Technical Appendix

Economic Analysis of Devils Lake Alternatives

Prepared for the U.S. Army Corps of Engineers

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Addendum
to the
Technical Appendix
Economic Analysis of Devils Lake Alternatives
October 2001

The primary purpose of this Addendum to the Technical Appendix is to amend the discussion regarding the Raise Natural Outlet alternative (WF-11). All of the amendments, corrections, and clarifications are given with reference to the pertinent section number of the Technical Appendix (to which the reader is referred). Sections of the Technical Appendix that are not referenced need no revisions.

Raise Natural Outlet: Revisions

Economic Analysis of Raise Natural Outlet (WF-11) (Section II.2.2.3)

It was assumed in the July 2001 analysis that damages resulting from the Raise Natural Outlet alternative would be limited to damages above the without-project condition peak lake level (1460.6). Further review and discussions regarding the Raise Natural Outlet alternative indicate that it is possible that the Federal government may be required to compensate for all damages above the natural overflow elevation (1459). All features above this elevation would be damaged for a longer duration as a result of the raise, and some of the features that might not have been damaged without the raise may incur damages. Further study was therefore completed and reported in this Addendum. The revised Raise Natural Outlet alternative analysis considers all damages and feature protection costs above elevation 1459 as project costs.

The revised results of the Raise Natural Outlet alternative are listed in the Tabular Data Addendum, Tables TD.3.WF-11.1 through TD.3.WF-11.11. The Technical Appendix's discussion of the Raise Natural Outlet alternative should be revised as follows:

Project Benefits (Section II.2.2.3.1)

The Raise Natural Outlet alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level. Since the Wet Future Scenario trace does overflow under without-project conditions, the peak lake level would rise higher under this alternative than for the without-project conditions. The lake level would also remain high for a longer duration, because the water is prevented from discharging. The damages to land, and the feature protection costs resulting from these higher lake levels, were attributed to the project as project costs.

A majority of the project benefits ($13.9 million) accrue as a result of the shift of land damages and feature protection costs (resulting from the higher lake levels) from strategy costs and damages to project costs. For example, the analysis shows a benefit for land between 1459 and 1460.6 (Features 8.1 and 8.2 Rural Areas) since the land is damaged under without-project conditions and the land is a project cost (not

damaged) under with-project conditions. Similarly, the costs to protect various features from 1459 to 1460.6 are shown as a benefit since the raises are strategy costs under without-project conditions but are counted as a project cost under with-project conditions.

Raising the natural outlet also prevents damages to downstream features, which registers as a benefit for the alternative. The natural overflows from Devils Lake would be eliminated under this alternative. The prevention of damages to downstream features is worth about $3.4 million annually (100% of all downstream damages related to Devils Lake outflow are eliminated).

Compared to the benefits under the set of most likely action strategies, all of the other sets of strategies have nearly identical downstream benefits—the benefits to downstream features do not change with the sets of strategies for features adjacent to the lake. However, the other sets of strategies show a wide range of computed benefits due to the shift of land damages and feature protection costs (resulting from the higher lake levels) from strategy costs and damages to project costs. As expected, under the no protection strategy, these benefits are very small since only a few features are protected. Under the set of maximum protection strategies, the benefits are also much smaller because the features are protected to the maximum lake level prior to the lake reaching the natural outlet elevation. The benefits under the set of cost-effective strategies are at a level similar to those computed under the most likely action strategies.

Project Costs (Section II.2.2.3.2)

The financial risks associated with this alternative are the total project costs ($311.8 million), which occur at project implementation. These costs include:

- Construction costs, at $1.3 million for permanent weir.
- Total present worth operation and maintenance costs of $0.07 million for the weir. Operation and maintenance costs were computed as 1% of the first costs.
- Purchase of land between elevation 1459 (the natural overflow elevation) and 1463, at a cost of $39.2 million ($18.7 million present worth).
- Costs for incremental protection for features above the natural overflow elevation of 1459. The total cost for these protection measures was $614.1 million ($292.4 million present worth).

The total present worth of the project ($311.8 million), when annualized, translates to $20.8 million annual cost for the 50-year planning period.

Net Benefits (Section II.2.2.3.3)

The annual net benefits under the Wet Future Scenario analysis are -$3.5 million. The BCR for this alternative is 0.83 under the Wet Future Scenario analysis.

Under the assumption that all damages and feature protection costs would be attributable as project costs, the Raise Natural Outlet alternative is not economically feasible under the Wet Future Scenario analysis.

Discussion of Results (Section II.2.2.3.4)

The Wet Future Scenario results (incorporating all damages and feature protection costs above the natural overflow as project costs) indicate that the Raise Natural Outlet alternative is not economically feasible under the Wet Future Scenario analysis. Although the actual project costs may not include all of the damages and feature protection costs (as computed under this analysis), this analysis does incorporate all reasonable costs associated with this alternative. There is also a risk associated with the additional environmental, social, and economic impacts within the basin.

TableII.WF-1

The attached Table II.WF-1 has been revised to include the results of the updated analysis of the Raise Natural Outlet alternative.

TableII.WF-3

The attached Table II.WF-3 has been revised to include the results of the updated analysis of the Raise Natural Outlet alternative.

Economic Analysis of Devils Lake Alternatives
Table II.WF-1

Wet Future Scenario Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
WF-1	Upper Basin Management	$2,650	$2,584	-$66	0.98	$3,191	$541	1.20
WF-2b	Expanded Infrastructure Measures	$4,063	$4,301	$238	1.06	$4,301	$238	1.06
WF-3	West Bay 300 cfs Constrained Outlet	$6,376	$16,760	$11,896	3.45	$19,718	$13,341	3.09
WF-4	West Bay 480 cfs Unconstrained Outlet	$12,188	$29,732	$21,938	3.81	$28,828	$16,640	2.37
WF-5	Pelican Lake 300 cfs Constrained Outlet	$8,731	$18,884	$11,665	2.62	$21,912	$13,181	2.51
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	$14,668	$29,943	$19,512	2.87	$30,198	$15,530	2.06
WF-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$6,491	$6,706	$214	1.03	$7,313	$821	1.13
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$11,165	$22,537	$12,883	2.33	$25,489	$14,324	2.28
WF-9	NOTE: WF-9 is the base condition – without project future condition.							
WF-10	East End 480 cfs Unconstrained Outlet	$9,885	$29,732	$25,863	7.68	$28,201	$18,315	2.85
WF-11	Raise Natural Outlet	$20,824	$13,858	-$6,966	0.67	$17,299	-$3,526	0.83

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Economic Analysis of Devils Lake Alternatives

Table II.WF-3

Wet Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
		Without-Project	$4,141	95%		$39,335		
		With-Project	$3,915	95%		$36,977		
WF-1	Upper Basin Management	Total Benefits	$226		5%	$2,358	6%	$2,584
		Without-Project	$4,141	95%		$39,335		
	Expanded Infrastructure	With-Project	$4,133	95%		$35,042		
WF-2b	Measures	Total Benefits	$9		0.21%	$4,293	11%	$4,301
		Without-Project	$4,141	95%		$39,335		
	West Bay 300 cfs Constrained	With-Project	$2,835	96%		$23,881		
WF-3	Outlet	Total Benefits	$1,307		32%	$15,454	39%	$16,760
		Without-Project	$4,141	95%		$39,335		
	West Bay480 cfs	With-Project	$1,810	95%		$11,935		
WF-4	Unconstrained Outlet	Total Benefits	$2,331		56%	$27,400	70%	$29,731
		Without-Project	$4,141	95%		$39,335		
	Pelican Lake 300 cfs	With-Project	$2,777	95%		$21,815		
WF-5	Constrained Outlet	Total Benefits	$1,364		33%	$17,520	45%	$18,884
		Without-Project	$4,141	95%		$39,335		
	Pelican Lake 480 cfs	With-Project	$1,810	95%		$11,724		
WF-6	Unconstrained Outlet	Total Benefits	$2,331		56%	$27,611	70%	$29,942
	Combination 1 – Upper Basin	Without-Project	$4,141	95%		$39,335		
	Management and Expanded	With-Project	$3,907	95%		$32,864		
WF-7b	Infrastructure Measures	Total Benefits	$235		6%	$6,471	16%	$6,706
	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure	Without-Project	$4,141	95%		$39,335		
		With-Project	$2,696	95%		$18,244		
WF-8b	Measures	Total Benefits	$1,445		35%	$21,091	54%	$22,537
WF-9	NOTE: WF-9 is the base condition – without project future condition.							
		Without-Project	$4,141	95%		$39,335		
	East End 480 cfs	With-Project	$1,810	95%		$11,935		
WF-10	Unconstrained Outlet	Total Benefits	$2,331		56%	$27,400	70%	$29,731
		Without-Project	$4,141	95%		$39,335		
		With-Project	$3,433	96%		$39,398		
WF-11	Raise Natural Outlet	Total Benefits	$708		17%	-$63	-0.16%	$646

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Technical Appendix
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Economic Analysis of Devils Lake Alternatives

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I.1.0 Introduction

I.1.1 Project Background

Devils Lake is a closed basin in northeastern North Dakota that receives runoff from a 3,814 square mile watershed. In the seven years between 1993 and 1999, the lake rose over 25 feet, from elevation 1422.5 (feet above mean sea level) in 1993 to a peak elevation of 1447.2 in 1999. In 2001, the lake peaked at elevation 1447.8. Recent lake levels are the highest on record, although the geologic record suggests that the lake has been this high and higher in the distant past.

During the past decade, the lake has expanded from 70 square miles to over 195 square miles. The lake has continued to rise and started overflowing into Stump Lake in 2001. If the lake were to reach elevation 1459, it would be combined with Stump Lake and overflow into the Sheyenne River. The Sheyenne River drains to the Red River of the North.

Rising lake levels have affected communities, transportation routes, and rural lands. Federal, state, and local agencies have adopted a three-part integrated approach to flood damage reduction in response to the rising lake levels. This approach includes:

1. Upper basin water management to reduce the amount of water reaching the lake.
2. Protection to structures and infrastructure in case the lake continues to rise. (Note that "structures and infrastructure" will be referred to as "infrastructure" for the remainder of this report.)
3. An outlet to release some lake water.

I.1.2 Purpose of Analysis

In 1997, Congress passed Public Laws (PL) 105-18 and 105-62, addressing the emergency outlet[1] for Devils Lake. PL 105-18 authorized the U.S. Army Corps of Engineers (Corps) to do planning, engineering, and design for an outlet and to prepare an Environmental Impact Statement (EIS). PL 105-62 set aside funds to initiate construction of an outlet, but final approval is contingent on the Corps reporting to Congress on several issues, including economic justification. These PL 105-62 funds were not sufficient to complete the outlet design and EIS. Supplemental appropriations were allocated in 2000 and 2001 to complete the preconstruction and engineering and design (PED) and associated EIS.

This Economic Analysis of Devils Lake Alternatives (Economic Analysis) responds to the economic justification requirement of the EIS by providing a preliminary economic assessment of alternatives.

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1 In this report, an "outlet" is defined as a constructed system by which Devils Lake water can be made to discharge to the Sheyenne River. The outlet could be operated with pumps, or with gravity flow. The term "natural outlet" is used to refer to the existing and naturally-occurring point of discharge from the Stump Lake, and/or the natural channel through which flow would go to the Sheyenne River.

Figure I.1 shows the study area (all Part I numbered tables, figures, graphs, and attachments are located at the end of Part I of the Technical Appendix).

The purposes of this Economic Analysis are:

- to provide a framework for Federal investment in flood damage reduction alternatives
- to provide information to evaluate the economic feasibility of Devils Lake emergency alternatives
- to evaluate the damages to features adjacent to Devils Lake that are caused by the rising lake
- to explore alternative flood damage responses for communities, roads, rail lines, etc.
- to evaluate the damages to features downstream of Devils Lake—damages that are caused by either a natural overflow or by an outlet

The major effects addressed by this study are physical and economic, i.e., the costs and benefits of the various flood reduction alternatives and their effect on flood protection actions within and downstream of the basin. This study also includes a cursory evaluation of social and environmental impacts of local flood protection measures—measures that might be adopted whether or not an outlet is constructed.

I.1.3 Organization of Report

An extremely large amount of modeling results was generated during the Economic Analysis, and the analysis itself is extremely complex. To communicate information effectively to a broad spectrum of people, it was necessary to separate the report on the Economic Analysis into three volumes:

- **Main Report**
  The Main Report summarizes the analyses and results of the Economic Analysis. After introductory sections, the report starts by describing the basic approach used to evaluate the economic feasibility of the various alternatives (Section 3). A listing of the economic modeling results, and overall review and comparison of the economic feasibility of the various project alternatives follows (Section 4). Section 5 gives a discussion of how the model results are sensitive to variations in climate assumptions, to assumptions regarding the local infrastructure protection measures, and to assumptions made regarding erosion at the lake's natural outlet. In Section 6, conclusions are drawn regarding the economic feasibility, risks, and effectiveness of the various alternatives.

- **Technical Appendix**
  By comparison to the Main Report, the Technical Appendix gives much more detail regarding the study methodology and results. Part I describes the methodology and general assumptions used in the detailed evaluation for the Economic Analysis. Data and assumptions used in the analysis of the identified features are included in the Part I Attachments. Part II of the Technical Appendix compares the economic feasibility of the various alternatives and evaluates the effects of different lake level futures on the results. Complete detailed results for one flood control alternative are also

included on a compact diskette in Part II, providing an example of how the costs and damages are computed for individual features.

- **Tabular Data**

  The Tabular Data document provides the detailed tabular results of the various alternatives that were analyzed, grouped by analysis (stochastic and scenario-based). The conclusions of the Economic Analysis are founded on the detailed results presented in the Tabular Data document.

As is indicated above, this Technical Appendix focuses on the technical details of the study. It gives a detailed explanation of what assumptions and methods were used to generate the economic indices and provide means by which each flood control alternative could be evaluated. The study is complex, and the details of the analysis are plentiful. However, it is important to keep in mind that the main goal of the Economics Analysis is to compare flood control alternatives, and identify those with the largest net benefits, taking into account the associated risk, effectiveness, and other non-quantifiable benefits. That more general discussion of the alternatives is found in the Main Report; this Technical Appendix should be considered as only supplementary to that volume.

At the end of this Technical Appendix can be found a glossary of terms used in the discussions.

I.2.0 Approach to the Analysis

This Technical Appendix serves mainly to provide the details of the methodology for the Economic Analysis. To assist the reader in understanding the general approach to the analysis, Section I.2 provides an overview of the process.

In general terms, the steps of the Economic Analysis were as follows:

1. A computer model simulating the hydrology of the Devils Lake basin provided the first set of projections. These 50-year lake level projections resulted from computer-generated patterns of climate fluctuations. The climate fluctuations, along with input parameters related to the specifics of the alternative under consideration, allowed the model to produce 10,000 stochastically-generated 50-year "traces" of projected lake levels (see also Section 3.3 of the Main Report). Note that for each 50-year with-project trace, it was necessary to produce a companion without-project trace to allow calculation of project costs and benefits.

2. A second computer model was used to give the projections regarding the downstream river water quality and quantity. This second model used the lake level trace output from the first model as input, along with climate projections and hydrologic information for the downstream rivers. In this way, normal river flows could be combined with any Devils Lake outflows to allow prediction of water quality constituent concentrations and flow rates over the same 50-year span (see also Section 3.4 of the Main Report). Again, for each with-project trace, a companion without-project trace was generated to allow calculation of project costs and benefits.

3. A third computer program used the lake levels and river water quality and quantity parameters to calculate the costs and damages for each of the features around Devils Lake and for each of those features downstream of the lake that could be affected by outflow from the lake. For each feature, costs and damages were summed for both the with-project and the without-project condition. Subtracting the summations of all the features' costs and damages with-project totals from the without-project summation of all features' costs and damages totals allowed calculation of the alternative's benefits. The project costs compared to these benefits provides the net benefits and BCR for the alternative. Project costs are described in Section I.3.1 of this Technical Appendix and Section 3.5 of the Main Report. The processes involved in arriving at the project benefits (costs and damages for the various features) are described in Sections I.4 and I.5 of this Technical Appendix and in Sections 3.6 and 3.7 of the Main Report.

4. Finally, further analysis of the alternatives was desired to determine the economic indices' sensitivity to variations in the assumptions made regarding the alternative. For several alternatives, therefore, additional sets of benefits and costs were computed. Each additional set was computed after making adjustments to one or more of the following:

   - Assumptions regarding the future climatic conditions.

- Assumptions regarding the simultaneous infrastructure protection measures around the lake that would be undertaken with or without the project.
- Assumptions regarding which, if any, infrastructure protection measures would be undertaken as part of the project.
- Assumptions regarding the way in which the natural outlet would erode if the Devils Lake/Stump Lake system overflowed. (Altering these erosion assumptions changes the flow rate of water spilling from the lake.)

A brief description of these portions of the analysis is given below.

