Risk and Consequence Analysis Focused on Biota Transfers Potentially Associated with Surface Water Diversions Between the Missouri River and Red River Basins

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Abstract. Section 1 provides a brief overview of the project, including a cursory summary of the history of the "Garrison Diversion" and how that history relates to this work focused on the analysis of risks and consequences potentially associated with interbasin biota transfers. The present study was initiated under the auspices of the Dakota Water Resources Act (DWRA) of 2000, which directed the Secretary of the Interior to conduct a comprehensive study of the water quality and quantity needs of the Red River Valley and the options for meeting those needs. As such, the Bureau of Reclamation (Reclamation) requested technical support from the U.S. Geological Survey (USGS) Columbia Environmental Research Center (CERC) for an evaluation of the risks and economic consequences of biota transfers potentially associated with interbasin water transfers that might occur between the Upper Missouri River and the Red River of the North (Red River) basins. Pursuant to guidance from National Academy of Sciences, National Invasive Species Council, regulatory agencies (e.g., US Environmental Protection Agency), and nongovernmental organizations such as The Nature Conservancy and awardees of Sea Grant program support, USGS/CERC entered into an iterative risk-assessment process with stakeholders interested in the biota transfer issue. Section 1 summarizes the implementation of the stepwise risk-assessment process, with the primary outcomes of the section detailed in the problem formulation phase of the USGS technical support project. Outcomes of problem formulation were focused on identifying biota of concern and related issues associated with interbasin biota transfers, pathways potentially linking Missouri River and Red River basins, and the potential confounding factors that might influence the interpretation of cause-effect relationships predicated on biota transfers, if these events did occur in the future.

1.0 Biota Transfer Project Overview

Under the auspices of the Dakota Water Resources Act (DWRA) of 2000, the Secretary of the Interior has been directed to conduct a comprehensive study of the water quality and quantity needs of the Red River Valley and the options for meeting those needs. As such, the

Bureau of Reclamation (Reclamation) requested technical support from the U.S. Geological Survey (USGS) Columbia Environmental Research Center (CERC) for an evaluation of the risks and economic consequences of biota transfers potentially associated with interbasin water transfers that might occur between the Upper Missouri River and the Red River of the North (Red River) basins. This project report summarizes the technical findings of CERC staff and their Department of the Interior (DOI) partners in the National Park Service (NPS) with respect to these concerns regarding interbasin biota transfer. As part of the risk analysis and assessment process, staff from the Reclamation Dakota Area Office (DAO) and stakeholders helped focus this technical support activity through a series of Technical Team meetings convened in Fargo, North Dakota in 2002 and 2003 (September 9 and 10, 2002; March 27, 2003; October 28, 2003) and through comments received consequent to those meetings.

This technical report consists of six sections with accompanying appendices. Section 1 provides a brief overview of the project and the historic context for this evaluation focused on potential biota transfers. Section 2 summarizes the technical tools applied to the analysis of risks and economic consequences that are summarized in Section 3. Section 4 characterizes the risks potentially associated with biota transfers directly resulting from interbasin water transfers and competing pathways, while the economic consequences that are derivatives of those risks are considered in Section 5. Section 6 presents a summary of risks and economic consequences detailed in the report. A series of appendices provides detailed technical materials that support the analysis of risks, economic consequences, and their attendant uncertainties.

1.1 Overview of Garrison Diversion

Past accounts from various perspectives (e.g,, WPA 1939; Bell 1963; Bureau of Reclamation 1974; Souris River Study Board 1978; Thorson 1994; Carrels 1999) and public domain summaries mirroring a similar diversity of perspectives (e.g., http://www.rrvwsp.com/; http://www.savethesheyenne.org/; http://www.dnr.mo.gov/ riverissues/riverissues.htm; http://www.gov.mb.ca/waterstewardship/transboundary/ positions/index.html; http://www.canadianembassy.org/environment/garrison-en.asp) provide the reader with background on the Garrison Diversion and the historic context of the current work concerning potential biota transfers between the Missouri River and the Red River basins. Additionally, other recent studies have addressed the interrelated environmental management issues associated with the Missouri River and its watershed (e.g., NRC, 2002), and the Red River and its watershed (e.g., USGS, numerous citations available at http://mn.water.usgs.gov/ redn/biblio.html).

The historic literature is rich with respect to the issues generated by the Garrison Diversion as it was originally envisioned under the Pick-Sloan Missouri Basin Program of 1944 (also referred to as the Missouri River Basin Project, or Pick-Sloan) as initially authorized by the Flood Control Act of December 22, 1944. As a comprehensive plan for the conservation, control,

and use of water resources in the entire Missouri River Basin, Pick-Sloan was subsequently modified as the Garrison Diversion Unit in response to sociopolitical comments and technical inputs regarding the original plan's feasibility (see http://www.garrisondiv.org; US Congress, 1975; IJC, 1976a-f, and references cited therein). The Dakota Water Resources Act[1] and the Northwest Area Water Supply (NAWS)[2] project in North Dakota (http://www.swc.state.nd.us/projects/nwwatsup.html; http://www.gov.mb.ca/waterstewardship/transboundary/pdf/sfxded.pdf) currently face similar scrutiny in response to various perspectives related to the water needs of the region. During the development of this report, technical issues concerning interbasin water diversions were defined through discussions with the Technical Team and Reclamation. As with most contemporary environmental issues, the immediate questions guiding the technical aspects of this project are easily linked to public needs (e.g., WPA 1939) that predate the signing of the Pick-Sloan legislation as it was captured in the Flood Act of 1944, which is the original point of departure for this technical report. Historic accounts that lead to Pick-Sloan, as well as early biological survey work that provided baseline information regarding the biological resources issues associated with each of the river basins in question were considered in this report (e.g., Young, 1924 and other citations; see Section 4).

