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RED RIVER VALLEY WATER SUPPLY PROJECT
BIOTA TRANSFER
SPECIFIC PLAN OF STUDY

RISK AND CONSEQUENCE ANALYSIS FOR BIOLOGICAL INVASIONS POTENTIALLY ASSOCIATED WITH INTER-BASIN WATER TRANSFERS: PROBLEM FORMULATION AND DEVELOPMENT OF THE CONCEPTUAL MODEL

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PRELIMIARY DRAFT

RED RIVER VALLEY WATER SUPPLY PROJECT

BIOTA TRANSFER

SPECIFIC PLAN OF STUDY

INTRODUCTION

Development of a quality water supply of sufficient quantity for the Red River Valley in North Dakota has been a subject of interest and concern to local residents, government officials, and others. On December 15, 2000, the 106th Congress passed the Dakota Water Resources Act of 2000 (DWRA), which was signed into law on December 21, 2000. Sections 5 and 8 of DWRA authorize the Red River Valley Water Supply Project (Red River Project). The Act directs the Secretary of Interior to conduct a comprehensive study of the water quality and quantity needs of the Red River Valley in North Dakota and possible options for meeting those needs. The Biota Transfer Specific Plan of Study (SPOS) identifies tasks which when completed will assist in the evaluation of risks and consequences of biological invasions associated with potential inter-basin water transfers between the Upper Missouri River and Red River basins as part of the Red River Valley Water Supply Project EIS process.

The general outline for the development of the Red River Project is provided in the Master Plan of Study (MPOS). The MPOS provides additional background, authority, scope, process, purpose, and overview of all study activities.

BIOTA 1 - STUDY AND RISK ANALYSIS OVERVIEW

The Bureau of Reclamation (Reclamation) requested technical support from USGS Columbia Environmental Research Center (CERC) for an evaluation of risks and consequences of biological invasions associated with potential inter-basin water transfers between the Upper Missouri River and Red River basins as part of the Red River Valley Water Supply Project EIS process (EIS 7.1.4). This expanded study plan is intended to characterize activities that CERC staff and their Department of the Interior partners will follow in completing this technical support project. A brief description of the risk analysis, and its incorporation into the National Environmental Policy Act (NEPA) process, is provided in EIS 7.1.4.

Risk analysis, and the subsequent process of assessing risks and consequences of targeted events, has a wide range of applications to

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

Each of these facets of the general process is relevant to issues that Reclamation faces in their management of water resources across the western United States. 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 (ASTM 2001, EPA 1992, EPA 1998, Levin 1989, NRC 1983, NRC 1994, Suter 1993). Decisions that result from the initial assessment may (1) yield sufficient management-critical support to respond to outcomes of 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 iterate were not sufficient to support management decisions within the level of uncertainty reflected by the risk-tolerance of the decision-makers. Additionally, sufficient technical support for a given management decision may be apparent following completion of the process, and as part of future planning, 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. 2001a, 2001b).

CERC will conduct technical analysis of risks and consequences associated with biota transfers potentially associated with inter-basin water transfers following the available guidance (ASTM 2001, EPA 1992, EPA 1998, Levin 1989, NRC 1983, NRC 1994, Suter 1993), including that developed for hazard and critical control point analysis for aquatic nuisance species and similar applications (Minnesota Sea Grant/Michigan Sea Grant 2001).

BIOTA 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 inter-basin water transfers, a conceptual model or nested conceptual models should be developed to characterize issues currently related to biota transfers associated with proposed inter-basin water transfers (ASTM 2001, EPA 1992, EPA 1998, Levin 1989, NRC 1983, NRC 1994, Suter 1993, Minnesota Sea Grant/Michigan Sea Grant 2001). This section includes preliminary models developed to meet this objective wherein (1) biota of concern (both potential and selected representative species) are identified and characterized with respect to their biological and ecological attributes promoting their transfer and establishment in previously unoccupied areas (e.g., life history attributes likely to influence invasiveness); (2) pathways are initially characterized that potentially link biota of the Upper Missouri River basin (source area) with the Red River basin (receiving area), acknowledging life history attributes that might enhance the likelihood for invasion and establishment; and (3) ecological receptors likely adversely impacted by invasive species are identified for the subsequent risk and consequence analysis. The identification of biota of concern will be based on the characterization of candidate species and pathways linking those species to the Red River basin, and the selection of representative invasive species that capture the range of biota potentially available for emigration from the Upper Missouri River basin (Minnesota Sea Grant/Michigan Sea Grant, 2001).

Pathways and potential risks associated with biota transfers should be described in a conceptual model that is a graphic representation of the environmental conditions of concern in the analysis (e.g., potential linkage of sources and receptors via pathways; ASTM 2001, EPA 1992, EPA 1998, Levin 1989, NRC 1983, NRC 1994, Suter 1993, Minnesota Sea Grant/Michigan Sea Grant 2001). As such, the conceptual model is developed early in the risk assessment process and is a critical outcome of problem formulation. The conceptual model may be refined through an iterative process as more data become available and stakeholder input is acquired. Ideally, the conceptual model helps identify uncertainties and data needs so that technical analysis completed in the risk assessment process can be minimized. In part the conceptual model helps identify ecological receptors most likely impacted by exposure to biological stressors, and if appropriate, identify representative invasive species and assessment endpoints selected to characterize potential adverse effects associated with a biological invasion.

