Mendoza. 2007. Outbreaks of phaeohypomycosis in the Chinook salmon (*Onchorhynchus tshawytscha*) caused by *Phoma herbarum*. Mycopathologia 163: 41-48.

Falkinham III, J.O. 2003. Factors influencing the chlorine susceptibility of *Mycobacterium avium, Mycobacterium intracellulare,* and *Mycobacterium scrofulaceum*. *Applied and Environmental Microbiology* 69: 5685-5689.

Federal Register. 2008. 73 FR 33694. National Pollutant Discharge Elimination System water transfers rule. June 13, 2008.

Federal Register. 2012. 46 CFR Part 162. Standards for living organisms in ships' ballast water discharged in U.S. waters. March 23, 2012.

Ferguson, C., A.M. de Roda Husman, N. Altavilla, D. Deere, and N. Ashbolt. 2003. Fate and transport of surface water pathogens in watersheds. *Critical Reviews in Environmental Science and Technology* 33: 299-361.

Ferguson, J.A., S.D. Atkinson, C.M. Whipps, and M.L. Kent. 2008. Molecular and morphological analysis of *Myxobolus* spp. of salmonid fishes with the description of a new *Myxobolus* species. *Journal of Parasitology* 94: 1322-1334.

Fisheries and Oceans Canada (DFO). 2010. Annual Summary of Fish Harvesting Activities, Volume 25, 2006-2007: xiii + 88 p.

Fisheries and Oceans Canada (DFO). 2011a. Science advice from the risk assessment of New Zealand mud snail (*Potamopyrgus antipodarum*) in Canada. Science Advisory Report 2010/065.

Fisheries and Oceans Canada (DFO). 2011b. Aquatic Invasive Species. Website (www.dfo-mpo.gc.ca) accessed February 2, 2012.

Fisheries and Oceans Canada (DFO). 2012a. The Lake Winnipeg Physa. A Species at Risk in the Prairie Provinces. Website (http://www.dfo-mpo.gc.ca/species-especes/species-especes/physa-physe-eng.htm) accessed January 30, 2012.

Fisheries and Oceans Canada (DFO). 2012b. Survey of Recreational Fishing. Fisheries and Oceans Canada Economic Analysis and Statistics. Supplemental Statistical Tables (CD-ROM). Custom query performed by Keith Brickley of DFO Canada for Devaja Shafer on January 23, 2012.

Fitzgeorge, R.B., A. Baskerville, M. Broster, P. Hambleton, and P.J. Dennis. 1983. Aerosol infection of animals with strains of *Legionella pneumophila* of different virulence: comparison with intraperitoneal and intranasal routes of infection. *Journal of Hygiene London* 90:81–89.

Francis-Floyd, R.J., J. Gildea, P. Reed, and R. Klinger. 1997. Use of Bayluscide (Bayer 73) for snail control in fish ponds. *Journal of Aquatic Animal Health* 9:41-48.

Francis-Floyd R. and P. Reed. 1997. *Ichthyophthirius multifiliis* (white spot) infections in fish. Department of Fisheries and Aquatic Sciences, Florida Cooperative Extention Service, Institute of Food and Agricultural Sciences, University of Florida.

Garretson, S. 2005. An examination of New Zealand mudsnail (*Potamopyrgus antipodarum*) mortality in association with GreenClean® PRO algaecide application. 4th Annual New Zealand Mudsnail in the Western USA Conference, Montana State University, Bozeman, MT, August 16-17, 2005.

Gates, K.K., C.S. Guy, and A.V. Zale. 2008. Adherence of *Myxobolus cerebralis* myxospores to waders: implications for disease dissemination. *North American Journal of Fisheries Management* 28:1453-1458.

Gavryuseva, T.V. 2007. First report of *Ichthophonus hoferi* infection in young coho salmon *Onchorhynchus kisutch* (Walbaum) at a fish hatchery in Kamchatka. *Russian Journal of Marine Biology* 33(1):43-48.

Geurden, T., J. Vercruysse, and E. Claerebout. 2010. Is Giardia a significant pathogen in production animals? *Experimental Parasitology* 124: 98–106.

Gilbert, M.A. and W.O. Granath, Jr. 2003. Whirling disease of salmonids fish: life cycle, biology, and disease. *Journal of Parasitology* 89: 658-667.

Gjessing, M.C., M. Davey, A. Kvellestad, and T. Vrålstad. 2011. *Exophiala angulospora* causes systemic inflammation in Atlantic cod (*Gadus morhua*). *Diseases of Aquatic Organisms* 96: 209-2011.

Goldsborough, William J. 2003. Testimony before the Subcommittee on Fisheries Conservation, Wildlife, and Oceans. Washington, D.C.: U.S. House of Representatives, October 14.

Gomez-Casado, E., A. Estepa, and J.M. Coll. 2011. A comparative review on European-farmed finfish RNA viruses and their vaccines. *Vaccine* 29: 2657-2671.

Gozlan, R.E., E.J. Peeler, M. Longshaw, S. St-Hilaire, S.W. Feist. 2006. Effect of microbial pathogens on the diversity of aquatic populations, notably in Europe. *Microbes and Infection* 8:1358-1364.

Granath, W.O. Jr., M.A. Gilbert, E.J. Wyatt-Pescador, and E.R. Vincent. 2007. Epizootiology of *Myxobolus cerebralis*, the causative agent of salmonid whirling disease in the rock creek drainage of west-central Montana. *Journal of Parasitology* 93: 104-119.

Green, A.J. and J. Figuerola. 2005. Recent advances in the study of long-distance dispersal of aquatic invertebrates via birds. *Diversity and Distributions* 11: 149-156.

Green, A.J., K.M. Jenkins, D. Bell, P.J. Morris, and R.T. Kingsford. 2008. The potential role of waterbirds in dispersing invertebrates and plants in arid Australia. *Freshwater Biology* 53: 380-392.

Greensmith, C.T., R.S. Stanwick, B.E. Elliot, and M.V. Fast. 1988. Giardiasis associated with the use of a water slide. *The Pediatric Disease Journal* 7: 91-94.

Grime, T. 1995. The Great Lakes' Other Mussel Menance! University of Guelph, Canada. Website (http://www.uoguelph.ca/Research/spark/oasis/environ4.html) accessed January 24, 2012.

Hagen, S.K., Isakson, P.T., and S.R. Dyke. 2005. North Dakota Comprehensive Wildlife Conservation Strategy. North Dakota Game and Fish Department. Bismarck, ND. 454 pp. Website (http://gf.nd.gov/conservation/cwcs.html).

Hallett, S.L., and J.L. Bartholomew. 2008. Effects of water flow on the infection dynamics of *Myxobolus cerebralis*. *Parasitology* 135: 371-384.

Halliday, M.M. 1976. The biology of Myxosoma cerebralis: the causative organism of whirling disease of salmonids. *Journal of Fish Biology* 9: 339-357.

Hammell, L., C. Stephen, I. Bricknell, O. Evensen, and P. Bustos. 2009. Salmon aquaculture dialogue working group report on salmon disease commissioned by the Salmon Aquaculture Dialogue. Accessed online: (http://wwf.worldwildlife.org/site/PageNavigator/SalmonSOIForm).

Havens, KE. 2008. Cyanobacteria blooms: effect on aquatic ecosystems. *Advances in Experimental Medicine and Biology* 619:733-747.

Hedrick, R.P. 1998. Relationships of host, pathogen, and environment: Implications for diseases of cultured and wild fish populations. *Journal of Aquatic Animal Health* 10(2):107-111.

Hedrick, R.P., T.S. McDowell, K. Mukkatira, M.P. Georgiadis, and E. MacConnell. 1999. Susceptibility of selected inland salmonids to experimentally induced infections with *Myxobolus cerebralis*, the causative agent of whirling disease. *Journal of Aquatic Animal Health* 11: 330-339.

Hedrick, R.P., B. Petri, T.S. McDowell, K. Mukkatira, and L.J. Sealey. 2007. Evaluation of a range of doses of ultraviolet irradiation to inactivate waterborne actinospore stages of *Myxobolus cerebralis*. *Diseases of Aquatic Organisms* 74:113-118.

Hedrick, R.P., T.S. McDowell, K. Mukkatira, E. MacConnell, and B. Petri. 2008. Effects of freezing, drying, ultraviolet irradiation, chlorine, and quaternary ammonium treatments on the infectivity of myxospores of *Myxobolus cerebralis* for *Tubifex Tubifex. Journal of Aquatic Animal Health* 20:116-125.

Herborg, L.-M., C.L. Jerde, C.L. Lodge, D.M. Ruiz, M. Gregory, and H.J. MacIsaac. 2007. Predicting invasion risk using measures of introduction effort and environmental niche models. *Ecological Applications,* Volume 17, No. 3, pp. 663-674.

Hershberger, P.K., C.A. Pacheco, and J.L. Gregg. 2008. Inactivation of Ichthyophonus spores using sodium hypochlorite and polyvinyl pyrrolidone iodine. *Journal of Fish Diseases* 31:853-858.

Higgins, S. N., and M. J. Vander Zanden. 2010. What a difference a species makes: A meta-analysis of dreissenid mussel impacts on freshwater ecosystems. *Ecological Monographs* 80: 179–196.

Hill, B.J., B.O. Underwood, C.J. Smale, and F. Brown. 1975. Physico-chemical and serological characterization of five rhabdoviruses infecting fish. *The Journal of General Virology* 27: 369–78.

Hlavsa, M.C., J.C. Watson and M.J. Beach. 2005. Centers for Disease Control (CDC). Cryptosporidiosis surveillance – United States 1999-2002. Website (http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5401a1.htm) accessed January 24, 2012.

Hoffman, G.L. 1974. Disinfection of contaminated water by ultraviolet irradiation, with emphasis on whirling disease (Myxosoma cerebralis) and its effects on fish. *Transactions of the American Fisheries Society* 103:541-550.

Hoffman, G.L., E.V. Raikova, and W.G. Yoder. 1974. *Polypodium* sp. (Colenterata) found in North American sturgeon. *Journal of Parasitology* 60:548–550.

Holeck, Kristen. 2008. Ecological Indicators and Sustainability of the Lake Ontario Ecosystem. Cornell Biological Field Station. 6 pp.

Holm, R. 2011. Garrison Dam National Fish Hatchery. Personal communication with E. Koppel, Staff Scientist, Cardno ENTRIX, September 23.

Hosea, R.C. and B. Finlayson. 2005. Controlling the spread of New Zealand mud snails on wading gear. California Department of Fish and Game. Office of Spill Prevention and Response Administrative Report 2005-02.

Houston Engineering, Inc., American Engineering P.C., Montgomery Watson, and Bluestem Incorporated. 2001. Northwest Area Water Supply Project Final Environmental Assessment. Prepared for North Dakota Water Commission, North Dakota Garrison Diversion Conservancy District and U.S. Bureau of Reclamation. Bismarck, North Dakota.

Houston Engineering, Inc. and Montgomery Watson. 2001. North Dakota State Water Commission and the Garrison Diversion Conservancy District – Northwest Area Water Supply Project biota control measures. Update. Prepared for the North Dakota State Water Commission. Bismarck, North Dakota.

Houston Engineering, Inc., Montgomery Watson, and American Engineering. 1998. North Dakota State Water Commission and the Garrison Diversion Conservancy District – Northwest Area Water Supply Project Biota Transfer Control Measures. Prepared for the North Dakota State Water Commission. Bismarck, North Dakota.

Hoyle, J.A., J.N. Bowlby, and B.J. Morrison. 2008. Lake whitefish and walleye population responses to dreissenid mussel invasion in eastern Lake Ontario. *Aquatic Ecosystem Health Management* 11(4):403-411.

Hoyle, J.A., T. Schaner, J.M. Casselman, and R. Dermott. 1999. Changes in Lake Whitefish (*Coregonus clupeaformis*) Stocks in Eastern Lake Ontario Following Dressena Mussel Invasion. Great Lakes Research Review 4(2):5-9.

Hsu, B-M. and H-H. Yeh. 2003. Removal of *Giardia* and *Cryptosporidium* in drinking water treatment: a pilot-scale study. *Water Research* 37:1111-1117.

Huberty, G. 2008. Office Memorandum, State of Minnesota Department of Natural Resources – Division of Fish and Wildlife. Red River Catfish Kill, September 2007. March 20.

Hudault, S., J. Guignot, and A.L. Servin. 2001. *Echerichia coli* strains colonising the gastrointestinal tract protect germfree mice against *Salmonella typhimurium* infection. *Gut* 49: 47-55.

Huq, A., E.B. Small, P.A. West, M.I. Huq, R. Rahman, and R.R. Colwell. 1983. Ecological relationships between *Vibrio cholerae* and planktonic crustacean copepods. *Applied and Environmental Microbiology* 45: 275–83.

Idrisi, N., E.L. Mills, L.G. Rudstam, and D.J. Stewart. 2001. Impact of zebra mussels (*Dreissena polymorpha*) on the pelagic lower trophic levels of Oneida Lake, New York. *Canadian Journal of Fish and Aquatic Science* 58: 1430-1441.

Inglis, V., R.J. Roberts, and N.R. Bromage. 1993. Chapter 12: Streptococcal infections. *In* Bacterial Diseases of Fish, Halsted Press, John Wiley & Sons, Inc., NY. pp. 196-197.

Iowa State University (ISU). 2005. Infectious Hematopoietic Necrosis. The Center for Food Security & Public Health, College of Veterinary Medicine, Ames, IA, USA.

Iowa State University (ISU). 2007a. Infectious Hematopoietic Necrosis. The Center for Food Security & Public Health, College of Veterinary Medicine, Ames, IA, USA.

Iowa State University (ISU). 2007b. Spring Viremia of Carp. The Center for Food Security & Public Health, College of Veterinary Medicine, Ames, IA, USA.

Iowa State University (ISU). 2007c. Viral Hemorrhagic Septicemia. The Center for Food Security & Public Health, College of Veterinary Medicine, Ames, IA, USA.

Iowa State University (ISU). 2010. Infection salmon anemia (ISA) factsheet. The Center for Food Security and Public Health and Institute for International Cooperation in Animal Biologics. March 15, 2010. 7 pp.

Iowa State University (ISU). 2012. VHS. Focus on Fish Health. Website (http://www.focusonfishhealth.org/vhs.php) accessed June 5, 2012.

Isaac-Renton, J.L., L.F. Lewis, C.S.L. Ong, and M.F. Nulsen. 1994. A second community outbreak of waterborne giardiasis in Canada and serological investigation of patients. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 88: 395-399.

Islam, M.S., B.S. Drasar, and D.J. Bradley. 1990. Long-term persistence of toxigenic *Vibrio cholerae* 01 in the mucilaginous sheath of a blue-green alga, *Anabaena variabilis*. *Journal of Tropical Medicine and Hygiene* 93: 133–39.

Iwanowicz, D.D. 2011. Overview on the effects of parasites on fish health. USGS, Leetown Science Center, National Fish Health Research Laboratory, Kearneysville, WV, USA.

Jerde, C.L., M.A. Barnes, J. McNulty, A.R. Mahon, W.L. Chadderton, and D.M. Lodge. 2010. Aquatic invasive species risk assessment for the Chicago Sanitary and Ship Canal. University of Notre Dame, Center for Aquatic Conservation, Notre Dame, IN.

Kappes, H. and P. Haase. 2012. Slow, but steady: dispersal of freshwater mollusks. *Aquatic Sciences* 74: 1-14.

Karanis, P., C. Kourenti, and H. Smith. 2007. Waterborne transmission of protozoan parasites: a worldwide review of outbreaks and lessons learnt. *Journal of Water and Health* 5: 1-38.

Karatayev A.Y., L.E. Burlakova, D.P. Molloy, and S.E. Mastitsky. 2007. *Dreissena polymorpha* and *Conchophthirus acuminatus*: what can we learn from host-commensal relationships. *Journal of Shellfish Research* 26(4):1153-1160.

Katona, R.J. 2010. Bacterial, viral, and parasitic assessments of walleye (*Sander vitreum*), sauger (*Sander canadensis*), and yellow perch (*Perca flavescens*) in the Wisconsin Mississippi River Drainage. Thesis: University of Wisconsin- La Crosse.

Katz, A., N. Narkis, F. Orshanky, E. Friedland, and Y. Kott. 1994. Disinfection of effluent by combinations of equal doses of chlorine dioxide and chlorine added simultaneously over varying contact times. *Water Research* 28:2133-2138.

Kerans, B.L., M.F. Dybdahl, M.M. Gangloff, and J.E. Jannot. 2005. *Potamapyrgus antipodarum*: distribution, density, and effects on native macroinvertebrate assemblages in the greater Yellowstone ecosystem. *Journal of the North American Benthological Society* 24: 123-138.

Kerr, S.J., C.S. Brousseau, and M. Muschett. 2005. Invasive Aquatic Species in Ontario - A Review and Analysis of Potential Pathways for Introduction. Website (http://www.tandfonline.com/doi/abs/10.1577/1548-8446%282005%2930%5B21%3AIASIO%5D2.0.CO%3B2) accessed February 17, 2012.

Khoo, L., A.T. Leard, P.R. Waterstrat, S.W. Jack, and K.L. Camp. 1998. Branchiomyces infection in farm-reared channel catfish, *Ictalurus punctatus* (Rafinesque). *Journal of Fish Diseases* 21:423-431.

Kipp, R.M. 2007a. *Aeromonas salmonicida*. United States Geological Survey Nonindigenous Aquatic Species Database. Website (http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=2353) accessed January 24, 2012.

Kipp, R.M. 2007b. *Renibacterium* (Corynebacterium) *salmoninarum*. United States Geological Survey Nonindigenous Aquatic Species Database. Website (http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=2736) accessed February 6, 2012.

Kipp, R.M., and A. Ricciardi. 2012. Novirhabdovirus sp. United States Geological Survey (USGS) Nonindigenous Aquatic Species Database. Website (http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=2656) accessed January 30, 2012.

Koel, T.M., B.L. Kerans, S.C. Barras, K.C. Hanson, and J.S. Wood. 2010. Avian piscivores as vectors for *Myxobolus cerebralis* in the Greater Yellowstone ecosystem. *Transactions of the American Fisheries Society* 139: 976-988.

Koren, C.W.R., and A. Nylund. 1997. Morphology and morphogenesis of infectious salmon anemia virus replicating in the endothelium of Atlantic salmon *Salmo salar*. *Diseases of Aquatic Organisms* 29: 99-109.

Kramer-Schadt S., J.C. Holst, and D. Skagen. 2010. Analysis of variables associated with the *Icthyophonus hoferi* epizootics in Norwegian spring spawning herring, 1992-2008. *Canadian Journal of Fish and Aquatic Sciences* 67:1862-1873.

Krkosek, M., B.M. Connors, A. Morton, M.A. Lewis, L.M Dill, and R. Hilborn. 2011. Effects of parasites from salmon farms on productivity of wild salmon. *Proceedings of the National Academy of Sciences* 108(35):14700-14704.

Kucuktas, H. and Y.J. Brady. 1999. Molecular biology of channel catfish virus 1. *Aquaculture* 172: 147-161.

Lafferty, K.D., and A.M. Kuris. 1999. How environmental stress affects the impacts of parasites. *Limnology and Oceanography* 44:925-931.

Lafferty, K.D., and A.M. Kuris. 2002. Trophic strategies, animal diversity and body size. *Trends in Ecology and Evolution* 17:507-513.

Lake Superior Working Group (LSWG). 2009. Draft Lake Superior Aquatic Invasive Species Complete Prevention Plan. December 18. Draft. 81pp.

Lake Winnipeg Implementation Committee. 2007. Restoring the Health of Lake Winnipeg. Winnipeg, MB.

Lake Winnipeg Quota Review Task Force. 2011. Technical Assessment of the Status, Health and Sustainable Harvest Levels of the Lake Winnipeg Fisheries Resource. Submitted January 11, 2011. Manitoba Minister of Water Stewardship.

Lake Winnipeg Stewardship Board. 2005. Our Collective Responsibility: Reducing Nutrient Loading to Lake Winnipeg. An interim report to the Minister of Manitoba Water Stewardship. January. 52 p. Website (http://www.gov.mb.ca/waterstewardship/water_quality/lake_winnipeg/LWSB%20Interim%20Report%20January%2005.pdf) accessed October 2011.

Lake Winnipeg Stewardship Board. 2011. Lake and Watershed Facts. Website (http://www.lakewinnipeg.org/web/content.shtml?pfl=public/downloads.param&page=000103&op9.rf1=000103) accessed December 1, 2011.

Lance, E., L. Brient, A. Carpentier, A. Acou, L. Marion, M. Bormans, and C. Gérard. 2010. Impact of toxic cyanobacteria on gastropods and microcystins accumulation in a eutrophic lake (Grand-Lieu, France) with special reference to *Physa* (= *Physella*) *acuta*. *Science of the Total Environment* 408: 3560-3568.

Leathe, S., T. Horton, T. McMahon, A. Munro, and A. Zale. 2002. Interaction of life history, fish size, and infection risk on population-level effects of whirling disease in wild rainbow trout. Final Report December 31, 2002.

LeChevallier, M.W., and K-K. Au. 2004. Water treatment and pathogen control – Process efficiency in achieving safe drinking water. World Health Organization. IWA Publishing, London, UK.

LeChevallier, M.W., T.M. Evans, and R.J. Seider. 1981. Effect of turbidity on chlorination efficiency and bacterial persistence in drinking water. *Applied and Environmental Microbiology* 42:159-267.

Lee, E-S., T-H. Yoon, M-Y. Lee, S-H. Han, and J-O, Ka. 2010. Inactivation of environmental mycobacteria by free chlorine and UV. *Water Research* 44: 1329-1334.

Lengerich, E.T., D.G. Addiss, and D.D. Juranek. 1994. Severe giardiasis in the United States. *Clinical Infectious Diseases* 18: 760-763.

Levri, E.P., and C.M. Lively. 1996. The effects of size, reproductive condition, and parasitism on foraging behavior in a freshwater snail, *Potamopyrgus antipodarum*. *Animal Behaviour* 51:891-901.

Li, D.-M., R.-Y. Li, G.S. De Hoog, M. Sudadham, and D.-L. Wang. 2011. Fatal *Exophiala* infections in China, with a report of seven cases. *Mycoses* 54:e136-e142.

Liltved, H., H. Hektoen, and H. Efraimsen. 1995. Inactivation of bacterial and viral fish pathogens by ozonation or UV irradiation in water of different salinity. *Aquacultural Engineering 14*: 107-122.

Lindgren, C.J. 2006. Angler Awareness of Aquatic Invasive Species in Manitoba. *Journal of Aquatic Plant Management* 44: 103-108.

Loch, T.P. and M. Faisal. 2010. Isolation of *Aeromona salmonicida* subspecies *salmonicida* from lake whitefish (*Coregonus clupeaformis*) inhabiting Lakes Michigan and Huron. *Journal of Great Lakes Research* 36: 13-17.

Loo, S.E., R. Mac Nally, and P.S. Lake. 2007. Forecasting New Zealand mudsnail invasion range: model comparisons using native and invaded ranges. *Ecological Applications* 17:181-189.

Lovell, S.J. and S. Stone. 2005. The Economic Impacts of Aquatic Invasive Species: A Review of the Literature. Working Paper # 05-02, U.S. Environmental Protection Agency, National Center for Environmental Economics, Washington D.C.

Ma, M., R. Liu, H. Liu, and J. Qu. 2012. Chlorination of Microcystis aeruginosa suspension: cell lysis, toxin release and degradation. *Journal of Hazardous Materials* 217-218: 279-285.

Macey, J., L. Lior, A. Johnson, L. Elliot, D. Krahn, and J. Wylie. 2002. Outbreak of diarrheal illness in attendees at a Ukrainian dance festival, Dauphin, Manitoba—May 2001. *Canadian Communicable Disease Report* 28(17): 141-145.

MacKenzie, W. R., N.J Hoxie, M.E. Proctor, M.S. Gradus, K.A. Blair, D.E. Peterson, J.J Kazmierczak, D.G. Addiss, K.R. Fox, J.B. Rose, and J.P. Davis. 1994. A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply. *New England Journal of Medicine* 331: 161–167.

Maclean, B. 2007. Climate change impacts on biological, social, cultural, and economic sustainability of freshwater fisheries in Fisher River Cree Nation (FRCN). Fish and fisheries notes from 13 interviews, January 23–26, 2007. Unpublished manuscript. Centre for Indigenous Environmental Resources, Winnipeg, Manitoba.

MacWilliams, C., G. Johnson, D. Groman, and F.S.B. Kibenge. 2007. Morphologic description of infectious salmon anaemia virus (ISAV)-induced lesions in rainbow trout (*Onchorynchus mykiss*) compared to Atlantic salmon (*Salmo salar*). *Diseases of Aquatic Organisms* 78: 1-12.

Madigan, M.T, M.M. Martinko, and J. Parker. 2003. *Brock Biology of Microorganisms*, Tenth Edition, G. Carlson, ed., 1019 pp.

Manitoba Catfish Invitational. 2012. Website (http://www.manitobacatfish.com/Home_Page.php) accessed January 26, 2012.

Manitoba. 2012. State of the Environment Reports: Fish of Manitoba. Website (http://www.gov.mb.ca/conservation/annual-reports/soe-reports/soe91/fish.html) accessed February 7, 2012.

Manitoba Finance. 2011. Manitoba Economic Highlights. Website (http://www.gov.mb.ca/finance/pdf/highlights.pdf) accessed November 29, 2011.

Manitoba Water Stewardship. 2007. Ecological Services Division. Comments: Draft environmental impact statement Northwest Area Water Supply Project. December 21, 2007.

Manitoba Water Stewardship. 2009. Manitoba fisheries five year report to the legislature year ending March 31, 2009. Final Report. 95p.

Manitoba Water Stewardship. 2010. A Profile of Manitoba’s Commercial Fishery. Website (http://www.gov.mb.ca/waterstewardship/fisheries/commercial/history.pdf) accessed January 10, 2012.

Manitoba Water Stewardship. 2011. Fisheries. Website (http://www.gov.mb.ca/waterstewardship/water_quality/lake_winnipeg/fisheries.html) accessed December 1, 2011

Manitoba Water Stewardship. 2012a. Manitoba Water Protection Handbook. Website (http://www.gov.mb.ca/waterstewardship/water_guide/index.html) accessed February 6, 2012.

Manitoba Water Stewardship. 2012b. Manitoba Fisheries Sustainable Development Value. Website (http://www.gov.mb.ca/waterstewardship/fisheries_education_sustain_dev/sustain/econ.html) accessed January 11, 2012.

Manitoba Water Stewardship. 2012c. The Zebra Mussel (*Dreissena polymorpha*). Website (http://www.gov.mb.ca/waterstewardship/stopais/zebra_mussel.html) accessed January 30, 2012.

Mari L., E. Bertuzzo, R. Casagrandi, M. Gatto, S.A. Levin, I. Rodrirguez-Iturbe, and A. Rinaldo. 2011. Hydrologic controls and the anthropogenic drivers of the zebra mussel invasion of the Mississippi-Missouri river system. Water Resources Research 47 DOI: 10.1029/2010WR009920.

Marjara, I.S., N. Bain, and Ø. Evensen. 2011. Naïve Atlantic salmon (*Salmo salar* L.) surviving lethal challenge with infectious pancreatic necrosis virus (IPNS) shows upregulation of antiviral genes in head-kidney, including Vig-2. *Aquaculture* 318: 300-308.

Markiw, M.E. 1992. Salmonid whirling disease. U.S. Fish and Wildlife Service, Fish and Wildlife Leaflet 17.

Markwardt, N.M., Y.M. Gocha, and G.W. Klontz. 1989. A new application for Coomassie Brilliant Blue agar: detection of *Aeromonas salmonicida* in clinical samples. *Diseases of Aquatic Organisms* 6: 231-233.

Marrone Bio Innovations. 2012. Press Release: EPA approves new formulation of Marron Bio Innovations’ Zequanox for invasive mussel control. 2121 Second St, Suite B-107, Davis, CA, March 13, 2012.

Marsden, E.J. and M. Hauser. 2008. Exotic species in Lake Champlain. *Journal of Great Lakes Research* 35:250-265.

Mayer, K. 2000. *Saprolegnia*: There’s a Fungus Among Us. Department of Fisheries and Wildlife, Oregon State University.

McAllister, P.E. 1983. Infectious pancreatic necrosis (IPN) of salmonid fishes. U.S. Fish and Wildlife, Washington D.C. Fish Disease Leaflet 65. 12pp.

McCuin, R.M. and J.L. Clancy. 2006. Occurrence of Cryptosporidium oocysts in U.S. wastewaters. Journal of Water and Health 4:437- 452.

McMahon, T., J. Robison-Cox, J. Rotella, T. Horton, and B. Kerans. 2010. A before-after control-impact comparison of the effects of whirling disease epizootices on trout population dynamics in Montana rivers. 12May2010. 112 pp.

Merck Animal Health. 2012. Aquatic Animal Health. Furunculosis. Website (http://aqua.merck-animal-health.com/diseases/furunculosis/ProductAdditional_127_113308.aspx) accessed January 11, 2012.

Merck Veterinary Manual. 2011. 9th Edition. Whitehouse Station, NJ, USA. Website (http://www.merckvetmanual.com/mvm/index.jsp) accessed December 10, 2011.

Metge, D. 2002. Fate and transport of bacterial, viral, and protozoan pathogens during ASR operations – what microorganisms do we need to worry about and why? Artificial Recharge Workshop Proceedings. Sacramento, CA. April 2002.

Meyer, F.P., J.W. Warren, and T.G. Carey (eds.). 1983. A Guide to Integrated Fish Health Management in the Great Lakes Basin. Great Lakes Fishery Commission, Ann Arbor, MI. Available online (http://www.glfc.org/pubs/SpecialPubs/sp83_2/).

Meyers, T., T. Burton, C. Bentz, and N. Starkey. 2008. Common Diseases of Wild and Cultured Fishes in Alaska. Alaska Department of Fish and Game. Fish Pathology Laboratories.

Michigan Department of Natural Resources. 2012. Fish Disease Control Order FO-245.

Michigan Department of Natural Resources. 2009. Viral hemorrhagic septicemia (VHS) briefing paper February 6, 2009.

Mills, E. L., J. H. Leach, J. T. Carlton and C. L . Secor. 1993. Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions. *Journal of Great Lakes Research* 19: 1-54.

Mills, E.L., G. Rosenberg, A.P. Spidle, M. Ludyanskiy, Y. Pligin, and B. May. 1996. A review of the biology and ecology of the quagga mussel (Dreissena bugensis), a second species of freshwater dreissenid introduced to North America. *American Zoologist* 36: 271-286.

Minagawa, T. T. Nakai, and K. Muroga. 1983. *Edwardsiella tarda* in eel culture environment. *Fish Pathology* 17: 243-250.

Minchin, D. 2007. Aquaculture and transport in a changing environment: overlap and links in the spread of alien biota. *Marine Pollution Bulletin* 55:302-313.

Minnesota Department of Natural Resources (MnDNR). 2011. Viral Hemorrhagic Septicemia. Website (http://www.dnr.state.mn.us/fish_diseases/vhs.html) accessed November 15, 2011.

Minnesota Department of Natural Resources (MnDNR). 2012. Fishes of Minnesota. Website (http://www.dnr.state.mn.us/fish/index.html) accessed January 19, 2012.

Mississippi State University (MSU). 2011. Commercial Catfish Production. Website (http://msucares.com/aquaculture/catfish/) accessed November 23, 2011.

Mitchum, D.L., and L.E. Sherman. 1981. Transmission of bacterial kidney disease from wild to stocked hatchery trout. *Canadian Journal of Fisheries and Aquatic Sciences* 38: 547.551.

Mladineo, I., S. Zrnčić, I. Lojkić, and D. Oraić. 2011. Molecular identification of a new strain of infectious pancreatic necrosis virus (IPNV) in a Croation rainbow trout (*Onchorynchus mykiss*) farm. *Journal of Applied Ichthyology* 27: 1165-1168.

Mofida, A.A., E.A. Meyer, P.M. Wallis, C.I. Chou, B.P. Meyer, S. Ramalingam, and B.M. Coffey. 2002. The effect of UV light on the inactivation of *Giardia lamblia* and *Giardia muris* cysts as determined by animal infectivity assay (P-2951-01). *Water Research* 36:2098-2108.

Montana Natural Heritage Program and Montana Fish Wildlife and Parks. 2009. Montana animal Species of Concern. Helena, MT: Montana Natural Heritage Program and Montana Department of Fish Wildlife and Parks. 17 pp.

Montana State University. 2012. Whirling Disease Initiative. Whirling Disease Transmission. Website (http://whirlingdisease.montana.edu/about/transmission.htm) accessed January 19, 2012.

Montgomery Watson Harza (MWH) and Houston Engineering, Inc. September 2007. Pilot-Scale Water Treatment Study Snake Creek Pump Station Data Compilation Report, Northwest Area Water Supply Project. Submitted to North Dakota State Water Commission and Bureau of Reclamation. Bismarck, North Dakota.

Mooney, H.A., and J.A. Drake (editors). 1986. *Ecology of the biological invasions of North America and Hawaii*. Springer-Verlag, New York.

Morita, S., A. Namikoshi, T. Hirata, K. Oguma, H. Katayama, S. Ohgaki, N. Motoyama, and M. Fujiwara. 2002. Efficacy of UV irradiation in inactivating *Cryptosporidum parvum* oocyts. *Applied and Environmental Microbiology* 68:5387-5393.

Morris, J.G., M.B. Szetein, E.W. Rice, J.P. Nataro, G.A. Losonsky, P. Panigrahi, C.O. Tacket, and J.A. Johnson. 1996. *Vibrio cholerae 01* can assume chlorine-resistant rugsoe survival form that is virulent for humans. Journal of Infectious Diseases 174: 1464-1468.

Moyle, P.B., and T. Light. 1996. Biological invasions of fresh water: empirical rules and assembly theory. *Biological Conservation* 78:149-61.

Muirhead, J.R., and H.J. MacIsaac. 2005. Development of inland lakes as hubs in an invasion network. *Journal of Applied Ecology*, Volume 42, pp. 80-90.

Munchan, C., O. Kurata, S. Wada, K. Hatai, A. Sano., K. Kamei, and N. Nakaoka. 2009. *Exophiala xenobiotica* infection in cultured striped jack, *Pseudocaranx dentex* (Bloch & Schneider), in Japan. *Journal of Fish Diseases* 32: 893-900.

Murcia, S. 2008. Dissertation: *Myxobolus cerebralis* in native cutthroat trout of three spawning tributaries to Yellowstone Lake: a qualitative ecological risk assessment. Montana State University, Bozeman, MT. July 2008.

Nair, G.B.,Y.Oku, Y.Takkeda, A. Ghosh, R.K. Ghosh, S. Chattopadhyay, S.C. Pal, J.B. Kaper, and T. Takeda. 1988. Toxin profiles of *Vibrio cholerae* non-O1 from environmental sources in Calcutta, India. *Applied and Environmental Microbiology* 54: 3180–3182.

National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (Service). 2005. Draft Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar). Silver Spring, MD: National Marine Fisheries Service, June.

National Oceanic and Atmospheric Administration (NOAA). Nd. The Impact of *Diporeia* spp. decline on the Great Lakes fish community. Great Lakes Environmental Research Laboratory. 2 pp.

National Oceanic and Atmospheric Administration (NOAA). 2012. The Zebra Mussel Invasion. Website (http://www.noaa.gov/features/earthobs_0508/zebra.html 19Mar12).

Natural Resources Canada. 2012. Canada in a changing climate. Adaptation – There's a lot we can do! Website (http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/380#toc) accessed February 20, 2012.

Nehring, R.B. 2006. Colorado's cold water fisheries: whirling disease case histories and insights for risk management. Colorado Division of Wildlife Aquatic Wildlife Research. Special Report Number 79. February.

Nehring, B. 2011. Formerly of Colorado Division of Parks and Wildlife. Personal communication with E. Koppel, Staff Scientist, Cardno ENTRIX, December 22.

New York State Department of Environmental Conservation (DEC). 2012. Fish Community Objectives for Lake Ontario. 6 pp.

Nico, L. and P. Fuller. 2012. *Pimephales promelas*. USGS Nonindigenous Aquatic Species Database. Website (http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=621) last revised September 16, 2011.

Nielson, R., C. Moffitt, and B. Watten. 2011. Hydrocyclonic separation of invasive New Zealand mudsnails from an aquaculture water source. *Aquaculture* 326-329:156-162.

North Dakota Game and Fish Department. 2012a. Fish of North Dakota. Website (http://gf.nd.gov/fishing/fish-north-dakota) accessed January 10, 2012.

North Dakota Game and Fish Department. 2012b. Paddlefish Questions and Answers. Website (http://gf.nd.gov/multimedia/pubs/docs/pad-fish-broch.pdf) accessed January 19, 2012.