I.2.1 Projections of Lake Levels

A major challenge for evaluating alternatives lies in predicting the future lake levels. Devils Lake is a landlocked lake, so the range of future fluctuations is more difficult to predict than in a simpler system such as a river. Future lake levels are affected by a variety of climatic factors, as well as by the lake level in previous years and the groundwater level. The Economics Analysis evaluated the alternatives using two approaches to defining the future lake levels: a stochastic approach and a Wet Future Scenario approach that is based on recent climatic conditions.

I.2.1.1 Stochastic Analysis

The stochastic analysis determined the likelihood of future lake levels using a large set of possible future lake levels—10,000 traces. The large number of traces was generated as a way of dealing with the uncertainty regarding future lake levels. Because the calculations of the costs and benefits for any alternative depend on the predictions of lake levels, any cost and benefit calculations can be no more reliable than the lake level predictions. The stochastic analysis provides a large number of lake level predictions varying according to fluctuations within reasonable expectations regarding future weather patterns. By computing an alternative's costs and benefits for each of the 10,000 traces, and then averaging those costs and benefits, a reasonable expectation of the cost and benefit for the alternative can be determined.

For the stochastic analysis, every set of 10,000 with-project traces has a companion set of 10,000 without-project traces. Because each trace reflects a particular 50-year projected climate future, each of the 10,000 50-year traces for each alternative is different.

The first 15 years of the stochastic traces were generated based on the assumption that climatic conditions would be similar to those experienced during 1980-99, reflecting the generally wetter conditions that the Devils Lake Basin has been experiencing since 1980. For the modeling, these conditions were assumed to persist until at least 2015.[2] After 2015, the simulation model assumes that climatic conditions can be

2 This assumption is based on the results of analysis conducted by Leon Osborne, Regional Weather Information Center, University of North Dakota.

represented by the longer historic period 1950-99. The average peak lake level resulting from the stochastic analysis was 1451.7 and the median was 1450.1.

I.2.1.2 Wet Future Scenario Analysis

The Wet Future Scenario analysis evaluated one set of 50-year lake levels that is based on recent climatic conditions. The Wet Future Scenario repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993–1999) for three cycles, causing the lake to overflow. The remaining years of the 50-year cycle were defined assuming climatic and hydrologic conditions similar to 1980–1999.

The Wet Future trace rises gradually for about 14 years until the natural overflow occurs in year 2014. The lake remains above the natural outlet elevation for about another 11 years. The peak lake level for this scenario occurs in year 19, at an elevation of 1460.6. There is a second peak that occurs near the end of the 50-year period, however, it has a lower peak flood level than the first peak and no additional overflow occurs. By comparison, this wet future is representative of approximately 10% of the Stochastic traces, representing those traces that have an average peak lake level of 1461.1.

I.2.2 Projections of Downstream River Characteristics

A natural overflow or the release of water from the Devils Lake basin will affect the flow rate and water quality of both the Sheyenne River and the Red River of the North. These changes will have impacts on those who use water from those rivers—impacts that need to be counted in the Economic Analysis. Therefore, it is necessary to have projections of the downstream flow rates and water quality to allow assessment of the benefits of any alternative that results in outflow from Devils Lake.

Generation of the 50-year traces of downstream river characteristics was accomplished through use of a lake model that tracks water quality in each of six bays of Devils Lake, using trace data from the lake level model described above as input. Tracking the water quality of the six bays allows determination of the water quality of a discharge from any bay of the lake. The discharge rate is determined based on the pumping rate allowed for a pumped outlet or on the lake level in the case of either a gravity outlet or an overflow at the natural outlet. Projections of discharge water quality and quantity from the lake is integrated with projections for the Sheyenne River and the Red River of the North; the projections based on the same weather conditions assumed for generating the lake level model's trace data.

I.2.2.1 Stochastic Analysis

Analysis of downstream river characteristics using sets of 10,000 traces was not feasible for the downstream features. Instead, the downstream features analysis was evaluated for a representative set of four downstream river traces. The four representative traces each correspond to one of four categories of the 10,000 traces—a Wet Future, two Moderate Futures, and a Dry Future—and each trace represents a certain percentage of the 10,000 traces (see table below). Using the four traces, therefore, costs and

benefits (whether positive or negative) could be determined for each and a weighted average for the downstream features could be determined for each alternative.

Categories of Traces for Evaluating Impacts of Alternatives

Scenario	Peak lake level during 2001-2050, with no outlet	Percent of traces (out of 10,000)	Average peak lake level
Dry	1,447.0 to 1,449.0	35.6	1,448.1
Moderate 1	1,449.1 to 1,452.0	29.9	1,450.2
Moderate 2	1,452.1 to 1,459.0	25.0	1,454.9
Wet	1,459.1 to 1,465.0	9.5	1,461.1

As with the portion of the Economic Analysis based on the evaluation of the set of 10,000 lake level traces, each downstream with-project trace must be compared to a corresponding without-project trace to allow a determination of the benefits of the alternative.

I.2.2.2 Wet Future Scenario Analysis

Downstream river characteristics for the Wet Future Scenario analysis were evaluated directly for each alternative, based on the 50-year trace of downstream water quality and quantity. Again, each downstream with-project trace must be compared to a corresponding without-project trace to allow a determination of the benefits of the alternative.

I.2.3 Benefit and Cost Calculations

Lake level and stream flow information was used as input to the economic models that calculated benefits and costs for each of the alternatives. A general description of how the benefits and costs were developed is presented in the Main Report (Sections 3.5 through 3.7). Later sections of this Technical Appendix provide detailed information regarding the assumptions and unit costs used in arriving at the computed benefits and costs.

I.2.4 Sensitivity Analysis

To gauge the economic model's sensitivity to varying baseline assumptions, these assumptions were changed, and the economic indices recalculated for the alternatives. The sensitivity analyses are described briefly below; for additional information regarding the generalities of the sensitivity analyses, see the Main Report (Sections 3.8 through 3.11).

I.2.4.1 Sensitivity Analysis – Local Flood Protection Strategies Adjacent to the Lake

Although the use of the set of *most likely actions* (as described in the Main Report, Section 3.6.3) most closely approximates the National Economic Development (NED) prescription for economic analysis of

the emergency outlet, other combinations of strategies were also examined in the analysis. This was done to determine how sensitive the results would be to the assumptions regarding local flood protection measures. Again, the with-project condition and without-project condition were compared while the local flood protection strategies were held constant.

The three other sets of local flood protection strategies that were analyzed as assumptions for the sensitivity analysis were:

- *Set of Cost-Effective Flood Protection Strategies*
- *Set of Maximum Flood Protection Strategies (at the First Decision/Action Level)*
- *Set of No Protection Strategies*

I.2.4.2 Sensitivity Analysis – Maximum Infrastructure Protection Adjacent to the Lake

In the Economics Analysis, it was generally assumed that the *most likely actions* with respect to local flood protection measures would be implemented—with or without a project. This set of *most likely actions* was assumed to be the without-project condition for most alternatives evaluated in this study, meeting the NED criteria as "the most likely condition expected to exist in the future in the absence of a proposed water resources project." The sensitivity (of the economic results) to this assumption was also evaluated, however, through analysis of the alternatives that included the Maximum Infrastructure Protection approach.

Analysis of the alternatives that include Maximum Infrastructure Protection provides a comprehensive evaluation of flood protection measures within the basin. For these alternatives, the types of emergency measures that are currently being pursued in the basin were assumed to be part of the **project**—rather than assumed to be present in the without-project condition. Therefore, for these alternatives, the without-project condition assumes no flood protection for the features.

I.2.4.3 Sensitivity Analysis – Moderate and Dry Future Scenarios

The stochastic analysis provides an average economic estimate based on the probability of future lake levels. Because the recent lake levels have exceeded the predictions that have been based on historical lake levels, the Wet Future Scenario analysis was also evaluated. However, it was necessary to also evaluate the economic feasibility of various alternatives based on average or dry scenarios to define the sensitivity under a wide range of potential futures.

This sensitivity analysis evaluated a set of three scenarios that are representative of three categories of future lake levels—a Dry Future and two Moderate Futures. These scenario analyses are representative of various categories within the stochastic traces, as noted.

Dry Future Scenario—The traces represented by this scenario generally show a decreasing pattern in the inflows and lake levels. The Dry Future represents those traces that have an average peak lake

level of 1448 (approximately 36% of the stochastic traces). This dry future trace was obtained from within the Stochastic traces, as a trace that was representative of this category.

Moderate Future 1 Scenario—Moderate Future 1 represents those traces that have an average peak lake level of 1450 (approximately 30% of the stochastic traces). This moderate future trace was obtained from within the Stochastic traces, as a trace that was representative of this category.

Moderate Future 2 Scenario—Moderate Future 2 represents those traces that have an average peak lake level of 1455 (approximately 25% of the stochastic traces). This moderate future trace was obtained from within the Stochastic traces, as a trace that was representative of this category.

Although the exact weather conditions assumed for these exact futures will probably never occur, examination of these futures helps determine the sensitivity of the model results to the assumptions made regarding future climatic and hydrologic conditions.

I.2.4.4 Sensitivity Analysis – Erosion of the Natural Outlet

The analysis of alternatives assumed that there would be no erosion of the natural outlet or Tolna Coulee channel. This assumption was based on the conjecture that state or Federal agencies would protect the natural outlet at its current configuration in the case of a natural overflow. Because it is impossible to predict what may actually be implemented because of environmental, political, or social reasons, a sensitivity analysis of this assumption was necessary to define the potential impacts to the economic feasibility of the alternatives.

I.3.0 Alternatives and Their Costs

Comprehensive flood reduction evaluations typically analyze a wide variety of flood control projects that either reduce or prevent damages. The intent is to identify the project that provides the largest net benefit. For the Devils Lake basin, the Economic Analysis evaluated a variety of alternatives[3] that could reduce the future lake levels, protect features[4] adjacent to the lake, and/or protect the downstream waters. The range of alternatives that were analyzed included measures strictly within the basin, a variety of outlet configurations, an earthen dike that would prevent any outflow from Devils Lake, and combinations of these. The following table lists the ten alternatives that were analyzed.

List of Alternatives Analyzed

Alternatives within the Basin
Upper Basin Management
Expanded Infrastructure Measures
Raise the Natural Outlet: Natural Overflow Protection
Outlet Alternatives
West Bay 300 cfs Constrained Outlet
West Bay 480 cfs Unconstrained Outlet
Pelican Lake 300 cfs Constrained Outlet
Pelican Lake 480 cfs Constrained Outlet
East End 480 cfs Unconstrained Outlet
Combination Alternatives
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures

A wide range of outlet projects were initially evaluated through a screening process conducted by the US Army Corps of Engineers, where eight basic designs were evaluated for their effectiveness in drawing down the lake levels while meeting objectives for downstream channel capacities, water quality criteria, and feasibility for implementation. The report summarizing this initial screening (Devils Lake Outlet Alternatives Screening, US Army Corps of Engineers, May 8, 2001) is included as Attachment I.A. A general description of each of the ten alternatives is provided in the Main Report. Additional details of the assumptions made in defining these alternatives and the associated project costs are given in the sections that follow.

3 The term "alternative" is defined as an overall approach to flood control and management, consisting of a single project or a combination of projects.

4 A "feature" is defined as a physical entity or group of entities that would be susceptible to damage from the rising lake or from flows released from the lake.

I.3.1 Alternatives Within the Basin

I.3.1.1 Upper Basin Management

The Upper Basin Management alternative increases the amount of available upper basin storage volume in the watershed. Based on current studies by West Consulting, this is estimated to be approximately 50 percent of the total available upper basin storage. Implementation of this alternative would require placement of 39,681 acres of land into an upper basin storage program. Much of this land is currently prime farmland.

The analysis assumes that the storage is in place when the lake is above elevation 1440. Previous programs have varied the duration of the storage program from an annual program to one with a 10-year contract. Therefore, an expanded program could involve contract lengths for any duration up to 10 years.

Implementation of an upper basin storage program was assumed to require the following:

- Construction of outlet structures at some of the storage sites. These measures could vary from no construction, to construction of a berm with an outlet structure, likely a gated pipe that allows flexibility for future conditions. Costs for these outlet structures would be based on site-specific conditions, and could vary from $0 up to $100,000 per site. The storage available at each site would also vary, depending on the sites selected and incorporated into the program.
- Purchase of an easement or lease for agricultural land. Costs for easements or leases could vary widely since some lands may be more valuable agricultural areas than others may (ranging from 10 to 70% of fee title). Land costs are currently averaging about $400 per acre (although prime farmland could be higher).
- Program administration and negotiations, including those to acquire land through condemnation (minimum of $4,800 per tract).
- Maintenance of the outlet structures, the cost of which would be based on the size and configuration of outlet structures.
- Potential removal of outlet structures when the lake recedes.

The project costs for implementation of the Upper Basin Management alternative could vary widely, depending on the sites selected for inclusion in the program. Annual costs for previous upper basin storage programs ranged from $40 to $90 per acre per year. However, it was assumed that the project costs would be computed as a one-time first cost (which includes acquisition or leasing of lands, construction of outlet structures, and other associated maintenance and/or removal costs). Therefore, computation of these costs was based on a up-front first cost per acre, estimated to be at least three times the land costs (an average per acre value of $1,000). Therefore, the total project costs for the Upper Basin Management alternative were estimated at $39.7 million.

I.3.1.2 Expanded Infrastructure Measures

There are several locations around Devils Lake in which roads are currently holding back water, providing barriers to the rising and expanding waters of Devils Lake. Since these roads are acting as dams, but are not constructed to function as dams, there is a potential safety hazard to road users and to the people living behind and using the areas being sheltered by these barriers.

This alternative examines the economic feasibility of taking additional measures to provide a safe level of flood protection behind these barriers. The alternative assumes that several perimeter dams would be constructed between high ground (to minimize the number of roads that need to be raised) and that any remaining exterior roads would be converted to dams (including: Highway 20 near the Acron Ridge development, BIA 4, and BIA 5). Figure I.2 shows the locations of these additional measures.

The construction costs for implementation of the Expanded Infrastructure Measures alternative were obtained from the *Roadways Serving as Water Barriers Report*, Devils Lake Surface Transportation Task Force, May 2000. The project costs include:

- Costs to raise Highway 20 near Acorn Ridge, BIA 4, and BIA 5. These costs occur incrementally as necessary due to the rising lake levels. Construction costs for these raises are listed in Table I.1. Inclusion of these raises as project costs was assumed to reduce the costs for raising road features and reduce the damages to land within the protected area. Table I.1 also lists the revised construction costs for raising these roads (these costs are lower than the costs presented in Attachment I.C for the other alternatives) and the revised damages to land.

- Costs for levee (perimeter dam) construction to connect high ground. These costs also occur incrementally as necessary due to the rising lake levels. Construction costs for these levee raises are listed in Table I.1.

- Operation and maintenance costs for the new levees. Operation and maintenance costs were assumed to be 1% of the total project costs. These costs were assumed to include operation of temporary pumping stations to remove interior drainage and maintenance of the levees.

The protection that was provided by this alternative also changed the extent of damages prevented within this area. These damages prevented modified feature costs as follows:

- Feature 5 (St. Michael) – Relocation costs were eliminated.

- Feature 24 (BIA 6) – Road raise costs were eliminated.

- Feature 22 (Highway 20 Between Highway 57 and Tokio) – Road raise costs were revised to reflect only those costs for raising the segment between Highway 57 and BIA 5 (at the perimeter dam). The revised raises were computed at $4,574,000 at elevation 1454 and $6,481,000 at 1459.

- Feature 8.1 (Devils Lake Rural Areas) – Damages and relocation costs at action level 1446.2 were decreased to account for houses where access was restored. Homes that would be within the protected

area include 7 homes on the reservation and 21 homes in the Acorn Ridge area (near Camp Grafton). The total reduction in damages to homes that are protected is $8,376,000. The total reduction in relocation costs was computed at $7,254,000. Land that is protected by this alternative (valued at $178,600) was also removed from the potential damages.

I.3.1.3 Raise Natural Outlet

The natural outlet from Stump Lake is at about elevation 1459.1. If Devils Lake were to rise above the natural outlet elevation, water would flow down Toulna Coulee into the Sheyenne River. The water quality of this natural overflow may be very poor, impacting the downstream river and users of the river water.

This alternative evaluates the potential effects of reducing the downstream impacts through construction of a permanent concrete weir at the natural outlet. The weir had an assumed top elevation of 1463. The alternative computes the reduction in downstream impacts and the related expenses for flood-related damages to adjacent lake features. The weir was assumed to be about 380 feet long and has been conceptually designed to remain in place even if the outlet erodes to 1450 in the downstream channel.