Biota 2.1 - Initial Characterization of Conceptual Model(s) for Inter-basin Water Transfers

This section summarizes the basin-specific implementation of ecological and human health risk assessment guidance (ASTM 2001, EPA 1992, EPA 1998, Levin 1989, NRC 1983, NRC 1994, Suter 1993, Minnesota Sea Grant/Michigan Sea Grant 2001), with a particular emphasis on the evaluation of biological stressors (here, invasive biota). In general, the risk assessment process evaluates the likelihood that adverse effects may occur as a result of exposure to one or more stressors, including biological stressors that can induce an adverse ecological response or mediate adverse effects on public health via transmission of disease-causing agents.

As summarized in Figure 1, inter-basin water transfers may be associated with invasive species originating in any of various spatially-linked river or lake basins. Within a landscape level

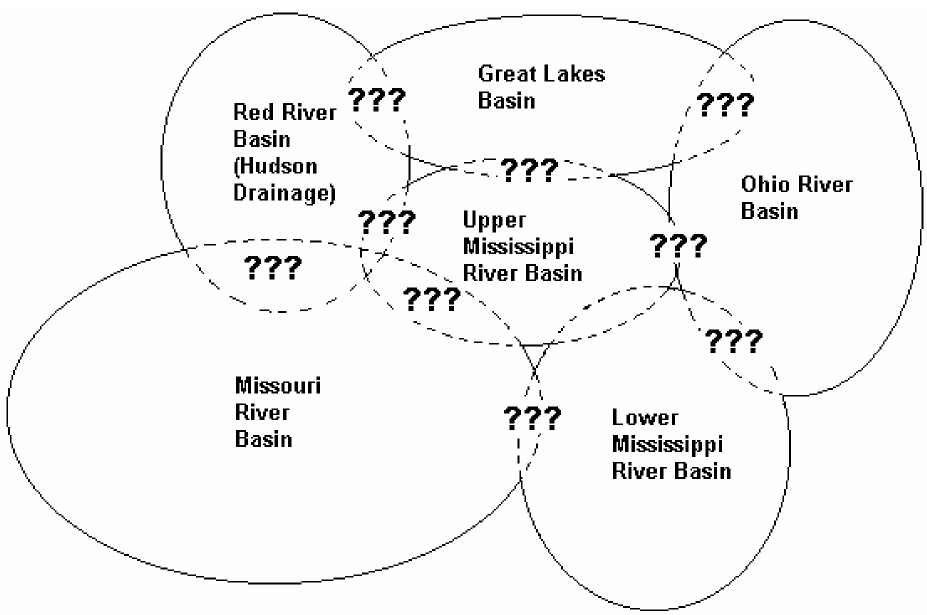

Figure 1. Interrelated river and lake basins.

setting, however, the issue driving the analysis is focused on invasive species expanding their distributions from the Upper Missouri River basin to the Red River basin. 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. Figure 2 (at the end of this section), for example, 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 that bring other potential invaders to our discussion. Here, 2-digit hydrological units codes (HUCs) are used to define major river and lake basins across the continental United States (and North America; see NRC 1999; Abell, *et al*. 2000). Appendix 1 and Appendix 2 list HUCs of specific interest and display aquatic ecoregions of North America, respectively, with the latter's map illustrating the potential transboundary setting for questions focused on biota transfer.

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As presented in Figure 2, HUCs are subdivisions of the United States made by USGS 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 sub-basins nested within a particular 2-digit HUC have 4-, 6-, and 8-digit codes. For example, a large river basin zone may have a HUC2 code of 010 or 09 for the Missouri River and Red River basins, respectively, while smaller sub-basins 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). Sub-basins may be further sub-divided by using HUC6 and HUC8 identifiers (e.g., NRC 1999). As such 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. With 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.

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For the present analysis, the focus resolves about Region 10, the Missouri River basin, and Region 09, the Souris-Red-Rainy River basins. Compared to the Missouri River basin, Souris-Red-Rainy basin (Region 09) covers a relatively small area, but includes a well-characterized drainage within the United States and Canada. Within the United States, the region includes the Lake of the Woods and the Rainy, Red, and Souris River basins that ultimately discharge into Lake Winnipeg and Hudson Bay. The region includes parts of Minnesota, North Dakota, and South Dakota, and consists of three subregions, two of which are spatially juxtaposed to subregions of the Missouri River basin (Region 10). Within the United States two subregions will be of primary interest. The Souris subregion (0901) includes the Souris River basin within North Dakota and Subregion 0902, the Red River basin, occurs within Minnesota, North Dakota, and South Dakota, including the closed basin of Devils Lake.

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In contrast to Region 09, the Region 10 is spatially quite extensive. The Missouri River basin includes the drainage of the Missouri River basin and several small closed basins with the area. Geographically, the Missouri River basin includes all of Nebraska and parts of Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, North Dakota, South Dakota, and Wyoming. Numerous subregions occur within the region, but the present analysis will focus on those likely to influence or those immediately adjacent to neighboring 2-digit HUCs in Region 09 and, to a lesser extent, Region 07. For example, Missouri-Poplar (Subregion 1006) covers the drainage from Fort Peck Dam to the confluence with the Yellowstone River basin in western Montana and will be viewed within the context of source area for biological invaders of aquatic from the west. Invasions of Region 09 from pathways other than those associated with inter-basin water transfers will be critical to the evaluation of confounding risks. And, although distant from either Region 07 or Region 09, as a source area for invading biota potentially misassigned to origins of inter-basin transfer, the region (as well as headwaters of the Missouri River) will be considered as a potential confounding factor in the analysis.