Numerous government reports on the Red River basin of North Dakota written prior to Pick-Sloan and contemporary legislation acknowledged environmental management issues of the day. For example, the North Dakota State Planning Board under the auspices of the Works Progress Administration (1939) recommended in part that future work "concentrate on the water problem . . . to include construction of facilities for rural water supplies, regulating the flow in various streams and supplementing the flow in the Red River" and "reduce stream pollution"—recommendations that are similar to issues motivating the current investigation on biota transfer. Although reducing stream pollution was an insightful recommendation for its day, the focus at that time was on "traditional chemical pollution" such as nutrient enrichment from return irrigation flows that were then, and still remain, problematic throughout the western states. Today's version of "reduce stream pollution" also reflects heightened concerns for introduction of species foreign to the Red River basin; hence, the current work's focus may be seen as responsive not only to contemporary concerns of biota transfer but also as a continued response to those concerns of stream pollution voiced over 60 years ago. Observations since Pick-Sloan regarding water needs in the Red River and other drainages of North Dakota continually mark the path toward the DWRA.

Regardless of the water needs—irrigation, hydroelectric power, municipal, or industrial—that historically motivated proposals for water diversions from the Missouri River to

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[1]DWRA is a reauthorization of the 1986 Reformulation Act which was a reauthorization of the 1965 Act (see §1.2 for additional background and references focused on historic setting).

[2]NAWS is a component of the Garrison Diversion Unit (GDU) Municipal, Rural, and Industrial (MR&I) Grants Program.

the Souris River-Red River systems, the interrelationships between the potential source of water exports (the Missouri River) and the system currently proposed for water imports (Red River) reflect the spatial and temporal attributes of water quality and quantity reflected in contemporary debates associated with stakeholder concerns. For example, from a Canadian perspective, early interagency provincial studies such as the Souris River Basin Study Report (1978) reflected concerns including those of biota transfers that were in part captured by U.S. congressional testimonies of the 1970s (e.g., US Congress, 1975). From early studies of potential problems associated with interbasin water transfers (see IJC 1976a-f; IJC 1977), the current study was developed to address species of concern as well as engineering alternatives to reduce risks associated with biota transfers resulting from such water diversions.

1.2 Pick-Sloan and Beyond: Path to USGS/NPS Biota Transfer Project

Pick-Sloan as embedded in the Flood Control Act was authorized by Congress in late December 1944. Originally developed as two plans, one from the U.S. Army Corps of Engineers (Pick Plan) and another from Reclamation (Sloan Plan), Pick-Sloan reflected a joining of these independent water management projects, in part because of similar infrastructure needs and river management issues that politically justified their union. Pick-Sloan as realized with passage of the Flood Control Act of 1944 responded to the issues of flood control, river navigation, irrigation, and hydroelectric power with six main stem dams on the Missouri River between 1933 and 1966. Today Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point dams[3] are managed by the US Army Corps of Engineers in cooperation with the Bureau of Reclamation (see Figure 1).

As summarized in various public domain sources (e.g., http://www.garrisondiv.org/; http://www.rrvwsp.com/; http://www.savethesheyenne.org/; http://www.dnr.mo.gov/riverissues/riverissues.htm; http://www.gov.mb.ca/waterstewardship/transboundary/positions/index.html; http://www.canadianembassy.org/environment/ garrison-en.asp) and contemporary retrospectives (see NRC 1992; Thorson 1994; Licht 1997; Carrels 1999; Silberman and Gudmundson 2002), the irrigation component of Pick-Sloan originally intended to deliver irrigation water to more than 5 million acres of land in seven different states within the Missouri River basin. One project funded under Pick-Sloan, the Missouri-Souris Project, was originally intended to bring water from the Missouri River to North Dakota through a diversion from Fort Peck Reservoir in eastern Montana. The target lands for irrigation in northwest North Dakota, however, were not amenable to irrigated agriculture due to their poor drainage

[3]Authorized and completed as follows: Fort Peck (authorized under the Works Progress Administration in 1933 with construction completed in 1940), Garrison (authorized in 1944 with construction initiated in 1947 and completed in 1953), Oahe (authorized in 1944 with construction initiated in 1948 and hydroelectric generation facility completed in 1962), Big Bend (authorized in 1944 with hydroelectric generation facility completed in 1966), Fort Randall (authorized in 1944 and completed in 1956), and Gavins Point (authorized in 1944 and completed in 1957).