The project costs for the Raise Natural Outlet alternative include:

- Construction of a permanent weir at the natural outlet, at $1.3 million. Construction of the permanent weir was assumed to occur when the lake level exceeds 1458, or one foot prior to overtopping the natural outlet. This occurs in year 2012 under the Wet Future Scenario analysis.
- Operation and maintenance of the permanent weir structure, estimated at 1% of the total construction costs. Operation and maintenance of the weir is incurred starting in year 2013 under the Wet Future Scenario analysis.
- Purchase of additional land that is inundated by raising the lake level above the elevation at which it would have been without the weir (between 1460.6 and 1463). Under the Wet Future Scenario, it was assumed that 69,167 acres of land would be purchased, at a total land cost of $27,667,000. Land was estimated to cost $400 per acre.
- Flood protection to protect features adjacent to the lake above the elevation at which the lake would have been without the weir (between 1460.6 and 1463). Five features would be raised between these elevations (Features 6, 7, 17, 22, and 24). These raises were incurred as necessary due to the rising lake level. Construction costs (counted as project costs) for these raises are listed in Table I.2.
- Additional detour and restoration damages to roads and rail lines (between elevations 1460.6 and 1463).

I.3.2 Outlet Alternatives

Construction of the outlets was assumed to begin immediately and be operational in 2005. Costs for the outlets were assumed to be allocated in 2001.

I.3.2.1 West Bay Outlet

The West Bay outlet that directed water into Peterson Coulee was evaluated in detail in 1998, as the preliminary emergency outlet design. The outlet would draw water from the West Bay and direct it over the divide to the Sheyenne River. This bay has the best water quality within the lake that is located relatively near the Sheyenne River. The pump station was assumed to be located east of Round Lake and Highway 281. An underground pipeline was assumed to extend from the pump station to the Sheyenne River. This configuration minimizes environmental and social impacts along the outlet route in exchange for moderately high construction costs. Only the northernmost 1½ to 2 miles of this route lie within the Spirit Lake Reservation and no Tribal trust lands are impacted because affected reservation lands are all in private ownership.

Two projects were evaluated that use the West Bay outlet design—300 cfs constrained and 480 cfs unconstrained outlets. The 300 cfs constrained outlet was described in detail in *Devils Lake Emergency Outlet, Independent Assessment, Phase I,* Barr Engineering Company, October 30, 1997. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

The project costs for the West Bay outlets include:

- Construction costs, at $58.5 million for the 300 cfs constrained outlet or $92.2 million for the 480 cfs unconstrained outlet.
- Operation and maintenance costs for the outlet:
  - Average operating costs based on the yearly volume of water pumped. Pump efficiency was assumed to be 70% for the 300 cfs constrained and the 480 cfs unconstrained outlets. Electrical costs were assumed to be $0.02245 per KWH. Design head for the 300 cfs constrained outlet and the 480 cfs unconstrained outlet was assumed to be 240 feet.
  - Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating. The first costs used for this computation do not include the costs for Engineering and Design, Supervision and Administration, real estate, etc.
  - One-time cost of replacement pumps in year 2026. The replacement costs for the 300 cfs constrained outlet pumps were $2.6 million and the replacement costs for the 480 cfs unconstrained outlet pumps were $4.2 million.

- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed. The least expensive treatment technology or alternate water source was assumed for each facility, and identified by comparing the sum of the capital costs and the annual operating expenses of each technology or alternate source. The analysis was based on the concentrations given in the water quality trace data. Although the future water quality concentrations would not actually be known by facility operators in advance, an analysis of predicted future concentrations would likely occur as a basis for selection of water treatment methods. Therefore, the use of modeled future concentrations for identifying capital costs was assumed to be acceptable for the present reconnaissance-level economic analysis.

  The type of treatment system and the computed project cost at each facility under the various analyses is listed in Table I.3. These facility project costs were allocated in 2001.

- Natural resource up-front mitigation costs along the downstream rivers. These costs were computed based on mitigation of cultural resources, vegetation/wildlife/wetland resources, and aquatic resources. Present worth costs were computed at $12.9 million for the 300 cfs constrained outlet, or $40.7 million for the 480 cfs unconstrained outlet.

- Annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts. These costs include monitoring of: groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

I.3.2.2 Pelican Lake Outlet

The largest inflows into Devils Lake come from Mauvais Coulee and enter Devils Lake through Pelican Lake, which is located on the north side of the West Bay. Water quality in Mauvais Coulee is similar to that in the Sheyenne River, making Pelican Lake water much fresher than the rest of Devils Lake. Therefore, an outlet that withdraws water from Pelican Lake is attractive because it is the freshest water available in Devils Lake. When constrained by water quality impacts, this would allow the outlet to be more effective in drawing down the lake than could be expected at other locations. It would also have the least impacts on downstream features if used in an unconstrained mode to reduce the potential for a natural overflow.

The Pelican Lake alternatives assume that the outlet captures and releases as much of the Big Coulee hydrograph as possible within the constraints of pumping capacity and river channel capacity. In late spring/early summer, as coulee flow decreases, the outlet will pump a mixture of coulee and West Bay waters, with that mixture becoming predominantly West Bay water as the coulee flow decline to near zero in later summer and fall.

This version of the outlet project assumes construction of a 6.1-mile long open channel to a pump station located on the north side of Minnewaukan. The existing embankments for Highways 281 and 19 would used to keep the fresher water in Pelican Lake and the gravity channel separated from the West Bay of

Devils Lake. The pump station and pipeline would be similar to that required for the West Bay outlet through Peterson Coulee, but would have higher head requirements due to the longer length of the pipeline. To provide additional fresh water, it was assumed that the Channel A control structure would be closed to allow flows from Dry Lake to flow into Mauvais Coulee.

Two projects were evaluated that use the Pelican Lake outlet design—300 cfs constrained and 480 cfs unconstrained outlets. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

The project costs for the Pelican Lake outlets include:

- Construction costs, at $84.2 million for the 300 cfs constrained outlet, or $129.2 million for the 480 cfs unconstrained outlet.
- Operation and maintenance costs for the outlet:
  - Average operating costs based on the yearly volume of water pumped. Pump efficiency was assumed to be 85% for the 300 cfs constrained and the 480 cfs unconstrained outlets. Electrical costs were assumed to be $0.02245 per KWH. Design head for the 300 cfs constrained and the 480 cfs unconstrained outlets was assumed to be 270 feet.
  - Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating. The first costs used for this computation do not include the costs for Engineering and Design, Supervision and Administration, real estate, etc.
  - Costs for providing replacement pumps in year 2026. The replacement costs for the 300 cfs constrained outlet pumps were $3.0 million and the replacement costs for the 480 cfs unconstrained outlet pumps were $4.6 million.
- Construction costs to raise control structures along Highway 281 and Highway 19. The raises for these control structures would be incurred incrementally as necessary due to the rising lake. Costs for these raises are listed in Table I.4. Raising these roads as part of the project was assumed to reduce the costs for raising these features. Table I.4 also lists the revised construction costs for raising these roads (these costs are lower than the costs presented in Attachment C for the other alternatives).
- Operation and maintenance costs for the control structures along Highway 281 and Highway 19. These costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating (because the lake level would be low).
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed. The least expensive treatment technology or

alternate water source was assumed for each facility, and identified by comparing the sum of the capital costs and the annual operating expenses of each technology or alternate source. The analysis was based on the concentrations given in the water quality trace data. Although the future water quality concentrations would not actually be known by facility operators in advance, an analysis of predicted future concentrations would likely occur as a basis for selection of water treatment methods. Therefore, the use of modeled future concentrations for identifying capital costs was assumed to be acceptable for the present reconnaissance-level economic analysis.

The type of treatment system and the computed project cost at each facility under the various analyses is listed in Table I.3. These facility project costs were allocated in 2001.

- Natural resource up-front mitigation costs along the downstream rivers. These costs were computed based on mitigation of cultural resources, vegetation/wildlife/wetland resources, and aquatic resources. Present worth costs were computed at $12.9 million for the 300 cfs constrained outlet, or $40.7 million for the 480 cfs unconstrained outlet.

- Annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts. These costs include monitoring of: groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

I.3.2.3 East End Outlet

East Devils Lake is the closest point of Devils Lake to the Sheyenne River and also has the lowest divide elevation (1465 msl) between Devils Lake and the Sheyenne River basin. There is a naturally formed channel along the divide that undoubtedly was an outlet from the lake during high water level periods in the distant past. The path over the divide flows naturally down a circuitous route along Tolna Coulee to the Sheyenne River. Water quality is much worse in East Devils Lake than in the western part of the lake where most runoff enters. However, the outlet would be a low cost gravity system and just as effective as other alternatives in controlling further rises in lake levels.

The outlet from the east end of Devils Lake was assumed to be a grass-lined gravity flow channel that initially follows the natural outlet channel between Devils Lake and Stump Lake. At Stump Lake, the channel would follow the west side of the lake until it reached the natural outlet from Stump Lake. From there, it would continue along the natural Stump Lake outlet route until it meets the confluence of Tolna Coulee.

A channel was designed that could allow 480 cfs to flow out of Devils Lake when the lake elevation is 1446 or more. The channel has a starting inlet elevation of about 1437 and daylights in Tolna Coulee at about elevation 1432.

A gate structure would be constructed at a road crossing on the divide between Devils Lake and Stump Lake to control outflows within the operational constraints of the project. Excess water would be directed

into Stump Lake to prevent project-created damages around Devils Lake. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

The project costs for the East End 480 cfs unconstrained gravity outlet include:

- Construction costs at $57.4 million.
- Total present worth operation and maintenance costs, at 1% of the first costs. This was assumed to consist primarily of maintenance along the channel.
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed. The least expensive treatment technology or alternate water source was assumed for each facility, and identified by comparing the sum of the capital costs and the annual operating expenses of each technology or alternate source. The analysis was based on the concentrations given in the water quality trace data. Although the future water quality concentrations would not actually be known by facility operators in advance, an analysis of predicted future concentrations would likely occur as a basis for selection of water treatment methods. Therefore, the use of modeled future concentrations for identifying capital costs was assumed to be acceptable for the present reconnaissance-level economic analysis.

  The type of treatment system and the computed project cost at each facility under the various analyses is listed in Table I.3. These facility project costs were allocated in 2001.
- Natural resource up-front mitigation costs along the downstream rivers. These costs were computed based on mitigation of cultural resources, vegetation/wildlife/wetland resources, and aquatic resources. Present worth costs were computed at $12.9 million for the 300 cfs constrained outlet, or $40.7 million for the 480 cfs unconstrained outlet.
- Annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts. These costs include monitoring of: groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

I.3.3 Combination Alternatives

I.3.3.1 Combination of Upper Basin Management and Expanded Infrastructure Measures

This alternative combines the Upper Basin Management project with the Expanded Infrastructure Measures project. The alternative assumes that storage in the upper basin would be combined with expanded flood protection measures to ensure safe protection of features adjacent to the lake. The project costs for the combination Upper Basin Management and Expanded Infrastructure Measures alternative

include the combined costs listed in Sections I.3.1.1 and I.3.1.2. These costs include the implementation of upper basin storage, raising three roads as dams (Highway 20 near Acorn Ridge, BIA 4, and BIA 5), and constructing perimeter dams to protect Highway 20 and other BIA roads south of Devils Lake. Figure I.2 shows the locations of the roads and perimeter dams assumed for the expanded infrastructure measures. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

I.3.3.2 Combination of West Bay Outlet with Upper Basin Management and Expanded Infrastructure Measures

This alternative combines the West Bay outlet with the Upper Basin Management project and the Expanded Infrastructure Measures project. In addition to construction of an outlet that releases flow from the West Bay, the alternative assumes that upper basin storage and the expanded flood protection measures would be implemented to ensure safe protection of features around the lake. The project costs for the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures alternative include the combined costs listed in Sections I.3.1.1, I.3.1.2, and I.3.2.1. These costs include outlet construction, outlet operation and maintenance, the implementation of upper basin storage, raising three roads as dams (Highway 20 near Acorn Ridge, BIA 4, and BIA 5), and constructing perimeter dams to protect Highway 20 and other BIA roads south of Devils Lake. Figure I.2 shows the locations of the roads and perimeter dams assumed for the expanded infrastructure measures. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

I.4.0 Methodology for Features Adjacent to Devils Lake

I.4.1 General Description of Methodology

This section of the report describes the methodology and general assumptions for the analysis of features that are adjacent to Devils Lake. The potential flood threats from the rising lake levels were examined along with various protection strategies that would protect these features from the rising lake levels. Construction costs of these protection strategies were computed, as well as the value of potential damages that would occur with and without these protection strategies. The damages prevented by each protection strategy and the reduced costs represent the benefits of that strategy.

The set of most likely action strategies was selected to demonstrate the economic feasibility of each project. This set of strategies assumes that the types of emergency measures currently being pursued in the project area would continue to be implemented as necessary as the lake continues to rise. This set of most likely action strategies was the assumed condition for this analysis, under both the without- and with-project conditions. Table I.1 lists the assumed most likely action strategies by feature.

Two categories of project benefits were then determined for features adjacent to the lake:

- Net savings in construction costs for protection of the features under the with-project future.
- Direct damage reduction because of lower lake levels under the with-project future.

The potential combinations of analysis (future climatic condition), alternative (project type), and flood protection strategies (assumed protection of features adjacent to Devils Lake) that could be analyzed for economic feasibility are shown schematically on Figure I.3. To minimize the duration and cost of the Economics Analysis, the analyses were limited to select combinations that would allow interpretation of the results without redundancy of effort.

I.4.2 Adjacent Lake Features

Features were defined as physical entities or groups of entities that would be susceptible to damage by flooding from the rising lake or from flows released from the lake. Some discussion of the features is provided in the Main Report, but the following sections provide detail regarding the assumptions made in analyzing the features.

I.4.2.1 Adjacent Lake Features Independently Analyzed

The features were grouped into five types: communities and cities, certain state facilities, rural areas, roads, and rail lines. For this study, 24 significant independent features were selected based on the threats from flooding and the potential for protection. Table I.2 lists the features and shows how they are grouped by type for the analysis. Figure I.4 shows the location of all 24 features.

The individual features were generally evaluated independently in the feature analysis. For instance, communities were evaluated independently from the roads that provide access to the communities. Sections I.4.6.1 and I.4.6.2 describe the interdependencies and functional dependencies between features and notes where the feature analysis included the effects of another feature. The following section describes the physical dependencies of the features, emergency actions taken to date, and attributes of the features.

Communities and Cities

Of the 24 selected independent features, five were communities or cities: Churchs Ferry, Devils Lake, Fort Totten, Minnewaukan, and St. Michael (Figure I.5). The value of these communities is high because of the density of infrastructure. It was determined that all infrastructure within the communities (such as wastewater treatment facilities, schools, grain elevators, hospitals, schools, and airports) were dependent on the flood protection provided for the community. Therefore, infrastructure was included with the respective city features.

The City of Devils Lake levee was raised and extended in recent years under emergency authority. The community of Churchs Ferry had an emergency levee constructed in 1997 to protect the infrastructure, and therefore it was included as a feature in previous studies. However, in 2000 the community was disbanded under a relocation program with the Federal Emergency Management Agency (FEMA). This modified feature continues to be included in the analysis, although it is no longer considered a significant independent feature. The City of Minnewaukan invested about $800,000 in 1996 to move the city's sewage lagoon to high ground. The Bureau of Indian Affairs installed additional protection for the St. Michael sewage lagoons in 1997 to prevent damage due to the high lake level. Although Fort Totten has not been significantly affected by the rising lake level to date, it is a relatively large community and major center of activity in the area. All other communities in the area were included as part of the rural areas feature. The reasons for not identifying them as independent features are described in Section I.4.2.2.

State Facilities

Two of the selected features are state-owned facilities: Gilbert C. Grafton State Military Reservation and Grahams Island State Park. Figure I.6 shows the locations of these state facilities. The military base has a large economic impact on the community. Rising lake levels can have a substantial impact on access and use of the facility. A substantial amount of land used for military maneuvers at the base has been inundated in recent years. The base has also been pumping water from the west side of Highway 20 (just south of the City of Devils Lake levee) to protect several training areas.

Grahams Island State Park is considered a major tourist attraction in the area. Park staff estimate that a total of 73,770 visitors used the Park during 1999. Access to the park is affected by rising lake levels; the Park was closed in 1997 when the access road was under water. During 1997, approximately $2.2 million was invested in raising the access road to the park.

Rural Areas

The rural areas adjacent to the lake, including farmsteads and farmland, residences, small towns, and small parks, were combined into this feature. Although the cost of individual infrastructure and land in these rural areas is not high, the total impact of rising lake levels on rural areas is significant. The rural areas were divided into two features for purposes of analysis based on water level: Devils Lake Rural Areas and Stump Lake Rural Areas. Figure I.6 shows the area encompassed by the rural areas, delineated at the maximum flood boundary.

Rail Lines

Four rail lines in the area were initially selected as independent features because they would be impacted by the rising lake levels. The Red River Valley and Western spur line to Minnewaukan was recently closed and, therefore, was assumed to be abandoned in this analysis. Figure I.7 shows the locations of the rail line features. The Burlington Northern line that runs parallel to US Highway 2 is a major artery in the Upper Midwest's railroad system. Trains using this rail line have routes that extend from the State of New York to the State of Washington. Many local communities outside of the study area are dependent on this rail line, although the communities themselves are on high ground. The other two rail lines that were selected as features are spur lines whose main function is to provide service to collect grain from local grain elevators and deliver fertilizer to the area. The Canadian Pacific Railroad line from the City of Devils Lake to Harlowe was closed in 1998, and is currently considered "embargoed."