North Dakota Game and Fish Department. 2012c. Red River Angler's Guide. Website (http://gf.nd.gov/maps-and-water-access/red-river-anglers-guide) accessed January 19, 2012.

North Dakota State Water Commission (SWC). 2012. Potential Transfer Pathways for Biota from Devils Lake to Lake Winnipeg. Website (http://www.swc.state.nd.us/4dlink9/4dcgi/GetSubContentPDF/PB-102/BioTrans.pdf) accessed January 26, 2012.

Nucci, M., Y. Akiti, G. Barreiros, F. Silveira, S.G. Revankar, B.L. Wickes, D.A. Sutton, and T.F. Patterson. 2002. Nosocomial outbreak of *Exophiala jeanselmei* fungemia associated with contamination of hospital water. *Clinical Infectious Diseases* 34: 1475-1480.

Odoi, A., S.W. Martin, P. Michel, J. Holt, D. Middleton, and J. Wilson. 2004. Determinants of the geographical distribution of endemic giardiasis in Ontario, Canada: a spatial modeling approach. *Epidemiology and Infection* 132: 967-976.

Ogut, H., A. Akyol, and M.Z. Alkan. 2005. Seasonality of *Ichthyophthirius multifiliis* in trout (*Oncorhynchus mykiss*) farms of the eastern Black Sea region of Turkey. *Turkish Journal of Fisheries and Aquatic Sciences* 5: 23-27.

Ontario Ministry of the Environment. 2010. Economic Value of Protecting the Great Lakes: Literature Review Report, accessed online at: http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@subject/@greatlakes/documents/nativedocs/stdprod_086944.pdf.

Ontario Ministry of Natural Resources. 2009. Fisheries Management Plan for Fisheries Management Zone 17: November 2009. Website (http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@letsfish/documents/document/264321.pdf) accessed January 19, 2012.

Oplinger, R.W., P. Brown, and E.J. Wagner. 2009. Effect of sodium chloride, tricaine methanesulfonate, and light on New Zealand mud snail behavior, survival of snails defecated from rainbow trout, and the effects of Epsom salt on snail elimination rate. North American Journal of Aquaculture 71:157-164.

Oppenheimer, J., T. Gillogly, G. Stolarik, and R. Ward. 2002. Comparing the efficiency of low and medium pressure UV light for inactivating *Giardia muris* and *Cryptosporidium parvum* in waters with low and high levels of turbidity. Proceedings of the Annual Conference and Exhibition of the American Water Works Association, New Orleans, LA, June 16 – 20.

Oregon Department of Environmental Quality (ODEQ). 2009. Managing Aquatic Invasive Species Risks from Shipping Transport Pathways. Prepared by the Oregon Task Force on the Shipping Transport of Aquatic Invasive Species. 107 pp.

Ortega, Y.R. and R.D. Adam. 1997. *Giardia*: overview and update. *Clinical Infectious Diseases* 25: 545-550.

Osswald, J., S. Rellán, A.P. Carvalho, A. Gago, and V. Vasconcelos. 2007. Acute effects of an anatoxin-a producing cyanobacterium on juvenile fish – *Cyprinus carpio* L. *Toxicon* 49: 693-698.

Øye, AK., and E. Rimstad. 2001. Inactivation of infectious salmon anaemia virus, viral haemorrhagic septicemia virus and infectious pancreatic necrosis virus in water using UVC irradiation. *Diseases of Aquatic Organisms* 48:1-5.

Pachepsky, Y.A., A.M. Sadeghi, S.A. Bradford, D.R. Shelton, A.K. Guber, and T. Dao. 2006. Transport and fate of manure-borne pathogens: modeling perspective. *Agricultural Water Management* 86: 81-92.

Padilla, D.K. and S.L. Williams. 2004. Beyond ballast water: aquarium and ornamental trades as source of invasive species in aquatic ecosystems. *Frontiers in Ecology and the Environment* 2 131-138.

Pascho, R.J., M.L. Landolt, and J.E. Ongerth. 1995. Inactivation of *Renibacterium salmoninarum* by free chlorine. *Aquaculture* 131: 165-175.

Passantino, L., J. Malley, M. Knudson, R. Ward, and J. Kim. 2004. Effect of low turbidity and algae on UV disinfection performance. *Journal of the American Water Works Association* 96:128–137.

Patterson, K.R. 1996. Modelling the impact of disease-induced mortality in an exploited population: the outbreak of the fungal parasite *Ichthyophonus hoferi* in the North Sea herring (*Clupea harengus). Canadian Journal of Fisheries and Aquatic Sciences* 53:2870-2887.

Peeler, E.J., and S.W. Feist. 2011. Human intervention in freshwater ecosystems drives disease emergence. *Freshwater Biology* 56:705-716.

Peeler, E.J., and Taylor, N.G.H. 2011. The application of epidemiology in aquatic animal health – opportunities and challenges. *Veterinary Research* 42:94.

Peeler, E.J., B.C. Oidtmann, P.J. Nidtlyng, L. Miossec, and R.E. Gozlan. 2011. Non-native aquatic animals introductions have driven disease emergence in Europe. *Biological Invasions* 13: 1291-1303.

Peñaranda, M.M.D., M.K. Purcell, and G. Kurath. 2009. Differential virulence mechanisms of infectious hematopoietic necrosis virus in rainbow trout (*Oncorhynchus mykiss*) include host entry and virus replication kinetics. *Journal of General Virology* 90: 2172-2182.

Pierce, R., L. Eby, and R. Vincent. 2011. Impacts of whirling disease on mountain whitefish: a pilot study. Trout Unlimited. Website (http://www.tu.org/science/aquatic-invasive-species-ais/pathogens/research/mountain-whitefish-0) accessed November 17, 2011.

Port of Churchill Hudson Bay Port Company. Website (http://www.portofchurchill.ca/) accessed July 18, 2012.

Power, G.J., and F. Ryckman. 1998. Status of North Dakota's Fishes. North Dakota Game and Fish Department, Bismarck, ND. 30 pp.

Proctor, T., B. Kerans, P. Clancey, E. Ryce, M. Dybdahl, D. Gustafson, R. Hall, F. Pickett, D. Richards, R. Draheim Waldeck, J. Chapman, R.H. Wiltshire, D. Becker, M. Anderson, B. Pitman, D. Lassuy, P. Heimowitz, P. Dwyer. and E. Levri. 2007. National Management and Control Plan for the New Zealand Mudsnail (*Potamopyrgus antipodarum*). Report Prepared for the Aquatic Nuisance Species Task Force by the New Zealand Mudsnail Management and Control Plan Working Group. Website (http://www.anstaskforce.gov/Documents/NZMS_MgmtControl_Final.pdf) accessed September 21, 2011.

Public Health Agency of Canada. 2012. Entamoeba histolytica – Material Safety Data Sheets. Website (http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/msds58e-eng.php) accessed January 30, 2012.

Rahel, F.J. and J.D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology* 22: 521-533.

Rahimian, H. 1998. Pathology and morphology of *Ichthyophonus hoferi* in naturally infected fishes off the Swedish west coast. *Diseases of Aquatic Organisms* 34:109-123.

Raikova, E. V. 1994. Life cycle, cytology, and morphology of *Polypodium hydriforme*, a coelenterate parasite of the eggs of acipenseriform fishes. *Journal of Parasitology* 80:1–22.

Raikova, E. V., V. C. Suppes, and G. L. Hoffmann. 1979. The parasitic coelenterate, *Polypodium hydriforme* Ussov, from the eggs of the American acipenseriform *Polyodon spathula*. *Journal of Parasitology* 65:804–810.

Raikova, E.V. 2008. Cytomorphological peculiarities of *Polypodium hydriforme* (Cnidaria). *Journal of the Marine Biological Association of the United Kingdom* 88: 1695-1702.

Raikow, D.F. 2004. Food web interactions between larval bluegill (*Lepomis macrochirus*) and exotic zebra mussels (*Dreissena polymorpha*). *Canadian Journal of Fisheries and Aquatic Sciences* 61:497-504.

Rand, T.A., and S.M. Louda. 2012. Exotic weevil invasion increases floral herbivore community density, function, and impact on a native plant. *Oikos* 121:85-94.

Rasmussen, J.L., H.A. Reiger, R.E. Sparks, and W.W. Taylor. 2011. Dividing the waters: The case for hydrologic separation of the North American Great Lakes and Mississippi River Basins. Journal of Great Lakes Research 37: 588-592.

Rendtorff, R.C. and C.J. Holt. 1954. The experimental transmission of human intestinal protozoan parasites. IV: Attempts to transmit *Endamoeba coli* and *Giardia lamblia* cysts by water. *American Journal of Hygiene* 60: 327–38.

Richards, D.C., P. O'Connell, and D.C. Shinn. 2004. Simple control method to limit the spread of the New Zealand mudsnail *Potamopyrgus antipodarum*. *North American Journal of Fisheries Management* 24:114-117.

Riley, L.A., M.F. Dybdahl, and R.O. Hall, Jr. 2008. Invasive species impact: asymmetric interactions between invasive and endemic freshwater snails. *Journal of the North American Benthological Society* 27: 509-520.

Roberts, L.S. 1970. *Ergasilus* (Copepoda: Cyclopodoida): Revision and key to species in North America. *Transactions of the American Microscopical Society* 89: 134-161.

Rosas-Valdez, R., A. Choudhury, and G. Pérez-Ponce de León. 2004. Phylogenetic analysis on genera of Corallobothriinae (Cestoda: Proteocephalidea) from North American ictalurid fishes, using partial sequences of the 28s ribosomal gene. *Journal of Parasitology* 90: 1123-1127.

Rosenzweig, M.L. 2001. The four questions: what does the introduction of exotic species do to diversity? *Evolutionary Ecology Research* 3:361-367.

Sack, D.A., R.B. Sack, G. Balakrish, and A.K. Siddique. 2004. Seminar: Cholera. Lacet 363: 223-233.

Salit, I.E., K. Khairnar, K. Gough, and D.R. Pillai. 2009. A possible cluster of sexually transmitted *Entamoeba histolytica*: genetic analysis of a highly virulent strain. *Clinical Infectious Diseases* 49: 346-353.

Sandel, B., and E.M. Dangremond. 2012. Climate change and the invasion of California by grasses. *Global Change Biology* 18: 277-289.

Sanders, J.E., and Fryer, J.L. 1980. *Renibacterium salmoninarum* gen. nov., sp. nov., the causative agent of bacterial kidney disease in salmonid fishes. *International Journal of Systematic Bacteriology* 30: 496-502.

Savioli, L., H. Smith, and A. Thompson. 2006. *Giardia* and *Cryptosporidium* join the "Neglected Diseases Initiative." *Trends in Parasitology* 22: 203–208.

Sax, D.F. and S.D. Gaines. 2003. Species diversity: from global decreases to local increases. *Trends in Ecology and Evolution* 18:561-566.

Schachte, J.H. 1983a. Columnaris Disease. Chapter 23 in: Meyer, F.P., J.W. Warren, and T.G. Carey (eds.). A Guide to Integrated Fish Health Management in the Great Lakes Basin. Great Lakes Fishery Commission, Ann Arbor, MI. Available online (http://www.glfc.org/pubs/SpecialPubs/sp83_2/).

Schachte, J.H. 1983b. Furunculosis. Chapter 25 in: Meyer, F.P., J.W. Warren, and T.G. Carey (eds.). A Guide to Integrated Fish Health Management in the Great Lakes Basin. Great Lakes Fishery Commission, Ann Arbor, MI. Available online (http://www.glfc.org/pubs/SpecialPubs/sp83_2/).

Sepúlveda, M.S., T. Stefanavage, and R. Goforth. 2010. First record of a *Polypodium* sp. parasitizing eggs of shovelnose sturgeon from the Wabash River, Indiana. *Journal of Aquatic Animal Health* 22:36-38.

Shankar, K.M. and T. Yamamoto. 1994. Prevalence and pathogenicity of infectious pancreatic necrosis virus (IPNV) associated with feral lake trout, *Salvelinus namaycush* (Walbaum). *Journal of Fish Diseases* 17: 461-470.

Shivappa, R., S. Kozlowiscz, J. Rolland, F. Corsin, K. Way, and J. Levine. 2008. Spring viremia of carp in the United States of America: evaluation of current diagnostics. In Bondad-Reantaso, M.G., C.V. Mohan, M. Crumlish, and R.P. Subasignhe (eds.). Diseases in Asian Aquaculture VI. Fish Health Section, Asian Fisheries Society, Manila, Phillipines. 505 pp.

Skjesol, A., I. Skæveland, M. Elnæs, G. Timmerhaus, B.N. Fredricksen, S.M. Jørgensen, A. Krasnov, and J.B. Jørgensen. 2011. IPNV with high and low virulence: host immune responses and viral mutations during infection. *Virology Journal* 8:1-14.

Smolyanov, I.I., and E.V. Raikova. 1961. Finding of mature *Polypodium hydriforme* Ussov (Coelenterata) on larvae of acipenserid fishes. Doklady Academii Nauk USSR 141: 1271–1274.

Sodeman, W.A. 1996. Chapter 79 Intestinal Protozoa: Amebas *In* Baron, S. (Ed.). Medical Microbiology 4th Ed. Galveston, TX. University of Texas Medical Branch at Galveston. Website (http://www.ncbi.nlm.nih.gov/books/NBK7742/) accessed January 24, 2012.

Souter, B.W., A.G. Dwilow, K. Knight, and T. Yamamoto. 1986. Infectious pancreatic necrosis virus in adult Arctic char, *Salvelinus alpinus* (L.), in rivers in the Mackenzie Delta region and Yukon Territory. Canadian Technical Report if Fisheries and Aquatic Sciences No. 1441.

Srivastava, R.C. 1980. Fungal parasites of certain fresh water fishes of India. *Aquaculture* 21: 387-392.

Statistics Canada. 2006. Census of Population, Statistics Canada catalogue no. 97-564-XCB2006005.

Statistics Canada. 2007a. Winnipeg, Manitoba (Code4611040) (table). 2006 Community Profiles. 2006 Census. Statistics Canada Catalogue no. 92-591-XWE. Ottawa. (http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-591/details/page.cfm?Lang=E&Geo1=CSD&Code1=4611040&Geo2=PR&Code2=46&Data=Count&SearchText=winnipeg&SearchType=Begins&SearchPR=01&B1=All&Custom) Released March 13, 2007. Accessed March 26, 2013.

Statistics Canada. 2007b. Manitoba (Code46) (table). 2006 Community Profiles. 2006 Census. Statistics Canada Catalogue no. 92-591-XWE. Ottawa. (http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-591/details/Page.cfm?Lang=E&Geo1=PR&Code1=46&Geo2=PR&Code2=01&Data=Count&SearchText=Manitoba&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=48) Released March 13, 2007. Accessed March 26, 2013.

Statistics Canada. 2009. Aquaculture Statistics. Statistics Canada Catalogue no. 23-222-X. Website (http://www.statcan.gc.ca/pub/23-222-x/23-222-x2009000-eng.pdf) accessed January 26, 2012.

Statistics Canada. 2011. Custom Query. Website (http://www.ic.gc.ca/eic/site/pp-pp.nsf/eng/home). Page last modified December 21, 2012.

Statistics Canada. 2012. Canada at a Glance. Statistics Canada Catalogue no. 89-645-X. Website (http://www.statcan.gc.ca/pub/12-581-x/2012000/pop-eng.htm) accessed March 26, 2013.

Statistics Canada. 2013. Annual Average Unemployment rate. Economics and Statistics Branch (Newfoundland & Labrador Statistics Agency). (http://www.stats.gov.nl.ca/statistics/Labour/PDF/UnempRate.pdf) accessed March 26, 2013.

Steinbach Elwell, L.C., K.E. Stromberg, E.N.K. Ryce, and J.L. Bartholemew. 2009. Whirling disease in the United States. A summary of progress in research and management 2009. 66pages.

Stevens, D.K., and R.I. Krieger. 1991. Stability studies on the cyanobacterial nicotinic alkaloid anatoxin-a. *Toxicon* 29: 167–179.

Strayer, D.L., K.A. Hattala, and A.W. Kahnle. 2004. Effects of invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. *Canadian Journal of Fish and Aquatic Science* 61: 924-941.

Stringer, R. and C.W. Kruse. 1970. Amoebic Cysticidal Properties of Halogens. Conference proceedings, National Specialty Conference on Disinfection, ASCE, New York.

Suppes, V. C., and F. Meyer. 1975. *Polypodium* sp. (Coelenterata) infection in paddlefish (*Polyodon spathula*) eggs. *Journal of Parasitology* 61:772–774.

Suter, G.W. 2007. *Ecological Risk Assessment*. 2nd Edition. Glenn W. Suter II (Eds). CRC Press, Taylor & Francis Group, Boca Raton, FL. 643 pp.

Sutherland, D.R. and H.L Holloway. 1979. Parasites of fish from the Missouri, James, Sheyenne, and Wild Rice Rivers in North Dakota. Proceedings of the Helminthological Society of Washington 46: 128-134.

Svetlana, J., V. Ivetic, and V. Radosavljevic. 2006. *Rhabdovirus carpio* as a causative agent of disease in rainbow trout (*Onchorhynchus mykiss – Walbaum*). *Acta Veterinaria (Beograd)* 56: 553-558.

Taniguchi, Y., F.J. Rahel, D.C. Novinger, and K.G. Gerow. 1998. Temperature mediation of competitive interactions among three fish species that replace each other along longitudinal stream gradients. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 1894-1901.

Tarrab, E., J. Heppell, L. Berthiaume, and J. Lecomte. 1996. Antigenic diversity of eastern Canadian isolates of infectious pancreatic necrosis virus. *Journal of Fish Diseases* 19: 23-31.

TetrES. 2001. Technical report supporting the Canadian Appellant's Administrative Appeal to the Bureau of Reclamation regarding the Final Environmental Assessment and Finding of No Significant Impact for the Northwest Area Water Supply Project. Prepared for Environment Canada and Manitoba Conservation. Denver, CO.

Thaker, V.V., J.W. King, S. Handa, I. Brook, M.L. Windle, M.R. Schleiss, B.A. Cunha, and R.W. Steele. 2011. Medscape Reference. Cholorea. Updated July 19, 2011. Website (http://emedicine.medscape.com/article/962643-overview#a0101) accessed January 26, 2012.

Thoen, E., Ø. Evensen, and I. Skaar. 2011. Pathogenicity of *Saprolegnia* spp. to Atlantic Salmon, *Salmo salar* L., eggs. *Journal of Fish Diseases* 34:60-608.

Thomas, M.K., D.F. Charron, D. Waltner-Toews, C. Schuster, A.R. Maarouf, and J.D. Holt. 2006. A role of high impact weather events in waterbourne disease outbreaks in Canada, 1975-2001. *International Journal of Environmental Health Research* 16: 167-180.

Thomas, M.V. and P.M. Muzzall. 2009. First record of *Polypodium hydriforme* (Cnidaria) from lake sturgeon (*Acipenser fulvescens* Rafinesque) in the St. Clair River, Michigan. *Journal of Applied Ichthyology* 25:107-108.

Thompson, D.J., L.H. Khoo, D.J. Wise, and L.A. Hanson. 2005. Evaluation of channel catfish virus latency on fingerling production farms in Mississippi. Journal of Aquatic Animal Health 17: 211–215.

Thompson, T.M., W.N. Batts, M. Faisal, P. Bowser, J.W. Casey, K. Phillips, K.A. Garver, J. Winton, and G. Kurath. 2011. Emergence of viral *hemorrhagic septicemia virus* in North American Great Lakes region is associated with low viral genetic diversity. *Diseases of Aquatic Organisms* 96:29-43.

Tobback, E., Decostere, A., Hermans, K., Ryckaert, J., Duchateau, L., Haesebrouck, F., and Chiers, K. 2009. Route of entry and tissue distribution of *Yersinia ruckeri* in experimentally infected rainbow trout *Oncorhynchus mykiss*. *Diseases of Aquatic Organisms* 84: 219-228.

Todar, K. 2011. Pseudomonas In: *Todar's Online Textbook of Bacteriology*. Website (http://textbookofbacteriology.net/index.html) accessed November 21, 2011.

Traxler, G.S., J. Richard, and T.E. McDonald. 1998. *Ichthyophthirius multifiliis* (Ich) epizootics in spawning sockeye salmon in British Columbia, Canada. *Journal of Aquatic Animal Health* 10: 143-151.

Urban, M., J. Motteram, H-C. Jing, S. Powers, J. Townsend, J. Devonshire, I. Pearman, K. Kanyuka, J. Franklin, and K.E. Hammond-Kosack. 2011. Inactivation of plant infecting fungal and viral pathogens to achieve biological containment in drainage water using UV treatment. *Journal of Applied Microbiology* 110:675-687.

UC Santa Cruz. 2011. Biological and Satellite Oceanography Laboratory. Website (http://oceandatacenter.ucsc.edu/home/) accessed November 8, 2011.

U.S. Army Corps of Engineers (Corps). 2000. Browns Valley Dike History and Potential for Interbasin Flow. January 2000. St. Paul District. 31 pp.

U.S. Army Corps of Engineers (Corps). 2012. *Dreissena bugensis* - Quagga Mussel. Website (http://el.erdc.usace.army.mil/zebra/zmis/zmishelp4/dreissena_bugensis_quagga_mussel_larva.htm) accessed January 24, 2012.

U.S. Bureau of Reclamation (Reclamation) and Decision Support. 2000. Northwest Area Water Supply Project - NAWS Comparative Risk Analysis, Final Report. Bureau of Reclamation, Dakotas Area Office, Bismarck, North Dakota. 29 pp. July.

U.S. Bureau of Reclamation (Reclamation). 1998. Prediction of Embankment Dam Breach Parameters: A Literature Review and Needs Assessment. Dam Safety Research Report DSO-98-004. July.

U.S Bureau of Reclamation (Reclamation). 2001. Finding of No Significant Impact for the Northwest Area Water Supply Project in North Dakota. Bureau of Reclamation, Great Plains Regional Office, Dakota Area Office, Bismarck, North Dakota, FONSI No. DK-600-97-03, Revised and Reissued, September 10, 2001.

U.S Bureau of Reclamation (Reclamation). 2007. Final Environmental Impact Statement Red River Valley Water Supply Project. December 2007. Dakotas Area Office. 562 pp.

U.S. Bureau of Reclamation (Reclamation). 2008. Northwest Area Water Supply Project Final Environmental Impact Statement on Water Treatment. Bureau of Reclamation, Great Plains Regional Office, Dakota Area Office, Bismarck, North Dakota, December 2008.

U.S. Bureau of Reclamation (Reclamation). 2011. Milk River Project. Website (http://www.usbr.gov/projects/Project.jsp?proj_Name=Milk+River+Project) accessed October 26, 2011.

U.S. Coast Guard (USCG). 2012. Aquatic Nuisance Species. Website (http://www.uscg.mil/hq/cg5/cg522/cg5224/ans.asp) accessed February 5, 2012.

U.S. Department of Agriculture (USDA). 2003. Animal and Plant Health Inspection Service. Veterinary Technical Note. Spring Viremia of Carp. April 2003.

U.S. Department of Agriculture (USDA). 2009. Animal and Plant Health Inspection Services. Centers for Epidemiology and Animal Health National Surveillance Unit. Viral Hemorrhagic Septicemia Virus IVb Surveillance Report.

U.S. Department of Interior (USDOI). 2011. Endangered, Threatened, Proposed and Candidate Species. Montana Counties. Endangered Species Act. Fish and Wildlife Service. Ecological Services. Montana Field Office. Helena, MT 59601.

U.S. Environmental Protection Agency (EPA). 1986. Development of a qualitative pathogen risk assessment methodology for municipal sludge landfilling. Office of Health and Environmental Assessment. Washington, D.C. EPA/600/6-88/006. May 1986.

U.S. Environmental Protection Agency (EPA). 1998. Guidelines for ecological risk assessment. Washington, D.C. EPA/630/R-95/002F. April 1998.

U.S. Environmental Protection Agency (EPA). 1999. Alternative disinfectants and oxidants guidance manual. EPA 815-R-99-014.

U.S. Environmental Protection Agency (EPA). 2006. UV disinfection guidance manual for the final long term 2 enhanced surface water treatment rule (ESWTR), EPA 815-R-06-007. Website (http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf) accessed November 2006.

U.S. Fish and Wildlife Service (Service). 2011a. Wild Fish Health Survey Database. Website (http://www.fws.gov/wildfishsurvey/) accessed December 7, 2011.

U.S. Fish and Wildlife Service (Service). 2011b. Aquatic Invasive Species. Website (http://www.fws.gov/fisheries/invasive_species/invasive_main.html) accessed February 5, 2012.

U.S. Fish and Wildlife Service (Service). 2012a. Report. Case Number: 12-143; Case Type: diagnostic, wild fish kill; water body: Souris River, North Dakota; species: black bullhead. Bozeman Fish Health Center. April 3, 2012.

U.S. Fish and Wildlife Service (Service). 2012b. Endangered Species Fact Sheet. Pallid Sturgeon. Website (http://www.fws.gov/midwest/Endangered/fishes/palld_fc.html) accessed January 19, 2012.

U.S. Geological Survey (USGS). Nd. *Dreissena* species FAQs, a closer look. Website (http://fl.biology.usgs.gov/Nonindigenous_Species/Zebra_mussel_FAQs/Dreissena_FAQs/dreissena_faqs.html) accessed on June 4, 2012.

U.S. Geological Survey (USGS). 2005a. Risk and consequence analysis focused on biota transfers potentially associated with surface water diversions between the Missouri River and Red River basins. Prepared for the United States Bureau of Reclamation. USGS, Biological Resources Division, Columbia Environmental Research Center, Columbia, MI. July 2005.

U.S. Geological Survey (USGS). 2005b. Supplemental report: risk reduction captured by water supply alternatives and preliminary analysis of economic consequences associated with biota transfers potentially realized from interbasin water diversion. Prepared for the United States Bureau of Reclamation. USGS, Biological Resources Division, Columbia Environmental Research Center, Columbia, MI. 57 pp.

U.S. Geological Survey (USGS). 2006. Supplemental report: preliminary analysis of infrastructural failures and their associated risks and consequences related to biota transfers potentially realized from interbasin water diversion. Prepared for the United States Bureau of Reclamation. USGS, Biological Resources Division, Columbia Environmental Research Center, Columbia, MI.

U.S. Geological Survey (USGS). 2007a. Risks of biota transfers potentially associated with surface water diversions between the Missouri River and Hudson Bay watersheds – analysis of risk of interbasin biota transfers potentially linked to system failures in the Northwest Area Water Supply Project. Prepared for the United States Bureau of Reclamation. USGS, Biological Resources Division, Columbia Environmental Research Center, Columbia, MI. August 2007.

U.S. Geological Survey (USGS). 2007b. Zebra mussel distribution in U.S. lakes. Website (http://cars.er.usgs.gov/Nonindigenous_Species/Zebra_mussel_distribution/zebra_mussel_distribution.html) accessed February 5, 2012.

U.S. Geological Survey (USGS). 2011a. Free-living and parasitic copepods (including Branchiurans) of the Laurentian Great lakes: keys and details on individual species. Website (http://www.glsc.usgs.gov/greatlakescopepods/) accessed November 23, 2011.

U.S. Geological Survey (USGS). 2011b. Nonindigenous Aquatic Speces (NAS) Database. Website (http://nas.er.usgs.gov/) accessed June 4, 2012.

U.S. Geological Survey (USGS). 2011c. Watershed Boundary Dataset. Issued December 29. Available online: (http://web.apps.state.nd.us/hubdataportal/srv/en/metadata.show?currTab=simple&id=101).

U.S. Geological Survey (USGS). 2012. Surface water data for Montana: USGS surface-water monitoring stats. Website (http://waterdata.usgs.gov/mt/nwis/monthly?) accessed February 7, 2012.

Vanschoenwinkel, B., S. Gielen, H. Vandewaerde, M. Seaman, and L. Brendonck. 2008. Relative importance of different dispersal vectors for small aquatic invertebrates in a rock pool metacommunity. *Ecography* 31:567-577.

Venczel, L.V., M. Arrowood, M. Hurd, and M.D. Sobsey. 1997. Inactivation of Cryptosporidium parvum and Clostridium perfringens spores by a mixed-oxidant disinfectant and by free chlorine. *Applied and Environmental Microbiology* 63(4):1598-1601.

Vincent, E.R. 2002. Relative susceptibility of various salmonids to whirling disease with emphasis on rainbow and cutthroat trout. *In* Bartholomew, J.L., and J.C. Wilson (editors). 2002. Whirling Disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD USA.

Vincent, E. R. 2006. Are wild rainbow trout in the Madison River developing resistance to severe infections by the whirling disease parasite (*Myxobolus cerebralis*). Pages 18-19 in Proceedings of 12th Annual Whirling Disease Symposium, Denver, Colorado, Whirling Disease Foundation, Bozeman, Montana.

Vitousek, P.M., C. M. D'Antonio, L. L. Loope, and R. Westbrooks. 1996. Biological invasions as global change. *American Scientist* 84:468-478.

Wagner, M.W. 1986. Domestic hunting and fishing by Manitoba Indians: Magnitude, composition and implications for management. *Canadian Journal of Native Studies* 6:333–349.

Wakabayashi, H. 1991. Effect of environmental conditions on the infectivity of *Flexibacter columnaris* to fish. *Journal of Fish Diseases* 14: 279-290.

Warren, J.W. 1983a. Bacterial Kidney Disease. Chapter 21 in: Meyer, F.P., J.W. Warren, and T.G. Carey (eds.). A Guide to Integrated Fish Health Management in the Great Lakes Basin. Revision One. Great Lakes Fishery Commission, Ann Arbor, MI. Available online (http://www.glfc.org/pubs/SpecialPubs/sp83_2/).

Warren, J.W. 1983b. Enteric Redmouth Disease. Chapter 24 in: Meyer, F.P., J.W. Warren, and T.G. Carey (eds.). A Guide to Integrated Fish Health Management in the Great Lakes Basin. Great Lakes Fishery Commission, Ann Arbor, MI. Available online (http://www.glfc.org/pubs/SpecialPubs/sp83_2/).

Waterkeyn, A., O. Pineau, P. Grillas, and L. Brendonck. 2010. Invertebrate dispersal by aquatic mammals: a case study with nutria *Mycastor coypus* (Rodentia, Mammalia) in Southern France. *Hydrobiologia* 654: 267-271.

Weagle, K.V. 1973. The fisheries on the Lake Winnipeg outlet lakes: Exploitation and reproduction. Report prepared for the Lake Winnipeg, Churchill and Nelson Rivers Study Board. (Cited in Green and Derksen 1984.)

Wedekind, C., and C. Kung. 2010. Shift of spawning season and effects of climate warming on developmental stages of a grayling (Salmonidae). *Conservation Biology* 24(5):1418-23.

Weinstein, M.R., M. Litt, D.A. Kertesz, P. Wyper, D. Rose, M. Coulter, A. McGreer, R. Facklam, C. Ostach, B.M. Willey, A. Borczak, and D.E. Low. 1997. Invasive infections due to a fish pathogen, *Streptococcus iniae*. *The New England Journal of Medicine* 28: 589-594.

Welch, R.A. 2006. The Genus *Escherichia*. Chapter 3.3.3 in: Dworkin, M., S. Falkow, E. Rosenburg, K-H. Schleifer, and E. Stackebrandt (eds.). The Prokaryotes Volume 6: 60-71.

Western Area Water Supply project (WAWS). 2011. Website (http://www.wawsp.com/facts.asp) accessed October 26, 2011.

Whelan, G.E. 2009. Viral hemorrhagic septicemia virus (VHS) briefing paper. Michigan Department of Natural Resources. February 6, 2009.

Whirling Disease Initiative (WDI). 2006. Newsletter. Volume 2, Issue 1.

Whirling Disease Steering Committee. 2009. Whirling Disease Initiative Final Report. October 2009. 102 pp.

Whitman, K.A. 2004. *Finfish and Shellfish Bacteriology Manual: Techniques and Procedures*. 1st Edition. Iowa State Press, 2121 State Avenue, Ames, IA 50014.

Whiteshell Fish Hatchery. 2012. Personal communication with Deva Shafer, Assistant Staff Scientist, Cardno ENTRIX, March 5, 2012.

WiDNR. 2012. Fish Kill Investigations in 2012. Website (http://dnr.wi.gov/topic/fishing/documents/2012FishKillSummaries.pdf) accessed September 27, 2012.

Williamson, M. and A Fitter. 1996. The varying success of invaders. *Ecology* 77:1661-1666.

Winnipeg Water and Waste. 2011. Water quality test results. Website (http://www.winnipeg.ca/waterandwaste/water/testResults/default.stm#archive) accessed November 4, 2011.

Winterbourn, M. J. 1970. The New Zealand species of *Potamopyrgus* (Gastropoda: Hydrobiidae). Malacologia, 10, 283–321.

Wolf, K., S.F. Snieszko, C.E. Dunbar, and E. Pyle. 1960. Virus nature of infectious pancreatic necrosis in trout. *Proceedings of the Society for Experimental Biology and Medicine* 104: 105-108.

Wolfe, M.S. 1992. Giardiasis. *Clinical Microbiology Reviews* 5: 93–100.

Wood, B.J. and W.H. Holzapfel. 1995. *The Lactic Acid Bacteria: The Genera of Lactic Acid Bacteria* Vol. 2. 1st Edition. Chapman & Hall, 2-6 Boundary Row, London SE1 8HN, UK.

World Health Organization (WHO). 1999. Toxic cyanobacteria in water. A guide to their Public Health Consequences, Monitoring, and Management. Published by F&FN Spon, London, UK.

World Health Organization (WHO). 2007. Legionella and the prevention of legionellosis. (Eds. Bartram, J., Y. Chartier, J.V. Lee, K. Pond, and S. Surman-Lee). WHO Press, World Health Organization, Geneva, Switzerland.

Xu, D.-H., P.H. Klesius, and C.A. Shoemaker. 2005. Cutaneous antibodies from channel catfish, *Ictalurus punctatus* (Rafinesque), immune to *Ichthyopthirius multifiliis* (Ich) may induce apoptosis of Ich theronts. *Journal of Fish Diseases* 28: 213-220.

Xu, D.-H., P.H. Klesius, E. Peatman, and Z. Liu. 2011. Susceptibility of channel catfish, blue catfish, and channel x blue catfish hybrid to *Ichthyophthirius multifiliis*. *Aquaculture* 311: 25-30.

Yanong, R.P.E. and R. Francis-Floyd. 2006. Streptococcal infections of fish. Circular 57. University of Florida, Institute of Food and Agricultural Sciences (IFAS) Extension.

Yuasa, K., Kamaishi, T., Hatai, K., Bahnnan, M. and Borisuthpeth, P. 2005. Two cases of streptococcal infections of cultured tilapia in Asia, pp. 259-268. *In* Bondad-Reantaso, M.G., Mohan, C.V., Crumlish, M. and Subasinghe, R.P. (eds.). Diseases in Asian Aquaculture VI. Fish Health Section, Asian Fisheries Society, Manila, Philippines. 505 pp.

Zalar, P., M. Novak, G.S. De Hoog, and N. Gunde-Cimerman. 2011. Dishwashers- A man-made ecological niche accommodating human opportunistic fungal pathogens. *Fungal Biology* 115:997-1007.

Zhang, W. and Y.R. Rao. 2012. Application of a eutrophication model for assessing water quality in Lake Winnipeg. *Journal of Great Lakes Research* 38:158-173.

Zou, L., S.N. Miller, and E.T. Schmidtmann. 2006. Mosquito larval habitat mapping using remote sensing and GIS: implications of coalbed methane development and West Nile virus. *Journal of Medical Entomology* 43: 1034-1041.

Zubchenko, A.V. and T.A. Karaseva. 2002. *Ichthyophonus hoferi* as one of possible causes of increased marine mortality in post-smolts of Atlantic salmon. NPAFC Technical Report No. 4:90-92.