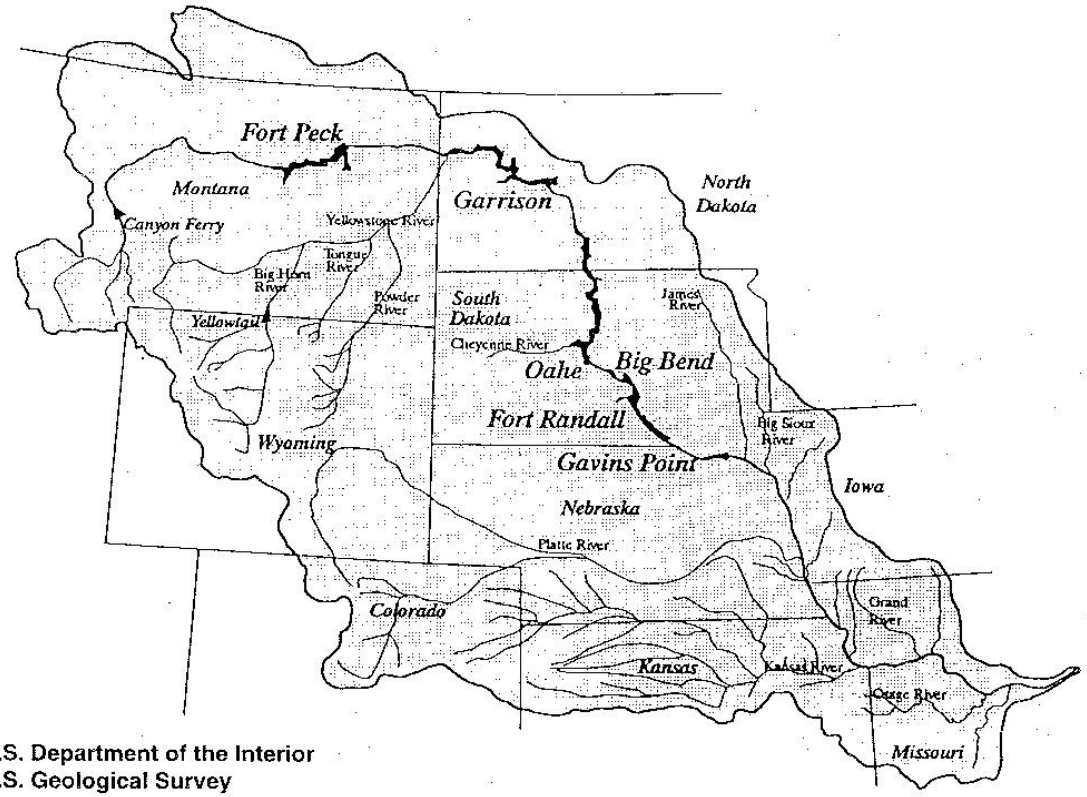

Figure 1. Dams along the main stem of the Missouri River, with diversions from waters behind Garrison Dam providing potential sources for interbasin biota transfers to the Red River system (Burke, et al. 1997).

properties reflecting their glacial origins. Given these soil limitations, the original Missouri-Souris Project was revised by Reclamation in 1957 wherein water from Garrison Reservoir was tabbed to irrigate lands in north-central and eastern North Dakota. The redesigned project was named the Garrison Diversion, and legislative support and appropriations were gained when Congress enacted and funded the Garrison Diversion in 1965. As realized under the 1965 congressional action, Garrison Diversion was focused on municipal and industrial water needs, development or enhancement of fish and wildlife resources, recreation, flood control, and irrigation, although the role of irrigation in the redesigned plans was considerably reduced compared with the Missouri-Souris Project of Pick-Sloan.

The Garrison Diversion Project was funded throughout the 1970s, 1980s, and 1990s. Under the Carter, Reagan, George H.W. Bush, and Clinton administrations, the project was reviewed by public and private stakeholders and government agencies. In part, the increased level of review and comment by stakeholders stemmed from the passage of the National Environmental Policy Act (NEPA) during the Nixon administration early in 1970. Under NEPA, the environmental impact statement (EIS) became a requirement for all "major construction activities," and EIS requirements under NEPA afforded opportunity for interested parties to comment on the ongoing efforts to develop the Garrison Diversion. The government of Canada, both provincial and federal, while always aware of water projects on shared water resources, became active in commenting on plans envisioned for Garrison. Under the auspices of the Boundary Waters Treaty of 1909, the Canadian government requested that plans for the Garrison

Diversion be discontinued until issues presented by the International Joint Commission were addressed. The International Joint Commission (IJC) had been commissioned under the auspices of the Carter Administration to study the proposed Garrison Diversion and had issued a report in 1977 (IJC, 1976a-f; IJC, 1977) that identified the possibility that return flows from irrigated fields in North Dakota would likely reach Canada (hence, source waters from the Missouri River would be discharged as irrigation drainage to surface waters in the watershed connected to the Hudson Bay). The IJC had also identified that biota, for example, fish, fish eggs, and pathogens, might also be introduced into waters destined for Hudson Bay with a particular focus on the fisheries of the region, for example, Lake Winnipeg. While concerns regarding reduced water quality associated with return flows of irrigation drain water were ultimately addressed by eliminating plans for irrigation in the Souris River watershed, concerns about biota transfer remained.

This evaluation of potential biota transfers between the Missouri River basin and the Red River basin are a direct outgrowth of the DWRA of 2000. DWRA amended the Garrison Diversion Reformulation Act of 1986 and was authorized by Congress in order to evaluate water quality and quantity needs of the Red River valley and the options for meeting those needs, including alternatives that might bring water from the Missouri River to the Red River valley for water programs intended for municipal and rural communities, industrial projects, and tribal needs. Given the history of the Garrison Diversion, it is not surprising that DWRA has again rekindled the biota transfer issue.

Even this brief summary of the current project's development suggests that the political history of the Garrison Diversion is rich, spanning 60 years under various program and project pseudonyms. Presently, the technical activities completed here under the auspices of DWRA may be viewed as an ongoing collaborative process intended to address the water needs of the region which, not surprisingly, are characterized at times by conflicting stakeholder views. The current work's focus on the biota transfer issue can be viewed as complementary to past efforts that focused on the interrelationships between the Missouri River and the Souris-Red rivers, and the evaluation of alternatives for meeting the water supply needs of North Dakota and the Red River Valley.

