Literature review
Costs and Benefits of Pick-Sloan Projects on North Dakota

Paper Submitted to the Missouri River Joint Water Resource Board
In completion of Step 1 of the Consultancy

Robert R. Hearne
Professor
Department of Agribusiness and Applied Economics
North Dakota State University
14 February 2019

1. Directly Pertinent Studies on Changes in North Dakota

A number of reports have been developed over the last 50 years on the impacts of the Pick Sloan project on North Dakota. Most of these have been the result of commissioned research and most have been released as reports of the NDSU Department of Agricultural Economics (later Agribusiness and Applied Economics). A standard algorithm has been employed for analysis with some variation. This algorithm, with frequent deviation, includes:

1) definition of a representative farm, both with and without irrigation, with a variety of crops suitable for the particular irrigated or non-irrigated area;
2) estimation of returns to land and management, using NDSU extension crop budgets for the representative farms, sometimes with simulated price variation; and
3) regional analyses, using input-output analysis and appropriate multipliers for impacts upon local agribusiness and commerce.

The earliest of these reports focused most directly with the impacts of inundation, later versions focused on more specific issues pertinent to policy issues of the time. In 1962, Johnson and Goodman (1962) detailed losses in North Dakota due to inundation and streambank erosion. This report is valuable in its details of acreage losses and previous use of acreage. Tables 1 and 2 detail lost acreage by land use type by inundation for 1 Garrison and 2 Oahe Reservoirs. The authors suggest that the previous use of most land was to grow: 1) wheat (unspecified what type), 2) barley, and 3) fallow. This report also provides some good observation about streambank erosion between Garrison dam Oahe headwaters. Most of this land (estimated at 60,000 acres, but expected to expand circa 1961) would be in the flood plain in any case, but is eroded due to high pressure, low siltation releases from Garrison. This is a good report with good detail, but does not have much of a reference list.

Leitch and Anderson (1978) featured a statewide perspective for benefit-cost analyses of Pick Sloan. The completion of the Garrison Diversion (GDU) was still expected, and expected irrigated returns were included in benefits. This study uses the full algorithm previously described. Costs include losses from land inundation and annual agricultural losses. Average prices from 1962-73 were used, which were considered "stable". Eight representative crop rotations were used, including inundated Lake Sakakawea and Oahe dryland and a variety of

GDU irrigated and dryland rotations. Losses from cottonwood stumpage, pasture loss, mineral loss, and streambank erosion were also calculated. Despite an estimation of stumpage losses, other values of woodlands, such as shelter for cattle and wildlife habitat are considered "intangible" (via 1970s understanding of valuation) and not estimated. Recreation is discussed and hunting impacts are quantified, but the economic values of these impacts are not estimated. Tradeoffs for water recreation are discussed but not measured. The report contains minor details on input-output analysis. There is a discussion of the compensation paid to inundated landowners. There are reasons why compensation for an unwilling seller might be low. But average compensation matched 1970s land values with 7% appreciation. Perceived benefits for the then planned GDU irrigation projects are estimated. This is a comprehensive study of costs and benefits given the state of knowledge in 1970s with unquantified losses in minerals, forestry, wildlife and unquantified but expected gains in recreation. Annual losses in personal income and gross business volume from inundation and streambank erosion were $34.1 and $93.3 million respectively (this translates to $107 and $293 million in 2019 $ (GDP deflator)). Existent benefits from hydropower were still considered negligible. GDU construction of 250,000 acres of irrigation could provide up to $51 million ($160 million in 2019) increase in personal income and $135 million ($431 million in 2019) in gross business volume.

This study was revisited by Leitch and Schaffner (1984). Once again, inundation losses and potential gains from GDU development were estimated using representative rotations and 10-year-average prices. Forestry and streambank erosion losses were also included in the estimation. The impact of two alternative GDU options were assessed. Physical changes from inundation losses are the same as previously reported in Johnson and Goodman (1962) and Leitch and Anderson (1978). Inundation losses are estimated to be $45 million in personal income and $131 in gross business volume. Note that this is less than the $34.1 and $93.3 million 1978 Leitch and Anderson estimates, when accounting for inflation (US Inflation Calculator). This probably accounts for reduced relative crop prices during the 10-year period. The authors concluded that if a 250,000 GDU option were developed, North Dakota would be a net gainer with gains from irrigation greater than inundation losses. A one-year delay in GDU implementation was estimated to cost North Dakota $3.3 million in personal income and $3.3 million in gross business volume. This paper is less detailed than the 1978 Leitch and Anderson study. There is no discussion of recreation and environmental changes.