APPENDIX E

Transbasin Effects Analysis Technical Report

Attachment 1

Contents

Page

Biota Distribution Maps 1
References 39

Figures

Figure A1-1 Virus Distribution – North America 3
Figure A1-2 Virus Distribution – Hudson Bay Basin 4
Figure A1-3 Virus Distribution – Missouri Region 5
Figure A1-4 Virus Distribution – Atlantic Ocean Basin (Great Lakes Region) 6
Figure A1-5 Virus Distribution – Pacific Ocean Basin 7
Figure A1-6 Virus Distribution – Upper Mississippi Region 8
Figure A1-7 Bacteria Distribution – North America 9
Figure A1-8 Bacteria Distribution – Hudson Bay Basin 10
Figure A1-9 Bacteria Distribution – Missouri Region 11
Figure A1-10 Bacteria Distribution – Atlantic Ocean Basin (Great Lakes Region) 12
Figure A1-11 Bacteria Distribution – Pacific Ocean Basin 13
Figure A1-12 Bacteria Distribution – Upper Mississippi Region 14
Figure A1-13 New Zealand Mudsnail Distribution – North America 15
Figure A1-14 New Zealand Mudsnail Distribution – Hudson Bay Basin 16
Figure A1-15 New Zealand Mudsnail Distribution – Missouri Region 17
Figure A1-16 New Zealand Mudsnail Distribution – Atlantic Ocean Basin (Great Lakes Region) 18
Figure A1-17 New Zealand Mudsnail Distribution – Pacific Ocean Basin 19
Figure A1-18 New Zealand Mudsnail Distribution – Upper Mississippi Region 20
Figure A1-19 Quagga Mussel Distribution – North America 21
Figure A1-20 Quagga Mussel Distribution – Hudson Bay Basin 22
Figure A1-21 Quagga Mussel Distribution – Missouri Region 23
Figure A1-22 Quagga Mussel Distribution – Atlantic Ocean Basin (Great Lakes Region) 24
Figure A1-23 Quagga Mussel Distribution – Pacific Ocean Basin 25
Figure A1-24 Quagga Mussel Distribution – Upper Mississippi Region 26
Figure A1-25 Zebra Mussel Distribution – North America 27
Figure A1-26 Zebra Mussel Distribution – Hudson Bay Basin 28
Figure A1-27 Zebra Mussel Distribution – Missouri Region 29
Figure A1-28 Zebra Mussel Distribution – Atlantic Ocean Basin (Great Lakes Region) 30
Figure A1-29 Zebra Mussel Distribution – Pacific Ocean Basin 31
Figure A1-30 Zebra Mussel Distribution – Upper Mississippi Region 32
Figure A1-31 Animal Parasite Distribution – North America 33
Figure A1-32 Animal Parasite Distribution – Hudson Bay Basin 34
Figure A1-33 Animal Parasite Distribution – Missouri Region 35

Figure A1-34 Animal Parasite Distribution – Atlantic Ocean Basin (Great Lakes Region) 36
Figure A1-35 Animal Parasite Distribution – Pacific Ocean Basin 37
Figure A1-36 Animal Parasite Distribution – Upper Mississippi Region 38

Biota Distribution Maps

Maps were generated using Geographic Information Systems to present the current known distribution of aquatic invasive species of concern (AIS) in the Hudson Bay basin (HBB) and major adjacent watersheds. Neighboring hydrologic basins were evaluated due to their proximity and potential to contribute non-indigenous organisms to the HBB. Five United States (U.S.) regions were co-located in four Canadian basins including: the Souris-Red-Rainy region within the Hudson Bay basin, the Missouri region within the Gulf of Mexico basin, the Great Lakes and New England regions within the Atlantic Ocean basin, and the Pacific Northwest region within the Pacific Ocean basin. The Upper Mississippi region, whose drainage area lies completely within the continental U.S., represents another area of consideration.

At the basin/region scale, subregions provide greater detail of larger scale boundaries in the U.S. Regions (HUC-2) and subregions (HUC-4) are the two largest units of the U.S. Geological Survey (USGS) hydrological unit code (HUC) system. The nested hierarchy of boundaries within the U.S. range from the largest continental units of regions at HUC-2 (e.g., Missouri River region) and HUC-4 (e.g., Missouri-Oahe subregion) to the smallest unit of subwatersheds at HUC-12 (not displayed on the maps).

Distribution maps were developed for viral pathogens, bacterial pathogens, parasitic animals, and invasive mollusks. Recorded observations of AIS were gathered from multiple sources. Despite the use of multiple sources, some geographic regions are not as well represented as others. For example, *Myxobolus cerebralis*, the agent of whirling disease, is known to occur in the state of Utah, but data for that state are not available in the U.S. Fish & Wildlife Service's (Service) Wild Fish Health Survey Database (WFHSDb; Service 2011). In addition, numerous observations recorded in published literature were not uploaded to the WFHSDb, as well as other data repositories.

The WFHSDb provides regularly updated data for several fish pathogens monitored in the U.S., with the following exceptions that are included in the list of AIS for this *Transbasin Effects Analysis*:

- *Actheres ambloplitis*
- *Ergasilus* spp.
- *Corallataenia minutia*
- *Icelanonchohaptor microcotyle*
- *Polypodium hydriforme*
- *Pseudomonas* spp.
- *Streptococcus faecalis*

Distribution data for *Aeromonas salmonicida* (furunculosis), *Yersinia ruckeri* (enteric redmouth disease), *Edwardsiella tarda* (enteric septicemia), *Myxobolus cerebralis*, *Renibacterium salmoninarum* (bacterial kidney disease), channel catfish virus, infectious salmon anemia virus, infectious hematopoietic viral necrosis virus, infectious pancreatic necrosis virus, spring viremia of carp virus, and viral hemorrhagic septicemia virus were acquired from the WFHSDb on December 7, 2011.

Efforts were conducted to obtain additional data for fish diseases occurring in the potential source basins and the HBB. Select data points for the Province of Manitoba were acquired from the recently published *Devils Lake – Red River Basin Fish Parasite and Pathogen Project Qualitative Risk Assessment* (Bensley et al. 2011).

Distribution data for invasive mollusks (zebra mussels, quagga mussels, and New Zealand mudsnails) were acquired from the USGS Non-indigenous Aquatic Species (NAS) database on June 4, 2012 (USGS 2012). The NAS was developed for tracking vertebrate and invertebrate aquatic invasive organisms in U.S. waters.

Extensive literature searches were conducted with the intent to obtain additional observational location data to further develop the distribution maps, especially for Canadian portions of the basins/regions. However, specific location coordinates were not always presented in the publications. In these cases, qualitative descriptions provided by the authors were used to estimate approximate locations on the maps.

Data were plotted with ArcGIS 10 (ESRI 2011) for each AIS and then grouped by major taxonomic groups (e.g., viruses, bacteria, animal parasites, and mollusks) and presented on individual maps focusing on each of the five major basins. The map set presents a relative understanding of AIS distributions in aquatic systems, but likely does not provide the extent and range of distribution (and abundance) in the areas evaluated.

Figure A1-1 Virus Distribution – North America

Sources:

Bowser 2009

Garver et al. 2007

ISU 2007

ISU 2010

Leighton 2011

Midwest Pond and Koi Society 2012

MnDNR 2011

Service 2011

Tarrab et al. 1996

USDA 2004

Whelan 2009

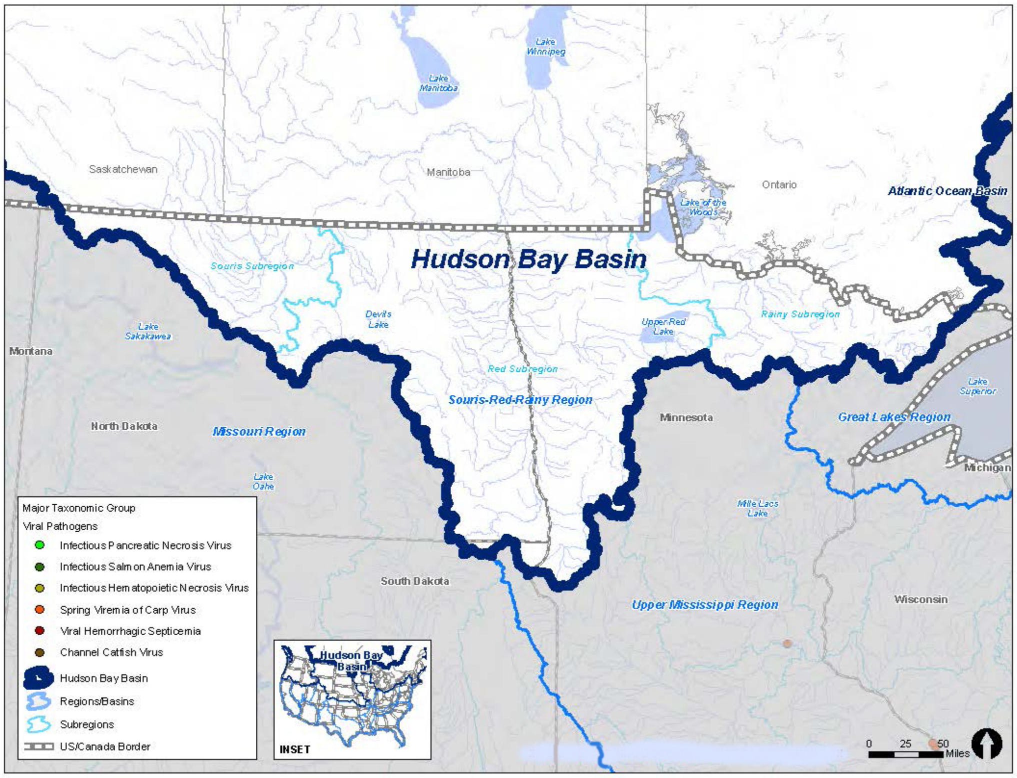


Figure A1-2 Virus Distribution – Hudson Bay Basin

Source: Service 2011

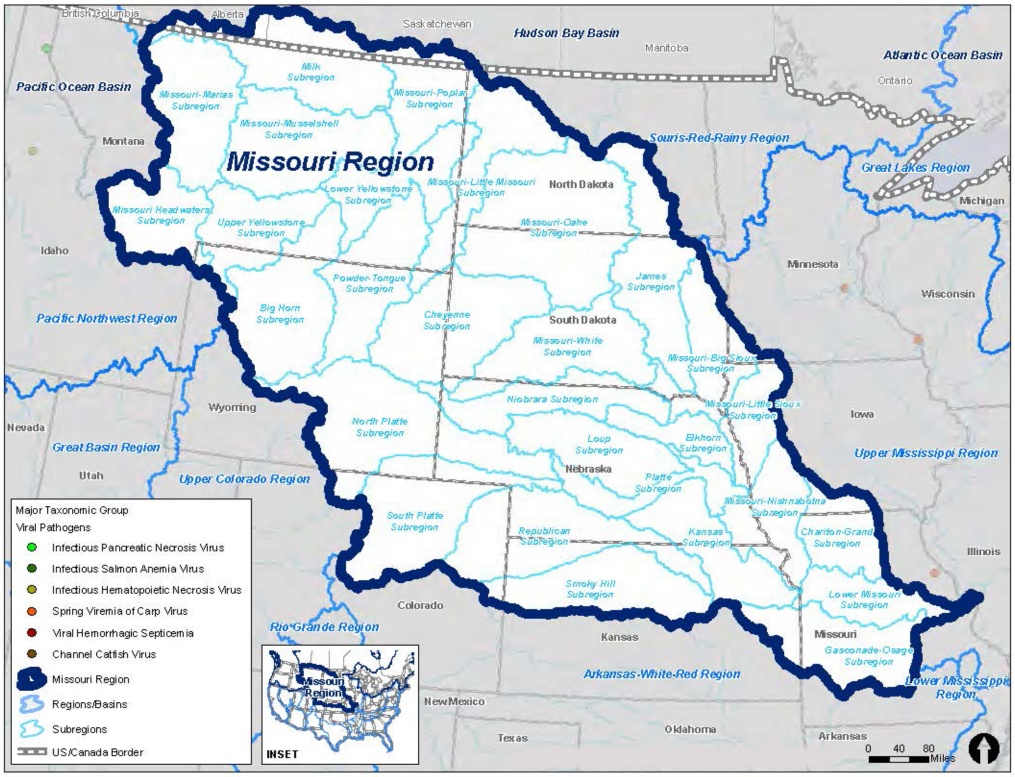


Figure A1-3 Virus Distribution – Missouri Region

Sources:

Service 2011

USDA 2004

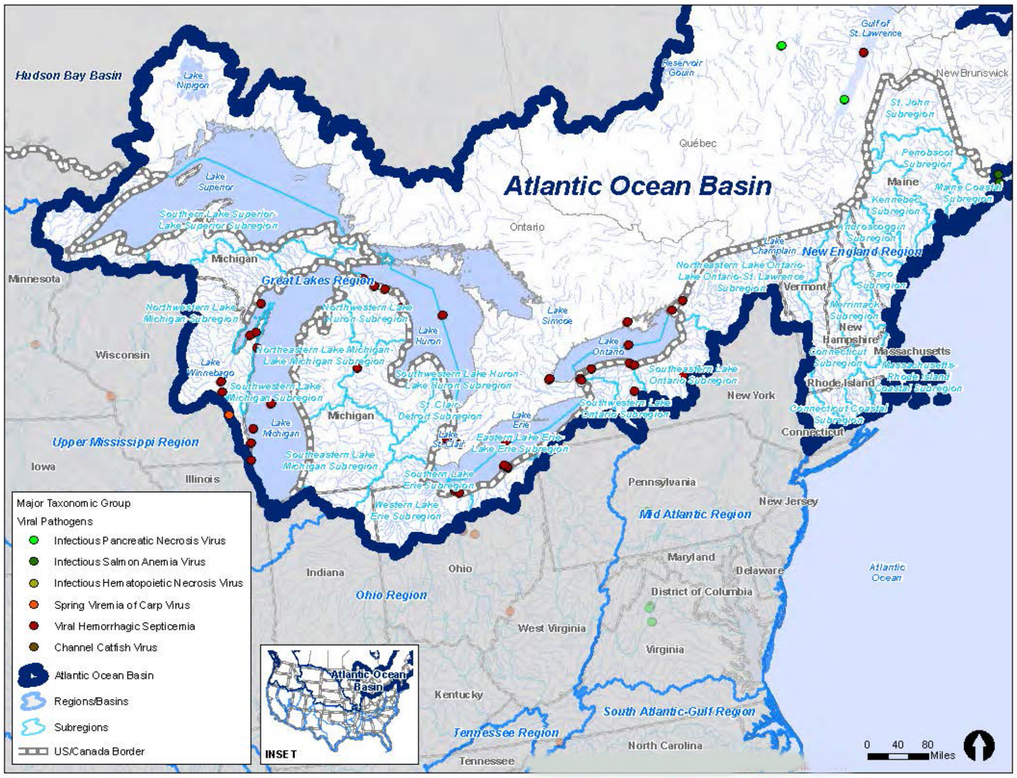


Figure A1-4 Virus Distribution – Atlantic Ocean Basin (Great Lakes Region)

Sources:
ISU 2010
Leighton 2011
Service 2011
Whelan 2009

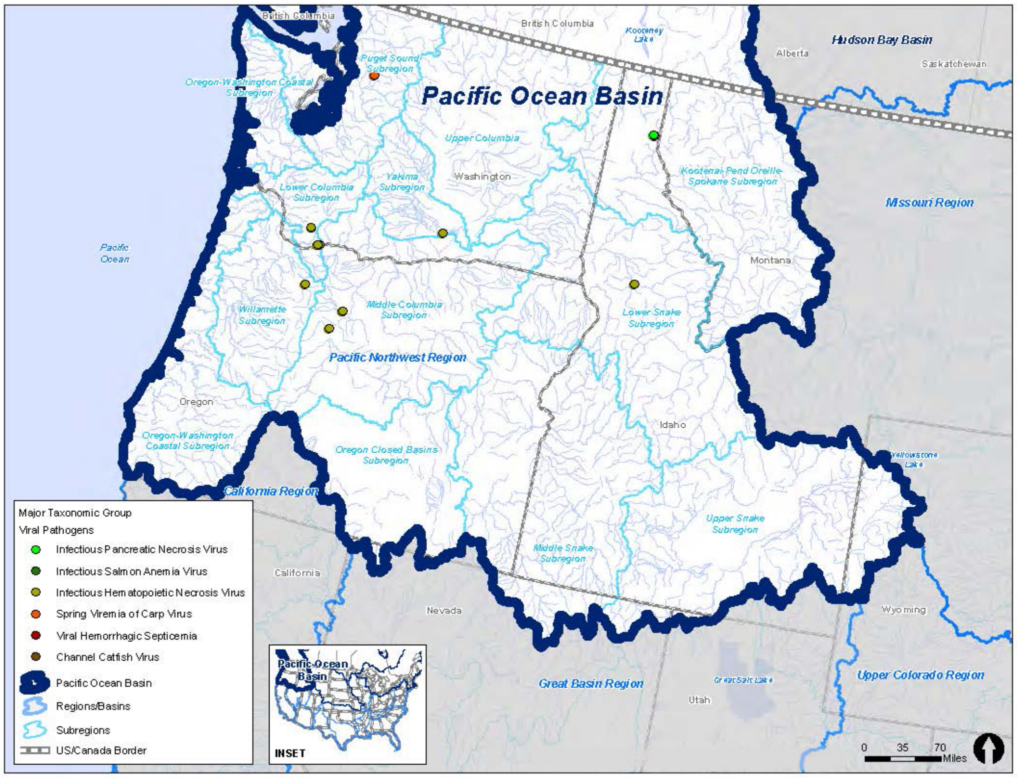


Figure A1-5 Virus Distribution – Pacific Ocean Basin

Sources:

Midwest Pond and Koi Society 2012

Service 2011

Whelan 2009

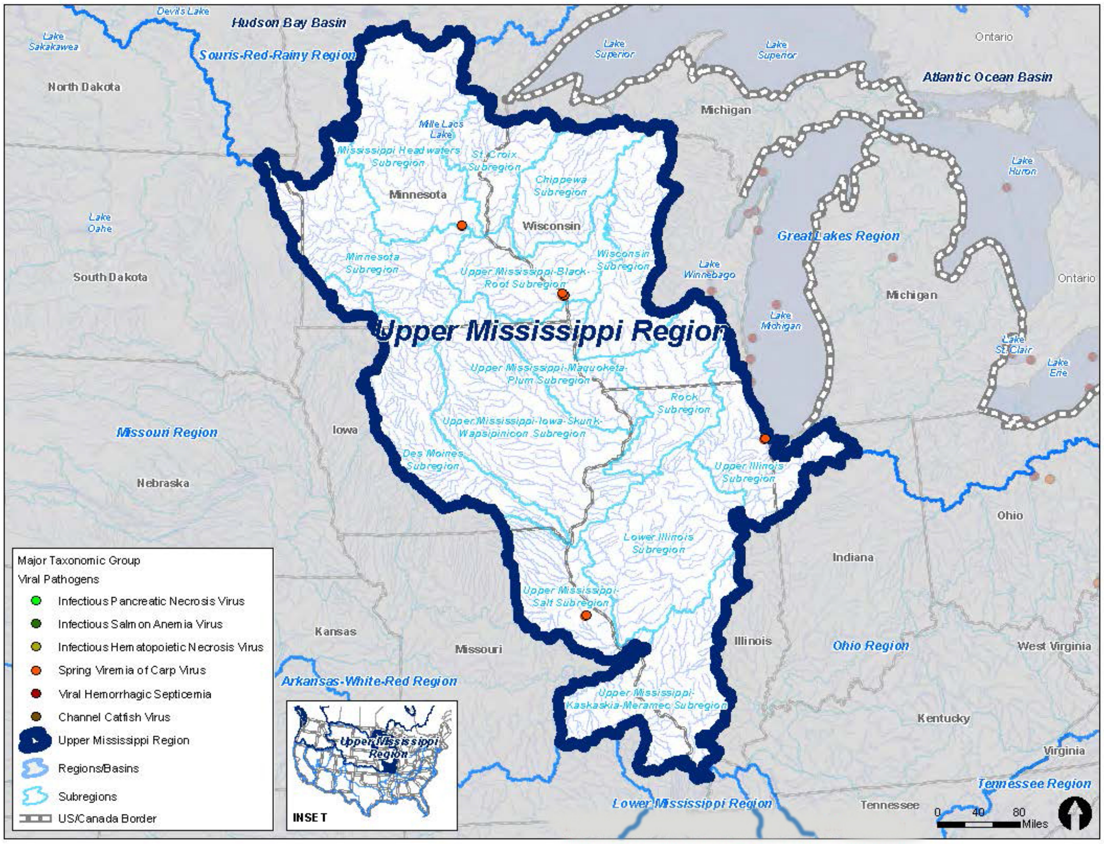


Figure A1-6 Virus Distribution – Upper Mississippi Region

Sources:
ISU 2007
MnDNR 2011
Service 2011
Whelan 2009

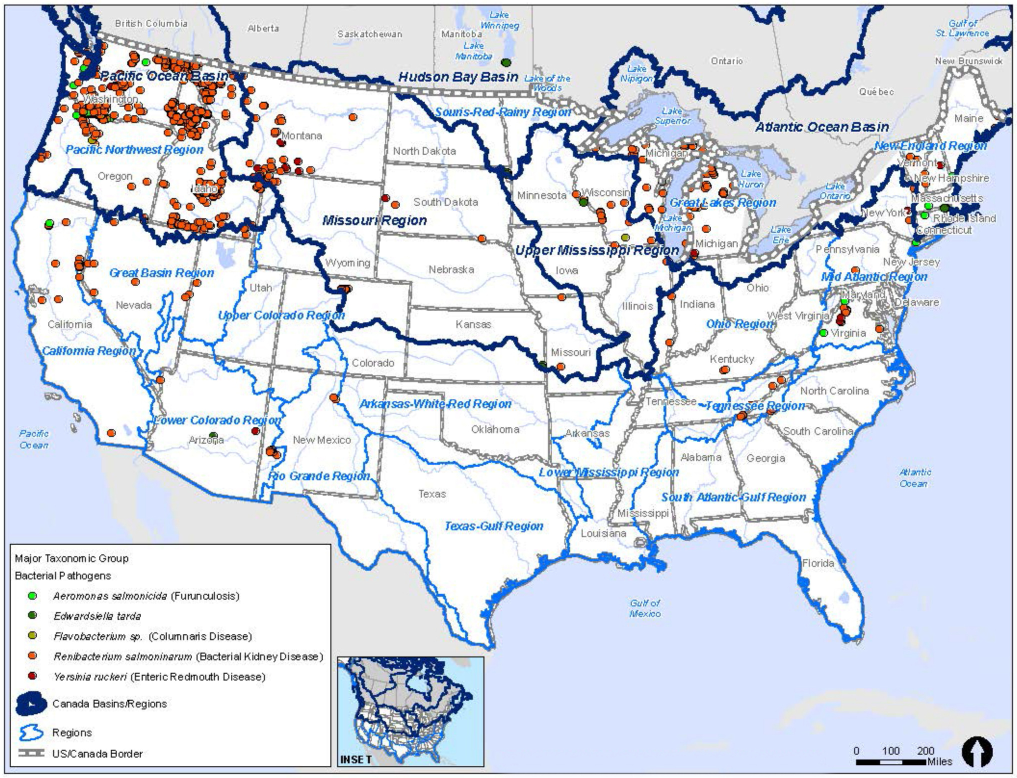


Figure A1-7 Bacteria Distribution – North America

Source: Service 2011

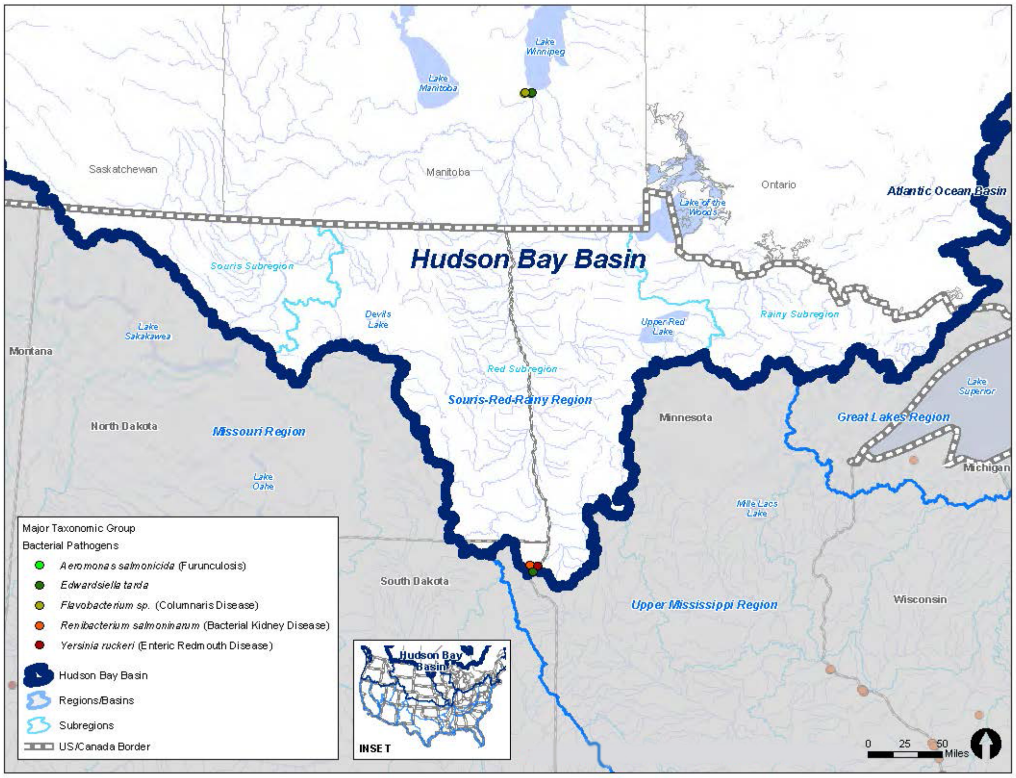


Figure A1-8 Bacteria Distribution – Hudson Bay Basin

Source: Service 2011

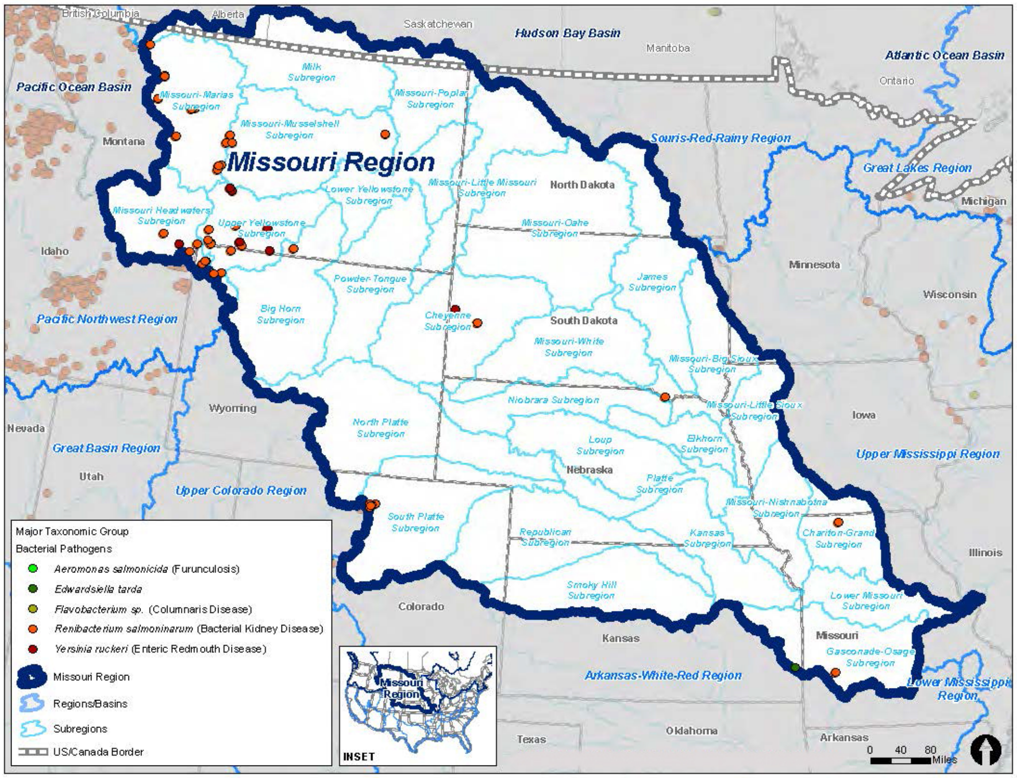


Figure A1-9 Bacteria Distribution – Missouri Region

Source: Service 2011

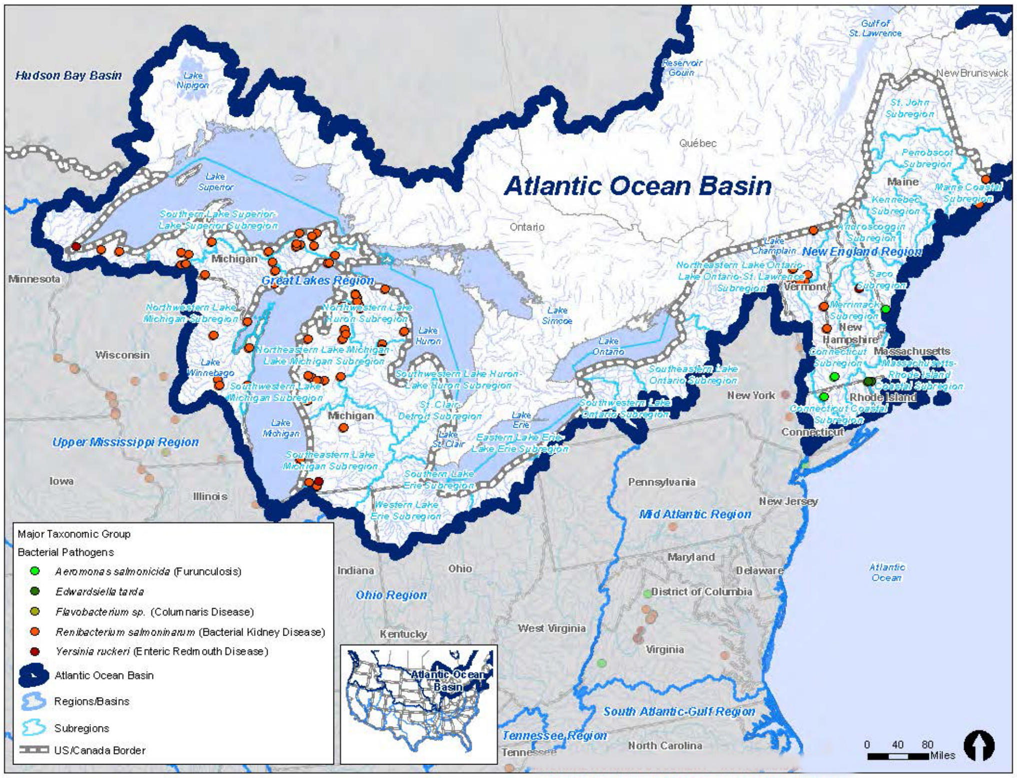


Figure A1-10 Bacteria Distribution – Atlantic Ocean Basin (Great Lakes Region)