1.3 Risk Analysis, Risk Assessment and Management Overview

The process commonly pursued during risk assessment, particularly within the context of environmental issues and a multiple stressor approach to cumulative risk assessment, is highly interactive (Figure 2; see EPA 2003; Ferenc and Foran 2000; Foran and Ferenc 1999). The current technical support activity is focused on biota transfers and considered both human and nonhuman receptors as targets of biological agents that will potentially enter the Red River basin as a consequence of water diversion from the Missouri River. Given the focus of the current

analysis of risks and consequences ranges across various levels of biological organization and spatial scales, much of the process and language used in completing the work reflects a dependence on an ecological context for evaluating and characterizing risks potentially associated with biota transfers. However, USGS/CERC did not conduct an ecological risk assessment nor a human health risk assessment as part of this analysis focused on risks and consequences of biota transfers potentially associated with water diversions from the Missouri River or competing pathways for such biological incursions. The present analysis is asymmetric, given our focus on water imports to the Red River basin. Analysis of risks associated with water exports from the Missouri River is limited to the role that water exports have in characterizing uncertainties in our analysis of risks associated with biota imported as a result of water diversions between Missouri River and Red River basins.

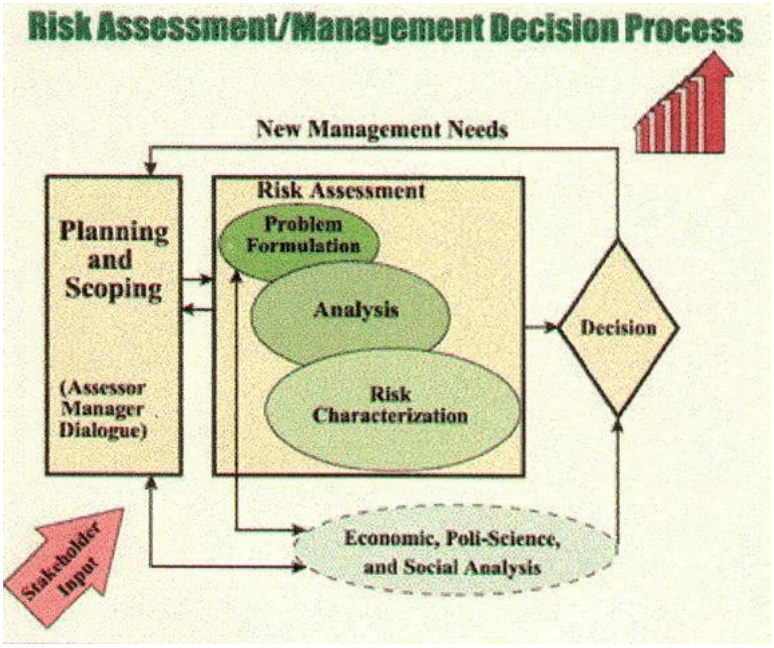

Figure 2. Process for evaluating risks associated with biota transfers potentially associated with interbasin water diversions proposed under DWRA. Figure from EPA 2003.

Figure 2 summarizes the process we have completed and places this report and subsequent work into a larger picture of risks and consequences. Through a series of communications with Reclamation and Technical Team meetings, USGS/CERC identified biota transfer issues that appeared as “drivers” for the technical support request issued from Reclamation. Planning and scoping discussions with Reclamation regarding biota transfer issues were reinforced and additional guidance was gained from Technical Team meetings that were the primary activities during Problem Formulation. As characterized across the various implementation strategies available for the risk assessment process, identification of biota of

concern and pathways linking source and receiving systems were incorporated into conceptual models serving as the primary outcomes to Problem Formulation. The process summarized in Figure 2 is briefly characterized and outcomes from Problem Formulation that provided the foundation for the analysis and characterization of risks are summarized to close the chapter.

1.3.1 Introduction. Risk analysis and the subsequent process of assessing risks and consequences of targeted events has a wide range of applications to evaluations of:

- ecological health,
- accidental events,
- financial concerns, and
- technology issues.

Each of these applications is relevant to the issues that Reclamation faces in its management of water resources across the western US.

In its simplest summary, the analysis, assessment, and management of risks is captured by a stepwise, iterative process wherein (1) questions are formulated, (2) observations or "experiments" are conducted wherein answers are developed to address those questions, and (3) decisions are made given the answers to the questions that initiated the process (EPA 1992, EPA 1998, NRC 1983, NRC 1994; Figure 2). Decisions that result from the initial assessment may (1) yield sufficient management-critical support for a particular management action, or (2) the analysis process may be reiterated to address critical data gaps identified as outcomes of the initial "query-answer routine." For example, answers developed during the first iteration may not be sufficient to support management decisions when the level of uncertainty exceeds the risk-tolerance of the decision-makers. Additionally, if sufficient evidence in support of a management decision is derived following completion of the process, parallel technical support efforts may be conducted as part of an adaptive management program, for example, development of a monitoring program that parallels an on-going management activity (Stahl, et al. 2001).

CERC conducted the technical analysis of risks and consequences associated with biota transfers potentially associated with interbasin water transfers following available guidance (EPA 1992, EPA 1998, NRC 1983, NRC 1994), including that developed for hazard assessment and critical control point analysis for aquatic nuisance species and similar applications (e.g., see Minnesota Sea Grant/Michigan Sea Grant, 2001).