Roads

There were 12 sections of roads that were selected as independent features, based on the results of a recent study of transportation in the region (Devils Lake Flood Control, Economics Database Update: Transportation Report, Barr Engineering Company, January 1998). Figure I.8 shows these features. Roads were typically selected if they had average daily traffic counts (ADTs) greater than 1,000 prior to the effects of the rising lake level. The roads included as independent features are described below.

US Highway 2 is a major highway in the Upper Midwest. Both interstate travel and local communities outside of the study area would be affected by disruption of this road. The low portions of Highway 2 below the current lake level are protected by the City of Devils Lake levee.

Two other roads that are heavily used for east-west travel in the area are Highways 57 and 19. The low portions of both of these roads have been raised in recent years to maintain east-west travel. The Highway 57 bridge was recently built across The Narrows.

There are three major highways used for north-south travel in the area: Highways 281, 20, and 1. The low portions of Highways 281 and 20 were raised in recent years to maintain north-south travel. Highway 1 is located near Stump Lake, and is close to being affected by the rising level of Stump Lake. Plans to reroute Highway 1 during 2001 were assumed to be completed, therefore no costs were assumed for this feature.

Two roads on the Spirit Lake Nation Reservation had average daily traffic counts that were greater than 1,000: BIA 1 and BIA 6. The low portions of both of these roads were raised in recent years to maintain travel in the area.

Three of the highways (Highways 57, 281, and 20) were subdivided into multiple sections, and each section was included as a separate feature. The multiple segments allow separate analysis of roads where there are different traffic patterns, different potential reroute paths, and different lake elevations at which the road section would be affected by flooding.

I.4.2.2 Adjacent Lake Features Not Independently Analyzed

Several facilities or infrastructure that were not analyzed as independent features are discussed below:

- **Community of Penn**
  The community is at about elevation 1460 and would become isolated by the lake at approximately lake level 1457. It is located adjacent to US Highway 2 and is dependent on it for access at high lake levels. The population of the community is estimated to be just under 150 and was included in Feature 8.1: Devils Lake Rural Areas.

- **Spirit Lake Casino**
  The casino is above elevation 1463, so it would not be damaged directly by the rising lake. Therefore, the casino was not included as a separate feature. Access to the facility would be disrupted if local highways were closed.

- **Other Parks and Recreation Areas**
  Other parks and recreation areas in the region, including Shelver's Grove, Black Tiger Bay, and Settler's Park, were included in Feature 8.1: Devils Lake Rural Areas and Feature 8.2: Stump Lake Rural Areas. These facilities are similar to Feature 7: Grahams Island State Park, in that the infrastructure would likely be relocated (which does not require independent analysis as a feature). Conversely, they differ from Feature 7 in that none of these facilities have the land area and the volume of visitors that the State Park has, or would have access eliminated by the high lake levels.

- **Water Supply Systems**
  The City of Devils Lake wells are located on high ground south of Tokio and the Ramsey County Rural Utility wells are located on high ground south of Tolna. The community water treatment facilities would be affected with the respective community and were included in the respective feature.

- **Power and Utilities**
  Power and utility lines throughout the area were analyzed with Feature 8.1: Devils Lake Rural Areas and Feature 8.2: Stump Lake Rural Areas.

- **Wastewater Treatment Plants**
  Wastewater treatment plants would be affected with the respective community and were included in the respective feature.

- **Hospitals and Schools**
  Hospitals and schools would be affected with the respective community and were included in the respective feature.

- **Devils Lake Municipal Airport**
  The Devils Lake Municipal Airport is currently protected by the City of Devils Lake levee. The airport would be affected with the city and was, therefore, included in Feature 2: City of Devils Lake.

- **Woods-Rutten Road**
  Prior to the rising lake level, this road had an average daily traffic (ADT) count of less than 200, well below the ADT criterion of 1,000 to qualify as a feature. The recent transportation study indicated that this road was not a primary route, even when The Narrows were assumed to be closed (Devils Lake Flood Control, Economics Database Update: Transportation Report, Barr Engineering Company, January 1998). During 1997, this road was used as a detour for Highways 20 and 57. However, the study showed that the route from Highway 57 to Highway 281 was preferred as a detour because of the better road surface and shorter distance. Also, at higher lake levels, this road would require a significant raise to remain open.

- **Ramsey County 4**
  Prior to recent high lake levels, this road had an average daily traffic (ADT) count of less than 200, well below the ADT criterion of 1,000 to qualify as a feature. The recent transportation study shows results similar to Woods-Rutten Road. Ramsey County 4 is higher than Woods-Rutten Road, and was analyzed as a reroute for Highways 20 and 57. However, it would also require a significant raise to remain open at high lake levels.

- **BIA 4 and BIA 5**
  These BIA roads were raised in recent years to remain open to local traffic and have been used as reroutes for other closed roads in the area. However, the average daily traffic (ADT) on these roads prior to the flooding was about 200, well below the ADT criterion of 1,000 to qualify as a feature. Furthermore, the recent transportation study indicated that these roads were not primary routes. They serve mainly local residences that would be relocated if the lake level continues to rise, resulting in relatively little traffic in the area.

- **Minnewaukan Flats Road**
  This east-west road (Benson County 22) was closed because of flooding in recent years. It previously served traffic to Grahams Island from the southwest. Prior to the rising lake level and closure of the road, the average daily traffic (ADT) for the road was less than 200, well below the ADT criterion of

1,000 to qualify as a feature. It was assumed that the park administration would maintain only one road for access, and that they would continue to raise the north-south Grahams Island Road that was raised in 1997 (Ramsey County 7).

I.4.3 Flood Threats and Response Strategies

As the lake rises, it threatens to damage structures and infrastructure adjacent to the lake. Both the type of damages and the methods of flood protection depend on the type of feature. A description of the potential flood threats to adjacent features and the various strategies that can be used to protect the features are presented in this section. Many of the features are also dependent on other features to maintain their functionality (e.g., communities depend on the roads that provide access to the community). These dependencies are discussed in Section I.4.6.1.

I.4.3.1 Flood Threats to Adjacent Lake Features

Flood threats to features that are adjacent to Devils Lake could include:

- Damages that occur once per event (every time the lake reaches the feature),
- Continuing damages that persist until the lake recedes below the feature level, and
- Damages that occur once only (the first time the lake reaches the feature).

These flood threats are discussed by feature type below.

Communities and Cities

The potential damages that occur in adjacent communities and cities include residential, commercial, industrial, public, infrastructure, etc. It was assumed that these damages would be incurred once, at the first time that the lake level reaches the entity.

The communities are all heavily dependent on the area transportation system, and would be threatened by loss of access if roads were closed because of flooding. Therefore, the major roads that provide access to the communities were assumed to remain open for the incremental levee and maximum protection levee strategies for communities. These roads are features that were analyzed separately in this study. The interdependencies between communities and roads are described in Section I.4.6.1.

State Facilities

Two state facilities were selected as separate features—Grahams Island State Park and Gilbert C. Grafton State Military Reservation. The rising lake would threaten the access roads from major highways into the facilities. These facilities are also heavily dependent on the area transportation system, and would be threatened by loss of access if major roads were closed because of flooding. The major roads that provide access to the facilities were assumed to remain open for the strategies that raise the state facilities' access road. These major roads are features that were analyzed separately in this study.

Both of the state facilities would experience structural damages and loss of land as the lake level rises. It was assumed that structural damages would be incurred once, at the first time that the lake level reaches the structure. The use of agricultural and forested land could be adversely affected by high salinity water to the extent that damages would be equal to the full value of the land, which was assumed. Therefore, it was assumed that the damages to land would be incurred once, at the first time that the lake level reaches the land.

Rural Areas

The rural areas would experience structural damages and loss of land as the lake level rises. It was assumed that structural damages would be incurred once, at the first time that the lake level reaches the structure. The use of agricultural land could be adversely affected by high salinity water to the extent that damages would be equal to the full value of the land, which was assumed. Therefore, it was assumed that the damages to land would be incurred once, the first time that the lake level reaches the land.

Rail Lines

The physical threat to rail lines is the potential damage to the rails, ballast, signals, and ties causing temporary closure during flooding. It was assumed that the damage to rail lines would be incurred once per event, with restoration assumed when the lake level recedes below the track. Temporary closure of the rail lines would also threaten the transportation of goods, which is a continuing damage for the full duration of each flood event.

Grain elevators in Churchs Ferry and the City of Devils Lake are dependent on the rail lines that provide service to the area. The operation of these facilities is threatened as the rising lake impacts the rail lines. This was assumed to be a damage that would occur only during flooding events if rail lines were temporarily closed.

Roads

The physical threat to roads is the potential damage to the road, causing temporary closure during flooding. It was assumed that the damage to roads would be incurred once per event, with restoration of the road when the lake level recedes below the road. Temporary closure of the roads also disrupts traffic, which results in continuing detour costs (damages) for the full duration of flood events.

I.4.3.2 Flood Response Strategies for Adjacent Lake Features

For each feature, different strategies can be used to deal with the problem of flooding. The various types of strategies analyzed for the features are described below.

- **No Protection**
  The no protection strategy provides no flood protection for impacted features.

- **Incremental Protection**
  Strategies that provide flood protection in a series of small elevation increments, such as raising a levee or a road 5 feet at a time, are designated “incremental protection strategies.” Relocation of

structures can also be done in small increments by relocating groups of flood-prone homes and structures based on the water level.

- **Maximum Protection**
  One-step strategies are designated the "maximum protection strategies" because no additional actions would be necessary for that feature even if the lake should rise to its potential maximum elevation of 1463. These strategies would include relocating portions of a community that would be threatened by the lake's maximum elevation, raising a levee to protect a community against the lake's maximum elevation, or raising or rerouting a road (or rail line) to a new alignment above the lake's maximum level.

- **Hybrid**
  It is also possible to institute hybrid strategies that are a combination of the incremental and maximum protection strategies. For example, a plan could call for initially raising a road for one 5-foot increment (incremental protection strategy). Then, if water levels continue to rise, the plan could call for rerouting the road (maximum protection strategy).

This study provides a preliminary evaluation of all these strategies for each feature. This preliminary evaluation was needed as a first step in evaluating the economic effect of each project. It does not constitute a complete study of all local strategies. Further study would be needed before a final action plan for local protection could be completed. Most features have at least one type of no protection strategy, incremental strategy, and maximum protection strategy. Construction of flood protection measures for all of the features would be a significant cost no matter which type of flood protection strategy is selected. The local, state and/or Federal governments may not have the resources to finance the protection measures for all features. Because of the large number of features affected by the rising lake level in recent years, the no protection strategy has been adopted for various features around the lake.

During the current emergency, the incremental approach to flood protection has been used for many of the features independently analyzed in this study. Incremental protection strategies are easier to implement than maximum protection strategies because each increment is relatively low in cost and, therefore, easier to fund for local and state governments. However, the funding for incremental protection strategies requires continued approval, magnifying the continual stress of the flooding problem. In addition, the incremental approach is based on the widespread hope that the lake level will peak and start to decrease, potentially eliminating the actions at the higher lake levels. The total cost for implementation of incremental protection may be greater than a one-time protection because of the additional project planning, management, and mobilization/demobilization costs.

Maximum protection strategies for road raises, railroad raises, and levee raises were considered to be feasible strategies, although a "one-step" raise would be costly, might not receive full funding, and might not be a good investment if the lake never reached the maximum lake level. It is possible, however, that a maximum protection strategy may have a greater net benefit over the long run than an incremental

strategy that requires a series of projects. This one-step approach would also eliminate the need to continually revisit the decisions on funding.

Hybrid strategies have advantages and disadvantages similar to the incremental strategies at the lower action levels and similar to the maximum protection strategies at higher action levels. If the lake level never reaches the action level where maximum protection is implemented, the hybrid strategy is identical to the incremental strategy.

To analyze the economic feasibility of each project, the features were combined using the Set of Most Likely Action Flood Protection Strategies. The most likely action for each feature assumes that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise. This set of most likely action strategies was assumed to be the baseline condition for this study, meeting the National Economic Development (NED) criteria as "the most likely condition expected to exist in the future in the absence of a proposed water resources project." These emergency measures include such actions as raising the levees protecting the City of Devils Lake and relocating homes if the lake level continues to rise. For example, if a road has been raised in recent years, it is likely that they will continue to raise that road. If a feature has not been threatened by lake levels in the past, there is no previous history on which to base the decision of protection strategy. In this case, the most likely action was based on both the cost-effective strategy and on the relative importance of the feature (evaluated through conversations with local agencies).

Other sets of strategies were evaluated as a part of the sensitivity analysis for the Economics Analysis. Under each set of strategies, the costs of the flood protection measures and the flood damages were aggregated for all features. For each feature, the decisions that determine the strategy being analyzed and the actions that are required at specific lake levels were defined as follows:

- An action level is an elevation at which an action is taken (costs are incurred to construct or implement a flood protection measure) based on a decision made at a prior, lower decision/action level. No decision is required.
- A decision level is an elevation at which a decision is required, but no action is taken as a result of the decision (no decision levels were identified in this study).
- The decision/action level is an elevation at which a decision is made and an action may be taken (depending on the decision made). In some cases, later actions may also be taken at subsequent, higher action levels based on the decision made at the original decision/action level.

The flood protection strategies that were analyzed for the various feature types are described below. The no protection strategy was analyzed for all features in this study. Assumptions regarding the no protection strategy for rail lines and roads are also included in the following description.

Communities and Cities

The most likely action strategies for communities and cities is typically incremental protection in the form of levee raises or relocation of structures.

The incremental protection strategies considered for the communities were levee raises or relocation of structures in a series of increments. If the preliminary analysis of incremental levee raises indicated that at all decision/action levels the cost of the levees was greater than the value of the property in the community, the incremental and maximum protection levee strategies were not analyzed. For the set of cost-effective strategies, it was assumed that no flood protection would not be an acceptable strategy (levees and/or structure relocations were assumed to be used for flood protection).

The communities and cities have two types of maximum protection strategies:

- Relocation of all structures potentially affected at the maximum lake level
- A levee raise to protect to the maximum lake level.

A preliminary groundwater modeling analysis was conducted using groundwater data from the City of Devils Lake to examine the continued viability of a levee at higher lake levels and the potential effects of the high water levels on the structures and infrastructure protected by the levee. It was assumed that the information learned from the City of Devils Lake would apply to other communities around the lake. The analysis was completed using the MLAEM model and was based on data from the Hydrogeology of the Shallow Water Table at the City of Devils Lake, North Dakota, North Dakota State Water Commission, 1998. The analysis indicates a nearly linear relationship between the lake level and the groundwater flow into the wastewater treatment lagoons. These flow rates are very low (a peak flow rate of less than 2,000 gallons per day), and would not likely affect operation of the City of Devils Lake facilities. The low flow rates are believed to be the result of the thick, low-permeability, clayey soils. Similarly, it was assumed that other treatment lagoons around the lake would not be severely impacted by groundwater inflows.

Based on the analysis, the effects of the high lake level on other structures within a levee in the Devils Lake region would vary depending on the structure type, construction, distance from the levee, and the surrounding soil conditions. In general, the region has natural clay deposits that are about 50 feet thick, and head losses would be considerable. It appears unlikely that the uplift pressures could be translated through this clay deposit. However, anomalies within the clay deposits exist in the form of more permeable granular strata. These strata do not appear to be continuous or of uniform thickness. The more granular strata are more permeable and do not offer the same head loss potential as the predominant clay soils described. Where more permeable granular layers are in contact with or relatively close to a structure, seepage rates would be faster. Where problems are noted, they would likely be spatially irregular and would require investigation and remediation on an individual basis. Remedies to seepage problems in most situations would likely take the form of installation of draintile systems and sump pumps to drain below-grade spaces. Therefore, levees were assumed to remain feasible as a flood protection measure to the maximum lake level.

State Facilities

The most likely action strategies for state facilities is incremental protection.

The maximum protection strategy for Grahams Island State Park included raising the park's access road to elevation 1468 and relocating any low structures at the first decision/action level. The incremental strategy for this facility was raising of the park's access road and relocation of any low structures in a series of increments. A levee was not considered feasible for the facility because of the relatively low value of infrastructure at the facility.

The majority of infrastructure at the Gilbert C. Grafton State Military Reservation facility is located above elevation 1463. The incremental strategy for this facility was access road raises, construction of a levee to protect the munitions storage area, and construction of a ring dike to protect structures in a series of increments. The maximum protection strategy assumes these actions would all be implemented at the first decision/action level. For the set of cost-effective strategies, it was assumed that the facility would remain open, based on conversations with Camp Grafton staff. Attachment I.C (State Facilities) contains more details regarding the facility.