Source: Service 2011

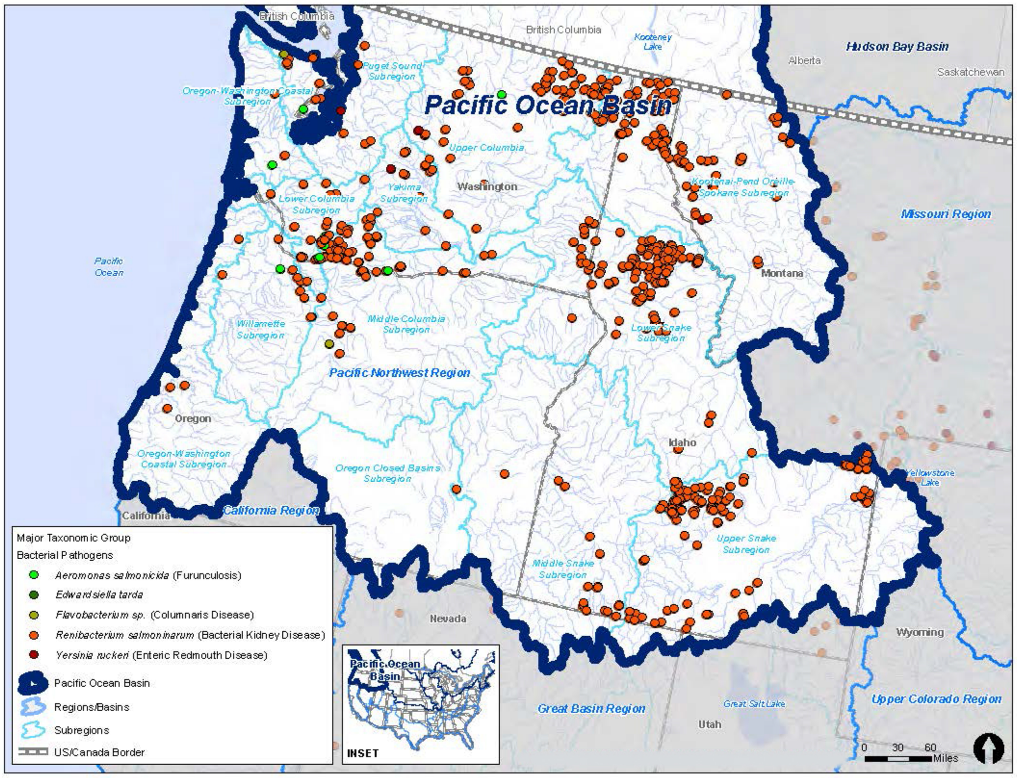


Figure A1-11 Bacteria Distribution – Pacific Ocean Basin

Source: Service 2011

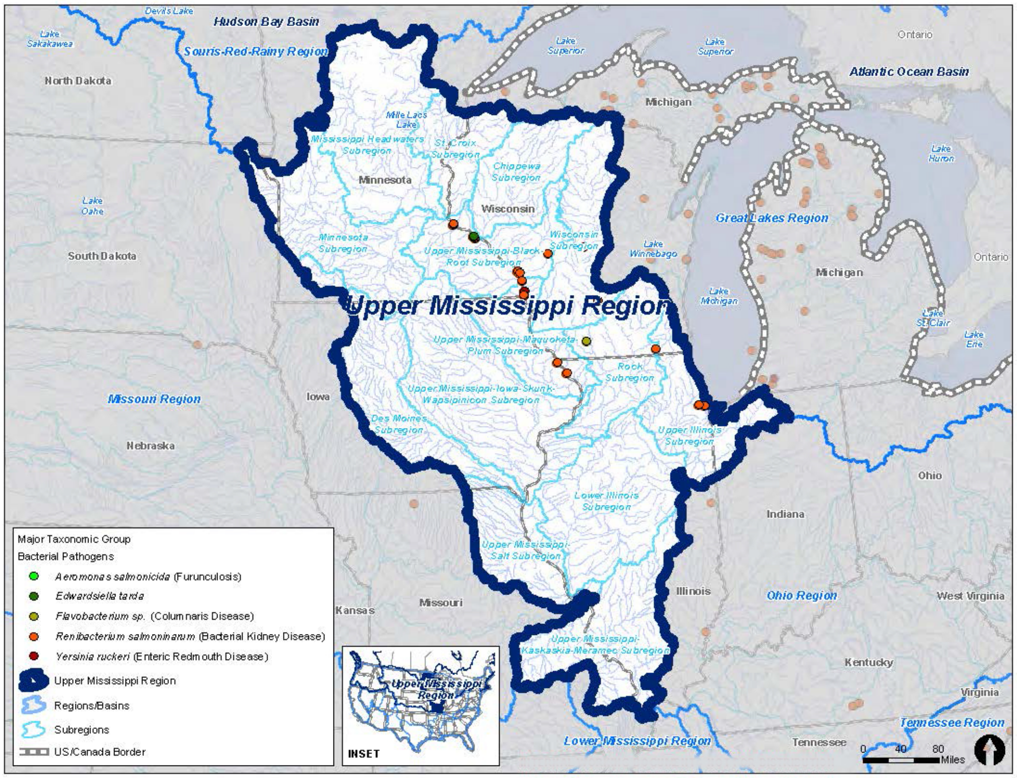


Figure A1-12 Bacteria Distribution – Upper Mississippi Region

Source: Service 2011

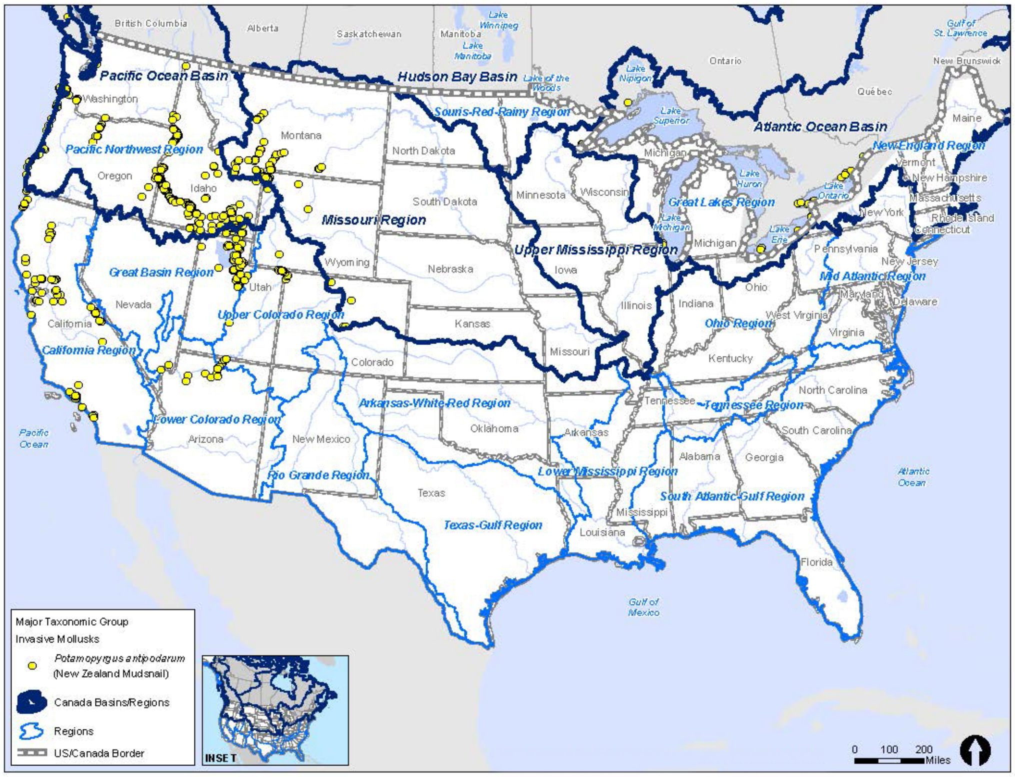


Figure A1-13 New Zealand Mudsnail Distribution – North America

Source: USGS 2012

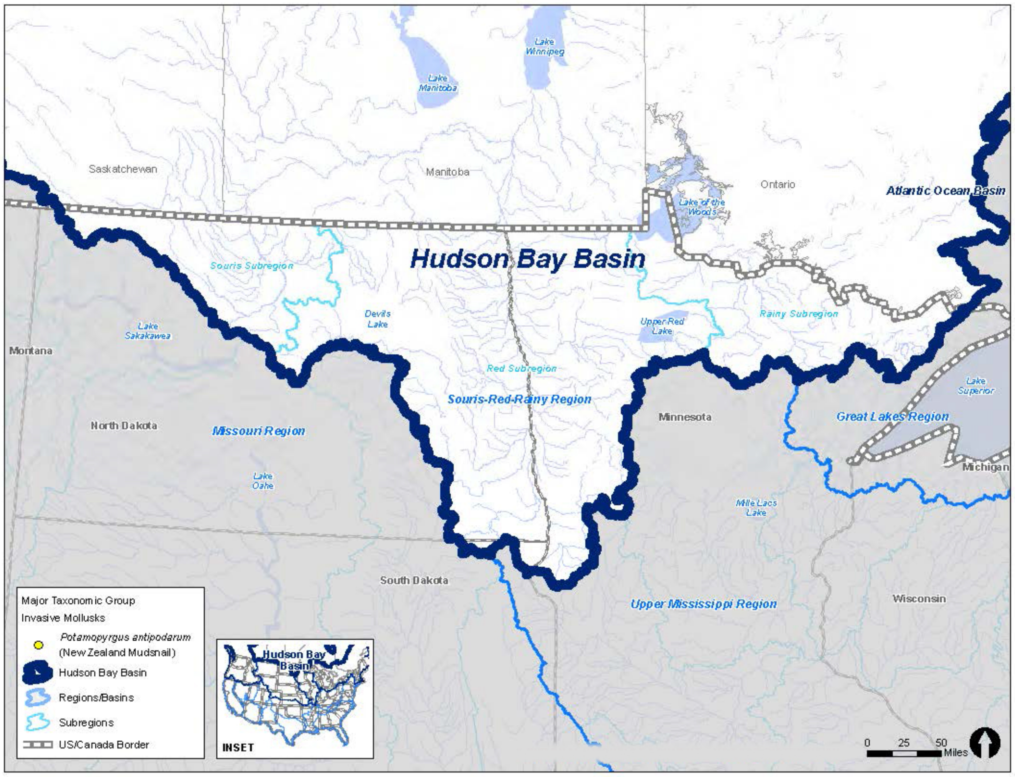


Figure A1-14 New Zealand Mudsnail Distribution – Hudson Bay Basin

Source: USGS 2012

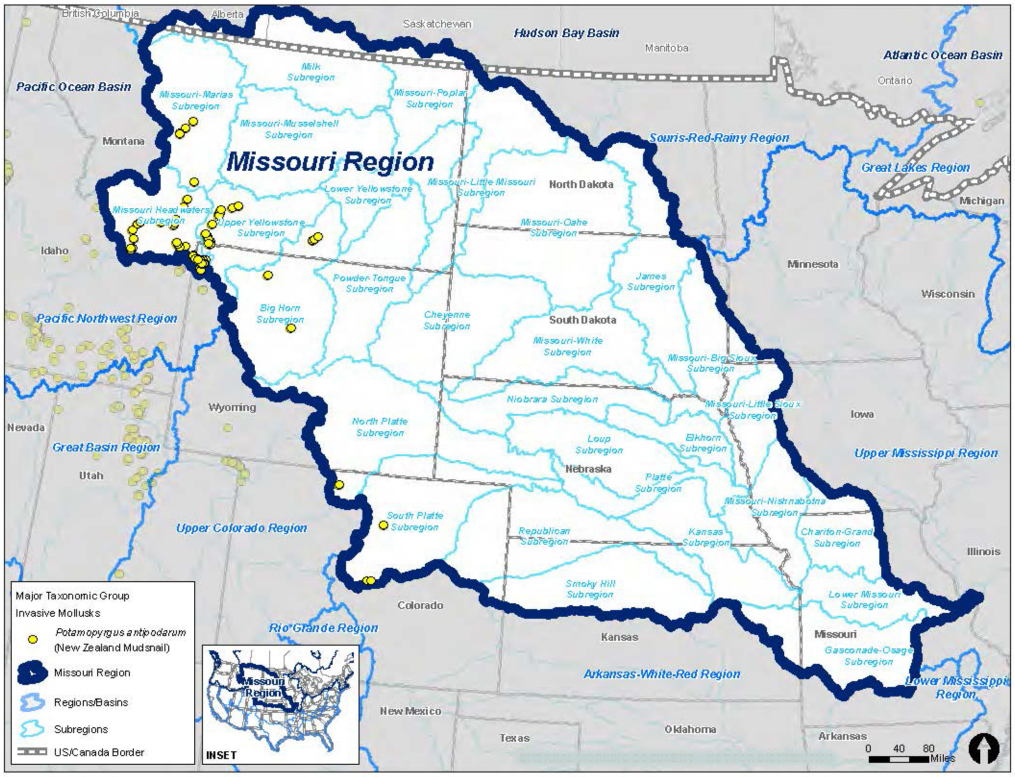


Figure A1-15 New Zealand Mudsnail Distribution – Missouri Region

Source: USGS 2012

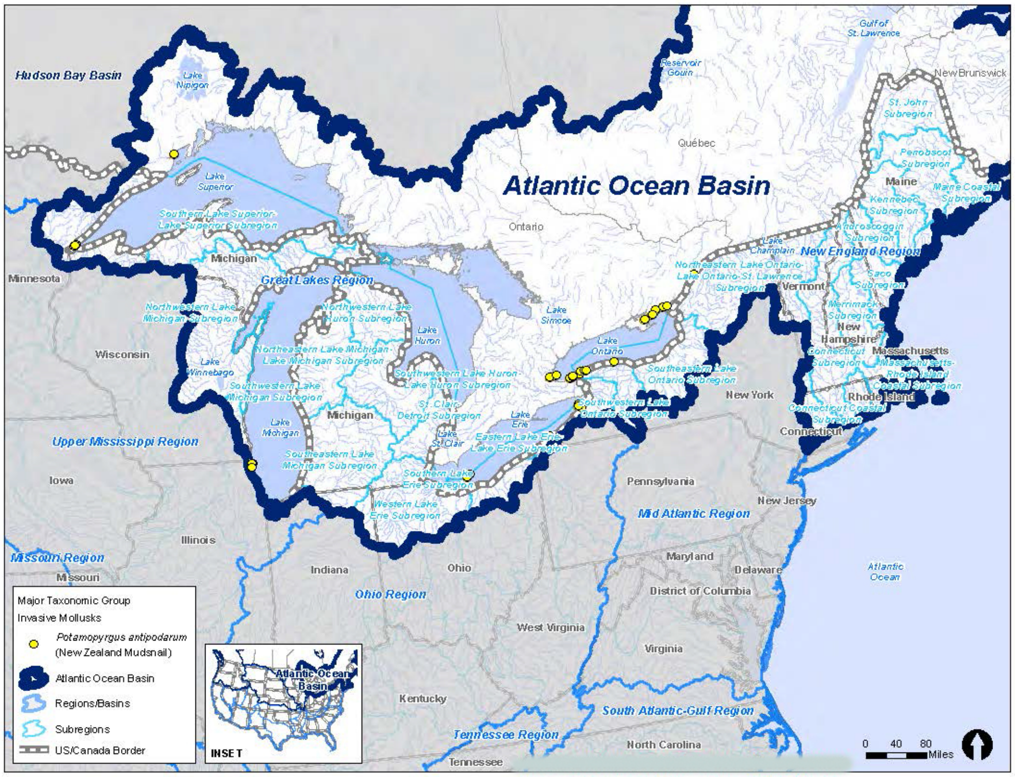


Figure A1-16 New Zealand Mudsnail Distribution – Atlantic Ocean Basin (Great Lakes Region)

Source: USGS 2012

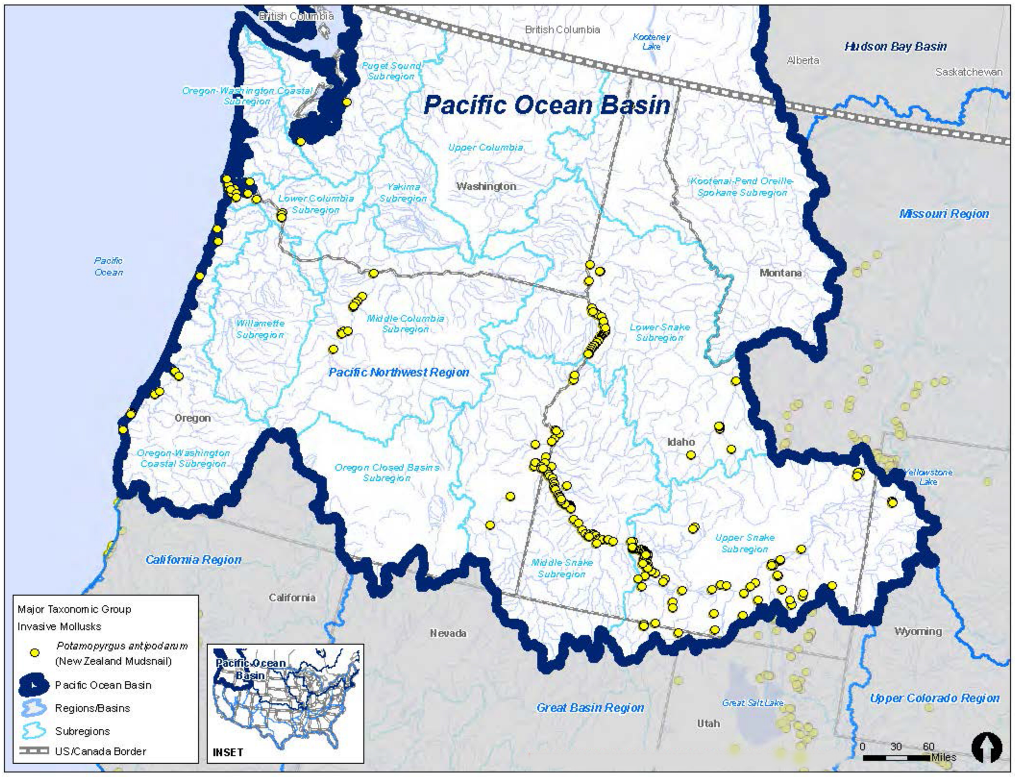


Figure A1-17 New Zealand Mudsnail Distribution – Pacific Ocean Basin

Source: USGS 2012

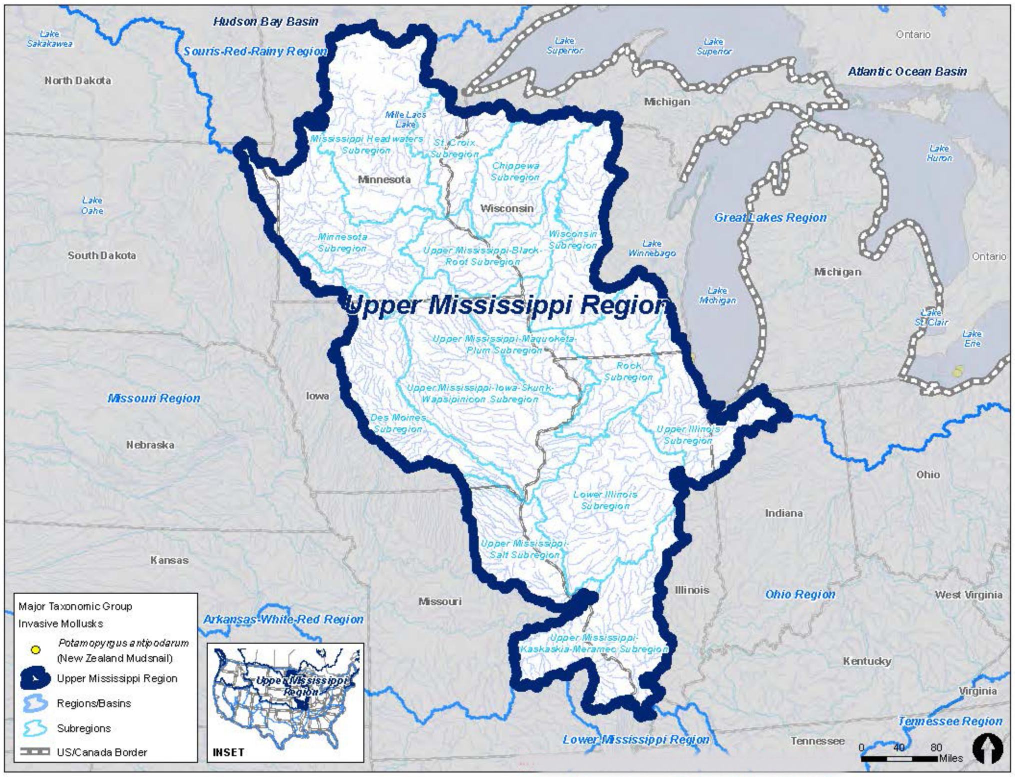


Figure A1-18 New Zealand Mudsnail Distribution – Upper Mississippi Region

Source: USGS 2012

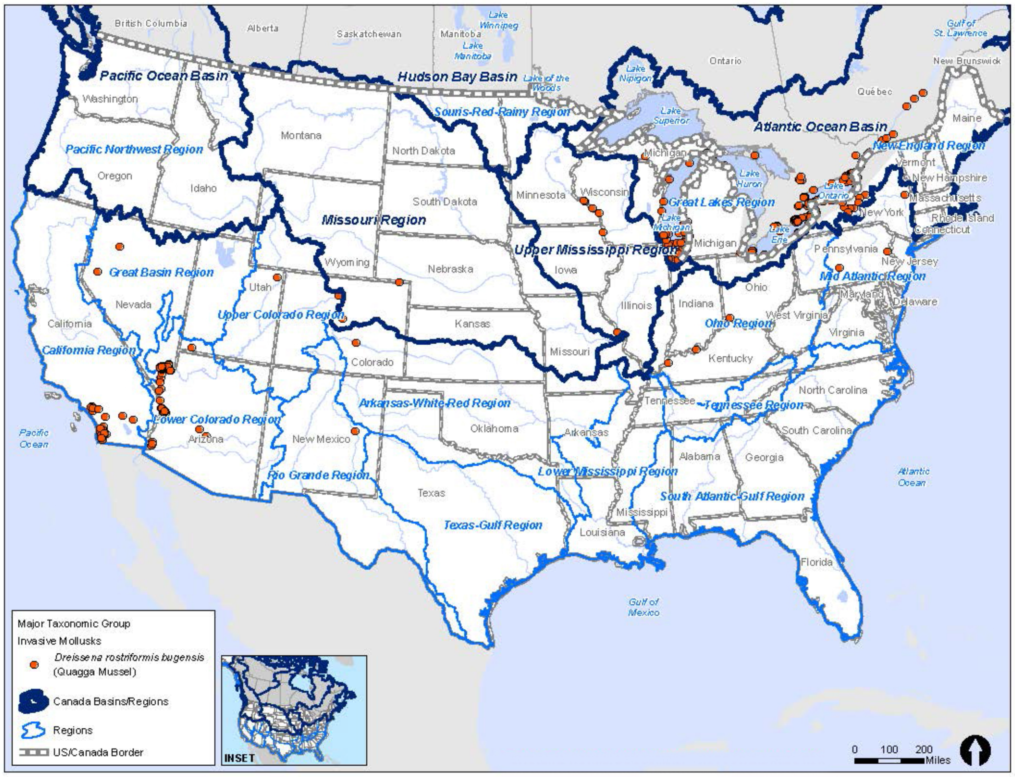


Figure A1-19 Quagga Mussel Distribution – North America

Source: USGS 2012

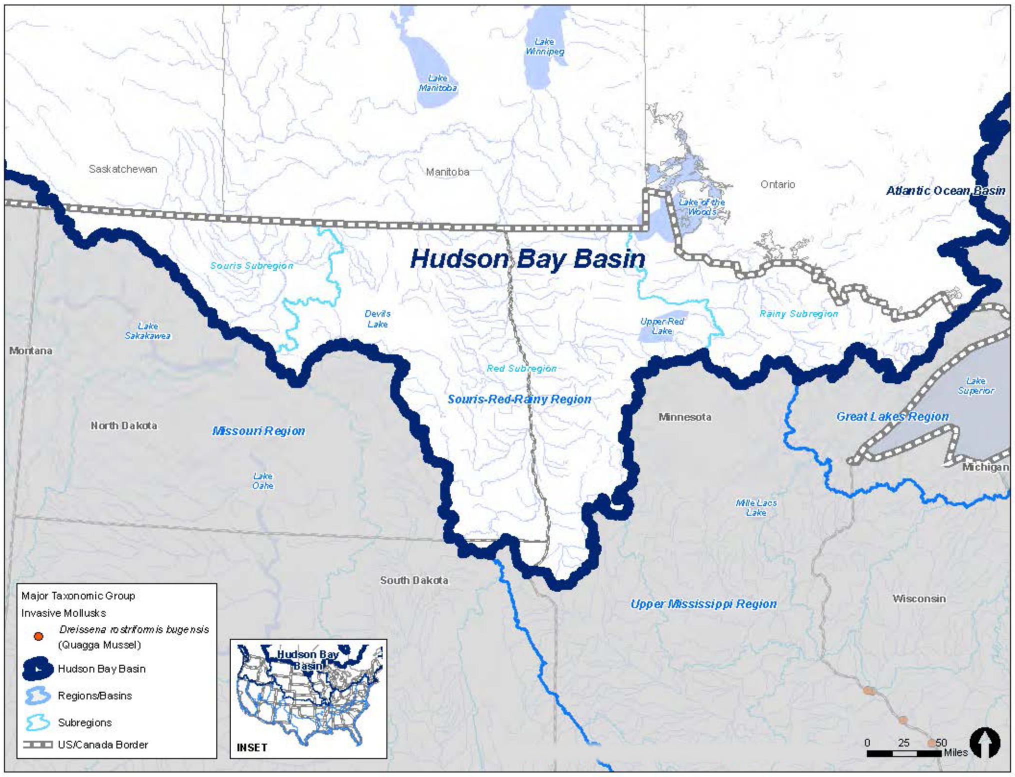


Figure A1-20 Quagga Mussel Distribution – Hudson Bay Basin

Source: USGS 2012

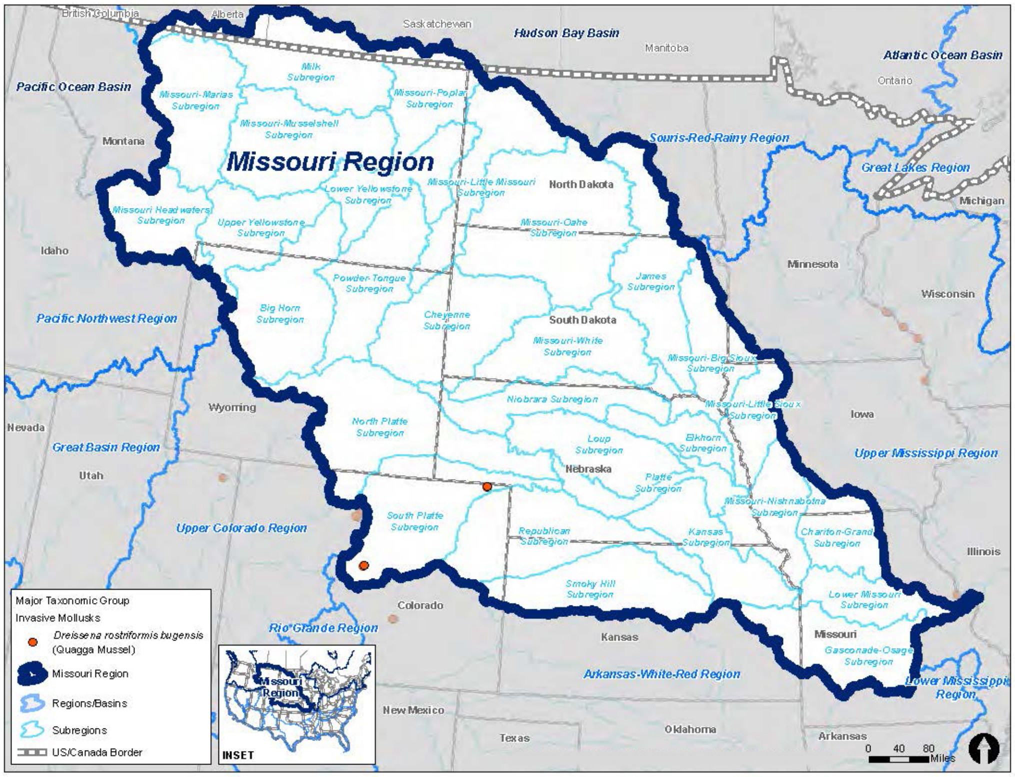


Figure A1-21 Quagga Mussel Distribution – Missouri Region

Source: USGS 2012

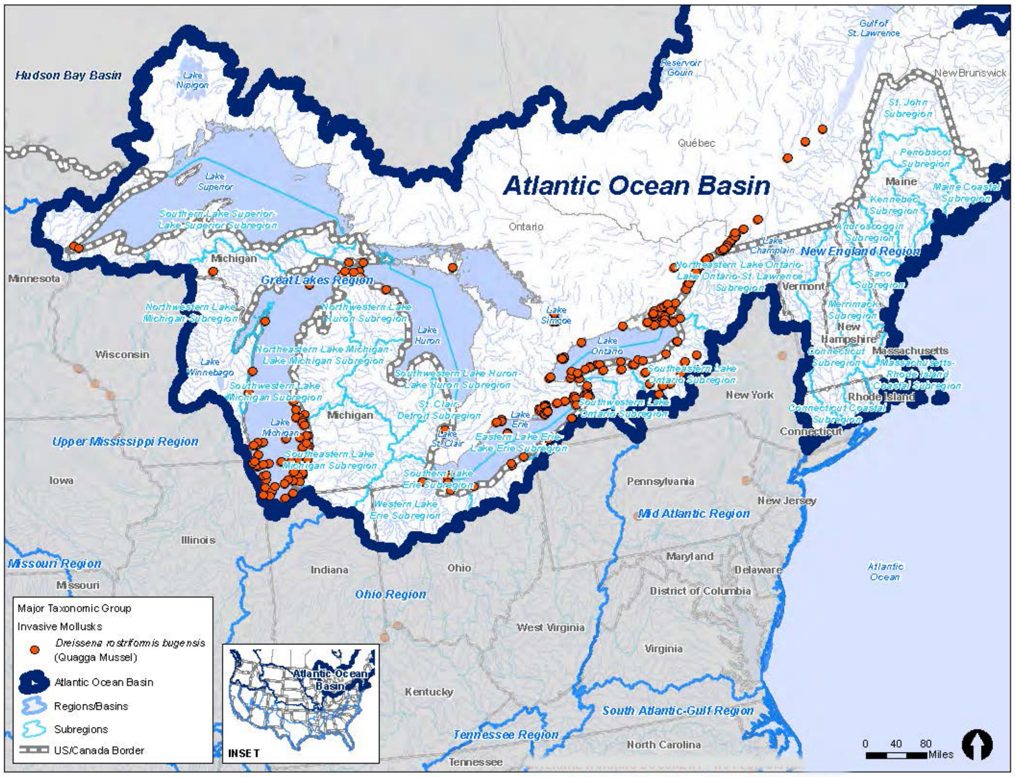


Figure A1-22 Quagga Mussel Distribution – Atlantic Ocean Basin (Great Lakes Region)

Source: USGS 2012

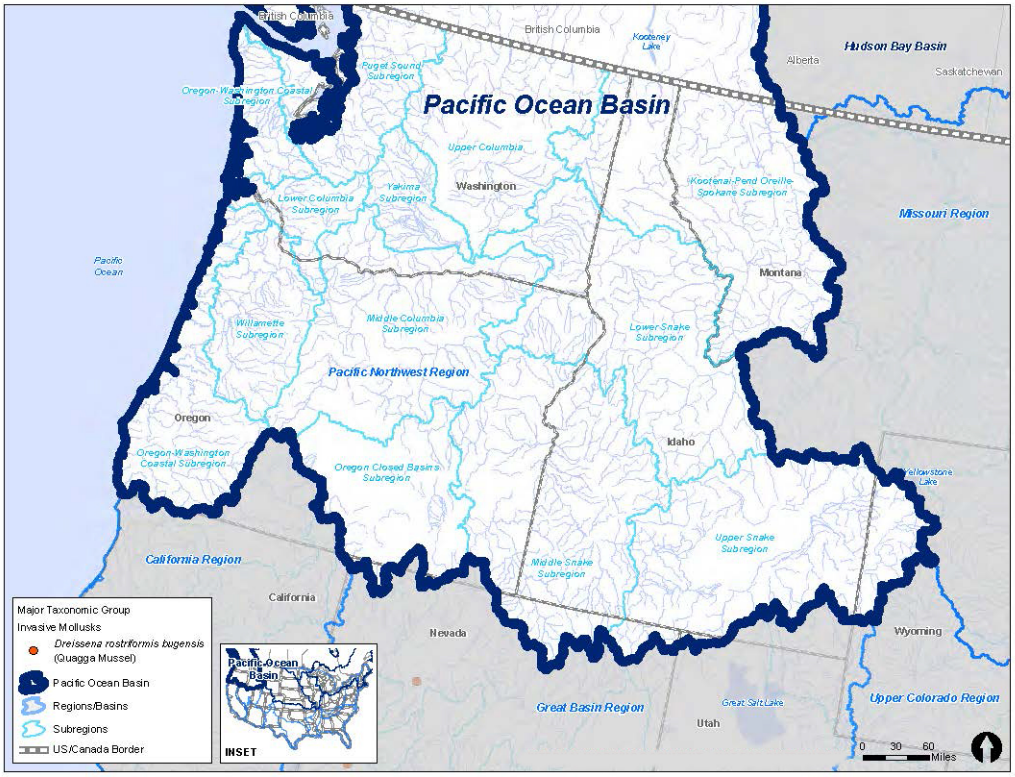


Figure A1-23 Quagga Mussel Distribution – Pacific Ocean Basin

Source: USGS 2012

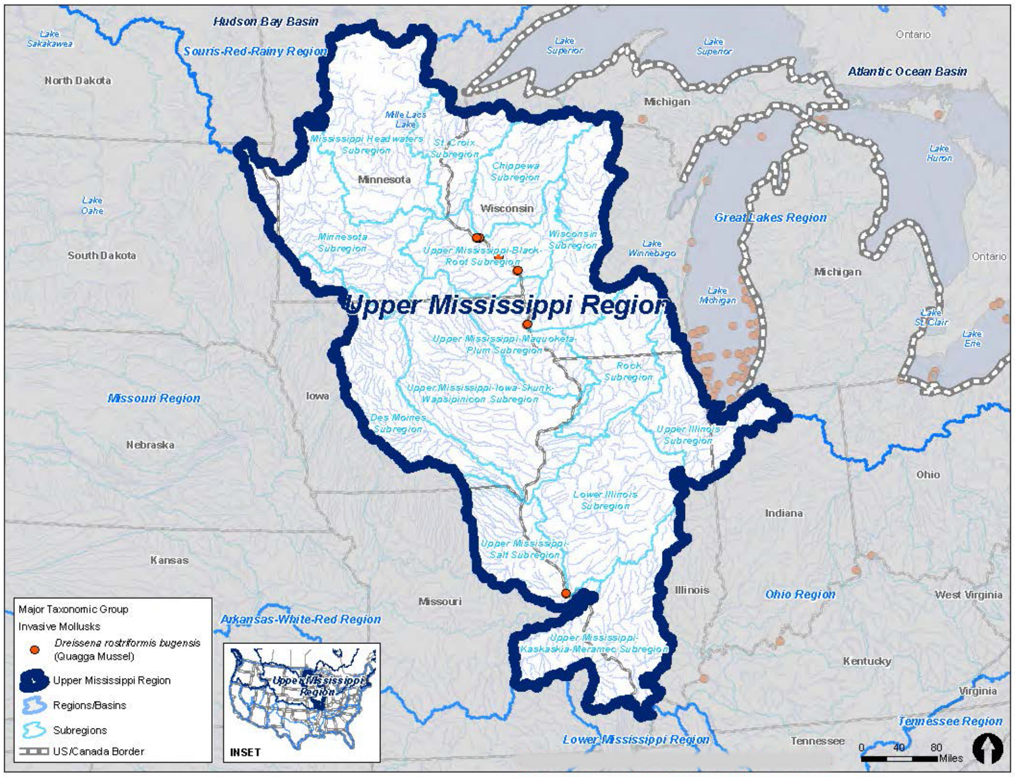


Figure A1-24 Quagga Mussel Distribution – Upper Mississippi Region

Source: USGS 2012

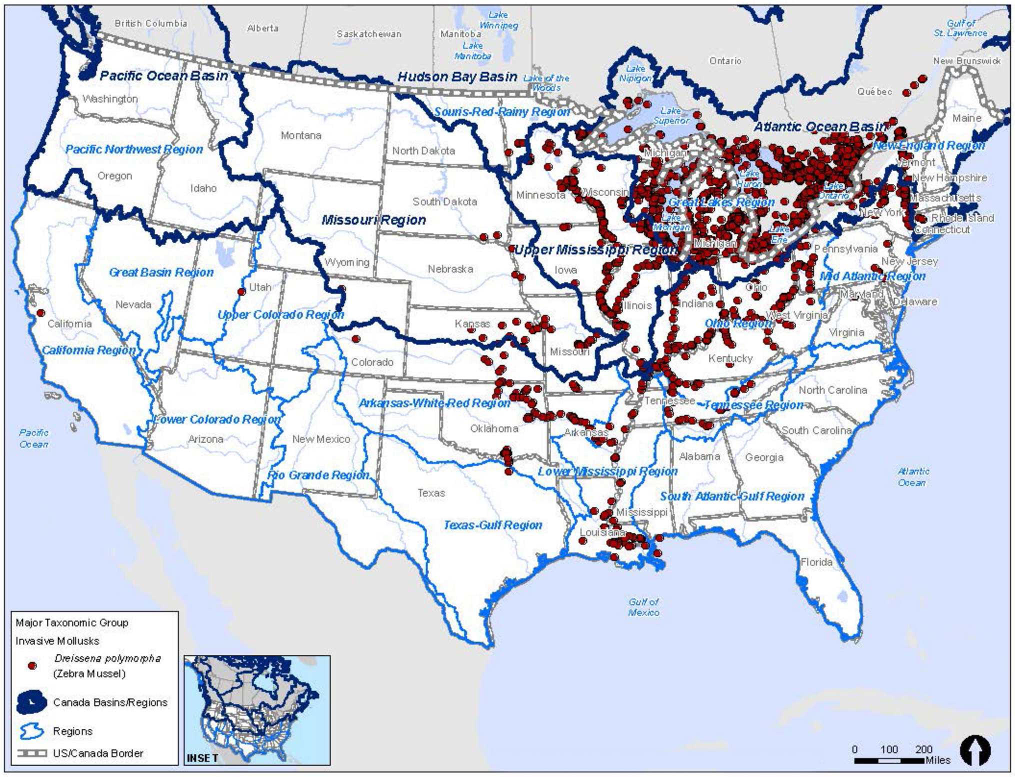


Figure A1-25 Zebra Mussel Distribution – North America

Source: USGS 2012

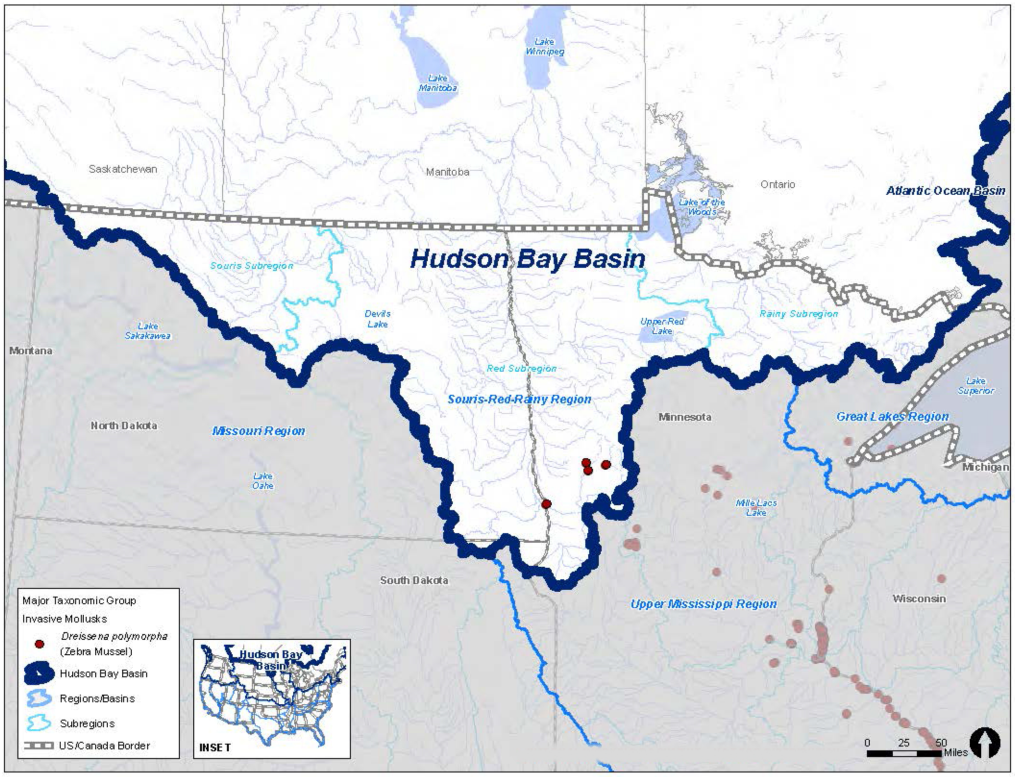


Figure A1-26 Zebra Mussel Distribution – Hudson Bay Basin

Source: USGS 2012

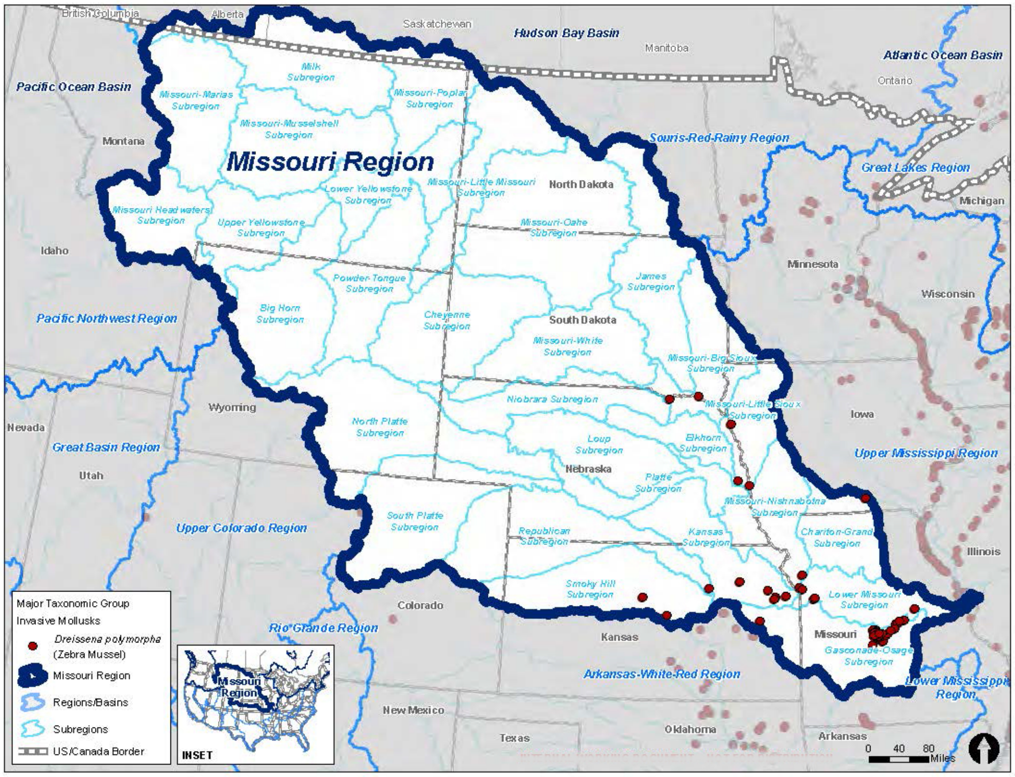


Figure A1-27 Zebra Mussel Distribution – Missouri Region

Source: USGS 2012

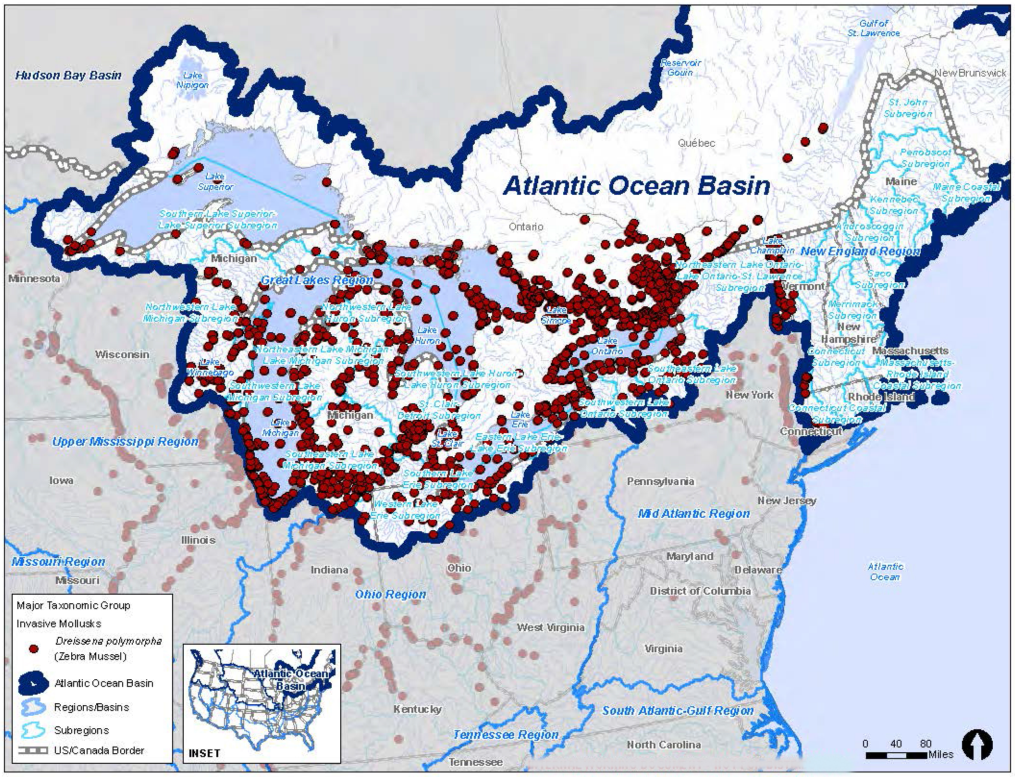


Figure A1-28 Zebra Mussel Distribution – Atlantic Ocean Basin (Great Lakes Region)