Similarly, the Missouri-Marias (Subregion 1003), which consists of the Missouri River basin below the confluence of the Gallatin, Jefferson, and Madison River basins to and including the Marias River basin of Montana, will be considered within the context of source areas outside the inter-basin focus. Other 4-digit HUCs of the Upper Missouri River basin will also be incorporated into the analysis, given their potential role as source areas of potential emigrants to the Red River basin of Subregion 09.

For example, Subregion 1011, the Missouri-Little Missouri basin occurs below the confluence with the Yellowstone River basin and extends to Garrison Dam, including Lake Sakakawea. As such, an area of 17,300 square miles of Montana, North Dakota, South Dakota, and Wyoming potentially provide sources of western-origin invasives. Similarly, the Sheyenne River basin (Subregion 1012), which occurs above the normal operating pool of Lake Oahe and includes drainage in Montana, Nebraska, South Dakota, Wyoming, and Missouri-Oahe of North Dakota and South Dakota (Subregion 1013, which includes the Missouri River basin from Garrison Dam to Oahe Dam, excluding the Sheyenne River basin above the normal operating pool of Lake Oahe) will be considered as confounding sources for biotic invasions.

Subregions of the Missouri River basin that occur below the Garrision Dam will also be key to the analysis of biota transfers potentially linked to inter-basin water transfers. These are numerous and include:

- Subregion 1014, the Missouri-White, which includes the basin from Oahe Dam to Fort Randall Dam within South Dakota and Nebraska.

- Subregion 1015, the Niobrara River basin and Ponca Creek basin of Nebraska, South Dakota, and Wyoming.

- Subregion 1016, the James River basin of North Dakota and South Dakota.

- Subregion 1017, the Missouri-Big Sioux subregion which includes the Missouri River basin from Fort Randall Dam to and including the Big Sioux River basin, but excluding the Ponca Creek, Niobrara River, and James River basins (and including part of Iowa, Minnesota, Nebraska, South Dakota).

- Subregion 1018, the North Platte River basin of Colorado, Nebraska, Wyoming.

- Subregion 1019, the South Platte River basin of Colorado, Nebraska, Wyoming.
- Subregion 1020, the Platte River basin below the confluence of the North and South Platte River basins, excluding the Elkhorn and Loup River Basins of Nebraska.
- Subregion 1021, the Loup River basin of Nebraska.
- Subregion 1022, the Elkhorn River basin of Nebraska.
- Subregion 1023, the Missouri-Little Sioux subregion which in Minnesota, Iowa, and Nebraska and occupies the Missouri River basin below the confluence with the Big Sioux River basin to the confluence with the Platte River basin.
- Subregion 1024, the Missouri-Nishnabotna subregion of Iowa, Kansas, Missouri, and Nebraska which occurs below the confluence with the Platte River Basin to the confluence with the Kansas River Basin.
- Subregion 1025, the Republican River Basin of Colorado, Kansas, Nebraska.
- Subregion 1026, the Smoky Hill River Basin of Colorado and Kansas.
- Subregion 1027, the Kansas River Basin of Kansas, Nebraska, and Missouri, excluding the Republican and Smoky Hill River Basins.
- Subregion 1028, the Chariton, Grand, and Little Chariton River basins of Iowa and Missouri.
- Subregion 1029, the Gasconade-Osage subregion, which includes the Gasconade and Osage River basins of Kansas and Missouri.

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- Subregion 1030, the Lower Missouri River Basin that occurs in Kansas and Missouri below the confluence with the Kansas River Basin to the confluence with the Mississippi River, excluding the Chariton, Gasconade, Grand, and Osage River basins.

While tracing potential linkages between biota from Region 10 and those of Region 09 will likely not be resolved at the 4-digit HUC level, focusing on HUCs immediately bordering the Missouri River and those immediately adjacent to 4-digit HUCS within Region 09 will assure a characterization of necessary and sufficient conditions in the diagnosis of potential sources for invasives and other emigrants to the Red River basin (Serrano 2001). Given its proximity to the inter-basin boundary of primary interest in the present analysis, Region 07, Upper Mississippi River basin, will necessarily be incorporated into the differential analysis required of the risk assessment for biological invasions associated with water transfers from Missouri River to Red River basins. The Upper Mississippi River basin (Region 07) includes the drainage of the Mississippi River Basin above the confluence with the Ohio River, excluding the Missouri River basin. As such, the region includes parts of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, South Dakota, and Wisconsin, so potential spatial linkages between 2-digut HUCs on the northern and western boundaries of Region 07 are apparent. There are numerous subregions within the Upper Mississippi River basin spatially juxtaposed to the Souris-Red-Rainy and Missouri River basins, including:

- the Mississippi Headwaters (Subregion 0701) which includes the Mississippi River Basin above the confluence with the St. Croix River Basin, but excluding the Minnesota River Basin.

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- the Minnesota River Basin (Subregion 0702) of Iowa, Minnesota, South Dakota,

- the Upper Mississippi-Salt basin (Subregion 0711) which includes parts of Illinois, Iowa, and Missouri, and marks the Mississippi River Basin below the confluence with the Des Moines River basin to the confluence with the Missouri River basin, excluding the Illinois River Basin.