Taylor, Erickson, and Schaffner produced two 1972 reports on the feasibility and financing of sprinkler irrigation in the GDU area. The first report (1972a) uses data from a farmer survey and highlights the advantages of sprinklers, including central pivot and boom. Estimates show low variable costs for sprinkler irrigation and positive returns for corn, corn silage, and alfalfa. The second paper (1972b) discusses options to finance the cost of irrigation capital equipment.

In a general study, Carkner and Schaffner (1975) reviewed the financial returns to irrigation development in North Dakota's crop reporting Region 7, which falls mostly, but not exclusively in the Missouri Basin. Again, representative dryland and irrigated crop acres were used and field level analysis was later incorporated into input-output analysis to show regional impacts. This study addresses the possibility of growing and expanded groundwater irrigation in region 7. The authors claim that a large physical potential for irrigation expansion, characterized by suitable soils overlying available groundwater, exists in this region. A simple acre level analysis shows

financial feasibility of returns to irrigation repaying the costs of irrigation investment and added labor. Regional multipliers from the input-output analysis show that for every $1.00 in added farm income increases gross business volume by $2.04.

A number of studies assessed irrigation potential in returns to smaller areas. Hvinden and coauthors (1979) studied the potential for sprinkler irrigation of the proposed Apple Creek Irrigation unit in southern Burleigh County. This 32,000-acre development is in a region with frequent droughts and dryland crops including wheat, oats, alfalfa, and corn. Expected irrigated crops are corn and alfalfa. Most farms have beef operations. Survey of farm owners was used for data collection. Returns were simulated for 100 years. The difference in annual income streams (returns to land and water) between dryland and irrigated farms is $63,000 (1979 US$ = $182,550 in 2019 US$). On farm irrigation costs are included but water costs and main system development costs are not included. The increased income stream at 7% discount rate is $590,000 for the representative farm which translates to $49 million for the entire unit. No regional impact analysis or input-output models were added to this figure. The conclusions of this report do a good job warning the reader about the assumptions used, such as the lack of a good dataset of irrigated land uses.

Similarly, Baltezore and coauthors (1991) analyze the economic impact of irrigation in the Buford-Trench Irrigation District near Willison. This project precedes the Pick-Sloan legislation but is part of the Bureau of Reclamation's (BuRec's) efforts in North Dakota and receives benefits from Fort Peck Dam and integrated reservoir water storage. The BuRec history of this project enumerates many technical problems, redesigns, and loss of acreage due to Garrison inundation, but affirms the project's success in stabilizing population and economic recovery in Williams county (Bogener, 1993). Baltezore et al's (1991) analysis uses crop budgets for irrigated and non-irrigated farms. Payment for water and irrigation maintenance are included in crop budgets. Input output models are used to add secondary impacts upon field/farm level analysis. This study shows losses of $197 per acre ($336/acre in 2019) if the district were to be converted to dryland. Accounting for secondary impacts, the 1990 state-level impact was estimated to be $10 million ($17.1 million in 2019) in total business activity and 130 fewer jobs.

Leitch and coauthors (1991) reassess the potential impact of irrigation development of 75,000 additional acres in three GDU areas. Composite acres of dryland and irrigated crops were used. Potatoes, and dry edible beans were used as the high-valued irrigated crops of potential choice. This analysis features 10-year averages of agricultural prices and complicated adjustments to account for the expansion of USDA program crops already considered to be in surplus and receiving payment supports under the existing farm-bill. Under the 1986 GDU Reformation Act, the Conservancy District was to be assessed a surplus crop production charge if area GDU farmers were to produce crops considered to be "in surplus" and eligible for support payments under the farm bill. These surplus charges as well as Irrigation ownership and O&M costs for irrigated acres were incorporated into the analysis. On farm returns were dependent upon crop selection and support payments and surcharges, but ranged from $35 to $108 ($60 - $184 in 2019) per acre increases with irrigation. This translated into $48 to $77 million in annual increased regional business activity ($82 - $131 in 2019).