Source: USGS 2012

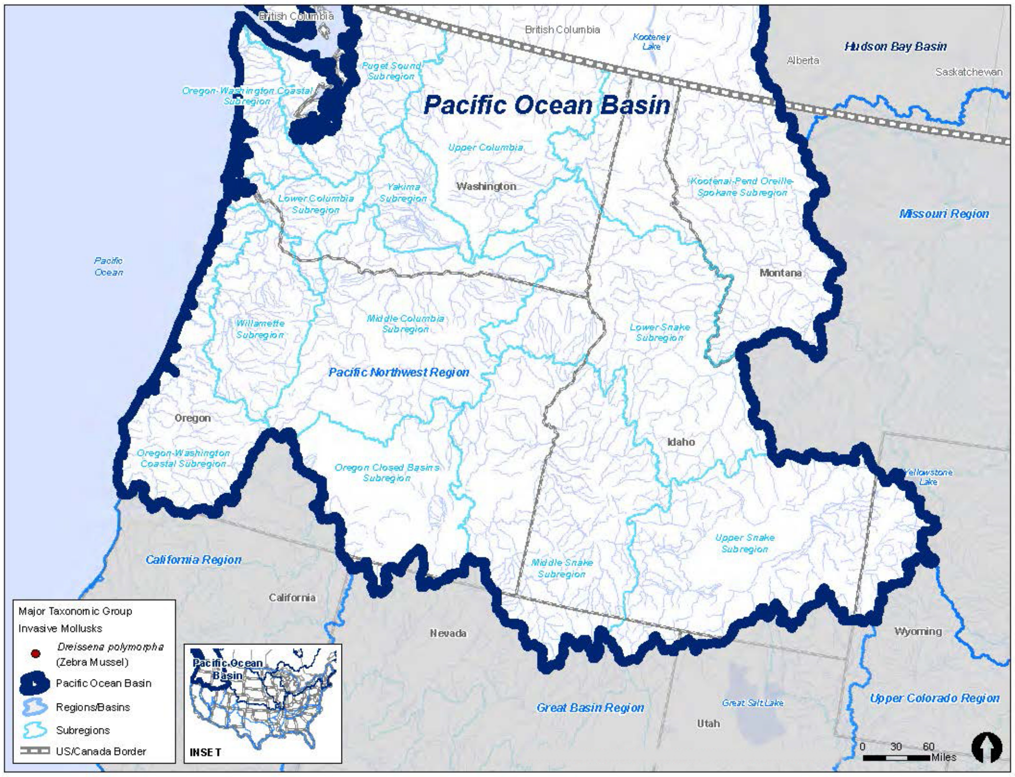


Figure A1-29 Zebra Mussel Distribution – Pacific Ocean Basin

Source: USGS 2012

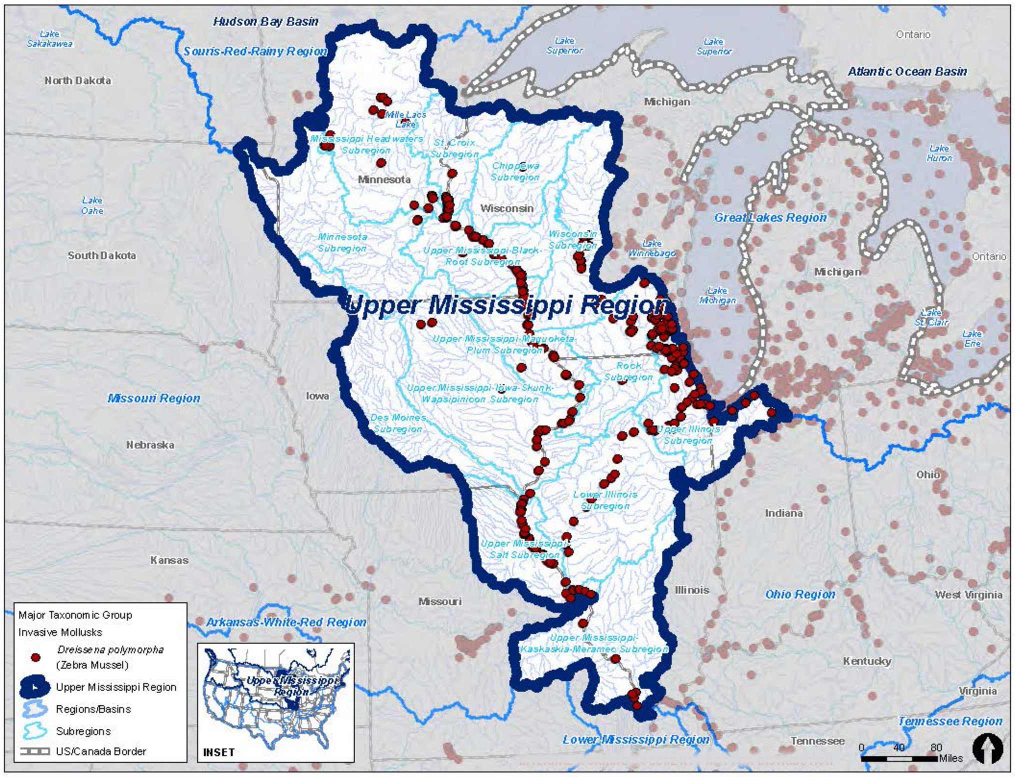


Figure A1-30 Zebra Mussel Distribution – Upper Mississippi Region

Source: USGS 2012

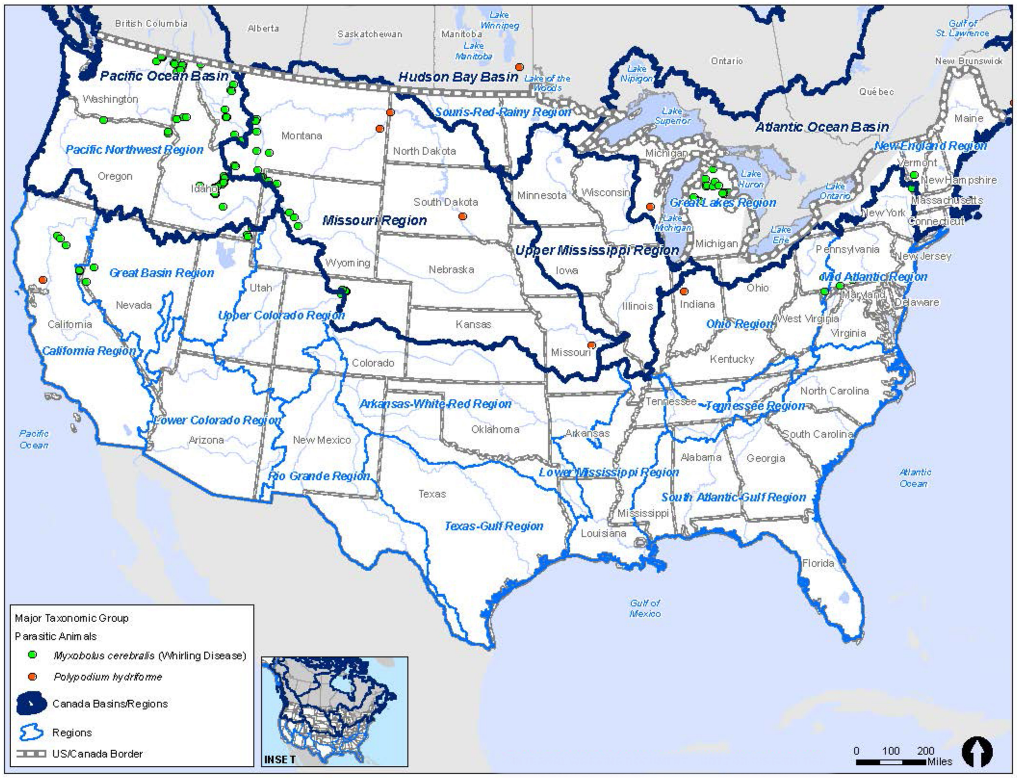


Figure A1-31 Animal Parasite Distribution – North America

Sources:

Bartholomew et al. 2002
Bensley et al. 2011
Choudhury et al. 1993
Hoffman et al. 1974
Holloway et al. 1991
Indiana Department of Natural Resources 2005
Raikova et al. 1979
Sepúlveda et al. 2010
Service 2011
Thomas et al. 2009

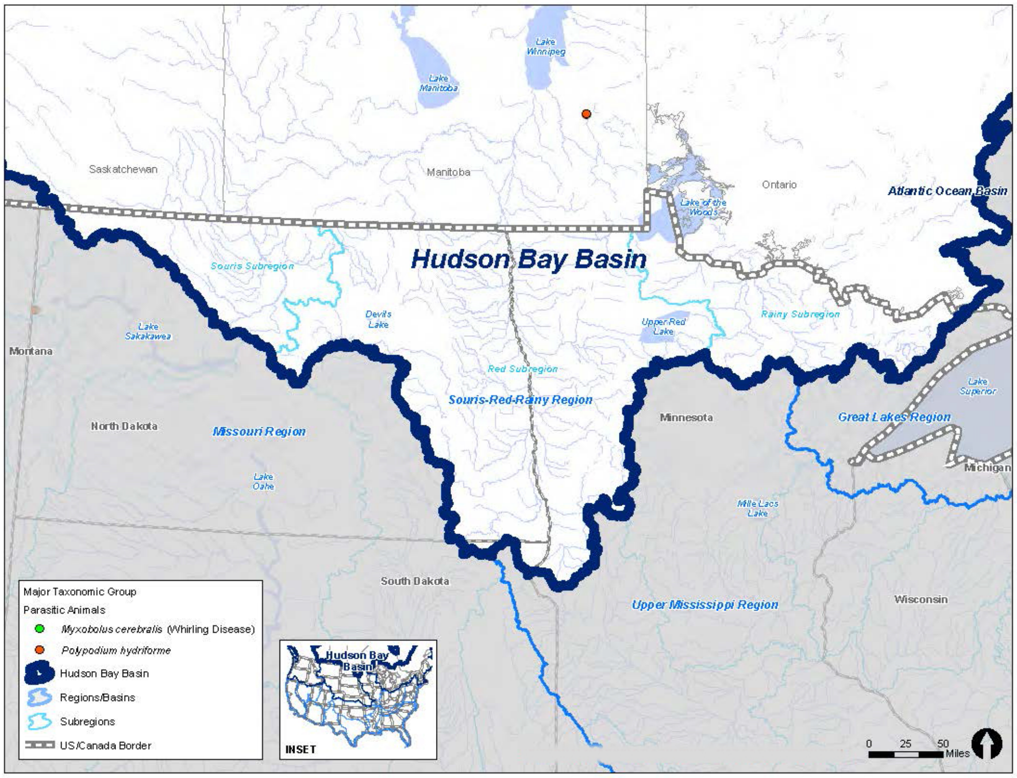


Figure A1-32 Animal Parasite Distribution – Hudson Bay Basin

Sources:

Bartholomew et al. 2002

Bensley et al. 2011

Choudhury et al. 1993

Service 2011

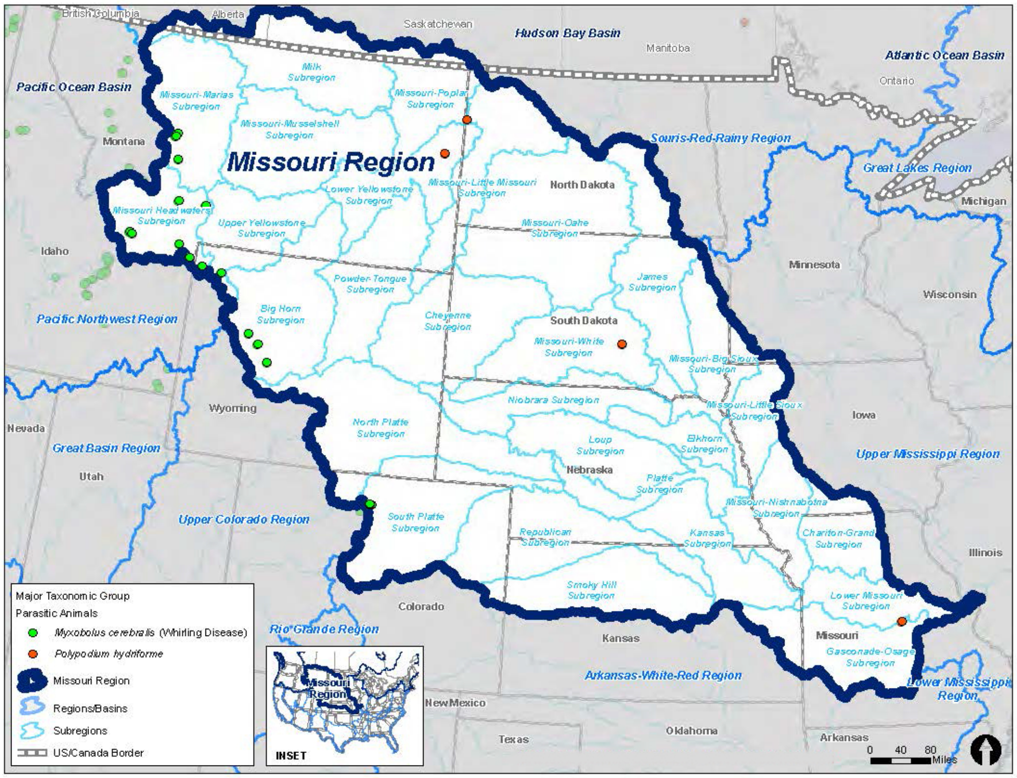


Figure A1-33 Animal Parasite Distribution – Missouri Region

Sources:

Bartholomew et al. 2002

Holloway et al. 1991

Raikova et al. 1979

Service 2011

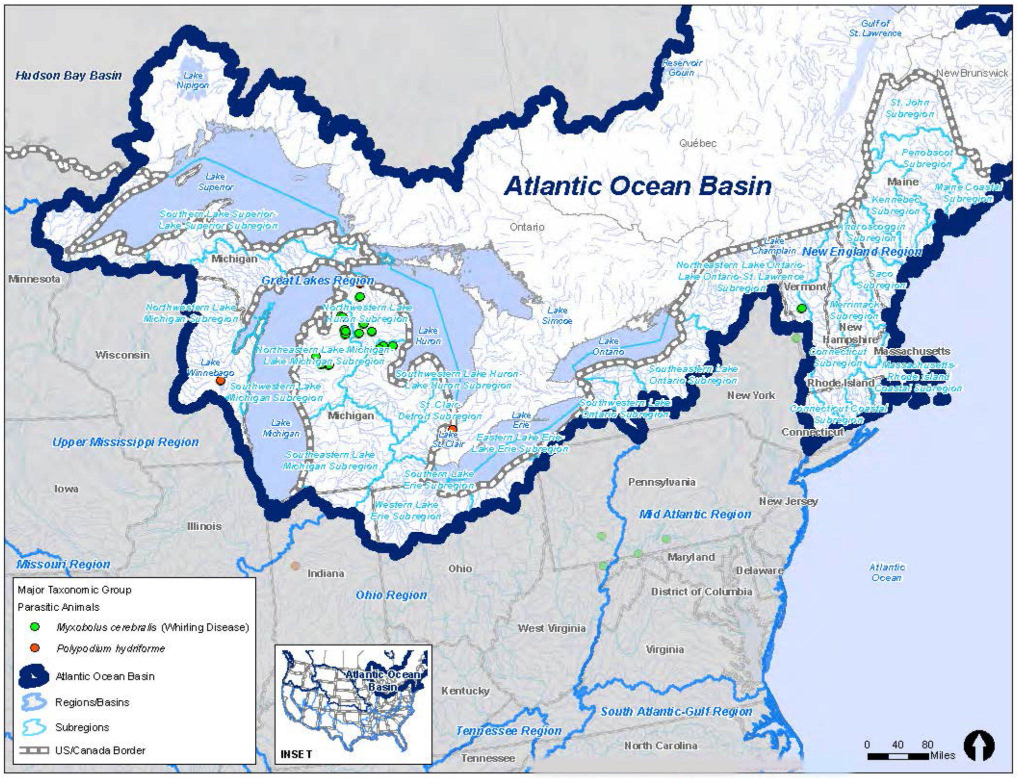


Figure A1-34 Animal Parasite Distribution – Atlantic Ocean Basin (Great Lakes Region)

Sources:

Bartholomew et al. 2002

Choudhury et al. 1993

Hoffman et al. 1974

Holloway et al. 1991

Service 2011

Tarrab et al. 1996

Thomas et al. 2009

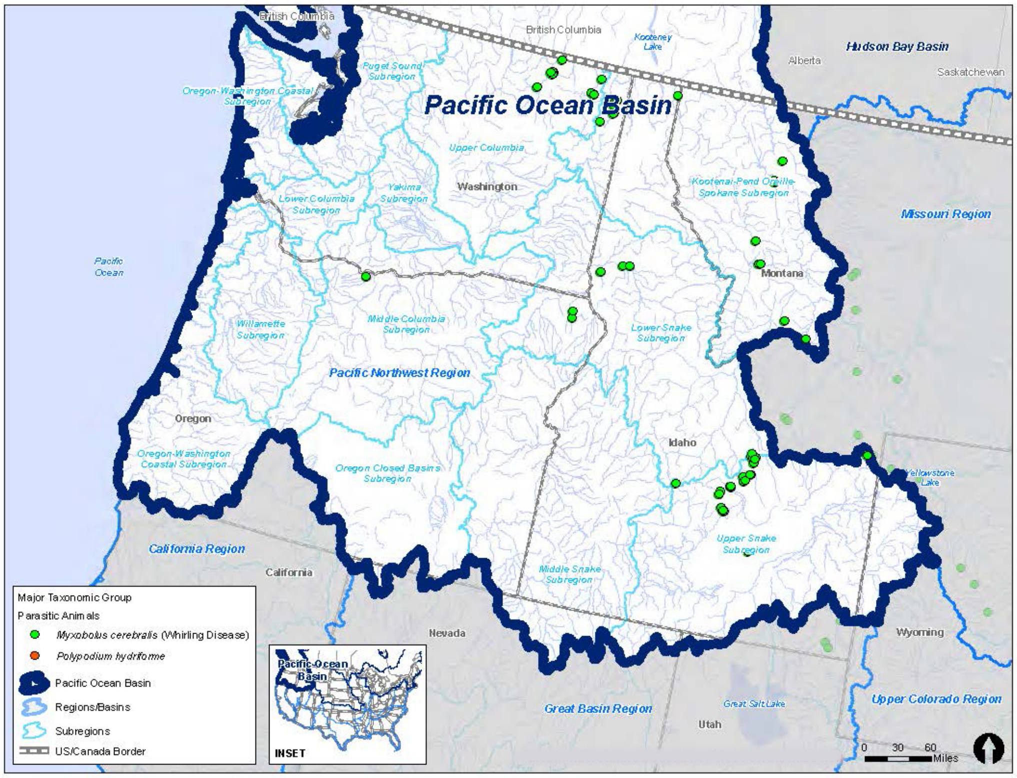


Figure A1-35 Animal Parasite Distribution – Pacific Ocean Basin

Sources:

Bartholomew et al. 2002

Service 2011

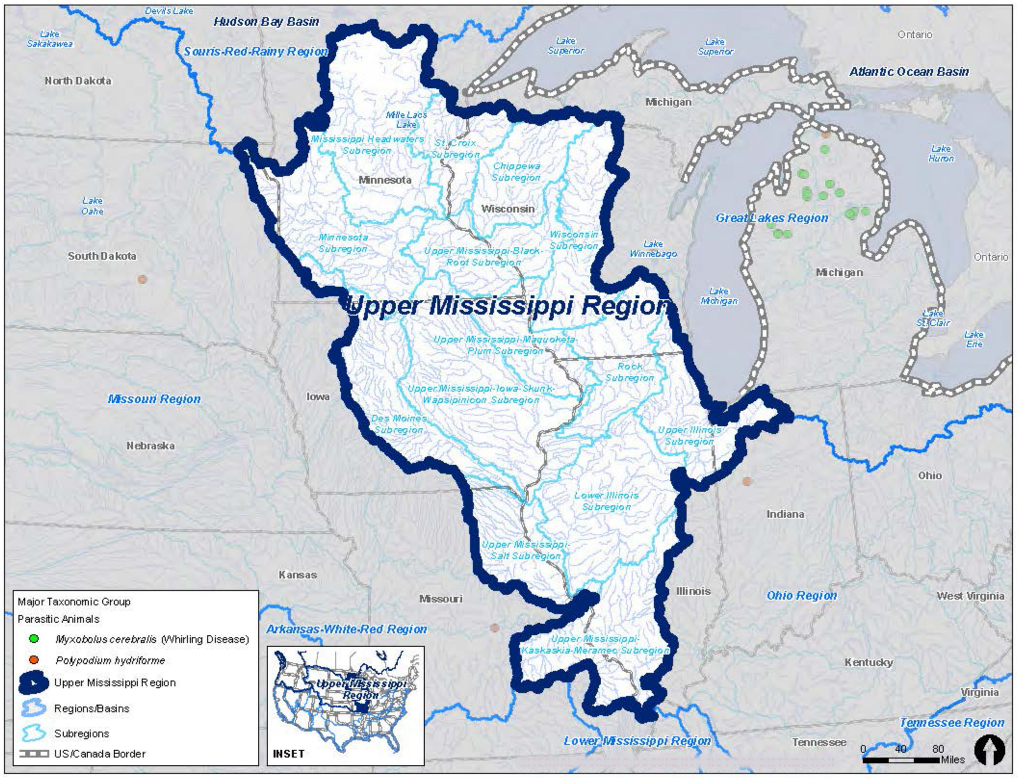


Figure A1-36 Animal Parasite Distribution – Upper Mississippi Region

Sources:
Bartholomew et al. 2002
Service 2011

References

Bartholomew, J.L. and P.W. Reno. 2002. The history and dissemination of whirling disease, pp. 3-24. In: *Whirling Disease: Reviews and Current Topics. American Fisheries Society Symposium 29.* (J.L. Bartholomew and J.C. Wilson, Eds.). Bethesda, MD: American Fisheries Society.

Bensley, M., T.A. Dick, C. Hudson, J.S. Lumsden, K.K. Peters, B.W. Souter, L. Vannest, D.B. Donald, and R. Nelson. 2011. Devils Lake – Red River Basin Fish Parasite and Pathogen Project Qualitative Risk Assessment October 2011.

Bowser, P.R. 2009. Fish Diseases: Viral Hemorrhagic Septicemia (VHS). Northeast Regional Aquaculture Center, USDA. University of Maryland, College Park, MD. NRAC Publication No. 201-2009. 7 pp.

Choudhury, A., and T.A. Dick. 1993. Parasites of the lake sturgeon , *Ascipenser fulvescens* Rafinesque, 1817 (Chondrostei: Ascipenseridae) from Central Canada. *Journal of Fish Biology* 42: 571-584.

ESRI. 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Garver, K.A., A.G. Dwilow, J. Richard, T.F. Booth, D.R. Beniac, and B.W. Souter. 2007. First detection and confirmation of spring viremia of carp virus in common carp, *Cyprinus carpio* L., from Hamilton Harbour, Lake Ontario, Canada. *Journal of Fish Diseases* 30: 665-671.

Hoffman, G.L., E.V. Raikova, and W.G. Yoder. 1974. *Polypodium* sp. (Colenterata) found in North American sturgeon. *Journal of Parasitology* 60:548–550.

Holloway, H.L., T.A. Dick, and C.A. Ottinger. 1991. *Polypodium hydriforme* (Coelenterata) in paddlefish from the Upper Mississippi River drainage. *Journal of Aquatic Animal Health* 3: 210-212.

Indiana Department of Natural Resources. Aquatic Invasive Species. 2005. Spring Viremia of Carp. Website (http://www.in.gov/dnr/files/SPRING_VIREMIA_OF_CARP.pdf) accessed March 22, 2012.

Iowa State University (ISU). 2007. Spring Viremia of Carp. The Center for Food Security & Public Health, College of Veterinary Medicine, Ames, IA, USA.

Iowa State University (ISU). 2010. Infectious Salmon Anemia. The Center for Food Security & Public Health and the Institute for International Cooperation in Animal Biologics, College of Veterinary Medicine, Ames, IA, USA.

Leighton, F.A. 2011. Wildlife pathogens and diseases in Canada. Canadian Biodiversity Ecosystem Status and Trends 2010. Technical Thematic Report No. 7. Canadian Councils of Resource Ministers. Ottawa, ON. iv + 53 p.

Midwest Pond and Koi Society. 2012. SVCV/KHV. Reprint from Ornamental Fish Health Newsletter 3:1 (T. Miller-Morgan, DVM). Website (http://www.mpks.org/articles/scvc_khv.html) accessed March 22, 2012.

MnDNR. 2011. Viral Hemorrhagic Septicemia. Website (http://www.dnr.state.mn.us/fish_diseases/vhs.html) accessed November 15, 2011.

Raikova, E.V., V.C. Suppes, and G.L. Hoffmann. 1979. The parasitic coelenterate, *Polypodium hydriforme* Ussov, from the eggs of the American acipenseriform *Polyodon spathula*. *Journal of Parasitology* 65:804–810.

Sepúlveda, M.S., T. Stefanavage, and R. Goforth. 2010. First record of a *Polypodium* sp. parasitizing eggs of shovelnose sturgeon from the Wabash River, Indiana. *Journal of Aquatic Animal Health* 22:36-38.

U.S. Fish and Wildlife Service (Service). 2011. Wild Fish Health Survey Database. Website (http://www.fws.gov/wildfishsurvey/) accessed December 7, 2011.

Tarrab, E., J. Heppell, L. Berthiaume, and J. Lecomte. 1996. Antigenic diversity of eastern Canadian isolates of infectious pancreatic necrosis virus. *Journal of Fish Diseases* 19: 23-31.

Thomas, M.V., and P.M. Muzzall. 2009. First record of *Polypodium hydriforme* (Cnidaria) from lake sturgeon (Acipenser fulvescens Rafinesque) in the St. Clair River, Michigan. *Journal of Applied Ichthyology* 25 (Suppl. 2): 107-108.

U.S. Department of Agriculture (USDA). 2004. Animal and Plant Health Inspection Service. Spring Viremia of Carp, United States July 20, 2004 Impact Worksheet.

USGS. 2012. Nonindigenous Aquatic Speces (NAS) Database. Website (http://nas.er.usgs.gov/) accessed June 4, 2012.

Whelan, G.E. 2009. Viral hemorrhagic septicemia (VHS) briefing paper. Michigan Department of Natural Resources. February 6, 2009.

Appendix F

Best Management Practices and Environmental Commitments

Appendix F
Best Management Practices and Environmental Commitments

Introduction

This appendix describes best management practices (Table F-1) and environmental commitments (Table F-2). The following definitions apply to best management practices and environmental commitments in this SEIS.

Best Management Practices - Methods intended to avoid or reduce effects while an action is being implemented. These methods are commonly implemented in projects of this nature.

Environmental Commitment - Methods or plans to reduce, offset, or eliminate adverse project effects. Action taken to avoid, reduce the severity of, or eliminate an adverse effect. Environmental commitments could include one or more of the following:

- Avoiding effects.
- Minimizing effects by limiting the degree or magnitude of an action.
- Rectifying effects by restoration, rehabilitation, or repair of the affected environment.
- Reducing or eliminating effects over time.
- Compensating for the effect by replacing or providing substitute resources or environments to offset the loss.

Implementation

The Bureau of Reclamation has entered into a cooperative agreement with the Garrison Diversion Conservancy District to construct the North Dakota State Municipal, Rural, and Industrial (MR&I) Program. Garrison Diversion has been authorized under state law as the organization to administer rural water projects for the Garrison Diversion Project (which includes the Project). Individual rural water organizations and the North Dakota State Water Commission, under agreements with Garrison Diversion, perform the direct design and construction activities. These agreements facilitate the best management practices included in this appendix. The cooperative agreement (R12AC60014) with Garrison Diversion ensures that all projects constructed under the agreement will be reviewed and approved by the Bureau of Reclamation and that they will ensure that all National Environmental Policy Act and National Historic Preservation Act requirements have been met, including application of these best management practices and environmental commitments.

Table F-1 Best Management Practices

Resource	Best Management Practices[1]
General	Construction activities would comply with all appropriate federal, state, and local laws and regulations. This list may include but is not limited to stormwater discharge permits, National Pollution Discharge Elimination System permits, Clean Water Act, and the Migratory Bird Treaty Act.
	Erosion control measures would be employed as appropriate and at stream crossings at all times: (a) Care would be exercised to preserve existing trees along the streambank. (b) Stabilization, erosion controls, restoration, and revegetation of all streambeds and embankments would be performed as soon as a stream crossing is completed and maintained until stable. (c) Riparian woody shrubs and trees would be replanted as necessary to preserve the shading characteristics of the watercourse and the aesthetic nature of the streambank. (d) At locations where soil conditions or slopes are such that erosion may occur along the pipeline trench, construction contractors would be required to construct earth berms perpendicular to the trench line at intervals sufficient to divert water from the trench. (e) In pasture and hayland, straw wattles shall be furnished and installed within 14 days of pipeline installation, at approximately the following intervals: Slope (%) — Interval (feet) 7-10 — 120 10+ — 50 (f) Straw wattles shall be a minimum of 6" diameter, and shall be installed across the entire width, plus 3' either side, of the disturbed area.
	Dump grounds, trash piles, and potential hazardous waste sites would be avoided.
	All construction waste materials and excess or unneeded fill associated with construction would be disposed of on uplands; non-wetland areas.
	Standard construction, industry measures would be taken to minimize fugitive dust emissions during construction activities. Any complaints that may arise would be dealt with by the project sponsor and contractor in a timely and effective manner.
	New pipeline, to the extent possible, would be placed just outside and parallel to the road right of way.
	To the extent possible, construction would avoid wetlands; federal, state, and local wildlife areas and refuges; designated critical habitats; migratory bird habitat during the critical nesting and brood-rearing season; known cultural resources and historic sites; hazardous material sites; and other resource sensitive areas noted below.
	During the final engineering design phase, Project components would be sited to minimize impacts on or avoid permanent structures and limit, to the extent practicable, impacts on existing land use.
	Construction limits would be clearly marked with stakes or fencing prior to beginning ground disturbing activities. No disturbance would occur beyond these limits other than non-destructive protection measures for erosion/sediment control.
	Material and equipment storage would be only within well-defined, designated staging areas placed outside of wetlands and other sensitive areas.
	Structures affected by pipeline construction, including utilities, roads, highways, rivers, canals, railroads, agricultural irrigation facilities, fences, and other structures, would be replaced, repaired, or restored to their current condition or better after construction.
	Construction debris would be hauled from the work site to a disposal location approved by

[1] If BMPs are changed after Final Engineering or during Project Construction then all changes to the BMPs would require the coordination and agreement of the Impact Mitigation Team.

Resource	Best Management Practices[1]
	the Contracting Officer or his/her representative.
	If established survey bench marks must be removed or should any monuments be dislodged or damaged during construction, the National Geodetic Survey (Attn: N/CG 162, Rockville, Maryland 20852) would be contacted.
	No above ground structures that would interfere with the above ground movement of floodwaters would be placed in the flood plain, or would be protected with flood protection.
Surface Water	Contractors would be required to make at least two boring attempts before using an alternate wetland, stream or river crossing method.
	Intermittent streams would be crossed only during low-flow periods and preferably when the streambeds are dry.
	Identified river or stream crossings would be performed by horizontal directional drilling operations whenever practicable, which would not disturb the stream channel or the adjacent wetlands.
Groundwater	Established ground water monitoring wells would be avoided. However, if any monitoring wells are inadvertently damaged or impacted during project construction, the Water Appropriation Division of the North Dakota Office of the State Engineer would be contacted.
Water Quality	As part of the National Pollution Discharge Elimination System permitting requirement, a Stormwater Pollution Prevention Plan would be developed and submitted to the ND Department of Health prior to commencing construction activities.
	The Stormwater Pollution Prevention Plan would include erosion control measures to prevent or reduce erosion, soil loss, and nonpoint source pollution. These practices may include, but are not limited to, silt fencing, filter fabric, sediment logs, hay bales, temporary sediment ponds, check dams, and/or immediate mulching of exposed areas to minimize sedimentation and turbidity effects as a result of construction activities. The placement and specific measures used would be dictated by site specific conditions.
	In-stream flows would be maintained during stream crossing construction. Spoil, debris piling, construction materials, and any other obstructions would be removed from stream crossings to preserve normal water flow.
	Stream crossings would be routed, as practicable, to minimize disturbance. Intermittent streams would be crossed only during low-flow periods and preferably when streambeds are dry.
	Disturbed portions of the stream banks and beds of rivers, streams, and other waterways would be protected by rock riprap of adequate size and type to minimize erosion and scour. Any slopes greater than 3:1 would be protected with erosion-control blankets after seeding.
Aquatics	In-stream flows would be maintained during stream crossing construction. Water would be allowed to flow around or past stream crossings to preserve normal water flow downstream from construction.
	To minimize impacts to fisheries resources any stream identified as a fishery (confer with ND Game and Fish Department) that cannot be directionally bored would be avoided from April 15 to June 1 and crossed later in the summer or fall when flows are low or the stream is dry.
	Avoid work in Class II or higher waters (fisheries – confirm with ND Game and Fish Department) April 15 – June 1, or directionally bore. (ND Century Code: CHAPTER 33-16-02.1 STANDARDS OF QUALITY FOR WATERS OF THE STATE)
	In consultation with the Service, the following screen and velocity recommendations would be incorporated into the design of intake structure(s) of the Project: 1) Intakes shall be screened and maintained with 1/4-inch or smaller mesh size opening. 2) Johnson intake screens shall have wire spacing 1/8 inch or smaller. 3) Intake velocities shall not exceed 1/2 foot per second with 20 feet of overhead water. 4) Intake velocities shall not exceed 1/4 foot per second where 20 feet of overhead water cannot be achieved.