1.3.2 Problem formulation and development of conceptual models. Consistent with the risk assessment process practiced for issues related to environmental and technological interactions such as interbasins water transfers, nested conceptual models were developed to characterize the issues related to biota transfers associated with interbasin water diversions. As part of Problem Formulation, preliminary models were developed in collaboration with

Technical Team members wherein (1) biota of concern (potential and selected representative species) were identified and characterized with respect to their biological and ecological attributes that may promote their transfer and establishment in previously unoccupied areas (e.g., life-history attributes likely to influence invasiveness); (2) pathways that potentially link biota of the Upper Missouri River basin (source area) with the Red River basin (receiving area) were characterized, acknowledging life-history attributes of biota of concern that might enhance the likelihood for invasion and establishment; and (3) ecological receptors likely to be adversely impacted by invasive species were identified. The identification of biota of concern was based on Technical Team input, on the characterization of candidate species, and pathways linking those species to the Red River basin. The selection of representative species of concern captured the range of biota potentially available for emigration from the Upper Missouri River basin (Table 1).

Pathways and potential risks associated with biota transfers were incorporated in the conceptual model, which became a graphical illustration of the environmental conditions critical to the analysis of risks (e.g., potential linkage of sources and receptors via pathways). As such, the conceptual model was developed collaboratively with the Technical Team early during the risk assessment process and was a critical outcome of Problem Formulation.

While many of those representative species included in Table 1 reflect Technical Team's and Reclamation's focus on biota considered exotic or invasive to the receiving system, biota whose current distributions reflect occurrence in both exporting and importing systems were also included in the analysis. Technically, biota transfers of species already occurring in both exporting and importing systems would not constitute an incursion potentially characterized as a "biological invasion." Nonetheless, transfers of these representative species might yield with a shift in metapopulations that could be associated with adverse effects, e.g., increased incidence of disease in the importing system—hence, their inclusion in this analysis.

Collaborative development of nested conceptual models reflected the iterative process characteristic of the risk-assessment process, and helped identify data needs and potential uncertainties. As the primary outcome of Problem Formulation, the nested conceptual models helped identify ecological receptors most likely impacted by exposure to biota potentially transferred to the Red River basin from the Missouri River basin. Additionally, the conceptual models helped identify assessment endpoints potentially of concern when potential adverse effects associated with a biological invasion were considered within the context of risk characterization and evaluation of economic consequences.

Table 1. Biota of concern identified for analysis focused on biota transfers from Upper Missouri River basin to Red River basin.

Microorganisms and Infectious Diseases Enteric redmouth Infectious hemtopoietic necrosis virus (IHNV) *Escherichia coli* (various serotypes)* *Legionella* spp.* *Salmonella* spp. *(*including, but not limited, to *S. typhi, S. typhmurium,* other *Salmonella* serotypes, and other water-borne infectious diseases*)** **Protozoa and Myxozoa** *Myxosoma cerebralis (Myxobolus cerebralis)* *Polypodium hydriforme* *Cryptosporidium parvum** *Giardia lamblia** **Cyanobacteria** *Anabaena flos-aquae** *Microcystis aeruginosa** *Aphanizomenon flos-aquae** **Vascular plants** Hydrilla (*Hydrilla verticillata*) Eurasian water-milfoil (*Myriophyllum spicatum*) Water hyacinth (*Eichhornia crassipes*) Purple loosestrife (*Lythrum salicaria*) Salt cedar (*Tamarix* spp.; at least eight species have been listed as introduced into the U.S. and Canada)	**Aquatic invertebrates: Mollusks** Zebra mussel (*Dreissena polymorpha*) Asian clam (*Corbicula fluminea*) New Zealand mudsnail (*Potamopyrgus antipodarum*) **Aquatic invertebrates: Crustaceans** Spiny water flea (*Bythotrephes cederstroemi*) **Aquatic vertebrates: Fishes** Gizzard shad (*Dorosoma cepedianum*) Rainbow smelt (*Osmerus mordax*) Paddlefish (*Polyodon spathula*) "Asian carp"† Pallid sturgeon (*Scaphirhynchus albus*) Utah chub (*Gila atraria*) Zander (*Sander* [*Stizostedion*] *lucioperca*) **Invasive biota associated with sludge disposal and indirect pathways associated with interbasin water transfers, including:** Potential transfer of plant and disease organisms (plant, wildlife, and human) Potential transfer of genetically manipulated organisms Potential biota transfers derived from sludge disposal

* Reclamation and Technical Team acknowledged the potential for interbasin water diversions to influence existing local populations in Missouri River and Red River basins. Species that currently occupy both basins were included on the list of biota of concern, since their potential interbasin water transfer may have adverse impact on fish and wildlife or human health.

† Composite grouping of species of carp originally entering North America from source areas in Asia; species include bighead carp (*Hypophthalmichthys* [*Aristichthys*] *nobilis*), silver carp (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*).

1.3.3 Initial characterization of conceptual model(s) for interbasin water transfers.

As discussed earlier, interbasin water transfers may be associated with biota originating in any of various spatially-linked river or lake basins (Figure 3). Pathways linking Red River basin with surrounding watersheds are numerous, and the number of species potentially capable of being transferred among basins through natural (i.e., not aided by human intervention) or anthropogenic means is practically limitless, being bound only by the species occurrence in source areas. Within a landscape-level setting, however, the issue driving the analysis is focused on species expanding their distributions from Upper Missouri River basin to the Red River basin.