Rural Areas

For the rural areas, the only viable strategy was relocation of the structures to high ground and the loss of the value of inundated property, analyzed for the most likely action, incremental, and maximum protection strategies. The infrastructure in these areas is scattered and could not be effectively protected because of the relatively high costs and the lack of access during high lake levels. The maximum protection strategy relocates all potentially affected structures at the first decision/action level.

Rail Lines

The most likely action strategies for rail lines is typically incremental protection, involving railroad raises in a series of incremental steps.

The maximum protection strategy for railroads was a raise to elevation 1468 at the first decision/action level. The no protection strategy for rail lines includes temporary closure during high lake levels, assuming that the railroad will be restored when the lake recedes. Temporary closure of the Burlington Northern Railroad adjacent to US Highway 2 was assumed to be unacceptable for the set of cost-effective strategies due to the high usage of the railroad and the impact on interstate transportation. However, it was included in the set of no protection strategies.

Roads

The most likely action strategies for roads is typically incremental protection, involving a series of road raises.

The maximum protection strategy for roads could be either raising the road to elevation 1468 or rerouting the road along a new alignment at the first decision/action level. The no protection strategy includes temporary closure during high lake levels, assuming that the road would be restored when the lake

recedes. Rerouting of roads was considered feasible for three roads: Highway 1 (assumed to have already occurred), Highway 281 south of US Highway 2, and Highway 281 north of US Highway 2.

I.4.3.3 Decision Trees for Adjacent Lake Features

The strategies for each feature can be graphically represented as "decision trees" showing decisions and actions at various critical elevations. A decision tree was developed for each feature indicating lake elevations at which decisions and actions would be required and the options at those levels.

Decision/action levels were assumed to occur 1 foot below the design level of protection to provide lead time for construction of protection measures before damages would occur. The design level of protection is defined for the various flood protection measures in Section I.4.4, along with a description of the impacts of the assumed decision/action levels.

The decision/action levels for each feature are based on the flood protection measures that have been completed during the past several years and current plans to increase protection as the lake level rises. Decision trees and assumptions for all 24 features are included in Attachment I.C. The decision trees indicate which strategies were analyzed and the assumed action levels. Strategies that showed first costs much greater than the value of the structures and infrastructure protected at that decision/action level were eliminated from further consideration. Such strategies are shown as a dashed line on the decision trees.

I.4.3.4 Potential Lake Level Variations Between Bays

There are six main bays that comprise the Devils Lake basin. Relatively narrow areas and bridges separate these bays. Since the majority of the inflows to the lake flow into the west bay, there could be a potential variation in the actual levels between the various bays at any point in time, creating a potential lake surcharge. Features that are adjacent to Devils Lake are scattered around these various bays of the lake, and therefore could potentially be affected at different times, depending on their location.

Several local agencies were contacted to define the potential for this lake surcharge between the bays. Survey data was obtained from the U.S. Geological Survey (USGS) and the North Dakota State Water Commission (NDSWC). The NDSWC survey was conducted on May 26, 1999, and indicated approximately 0.7-foot difference in water levels between Highway 20 (near The Narrows) and County Road 4 (near Churchs Ferry). The USGS gage data provided daily water levels at the Big Coulee below Churchs Ferry and near the City of Devils Lake for 1998 and 1999. The maximum difference in annual peak lake levels was measured at 1.47 feet during 1998 and 0.57 feet during 1999. Although there may have been temporary surcharges that were larger, the Economic Analysis only compares the peak yearly lake level.

Based on this data, it was assumed that the lake surcharge in Devils Lake was not significant enough to modify the feature analyses based on location. It should be noted, however, that the analysis does use separate levels for Stump Lake and Devils Lake. Features adjacent to Stump Lake are analyzed based on Stump Lake levels, and features adjacent to Devils Lake are analyzed based on Devils Lake levels.

I.4.4 Cost and Damage Computations for Adjacent Lake Features

Each feature was analyzed using reconnaissance-level investigation of the costs, damages, and damages prevented. These evaluations were made for both with- and without-project conditions (i.e., with- and without-project futures).

The purpose of the Economics Analysis is to provide information to determine the economic benefit of each proposed project; individual feature information is considered preliminary. The results of the feature computations should not be used by local officials as a road map for decisions on specific features. When a future plan regarding flood protection for a given feature is actually needed, the appropriate Federal, state, and local officials should conduct a more detailed, updated assessment to make sure they are selecting the best technically, economically, environmentally, and socially sound plan of action.

The costs for construction of alternative protection measures and associated damages and damages prevented were computed at the decision/action levels shown on the decision trees. The elevation increments shown on the decision trees were determined from recent flood protection construction in the region. Both damages and costs were assumed to occur at the decision/action levels for all damages and costs, up to the next decision/action level. For example, when the lake reaches a decision/action level at elevation 1446, both the damages and costs would be counted at that point for all damages and costs up to the next higher decision/action level.

The costs for operation and maintenance of the feature protection measures were not included in this analysis. These general operation and maintenance costs are presumed to be costs that the local sponsor would commit to as part of the requirements for construction of the project, and as such they would not affect the economic feasibility of the project.

Tables I.3, I.4, and I.5 list the total damages by elevation for the features analyzed. These tables are not directly comparable since they show different types of damages—one-time only, continuing, and once per event (as described in Section I.4.3).

Table I.3 lists the cumulative one-time damages to land and structures, assuming no flood protection measures are taken. Table I.4 lists the cumulative annual damages to roads, rail lines, and Grahams Island State Park, assuming temporary closure. The cumulative restoration damages to roads and rail lines are listed in Table I.5, assuming no action is taken except restoration when the lake level recedes (for each event).

Decision/action levels shown on the decision trees are 1 foot below the design level of protection or 1 foot below the feature's low point:

- For relocations—The decision/action level is 1 foot below the structure's elevation. Depending on the local ground relief, a structure might incur damages from wave action prior to this level.
- For land—The decision/action level is 1 foot below the lowest elevation within the elevation increment being analyzed. Damages for all land within these elevation increments would be

computed before the land was actually inundated; however, wave action might affect the land even prior to this level.

- For roads and rail lines—The decision/action level is 1 foot below the top of the road or rail. However, a road or rail line is likely to incur damages from wave action prior to this level.

- For levee raises—The decision/action level is 1 foot below the design level of protection which, in this study, is 5 to 7 feet below the top of the levee (i.e., this study uses a levee freeboard ranging from 5 to 7 feet). Therefore, damages would be computed 1 foot lower than they might actually occur, assuming the levee would fail at the design level of protection. Construction of protection measures might actually be initiated before the lake is within 1 foot of the design level of protection to allow adequate time to complete construction prior to the lake rising. Therefore, costs may be computed later than they might actually occur.

A brief review of the methods used in the computations is provided in the following sections, by feature type. Attachment I.C presents the list of pertinent assumptions, a map, a decision tree, and cost and damage tables for each feature. The majority of costs and damage valuations listed in Appendix I.C were developed during the 1998 economic analysis, and have been updated for this study to represent 2001 values. Several sources were used to update these values (the source used to update each of the costs and damages are also noted in each feature description in Appendix I.C). The source that provided the most current and reliable data was used for each cost and damage evaluated. Some of the particulars of the valuation updates are given below:

- The average increase in the value of homes within the City of Devils Lake was estimated to be 3% per year for the past 3 years (9% inflation from 1998 to 2001), according to the Ramsey County Assessor and the City of Devils Lake Assessor. Since the increase in home values may not be tied to the general inflation rate, this actual increase in assessed value was used for homes within the city. Because it is likely that all building within the city increased in similar proportion, the 9% inflation value within the City of Devils Lake was also used as the average increase of commercial and public structures within the city. The number of homes within the city also increased during this period, at an average of 2.5% per year. This increase was also factored into the total value for homes in the City of Devils Lake.

- In 2000, the North Central Planning Council (NCPC), in cooperation with the Federal Emergency Management Agency (FEMA), relocated many homes that were within the community of Churchs Ferry. FEMA also completed an extensive and detailed evaluation of home values outside of the City of Devils Lake, using certified flood insurance adjusters. This study provided the best current data for the number and value of homes outside of the City of Devils Lake, and therefore values were primarily obtained from this FEMA study (where possible). The study did not evaluate the value of structures other than homes. Relocation costs were primarily obtained from the NCPC.

- The ENR Building Cost Index of 4.2% (inflation rate from 1998 to 2001), was typically used to computed the inflated value of buildings (other than homes) that are located outside of the City of

Devils Lake. The only exception was in cases where other more detailed costs were available (such as at Camp Grafton).

- The ENR Construction Cost Index of 6% (inflation from 1998 to 2001), was typically used to compute the inflated costs for construction of protection measures (restoring roads, building pump stations, raising levees, etc.). The only exception was for certain items (e.g., riprap) for which the costs were known to have otherwise changed significantly.

I.4.4.1 Communities and Cities

If a protection strategy (such as levees or relocations) is used for a community, it is assumed that construction could be done in time to prevent any damages; therefore, there would be no residual damages for a project to reduce. The damages prevented to infrastructure were assumed to equal the value of the existing infrastructure. The costs for levee raises were based on approximate levee alignments and construction costs from recent levee raises at the City of Devils Lake. Assumptions on levee construction and valuation of structures can be found in Attachment I.C, grouped by feature type and number (Features 1 through 5).

The cost for community relocation strategies included the cost to relocate or replace structures and infrastructure, as the building or facility dictated. Hereinafter, the phrase 'relocation of structure and infrastructure' shall imply relocation or replacement as necessary. Although it was determined that relocation costs would not vary greatly for different regional destinations, a preliminary examination of the future location and layout of each community was completed.

- In the relocation maximum protection strategy for Churchs Ferry, the community was assumed to be entirely dispersed, and the residents incorporated into other communities and/or rural areas.
- The City of Minnewaukan is the county seat. For the maximum relocation strategy, the city was assumed to be moved in its entirety to high ground west of its current location. If Highway 281 is rerouted to the west, that would also be a prime relocation site for the City of Minnewaukan and a reason to consider relocation of the City.
- The Fort Totten and St. Michael maximum relocation strategies assume that only the portion of the city affected by the lake would be relocated to high ground.
- The maximum relocation strategy for the City of Devils Lake assumes that the affected structures and infrastructure would be relocated to high ground north and east of the city and the portions of the city above elevation 1464 would not be relocated. The social impacts of this assumption are discussed in Section I.4.7.2.

At the first decision/action level in the City of Devils Lake where structure relocation is selected as the strategy, it was assumed that the levee is no longer raised. Since the existing levee protects sections of Highways 19, 20, and 2, these roads must be raised to maintain transportation service. The total cost to

raise these roads that are behind the levee to protect to the maximum lake level were included in the first relocation decision/action for each strategy.

Graph I.1 shows the cumulative costs for all of the communities and cities, grouped by strategy (incremental levee, incremental relocation, maximum relocation, and maximum levee). The greatest costs would be for relocation of all communities and cities, totaling $343 million at the maximum lake level. The cost for levee construction to protect all the communities would be much less, about $113 million at the maximum lake level. In reality, a combination of these strategies would probably be used, with each feature having its own selected protection plan. The cumulative damage (assuming no protection) for communities and cities is shown on Graph I.2, totaling about $333 million at the maximum lake level.

I.4.4.2 State Facilities

For Grahams Island State Park, the costs of flood protection included raising the access road and relocating low structures. If the road was temporarily closed due to flooding, the damages would include restoration of the access road and damages to the structures that would be affected by the lake (since there would be no access to move the structures). The damage for lost recreation value was also included, based on the usage of the facility prior to the flooding. Details on these computations are in Attachment I.C, grouped as Feature 7.

For Gilbert C. Grafton State Military Reservation, the costs included raising the access road, constructing the munitions storage area levee, and constructing a ring dike to protect structures. The munitions levee and ring dike costs were based on construction costs from recent levee raises at the City of Devils Lake. Assumptions on access road construction, levee construction, and valuation of structures can be found in Attachment I.C, grouped as Feature 6. For the no flood protection strategy, annual costs associated with the loss of Camp Grafton's function would be applicable. However, these annual loss costs could not be obtained and therefore were not included in that analysis.

Graph I.3 shows the cumulative costs for the state features, grouped by strategy (incremental or maximum protection for both features). The costs for protection of the two facilities total $43 million at the maximum lake level. Graph I.4 shows the cumulative damages for the state features (assuming no flood protection), about $36 million at the maximum lake level. The annual loss of recreational value for Grahams Island State Park is time dependent and, therefore, was not included on Graph I.4.

I.4.4.3 Rural Areas

The flood protection costs for the rural areas included relocating affected structures. Flood damages to land were assumed to equal the value of the land. Details on these computations are in Attachment I.C, grouped as Feature 8.

Graph I.5 shows the cumulative costs for the rural areas, totaling $38.8 million at the maximum lake level. Although the graph groups the costs of protection at Stump Lake and Devils Lake, the costs are actually functions of the level of the two separate lakes. The cumulative damages for the rural areas is

shown on Graph I.6 (assuming no flood protection), totaling $151 million at the maximum lake level. The costs shown on Graph I.5 would eliminate the damages to structures, not to land and, therefore, would reduce the damages in Graph I.6 by only $47 million because the land damages would still occur.

I.4.4.4 Rail Lines

The flood protection costs for the rail lines included raising the rail lines. Flood damages to the rail lines that were assumed to be temporarily closed due to flooding were computed as the cost to restore the rail line after the lake recedes. The damages also included the additional annual expenditure to truck grain during the period that the rail line is closed. Details on these computations are in Attachment I.C, grouped by feature (Features 9 through 12).

Graph I.7 shows the cumulative costs for raising all rail lines, grouped by strategy (incremental raise or maximum raise at the first decision/action level). The first costs for raising all rail lines would total $225 million at the maximum lake level. The damages for temporary closure of rail lines include continuing trucking and rail passenger train costs over the full duration of each flood event, which are shown as annual damages on Graph I.8 for all rail lines. The total annual damages at the maximum lake level would be almost $5.0 million.

I.4.4.5 Roads

The flood protection costs for the roads included raising or rerouting the road, depending on the strategy and specific road. Flood damages to roads that were assumed to be temporarily closed due to flooding were computed as the cost to restore the road after the lake recedes. The damages also included the annual detour costs while the road is temporarily closed. Annual detour damages for traffic that is permanently rerouted was also included. Details on these computations are in Attachment I.C, grouped by feature (Features 13 through 24).

Graph I.9 shows the cumulative costs for all roads, grouped by strategy, i.e., incremental raise versus maximum protection (raise or reroute at the first action level). The first costs for raising all roads would total $778 million at the maximum lake level. The first costs for the combination of rerouting and maximum raise would total $551 million at the maximum lake level. The damages for temporary closure of roads include continuing detour costs over the full duration of each flood event, shown as annual damages on Graph I.10 for all roads. The total annual damages at the maximum lake level would be about $73 million.

I.4.5 Analysis of Adjacent Lake Features

I.4.5.1 General Description

Evaluation of the economic feasibility of the with- and without-project conditions requires an estimate of the lake's future flood levels, which cannot be predicted with certainty. However, the US Geological Survey (USGS) developed a lake level-probability model that generates hypothetical 50-year futures (i.e.,

"traces"). The Economics Analysis used output from this model to analyze paired without- and with-project futures to assess each project's economic feasibility.

The Economics Analysis evaluates the potential benefits of a project over a 50-year period, selected for planning purposes. If an outlet alternative is selected, it is possible that the Canadian Government might choose to concur with outlet operation only for the current emergency situation, for a single use of an outlet until the Devils Lake level recedes and pumping is discontinued.

The general approach was to look at all possible strategies, and to evaluate these strategies for each analysis—for all 10,000 stochastic traces (Section I.2.1.1) and for the Wet Future Scenario (Section I.2.1.2). To analyze the various strategies for each feature, a series of flow charts or 'algorithms' were developed. These algorithms define the steps necessary to compute costs and damages for the 50-year traces. To illustrate the analysis of the traces for various strategies, an example trace was plotted; it is shown in Attachment I.B with the decision trees for two features—the City of Devils Lake and Highway 281. The strategy being analyzed on each sample graph is indicated in bold on the decision tree. The sample graph at the top of the page shows decision/action levels and the sample trace for the strategy being analyzed. Notes on the graph indicate the action being taken as specified by the decision tree for that strategy. If the lake level on the trace never reaches a particular action level, that action is not taken and associated costs are not incurred. The graphs also show the duration of recurring detours or when detours are prevented.

These algorithms were used to develop computer programs for each feature. The program for each feature steps through each trace, computing costs and damages for each of the 50 years and bringing those costs and damages back to present worth. When there are multiple traces, the program then moves to the next trace until all traces are reduced to present values. For stochastic traces, the average of the 10,000 values reflects the full range of possible lake futures. The results of these analyses are shown in tabular format in Part II, grouped by analysis.