- the Upper Mississippi-Kaskaskia-Meramec (Subregion 0714) which includes parts of Illinois and Missouri that occur in the Mississippi River basin below the confluence with and excluding the Missouri River Basin to the confluence with the Ohio River.

As noted earlier in the discussion on HUCs, various sub-divisions have been delineated within these and other 4-digit HUCs of the Upper Mississippi River basin, including those most likely of concern as confounding sources for the analysis of inter-basin water transfers. Although not exhaustive of potential sources of confounding variables, spatial linkages between regions will be incorporated into the analysis of risks potentially linked to inter-basin transfers between Missouri River basin and Red River basin, and relying on 4-digit HUCs illustrates the basis wherein uncertainty due to multiple potential source areas is concerned.

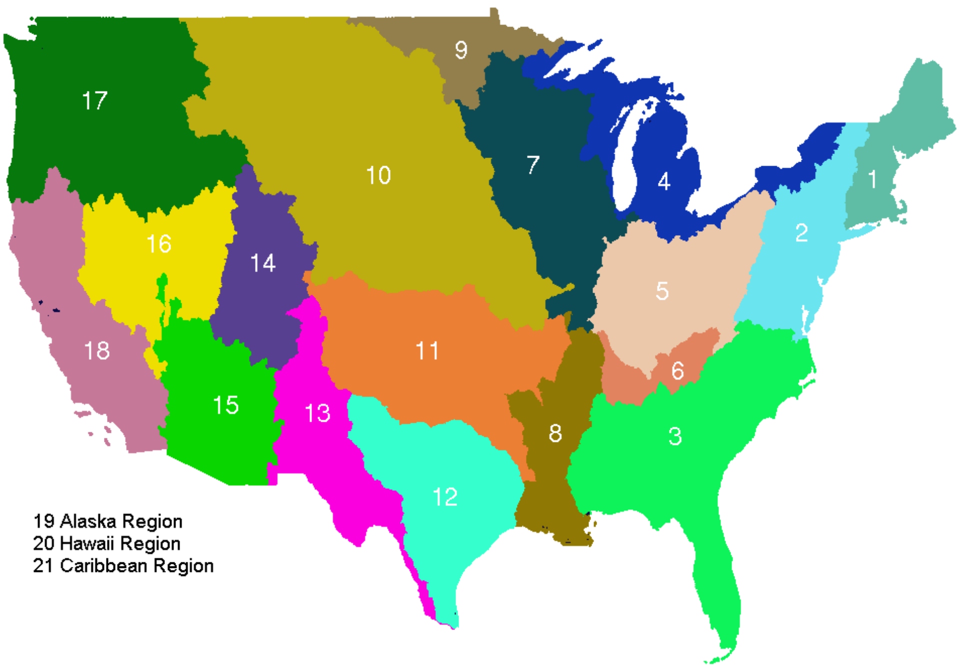

Figure 2. Regions of the United States based on aquatic resources as defined by 2-digit HUCs (hydrological unit codes) of USGS.

In setting the stage for the analysis, Figures 1 and 2 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" 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 inter-basin transfer).

Biota 2.1.1 - 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. Here, pathways are those focused on invasive species potentially associated with inter-basin water transfers that are summarized in Figure 3 below. 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 inter-basin water transfers.

Pathways for species invasions: Red River Basin

+ Species distribution expansion without human intervention (intentional or accidental)
+ Intentional
+ Accidental
  - Associated with interbasin water transfers
  - Aquaculture (e.g., aquatic invertebrates, aquatic plants)
  - Aquarium trade and unintentional releases
  - Biological control
  - Transfer from boat, ships, and barge
    - Commercial
    - Recreational
  - Canals, locks, channels
  - Live bait and releases from recreational/commercial fisheries
  - Releases associated with other sources (e.g., food business)

Figure 3. 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.

While Figure 3 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. 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 characterized, 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 non-native 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.

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Biota 2.1.2 - Identification of Biota of Concern

For purposes of the present study, which is focused on biological invasions potentially associated with inter-basin water transfers, definitions of terms are critical to the analysis. Five terms in particular must be clearly understood. An "introduction" means the intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity. "Native species" are those that, other than as a result of an introduction, historically occurred or currently occurs in specific region. An "alien species" means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem. In contrast, our definition of "invasive species" follows as an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Office of the President, Executive Order 13112, 1999). Although not an alien or invasive species, a limited focus of the analysis will also fall on biota transfers between regions that merely reflect a movement of species across basin boundaries; that is, the species presently occurs in each region but the inter basin transfer of water expedites movements of subpopulations between regions. Although not invasions by definition, potential biota of concern in the present analysis is extended to include selected species that are present in each basin regardless of population levels and current distributions, and potentially associated with adverse impacts on public or ecological health.