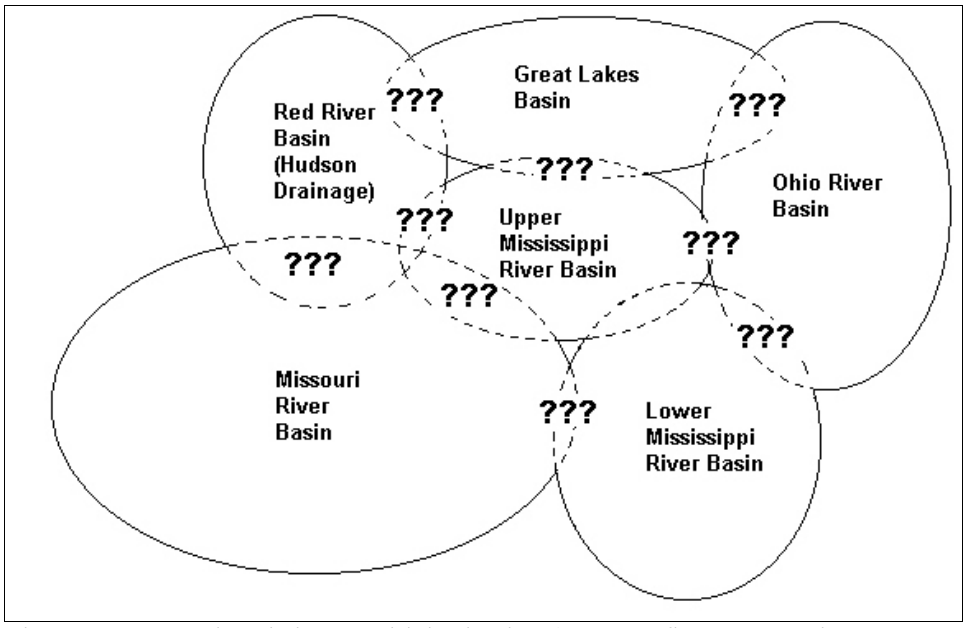

Figure 3. Interrelated river and lake basins ("???" reflect uncertain status of current state of species exchange among watersheds).

Conceptually, the areas surrounding the basins of concern—Upper Missouri River and Red River basins—fit into those regions defined by aquatic resources and used by various environmental management agencies in characterizing the resources for which they are responsible. As presented in Figure 4a and Figure 4b, hydrological unit codes (HUCs) have been assigned to subdivisions of the US by USGS (e.g., Figure 4a) to show major and minor river basins. Each river basin has a numeric code. Major river basins have a 2-digit HUC boundary code, while smaller subbasins nested within a particular 2-digit HUC have 4-, 6-, and 8-digit codes. For example, the Missouri River and Red River basins have 2-digit HUC codes of 010 and 09, respectively, while smaller subbasins within a particular zone would have 4-digit HUCs of 1001, 1002, etc., depending upon the number of topographic basins in the region (here, the Upper Missouri River basin). Subbasins may be further subdivided by using HUC6 and HUC8 identifiers (e.g., NRC 1999).

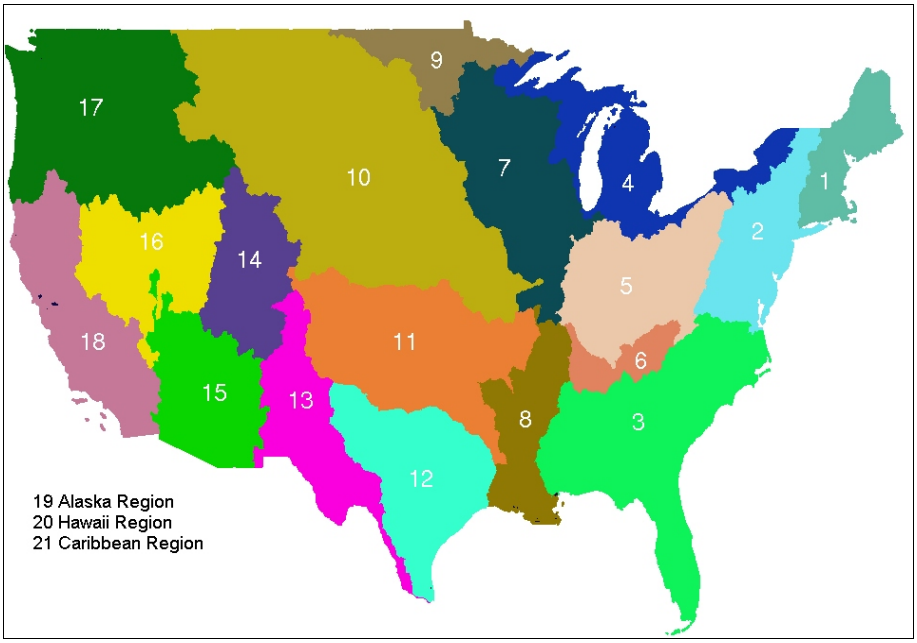

Figure 4a. River basins of the US defined by 2-digit HUCs (hydrological unit codes) of USGS.