Givers et al. (1994) assess irrigation expansion in McKenzie County. Again, a field-based analysis of returns to irrigation with secondary impacts is presented. Notably this report does not provide any context about the source of water, irrigation technology, cost of irrigation and pumping, nor other irrigation specifics. Much of the expected benefits of irrigation development were contingent upon the expansion of potato acreage, being the most likely high-valued irrigated crop with expansion potential. Modest increases in returns of $16 per acre ($25.50 in 2019) shifted to $177 per acre with potatoes. Expanded annual regional economic activity was $252 million ($402 million in 2019)with potatoes.

In a more recent study Ripplinger et al. (2014) provide an updated analysis of the protentional to irrigate 51,700 acres adjacent to the McClusky Canal authorized under the 2000 Dakota Water Resources Act. Once again, irrigated and dryland, crop budgets are used, with simulated variation in yields, using @risk. Rotations are somewhat similar to those used in previous studies, with the addition of soybeans. Notably 2014 crop budgets, with relatively high 2014 prices were used, instead of 10-year averages. The results show irrigation benefits of $56.71 per acre , ($61 in 2019), which would imply an increase in land value to $1,400/acre ($1,518/acre). This may be a function of high 2014 prices. In a companion study, Banglund et al (2014) uses IMPLAN input-output analysis to assess regional multipliers and estimate state-wise impacts to be $82 million with an accompanying $1.1 million in state and local government revenue.

A more general study by Johnson and coauthors (1987) on the benefits of expanded irrigation in a range livestock economy uses linear programming (LP) models. This particular study highlights the methodical differences between static and dynamic LP models. It also shows gains from irrigation for livestock operations.

Hellefstine (1964) conducted a parallel study of the expected benefits of the Oahe Irrigation Unit in the James River Basin of South Dakota. The study assesses crop budgets of dryland and irrigated acres. It pays particular attention to community benefits. Similar to the Garrison Diversion this project was also not developed (Hearne and Prato, 2016). The history of this controversy was described by Carrels (1999) as a struggle of grass roots against entrenched bureaucrats, local power brokers, and existing biases. The final decision was part of President Carter's revision of water policy.

2. General Books

John E. Thorson, a legal scholar and western US water specialist, authored a very valuable volume on Missouri River politics and management (1994). Although the author has a distinguished legal career, this particular volume is written for a general audience. Chapters focus on history, geography, and political history. Of particular importance to this literature review is Chapter Four's section entitles "Costs and Benefits to the States." This section revisits the particular Pick-Sloan project benefits, disaggregated by states. Hydroelectric power value has increased throughout the years. Power is produced in Montana, Wyoming, North Dakota, and South Dakota, but two-thirds of the benefits go to Minnesota, Colorado, Iowa and Nebraska (see USACE 1993 Hydropower Economics for more detail). Only 12.33% of Pick-Sloan hydropower is consumed in North Dakota. Since the 1960s, recreation has also increased in importance. Visitor days have increased significantly, with most visits occurring in the

downstream dams. On the other hand, navigation has declined substantially in importance over the years. Commercial and agricultural tonnage has declined with an increase in the use of the navigation travel for excavating and moving sand and gravel over small distances.

Irrigation has failed to meet the expectations of early planners. Cancellation of projects in the Dakotas was significant. Of the total planned 5.3 million acres in eight states, over 500,000 acres of irrigation has been developed, mostly, in order of acreage, in Nebraska, Wyoming, Kansas, and Montana. Noteworthy is the very small amount of developed irrigation in South Dakota and especially North Dakota with only 9,000 acres.

Although economic estimates are not provided, Table 4.2 of Thorson's volume clearly labels Nebraska as a "Big Winner and the downstream states of Minnesota, Iowa, Missouri, and Kansas as "Winners." Colorado and Wyoming are labeled "Losers" and the states with the inundated reservoirs, Montana, North Dakota and South Dakota are listed as "Big Losers." However, Thorson quickly augments this calculus of relative benefits and costs with details on the "Special Damage to the Tribes." Inundated lands particularly damaged the communities of the Three Affiliated Tribes of the Fort Berthold Reservation and the Standing Rock Sioux Tribe.

The book precedes the 2000s struggle to incorporate ecosystem services into reservoir management, and popular concern over impacts of global climate change. The book's concluding chapter calls for a new Pick-Sloan compact calling for ecosystem protection and conservation as well as equitable distribution of the system's benefits.