I.4.5.2 Summary of US Geological Survey (USGS) Model

The USGS 6-Box Lake Level-Probability Model is a statistical water and sulfate mass-balance model that stochastically generates potential future lake levels and sulfate concentrations for Devils Lake and corresponding discharges and sulfate concentrations in the Sheyenne River. The 6-box model has been developed and upgraded over the past several years in cooperation with the Corps of Engineers and the North Dakota State Water Commission (NDSWC), and is constantly being updated as new information becomes available. This section describes the 6-Box model and how it relates to the analysis of features adjacent to the lake. Later sections of this Technical Appendix describe the relationship of the 6-Box model to the analysis of the downstream features.

The 6-Box model represents 6 bays within the combined lake: West Bay, Pelican Lake (the bay northeast of Highways 281 and 19), Main Bay, East Bay, East Devils Lake, and Stump Lake. For the analysis of features adjacent to the lake, the USGS used the 6-Box model to supply 40,000 traces for each stochastic analysis alternative—10,000 each for both Devils Lake and Stump Lake for the with-project and without-

project futures. Each trace represents a hypothetical 50-year future. For each specific climate scenario, the USGS supplied four traces, one each for both Devils Lake and Stump Lake for the with-project and without-project futures.

The traces were analyzed to determine the probability of Devils Lake reaching levels between 1447 and 1463 and of Stump Lake reaching levels between 1409 and 1463. For each alternative analyzed, a table is included in the Tabular Data document listing the probability of reaching each action level without and with the project, indicating which action levels are applicable to each feature. These probabilities are also summarized in Part II of this Technical Appendix, grouped by analysis.

Some major features and assumptions used by the USGS model include:

- All lake-level traces start on October 1, 2000, with Devils Lake at elevation 1446.0 and Stump Lake at elevation 1409.3, and are based on known antecedent values of precipitation, evaporation, Devils Lake inflow, and Sheyenne River discharge through September 30, 2000.

- The stochastic traces from the USGS simulation model were generated assuming that climatic conditions during 2001-15 are represented by climatic conditions during 1980-99. Since 1980, the Devils Lake Basin has been experiencing generally wetter conditions than during the decades prior to 1980. Based on analysis by Leon Osborne, Regional Weather Information Center, University of North Dakota, the generally wetter conditions are expected to persist until at least 2015. After 2015, the simulation model assumes that climatic conditions are represented by the longer historic period 1950-99.

- The wet future representative trace was generated using the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993-1999). These seven years were repeated three times, back-to-back, causing the lake to overflow in 2014 and remain above spill elevation for several years. The remaining 29 years of the 50-year simulation were generated using recorded precipitation, evaporation, and inflow for 1981-99 (20 years) followed by 1981-89 (9 years).

- The USGS model includes components for simulating the flux of sulfate between the water column and bottom sediment in West Bay, Pelican Lake, Main Bay, East Bay, East Devils Lake, and Stump Lake. The bottom sediments were found to contribute a significant portion of the sulfate flux into Devils Lake, particularly during periods of high inflows. The model also includes components for simulating mixing of sulfate and other dissolved solids between West Bay and Main Bay (Ziebach Pass), Main Bay and East Bay (Highway 20 and Highway 57 bridge openings), and East Bay and East Devils Lake (Culverts in Woods Rutten Road). Both wind-driven mixing during open-water and buoyancy-driven mixing under ice were modeled. It was determined that significant amounts of sulfate and other dissolved solids can migrate from East to West, causing the lake to be more uniform in concentration than would be expected without mixing.

- The actual pumping volumes from the lake may be limited by the channel capacity and sulfate standard for the Sheyenne River. The NDSWC determined that the flow capacity of the Sheyenne

River was about 600 cfs at the point where a Devils Lake outlet would discharge into the river. The sulfate standard for the Sheyenne River is 450 mg/L.

- The rate of flow of water discharged through the natural outlet from Stump Lake to the Sheyenne River via the Tolna Coulee outlet is determined using a stage-discharge rating curve developed by the North Dakota State Water Commission. Flow begins to trickle when Stump Lake reaches an elevation of 1459.1 feet, flow reaches about 1,000 cfs when Stump Lake rises to 1462 feet, and flow reaches about 5,000 cfs when Stump Lake rises to 1464 feet. There was assumed to be no erosion of the natural outlet or Tolna Coulee channel.

- The effect of the current upper basin storage programs was included for all alternatives. Runoff from the watershed was assumed to be reduced by 800 acre-feet when the lake is at or above elevation 1440.

The following assumptions were also used for some of the USGS analyses, with variations as noted for the various alternatives that were analyzed:

- Upper Basin Management alternatives incorporate other potential upper basin storage programs, evaluating the sensitivity to the amount of available upland storage. These analyses assume that 50 percent of the total available storage is placed into an upper basin storage program, which reduces the runoff from the watershed when the lake is at or above elevation 1440.

- The outlet alternatives use preliminary information available for the proposed emergency outlet (Devils Lake Outlet Alternatives Screening, US Army Corps of Engineers, May 8, 2001). The outlets were assumed to be available to start pumping on May 1, 2005. The on/off trigger elevation for the pumps was assumed to be 1441.1. The “window” for pumping was assumed to be seven months per year, from May 1st to November 30th.

- The Pelican Lake Outlet alternatives assume that Highway 19 and Highway 281 are raised to minimize mixing of flows from the West Bay. They also assume that the Channel A structure is closed and flows from Dry Lake are allowed to flow into Mauvais Coulee.

I.4.5.3 Algorithms and Programs

To allow use of the lake-level output from the 6-Box model, algorithms were developed to analyze the various flood protection strategies for each feature adjacent to the lake. These algorithms divide each strategy into specific steps for computation of costs and damages for the 50-year traces. These algorithms were the basis for developing computer programs for each feature that step through the traces by year and compute the total costs and damages for all 50 years, bring those values back to present worth, and then determine the average annual values.

The computer programs were developed using Microsoft Excel and Microsoft Visual Basic computer software on a Pentium Pro computer. Microsoft Visual Basic is “zero” based software, meaning that the first record referenced is labeled record zero. For this analysis, this means that the 50 years of lake level

for each trace are read from record 0 to record 49. For the stochastic analysis, the 10,000 traces are read from 0 to 9,999.

Separate programs were developed for the six feature types—roads, rail lines, towns, City of Devils Lake, public (certain state facilities), and other (rural areas). The programs are executable files that were combined using a graphical user interface (GUI) so that individual or multiple programs can be run sequentially. The computer model is termed the Feature Analysis Model (FAM), and an operator's manual is available with instructions on using the model.

The algorithms define several variables used in the computer programs. The variables t1 and n1 were picked to represent the trace and year respectively, and were initially set to zero. Other variables were necessary to act as either "flags" or "counters" to gather statistical data on the feature and strategy, such as the number of times a road would be temporarily closed. The following variables were used as counters—traise, tclosed, trestore, tafterrelocate, trelocate, tlostbusiness, and tresidualdamages. The variables j1, k1, l1, m1, o1, p1, q1, r1, s1, u1, and v1 were used for internal comparison at various times throughout the programs. The variable j2 was used to track maximum lake level as required for certain strategies. In addition, numerous variables were used for computation of the present value, tracking the cumulative summation of various calculations and tracking the record sets and data base. The interest rate subroutine uses the variables x and iy as the interest rate and interest year variables, respectively. Due to the "zero" based record referencing of the program, the interest year (iy) was set equal to the current "zero" based year plus 1.

I.4.5.4 Analysis of Features with Traces

To run the analyses, the Feature Analysis Model (FAM), lake traces, and input files must be copied onto the hard drive to be used for the analysis. The analysis is run through the GUI titled fam.exe. The GUI requires selection of both features and lake trace input files. A complete description of operating instructions can be found in the operator's manual.

The program runs the features listed in the features input file and the strategies defined for those features. This file includes the feature number, interest rate, number of decision/action levels, and the elevations of decision/action levels to be analyzed. Input of the interest rate is required for the determination of annualized costs and damages.

The general operation of the program is as follows. First, the program sets the variables and counters to zero. Then, starting with year zero and trace zero, the program looks up the lake level from the specified source table. The program uses this lake level in conjunction with the action levels to perform a number of loops, checks, and read-and-write statements. When no additional computations are required for year zero, the program checks the year counter and if it is less than 49, the year counter is advanced, the loop is restarted and another lake level is looked up. The program continues this until the year is equal to 49, when the counters are printed for that trace and the trace counter is advanced. The program proceeds with analysis of the next trace just as with the first trace, and the analysis of the traces proceeds until the trace

number is 9,999. If there are less than 10,000 traces being analyzed, the program exits after the last trace is analyzed. The program places the output directly into a Microsoft Excel output file.

I.4.6 Interdependencies

I.4.6.1 Between Features

Some of the adjacent lake features are dependent on the flood protection of other adjacent lake features. For instance, raising a levee to protect a community without raising the road to provide access to the community would not be a viable alternative for the community. However, the costs included for the community do not include the costs to raise the road, which would be necessary for the community to function. All feature interdependencies are between transportation systems and communities or state facilities. This section discusses these interdependencies and is organized by the transportation feature. Table I.6 shows feature interdependencies—the functional dependencies of features on the transportation features that provide access and the increase in road traffic on the detour routes due to temporary closure of a road feature.

Feature 11.Burlington Northern Railroad: Along US Highway 2
Within the study area, the grain elevators at Churchs Ferry and the City of Devils Lake are dependent on this railroad.

Feature 12.Burlington Northern Railroad: Churchs Ferry to Cando
The grain elevator at Churchs Ferry is dependent on this spur line.

Feature 13.US Highway 2
Within the study area, the features of Churchs Ferry (Feature 1), the City of Devils Lake (Feature 2), and rural areas (Features 8.1 and 8.2) are dependent on this road. Dependent rural development includes both unincorporated areas as well as the communities of Penn and Grand Harbor.

Feature 14.Highway 57 between Highway 20 and BIA 1
Traffic between the City of Devils Lake and the communities south of the lake (St. Michael and Fort Totten) are dependent on the two causeways over The Narrows for access as well as emergency services and school transportation (including Features 14, 21, and 22).

Feature 15.Highway 57 between BIA 1 and Highway 281
The community of Fort Totten is dependent on this road for travel to and from the City of Devils Lake. Traffic between the City of Devils Lake and Fort Totten are dependent on this road.

Feature 16.Highway 281 South of US Highway 2
The City of Minnewaukan, the Benson County seat, is located on this section of Highway 281 and is dependent on this feature for access. Relocation of the City of Minnewaukan was reviewed in conjunction with rerouting this feature. Highway 19 ends at this feature and would, therefore, need to be extended west of Highway 281 if Highway 281 was abandoned or rerouted.

Feature 17.Highway 281 North of US Highway 2
The communities of Maza and Cando are located on this section of Highway 281.

Feature 18.Highway 19 from the City of Devils Lake Levee to Highway 281
Access to Grahams Island State Park is dependent on Highway 19 being open.

Feature 19.Highway 1
The residents in the rural Stump Lake area are dependent on this road for travel to and from the City of Devils Lake.

Feature 20.Highway 20 North of the City of Devils Lake
Relocation of the low-lying portions of the City of Devils Lake is dependent on having Highway 20 north of US Highway 2 to provide access to the remaining portion of the city. The community of Webster is also dependent on this road for travel to the south.

Feature 21.Highway 20 from the City of Devils Lake Levee to Highway 57
Communities south and north of the lake are dependent on this road for access to the causeways across The Narrows for access to and from the City of Devils Lake. Camp Grafton is also dependent on this road for access to the camp.

Feature 22.Highway 20 between Highway 57 and Tokio
Traffic between the City of Devils Lake and the communities south of the lake (St. Michael and Fort Totten) are dependent on the two causeways over The Narrows for access as well as emergency services and school transportation (including Features 14, 21, and 22).

Feature 23.BIA 1 from Highway 57 to BIA 6
The community of St. Michael is dependent on this road for travel to and from the City of Devils Lake.

Feature 24.BIA 6 from Highway 20 to Fort Totten
Traffic between the communities of Fort Totten and St. Michael are dependent on this road.

I.4.6.2 Traffic Modeling Interdependencies

Because the road features are all a part of the same traffic network, the temporary closure of one feature will generally increase the traffic on other features. This section outlines feature interdependencies based on QRS II output—the model used in the recent transportation study (Devils Lake Flood Control, Economics Database Update: Transportation Report, Barr Engineering Company, January 1998). Table I.6 illustrates the traffic increases in summary fashion with a plus indicating an increase in road traffic on the detour route due to temporary closure of a road feature.

Detour paths for individual road features assume that all other road features would be open. However, there were three exceptions to this, based on the preliminary results of the analysis:

- Feature 21: Highway 20 from the City of Devils Lake levee to Highway 57
- Feature 23: Between Highway 57 and BIA 6
- Feature 24: Between Highway 20 and Fort Totten

For Feature 21, it was assumed that Highway 20 across The Narrows is temporarily closed during high lake levels. For Features 23 and 24, it was assumed that Highway 20 between Highway 57 and Tokio is temporarily closed during high lake levels.

If Feature 21 (Highway 20 from the City of Devils Lake Levee to Highway 57) is temporarily closed, traffic will increase on Features 13, 15, 16, 18, and 24. Detour damages and interdependencies for Feature 21 (Highway 20 from the City of Devils Lake Levee to Highway 57) are the same as those for Feature 14 (Highway 57 between Highway 20 and BIA 1) because the Highway 57 causeway across The Narrows is useless to traffic if Highway 20 is closed on the north side of The Narrows.

The effects of simultaneous road closures at increasing lake levels were compared to the cumulative road closure effects analyzed in this study. The effects of the simultaneous road closures were reported as part of the recent Devils Lake Flood Control, Economics Database Update: Transportation Report, Barr Engineering Company, January 1998. Both analyses were based on detour distances and times. The simultaneous closure of roads assumes all roads in the region below a given lake level are closed at the same time. The Economics Analysis looked at the effects of road closure on an individual feature basis, assuming all other feature roads remain open to traffic. Although the two analyses had different assumptions, the results of the two analyses were similar. Differences between the results of the analyses above elevation 1446 ranged from 3 to 25 percent. Below elevation 1446, the simultaneous closure of roads analysis had significantly higher detour costs, likely because several roads had not been raised at the time of the Transportation Report. Therefore, the methods used in this study are consistent with the methods used in the recent Transportation Report.

I.4.7 Environmental, Social, and Economic Impacts of Flood Protection Measures Adjacent to the Lake

The environmental, social, and socioeconomic impacts of the rising lake level, an emergency outlet, the upper basin storage program, or other alternative projects were not evaluated as part of the Economics Analysis. Although this study was not intended to be a detailed investigation of the environmental, social or socioeconomic impacts of flood protection measures for infrastructure around Devils Lake, in the course of the study several impacts of the flood protection measures adjacent to the lake were noted. These impacts are described in the following sections.

I.4.7.1 Environmental Impacts

- There might be encroachment into wetlands by levee, road or railroad construction.
- Construction of levee, road or railroad raises might impact as-yet unidentified historic and archaeologic sites, particularly on the Spirit Lake Reservation.

- Tree removal would be required to lengthen and/or raise levees, roads and railroads, which would remove some of the valuable forest resources in the region.
- There are potential environmental concerns with utility lines or storage tanks that are abandoned and remain under water. There is a potential for leakage of contaminants into the water or tanks popping up unexpectedly.
- There may be residual impacts of infrastructure and structure-related appurtenances that could be left under water after structures are relocated, such as fences, decks, poles, utility boxes, etc.

I.4.7.2 Social and Socioeconomic Impacts

- Loss of access to the recreational facilities could result in a decrease in the area's local recreation and tourism.
- There would be a relocation of recreational facilities as the park facilities are affected by the lake level, potentially changing the location of local activities.
- The social structure of small communities and townships could be disrupted as minor roads are closed and residents are relocated to high ground.
- If major roads are temporarily closed due to flooding, access to schools is reduced, and the distance and time for bus travel to schools increases.
- The social structure of communities and townships might be disrupted as major roads are temporarily closed and existing facilities are separated. Likewise, there could be impacts on local businesses if distances and time to businesses and services is increased. Also the location where people shop may change. If people who used to shop in Devils Lake now go to Jamestown or elsewhere, it will affect the economy of the area. There could also be an increased financial burden on area residents due to increased travel times and distances, which was analyzed as part of this study.
- The social structure of the City of Devils Lake would be disrupted if large portions of the city were separated from the downtown area by the lake, as assumed for all relocation strategies. However, the downtown area contains many of the historic buildings in the city, and relocating the downtown areas would destroy much of the city's historic center.
- While major roads are temporarily closed due to flooding, access to hospitals is reduced, and the distance and time for emergency vehicles to get to emergency care services increases.
- If spur lines were temporarily closed due to flooding, there may be an increase in the local truck traffic to transport grains and fertilizer to the grain elevators. However, it is likely that at high lake levels, the agricultural activity in the region would be reduced significantly from the extent of flooding, resulting in few (if any) grain and fertilizer shipments.
- Safety may be compromised as the railroads are raised with the lake on both sides. There may be damage to the railroads and/or a softer rail bed due to ice and wave action.