<table>
<tr><th>Resource</th><th>Best Management Practices[1]</th></tr>
<tr><td></td><td>5) The intake shall be placed at a maximum practicable depth in relation to extreme, low water elevations experienced between 2003 and 2008.
6) Intakes shall be marked so they are observable during day and night hours, as appropriate.</td></tr>
<tr><td rowspan="4">Wetlands/Riparian Areas</td><td>Long- and short-term effects on wetlands and riparian areas would be avoided to the extent practicable and in compliance with Section 404 of the Clean Water Act</td></tr>
<tr><td>Erosion control measures would be employed as appropriate and at stream crossings prior to construction activities. In addition:
▪ Preserve, if feasible, existing trees along the stream bank.
▪ Stabilize, control erosion, restore, and revegetate streambeds and embankments as soon as a stream crossing is completed, following vegetation best management practices, and maintain until stable.
▪ Replant riparian, as necessary, woody shrubs and trees appropriate to ecological characteristics of the site to preserve shading characteristics of the watercourse and the aesthetic nature of the stream bank.</td></tr>
<tr><td>Any equipment used previously in a water body that is jurisdictional under the Clean Water Act or a water body designated as infested by the North Dakota Game and Fish Department would be disinfected to prevent the spread of invasive aquatic species.</td></tr>
<tr><td>All temporarily disturbed wetlands would be reestablished following construction by doing the following:
▪ Restore contours to previous elevations
▪ Compact trenches sufficiently to prevent drainage along the trench or via bottom seepage
▪ Salvage and replace topsoil
▪ Backfill in such a manner as to not drain wetland or stream
▪ Reestablish wetlands to similar type of wetland and wetland function</td></tr>
<tr><td rowspan="4">Vegetation and Land Use</td><td>To the extent practicable, construction would avoid:
▪ Wetlands
▪ Federal, state, and local wildlife areas and refuges
▪ Native prairie
However, if these areas are disturbed during pipeline construction, topsoil would be replaced and revegetation plans would be specifically designed for these areas to ensure reestablishment of a similar type and quality of native vegetation recommended by local National Resources Conservation Service (NRCS) office and approved by the landowner. Impacts to federal or state wildlife areas may require additional agency review.</td></tr>
<tr><td>Vegetated areas temporarily disturbed by construction (except cropland) would be revegetated with species appropriate to ecological conditions of the surrounding area, and in a manner that prevents erosion and noxious weed invasion. Revegetation would occur as soon as practicable after construction and would follow all pertinent local and state regulations. Temporary seeding may be required when areas remain disturbed for more than 30 days.</td></tr>
<tr><td>Woody species including those bordering wetlands, shelterbelts, riparian woodlands, woody draws, or woodland vegetation would be avoided to the extent practicable. For unavoidable impacts to woody habitats, credit for equal value or environmental equivalent:
(a) would be applied toward the impact and deducted from Reclamation's Mitigation Enhancement Ledger
or
(b) the Project sponsor may develop separate acceptable mitigation.</td></tr>
<tr><td>Prior to beginning construction through Conservation Reserve Program lands, program or private wetlands, the project sponsor would consult with:
(a) respective landowners, NRCS, and U.S. Department of Agriculture Farm Services Agency to ensure that landowner eligibility in farm subsidy programs (if applicable) would not be jeopardized by project actions and</td></tr>
</table>

Resource	Best Management Practices[1]
	(b) ensure that Swampbuster requirements would not be violated by construction activities
	Reclamation would complete and submit a Farmland Conversion Form (AD-1006) to the NRCS in compliance with the Farmland Protection Policy Act, if required.
	Topsoil would be removed and stockpiled separately from surface soils for reapplication following construction. In-stream flows would be maintained during stream crossing construction. Water would be allowed to flow around or past stream crossings to preserve normal water flow downstream from construction.
	Topsoil, soil amendments, fertilizers, and mulches would be reapplied selectively as appropriate, prior to revegetation during favorable plant establishment climate conditions to match site conditions and revegetation goals.
Wildlife	Identified potential habitat for federal or state threatened, endangered, and sensitive species would be avoided if feasible.
	Construction would be prohibited within 1/2 mile of designated piping plover or Interior least tern breeding areas during the breeding season (April 15 through August 31) when these species are present.
	If threatened or endangered species are identified and encountered during construction, all ground-disturbing activities in the immediate area would be stopped to consult with the U.S. Fish and Wildlife Service (Service) and determine appropriate steps to avoid affecting the species.
	Project is responsible for compliance with the Migratory Bird Treaty Act. Sites for project features would be selected to minimize potential for environmental impacts to nesting migratory birds. Construction around wildlife habitats would be timed to avoid migratory bird nesting and wildlife parturition dates. Avoid work around wetlands April 1 through July 15.
	Construction within 660 feet of visible nesting bald eagles or other raptors would be avoided from February through August.
	Project sponsor would coordinate with the Service's appropriate Refuges and Wetland Management Districts and provide the latest map version of project features to avoid impacts to Service lands, including wetland and grassland easements, national wildlife refuges, and waterfowl production areas (WPAs), allowing for identification of an avoidance route for the contractor. Any impacts to national wildlife refuges or WPAs would have to go through a refuge compatibility determination.
	Project power lines would be: (a) Buried (Service 2010a) to minimize electrocution hazards to raptors and minimize impacts to all birds, bats, and particularly benefit whooping cranes. Use *Suggested Practices for Avian Protection on Power Lines - The State of the Art in 2006*, Avian Power Line Interaction Committee, Edison Electric Institute, Raptor Research Foundation, Washington, D.C., or similar standards would be used. Available online at http://www.eei.org/ourissues/TheEnvironment/Land/Documents/AvianProtectionPlanGuidelines.pdf (see pages 31 through 42) ***or*** (b) Any new, aboveground power lines and an additional equal length of existing power lines in the same vicinity must be marked with visibility enhancement devices to benefit migrating whooping cranes as well as all migratory birds and bats. Construction within 660 feet of visible nesting bald eagles or other raptors would be avoided from February through August.
Noise and Vibration	Night construction would be avoided near residential and populated areas.
Visual Resources	As noted for vegetation, short-term disturbances associated with constructing facilities would be revegetated and/or landscaped.
	Existing topographic grades would be restored following pipeline excavation.
	Constructed facilities would be designed to blend with the architectural characteristics of

Resource	Best Management Practices[1]
	surrounding structures.
	Valve boxes would be left above grade in a cultivated field if agreeable to the landowner, or moved to the nearest fence or right-of-way. Valves would not be located adjacent to or in close proximity to a paved or graveled road and would be painted a neutral color that blends with the background, reduces visibility, and maintains the viewshed.
Historic Properties	Direct disturbance to historical properties would be avoided to the extent feasible.
	All known burials or cemeteries would be avoided to the extent possible. All such burials or cemeteries would be avoided to the extent possible. If a burial or cemetery cannot be avoided or is encountered during construction, Reclamation would comply with the Native American Graves Protection and Repatriation Act if graves are discovered on federal or trust lands or within reservation boundaries. Reclamation would comply with North Dakota Century Code 23-06-27: "Protection of Human Burial Sites, Human Remains, and Burial Goods" for graves on private or state-owned lands and the Section 106 programmatic agreement.
	If unrecorded cultural resources or traditional cultural properties are encountered during construction, all ground disturbance activity within the area would be stopped, Reclamation and appropriate authorities would be notified, and all applicable stipulations of the Section 106 programmatic agreement would be followed. Activities in the area would resume only when compliance has been completed.
	All appropriate cultural resource compliance activities would be completed in accordance with the Section 106 programmatic agreement.
Paleontological Resources	All previously recorded paleontological resources and paleontologically sensitive zones within the path of the alternative selected in the Record of Decision would be inspected in the field by a qualified paleontologist. Avoidance measures would be developed to avoid significant resources.
	Reclamation would consult with North Dakota Geological Survey to identify areas for paleontological survey where significant fossils are likely. Paleontological surveys would be completed prior to construction. Based upon survey data, Reclamation would consult with a qualified paleontologist about revising routes to avoid damaging significant fossil locations.
Hazardous Materials	A Hazardous Spill Plan or Spill Prevention, Control and Countermeasures Plan, whichever is appropriate, would be in place, stating what actions would be taken in the event of a spill, notification measures, and preventive measures to be implemented, such as the placement of refueling facilities, storage, and handling of hazardous materials.
	All equipment would be maintained in a clean and well-functioning operating condition to avoid or minimize contamination from automotive fluids.
	Before construction, a more detailed hazardous materials assessment in conformance with the scope and limitations of American Society for Testing Materials (ASTM) 1527-05: "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process" would be conducted to identify sites with soil and/or groundwater contamination not documented in readily ascertainable agency files (ASTM 2005).
	Any known solid waste disposal areas identified in the construction sites would be avoided or removed and properly disposed at a permitted solid waste disposal facility
	Equipment or vehicles would not be refueled within 100 feet of rivers, streams, or identified wetlands. If onsite fuel tanks are used, approved containment devices would be required.
	Identified evidence of hazardous materials, petroleum product spills, or other contamination would be avoided or excavated and properly disposed at a permitted waste disposal facility.
	If soil and/or groundwater contamination is encountered during construction, mitigation procedures would be implemented to minimize the risk to construction workers and to future operations.
Unique and Prime Farmland/ Agricultural Lands	To the extent feasible, construction activities on irrigated lands would be avoided during the growing season.
	Cropland disturbed by construction would be restored with topsoil to the depth, quality, grade, and relative density as the original surface as described for soils below. Pipelines

Resource	Best Management Practices[1]
	crossing agricultural fields would be backfilled and compacted to prevent settling when the field is irrigated.
	Long-term effects on prime and unique farmland would be avoided to the extent feasible. If avoidance is not possible, Reclamation would complete and submit a Farmland Conversion Form (AD-1006) to the NRCS in compliance with the Farmland Protection Policy Act for any long-term change in land use.

Table F-2 Environmental Commitments

Resource	Environmental Commitments
Surface Water	When pipeline construction through a stream or wetland basin is unavoidable, existing basin contours would be restored and trenches would be sufficiently compacted to prevent any drainage along the trench or through bottom seepage.
	Where open trench crossing of stream is required, the stream channel would be reestablished following pipe installation.
	Reclamation would develop an Adaptive Management Plan, in accordance with the Department of the Interior's policy guidance (Order 3270) and the report Adaptive Management, the U.S. Department of The Interior Technical Guide (Williams et al. 2007). The plan would be implemented to address Project uncertainty as identified in the SEIS in relation to water resources and potential impacts to the national wildlife refuges.
	Project construction would be coordinated with operation of the Snake Creek Pumping Plant, especially during the filling of Audubon Lake.
Water Quality	Reclamation would consult with the U.S. EPA, Project sponsor, and other stakeholders as appropriate to develop an adaptive management plan to identify the appropriate level of water quality monitoring necessary to ensure that treatment processes included at the Biota WTP would not result in any violations of the Safe Drinking Water Act. The plan would be developed in accordance with the U.S. Department of the Interior Policy guidance (Order 3270) and the report Adaptive Management, the U.S. Department of the Interior Technical Guide (Williams et al. 2007).
Vegetation and Wetlands	Where construction cannot avoid: ▪ Wetlands ▪ Federal, state, and local wildlife areas and refuges, and ▪ Native prairie. If these areas are disturbed during pipeline construction, topsoil would be replaced and revegetation plans would be specifically designed for these areas to ensure reestablishment of a similar type and quality of native vegetation recommended by local NRCS office and approved by the landowner.
	Effects on jurisdictional wetlands and waters of the United States would require authorization from the U.S. Army Corps of Engineers. A compensatory mitigation plan may be required for the loss of any wetlands and would include methods to replace specific functions of affected wetlands.
	Lost wetlands would be replaced acre for acre with ecological equivalency or 1/2 acre for acre with ecological equivalency (adversely affected wetlands) as required by the Project's authorizing legislation: (a) by crediting previously completed wetland restoration for the Garrison Diversion Unit (GDU) and deducting those credits from Reclamation's Mitigation and Enhancement Ledger (MEL)[2]

2 Reclamation has credits for created and restored wetlands in the MEL that can be used to mitigate impacts to wetlands. The GDU MEL was developed according to the 1985 memorandum of understanding between Reclamation, the U.S. Fish and Wildlife Service (Service), and the North Dakota Game and Fish Department regarding the establishment of mitigation and enhancement debits and credits for wildlife purposes. The MEL documents GDU project impacts, mitigation requirements, and

Resource	Environmental Commitments
	or (b) the Project sponsor may develop separate acceptable mitigation.
	Lost woodlands would be mitigated 2:1 (acres) in accordance with MEL[2]
	Lost grasslands would be mitigated acre for acre in accordance with MEL[2]
Wildlife	Pipelines, water treatment plants, and pump station facilities would be realigned, where feasible, to avoid sensitive wildlife habitat. If sensitive wildlife habitat cannot be avoided then mitigation would be determined in coordination and agreement with the Impact Mitigation Team including pertinent regulatory agencies.
	Preconstruction surveys with the Impact Mitigation Team would identify sensitive habitats and wildlife use before construction to allow implementing best management practices and mitigation measures.
Invasive Species/Biota Transfer	Reclamation would consult with the U.S. EPA and other stakeholders as appropriate to develop an adaptive management plan to assess control system efficacy and make modifications to the control system if the risk changes significantly. The plan would be developed in accordance with the U.S. Department of the Interior Policy guidance (Order 3270) and the report Adaptive Management, the U.S. Department of the Interior Technical Guide (Williams et al. 2007).
Historic Properties	Reclamation will continue complying with stipulations in *Programmatic Agreement Between the Bureau of Reclamation, The Advisory Council on Historic Preservation, and the North Dakota State Historic Preservation Officer for the Implementation of Reclamation Undertakings in North Dakota* for the life of the project and in consultation with tribes.
	Avoidance will be the preferred method for treating historic properties. However, should that not be possible, the programmatic agreement identifies the standards to be used in developing mitigation plans.
	Reclamation will consult under Section 106 of the National Historic Preservation Act with appropriate Indian Tribes regarding the locations of and potential impacts to properties of traditional religious and cultural importance. If any such properties cannot be avoided and must be mitigated, Reclamation will invite the appropriate Tribes to participate in development of an appropriate treatment plan.
	All gravel, fill, and rock materials will be obtained from a source approved by Reclamation to ensure compliance with Section 106 of the National Historic Preservation Act.

concurrence for planning purposes and for review by other agencies and the public. Projected impacts listed were first presented in the GDU Commission Report. The GDU Reformulation Act of 1986 resulted in the adjustment of the projected impacts to reflect modifications to the project. Impacts to date reflect modifications to the project.

Appendix G
Biological Resources

Northwest Area Water Supply Project
Supplemental Environmental Impact Statement

APPENDIX G1

Scientific Names of Species Mentioned in SEIS

Table G1-1 Scientific Names of Aquatic Invasive Species Mentioned in the SEIS

Taxonomic Group		Scientific Name	Common Name of Species or Disease/Condition
Virus		*Aquabirnavirus spp.*	Infectious pancreatic necrosis virus
		Family Rhabdoviridae	Infectious hematopoietic necrosis virus
		Novirhabdovirus spp.	Viral hemorrhagic septicemia
		Ictalurid Herpesvirus 1	Channel catfish virus
		Rhabdovirus carpio	Spring viremia of carp virus
		Isavirus spp.	Infectious salmon anemia virus
Bacteria		*Renibacterium salmoninarum*	Bacterial kidney disease
		Aeromonas salmonicida	Furunculosis
		Streptococcus faecalis	Strep
		Flavobacterium columnare	Columnaris disease
		Pseudomonas aeruginosa	Pseudomonas aeruginosa
		Vibrio cholera	Cholera
		Edwardsiella spp.	Edwardsiella spp. infections
		Mycobacterium spp.	Mycobacterium spp. infections
		Yersinia ruckeri	Enteric redmouth disease
		Escherichia coli	E. coli
		Legionella spp.	Legionnaire's disease
		Salmonella spp.	Salmonella
Animalia	Mollusks	*Dreissena polymorpha*	Zebra mussel
		Dreissena rostriformis bugensis	Quagga mussel
		Potamopyrgus antipodarum	New Zealand mudsnail
	Parasites	*Polypodium hydriforme*	Polypodium
		Myxobolus cerebralis	Whirling disease
		Actheres pimelodi	Actheres pimelodi (parasitic copepod)
		Ergasilus spp.	Ergasilus spp.(parasitic copepod)
		Icelanonchohaptor microcotyle	Icelanonchohaptor microcotyle (parasitic flatworm)
		Corallotaenia minutia	Corallotaenia minutia (parasitic tapeworm)
Protozoa		*Giardia lamblia*	Giardia (backpacker's diarrhea)
		Entamoeba histolytica	Entamoeba histolytica
		Cryptosporidium parvum	Cryptosporidium
		Ichthyophthirius multifillis	Ich or white spot disease
		Ichthyophonus hoferi	Ichthyophonosis

Taxonomic Group	Scientific Name	Common Name of Species or Disease/Condition
Fungi	*Branchiomyces spp.*	Branchiomycosis
	Saprolegnia spp.	Saprolegniosis or winter fungus disease
	Exophiala spp.	Black yeast
	Phoma herbarum	Phoma herbarum
Cyanobacteria	*Anabaena flos-aquae*	Anabaena flos-aquae (blue-green algae)
	Microcystis aeruginosa	Microcystis aeruginosa (blue-green algae)
	Aphanizomenon flos-aquae	Aphanizomenon flos-aquae (blue-green algae)

Notes:
NA – not applicable

Table G1-2 Scientific Names of Non-game Birds not included in Appendix G2

Scientific Name	Common Name
Passer domesticus	House sparrow
Sturnus vulgaris	European starling

Table G1-3 Scientific Names of Invertebrate Species Mentioned in the SEIS

Scientific Name	Common Name
Carcinus maenas	Green crab
Corbula amurensis	Overbite clam
Physa winnipegensis	Lake Winnipeg physa snail
Quadrula quadrula	Mapleleaf mussel

Table G1-4 Scientific Names of Fish Species Mentioned in the SEIS

Scientific Name	Common Name
Acipenser fulvescens	Lake sturgeon
Ambloplites rupestris	Rock bass
Ameiurus melas	Black bullhead
Ameiurus nebulosus	Brown bullhead
Aplodinotus grunniens	Freshwater drum
Carpiodes carpio	River carpsucker
Catastomus commersoni	White sucker
Coregonus clupeaformis	Lake whitefish
Coregonus zenithicus	Shortjaw cisco

Scientific Name	Common Name
Cyeleptus elongatus	Blue sucker
Cyprinus carpio	Common carp
Dorosoma cepedianum	American gizzard shad
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
Hiodon alosoides	Goldeye
Ictalurus punctatus	Channel catfish
Lepomis cyanellus	Green sunfish
Lepomis macrochirus	Bluegill
Lota lota	Burbot
Macrhybopsis gelida	Sicklefin chub
Macrhybopsis meeki	Sturgeon chub
Margariscus margarita	Pearl dace
Micropterus dolomieu	Smallmouth bass
Micropterus salmoides	Largemouth bass
Morone chrysops	White bass
Neogobius melanostomus	Round goby
Notropis atherinoides	Emerald shiner
Onchorhynchus kisutch	Coho salmon
Oncorhynchus mykiss	Rainbow trout
Onchorhynchus nerka	Sockeye salmon
Oncorhynchus tshawytscha	Chinook salmon
Osmerus mordax	Rainbow smelt
Perca flavescens	Yellow perch
Pimephales promelas	Fathead minnow
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Prosopium williamsoni	Mountain whitefish
Rhinichthys atratulus	Blacknose dace
Rhinichthys osculus	Speckled dace
Salmo salar	Atlantic salmon
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
Salvelinus namaycush	Lake trout
Sander canadensis	Sauger
Sander vitreus	Walleye

Scientific Name	Common Name
Scaphirhynchus albus	Pallid sturgeon
Scaphirhynchus platorynchus	Shovelnose sturgeon

Table G1-5 Scientific Names of Plant Species Mentioned in the SEIS

Scientific Name	Common Name
Acer negundo	Boxelder maple
Achillea millefolium	Yarrow
Agropyron desertorum, A. cristatum, and A. desertorum x cristatum	Crested wheatgrass
Amelanchier alnifolia	Serviceberry
Amorpha canescens	Lead plant
Andropogon gerardii	Big bluestem
Andropogon hallii	Sand bluestem
Anemone patens	Pasque flower
Artemisia frigida	Fringed sage
Artemisia spp.	Sagebrush
Artemisia tridentata	Big sagebrush
Astragalus missouriensis	Missouri milkvetch
Betula papyrifera	Paper birch
Bouteloua curtipendula	Sideoats grama
Bouteloua curtipendula	Side-oats grama
Bouteloua gracilis	Blue grama
Bromus inermis	Smooth brome
Calamovilfa longifolia	Prairie sandreed
Calamovilfa longifolia.	Prairie sandreed
Campanula rotundifolia	Harebell
Carex inops ssp. heliophila	Sun sedge
Centaurea spp.	Knapweeds
Chrysopsis villosa	Golden aster
Cornus sericea	Redosier dogwood
Corylus cornuta	Beaked hazelnut
Dalea purpureum	Purple prairie-clover
Dasiphora fruticosa ssp. floribunda	Shrubby cinquefoil
Echinacea angustifolia	Purple coneflower
Elaeagnus commutata	Silverberry

Scientific Name	Common Name
Elymus trachycaulus	Slender wheatgrass
Fraxinus pennsylvanicus	Green ash
Gaura coccinea	Gaura
Grindelia squarrosa	Gumweed
Hesperostipa comata	Needle and thread
Hesperostipa spartea	porcupinegrass
Juniperus horizontalis	Horizontal rug juniper
Juniperus monosperma	One-seed juniper
Juniperus scopulorum	Rocky Mountain juniper
Koeleria macrantha	Prairie junegrass
Nassella viridula	Green needlegrass
Nassella viridula	Green needlegrass
Oxytropis lambertii	Purple loco
Panicum virgatum	Switchgrass
Pascopyrum smithii	Western wheatgrass
Pascopyrum smithii	Western wheatgrass
Phalaris arundinacea	Reed canary grass
Populus balsamifera	Balsam poplar
Populus deltoides	Eastern cottonwood
Populus tremuloides	Aspen
Prunus virginiana	Chokecherry
Psathyrostachys juncea	Russian wild rye
Quercus macrocarpa	Bur oak
Rhus trilobata	Skunkbush sumac
Rhus trilobata	Three leaf sumac
Rosa arkansana	Prairie rose
Salix sp.	Willow
Schizachyrium scoparium	Little bluestem
Schizachyrium scoparium	Little bluestem
Sheperdia argentea	Silver buffaloberry
Solidago spp.	Goldenrod
Sorghastrum nutans	Indiangrass
Sporobolus heterolepis	Prairie dropseed
Symphoricarpos spp	Snowberry
Thinopyrum intermedium	Intermediate wheatgrass

APPENDIX G2

Fish and Wildlife Resources

Table G2-6a Spawning and Habitat Requirements of Freshwater Fish of Commercial or Recreational Value in the Project Area

Common Name	Habitat	Spawning Period	Spawning Habitat
Black Bullhead	Ponds, small lakes, river backwaters, swamps, impoundments, small stream pools with warm and turbid water, muddy bottoms, slow currents, and few other fish species. Adults inactive in schools in aquatic vegetation during day.	Spring and Summer	Eggs are laid in shallow nest made by female on bottom in mud or sand, in secluded areas such as under logs or mats of aquatic vegetation; adults fan water over eggs.
Brown Bullhead	Ponds, lakes, sluggish streams, sloughs, backwaters, reservoirs. Usually in vegetated shallows over sand, rock, mud, or silt, in clear to turbid water. May burrow into soft bottom and become inactive in winter.	Late Spring and Summer	Eggs are laid in open excavation in sand, gravel, or (rarely) mud, often in shelter of logs, rocks, or vegetation; in holes, burrows, or debris. Nest made by one or both sexes usually around shore or in coves or creek mouths.
Freshwater Drum	Prefers large silty lakes and medium to large rivers but occurs in a variety of habitats. Prefers open water over mud bottom.	Spring and Summer	Spawns pelagically in open water, usually far from shore; eggs float at surface
Shortjaw Cisco	Deep water of large lakes.	Variable	Spawning has been observed at depths of 18-73 meters (m) over sand or clay bottoms.
Blue Sucker	Largest rivers and lower parts of major tributaries. Usually in channels and flowing pools with moderate current. Some impoundments. Adults winter in deep pools, young in shallower and slower water.	Spring	Migrates upstream to spawn on riffles
Northern Pike	Clear small lakes, shallow vegetated areas of larger lakes, marshes, creeks, and small to large rivers. Moves to deeper cooler water in summer. Generally does not do well with low or widely fluctuating water levels.	Early Spring	Shallow flooded marshes associated with lakes or with inlet streams to those lakes (or flooded terrestrial vegetation at reservoir edge); basically a flooded area with emergent vegetation (optimally over short grasses or sedges). Young remain here for several weeks after hatching.
Muskellunge	Warm, heavily vegetated lakes, stumpy weedy bays, pools and backwaters of creeks and small to large rivers with abundant vegetation; often in large lakes with both extensive deep and shallow basins and tributary streams.	Spring	Water less than 1 m deep in heavily vegetated flooded areas. Eggs sink and stick to bottom or vegetation.
Channel Catfish	Main channels of small to large rivers; clear, rapidly flowing, firm-bottomed ones to turbid, mud-bottomed ones; avoids upland streams; also in ponds, reservoirs, lakes. Adults often in pools, under log jams or cut banks by day, move into riffles at night.	Late Spring and Summer	Eggs are laid in cave-like sites, such as old muskrat burrows, undercut banks, or log jams, or debris (e.g., barrels). In streams, YOY live fulltime in riffles
Green Sunfish	Sluggish warm streams, ponds, and shallow weedy margins of lakes. Often in vicinity of weed beds and both clear and turbid water. Characteristic of and one of	Spring and Summer	Eggs are deposited in a single or colonial nest made by the male, often on fine gravel or sandy silt near cover in shallow water 4-355 cm deep

Common Name	Habitat	Spawning Period	Spawning Habitat
	the last survivors in, residual pools in intermittent streams in Great Plains region.		
Bluegill	Warm shallow lakes, reservoirs, ponds, swamps, sloughs, and slow-flowing rivers and streams. Often associated with rooted aquatic plants and bottoms of silt, sand, or gravel. Seldom go deeper than 5 m.	Extended Spring and Summer	Eggs are laid in nests made in shallow water by males, on bottoms of gravel, sand, or mud that contain pieces of debris.
Smallmouth Bass	Large clear lakes and clear midorder streams with many large pools, abundant cover (rocks, shelves, logs, etc.), and cool summer temperatures. Adults seek shelter of pools or deep water during day.	Late Spring and Early Summer	Shallow water in lakes, quiet areas of streams, often fairly close to shore. Lake populations may move a short distance upstream to spawn. Females deposit eggs in nests made by males, often near cover on gravel or sand bottoms. Individual males may nest close to last year's nest site.
Largemouth Bass	Warm, quiet waters with low turbidity, soft bottoms, and beds of aquatic plants. Typical habitats include farm ponds, swamps, lakes, reservoirs, sloughs, creek pools, and river coves and backwaters. Many of the largest populations are in mesotrophic to eutrophic lakes or reservoirs. In lakes and reservoirs these fishes are usually close to shore.	Spring and Early Summer	Eggs are laid in shallow cleared depressions (nests) made by males in sand, gravel, or debris-littered bottoms, often at depths of 40-80 inches (1-2 m) but up to at least 23 feet (7 m) or as shallow as 8-12 inches (about 20-30 cm). Nests are often next to submerged objects and usually are more than 30 feet (9 m) apart.
White Bass	Open waters of large lakes and reservoirs and pools of slow-moving small to large rivers. This species usually occurs in surface waters, roaming in schools. It tends to be offshore during the day, inshore at night. It generally avoids areas of continuous turbidity.	Spring	Running water of tributary streams appear to be preferred, but this fish may also spawn along lake shores with high wave action. Spawning substrate is often rock or gravel bottoms in water 0.6-3 meters deep; eggs sink and stick; individuals generally return to specific spawning areas.
Rainbow Trout	Small headwater streams, large rivers, lakes, or reservoirs; often in cool clear lakes and cool swift streams with silt-free substrate. In streams, deep low velocity pools are important wintering habitats.	Spring (February-June)	Usually require a gravel stream riffle for successful spawning. Lake populations move to tributaries to spawn. Eggs are laid in gravel in a depression made by the female.
Chinook Salmon	NA[a]	Fall	Eggs are deposited in gravel bottoms of large streams and rivers.
Yellow Perch	Clear weedy backwaters or pools of creeks and small to large rivers, shallow waters of lakes, and large ponds. Often associated with heavy growths of aquatic plants in lakes.	Late Winter/ Spring	Spawning occurs over submerged beds of aquatic plants or brush, or over sand, gravel, or rubble, in quiet water
White Crappie	Most abundant in sand- and mud-bottomed pools and backwaters of warm turbid creeks, small to large rivers, lakes, and reservoirs. During day, tends to congregate around submerged logs or boulders in quiet water 2-4 m deep, or in dimly lit profundal	Spring and Early Summer	Eggs are laid in an ill-defined nest made by the male on the bottom in water usually less than 1.5 m deep. Nest often is near or in beds of vegetation or plant debris (including flooded terrestrial vegetation),

Common Name	Habitat	Spawning Period	Spawning Habitat
	zone of reservoir. May move into open water in evening and early morning. Shallow littoral zone is occupied by young and by foraging adults.		sometimes under or near overhanging bushes or banks.
Black Crappie	Most abundant in large, warm, clear lakes and reservoirs and clear river backwaters; usually associated with large beds of aquatic plants and sandy to mucky bottoms. Usually in localized schools near submerged objects during day.	Spring and Summer	Eggs are laid in a nest made by the male in bottoms ranging from mud to gravel, usually in water less than 1 m deep near or in beds of aquatic plants.
Brown Trout	Mostly in cold, medium to high gradient streams, but lake-run populations also exist. Tends to occupy deeper, lower velocity, and warmer waters than other species of trout. Some migratory populations spend first 2 years in river, 1-2 years in lake, then return to river to spawn at 3-4 years.	Fall and Early Winter	Waters ranging from large streams to small spring- fed tributaries; in shallow gravelly headwaters, rocky lake margins, or sometimes over sand or hard clay if no gravel available. Spawns in natal stream. Fry occupy quiet waters along shorelines or in shelter of objects that deflect flows
Brook Trout	Clear, cool, well-oxygenated creeks, small to medium rivers, and lakes. Individuals may move from streams into lakes to avoid high temperatures in summer. Populations (known as "coasters") live in lakes and migrate to streams to spawn, or remain in the lake to spawn. Preferred water temperature is around 14-16°^{C}; they do poorly where water temperature exceeds 20°^{C} for extended periods.	Late Summer and Fall (Oct-Nov)	Cool water (usually less than 15°^{C}) often over gravel beds in shallow headwaters but also may occur in gravelly shallows of lakes if spring (groundwater) upwelling and moderate current or nearby surficial inflow are present.
Lake Trout	Usually in deep water, especially in summer when surface waters warm. Prefers temperatures below 13°^{C}. Rarely in lakes with pH less than 5.2.	Fall	Boulder or rubble bottom in shallower part of lake (less than 12 m in inland lakes, less than 37 m in Great Lakes). Eggs fall into crevices between rocks. Sometimes spawn in rivers.
Sauger	Sand and gravel runs, sandy and muddy pools and backwaters, of small to large rivers; less often in lakes and impoundments. Typical in large, cool or warm, often turbid, slow-flowing rivers.	Spring (late-June)	In lakes, spawns along sandy and rocky shores and over rocky reefs at depths of 0.6-3.6 m. In rivers, spawns in deep rocky runs. May leave lake to spawn upstream in river.
Walleye	Lakes, pools, backwaters, and runs of medium to large rivers; generally in moderately deep waters. Avoids bright light. Generally in quiet water when not spawning. Often in beds of aquatic vegetation, in holes among tree roots, or in or near similar cover by day. A pH of 8-9 is most suitable. Adults avoid temperatures above 24°^{C}, if possible. Greatest population densities under moderately turbid conditions or in deep clear lakes with strong deepwater forage base.	Spring and Early Summer	Turbulent rocky areas in rivers, boulder to coarse gravel shoals of lakes, along riprap on dam face of reservoirs, and flooded marshes. Eggs are broadcast and abandoned, adhesive but may drift great distances. Larvae initially are pelagic, soon become bottom dwellers. Adults tend to return to formerly used spawning (and feeding) areas.

(a) Notes:
(b) [a] NA: Landlocked habitat not well known
(c) Source: NatureServe 2012

Table G2-6b Common Fish Expected to be Present in Souris River Watershed

Common Name	Scientific Name
Black bullhead	*Ameiurus melas*
Blacknose dace	*Rhinichthys atratulus*
Blackside darter	*Percina maculata*
Bluegill	*Lepomis macrochirus*
Brassy minnow	*Hybognathus hankinsoni*
Brook stickleback	*Gasterosteus*
Central mudminnow	*Umbra limi*
Common shiner	*Luxilus cornutus*
Creek chub	*Semotilus atromaculatus*
Fathead minnow	*Pimephales promelas*
Golden shiner	*Notemigonus crysoleucas*
Iowa darter	*Etheostoma exile*
Johnny darter	*Etheostoma nigrum*
Largemouth bass	*Micropterus salmoides*
Longnose dace	*Rhinichthys catarактae*
Northern pike	*Esox lucius*
Pearl dace	*Margariscus margarita*
Sand shiner	*Notropis stramineus*
Smallmouth bass	*Micropterus dolomieu*
Spottail shiner	*Notropis hudsonius*
Tadpole madtom	*Noturus gyrinus*
Trout perch	*Percopsis omiscomaycus*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersoni*
Yellow perch	*Perca flavescens*

Notes: Some of these species are also of recreational value

Source: Gangl, pers. comm., 2013

Table G2-7 GFD Level I Species of Conservation Priority and USFWS Birds of Conservation Concern

Common Name	Scientific Name	GFD Level I Species of Conservation Priority	USFWS BCC BCR 11	USFWS BCC Region 6	Present in Project Area
American bittern	Botaurus lentiginosus	X	X	X	X
American white pelican	Pelecanus erythrorhynchos	X			X
Baird's sparrow	Ammodramus bairdii	X	X	X	X
Bald eagle (b)	Haliaeetus leucocephalus		X	X	
Bell's vireo (c)	Vireo bellii			X	
Bewick's wren	Thryomanes bewickii			X	
Black rail	Laterallus jamaicensis			X	
Black rosy-finch	Leucosticte atrata			X	
Black tern	Chlidonias niger	X	X		X
Black-billed cuckoo	Coccyzus erythropthalmus	X	X	X	X
Black-tailed prairie dog	Cynomys ludovicianus	X			
Brown-capped rosy-finch	Leucosticte australis			X	
Buff-breasted sandpiper (nb)	Tryngites subruficollis		X	X	X
Burrowing owl	Athene cunicularia			X	X
Canadian toad	Bufo hemiophrys	X			X
Cassin's finch	Carpodacus cassinii			X	
Chestnut-collared longspur	Calcarius ornatus	X	X	X	X
Dickcissel	Spiza americana		X		X
Ferruginous hawk	Buteo regalis	X		X	X
Flammulated owl	Otus flammeolus			X	
Franklin's gull	Larus pipixcan	X	X		X
Golden eagle	Aquila chrysaetos			X	X
Grasshopper sparrow	Ammodramus savannarum	X	X	X	X
Gray vireo	Vireo vicinior			X	
Gunnison sage-grouse	Centrocercus minimus			X	
Henslow's sparrow	Ammodramus henslowii			X	
Horned grebe	Podiceps auritus	X	X	X	X

Common Name	Scientific Name	GFD Level I Species of Conservation Priority	USFWS BCC BCR 11	USFWS BCC Region 6	Present in Project Area
Hudsonian godwit (nb)	Limosa haemastica		X	X	
Lark bunting	Calamospiza melanocorys	X			X
Least bittern	Ixobrychus exilis		X	X	
Lesser prairie-chicken (a)	Tympanuchus pallidicinctus			X	
Lewis's woodpecker	Melanerpes lewis			X	
Loggerhead shrike	Lanius ludovicianus			X	X
Long-billed curlew	Numenius americanus	X	X	X	
Marbled godwit	Limosa fedoa	X	X	X	X
McCown's longspur	Rhynchophanes mccownii		X	X	X
Mountain plover	Charadrius montanus		X	X	
Nelson's sharp-tailed sparrow	Ammodramus nelsonii	X	X	X	X
Pearl dace	*Margariscus margarita*	X			X
Peregrine falcon (b)	Falco peregrinus		X	X	
Pinyon jay	Gymnorhinus cyanocephalus			X	
Plains spadefoot toad	Spea bombifrons	X			X
Prairie falcon	Falco mexicanus			X	X
Red-headed woodpecker	Melanerpes erythrocephalus		X	X	X
Sage sparrow	Amphispiza belli			X	
Sage thrasher	Oreoscoptes montanus			X	
Short-billed dowitcher (nb)	Limnodromus griseus		X	X	
Short-eared owl	Asio flammeus		X	X	X
Sicklefin chub	*Macrhybopsis meeki*	X			
Smith's longspur (nb)	Calcarius pictus		X	X	X
Smooth green snake	Liochlorophis vernalis	X			X
Snowy plover (c)	Charadrius alexandrinus			X	

Common Name	Scientific Name	GFD Level I Species of Conservation Priority	USFWS BCC BCR 11	USFWS BCC Region 6	Present in Project Area
Solitary sandpiper (nb)	Tringa solitaria		X		X
Sprague's pipit[a]	Anthus spragueii	X	X	X	X
Sturgeon chub	*Macrhybopsis gelida*	X			
Swainson's hawk	Buteo swainsoni	X	X		X
Upland sandpiper	Bartramia longicauda	X	X	X	X
Western hognose snake	Heterodon nasicus	X			X
Willet	Catoptrophorus semipalmatus	X			X
Willow flycatcher (c)	Empidonax traillii			X	X
Wilson's phalarope	Phalaropus tricolor	X			X
Yellow rail	Coturnicops noveboracensis	X	X	X	X

Notes:

[a] Sprague's pipit is addressed in Section: Federally Protected Species.