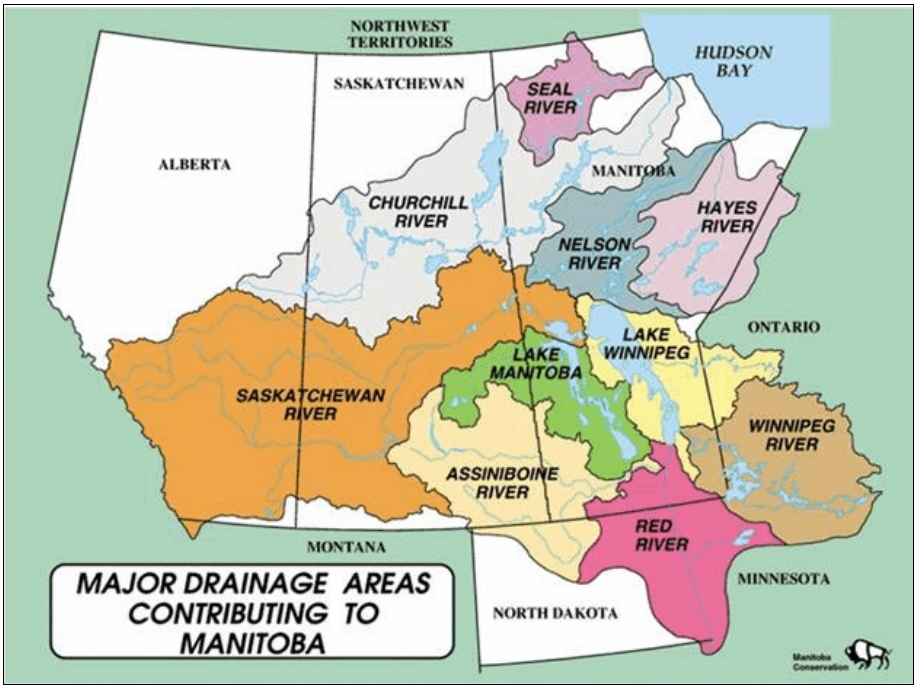

Figure 4b. River basins within the northern Great Plains of US and Prairie Provinces of Canada lying north of Missouri River basin (HUC 10).

HUCs provide a long-practiced technical foundation for the characterization of aquatic regions across the United States, with boundaries and numeric codes being characterized for 21 regions and 222 subregions. Within each region, river basins are specified for drainages of greater than 700 square miles (NRC 1999). While the resolution of available data, e.g., species lists and other information, are not necessarily available for these finer-resolution identifiers, the spatial interrelationships between 4-, 6-, and 8-digit HUCs potentially influence the analysis of biota transfers between the 2-digit HUCs of primary interest, Missouri River (10) and Red River (09) basins. Figure 4 clearly identifies the unique landscape signatures of the Upper Missouri River and Red River basins within the boundaries of the United States, as well as those surrounding basins which bring other potential "biological invaders" to our discussion. Major river and lake basins across continental United States (and North America; see NRC 1999; Abell, et al. 2000) are identified by their 2-digit HUCs. For the current study, Appendix 1 lists 4-digit HUCs within Missouri River (HUC 10) and Souris River-Red River-Rainy River (HUC 09), and Appendix 2 displays aquatic ecoregions of North America with the latter's map illustrating the potential transboundary setting for questions focused on biota transfer.

In setting the stage for the characterization of tools used in the analysis (Section 2) and results of the analysis of risks (Section 3), Figure 3 and Figure 4 illustrate nested landscape-level conceptual models primarily focused on water resources bound by major river and lake basins, which define the spatial context of the analysis in this report. Complementary to these conceptual settings, the nested model(s) that follow are focused on (1) pathways linking those invasive species as emigrants to the Red River basin from the Upper Missouri River basin and (2) "biological agents" or biota of concern, given the regional context for the analysis of biota transfers between Upper Missouri River and Red River basins (i.e., target species presumptively representative of unknown agents potentially subject to interbasin transfer).

1.3.4 Identification of potentially complete pathways. Within the aquatic habitats characteristic of the Upper Missouri River and the Red River, pathways exist that potentially provide "safe passage" from one basin to the other. Pathways are those focused on species potentially associated with interbasin water transfers, with examples being summarized in Figure 5 where broad categories of potential pathways are listed. While expansion of species distributions may occur as a consequence of natural processes that occur in the absence of human intervention, the main focus of the present analysis resides in those anthropogenic events (accidental or intentional) likely to promote a biota transfer either linked to movement of water from one basin to the other or linked to a species' emigration that could be interpreted as a biota transfer mistakenly associated with interbasin water transfers. The misinterpretation of causal linkage(s) between basins will mostly likely result from outcomes that are derivative of competing pathways. While Figure 5 simply lists a single entry for expansion of species distribution in the absence of human intervention, the evaluation of biota transfers mediated by mechanisms other than those associated with anthropogenic activities will be discussed with a particular focus on how such transfers may serve to confound causal linkages characterizing the

transfer process (Section 3; see also Appendix 3A and Appendix 3B). For example, biotic factors other than human-aided transfer (accidental or intentional) will be identified such as vertebrate and invertebrate phoresy (animal transport). Abiotic factors such as wind dispersal will also be noted, again with a particular focus on the role that these alternative mechanisms may play in confounding the characterization of risks associated with interbasin water transfer. Also, factors that are listed as being associated with human intervention, e.g., biological control, may actually represent a combination of mediating factors that are associated with dispersal of invasive organisms or movement of biota from one basin to another. For example, biological control agents such as nonnative predators of pest species may be used in adaptive management programs, and their release, although intentional, may ultimately be recognized as an "invasion," if unintended negative outcomes are realized and their role as control agents is overshadowed by their invasiveness.