- Road safety might be compromised as the roads continue to be raised. While the roads are being raised, they might temporarily have narrower shoulders, there might be damage to the roads during construction due to ice and wave action, and there might be a temporary decrease in signage along roads before the raise is complete. Road safety could also be a concern when the lake recedes, leaving causeways that are 20 or 30 feet high. Vehicles going over the edge of that high of a shoulder would be in serious danger of rolling, etc.
- There might be an increase in airborne dust particles from traffic on roads that are temporarily gravel-surfaced during road raises, hampering driver visibility.

I.5.0 Modeling Methodology for Features Downstream of Devils Lake

I.5.1 General Description of Methodology

In addition to the flood damages incurred at features adjacent to Devils Lake, damage may occur to features downstream of Devils Lake. Damages to downstream features may result if water from Devils Lake (and Stump Lake) flows out of the lake and into downstream receiving waters. The outflow may occur as a result of the lake overflowing naturally, or as a result of the creation of an outlet for the lake. Outflow from Devils Lake will flow into the Sheyenne River, which drains to the Red River of the North.

Because Devils Lake water has dissolved solids concentrations significantly higher than those of the receiving waters, lake outflow may result in damages to downstream features, including municipal water treatment facilities, industrial facilities, and irrigation operations. In addition, the outflow from Devils Lake will increase the flow rate in the Sheyenne River, and therefore has potential to cause flood damage to other downstream features such as roads, bridges, buildings, crops, and agricultural property.

This section of the report describes the methodology and assumptions used in estimating the damage to downstream features under the various flood control alternatives.

I.5.2 Downstream Features

I.5.2.1 Downstream Features Analyzed

Estimates of damage to several downstream features were made for this report. These features include three that would be expected to incur damage as a result of changes in water quality[5]:

1. Municipal Water Treatment Facilities (MWTFs) along the Sheyenne River and the Red River of the North. These include the water treatment facilities at Valley City, Fargo, Grand Forks, Grafton, Drayton, Pembina, Letelier, and Morris. Damage would occur principally in the form of increased costs of water treatment to remove dissolved solids.

2. Industrial Facilities (currently using river water) along the Sheyenne River and the Red River of the North. Examination of the lists of permitted industrial users, and interviews with permit holders narrowed the list of potentially affected industrial facilities to two. These are: a sugar beet processing facility and a coal-fired power plant, both located on the Red River of the North. As is the case with the MWTFs, damage would be registered as increased costs of water treatment to remove dissolved solids.

5 The downstream features expected to incur damage as a result of changing water quality were investigated for the *Devils Lake ND Downstream Surface Water Users Study* (March 1999; Barr). The investigations for that report formed the basis for the evaluation of those downstream features for this Economic Analysis.

3. Irrigation Operations. Examination of the Canadian and U.S. water withdrawal permits along the Sheyenne River and Red River of the North shows that many of the permits list the water use as "irrigation." For this study, an estimate was made of the number of irrigative users in each of the study reaches. In this case of irrigation operations, damages are in the form of reduced yields (and therefore reduced dollar values) in cases where irrigation would have to be suspended due to unacceptable water quality and its potential for damages to crops.

Four other downstream features can be expected to incur damage not as a result of changes in water quality, but as a result of flooding that may result from increased flows from Devils Lake. These flow-related damages are expected to occur only along the Sheyenne River; the increase in river flow resulting from Devils Lake outflows is not expected to significantly alter river elevations along the Red River of the North (because of its larger flow capacity). Flow-related damages along the Sheyenne River may be expected for the following features:

4. Crops. Flow from Devils Lake may cause or exacerbate flooding along the Sheyenne River; agricultural crops in low-lying areas may be affected. Damages result when the flooding reduces crop yields, and is registered as lost revenue. It should be noted that flood-related crop damage is treated separately from the damage that may be incurred by irrigation operations.

5. Other Agricultural Property. Flooding made worse by Devils Lake outflows may affect agricultural property such as homes, equipment, outbuildings, fences, etc. A flood-related dollar value for the damage to property can be assigned.

6. Transportation Infrastructure, including roads, highways, bridges, etc. Transportation damages result when roads are closed due to flooding, and must later be restored and repaired. Transportation damages thus represent the expenses resulting from detours, and from having to repair transportation infrastructure (above that which would occur without the Devils Lake outflows).

7. Urban Property. Damage due to flooding of Urban Property in two cities—Valley City and Lisbon. Other cities near the Sheyenne River are not included in the damage assessments; the increases in river flows would not be likely to cause any significant increase in flood damage at these communities.

I.5.2.2 Downstream Features Not Analyzed

Only the seven features listed in Section I.5.2.1 were included in the assessment of damages downstream of Devils Lake. Other features were considered for inclusion in the model, but were excluded for various reasons. Some of the features considered but excluded from the economic algorithms were:

- Streambanks, particularly along the Sheyenne River, that could be damaged by erosion due to the additional flows from Devils Lake. Quantification of potential streambank erosion was judged to be too difficult to assess on a flow-related basis, and putting a dollar value to the erosion would also be difficult to do with accuracy.

- Flora and fauna; riverine habitat. Stream biota—including fish; crustaceans, aquatic insects, and other invertebrates; and algae and macrophytes—might well be affected by the change in water quality and increase in flow occasioned by flows from Devils Lake. As was the case with streambank erosion, the effect of flow or water quality on riverine habitat was judged to be too difficult to allow its inclusion in the model's algorithms.

- Livestock. Farmers use the Sheyenne River and the Red River of the North to provide water for grazing animals, and possibly hogs and poultry. Effects on livestock were not included, however, because of the extensive research that would have been required to determine the location and number of animals potentially affected. The effects of the changed water quality on livestock are also somewhat indeterminate; see the *Devils Lake ND Downstream Surface Water Users Study* (March 1999; Barr).

- Fisheries. There are at least two fish hatcheries that use water from the Sheyenne River: the Bald Hill National Fish Hatchery and Valley City National Fish Hatchery. Other permits for river withdrawal for "Fish and Wildlife" use also exist. Effects on such users are somewhat indeterminate, but research suggests that changing salinity in the river water can affect fish, at least at some life stages.

- Non-agricultural permitted users. Investigations revealed that many of those holding permits for withdrawing river water use the water for irrigating lawns, gardens, and small vegetable plots. The numbers of these users and the quantity of water used for these purposes, however, was not available, and the total impact with respect to the flood control alternatives was judged to be too small to merit inclusion in the model.

- Non-permitted users. Along both the Sheyenne River and the Red River of the North, people owning land adjacent to the river withdraw river water for various purposes. The numbers of these users and the quantity of water used for these purposes, however, was not available, and the total impact with respect to the flood control alternatives was judged to be too small to merit inclusion in the model.

Note: Despite the fact that environmental damages were not dealt with in the algorithms relating costs and damages to river flow and water quality, costs for environmental mitigation and monitoring were included in the calculation of net benefits. These costs were, however, assumed to be fixed—they did not vary with the rivers' water quality or flow rate. As a result, "Environment" is not treated as one of the downstream features. The projections of environmental costs resulting from the development of a Devils Lake outlet were based on a hypothetical West Bay outlet location, but are presumed to apply generally to any 300 cfs or 480 cfs outlet that might be considered. The development of the costs related to potential environmental effects is discussed in Attachment I.E.

I.5.3 Water Quality Threats and Response Strategies

The damages to features adjacent to the lake, as modeled in this Economic Analysis, occur as a consequence of lake level rather than as a consequence of lake water quality. Should water be discharged from Devils Lake to downstream waters, however, the high salinity of the lake water **is** expected to have

adverse consequences on downstream features. The increased salinity is expected to be problematic for MWTFs, industrial water users, and irrigation operations.

I.5.3.1 Water Quality Threats to Downstream Features

Threats resulting from changes in water quality in the Sheyenne River and the Red River of the North vary according to the downstream feature. These threats are described below:

Municipal Water Treatment Facilities (MWTFs)

Should Devils Lake water flow to the Sheyenne River and Red River of the North, several MWTFs would be affected. The river water would experience an increase in total dissolved solids (TDS), so that the MWTFs withdrawing water from the rivers would have to contend with higher concentrations of calcium and magnesium (hardness), sulfates, and other dissolved materials.

The MWTFs would, as a result, incur higher costs for their softening operations. Increases in the amounts of softening chemicals would be required, and disposal costs would increase due to increases in the amount of softening sludge produced.

To allow the MWTFs to produce water that is comparable to that produced previous to outflow from Devils Lake, the facilities may have to turn to alternative supply sources. These alternatives—including installed wells and pumping systems, or water purchased from "rural water supply" companies—may be quite costly. Another costly treatment alternative, ion exchange, may in some cases have to be used to bring TDS levels to acceptable levels.

Industrial Facilities

Several river water users along the Sheyenne River and the Red River of the North indicate that their principal use for the water is with industrial processes. As these permit holders were interviewed, however, it became apparent that most of the industrial use permit holders would not be adversely affected by the expected changes in water quality. Increases in TDS levels in the rivers downstream of Devils Lake is expected to cause problems for only two industrial users of the river water:

- A coal-fired power plant on the Red River of the North currently withdraws river water for use as once-through cooling water, and to transport fly ash. The plant also uses a small amount of water for boiler feed pump cooling, and for boiler water makeup. This water must be demineralized, so it is currently treated by means of ion exchange. Were the river water to increase in TDS, the increased solids load would result in additional costs for the power plant.

- A sugar beet processing facility on the Red River of the North uses river water to supplement the plant's process water. This river water must be treated for hardness. The facility currently softens the water with lime, so chemical feed and sludge handling costs would increase if TDS (including calcium and magnesium) levels in the river increased.

Irrigation Operations

Those using river water to irrigate crops—both along the Sheyenne River and along the Red River of the North—may experience problems if Devils Lake water spills to the rivers and causes elevations in TDS levels. Crop damage may occur if water with elevated salinity is used for irrigation. Certain crops are particularly sensitive to damage from saline irrigation. Farmers currently using river water for irrigation may be faced with the difficult choice of continuing to irrigate despite the high salinity, ceasing irrigation and relying solely on rainfall, or arranging for alternative water supplies for irrigation water. Unless alternative supplies can be provided, crop yields would likely decline.

As has been mentioned, the number of irrigators is difficult to establish with certainty. For this study, interviews were conducted with county officials and a sample of the permit holders listing their water use as Irrigation. Information from these interviews and data from county agricultural officials was used to make assumptions regarding how much irrigated land might be affected.

I.5.3.2 Water Quality Response Strategies for Downstream Features

Water from Devils Lake, should it reach the Sheyenne River and the Red River of the North—either as a result of a natural overflow or a constructed outlet for the lake—would result in increase in TDS levels for the rivers. For each of the downstream features, the response to an increase in TDS levels would be different. The response that actually would be made cannot be predicted with certainty. However, based on interviews[6] with the river water permit holders, it is reasonable to make assumptions about how the permit holders are likely to respond to changing water quality. These assumptions are given in the following paragraphs.

Municipal Water Treatment Facilities

The responses of the individual MWTFs are likely to vary, and will depend on several factors including the TDS increase actually experienced (which depends mostly on proximity to the point of outfall from Devils Lake), the availability of an alternate water supply, and the degree of pressure exerted by the local community. Similarly, the timing of the responses may vary; some facility operators may be inclined to wait to try to gage the real effects of an overflow or an outlet. Others may be inclined to take action in anticipation of an overflow or outlet installation, and before TDS levels actually increase.

Based on interviews conducted with MWTF operators, it was assumed for this study that no major facility expansions would be required for dealing with the elevated TDS levels. None of the constituents of the Devils Lake water would put the MWTFs at risk for violating primary drinking water standards. Hardness would be of principal concern, and would be an issue in all cases where the flood control alternative for Devils Lake resulted in discharge of lake water. In all cases where there was lake water discharge to the downstream rivers, it was assumed that the additional hardness in the river water would

6 The methodology of the interviews, and the data collected from the interviews, is summarized in the *Devils Lake ND Downstream Surface Water Users Study* (March 1999; Barr).

simply be treated back to normal finished water levels through the addition of additional softening chemicals.

Mere treatment for hardness, however, would not reduce the concentrations of non-hardness constituents elevated as a result of flows from Devils Lake—constituents such as sodium, sulfate, and chloride. These ions are naturally present in the river water at present, but the addition of Devils Lake water would cause the concentrations to increase. Neither primary nor secondary drinking water standards have been established for any of these constituents. It is expected nevertheless that MWTF may feel obliged to provide their communities with finished water that is similar in TDS concentrations to that provided previous to any outflows from Devils Lake.

For purposes of this analysis it was assumed that the additional treatment would be provided in cases where the discharge from Devils Lake was relatively large and of relatively poor water quality. This would be the situation in cases of natural overflow from the lake, and from operation of any unconstrained outlet at 480 cfs. Therefore, it is assumed that in these cases the MWTF operators will find a way to reduce these concentrations in the finished water—either through the installation and operation of ion exchange units, or through use or development of alternate water sources.

Industrial Facilities

Research conducted[7] regarding the operations of the industrial users of river water suggests that only two of the permittees would be affected by changing TDS levels in the Sheyenne River and the Red River of the North. These users are:

- A sugar beet processing facility on the Red River on the North that uses the water to supplement their process water. The process water is treated for hardness, so the with-project water quality would result in a necessity for increased hardness removal.
- A coal-fired power plant on the Red River of the North uses river water mainly as once-through cooling water and to transport fly ash. However, a small amount (less than one percent) is treated for hardness and used for boiler feed pump cooling and occasionally for boiler water makeup.

Information was gathered regarding the water use at the two industrial facilities likely to be adversely affected by Devils Lake water. This information suggests that the response of the two facilities is fairly predictable.

In the case of the coal-fired power plant that currently uses ion exchange technology to demineralize the water it needs, the plant is likely to simply continue using the ion exchange equipment. The volume of water treated would not change, so additional ion exchange units would not be required. The increase in

7 For details of this research, consult the *Devils Lake ND Downstream Surface Water Users Study* (March 1999; Barr).

TDS would, however, result in increases in the frequency of regenerating the ion exchange resin, and an increase in the rate of brine production.

Similarly, the needs of the sugar beet processing facility would not be expected to change significantly from what they are now. The additional hardness resulting from the addition of Devils Lake water would need to be removed, but that could be done by methods already in place. Softening of the river water would simply continue, although additional amounts of softening chemicals would be required, and additional sludge would be produced.

Irrigation Operations

It is difficult to predict how those using river water for irrigation may respond to changes in water quality. There may be no response at all—users may simply continue irrigating on an as-needed basis. These users would be assuming that despite the addition of the water from Devils Lake, the salinity of the river water will not be sufficiently high to cause crop damage. The other assumption inherent in this approach would be that local rainfall and snowmelt percolating through the soils will be sufficient to wash any accumulated salts from the topsoil.

However, other users may be more cautious when TDS levels in the river water become elevated. Fearing soil and crop damage, and resulting reduced yields, they may limit the amount of river water they apply to their crops. If a series of high TDS years is anticipated, they may shift their plantings to a more salt-tolerant crop. Or, irrigators may in fact decide to avoid irrigating entirely during periods where TDS levels in the river have become elevated. These irrigators would accept the risk of reduced yields due to insufficient water for their crops rather than risk crop damage and possible soil damage due to the high salinity levels.

For the purposes of this study, it was assumed that all irrigators of salt-sensitive crops would be of this last category—turning off their sprinklers until TDS levels dropped below a certain threshold. In dry years, crop yields may be reduced, but permanent damage to the soil would be certainly avoided.

I.5.4 Flood Threats and Response Strategies

As a result of periodic extreme hydrologic events—above-average snowmelt and rainfall quantities and rates—the Sheyenne River periodically exceeds the capacity of its channel and floods adjacent lands. This occurs with or without any increased flow emanating from Devils Lake. However, flow from Devils Lake, if it occurs during a period when flooding would already be occurring within the Sheyenne River basin, would make the flooding problem worse. Agricultural and urban properties would be damaged more than they would if no water from Devils Lake had been added.

In the analysis of downstream damages (and by contrast to flood response strategies for features around Devils Lake itself), it was assumed that no protective measures would be taken. Flood damages would simply be incurred along the river, as they are now, but would be slightly higher when there are increases in flood flows resulting from water released from Devils Lake.

I.5.4.1 Flood Threats to Downstream Features

Damage to downstream features is expected to occur periodically, the timing of the flood events depending principally on natural hydrologic (snowmelt and rainfall) events. It was assumed that flood damage to downstream features will occur each time that river flows exceed channel capacity. When outflow from Devils Lake coincides with a naturally-occurring flood flow in the Sheyenne River basin, problems due to flooding will be made worse. As has been mentioned, flooding along the Red River of the North is not expected to be made worse by the relatively small flows coming from Devils Lake.

The threat of flood damage to each feature varies according to the nature of the downstream feature. These threats are described below.