Species lists (as available) for Red River and Upper Missouri River basins will be used to compile candidate lists of potential alien species. Then representative or otherwise selected species (e.g., widely known as invasive species) will be identified as either [1] species likely to emigrate from Upper Missouri River basin to Red River basin or [2] ecological receptors, those species in Red River basin likely to be adversely affected if a given species invades from the Upper Missouri River basin. Any given invasive species may impact single- or multiple-species as ecological receptors. The species identified as "likely to emigrate" are biota of concern and those species "likely to be adversely affected" are ecological receptors adversely impacted as a consequence of invasion. A draft list of biota of concern is identified in Table 1. Criteria for inclusion on this draft list of biota of concern were:

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- organisms identified as biota of concern were included on lists of invasive species previously compiled by the Invasive Species Council or similar organizations, with a particular emphasis on lists having geographic origins in the northern Great Plains and Great Lakes regions;
- organisms identified as biota of concern were cited by Centers for Disease Control and Prevention as causative agents of water-borne disease in the states of the northern Great Plains;
- organisms identified as biota of concern have been reported as disease-causing agents in fish, wildlife, or domestic livestock; and
- initial literature surveys suggested that these species might be support by data previously published or available for analysis.

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

Aquatic plants and algae: **Blue-green algae (Cyanobacteria)** *Anabaena flos-aquae** *Microcystis aeruginosa** *Aphanizomenon flos-aquae**	**Microorganisms and Disease Agents:** **Protozoa and Metazoa** *Myxosoma cerebralis (Myxobolus cerebralis)* *Polypodium hydriforme* *Cryptosporidium parvum*[1]* *Giardia lamblia**
Vascular plants Hydrilla (*Hydrilla verticillata*) Eurasian water-milfoil (*Myriophyllum spicatum*) Water hyacinth (*Eichhornia crassipes*)	**Bacteria and viruses** 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)*
Aquatic invertebrates: **Mollusks** *Dreissena polymorpha* (zebra mussel) *Corbicula flum*inea (Asiatic clam) *Potamopyrgus antipodarum* (New Zealand mud snail)	**Aquatic vertebrates** Gizzard shad (*Dorosoma cepedium*) Rainbow smelt (*Osmerus mordax*)
Crustaceans *Bythotrephes cederstroemi* (spiny water flea)	**Invasive biota associated with sludge disposal** TBD

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*Salmonella typhi**

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Biota 2.1.3 - Identification of Ecological Receptors Adversely Affected by Biological Invasions

In our current application, ecological receptors of concern are those native biota (native species) of the Red River Basin most likely adversely affected by a successful biological invasion by biota that compete (directly or indirectly). For example, Zebra mussels (e.g., Johnson and Padilla 1996, Johnson and Carlton 1996, Johnson *et al.* 2001) are well characterized with respect to their competitive advantage over indigenous bivalves, and salmonids are potentially ecological receptors adversely affected by a successful invasion of whirling disease, *Myxosoma cerebralis (Myxobolus cerebralis)* (Noga 1996). As outputs of the analysis, more detailed summaries of the risks and consequences associated with these invasions, as well as others linked to the list of biota of concern (Table 1) and mostly likely impacted ecological receptors will be developed.

Biota 2.1.4 - Summary Conceptual Model for Biological Invasions of Red River Basin from Upper Missouri River Basin

A summary conceptual model incorporates sources of invasive species from the Upper Missouri River basin emigrating to the receiving Red River basin through various pathways, including those [1] directly reflecting inter-basin water transfers proposed as an alternative in the Red River Valley Water Supply Project (Red River Project), [2] others invasions mediated by alternate routes of invasion dependent on human intervention (but not Red River Project-related), or [3] invasions independent on anthropogenic activities (Figure 4).

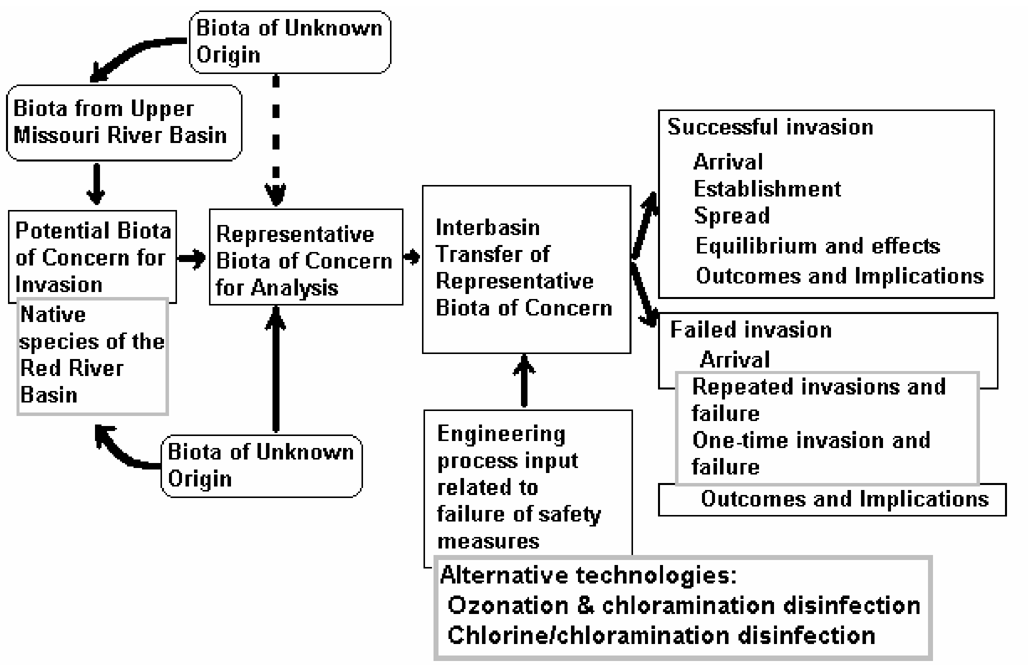

Figure 4. Conceptual model reflecting invasion process given pathways and basins identified in Figure 1 and Figure 2.