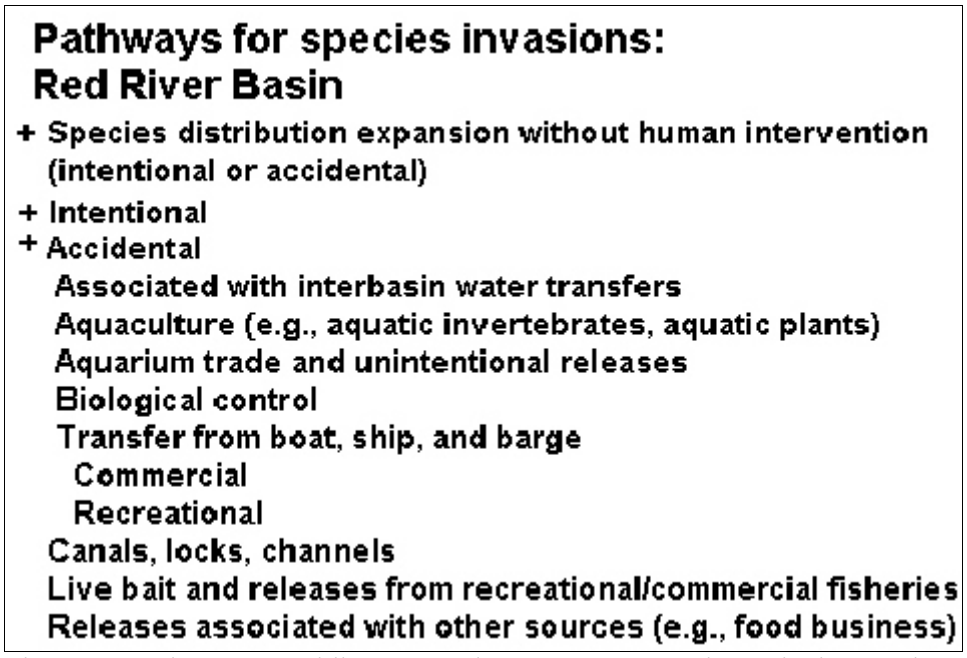

Figure 5. Pathways providing routes between Upper Missouri River and Red River basins (and other biota transfers potential confounding source and receiving water characterizations in this report). Expansion of species distributions associated with factors other than human intervention (accidental or intentional) will consider biotic and abiotic factors directly or indirectly related to the biota transfer process, e.g., animal transport.

1.3.5 Pathways: Linking source and receiving systems. Efforts to characterize the process of linking source areas for biological invasions with receiving areas (e.g., see http://www.invasivespecies.gov/vectors/main.shtml) apply common themes to their analysis and discussion of pathways. Here, an evaluation of biological invasions follows a process consistent

with that reflected in the current effort where two complementary tasks: a life-history characterization task and a pathways task were considered. Given stakeholder input during Problem Formulation, selection of biota of concern was a collaborative effort in this iteration of the evaluation of risks. Subsequent iterations of the risk-assessment process could incorporate "screening" tasks in order to rank representative biota with respect to their risk as invasives.

As a derivative of the biota of concern selection process, the evaluation of economic consequences of biota transfers potentially associated with water diversions from the Missouri River basin to the Red River basin will focus on case study analyses supported by data sufficient to the analysis. As such, the selection of biota of concern captured a wide range of potential biota of concern which are intended as representative species that present life-history attributes amenable to generalizations regarding the invasiveness of other biota characterized by similar life-history attributes. The nearly limitless variety of life-forms potentially acting as biological invaders precludes a simple "one model suits all" analysis, an analysis option that would highly likely yield uncertainties that merit technical scrutiny.

Complementary to the collaborative effort undertaken with the Technical Team to develop a list of biota of concern, a pathways analysis was pursued, in part because of the multiple exchange venues and mechanisms that are characteristic of complex adaptive systems such as those of the northern Great Plains. While the primary focus of the current analysis resides with biota transfers between the Missouri River and Red River basins directly related to water-diversion structures or processes, a larger spatial scale must be incorporated into the analysis of pathways, since these alternative pathways potentially serve as confounding factors in the characterization of risks.

Ideally, a proactive analysis of pathways helps to reduce risk of unintentional or accidental introductions of species that would expand their distributions, if they become established in the Red River basin. Introductions of plants, animals, and other biota may be accepted within the context of the current investigation, but these acceptable "imports" to the Red River basin (e.g., as species expansions that have been ongoing since the northern Great Plains was released from Laurentian glaciations) potentially act as confounding, coincidental linkages between source, or exporting, region (Missouri River, HUC10) and receiving, or importing, region (Red River, HUC09). Also, organisms characterized as "acceptable" introductions (for example, for commercial or recreational purposes) are likely confounding agents in the characterization risk, since pathways for these accepted introductions may affect the subsequent importation of associated, but unintended organisms, including insects, other invertebrates, aquatic animals, terrestrial vertebrates, disease pathogens, and plant seeds and propagules.

The outcomes of Problem Formulation, and in particular the (1) biota of concern, (2) pathways of concern (both water diversion and potentially confounding alternative pathways for

biota transfer), (3) spatial interrelationships between Missouri River basin and Red River basin, and (4) spatial interrelationships among these basins and other lake and river basins adjacent to the basins of concern, guided the development of the technical support structure summarized in the Section 2 and influenced the tools selected for the analysis of risks and economic consequences.

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