Another valuable volume was the National Research Council's 2002 study on the potential of modifying Missouri River management in order to better accommodate ecosystem services. This volume was authored by a committee designated by the National Research Council, including experts on ecology, aquatic biology, law, engineering, economics, and policy. Chapters include: 1) an introduction to changing us context for river management and adaptive management: 2) a review of the geography, history, and institutional background of the river; 3) a review of the ecology of the river and floodplain; 4) a look at the economic outcomes of Missouri River management; and 5) subsequent chapters on the potential of the implementation of adaptive management in the Missouri River system. The chapter on the geographic, historic and institutional background of Missouri River is very valuable.

The chapter on the economics of Missouri River management affirms that: 1) wealth and population are concentrated in the lower basin; 2) the river's commercial centers are no longer linked economically to the river; and 3) the basin is characterized by rural to urban migration. The authors affirm that new developments in environmental economics have provided tools to estimate values for services, such as recreation and ecosystem services, previously deemed to be "intangible" or "uneconomic." Annual benefits in the hundreds of millions of dollars come from 1) hydropower, 2) water supply (which includes irrigation), and 3) flood damage. Annual benefits in the tens of millions of dollars come from recreation. And navigation benefits are measured in the millions of dollars.

The principle economic values of the Pick Sloan project are enumerated. Estimates come from the economic analysis provided by the USACE (1994 and 1998). The committee concludes that

navigation benefits are low and decreasing in the upstream segments. The committee suggests that it may be beneficial to forego the guarantee of minimum flows for upstream segments (i.e. Sioux City to Omaha) in order to achieve alternative management goals. The book coincides with a period in expanding knowledge about the economic valuation of non-market ecosystem services, but does not estimate these. Instead the authors summarize USACE estimates of the value of Pick-Sloan project services and suggests that the value of managing the river to increase ecosystem services would comfortably exceed the opportunity cost of reduced navigation.

Water supply benefits come from municipal, commercial, industrial, irrigation outtakes as well as for cooling thermal power plants. The value of these estimates comes from the avoided cost of the next best alternative supply. Water supply benefits are mostly from cooling power plants (91.4% of total). Municipal water (5.6%) and irrigation (2.3%) are also included in this total. Of total annual water supply benefits of $541 million ($863 million in 2019), Nebraska receives 44.8%, followed by Iowa (16.4%) and Missouri (15.9 %).

Recreation benefits are estimated for 1994 using USACE and state visitor data and willingness-to-pay estimates from economic literature. Over 75% of the estimated $87.1 million in benefits come from South Dakota (36%), North Dakota (26%), and Nebraska (16%).

Hydropower supplies the highest benefit of all Pick Sloan project purposes, at $615 million per year. Hydroelectric potential is greater than in the original project planning because of fewer irrigation withdrawals than originally planned. As per the rules established by the 1944 Flood Control Act, most hydropower benefits flow to those receiving favorable power (Hearne and Prato 2016) including rural electric cooperatives (40.7%) and municipalities (35.7%). Because of the coverage area of the Western Area Power Admirations' Mid-Continent Power Pool, hydropower benefits flow out of the states were power is produced to the region, including Nebraska (27.3%), Minnesota (21.1%), South Dakota (18.6%). The remaining flows to Iowa, North Dakota, and Montana.

Flood control benefits are calculated using 100 years of hydrological data and cumulative flood damage reduction. Average annual flood damage reduction benefits are estimated to be $414 million ($661 million in 2019). The benefits are divided into the following sectors: 1) Commercial/industrial (35.25%); 2) residential (25.8%); 3) roads/railroads (20.6%); and 4) crops (17.7%). Missouri receives the highest share of benefits (25.4%), followed by Iowa (24.8%), Nebraska (18.7%), and North Dakota (17.5%).

3. USACE and USBR Economic Analysis Studies

In 1994 and 1998, the USACE released lengthy "Review and Update" studies as part of the Missouri River Master Water Control Manual. Most of these are filled with pages of methodology and summarized data. Key results of these studies have been summarized in the National Research Council's 2002 volume. However, these reports extend beyond the simple cost-benefit analysis and address questions of water levels. Thus, the analyses do not address the 1940s question of dam-or-no-dam. Instead the up-to-date question of the impact of dam operations on the benefits is explored.