Biota 2.1.4.1-Assessment Endpoints

[1]Asterisk (*) indicates the organisms is not invasive, but may be transported via interbasin water transfer and have adverse impact on fish and wildlife or human health.

During problem formulation, assessment endpoints may be selected for risk assessment. Agreed-upon assessment endpoints represent valued ecosystem components to be protected, usually species populations and habitats, and reflect all complete or potentially complete exposure pathways identified during preliminary problem formulation in the screening-level ecological risk assessment. Good assessment endpoints are ecologically relevant, measurable or predictable, susceptible to biological stressors such as invasive species, logically related to environmental management and policy decisions, and are socially relevant (EPA 1992, EPA 1998, Levin 1989, Suter 1993, Minnesota Sea Grant/Michigan Sea Grant 2001) as illustrated below.

Population-level	**Community-level**	**Ecosystem-level**
Extinction	Market/sport value	Productive capability
Abundance	Recreational Quality	
Yield/Production	Change to less useful/ desired type	
Age/size class		
Structure		
Disease		

If appropriate, assessment endpoints should include measurable ecosystem effects, including public health endpoints, and measurable effects at lower levels of organization (e.g., populations, communities, or habitats). Measurements of ecological effects at lower levels of organization should be considered and may be important even if these are not linked to assessment endpoints addressing ecosystem effects. During the development of assessment endpoints, ecological relevance is an important consideration in selecting appropriate ecological receptors representing the assessment endpoints. From ecological and public health perspectives, relevant conditions are illustrated by:

- Absence of a species normally expected to occur
- Reduction in population size
- Change in community structure
- Habitat degradation or loss
- Diminishment or loss of ecological function

Biota 2.1.4.2-Measures of Adverse Effects

Measurements of adverse effects, traditionally identified as measurement endpoints, are used to quantify exposure and effects in the risk assessment. Good measurement endpoints correspond to, or are predictive of, the selected assessment endpoints. The conceptual model should illustrate linkages between assessment endpoints and measurement endpoints. For the present study, our focus on invasive species or species having otherwise adverse impacts on receptors (ecological or public health) expedites the identification of measures of adverse effects, and their linkage to assessment endpoints assures a technically founded transition between non-economic and economic aspects of the risk and consequence analysis.

Biota 2.1.4.3-Pathway Analysis

The analysis pathway combines spatial and temporal distributions of sources and receptors. As such, a brief listing of pathways in Figure 3 clearly suggests modes of transit that potentially serve the summary conceptual model of Figure 4. In part, the inter-basin transfer scenarios will be straight-forward in analysis. Differentiation between invasions associated with intentional transfers from those that are unintentional and largely accidental will be critical to the uncertainty analysis and associated evaluation of economic consequences of biota transfers in general and those dependent on inter-basin transfers derived from proposed RRVWSP activities.

Biota 2.1.4.4 -Characterization of Risk

The primary tasks that characterize this objective of the current study focuses on the derivation of estimates of risk and the consequences potentially associated with those risks. Although oversimplified for our present purposes (and highly dependent on data sufficient for implementation), in general the analysis of risks will consider conditional probabilities that describe the invasion of the Red River basin by any species originating from the Upper Missouri basin as:

$$P(Ai|B) = \frac{P(B|Ai)P(Ai)}{\sum_{j=1} P(B|Aj)P(Aj)}$$

where the event, Ai, is predicated on B repeatedly over space-time. Such tools are commonly applied to engineering systems (Bedford and Cook 2001, Serrano 2001) and biological systems, including species invasions (Hayes 1996, Levin 1989, Williamson 1989, Williamson 1996, Paine, et al. 1998). Biologically, the generalized event might be "successful biological invasion of Red River basin by biota originating from Upper Missouri River basin." Here, the success of invasion would be predicated on prior events occurring such as [1] "biota transfer successfully completed," [2] "invasive species established a reproductive population," and [3] "a reproductive population attains sustainable numbers to compete against indigenous species," with each prior event amenable to decomposition and more comprehensive characterization as data allow (e.g., pathways may be incomplete, biota transfer from source area may not lead to establishment of invasive species population given failure to find suitable habitats or hosts, etc. in the target area). Ultimately, the statements of probability of invasive species established in the target area (Red River basin) would be developed for each of the biota of concern identified in the conceptual model(s).

The derivation of probabilities for biota of concern will only be as good as the data used in their calculation, which necessarily means the characterization of risks must be completed in parallel with an evaluation of data quantity and data quality. As a source of uncertainty, data quality and quantity will be critical to the interpretation of species invasion probabilities. Also, uncertainty will vary from one species to the next, depending on the available data; hence, risks dependent on probability estimates will also be characterized by an estimate of the associated uncertainty.