(a) ESA candidate
(b) ESA delisted
(c) non-listed subspecies or population of Threatened or Endangered species,
(d) (nb) non-breeding in this BCR.

Table G2-8 Common Terrestrial Wildlife Resources within the Project Area

Sporting Status and Species	Occurrence in Project Area	Habitat Association
Big Game Animals		
Elk (*Cervus canadensis*)	Two populations of elk occupy western North Dakota, both outside of the Project Area.	Found over a range of habitats. Uses open areas, such as alpine pastures, marshy meadows, river flats, and aspen parkland, as well as coniferous forests, brushy clear cuts or forest edges, and semi-desert areas.
Moose (*Alces alces*)	Burke, Renville, Bottineau, Mountrail, Ward, McHenry, and Pierce counties	Moose typically inhabit boreal and mixed deciduous forests in temperate to subarctic climates. Primary moose range in North Dakota is in the northeastern counties of the Project Area.
Mountain lion (*Puma concolor*)	Primary range is outside of the Project Area, but also occasionally found elsewhere, throughout North Dakota.	Main habitat requirement for mountain lions is stalking cover to successfully hunt prey. Stalking cover can be in the form of trees, brush or rugged topography. There is a stable mountain lion population in western North Dakota, where there is a limited hunting season.
Mule deer (*Odocoileus hemionus*)	Primary and secondary range is outside of Project Area. Mule deer are found in the remainder of the state, but in very low numbers.	Found in coniferous forests, desert shrub, chaparral, grasslands with shrubs, and badlands. Often associated with successional vegetation, especially near agricultural lands. Generally more common southwest of the proposed Project Area.
Pronghorn [antelope] (*Antilocapra americana*)	Primarily distributed across western North Dakota, although small numbers do exist east of the Missouri River.	Found in grasslands, sagebrush plains, deserts, and foothills. Need for free water varies with succulence of vegetation in the diet. More common southwest of the proposed Project Area.
White-tailed deer (*Odocoileus virginianus*)	Common throughout North Dakota.	Found statewide in various habitat types—from forest to fields—with adjacent cover. In the badlands, they are most often found in river bottoms.
Small and Medium Game Animals and Furbearers		
American badger (*Taxidea taxus*)	Found throughout North Dakota, but are most abundant on the prairies.	Prefers open grasslands and fields, and may also frequent shrublands with little groundcover. When inactive, occupies underground burrows.
American beaver (*Castor canadensis*)	Found in all counties in Project Area.	Inhabits permanent sources of water of almost any type in its range, which extends from arctic North America to the Gulf of Mexico and arid Southwest, and from sea level to over 6,800 feet in mountains. Prefers low-gradient streams, which it modifies, ponds, and small mud-bottomed lakes with outlets that can be dammed. Associated with deciduous tree and shrub communities. Beavers are common in

Sporting Status and Species	Occurrence in Project Area	Habitat Association
		North Dakota waterways and have a year-round open harvest season.
Coyote (*Canis latrans*)	Found in all counties in Project Area.	Wide ranging and found in virtually all habitats from open prairies in west to heavily forested regions in northeast. Den in burrow or at base of tree under branches, in hollow log or rock crevice, reuses den site. Often considered a pest, especially by the livestock industry. Control programs have been largely ineffective.
Eastern cottontail (*Sylvilagus floridanus*)	Found throughout North Dakota.	Found in brushy areas, open woodlands, swampy areas, stream valleys, grasslands, and suburbs. Very adaptable species. Nests usually are in shallow depressions, in thick vegetation or in underground burrows.
Fox squirrel (*Sciurus niger*)	Found throughout North Dakota.	Found in open mixed hardwood forests or mixed pine-hardwood associations; species also has adapted well to disturbed areas, hedgerows, and city parks. Prefers savanna or open woodlands to dense forests. Dens are in tree hollows or leaf nests.
Long-tailed weasel *(Mustela frenata*)	Found throughout North Dakota.	Uses variety of habitats as available including open forests and woodlands, farmlands, grassy fields and meadows, riparian grasslands and woodlands, swamps and marshes, hedgerows, prairies and sometimes residential areas. Young born in abandoned burrows, rests in nests in abandoned burrows, rock crevice, brush pile, stump hollow or among tree roots or holes in walls, or under out buildings.
Mink (*Mustela vision*)	Found in all counties in Project Area.	Prefers forested, permanent or semipermanent wetlands with abundant cover, marshes, and riparian zones. Dens in muskrat burrow, abandoned beaver den, hollow log, hole under tree roots or in stream bank burrows.
Muskrat (*Ondatra zibethicus*)	Found throughout North Dakota, but are most common east of the Missouri River.	Muskrats live in wetlands, ponds, lakes, streams and backwaters. Prefers fresh or brackish marshes, lakes, ponds, swamps, and other bodies of slow-moving water, most abundant in areas with cattail. They either build huts made of plant material or dig burrows into banks.
North American porcupine (*Erethizon dorsatum*)	Found in all counties in Project Area.	Prefers coniferous and mixed forests, also uses riparian zones, grasslands, shrublands, and deserts in some parts of range. Winter dens in rock outcrops, hollow trees, hollow logs or outbuildings, may shelter in dense conifers in winter.
Raccoon (*Procyon lotor*)	Found throughout North Dakota.	Found in variety of habitats usually with moisture, often along streams and shorelines; prefers riparian and edges of wetlands, ponds, streams, and lakes. Dens under logs or rocks, in tree hole, ground burrow, or in bank den.
Red fox (*Vulpes vulpes*)	Primary range includes Burke, Renville,	Found in open and semi-open habitats. Usually avoids dense forest, although open

Sporting Status and Species	Occurrence in Project Area	Habitat Association
	Bottineau, Mountrail, Ward, McHenry, Pierce and McLean counties.	woodlands are frequently used. Sometimes occurs in suburban areas or cities. Maternity dens are in burrows dug by fox or abandoned by other mammals, often in open fields or wooded areas; sometimes under rural buildings, in hollow logs, or under stumps.
Striped skunk (*Mephitis mephitis*)	Found in all counties in Project Area.	Prefers semi-open country with woodland and meadows interspersed with brushy areas, and bottomland woods. Frequently found in suburban areas. Dens often under rocks, logs, or buildings. May excavate burrow or use burrow abandoned by other mammals.
White-tailed jackrabbit (*Lepus townsendii*)	Found throughout North Dakota.	Found in sage-grasslands, open areas, woodlots and riparian areas. Nests in depression in ground or burrows abandoned by other animals. During day usually in shallow depressions at base of bush or in or near cavity in snow.
Game Birds - Upland		
Gray/Hungarian partridge (*Perdix perdix*)	Divide, Williams, Mountrail, Ward, and McLean counties.	Non-native game bird; found in cultivated lands with marginal cover of bushes, undergrowth or hedgerows. Hungarian partridge will tunnel into the snow to gain protection from wind and a buffer from the bitter cold.
Mourning dove (*Zenaida macroura*)	Found throughout North Dakota.	Found in open woodlands, forest edge, cultivated lands with scattered trees and bushes, parks and suburban areas, and arid and desert country. Usually nests in tree or shrub, may also use stumps, rocks, buildings, or ground.
Ring-necked pheasant (*Phasianus colchicus*)	Found in all counties in Project Area.	Found in open country (especially cultivated areas, scrubby wastes, open woodland, and edges of woods), grassy steppe, desert oases, riverside thickets, swamps, and open mountain forest. Winter shelter includes bushes and trees along streams, shelterbelts, and fencerows. Usually nests in fields, brushy edges, or pastures; also along road rights-of-way. Nest is shallow depression.
Ruffed grouse (*Bonasa umbellus*)	Bottineau County within Turtle Mountains only.	Inhabits mixed and deciduous woodlands.
Sandhill crane (*Grus canadensis*)	Many parts of the state, but the best areas are Mountrail, Renville, Bottineau, Ward, McHenry, Pierce and McLean counties.	During migration, roosts at night along river channels, on alluvial islands of braided rivers, or natural basin wetlands. Communal roost site consisting of an open expanse of shallow water is key feature of wintering habitat. Sandhill cranes are found all over the state.
Sharp-tailed grouse (*Tympanuchus phasianellus*)	Primary range is found within Divide, Williams, Mountrail, Ward, McHenry and	Requires a mosaic of dense grass and shrubs with rich forb and insect foods during nesting, relies on riparian areas during winter, also uses cultivated grains

Sporting Status and Species	Occurrence in Project Area	Habitat Association
	McLean counties.	and hedgerows.
Wild turkey (*Meleagris gallopavo*)	Primary range includes Williams Mountrail, and McLean counties. Secondary range includes all other counties except Divide County.	Found in forests and open woodland, scrub oak, deciduous or mixed deciduous-coniferous forests, also agricultural areas. Roosts in trees at night and nests on ground, usually in open areas at the edge of woods. Widely hunted.
Wilson's snipe (*Gallinago gallinago*)	Found throughout North Dakota.	Nests in wet grassy or marshy areas, non-breeding in wet meadows, flooded fields, bogs, swamps, marshy banks of rivers and lakes.
Game Birds - Waterfowl		
Dark Geese		
Canada goose (Branta canadensis) White-fronted goose *(Anser albifrons*)	Found in all counties in Project Area.	Found in various habitats near water, from temperate regions to tundra. Usually breeds and feeds in areas near lakes, ponds, large streams, and inland and coastal marshes. Forages in pastures, cultivated lands, grasslands, and flooded fields. Widely hunted.
Light Geese		
Ross's goose (*Chen rossii*) Snow/Blue goose (*Chen caerulescens*)	Common migrants to eastern part of North Dakota.	Found in various habitats near water, from temperate regions to tundra. Winters in both freshwater and coastal wetlands, wet prairies, and extensive sandbars; forages in pastures, cultivated lands, and flooded fields. Migrate and winter in the proposed Project Area. Widely hunted.
Dabbling Ducks		
Black duck (*Anas rubripes*) Blue-winged teal (*Anas discors*) Baldpate/ American wigeon (*Anas americana*)	Common migrants and summer residents throughout North Dakota.	Primarily found in shallow waters, such as ponds, lakes, marshes, and flooded fields; in migration and in winter, mostly found in fresh water and cultivated fields, less commonly in brackish situations. Widely hunted.
Gadwall *(Anas strepera)* Green-winged teal (*Anas crecca*)	Common migrants and summer residents throughout North Dakota.	Primarily found in shallow waters, such as ponds, lakes, marshes, and flooded fields; in migration and in winter, mostly found in fresh water and cultivated fields, less commonly in brackish situations. Widely hunted.

Sporting Status and Species	Occurrence in Project Area	Habitat Association
Mallard (*Anas platyrhynchos*) Northern shoveler (*Anas clypeata*) Northern pintail (*Anas acuta*)		
Diving Ducks		
Canvasback (*Aythya valisineria*) Redhead (*Aythya americana*) Ring-necked duck (*Aythya collaris*) Ruddy duck (*Oxyura jamaicensis*) Scaup duck (*Aythya* spp.)	Occasional to common migrants and summer residents throughout North Dakota.	Commonly found on marshes, ponds, lakes, rivers, and bays. Widely hunted.
Non-Game Waterbirds		
American/Common merganser (*Mergus merganser*) American coot (*Fulica americanan*) Red breasted merganser (*Mergus serrator*)	Common migrants and summer residents.	Commonly found on marshes, ponds, lakes, rivers, and bays. Widely hunted.
Non-Game Animals		
Mammals		
Big brown bat (*Eptesicus fuscus*)	Found in all counties in Project Area.	Roosts during the day in hollow trees, beneath loose tree bark, in the crevices of rocks or in man-made structures such as attics, barns, old buildings, eaves and window shutters.
Hoary bat (*Lasiurus cinereus*)	Found in all counties in Project Area.	Prefers woodland, mainly coniferous forests, but hunts over open areas or lakes. Normally roosts alone on trees, hidden among foliage, but on occasion has been seen in caves with other bats.
Little brown bat (*Myotis lucifugus*)	Found throughout North Dakota.	Found using human-made structures for resting and maternity roosts, also uses

Sporting Status and Species	Occurrence in Project Area	Habitat Association
		caves and hollow trees. Forages in woodlands near water, requires caves, tunnels, abandoned mines in winter.
Masked Shrew (*Sorex Cinereus*)	Found throughout North Dakota.	Found in most terrestrial habitats, except areas with little or no vegetation, thick leaf litter in damp forests may be favored habitat. Nests in shallow burrows or in logs and stumps.
Meadow vole (*Microtus pennsylvanicus*)	Found in all counties in Project Area.	Found in lush, dense vegetation along edges of sloughs, streams, or rivers. They are sometimes found in drier habitats given sufficient cover is available.
Red bat (*Lasiurus boreali*)	Found in all counties in Project Area.	Often roost amongst live or dead leaves on the branches of live hardwood trees.
Silver-haired bat (*Lasionycteris noctivagans*)	Found in all counties in Project Area.	Found in forested areas in trees cavities and spaces under loose bark but may also use buildings.
Southern red-backed vole (*Clethrionomys gapperi*)	Found in all counties in Project Area.	Found in coniferous, deciduous, and mixed forests, often near wetlands. They use runways through the surface growth in warm weather and tunnel through the snow in winter.
Thirteen-lined ground squirrel (*Spermophilus tridecemlineatu*)	Found in all counties in Project Area.	Prefers well-drained soils for digging burrows and can be found in pasture land, along roadsides, golf courses, and the edges of farm fields.
White-footed mouse (*Peromyscus leucopus*)	Found in all counties in Project Area.	Prefers woodland edges, brushy fields, riparian zones. Nests underground, under debris, in buildings, in logs or stumps, tree cavities, old squirrel or bird nests.
Birds		
American avocet (*Recurvirostra americana*)	Found in all counties in Project Area.	Breeding habitat is marshes, beaches, prairie ponds, and shallow lakes, and shallow fresh and saltwater wetlands.
American crow (*Corvus brachyrhynchos*)	Found in all counties in Project Area.	Found in open and partly open country, agricultural lands, suburban areas. Nests in open forests and woodlands
American goldfinch (*Carduelis tristis*)	Found throughout North Dakota.	Found in woodlands and brushland, including wooded areas of high moraines, buttes, river bluffs, stream valleys, and lake margins, and brushy thickets on the prairie. Also present in partially wooded residential areas of towns and farmsteads, and shelterbelts.
American kestrel (*Falco sparverius*)	Found in all counties in Project Area.	Favors open areas with short ground vegetation and sparse trees. Found in meadows, grasslands, deserts, parks, farm fields, cities, and suburbs.

Sporting Status and Species	Occurrence in Project Area	Habitat Association
Belted kingfisher (*Ceryle alcyon*)	Found in all counties in Project Area.	Breeds along streams, rivers, lakes, and estuaries with banks for nest holes. Winters along coast, streams, and lakes.
Burrowing owl (*Athene cunicularia*)	Found in prairie habitats in North Dakota.	Found in prairie grass habitats, closely associated with prairie dog towns. Nest in underground burrows.
Eared grebe (*Podiceps nigricollis*)	Found in all counties in Project Area.	Inhabits shallow lakes and ponds with vegetation and macroinvertebrate communities, rarely on ponds with fish. Prefers saline habitats at all seasons, allowing escape from fish predators with an abundance of invertebrates as prey.
Golden eagle (*Aquila chrysaetos*)	Mainly found in western North Dakota, outside of the Project Area.	Found throughout the badlands and along the upper reaches of the Missouri River in western North Dakota. Often seen perching on ledges and rocky outcroppings or soaring effortlessly over hillsides in search of prey.
Great blue heron (*Ardea herodias*)	Found in all counties in Project Area.	Found in freshwater and brackish marshes, along lakes, rivers, fields, meadows. Nests in high trees in swamps and forested areas, often with other herons close to foraging habitat.
Great horned owl (*Bubo virginianus*)	Found in all counties in Project Area.	Found in various forested habitats, moist or arid, deciduous or evergreen lowland forests to open woodlands, swamps, riverine forests. Nests in trees, tree cavities, stumps, rocky ledges, barns. Year-round resident throughout proposed Project Area.
House sparrow (*Passer domesticus*)	Found in all counties in Project Area.	Closely associated with people and buildings. Found in cities, towns, suburbs, and farms (particularly around livestock).
Lark bunting (*Calamospiza melanocorys*)	Found within grasslands throughout Project Area.	Utilize short-grass and mixed-grass grass communities as well as fallow fields, roadsides, and hayfields. Nests under protective vegetation.
Prairie falcon (*Falco mexicanus*)	Found throughout Project Area from March through October.	Found in native prairie and cropland that includes badlands, cliffs, and isolated buttes in western North Dakota. Most nesting pairs of prairie falcons are found west of the Missouri River and concentrated along the Little Missouri River Valley and adjoining prairie. Prefers to nest on ledges of cliffs with small holes, caves, or crevices.
Red-tailed hawk (*Buteo jamaicensis*)	Found in all counties in Project Area.	Found in wide variety of open woodland and open country with scattered trees, nests in forests, elevated perches are important habitat component. Often reuses nest trees.
Short-eared owl (*Asio flammeus*)	Found in all counties in Project Area.	Found in open country, including prairie, meadows, tundra, moorlands, marshes, savanna, and open woodland.

Sporting Status and Species	Occurrence in Project Area	Habitat Association
Tundra swan (*Cygnus columbianus*)	Found in all counties in Project Area.	Generally found in lakes, sloughs, rivers, and sometimes fields during migration. Open marshy lakes and ponds, and sluggish streams in summer.
Turkey vulture (*Cathartes aura*)	Found in all counties in Project Area.	Prefer landscapes with a mixture of open and wooded areas, but can be found almost anywhere including along coastlines, in deserts, throughout plains, and even in inland tropical forests.
Western meadowlark (*Sturnella neglecta*)	Found in all counties in Project Area.	Grasslands, open fields, pastures, cultivated lands, sometimes marshes. Nests on ground in vegetation. Primarily feed on insects, grains seeds.
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*)	Found in all counties in Project Area.	Found in wetlands and in surrounding grasslands and croplands. Breeds in prairie wetlands and along other western lakes and marshes where tall reeds and rushes are present. In winter large flocks forage in agricultural areas.
Amphibians		
Bufonid toads (Woodhouse's toad, Great Plains toad, Canadian toad) (*Bufo* spp.)	Found in all counties in Project Area.	Found in variety of lowland habitats, deserts, prairie grasslands, pastures, woodlands. Reproduction dependent on rain pools, flooded areas, ponds in shallow water. Adults feed primarily on invertebrates. Hibernates during winter months and during summer dry spells, burrows underground when inactive.
Plains spadefoot toad (*Scaphiopus bombifrons*)	Found in all counties in Project Area except Pierce County.	Inhabit the dry grasslands of western North Dakota which have sandy or loose soil. Their back feet have a digging spur (spade) which they use to burrow into the soil.
Ranid frogs (northern leopard frog, wood frog) (*Rana* spp.)	Found throughout North Dakota.	Found in variety of aquatic and wetland habitats. Adults feed primarily on invertebrates. Hibernates during winter months, burrows in benthic sediments, generally underwater.
Tiger salamander (*Ambystoma tigrinum*)	Found throughout North Dakota.	Found in almost any damp place; debris near water, damp cellars, and even small mammal burrows, and are often seen at night after a heavy rainfall. This is even more true during the breeding season.
Western chorus frog (*Pseudacris triseriata*)	Found throughout North Dakota.	Found mostly in permanent freshwater areas, such as marshes, river swamps, meadows, grassy pools and other open areas found in mountains and prairies. Less commonly found in fallowed agricultural fields, damp woodlands, roadside ditches and wooded swamps.
Reptiles		
Bullsnake (*Pituophis catenifer*)	Found in Williams and Mountrail	Found in grasslands, meadows, or fields.

Sporting Status and Species	Occurrence in Project Area	Habitat Association
	counties and possibly in Divide County.	
Common snapping turtle (*Chelydra serpentine*)	Found throughout North Dakota.	Prefer warm water with a muddy bottom and plenty of aquatic vegetation. They are often found on the margins of ponds buried in the mud of the warm shallows with only their eyes and nostrils exposed.
Garter snakes (*Thamnophis* spp.)	Found throughout North Dakota.	Commonly inhabit the edges of woodlands, meadows, wetlands, and areas around housing developments.
Prairie rattlesnake (*Crotalus viridis*)	Probable range includes Williams, Mountrail, and McLean counties.	Found in a wide variety of habitats; forests, prairies, riparian habitats often associated with rocky outcroppings. In the hot summer months they take shelter from the heat by finding a shaded area or rocky outcrops. In the winter these snakes will hibernate together in prairie dog burrows or rocky crevices.
Racer (*Coluber constrictor*)	Found in the Williams and Mclean counties and possibly in Divide, Burke, Mountrail, Ward, and Renville counties.	Inhabit the sagebrush prairies of western North Dakota and are commonly found near a source of water.
Redbelly snake (*Storeria occipitomaculata*)	Found in Bottineau and McHenry counties and probably also in Pierce County.	Found in or around woodlands, and prefer the margins of woodlands for foraging. They hide during the day under stones, boards, rotten logs, or other forest cover and come out toward evening. Seldom seen due to their small size, shyness, and nocturnal habits.
Short horned lizard (*Phrynosoma douglassi*)	Found in Williams County and possibly Divide County.	Found in a wide range of habitats including shortgrass prairies, sagebrush deserts and juniper, pine or fir forests.
Smooth green snake (*Opheodrys vernalis*)	Found Williams, Burke, and Ward counties and probably also in Divide, Renville, Bottineau, Mountrail, McHenry, Peirce and McLean counties.	Found in many different habitats, including marshes, meadows, the edges of streams, and open woods. Prefer to be on the ground, in opens areas without a lot of shrubs. Hibernates in burrows, ant hills, and other dug-out underground areas
Western hognose snake (*Heterdon nasicus*)	Found in Bottineau, McHenry, and Pierce counties probably in Divide, Williams, Burke, Renville, and McLean counties.	Prefer sandy, graveled areas that occur in grassland, prairie and mixed forest habitats. Hognose snakes have been collected throughout the state. Most of the specimens have been found in north central, southwest, and southeast North Dakota.
Western painted turtle (*Chrysemys picta belli*)	Found throughout North Dakota.	Found in slow-moving fresh waters. Active only during the day when basking for hours on logs or rocks. Hibernates during winter usually in the muddy bottoms of waterways.

Sporting Status and Species	Occurrence in Project Area	Habitat Association
Insects		
Butterflies (e.g., skippers, swallowtails, whites and sulphurs, gossamer and winged butterflies, brush-footed butterflies)	Found in all counties in Project Area.	Found in various habitats dependent upon species, from deciduous and evergreen-deciduous woods to open habitats including fields, meadows, weedy areas, marshes, and roadsides.
Dot-tailed whiteface dragonfly (*Leucorrhinia intacta*)	Found in Bottineau, McHenry, Burke, and Mountrail counties.	Inhabits ponds, lakes and slow-moving streams.
Plains forktail damselfly (*Ischnura damula*)	Found in Divide, Burke, and McHenry counties.	Found in ponds with dense vegetation.
Tiger beetle (*Cicindela hirticollis*)	Found in Williams and McLean counties.	Found on sandy beaches of oceans, lakes, rivers and streams.

Sources: Abbott 2007; Cornell University 2011; Dyke 2011; Hoback and Riggins 2001; NDGFD 2010, 2011a, 2011b; North Dakota Parks and Recreation Department 2012; Paseka 2010; Royer 2004; USGS 2006

Appendix H
Socioeconomic Resources

Northwest Area Water Supply Project
Supplemental Environmental Impact Statement

Table of Contents

Tables

Table H-1 Employment by Industry and Unemployment Rate in 2011 .... H-2
Table H-2 Income Characteristics in 2011 .... H-4
Table H-3 Agricultural Characteristics in 2007 .... H-5
Table H-4 Property Tax Levy and Assessment Valuation in 2010 .... H-6
Table H-5 Potential Property Tax Losses on Agricultural Land H-6

Appendix H
Socioeconomic Resources

Introduction

This appendix contains information used to help focus the analysis included in the Socioeconomic Resources sections of Chapters 3 and 4 of the Supplemental Environmental Impact Statement (SEIS). While this information is important to the analysis, it is beyond that necessary to present in the main body of the SEIS. It is therefore included as an appendix and may provide useful context to some SEIS reviewers.

Table H-1 Employment by Industry and Unemployment Rate in 2011

Employment Sectors	Bottineau	Burke	Divide	McHenry	McLean	Mountrail	Pierce	Renville	Ward	Williams	Total Project Area	State of North Dakota	U.S.
Agriculture, forestry, fishing and hunting, and mining	558 (18.5%)	335 (32.7%)	345 (30.7%)	424 (16.3%)	960 (21.5%)	703 (18.0%)	344 (16.2%)	338 (25.8%)	1,424 (4.7%)	2,807 (22.7%)	8,238 (13.2%)	30,941 (8.6%)	2,669,572 (1.9%)
Construction	211 (7.0%)	41 (4.0%)	69 (6.1%)	230 (8.8%)	340 (7.6%)	213 (5.5%)	186 (8.8%)	62 (4.7%)	2,746 (9.0%)	829 (6.7%)	4,927 (7.9%)	25,235 (7.0%)	9,642,450 (6.8%)
Manufacturing	103 (3.4%)	31 (3.0%)	21 (1.9%)	150 (5.8%)	120 (2.7%)	201 (5.1%)	173 (8.2%)	73 (5.6%)	1,212 (4.0%)	328 (2.7%)	2,412 (3.9%)	26,441 (7.4%)	15,281,307 (10.8%)
Wholesale trade	39 (1.3%)	23 (2.2%)	10 (0.9%)	145 (5.6%)	105 (2.4%)	149 (3.8%)	52 (2.5%)	50 (3.8%)	1,179 (3.9%)	661 (5.3%)	2,413 (3.9%)	11,681 (3.3%)	4,158,689 (2.9%)
Retail trade	360 (11.9%)	63 (6.2%)	94 (8.4%)	214 (8.2%)	450 (10.1%)	369 (9.4%)	220 (10.4%)	129 (9.8%)	4,551 (14.9%)	1,177 (9.5%)	7,627 (12.2%)	43,396 (12.1%)	16,336,915 (11.5%)
Transportation and warehousing, and utilities	128 (4.2%)	89 (8.7%)	42 (3.7%)	318 (12.2%)	365 (8.2%)	172 (4.4%)	134 (6.3%)	46 (3.5%)	1,404 (4.6%)	785 (6.3%)	3,483 (5.6%)	19,176 (5.4%)	7,171,438 (5.1%)
Information	20 (0.7%)	5 (0.5%)	12 (1.1%)	23 (0.9%)	41 (0.9%)	127 (3.2%)	24 (1.1%)	12 (0.9%)	602 (2.0%)	124 (1.0%)	990 (1.6%)	6,000 (1.7%)	3,256,311 (2.3%)
Finance and insurance, and real estate and rental and leasing	207 (6.9%)	52 (5.1%)	40 (3.6%)	108 (4.2%)	194 (4.3%)	130 (3.3%)	54 (2.5%)	48 (3.7%)	1,853 (6.1%)	561 (4.5%)	3,247 (5.2%)	21,387 (6.0%)	9,738,275 (6.9%)
Professional, scientific, and management, and administrative and waste management services	181 (6.0%)	54 (5.3%)	36 (3.2%)	146 (5.6%)	168 (3.8%)	97 (2.5%)	137 (6.5%)	112 (8.5%)	1,991 (6.5%)	545 (4.4%)	3,467 (5.5%)	23,553 (6.6%)	14,942,494 (10.5%)

Employment Sectors	Bottineau	Burke	Divide	McHenry	McLean	Mountrail	Pierce	Renville	Ward	Williams	Total Project Area	State of North Dakota	U.S.
Educational services, and health care and social assistance	706 (23.4%)	157 (15.3%)	192 (17.1%)	519 (19.9%)	1,130 (25.3%)	793 (20.3%)	442 (20.8%)	233 (17.8%)	7,301 (23.9%)	2,623 (21.2%)	14,096 (22.5%)	88,132 (24.6%)	31,927,759 (22.5%)
Arts, entertainment, and recreation, and accommodation and food services	165 (5.5%)	33 (3.2%)	99 (8.8%)	88 (3.4%)	203 (4.5%)	472 (12.1%)	143 (6.7%)	68 (5.2%)	2,868 (9.4%)	868 (7.0%)	5,007 (8.0%)	28,267 (7.9%)	12,779,583 (9.0%)
Other services, except public administration	99 (3.3%)	39 (3.8%)	39 (3.5%)	103 (4.0%)	199 (4.5%)	93 (2.4%)	148 (7.0%)	46 (3.5%)	1,565 (5.1%)	567 (4.6%)	2,898 (4.6%)	16,399 (4.6%)	6,960,820 (4.9%)
Public administration	243 (8.0%)	101 (9.9%)	124 (11.0%)	134 (5.1%)	187 (4.2%)	389 (10.0%)	64 (3.0%)	94 (7.2%)	1,878 6.1%)	491 (4.0%)	3,705 (5.9%)	17,498 (4.9%)	6,966,886 (4.9%)
Unemployment Rate													
Unemployed	113 (2.1%)	8 (0.5%)	6 (0.3%)	101 (2.3%)	125 (1.7%)	155 (2.6%)	34 (0.9%)	22 (1.1%)	910 (1.9%)	174 (1.0%)	1,648 (1.7%)	12,772 (2.4%)	13,488,016 (5.6%)
Total employed, all sectors	**3,020**	**1,023**	**1,123**	**2,602**	**4,462**	**3,908**	**2,121**	**1,311**	**30,574**	**12,366**	**62,510**	**358,106**	**141,832,499**

Source: U.S. Census Bureau 2013

Table H-2 Income Characteristics in 2011

County	Median Household Income	Mean Household Income	Per Capita Income
Bottineau	$44,399	$61,165	$28,573
Burke	$54,402	$69,843	$34,630
Divide	$47,545	$65,964	$29,512
McHenry	$41,989	$52,655	$24,398
McLean	$52,996	$62,752	$27,945
Mountrail	$56,593	$72,008	$28,998
Pierce	$40,139	$48,152	$22,011
Renville	$50,093	$64,470	$28,704
Ward	$51,081	$63,185	$26,026
Williams	$62,082	$75,804	$31,822
State of North Dakota	$49,415	$64,106	$27,305
United States	$52,762	$72,555	$27,915

Source: U.S. Census Bureau 2013

Table H-3 Agricultural Characteristics in 2007

Item	Bottineau	Burke	Divide	McHenry	McLean	Moun-trail	Pierce	Renville	Ward	Williams	Total Project Area	State of North Dakota
Farm Summary												
Total number of farms	899	463	503	928	1,001	659	530	370	946	857	7,156	31,970
Average size of farm (acres)	1,144	1,232	1,408	1,167	1,162	1,573	1,097	1,498	1,127	1,336	1,274	1,241
Irrigated land acreage	(D)[a]	-	2,289	8,650	6,748	(D)[a]	(D)[a]	-	770	16,539	34,996	236,138
Market Value ($)												
Crops, including nursery and greenhouse crops ($1,000s)	$158,991	$55,256	$73,992	$90,288	$145,847	$92,746	$58,702	$103,034	$153,487	$115,992	$1,048,335	$5,038,521
Livestock, poultry, and their products ($1,000s)	$8,890	$6,331	$6,935	$43,672	$17,593	$15,256	$14,012	$3,237	$14,110	$11,340	$141,376	$1,045,697
Market value of agricultural products sold ($1,000s)	$167,882	$61,587	$80,927	$133,960	$163,440	$108,002	$72,713	$106,271	$167,597	$127,333	$1,189,712	$6,084,218
Selected Livestock												
Number of cattle and calves sold	9,830	9,136	9,380	46,728	21,549	21,585	14,699	3,500	17,670	15,793	169,870	1,109,460
Crops Harvested												
Acreage of corn for grain harvested	3,521	999	1,941	28,884	29,246	2,551	20,808	1,830	9,136	2,116	101,032	2,348,171
Acreage of wheat for grain harvested	312,075	178,866	244,180	175,265	381,004	291,590	130,934	196,707	390,347	379,685	2,680,653	8,428,462

Notes:

[a] (D) indicates data withheld to avoid disclosing data for individual farms.

Source: USDA 2007 (The Census of Agriculture is released every 5 years, and 2007 is the most current available as of July 2013).

Table H-4 Property Tax Levy and Assessment Valuation in 2010

County	Taxable Value ($)	Ad Valorem Taxes ($)	Average Mill Rate[a]
Bottineau	$36,678,940	$9,059,668	$0.247
Burke	$10,802,212	$2,332,258	$0.216
Divide	$12,180,268	$2,766,682	$0.227
McHenry	$26,266,546	$6,468,961	$0.246
McLean	$37,700,013	$8,458,517	$0.224
Mountrail	$35,874,867	$8,042,897	$0.224
Pierce	$17,660,939	$5,083,143	$0.288
Renville	$13,013,142	$3,055,986	$0.235
Ward	$183,953,530	$54,907,979	$0.298
Williams	$68,683,052	$18,729,492	$0.273
Total Project Area	$442,813,509	$118,905,583	$0.248
State of North Dakota	$2,289,117,930	$721,988,441	$0.315

Notes:

[a] The average mill rate is applied per $1,000 of assessed property value.

Source: North Dakota Office of State Tax Commissioner 2010

Table H-5 Potential Property Tax Losses on Agricultural Land

County	Average Mill Rate[a]	Cultivated Cropland				Hay/Pasture			
		Permanent Effects on Cultivated Cropland (Acres)	2012 Average Value per Acre ($)	Total Value Lost Cropland ($)	Foregone Property Taxes ($)	Permanent Effects on Hay/Pasture (Acres)	2012 Average Value per Acre ($)	Total Value Lost Hay/Pasture ($)	Foregone Property Taxes ($)
McLean	$0.224	8.8	$1,124	$9,891	$2.20	0.0	$526	$0.00	$0.00
Ward	$0.298	49.4	$1,060	$52,364	$15.60	0.2	$469	$93.80	$0.03

Notes:

[a] The average mill rate is applied per $1,000 of assessed property value.