The volumes on water supply economics and recreation explore the impact of reduced reservoir levels on water intakes, pumping costs, and visitation (USACE 1994a). In the case of water supply many intakes are portable and low reservoir levels do not generally imply constructing new intakes. Often the cost of reduced reservoir levels is only in increased vertical pumping cost. The analysis suggests that this corresponding increase in O&M costs would decrease irrigated acreage (Hearne is skeptical of this - reduced reservoir levels would correspond to drought and decreased dryland acreage and increased crop and feed prices). When intakes are very low irrigation stops and dryland cropping is the alternative with a loss of income.

Recreation economics (USACE 1994b) is also analyzed with a concern for the reduced access and visitation from lower reservoir water levels. Visitation data was provided by states' angler surveys and a recreation site visitor surveys. Frank Ward provides a travel cost estimation with a nice explanation of the methodology. Four models are estimated: a reservoir day-use, a reservoir camping, a river reach day-use and a river reach camping model. The dependent variable used in both day-use models is the estimated number of total annual day-use visitors from county *i* to destination *j*. Site specific average value of a recreation day were estimated, as $4.85 on Lake Oahe; $5.37 Lake Fort Peck; and $14.59 on Lake Sakakawea (in 2019 these figures translate to $7.74, $8.57, and $23.29). Aggregating a number of different studies recreation benefits as a function of Lake levels are estimated for the three large upstream reservoirs and the downstream sectors (pp 24-26). And benefits for each reservoir and river segment are then estimated for 8 different operating plan alternatives (table 13 page 28).

The USACE report on Hydropower Economics (1994c), provides some excellent background on the hydropower generated all six mainstem dams. Due to the Mid-Continent Area Power Pool, most power sales are not in the states where hydropower is produced. 1986-1991 power sales are to Minnesota (24%), Nebraska (21%), South Dakota (19%), Iowa (15%), North Dakota (13%), and Montana (8%). While most dams supply peaking and semi-peaking power. However, the Gavins Point Dam is used for base load. Note that the value of hydropower is based upon the avoided costs of alternatives, not upon revenues. The value of the capacity provided by hydropower is in the thermal plants that are not needed to meet the peak period energy that is provided by the hydropower. Capacity is a function of reservoir levels, when levels are high the head is large. In addition to capacity, the analysis calculates a penalty function for periods when low reservoirs reduce capacity and for periods when peak power requirements cannot be met with reservoir flows. Once again, the values of the hydropower benefits are estimated under many alternative management options.

The USACE report on Flood Control Economics is in the same 1994 volume as hydropower (1994c) and was updated in a 1998 report (USACE 1998). Note that the USACE dam operation consistently prioritizes a large deal of reservoir storage to flood control. The 1994 study more explicitly analyzes flood control impacts under alternative dam management alternatives. Flood damages for each river stretch (not the reservoirs themselves) are estimated for 1) recreation, 2) agriculture, and 3) residential and urban activities. The North Dakota flood protection is thus the stretch from Garrison Dam to Lake Oahe. After "potential damages" are estimated, a simulation of expected damages under different dam management alternatives is estimated. The 1998 report follows a similar format but more explicitly uses the 100-year hydrological data from 1898 – 1997.

Additional studies on navigation economics, interior drainage, and groundwater and "Mississippi River Economics," are outside of the scope of this literature review in that they focus on river stretches, downstream of Gavins Point Dam and the land area behind downstream levees (USACE 1994d, 1998c, 1998d). Other volume focuses on Regional Economics, and incorporate the results of the other economic analyses into regional input-output models to understand secondary effects and regional impacts.

Throughout the years, Bureau of Reclamation has provided a number of documents on the environmental and economic impacts of the GDU and other irrigation development projects in North Dakota. A number of preliminary environmental impact statements were circulated and finally a "Final Environmental Statement" (FES) was released in early 1974. Of note is an opinion from a 1973 "Statement on Environmental Impact" that states

> "The Garrison Diversion Unit is the only project of its nature and magnitude in the state of North Dakota. Any alternative development would either have foregone the economic and social benefits that will be derived from the construction or would have transposed these benefits to another area of the Missouri River Basin. There are no alternative means of utilizing the land and water resources that will provide equivalent economic, social, and environmental benefits at comparable costs."