Consequence analysis will be completed in conjunction with the risk analysis that yields probability estimates for species invasions. The consequence analysis will be conducted using a customary "cost-benefit analysis" approach dependent on analysis tools common to natural resource or environmental economics (Belzer 2001, Costanza, et al. 1997, Field 1996, Field 2000, Hartwick and Olewiler 1998, Hill and Greathead 2000, Knowler and Barbier 2000, Pimintel et al. 2000). Also, given the similarities in the economic tools applied to the calculation of restoration and compensatory costs in Natural Resource Damage Assessments (NRDA) and their intentional comparative application, once existing data have been reviewed and evaluated with respect to their quality and quantity, the evaluation of costs and benefits associated with

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water transfers will incorporate NRDA-like analysis as appropriate (e.g., NOAA 1997). For example, the costs of compensatory measures that offset the loss of wildlife habitat function associated with invasive species could be incorporated through Habitat Equivalency Analysis.

Also, tools available to the natural resource and environmental economist will be applied to resource valuation, including those tools applied to non-market valuation and characterization of non-use, option, and existence values.

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Confidence in the conclusions of risk characterization may be increased by using several lines of evidence to interpret and compare risk estimates, including an evaluation of the relevance of evidence to the assessment endpoints, the relevance of evidence to the conceptual model, the sufficiency and quality of existing data, the strength of cause and effect relationships noted in comparative studies, and the relative uncertainty associated with each line of evidence and the concordance (or absence of concordance) across various lines of evidence.

Biota 2.1.4.5 - Focus on Ecological Adversity

Risk characterization should discuss whether ecological receptors exposed to invasive species that are capable of causing harm, can cause adverse effects to the overall ecosystem or to the particular valued species within that ecosystem (assessment endpoint). Risk characterization also includes a discussion of whether ecological receptors may be adversely affected in the future (EPA 1992, EPA 1998, Suter 1993, Minnesota Sea Grant/Michigan Sea Grant 2001).

The nature and intensity of effects should be evaluated to distinguish adverse effects from effects occurring within the normal patterns of variability. Spatial and temporal scales also need to be considered in assessing adverse effects. The spatial dimension involves both the extent and pattern of adverse effects, as well as the context of the effects within the ecosystem. Factors to consider include the absolute area affected, the extent of sensitive habitats affected compared with a larger area of interest, and the current and future land and water use within the ecosystem. The temporal scale of adverse effects for ecosystems can vary from short-term (e.g., seconds to minutes to days for altered photosynthesis yielding advantages to invasives for establishing sustainable populations) to long-term (e.g., decades to centuries for adverse effects reflected in changes in biodiversity). Risk assessors should recognize that the time scale of adverse effects operates within the context of multiple natural time scales. For example, visible changes in the productivity of an aquatic system may not become evident for many years after initial biological invasion.

The potential for recovery of a system should also be considered in assessing ecological adversity. Recovery is the rate and extent of return of a population or community to a condition that existed before the introduction of invasive species. Examples include reestablishment of a species to a specified density or re-colonization during recovery following removal of a biological invader.

Biota 2.1.4.6 - Uncertainty Analysis

A discussion of uncertainties or the lack of relevant information is a necessary part in an even-handed characterization of risks associated with a biological invasion. Sources of uncertainty contribute to possible overestimation or underestimation of ecological risks. The objective of uncertainty analysis is to describe and quantify, where possible, what is known and not known about exposure and effects. Uncertainty analysis increases assessment credibility by explicitly characterizing the magnitude of uncertainties and their relationship to risk characterization (ASTM 2001, EPA 1992, EPA 1998, Levin 1989, NRC 1983, NRC 1994, Suter 1993, Minnesota Sea Grant/Michigan Sea Grant 2001, Bedford and Cooke 2001, Serrano 2001).

Uncertainties may be addressed and their effects minimized for any risk assessment, with the results of uncertainty analysis being used to identify data gaps and direct data collection activities. For the evaluation of biota transfers and the biological invasions subsequent to water transfers between Upper Missouri basin and Red River, species distributions will be critical data to the risk analysis. Additionally, and as available, the risk analysis will depend on data that reflect a quantitative basis for evaluating the transfer and establishment of invasive species; the spread and development of equilibrium populations of invasive species; and the effects and potential implications of invasive species. For example, although data may not be sufficient for each biota of concern, demographic data related to life table analysis would ideally be applied to the analysis wherein survivorship and maternity functions and reproductive rates would be

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considered as a basis of analysis. Ecologically, habitat data may be critical to the analysis (e.g., habitats not sufficient to sustain an invading species) as would potential environmental or engineering data that suggest limitations to successful invasions (e.g., ambient temperature extremes or water treatment may limit success). Similarly, data critical to a fully developed consequence analysis would encompass biological data (e.g., species distributions, functions key to life table analysis) and economic data essential to an analysis of the impacts of invasive species, and the determination of compensatory measures sufficient to offset those impacts.

The methodological approach will largely be observational and will rely on existing data or information in the form of peer-reviewed literature or government documents. Analytically and statistically, as possible, these encountered data will be reviewed for data quality, and when possible, primary data sources will be used in developing the risk and consequence analysis objectives of the study. Tools selected for the analysis will reflect the contingencies predicated by available data, and will included those tools commonly applied to encountered data analysis (Cochran 1977, Hayes 1998, Kalbfleish and Prentice 1980, Lee 1992, Levin 1989, Sokal and Rohlf 1981, Tukey 1977, Zar 1999). In the absence of primary data, peer-reviewed literature from open sources will be relied upon, as well as government documents that have met data quality objectives specified for the project reports being reviewed.