Sources: North Dakota Office of State Tax Commissioner 2013, USDA 2012

APPENDIX I
Other Minor Issues

Appendix I
Other Minor Issues

Introduction

The Northwest Area Water Supply Project (Project) Supplemental Environmental Impact Statement (SEIS) provides an in-depth analysis of issues determined to be of concern through internal and external scoping. NEPA regulations call for identifying, at an early state in the NEPA process, the significant environmental issues deserving of detailed study and deemphasizing insignificant issues, narrowing the scope of the EIS analysis (40 CFR 1501.1(d)). During the initial stages of preparing this SEIS, Reclamation conducted preliminary analyses on several issues that were not identified during public scoping (i.e., aesthetics, air quality, earth resources, noise, public services and utilities, and transportation); as well as a preliminary analysis on greenhouse gas emissions (GHG) generated by the proposed action, which was identified during public scoping. The Project would not result in significant impacts on these resources for the reasons discussed below, and they are not considered further in the SEIS. The following analyses focus on the potential impacts of constructing, operating, and maintaining new Project components. Best Management Practices (BMPs) that would be implemented to minimize potential impacts were considered in the following discussion. A detailed list of these BMPs is included in Appendix F. They include compliance of construction activities with all appropriate federal, state, and local laws and regulations.

Aesthetics

Aesthetics is considered a minor issue since visual changes from new components would be temporary or the new components would be visually compatible with the character of their surroundings or located underground and therefore not visible. The pipeline corridors would avoid most population centers and would be routed primarily along highways, roads, and railroads, where existing aboveground transmission lines and other utilities are in view. New pipelines would be buried, and disturbed areas would be revegetated. In particular, riparian, and as necessary, woody shrubs and trees appropriate to the ecological characteristics of sites near watercourses would be replanted to preserve the shading characteristics of the watercourse and the aesthetic nature of the stream bank. Existing topographic grades would also be restored following pipeline excavation; thus, visual qualities of the pipeline corridor would be restored after construction was completed. Meters would be installed in underground vaults, as would smaller booster pump stations, and some reservoirs may be partially buried. Disturbed areas would be revegetated as noted above. Valve boxes would be left above grade in a cultivated field if agreeable to the landowner, or moved to the nearest fence or right-of-way. Valves would not be located adjacent or in close proximity to a paved or graveled road and would be painted a neutral color that blends with the background. These measures would reduce the visibility of the valves and maintain the viewshed.

The aesthetic environment in the vicinity of Project aboveground structures (such as water treatment plants, recharge facilities, intakes, storage reservoirs, and some pump stations) is characterized by rural areas, fringes of small towns, and the developed area within the City of Minot. The Minot Water Treatment Plant (WTP) is an existing facility; its expansion would take place within the current site boundaries and would be consistent with the existing development. Recharge facilities and associated infrastructure would be located in existing wellfields and would be visually compatible with the existing facilities. Storage reservoirs and facilities such as pump stations are common features in rural areas, and their presence would not degrade the visual qualities of the surrounding area. The new Biota WTP would be located on the outskirts of Max in an agricultural area, adjacent to railroad tracks and a rail storage yard and near large grain elevators, and thus would be visually compatible with nearby development. All disturbed areas associated with Project facilities would revegetated and/or landscaped, and constructed facilities would be designed to blend with the architectural characteristics of surrounding structures. Implementing the BMPs included in Appendix F would minimize any potential impacts.

Air Quality

Air pollutants may be emitted from fossil fuel-burning equipment operated during construction. Routes requiring the minimum amount of pipeline construction have been selected. Additionally, standard construction industry measures would be taken to minimize fugitive dust emissions during construction activities. Any complaints that may arise would be dealt with by the Project sponsor and contractor in a timely and effective manner. Emissions would cease once construction was completed. The state of North Dakota is in attainment or unclassifiable / attainment for all criteria pollutants, including the particulate matter less than two microns in diameter (PM-2.5) and the 8-hour ozone (O_3) standards, and the temporary emissions generated during construction would not cause a violation of any air quality standards.

The Biota WTP and other Project components would be powered by electricity; therefore, their operation would not directly generate air emissions. Facilities that generated the power that would be used by these components would generate air emissions unless they relied on renewable sources, such as hydropower and wind energy. These power-generating facilities could be located a considerable distance from the Project Area and in multiple locations. Their operation would be regulated by local authorities in accordance with their permit conditions. Therefore, no air quality standards would be violated, either directly or indirectly.

Greenhouse Gas Emissions as a Contributor to Climate Change

Fossil fuel-burning equipment operated during construction would generate GHGs, which contribute to climate change. The generation of power required to operate pump stations and other Project components[1] would also generate GHG emissions. In February 2010, the Council on Environmental Quality (CEQ) issued its *Draft National Environmental Policy Act (NEPA)*

[1] Impacts of climate change on the proposed water sources for the Project are addressed in Chapter 4 of the SEIS.

Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions, which proposed that projects analyzed under NEPA should consider potential impacts associated with GHG emissions and climate change. The Guidance Memorandum addresses two related issues: (1) the treatment of GHG emissions that may directly or indirectly result from the proposed federal action and (2) the analysis of potential climate change impacts upon the proposed federal action. If a proposed action would be reasonably anticipated to cause *direct emissions of 25,000 metric tons or more of* CO_2*-equivalent GHG emissions on an annual basis* (emphasis added), agencies should consider this an indicator that a quantitative and qualitative assessment may be meaningful to decision makers and the public. For long-term actions that have *annual direct emissions of less than 25,000 metric tons of* CO_2*-equivalent emissions* (emphasis added), CEQ encourages federal agencies to consider whether the action's long-term emissions should receive similar analysis. CEQ does not propose this as an indicator of a threshold of significant effects, but rather as an indicator of a minimum level of GHG emissions that may warrant some description in the appropriate NEPA analysis for agency actions involving direct emissions of GHGs.

GHG emissions from construction of Project facilities would be temporary and would not occur on an annual basis. Thus, based on the CEQ guidance, further analysis of construction emissions is not needed. GHG emissions from operations would occur on an annual basis and thus are discussed in greater detail. The Project has been designed to reduce direct GHG emissions to the extent feasible by using electricity to power the Project components instead of petroleum-based fuels. Thus, no direct annual emissions would result from the operation of Project components. Negligible amounts of GHG emissions would be generated by vehicles used for periodic maintenance of Project components. The largest increase in vehicle trips is expected to be associated with the removal of sludge from the Minot WTP, but as discussed below under Transportation, this would result in an increase of only 4.5 truck trips per day on average during the peak month (fewer trips would be required during other months), and sludge would be disposed of locally. The GHG emissions generated by this limited number of trucks traveling a short distance and vehicles used to periodically maintain Project components would not make a perceptible contribution to climate change.

Emissions would be indirectly generated by the operation of power plants providing power to the Project components. Average annual power demand (in kilowatt hours per year [kW-hr/yr]) and GHG emissions estimated for each of the components associated with the inbasin and Missouri River alternatives whose operation would indirectly generate GHGs are shown in Tables I-1 and I-2, respectively. It is estimated that the inbasin alternatives would each generate approximately 9,484 metric tons of GHG per year (MT/yr), which is well below what the CEQ has identified as an indicator that agencies should consider further discussion.

Table I-1 Indirect GHG Emissions from Operation of the Inbasin Alternatives

Inbasin Alternative Components	Average Annual Power Demand	Average Annual GHG Emissions
	kW-hr/yr	MT/yr
Minot Peaking Well Facilities (4 units)	1,061,760	789
Sundre Peaking Well Facilities (2 units)	1,858,080	1,380
Surface Water Intake for Recharge – Minot Aquifer	1,682,960	1,250
Surface Water Intake for Recharge – Sundre Aquifer	1,661,520	1,234
Minot Recharge Facility	138,440	103
Sundre Recharge Facility	138,440	103
Lansford Pump Station	3,201,200	2,378
Bowbells Pump Station	232,380	173
Mohall Pump Station	687,900	511
Tolley Pump Station	615,180	457
Renville County Corner Pump Station	493,500	367
Bottineau West Pump Station	622,740	463
Bottineau North Pump Station	358,140	266
Lansford Reservoir	6,960	5
Bottineau Reservoir	6,960	5
Total	**12,766,160**	**9,484**

Source: Reclamation, 2013; The Climate Registry 2013

Table I-2 Indirect GHG Emissions from Operation of the Missouri River Alternatives

Missouri River Alternative Components	Average Annual Power Demand	Average Annual GHG Emissions
	kW-hr/yr	MT/yr
Lansford Pump Station	3,201,200	2,378
Bowbells Pump Station	232,380	173
Mohall Pump Station	687,900	511
Tolley Pump Station	615,180	457
Renville County Corner Pump Station	493,500	367
Bottineau West Pump Station	622,740	463
Bottineau North Pump Station	358,140	266
Lansford Reservoir	6,960	5
Bottineau Reservoir	6,960	5
South Prairie Reservoir	6,960	5
Modifications at the SCPP Intake, Missouri River and Conjunctive Use	11,526,150	8,563
Modifications at the SCPP Intake, Missouri River and Groundwater	13,764,000	10,225
Intake Adjacent to SCPP, Missouri River and Conjunctive Use	13,347,840	9,916
Intake Adjacent to SCPP, Missouri River and Groundwater	16,157,460	12,003

Missouri River Alternative Components	Average Annual Power Demand	Average Annual GHG Emissions
	kW-hr/yr	MT/yr
Biota WTP: Chlorination	14,623,055	10,864
Biota WTP: Chlorination/UV Inactivation	14,623,055	10,864
Biota WTP: Enhanced	17,032,055	12,653
Biota WTP: Conventional Treatment	24,253,799	18,018
Biota WTP: Microfiltration Treatment	24,253,799	18,018
Total	**varies**	**varies**

Source: Reclamation, 2013; The Climate Registry 2013

NEPA requires that impacts of action alternatives be compared to those of no action. If the Project were not implemented (i.e., no action), GHG emissions would be generated by pumping, treating, and distributing water to the Project members, which would offset the some of the increase that would be caused by the action alternatives. To illustrate this, GHG emissions from groundwater pumping were estimated by using the average depth to groundwater in the communities that would be served by the Project based on information available from the North Dakota State Water Commission (2013); estimating the amount of groundwater that would need to be pumped, along with the number of wells that would be required during the planning period based on the Water Needs Assessment Technical Report prepared for the Project (Reclamation 2012); estimating the amount of electrical power needed to pump the water based on the depth to groundwater, amount of water needed, and number of wells using standard engineering factors; and calculating the resulting indirect GHG emissions based on emission factors for the Project Area included in The Climate Registry (2013) (refer to Attachment 1, Tables B through E for additional details). As shown in Table I-3, total pumping in each of the member communities would generate up to 1,295 MT/yr of GHG by 2060. Additional GHG emissions would be generated by treating and distributing water to the Project members, which would further offset the emissions generated by the Project alternatives. These values have not been calculated because the information needed to do so is not readily available from the Project members; moreover, these details would not alter the conclusions of this analysis.

Table I-3 Average Annual Indirect GHGs from Pumping under No Action (MT/yr)

2020	2030	2040	2050	2060
1,199	1,223	1,247	1,271	1,295

Source: Reclamation; The Climate Registry 2013

Under some combinations of options, the net increase in emissions from the Missouri River alternatives would be less than the 25,000 MT/yr indicator identified by the CEQ. Under other options, the net increase may be greater than 25,000 MT/yr, depending on the emissions generated by treating and distributing the water. The U.S. Environmental Protection Agency's Greenhouse Gas Reporting Program showed that in 2011, power plants in the United States generated 2,221 million metric tons of CO2-e (GHGs). The Project would generate only an extremely small increment when compared to the GHGs emissions already being generated by power plants and thus would not result in a significant contribution to climate change.

Moreover, each of the existing power plants that would supply electricity to the Project is regulated in accordance with current standards; assuming that these standards become more stringent in the future (refer, for example, to the recent President's Climate Action Plan [Executive Office of the President 2013], which calls for reducing emissions from both existing and future power plants), emissions from existing power plants could decrease over time. Additionally, if the mix of power sources that would supply the Project changes in the future to include more renewal energy sources, the GHG emissions indirectly generated by the Project would decrease accordingly.

Earth Resources

Impacts on earth resources would occur primarily during construction and would be limited to the potential for erosion and sedimentation and the removal of topsoil. The Project would be designed based on detailed, site-specific topographic and geotechnical information; thus, it would be engineered to withstand identified geological hazards.

To minimize construction impacts, the following erosion control measures (documented in Best Management Practices, Appendix F) would be employed as appropriate and at stream crossings at all times:

- Care would be exercised to preserve existing trees along the streambank.
- Stabilization, erosion controls, restoration, and revegetation of all streambeds and embankments would be performed as soon as a stream crossing is completed and maintained until stable.
- Riparian woody shrubs and trees would be replanted as necessary to preserve the shading characteristics of the watercourse and the aesthetic nature of the streambank.
- At locations where soil conditions or slopes are such that erosion may occur along the pipeline trench, construction contractors would be required to construct earth berms perpendicular to the trench line at intervals sufficient to divert water from the trench.
- In pasture and hayland, straw wattles would be furnished and installed within 14 days of pipeline installation, at approximately the following intervals:

% Slope	Interval (feet)
7-10	120
10+	50

- Straw wattles would be a minimum of 6 inches in diameter, and would be installed across the entire width, plus 3 feet on either side of the disturbed area.

- As soon as a stream crossing was completed, streambeds and embankments would be stabilized, erosion controlled, and the area would be restored and re-vegetated, following vegetation BMPs. They would be maintained until stable

To minimize impacts on topsoil, topsoil would be removed and stockpiled separately from surface soils for reapplication following construction.

Seismic hazards are not expected to pose a risk for the Project. The Project would be located in a stable portion of the North American continent that has a low prevalence and history of seismic activity. Magnitude 5.0 earthquakes are generally considered to be the threshold for a destructive earthquake, and no known earthquake greater than magnitude 5.0 has occurred historically. The only measured earthquakes that have occurred in the Project Area are a magnitude 4.4 earthquake in south-central North Dakota in 1968 and a magnitude 4.8 earthquake occurring near Morris, Minnesota in 1975, which was felt in North Dakota (USGS 2006). Table I-4 lists earthquake probabilities for North Dakota cities for an earthquake greater than magnitude 5.0 occurring within 80 miles of that city over the next 1000 years. By comparison, Los Angeles would have a 90 to 100 percent probability using the same analysis (USGS 2006).

Table I-4 Earthquake Probabilities near Selected North Dakota Cities

City[a]	Probability Range (%)[b]
Williston	30-40
Wahpeton	15-20
Bismarck	10-20
Fargo	6-10
Valley City	6-10
Minot	5-10
Grand Forks	6-8
Jamestown	6-8
Devils Lake	5-6
Rugby	5-6
Dickinson	4-6

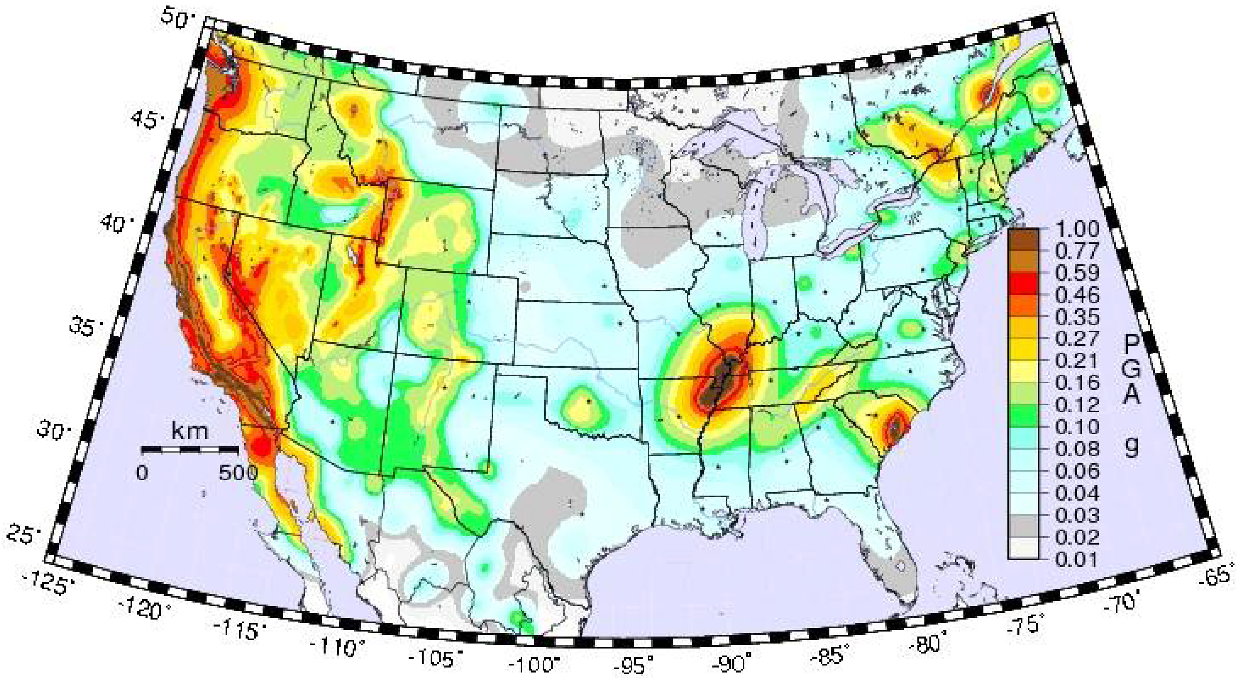
Notes:
[a] Cities ranked by probability.
[b] Probabilities based on the 2008 model have decreased for this region.
Source: USGS 2006, based on data from the USGS seismic probability calculator

Due to the distance to the nearest major fault systems (the New Madrid Fault near Memphis, Tennessee and those along the West Coast of the U.S.) and the stable underlying geology, North Dakota has some of the lowest probabilities for damaging earthquakes within the continental U.S. (USGS 2006). Figure I-1 shows earthquake magnitudes (in units of standard acceleration of gravity [g]) for a 2 percent probability earthquake over the next 50 years.

Noise

Construction activities would be the main source of noise. Pipeline construction would primarily occur in sparsely developed rural areas that are not in proximity to human noise-sensitive receptors such as residences, schools, churches, and hospitals[2]. Some construction would occur in more urbanized areas, however, and upgrades to the Minot WTP, portions of the pipelines, and certain pump stations, would be close enough to sensitive receptors for construction activities to be audible. The increased noise levels would be temporary, however, and night construction would be avoided near residential and populated areas, thus further minimizing the potential for annoyance and sleep disturbance. Moreover, construction activities would comply with all appropriate local laws and regulations, including those intended to minimize noise impacts. The Biota WTP is not in immediate proximity to any noise-sensitive receptors, and its pumps would be enclosed, which would minimize the potential for audible noise to be emitted from the facility.

[2] Impacts of noise on biological resources are addressed in the SEIS.



Notes: g = units of standard acceleration of gravity; PGA = peak ground acceleration

Source: USGS 2008

Figure I-1 Earthquake Hazard Map of the U.S.

Public Services and Utilities

Public services include police, fire, medical services, and schools within the Project Area. Utilities include solid waste disposal sites. The Project would result in negligible demands for public services. Neither construction nor operations pose a particular risk and would not result in an undue increase in the demand for police, fire, or medical services. The Project would provide bulk water service to rural areas, and use of the water would be regulated by the Project members. The Project would not directly result in any changes in population that would affect the demand for public services or utilities.

Construction would generate limited demand for solid waste disposal, and sludge and silt removed from Project facilities would also require disposal. All waste would be disposed of in approved facilities with adequate capacity. Construction debris would be hauled from the work site to a disposal location approved by the Contracting Officer or his/her representative. The capacity of the Minot WTP would be expanded under each of the Project alternatives, and the amount of sludge treated at this facility also would increase. It is estimated that the average volume of sludge handled at the facility would increase during the peak summer month from 98 tons per day to 143 tons per day. This volume of sludge would be within the capacity of the existing solids handling facility at the Minot WTP (Carollo Engineers 2013); the volume of sludge generated at other times of the year would be less. After dewatering at the solids handling facility, sludge likely would continue to be disposed of at the City of Minot's solid waste disposal facility as currently occurs or in another approved facility.

Transportation

Existing state highways, county roads, and city streets in the Project Area would be used to transport materials to and from areas of construction and by workers traveling to and from work sites. Open-trench construction techniques would be used in most locations where the pipeline would cross existing roadways. Pipeline installation at these locations would be accomplished in 1 to 2 days. Traffic impacts would be minimized by keeping at least one lane open through the active work areas and using flaggers as necessary. Major highways and railroads would be crossed using subsurface construction techniques, which would not affect traffic using these travel routes. Traffic though work zones would be controlled by guidelines established by the Federal Highway Administration, the Department of Transportation, and the American Association of State Highway Transportation Officials. Typical traffic control measures include use of signs, cones, drums, flaggers, reduced speed limits, lane closures, pavement markings, variable message signs, and movable concrete barriers. Such measures are commonly used to ensure the safe passage of vehicles during construction.

During operations, traffic would be generated primarily by disposal of sludge from the Minot WTP, likely at the City of Minot's municipal solid waste landfill. During the peak summer month in 2012 (July) when the volume of sludge transported was greatest, 263 truck trips were generated, for an average of 8.5 trips per day. The volume of sludge would increase as a result of the Project, and the number of truck trips generated during the peak summer month is expected to increase to 395, or an average 13 trips per day. The increase of 4.5 truck trips per day on average during the peak month would not result in a perceptible change in level of service on local roadways, particularly because these trips would likely be spread out during the day. Traffic impacts would be lessened during other months of the year when the volume of sludge produced would be lower.

References

Bureau of Reclamation (Reclamation). 2012. Water Needs Assessment Technical Report, Northwest Area Water Supply Project. North Dakota. Dakotas Area Office, Great Plains Region.

Bureau of Reclamation (Reclamation). 2013. Appraisal-Level Design Engineering Report.

Carollo Engineers. 2013. Memorandum regarding response to NDSWC comment related to solids handling capacity at the Minot WTP - Draft Appraisal Level Engineering Report.

The Climate Registry. 2013. General Reporting Protocol, Version 2.0. http://www.theclimateregistry.org/resources/protocols/general-reporting-protocol/.

Council on Environmental Quality. 2010. Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions.

Executive Office of the President. 2013. The President's Climate Action Plan.

Houston Engineering, Inc. and MWH. 2005. North Dakota State Water Commission and the Garrison Diversion Conservancy District. Northwest Area Water Supply Project, Electric Service Evaluation. Draft.

North Dakota State Water Commission. 2013. Ground and Surface Water Data Query. Website (http://www.swc.state.nd.us/4dlink2/4dcgi/wellsearchform/Map%20and%20Data%20Resources) accessed June 2013.

U.S. Environmental Protection Agency. 2013. Greenhouse Gas Reporting Program. 2011: Reported Data. Website (http://www.epa.gov/ghgreporting/ghgdata/reported/index.html) accessed July 2013.

U.S. Geological Survey (USGS). 2006. Preliminary Analysis of Infrastructural Failures and their Associated Risks and Consequences Related to Biota Transfers Potentially Realized from Interbasin Water Diversion. September 2006.

U.S. Geological Survey (USGS). 2008. National Seismic Hazard Maps. Website: http://earthquake.usgs.gov/hazards/products/conterminous/2008/maps/ accessed April 22, 2012.

ATTACHMENT 1

Greenhouse Gas Emissions Calculations

Table A GHG Emissions from Operation of Alternative Components

Components	Average Annual Power Demand	Peak Monthly Power Demand[1]	Average Annual GHG Emissions	Peak Monthly GHG Emissions	See Notes
	KW-hr/yr	KW-hr/mo	MT/yr	MT/mo	
Minot Peak Well Facilities (4 units)	1,061,760	176,960	788.8	131.5	2
Sundre Peak Well Facilities (2 units)	1,858,080	309,680	1,380.4	230.1	2
Surface Water Intake for Recharge – Minot Aquifer	1,682,960	591,047	1,250.3	439.1	3
Surface Water Intake for Recharge – Sundre Aquifer	1,661,520	580,327	1,234.3	431.1	3
Minot Recharge Facility	138,440	21,953	102.8	16.3	3
Sundre Recharge Facility	138,440	21,953	102.8	16.3	3
Minot Aquifer Collector Line	—	—	—	—	4
Sundre Aquifer Collector Line, Groundwater w Recharge	—	—	—	—-	4
Sundre Aquifer Collector Line, Groundwater w Recharge & Souris River	—	—	—	—	4
Pipeline: Glenburn to Renville Corner	—	—	—	—	4
Pipeline: Westhope and ASWUD III	—	—	—	—	4
Pipeline: Souris and ASWUD I	—	—	—	—	4
Pipeline: Bowbells, Columbus, and Noonan	—	—	—	—	4
Lansford Pump Station	3,201,200	306,247	2,378.2	227.5	3
Bowbells Pump Station	232,380	19,365	172.6	14.4	3
Mohall Pump Station	687,900	71,125	511.0	52.8	3
Tolley Pump Station	615,180	63,045	457.0	46.8	3
Renville County Corner Pump Station	493,500	49,525	366.6	36.8	3
Bottineau West Pump Station	622,740	63,885	462.6	47.5	3
Bottineau North Pump Station	358,140	34,485	266.1	25.6	3
Lansford Reservoir	6,960	580	5.2	0.4	3
Bottineau Reservoir	6,960	580	5.2	0.4	3
South Prairie Reservoir	6,960	580	5.2	0.4	3

Components	Average Annual Power Demand	Peak Monthly Power Demand[1]	Average Annual GHG Emissions	Peak Monthly GHG Emissions	See Notes
Modifications at the SCPP Intake, Missouri River & Conjunctive Use	11,526,150	1,263,450	8,562.8	938.6	3
Modifications at the SCPP Intake, Missouri River & Groundwater	13,764,000	1,512,100	10,225.3	1,123.3	3
Intake Adjacent to SCPP, Missouri River & Conjunctive Use	13,347,840	1,503,170	9,916.2	1,116.7	3
Intake Adjacent to SCPP, Missouri River and Groundwater	16,157,460	1,843,730	12,003.4	1,369.7	3
Biota WTP, Chlorination	14,623,055	1,218,588	10,863.5	905.3	5
Biota WTP: Chlorination/UV Inactivation	14,623,055	1,218,588	10,863.5	905.3	5
Biota WTP: Enhanced	17,032,055	1,419,338	12,653.2	1,054.4	5
Biota WTP: Conventional Treatment	24,253,799	2,021,150	18,018.2	1,501.5	5
Biota WTP: Microfiltration Treatment	24,253,799	2,021,150	18,018.2	1,501.5	5

Notes:

1) Derived from operational capacity of facilities as designed (see Appraisal-Level Design [ALD] Report, SEIS Appendix J).

2) Based on 70% of operation and maintenance (O&M) cost ($0.05/KW-hr) (see O&M Cost Tables in Appendix F of ALD Report.

3) See O&M cost table in ALD Report, Appendix F under "Power," assuming $0.05/kilowatts per hour (KW-hr).

4) No power consumption required.

5) Based on power demand estimated in ALD Report.

Source: The Climate Registry 2013; Reclamation 2013

Table B Changes in Water Demand, 2010-2060

Service Area[1]	County	2010 Historic Actuals			Projected Future Water Demand					Change in Demand from 2010 to 2060
		Total Pumping	Existing Wells	Average Flowrate	2020	2030	2040	2050	2060	
		mgd	qty	mgd	mgd	mgd	mgd	mgd	mgd	mgd
All Seasons Users	Multi-County	0.250	5	0.050	0.955	0.903	0.852	0.801	0.749	0.499
City of Berthold	Ward	0.030	2	0.015	0.033	0.034	0.034	0.035	0.035	0.005
City of Bottineau	Bottineau	0.220	3	0.073	0.259	0.249	0.241	0.235	0.229	0.009
City of Burlington	Ward	0.030	3	0.010	0.081	0.082	0.083	0.084	0.085	0.055
City of Columbus	Burke	0.019	1	0.019	0.017	0.017	0.017	0.017	0.017	-0.002
City of Deering	McHenry	0.010	1	0.010	0.009	0.009	0.009	0.009	0.009	-0.001
City of Des Lacs	Ward	0.002	1	0.002	0.003	0.003	0.003	0.003	0.003	0.001
City of Flaxton	Burke	0.005	2	0.003	0.006	0.006	0.006	0.006	0.006	0.001
City of Grenora	Williams	0.020	2	0.010	0.013	0.013	0.012	0.012	0.012	-0.008
City of Kenmare	Ward	0.030	3	0.010	0.076	0.074	0.073	0.071	0.070	0.040
City of Maxbass	Bottineau	0.010	1	0.010	0.009	0.009	0.009	0.009	0.009	-0.001
City of Minot	Ward	5.280	14	0.377	6.265	6.451	6.637	6.823	7.009	1.729
City of Mohall	Renville	0.080	5	0.016	0.138	0.134	0.131	0.129	0.126	0.046
City of Noonan	Divide	0.010	1	0.010	0.007	0.007	0.007	0.007	0.007	-0.003
NCRWC[2]	Multi-County	1.450	10	0.145	1.553	1.560	1.569	1.578	1.587	0.137
City of Rugby	Pierce	0.210	5	0.042	0.272	0.270	0.69	0.267	0.266	0.056
City of Sherwood	Renville	0.010	1	0.010	0.014	0.013	0.013	0.013	0.012	0.002
City of Souris	Bottineau	0.010	1	0.010	0.005	0.005	0.005	0.005	0.005	-0.005
City of Upham	McHenry	0.010	1	0.010	0.009	0.009	0.009	0.009	0.009	-0.001
Upper Souris Users	Multi-County	0.130	10	0.013	0.159	0.148	0.137	0.128	0.119	-0.011

City of Westhope	Bottineau	0.060	1	0.060	0.054	0.043	0.032	0.021	0.010	-0.050
City of Willow City	Bottineau	0.030	2	0.015	0.022	0.022	0.022	0.022	0.022	-0.008
Totals	**—**	**7.906**	**75**	**0.105**	**9.959**	**10.061**	**10.170**	**10.284**	**10.396**	**2.490**

Notes:

1) Each service area may be composed of several smaller service areas; water needs are shown only for the portion(s) of the service area that are in the Project Area.

2) For the purposes of water demand projections, the North Central Rural Water Consortium (NCRWC) includes the North Prairie Rural Water District and the West River Water and Sewer District service areas.

Source: Reclamation 2012

Table C Estimated Future Wells and Average Depth to Groundwater

Service Area	Estimated Future Well Count[1]							Estimated Average Depth to Groundwater
	2020	2030	2040	2050	2060	Max Wells	New Wells	
	qty	qty	qty	qty	qty	qty	qty	feet below land surface
All Seasons Users	19	18	17	16	15	19	14	35
City of Berthold	2	2	2	2	2	2	0	21
City of Bottineau	4	3	3	3	3	4	1	20
City of Burlington	8	8	8	8	9	9	6	10
City of Columbus	1	1	1	1	1	1	0	47
City of Deering	1	1	1	1	1	1	0	25
City of Des Lacs[2]	2	2	2	2	2	2	1	28
City of Flaxton	2	2	2	2	2	2	0	47
City of Grenora	1	1	1	1	1	1	0	40
City of Kenmare	8	7	7	7	7	8	5	40
City of Maxbass	1	1	1	1	1	1	0	25
City of Minot	17	17	18	18	19	19	5	110
City of Mohall	9	8	8	8	8	9	4	8
City of Noonan	1	1	1	1	1	1	0	25
NCRWC	11	11	11	11	11	1	1	125
City of Rugby	6	6	6	6	6	6	1	15
City of Sherwood	1	1	1	1	1	1	0	25
City of Souris	1	1	1	1	1	1	0	25
City of Upham	1	1	1	1	1	1	0	25
Upper Souris Users	12	11	11	10	9	12	2	45
City of Westhope	1	1	1	0	0	1	0	20
City of Willow City	1	1	1	1	1	1	0	25
Totals & Averages	**—**	**—**	**—**	**—**	**—**	**—**	**40**	**28**

Notes:

1) To meet maximum planning period demand under the No Action Alternative

2) Depth to groundwater not available, typical value assumed

Source: Reclamation 2012, North Dakota State Water Commission 2013

Table D Estimated Average Well Flowrate and Motor Input Power

Service Area	Average Flowrate					Average Motor Input Power				
	2020	2030	2040	2050	2060	2020	2030	2040	2050	2060
	gpm	gpm	gpm	gpm	gpm	kW	kW	kW	kW	kW
All Seasons Users	663.2	627.1	591.7	556.3	520.1	6.53	6.17	5.83	5.48	5.12
City of Berthold	22.9	23.6	23.6	24.3	24.3	0.14	0.14	0.14	0.14	0.14
City of Bottineau	179.9	172.9	167.4	163.2	159.0	1.01	0.97	0.94	0.92	0.89
City of Burlington	56.3	56.9	57.6	58.3	59.0	0.16	0.16	0.16	0.16	0.17
City of Columbus	11.8	11.8	11.8	11.8	11.8	0.16	0.16	0.16	0.16	0.16
City of Deering	6.3	6.3	6.3	6.3	6.3	0.04	0.04	0.04	0.04	0.04
City of Des Lacs	2.1	2.1	2.1	2.1	2.1	0.02	0.02	0.02	0.02	0.02
City of Flaxton	4.2	4.2	4.2	4.2	4.2	0.06	0.06	0.06	0.06	0.06
City of Grenora	9.0	9.0	8.3	8.3	8.3	0.10	0.10	0.09	0.09	0.09
City of Kenmare	52.8	51.4	50.7	49.3	48.6	0.59	0.58	0.57	0.55	0.55
City of Maxbass	6.3	6.3	6.3	6.3	6.3	0.04	0.04	0.04	0.04	0.04
City of Minot	4,351	4,480	4,609	4,738	4,867	134.64	138.63	142.63	146.63	150.63
City of Mohall	95.8	93.1	91.0	89.6	87.5	0.22	0.21	0.20	0.20	0.20
City of Noonan	4.9	4.9	4.9	4.9	4.9	0.03	0.03	0.03	0.03	0.03
NCRWC	1,078	1,083	1,090	1,096	1,102	37.93	38.10	38.32	38.54	38.76
City of Rugby	188.9	187.5	186.8	185.4	184.7	0.80	0.79	0.79	0.78	0.78
City of Sherwood	9.7	9.0	9.0	9.0	8.3	0.07	0.06	0.06	0.06	0.06
City of Souris	35	35	35	3.5	3.5	0.02	0.02	0.02	0.02	0.02
City of Upham	.3	.3	.3	6.3	6.3	0.04	0.04	0.04	0.04	0.04
Upper Souris Users	110.4	102.8	5.1	88.9	82.6	1.40	1.30	1.20	1.13	1.05
City of Westhope	37.5	29.9	2.2	14.6	6.9	0.21	0.17	0.13	0.08	0.04
City of Willow City	15.3	15.3	5.3	15.3	15.3	0.11	0.11	0.11	0.11	0.11

Notes:
gpm = gallons per minute
kW = kilowatt

Table E Estimated GHG Emissions from Pumping under No Action

Service Area	Average Annual Indirect GHGs (offsets)				
	2020 MT/yr	2030 MT/yr	2040 MT/yr	2050 MT/yr	2060 MT/yr
All Seasons Users	42.5	40.2	37.9	35.6	33.3
City of Berthold	0.9	0.9	0.9	0.9	0.9
City of Bottineau	6.6	6.3	6.1	6.0	5.8
City of Burlington	1.0	1.0	1.1	1.1	1.1
City of Columbus	1.0	1.0	1.0	1.0	1.0
City of Deering	0.3	0.3	0.3	0.3	0.3
City of Des Lacs	0.1	0.1	0.1	0.1	0.1
City of Flaxton	0.4	0.4	0.4	0.4	0.4
City of Grenora	0.7	0.7	0.6	0.6	0.6
City of Kenmare	3.9	3.8	3.7	3.6	3.6
City of Maxbass	0.3	0.3	0.3	0.3	0.3
City of Minot	876.2	902.2	928.2	954.2	980.2
City of Mohall	1.4	1.4	1.3	1.3	1.3
City of Noonan	0.2	0.2	0.2	0.2	0.2
NCRWC	246.8	247.9	249.4	250.8	252.2
City of Rugby	5.2	5.1	5.1	5.1	5.1
City of Sherwood	0.4	0.4	0.4	0.4	0.4
City of Souris	0.2	0.2	0.2	0.2	0.2
City of Upham	0.3	0.3	0.3	0.3	0.3
Upper Souris Users	9.1	8.5	7.8	7.3	6.8
City of Westhope	1.4	1.1	0.8	0.5	0.3
City of Willow City	0.7	0.7	0.7	0.7	0.7
Total GHGs, MT/yr	**1,199**	**1,223**	**1,247**	**1,271**	**1,295**

Source: The Climate Registry 2013; Assumed Variables

Midwest Reliability Organization (MRO) West (#15) Electric Power GHGs	*Global Warming Potential*	*Factor*	*Units*
Carbon Dioxide - CO_2	1	1628.60	lb/MegaWatt-hr
Methane - CH_4	21	0.02880	lb/ MegaWatt -hr
Nitrous Oxide - N_2O	310	0.02779	lb/ MegaWatt -hr
Carbon Dioxide Equivalents - CO_2 e	–	1637.82	lb/ MegaWatt -hr
	–	742.90	g/kiloWatt-hr