and a 1975 review of previous analyses that criticized the lack of a proper benefits-cost analysis. Pertinent was the disregard for "professorial" methodology, specifically, the absence of accounting for the opportunity cost of the proposed project, the estimated benefit of the increased production of crops that were generally in surplus and beneficiaries of government support payments, and the economic costs of environmental impacts. As stated in the 1975 review, both a regional (North Dakota) and national analysis are legitimate viewpoints for an economic analysis of the project. The 1975 review states that there are significant opportunity costs of both the land and the diverted water. This analysis shows a federal government investment of $1,221 per acre with repayment capacity of only $6.69 which may be sufficient to cover operation and maintenance costs. This would leave a substantial transfer of US Government expenditures to the area. The use of regional "indirect benefits" is criticized in its assumption of underemployed resources.

4. Studies that Focus on the Impacts to Tribes

A 1954 US Bureau of Indian Affairs study estimated damages to tribes from Lake Oahe inundation while comparing it to Lake Sakakawea cost estimates, already used for settling claims. Inundation values are estimated at the sum of 1) moving costs; 2) market value of inundated lands; 3) lost timber and wildlife; 4) potential lost increased value of land from irrigations; 5) and general intangibles. Intangibles are generally discussed and a number (approximately 18%) of the total is provided without estimation. It is noted that these estimates are not binding but subject to Congressional appropriation.

A number of volumes and studies have been written on costs of the Pick Sloan program to Native-American Tribes. Lawson (2009) provides an interesting overview of the Pick-Sloan project from a Native American viewpoint. This book provides a long history of disputes,

political impotence, failed negotiations, and unrealized aspirations for reparations for lost lands and incomes. Two chapters present benefits and costs to tribes without any quantification. This volume does a good job in discussion of the transfer, from the USACE to the State of South Dakota, of control over Lake Oahe riparian land. This transfer was opposed by most tribes, under the belief that tribes were worthier of returned lands. Although that value of reservoir recreation has increased since inundation, the tribes have mostly not been able to capitalize on increased tourism. Improved access to quality reservoir water has benefitted the tribes. Although it is acknowledged that flood control benefits do occur, tribes have also noted new types of flood damage, including: streambank erosion due to dam releases; and fluctuating water levels that surpass high water levels and encroach into tribal property not purchased by the project; and new siltation that causes tributaries to flood. Tribes have benefited from increased access to electric power through the Pick Sloan dams, but much of this can be attributed to increased wealth as opposed to increased power. Despite the failure of larger irrigation projects in the Dakotas, Missouri River tribes have all been able to develop irrigation projects benefitting from Missouri River water. However, the increased availability of water has not been used to settle tribal claims to priority water rights under the *Winters* Doctrine (Hearne and Prato, 2016).

Although acknowledging the impact of the 1930's drought and the severe floods of the 1940s, Brian Russell's MA thesis idealizes the economy of the tribal reservations prior to the inundation of Lakes Sakakawea and Lake Oahe. This description illuminates the "intangible" costs that not fully estimated in federal government analyses and appropriation. Much of this writing returns to a discussion of the unfulfilled hopes for the *Winters* decision that are complementary to but independent of the Pick-Sloan settlements.

5. Additional Academic Studies

In a descriptive article that includes little economics, Shneiders (1997) highlights the political impotence of and describes the political process of Pick-Sloan Dam selection. Due to the width of the floodplain project planners were restricted to upstream states for dams. With the need to protect cities, such as Williston, Bismarck, Pierre, Mobridge, and Sioux City, the remaining options implied inundation of many Indian lands. Tribes were not consulted, because of their lack of political influence and expected contribution to payments, such as electricity purchases.

Caldwell (1984) criticized the federal governments use (and abuse of) benefit-cost analysis as biased towards the governments wishes. He also criticizes early Environmental Impact Assessments (EIAs). The author criticizes the early analysis of the interbasin transfer and supports the need to consult the IJC and Canada as well as international scientific review of EIAs. This article features strong language on inequities brought upon the displaced white and Indian communities from dam inundation.