Biota 2.2 - Engineering Specifications

Specific technologies identified (Eng 1.4) that reduce the risk of transfer of biota of concern will be incorporated into the risk analysis. The recommendations provided by Engineering 1.4 that meet some (currently undetermined) acceptable level of risk will be used in the design of all features associated with the reduction of biota transfer for each trans-basin alternative. Specific technologies determined to be inadequate, based on the risk analysis, will be eliminated.

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BIOTA 3 - RISK ANALYSIS REPORT

Biota 3.1 - Draft Risk Analysis Report and Progress Reports

A draft Risk Analysis report will be completed following the identification of alternatives for preliminary study. The report will include the specific items discussed in this SPOS. In addition to the draft report, specific interim progress reports may be completed. Interim progress reports will be distributed to members of the Technical Team for technical review.

Biota 3.2 - Review Risk Analysis Report

Upon completion of the draft Risk Analysis report, the report will be distributed for Reclamation review. Following Reclamation review, the report will be distributed to members of the Technical Team and an independent outside entity (e.g., National Academy of Science) for review.

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Biota 3.3 - Complete Risk Analysis Report

Following review, a final Risk Analysis Report will be prepared. The conclusions from the final report will be incorporated into the alternatives evaluation process of the EIS (EIS 7.1.4).

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Appendix 1. HUCs (2-digit and 4-digit) of particular interest in the evaluation of biota transfers between Missouri River and Red River basins. Not all subregions are listed for each region, but these subregions represent those mostly closely associated (spatially) with geographic locations likely serving as routes of entry (NRC 1999).

Region	**Subregion**	**Name or comment**
Region 09		Souris-Red-Rainy basin
	Subregion 0901	Subregion includes the Souris River basin within North Dakota
	Subregion 0902	Subregion inclues Red River basin within Minnesota, North Dakota, and South Dakota (including the closed basin of Devils Lake)
Region 10		Missouri River basin includes the drainage of the Missouri River basin, the Saskatchewan River basin (into Lake Winnipeg), and several small closed basins within the area
	Subregion 1003	Missouri-Marias subregion consists of the Missouri River basin below the confluence of the Gallatin, Jefferson, and Madison River basins to and including the Marias River basin of Montana
	Subregion 1006	Missouri-Poplar subregion covers the drainage from Fort Peck Dam to the confluence with the Yellowstone River basin in western Montana
	Subregion 1011	Missouri-Little Missouri subregion occurs below the confluence with Yellowstone River basin and extends to Garrison Dam, including Lake Sakakawea
	Subregion 1012	Sheyenne River subregion occurs above the normal operating pool of Lake Oahe and includes drainage in Montana, Nebraska, South Dakota, Wyoming

	Subregion 1013	Missouri-Oahe subregion of North Dakota and South Dakota includes the Missouri River basin from Garrison Dam to Oahe Dam, excluding the Sheyenne River basin above the normal operating pool of Lake Oahe
	Subregion 1014	Missouri-White subregion includes the basin from Oahe Dam to Fort Randall Dam within South Dakota and Nebraska
	Subregion 1015	Subregion includes Niobrara River basin and Ponca Creek basin of Nebraska, South Dakota, and Wyoming
	Subregion 1016	Subregion includes James River basin of North Dakota and South Dakota
	Subregion 1017	Subregion includes Missouri-Big Sioux basin (Missouri River basin from Fort Randall Dam to and including the Big Sioux River basin, but excluding the Ponca Creek, Niobrara River, and James River basins which includes portions of Iowa, Minnesota, Nebraska, South Dakota)
	Subregion 1018	Subregion includes North Platte River basin of Colorado, Nebraska, Wyoming
	Subregion 1019	Subregion includes South Platte River basin of Colorado, Nebraska, Wyoming
	Subregion 1020	Subregion includes Platte River basin below the confluence of the North and South Platte River basins, excluding the Elkhorn and Loup River Basins of Nebraska

	Subregion 1021	Subregion includes Loup River basin of Nebraska
	Subregion 1022	Subregion includes Elkhorn River basin of Nebraska
	Subregion 1023	Missouri-Little Sioux subregion which in Minnesota, Iowa, and Nebrasks and occupies the Missouri River basin below the confluence with the Big Sioux River basin to the confluence with the Platte River basin
	Subregion 1024	Missouri-Nishnabotna subregion of Iowa, Kansas, Missouri, and Nebraska which occurs below the confluence with the Platte River Basin to the confluence with the Kansas River Basin
	Subregion 1025	Republican River Basin of Colorado, Kansas, Nebraska
	Subregion 1026	Smoky Hill River Basin of Colorado and Kansas
	Subregion 1027	Kansas River basin of Kansas, Nebraska, and Missouri, excluding the Republican and Smoky Hill River basins
	Subregion 1028	Chariton, Grand, and Little Chariton River basins of Iowa and Missouri
	Subregion 1029	Gasconade-Osage subregion, which includes the Gasconade and Osage River basins of Kansas and Missouri
	Subregion 1030	Lower Missouri River basin which occurs in Kansas and Missouri below the confluence with the Kansas River Basin to the confluence with the Mississippi River, excluding the Chariton, Gasconade, Grand, and Osage River basins

Appendix 2. Aquatic ecoregions of North America (after Abell *et al*., 2000). HUCs identified in Figure 2 are nearly identical to those ecoregions based on aquatic resources and are labeled as detailed in (Abell, et al. 2000).