Olson and Morton (2017) provides an overview of the Pick Sloan project and includes a good section on the changes in ND agriculture from the Lake Sakakawea displacement. In another unpublished monograph, Russel reviews the impact of Pick Sloan projects on North Dakota and summarizes a 1992 USACE analysis that states

> "The State of North Dakota has received $614 million in Federal appropriations since the Missouri River dams were constructed. Nearly 100,000 residents have received better drinking water. The

> Corps of Engineers estimates that the state also receives an estimated $130 million in annual benefits from flood control and low-cost hydroelectric power. Since the closure of Garrison in 1954 this potentially equates to roughly $5,980,000,000 in 1999 dollars." (p 28)

In a study that does not directly address upstream and downstream tradeoffs nor economic values, Prato (2014) presents a methodology for assessing alternative management plans. By assessing weights (that may be considered to be arbitrarily) to alternative values (i.e. conservation 40%, recreation 10%, jobs 15%, …) and using linear utilities, the adaptive management approach is considered to be favorable.

Conclusions and Observations from the Literature Review

Early studies, conducted by NDSU researchers have shown the cost of inundation on North Dakota, based upon the 1950s use of land. These studies can possibly be updated to account for 21st century land use and regional multipliers. Later analyses have updated benefits and costs of: irrigation development; municipal and industrial water supply, hydroelectricity, flood control, and recreation. The 1994 USACE and Frank Ward analysis of recreation benefits used state of the art methodology. And the incorporation of values for assorted operating plan alternatives is valuable information. Incorporation of the 2000s initiatives to manage dams and reservoirs to enhance habitat for endangered species and to understand how this impacts the value of recreation has not been found in the literature.

References

Bangsund, D., Saxowsky D. and D. Ripplinger 2014. Regional Economic Effects of Irrigation Along the McClusky Canal in North Dakota Departmental Paper 735. Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, N.D.

Baltezore, J.F., D.A. Bangsund, J.A. Leitch, and F.L. Leistritz. 1991. Economic Impact of Irrigation in the Buford-Trenton Irrigation District in 1990. AE Staff Paper 91008, Department of Agricultural Economics, North Dakota State University, Fargo. Available at http://purl.umn.edu/121417 Accessed November 2019.

Bogener, S. 1993. Buford-Trenton Project History. Bureau of Reclamation Available at https://www.usbr.gov/projects/pdf.php?id=89. Accessed January 2020.

Caldwell, L. K. (1984). Garrison diversion: Constraints on conflict resolution. *Natural Resources Journal*, 24(4), 839-864.

Carrels, P. 1999. *Uphill Against the Water*. Lincoln. University of Nebraska Press.

Givers, D.R., D.A. Bangsund, F.L. Leistritz, and J.A. Leitch. 1994. Economic Impact of Expanded Irrigation Development in McKenzie County, North Dakota. AE Staff Paper 94005, Department of Agricultural Economics, North Dakota State University, Fargo. Available at http://purl.umn.edu/121074. Accessed November 2019.

Hearne, R. R.; Prato, T. 2016. Institutional Evolution of Missouri River Management. *Water Policy* 2016, 18 (3), 619–634.

Helfinstine, R., 1964. "Community and Commercial Benefits from Water Resource Development of the Oahe Area." Agricultural Experiment Station Agricultural Economics Pamphlets. 131. Available at http://openprairie.sdstate.edu/agexperimentsta_ageconomics/131. Accessed November 2019.

Hvinden, S.C. D.F. Scott, and R.G. Johnson. 1979. An Economic Analysis of the Apple Creek Irrigation Unit. AE Rpt. No. 139, Department of Agricultural Economics, North Dakota State University, Fargo. Available at http://purl.umn.edu/23436 Accessed November 2019.

Johnson, J. E., and R.J. Goodman. 1962. Negative Impacts of Garrison and Oahe Reservoirs on the North Dakota Economy. AE Rpt. No. 24, Department of Agricultural Economics, North Dakota State University, Fargo.

Johnson, R.G., D.L. Watt, M.B. Ali, and L.J. Schluntz. 1987. Benefits of Irrigation in Mitigating the Impacts of Drought in a Range Livestock Economy. AE Rpt. No. 110, Department of Agricultural Economics, North Dakota State University, Fargo. Available at http://purl.umn.edu/119563 Accessed January 2020.

Lawson, M. L. (1994). *Dammed Indians: The Pick-Sloan Plan and the Missouri River Sioux, 1944-1980*. University of Oklahoma Press.

Leitch, J.A. and L.W. Schaffner. 1984. *Economic Activity Associated With the Garrison Diversion Unit in 1984*. AE Rpt. No. 190, Department of Agricultural Economics, North Dakota State University, Fargo.

Leitch, J.A. J.F. Baltezore, R.G. Johnson, and R.C. Coon. 1991. *A Reevaluation of GDU Irrigation*. AE Staff Paper 91006, Department of Agricultural Economics, North Dakota State University, Fargo.

National Research Council. 2002. *The Missouri River ecosystem: exploring the prospects for recovery*. National Academies Press.

Olson, K. R., & Morton, L. W. (2017). Managing the upper missouri river for agriculture, irrigation, flood control, and energy. *Journal of Soil and Water Conservation*, *72*(5), 105A-110A. https://doi.org/10.2489/jswc.72.5.105A

Prato, T., 2003. Multiple-attribute evaluation of ecosystem management for the Missouri River system. Ecol. Econ. 45:297–309. Available at http://dx.doi.org/10.1016/S0921-8009(03)00077-6 Accessed January 2020.

Ripplinger, D., Saxowsky, D, and D. Bangsund. 2014. Economic Feasibility of Irrigation Along the McClusky Canal in North Dakota: Farm-level returns. Departmental Paper 734. Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, N.D.

Russel, B. (undated) Flooded Dreams: Pick-Sloan and the Reclamation of North Dakota. Unpublished monograph available at http://www.riversimulator.org/Resources/USBR/ReclamationHistory/RussellBrian.pdf Accessed November 2019.

Thorson, J. E. 1994. *River of Promise, River of Peril: The Politics of Managing the Missouri River* (p. 14). Lawrence, KS: University Press of Kansas

United States Army Corps of Engineers, Missouri River Division, Missouri River Division,1987-1988 Annual Operation Plan, (Omaha: The Corps, December 1992), 90.

United States Army Corps of Engineers. 1994a. Volume 6B: Economic Studies, Water Supply Economics. In: Master Water Control Manual, Missouri River Review and Update Study. Omaha, NE: USACE Northwestern Division, Missouri River Region.

United States Army Corps of Engineers. 1994b. Volume 6C: Economic Studies, Recreation Economics. In: Master Water Control Manual, Missouri River Review and Update Study. Omaha, NE: USACE Northwestern Division, Missouri River Region.

United States Army Corps of Engineers. 1994c. Volume 6D: Economic Studies, Hydropower,

Flood Control, and Mississippi Economics. In: Master Water Control Manual, Missouri River Review and Update Study. Omaha, NE: USACE Northwestern Division, Missouri River Region.

United States Army Corps of Engineers. 1998a. Volume 6A-R: Economic Studies, Navigation Economics (Revised). In: Master Water Control Manual, Missouri River Review and Update Study. Omaha, NE: USACE Northwest Division, Missouri River Region.

United States Army Corps of Engineers. 1998b. Volume 6F: Economic Studies, Flood Control (Revised), Interior Drainage, Groundwater. In: Master Water Control Manual, Missouri River Review and Update Study. Omaha, NE: USACE Northwest Division, Missouri River Region.

United States Army Corps of Engineers. 1998c. Volume 6E-R: Economic Studies, Regional Economics (Revised). In: Master Water Control Manual, Missouri River Review and Update Study. Omaha, NE: USACE Northwest Division, Missouri River Region.

United States Bureau of Reclamation, 1955. Economic analysis: Missouri River Basin project. Available at http://hdl.handle.net/2027/coo.31924005006618 Accessed November 2019.

United States Bureau of Reclamation. (1957). Report on Garrison Diversion Unit, Garrison Division, North Dakota, South Dakota, Missouri River Basin Project. Bismarck, N.D.: Missouri-Souris Projects Off..

United States Bureau of Reclamation. l965. Supplemental report on Garrison Diversion Unit (Initial Stage — 250,000 acres). Department of the Interior, Missouri —-Souris Projects Office, Bismarck, North Dakota. 64 pp.

United States. Bureau of Reclamation. (1973). *Statement on environmental impact: Garrison diversion unit, Missouri River Basin project, North Dakota.* [Washington, D.C] Available at https://babel.hathitrust.org/cgi/pt?id=ien.35556021209044&view=plaintext&seq=1 Accessed January 2020.

United States. Bureau of Reclamation. Upper Missouri Regional Office. (1983). *Pick-Sloan Missouri Basin Program, Garrison Diversion Unit (initial stage): North Dakota and South Dakota.* [Washington, D.C.?]