Crops

Flood-related crop damage occurs when farm fields become inundated. The dollar amount of the damage to the crop varies according to several factors. Crops have different per-bushel values, so a more expensive crop will register more damage than a less valuable crop if flooding ruins it. The stage of growth of the crop also plays a role in determining the extent of damage to a farm field. Inundation may have very little adverse effect upon a newly planted field. Similarly, a nearly mature crop may be able to withstand the effects of several inches of water standing water for brief periods without major consequence. However, a recently emerged crop can be ruined by submergence for even a short period. Therefore, the type of crop, the depth and duration of the flooding, and the stage of growth of the crop will all affect the extent of flood damage incurred by the crop.

Other Agricultural Property

Rural homes and outbuildings, fences, storage structures, and agricultural equipment all may be damaged by flood waters. Access to these facilities may also be limited during a flood, resulting in additional losses.

Transportation Infrastructure

The roadways adjacent to the Sheyenne River can be physically damaged by flood waters, resulting in costs for repairing and rebuilding the roadways. These damages would be incurred each time a flood occurs. In addition, detours caused by road closures resulting from flooding can also result in detour costs (damages) during the full duration of the flood event.

Urban Property

As has been mentioned, only two communities—both along the Sheyenne River—are expected to be threatened by flooding made worse by Devils Lake outflows. These two communities, Valley City and Lisbon, both would incur similar sorts of damages due to flooding. Residential, commercial, and public buildings may be threatened. Infrastructure—including sanitary and storm sewer systems, and communications and electrical networks—may also be affected. In addition, transportation systems within the cities may be affected due to physical damage to the roadways. Detour costs due to flood-induced road closings can also occur.

I.5.4.2 Flood Response Strategies for Downstream Features

For the downstream features, the flood response strategy is considerably less complicated than that for the features adjacent to Devils Lake. No range of responses is anticipated for the downstream features. For each of the downstream features, only one flood response strategy is anticipated: the *No Protection* strategy.

For this study, damages are assessed for each of the downstream features threatened by flooding each time a flood occurs. No preventative or protective efforts are assumed to be undertaken during the 50-year period for which damages are projected. Therefore, for each feature, and for each flood event, damages are assessed in direct proportion to the maximum projected water surface elevation during the period of flooding. It should be noted that in some cases, this assumption will result in an overprediction of damages, because there may be lower-cost methods available for preventing damages for the features.

I.5.5 Cost and Damage Computations for Downstream Features

The economic model registers costs and damages for the downstream features only when Devils Lake discharges—either natural or via outlet—actually occur. (This is in contrast to the situation for features adjacent to the lake; for those features, just a rise in the water level at Devils Lake is required for the model to register damages.)

There are only three types of project **costs** associated with downstream features. First, there are two types of environmental costs, as detailed in Attachment I.E. The two types of environmental costs that are assumed to result from projects that include discharge of Devils Lake water downstream are: (1) expenses for environmental mitigation assumed to be incurred at project initiation, and (2) ongoing expenses associated with environmental monitoring during the lifespan of the project (these expenses are brought back to present worth and annualized).

The third type of costs is that of providing alternative water supplies for the MWTFs along the Sheyenne River and Red River of the North. In this analysis, these costs are incurred only for alternatives that include a 480 cfs unconstrained outlet. These costs include capital expenses for installing ion exchange equipment, connection to rural water supply systems, and installation of wells and pipes.

For the downstream features, however, the economic analysis deals mainly with **damages** resulting from discharges from Devils Lake. In some cases, these damages are registered in the form of increases in ongoing expenditures occurring as a result of the flows from Devils Lake. This is the case for the MWTFs and for the industrial water users, both of which would incur increased water treatment costs. For crops, Agricultural Properties, Urban Property, and Transportation Infrastructure, the damage incurred is the additional flood damage that is expected as a result of the flow increases. In the case of irrigation operations, damage takes the form of foregone revenue when crop yields fall due to inability to irrigate. Finally, the annual expense of environmental monitoring (that would likely be required if an outlet were installed) is treated as a damage in the economic modeling (see Attachment I.E).

Sources of Data

For the three downstream features for which costs and damages are dependent on the water quality (MWTFs, Industrial Operations, and Irrigation Operations), Barr conducted the research necessary to arrive at the cost and damage algorithms used in the economic model. Most of that research was conducted in preparation of the *Devils Lake, North Dakota Downstream Surface Water Users Study* (Barr, March 1999) for the Corps. Much of the data on which the algorithms are based is given in Attachment I.D of this Technical Appendix.

For the four downstream features for which costs and damages are dependent on the flow rate in the Sheyenne River and Red River of the North, the Corps provided the necessary data. Much of this data was collected during the course of the Sheyenne River flood control study of the early 1980s[8].

As was mentioned previously, the Corps also provided estimates of the project costs and damages related to environmental effects of Devils Lake water being added to the Sheyenne River and Red River of the North. These estimates were made in March of 2001. A detailed description of the assumptions behind the environmental mitigation and monitoring estimates is provided in Attachment I.E.

Reach-Specific Computations

Because the relatively high TDS water from Devils Lake will be diluted as it is mixed with the flow in the Sheyenne River and Red River of the North, the impacts on water quality in the rivers will be smaller as one proceeds downstream. Costs and damages for the features affected by changes in water quality, therefore, will depend to some extent on the feature's distance from the Devils Lake outflows. Eleven river reaches were used in the economic analysis for these features, and the cost and damage calculations were dependent upon the estimates of water quality in the reach in which the feature was located. The 11 river reaches were as follows:

Water Quality Reaches		
Reach	**Extents**	**River**
1	Outlet to Cooperstown	Sheyenne
2	Cooperstown to Valley City	Sheyenne
3	Valley City to Lisbon	Sheyenne
4	Lisbon to Kindred	Sheyenne
5	Kindred to Junction	Sheyenne
6	Junction to Halstad	Red
7	Halstad to Grand Forks	Red
8	Grand Forks to Oslo	Red
9	Oslo to Drayton	Red
10	Drayton to Emerson	Red
11	Emerson to Lake Winnipeg	Red

8 The report documenting this analysis is entitled *General Reevaluation and Environmental Impact Statement for Flood Control and Related Purposes, Sheyenne River, North Dakota* (August 1982).

("Outlet" refers to the approximate point at which any flows from Devils Lake reach the Sheyenne River; "Junction" refers to the point of confluence of the Sheyenne River and Red River of the North.)

For the features for which damages were related only to water quantity (and not quality), only five reaches were considered. The five reaches are all within the Sheyenne River, and are as follows:

Water Quantity Reaches	
Sheyenne River Reach	**Extents**
1	Insertion point of outlet to Baldhill Dam
2	Baldhill Dam to Kathryn ND
3	Kathryn ND to Soo Line Railway crossing
4	Soo Line Railway crossing to Kindred ND
5	Kindred ND to Horace ND

Because the Red River of the North carries so much more water than the Sheyenne, it was assumed that any additional flow from Devils Lake would be insignificant; flood damage on the Red River of the North would not be significantly increased by the addition of Devils Lake flows.

The Corps also provided reach-specific relationships between the river flow rates and the corresponding area flooded for the five reaches along the Sheyenne River. For Reaches 2 through 5, these relationships were based on data gathered as part of the 1982 Sheyenne River flood control study. For Reach 1, the relationship was developed through examination of USGS topographic maps, and of selected surveyed cross-sections within the reach. As was the case with the water quality-related damages, the damage calculations were dependent upon the estimates of water quantity in the reach in which the particular feature was located.

Overflows from the Devils Lake/Stump Lake System

It is possible that the water levels in the Devils Lake/Stump Lake system will rise to a point such that water will spill naturally from Stump Lake into the Sheyenne River. The spill would be expected to cause damage to downstream features, as a result of both the changed water quality and water quantity in the river. The Economic Analysis takes these damages into account in its calculations of the net benefits of the alternatives.

Modeling the water quantity effects of a spill is relatively straightforward, and was handled for both the without-project condition and the with-project condition by comparing projected river water levels to stage-damage curves for each feature of concern.

Modeling the water quality effects, however, was somewhat more complicated. The water quality effects of a spill are modeled in the same way as the water quality effects of discharges from a Devils Lake outlet. The difference between the with-discharge and without-discharge water quality is used to calculate the additional expenses incurred as a result of the rising TDS levels in the river. The additional

expenses are registered as damages, and damages under without-project conditions are compared to damages under with-project conditions.

When the without-project condition involves no discharge from the lake while the with-project condition includes discharge (for example, for an alternative that includes an outlet), downstream feature damages are registered for the alternative. In contrast, when the without-project condition includes discharge while the with-project condition does not (such as when the assumptions for the alternative analysis are such that the alternative prevents the spill from Stump Lake), negative damages—or benefits—result.

Two aspects of this analysis should be noted. First, because the analysis compares only the difference in water quality, the model never computes an absolute value for, say, the money spent for a MWTF to treat the water. Only the incremental expenses resulting from changed water quality are registered.

Second, in all cases the model input needed to be in terms of a difference in water quality. This meant that for analyses in which the without-project condition included a Stump Lake spill, a hypothetical no-spill trace for the same weather conditions had to be created for water quality in the Sheyenne River and the Red River of the North. This no-spill trace was compared with the spill trace to give damages under without-project conditions; these damages could then be compared with the damages computed for the with-project condition (compared to the no-spill trace) to give net damages for the alternative.

I.5.5.1 Municipal Water Treatment Facilities

Project Costs

As has been mentioned, the MWTFs will have need to provide water treatment beyond mere softening for the flood management alternatives that include a 480 cfs unconstrained outlet. If, for example, a 480 cfs outlet is installed at Devils Lake, downstream MWTF operators are likely to immediately install ion exchange equipment or seek alternative water supplies in order to be able to provide their customers with finished water of pre-project quality. The expense of doing so is registered as a project cost. For ion exchange, these costs are computed based on the treatment capacity of the facility, taking into account that blending will mean that only part of the water will need to be treated with ion exchange. In cases where an alternative water supply is already available, the cost of switching to that supply is assumed to be negligible. For MWTFs that would install wells to provide a better source of raw water, the anticipated expenditures depend on production needs, well depths, and distance to suitable aquifers. Connection to rural water supply systems may be an option for some of the MWTFs, the cost dependent on the required supply and the distance to the supplier. Costs for the MWTFs were calculated as part of the “Phase II” analysis (see below), and detailing of these costs was provided in Section I.3.2 and Table I.3.

Project Damages

The project damages for the MWTFs mainly take the form of increased expenditures required to treat the raw water. Raw water that is higher in hardness and TDS costs more to treat. The increased expenditures are related to the increased expense of chemical softening agents, and to an increase in expenses for

disposing of the larger amount of sludge that would result. These expenses are computed based on information acquired through interviews with MWTF operators, and relate to plant capacity, pre-project and predicted water quality, the MWTF's treatment objectives, and current chemical and sludge disposal costs.

For the MWTFs, the economic model computes treatment expenses based on the water quality "deltas"—the computed difference between the expected water quality constituent concentrations under outflow (from Devils Lake) and non-outflow conditions. Deltas are computed both for the without-project and the with-project conditions. As a result of the use of the water quality deltas, the model computes only the expected **increase** in expenses resulting from Devils Lake flows. No calculation of overall water treatment costs for the MWTFs—either for the with-project or the without-project condition—is ever made by the model.

Two separate damage-estimating models were used for the MWTFs. The first, the "Phase I" model, took into account only the increased water softening expenses (registered as damages) that would be incurred by the MWTFs when hardness levels increased as a result of Devils Lake flows. These expenses were calculated in all cases where flows from Devils Lake changed the water quality in the rivers.

The second model—the "Phase II" model—accounted for increased water softening expenses, but also calculated additional expenses for alternate water supply provision. It was assumed that these additional expenses would be incurred whenever flows from Devils Lake were unconstrained (i.e. for alternatives that included a 480 cfs outlet, or for alternatives that projected a natural overflow from the lake). The Phase II model assumes that the MWTFs would seek an alternative and better water supply as a supplement or substitute for what they would normally use. The alternate water supply would allow the MWTFs to provide finished water comparable in all respects (not merely softness) to that of pre-project conditions.

Whereas the expense of installing equipment was generally treated as a project cost, ongoing expense was registered as a damage. For example, in situations where it is anticipated that the MWTFs would require ion exchange equipment, the operations and maintenance expense for that treatment (including regenerant purchase, brine disposal, and periodic equipment replacement) are included as damages. These damages depend on the water quality treatment objectives, plant capacity, and predicted water quality in the raw water source (the Sheyenne River or the Red River of the North). As such, these O&M expenses vary greatly according to the MWTF location and production capacity.

I.5.5.2 Industrial Facilities

Project Costs

No project costs are associated with the industrial facilities, because information gathered for this study suggests that these facilities would make use of existing equipment to deal with increases in river water salinity.

Project Damages

The project damages incurred by the industrial facilities relate to the increases in treatment expenditures. For the coal-fired power plant, it is assumed that additional expenses for ion exchange treatment O&M would result from the increases in river water TDS. These additional expenses include those for increased needs for regenerant, equipment replacement, and brine disposal. Detailed information regarding water treatment at the plant was not available, so assumptions regarding treated water quantities were made based on water use typical for coal-fired plants with similar capacity. Unit costs are assumed to be typical of those for the region.

For the sugar beet processing facility, the additional expenditures (damages) are computed based on the production capacity of the plant, and from what is commonly known about cooling water and process water needs for a plant of this size. The analysis assumes conventional water softening methods, and uses regionally typical unit costs for softening chemicals and sludge disposal. The damage calculations are based on comparisons between existing and projected water quality ("deltas"—see previous discussion) in the reach of the river on which the beet processing facility is situated. Such comparisons are made, and damages are calculated, only for the months during which the plant withdraws river water.

I.5.5.3 Irrigation Operations

Project Costs

In the Economic Analysis, no project costs are registered for irrigation operations.

Project Damages

For this analysis, investigation was done to determine which crops are typically irrigated using river water along the Sheyenne River and the Red River of the North. Further investigation was conducted to determine the sensitivity of these crops to increased salinity. In this way, the projected water quality for the rivers could be compared to the salinity tolerance of the particular crop. It was assumed that if the monthly average salinity of the river exceeded the salinity tolerance of the crop at any time during the irrigating season (June through September), irrigation would not be allowed for that year for that crop. The difference between the yield for that crop when irrigated and when it is not irrigated was then used as the basis for the damage calculations. All per-acre yield and unit price information for the crops was gathered from state and county records.

Information regarding which crops are actually irrigated along the Sheyenne River and Red River of the North was generally unavailable. Similarly, state and local agencies were unable to provide records of the amount of acreage presently under irrigation using river water. Therefore, assumptions were made regarding the crop type and acreage, based on county records and interviews with a sample of permit holders. The assumptions made are likely to overestimate the irrigated acreage, but some overestimation was judged to be acceptable for purposes of this study.

I.5.5.4 Crops

Project Costs

In the Economic Analysis, no project costs are registered for crops.

Project Damages

"Damages to crops" in the context of this study excludes damages due to high salinity in river water used for irrigation (discussed above). "Damages to crops" refers exclusively to the flood-related crop loss or reduction in yield that occurs due to inundation of the maturing plants adjacent to the Sheyenne River. Flood damages attributed to the Devils Lake flood control alternative in question are computed by considering the increase (or decrease) in flooding caused by the project.

The expected per-acre flood damages along the Sheyenne River were computed by the Corps of Engineers as part of the Sheyenne River flood control study that was referenced previously. For that study, data was collected regarding: types of crops grown along the river, the mix of crops expressed as a percentage of total agricultural land use, crop yields and prices, and various farming operations and costs required for raising a crop. It should be noted that crop damage varies according to the date on which flooding occurs, reflecting the fact that plants' susceptibility to damage from inundation varies according to the stage of growth. Using the data that had been collected regarding crop production and seasonal susceptibility to flooding, crop damages were summarized in "seasonal crop damage curves." These curves relate per-acre crop damage to the date of flooding.

The damages reflected by the curves are not broken out by crop, but are aggregated to reflect typical damages that would be expected for each reach of the river. Damages are for both crops and pasture land. The 1982 curves were updated for this study to reflect current (2001) pricing.

The crop damage calculations for each reach were completed as follows: First, the number of acres flooded on each day of the growing season was calculated using the flow rate for the reach (output by the HEC-5/5Q model), along with the flow vs. acres flooded relationship provided by the Corps for that reach. Next, the reach-specific crop damage per acre (calculated using Corps damage tables) for each day of the growing season was multiplied by the number of acres flooded in that reach. This gave a value for the flood-induced crop damage for each day.

Finally, from all the daily values of crop damage for the year, the maximum daily value was selected, and the maxima from all the reaches were summed to provide an annual crop damage amount. The without-project damage was subtracted from the with-project damage to give the damage (or benefit, if there is less damage with the project) attributable to the project.

I.5.5.5 Agricultural Properties

Project Costs

In the Economic Analysis, no project costs are registered for Agricultural Properties.

Project Damages

Agricultural Properties include all property on a farm other than the crop in the fields. Therefore, this feature refers to an aggregate of farm buildings, machinery and equipment, stored grain and hay, livestock, fences, etc. Damages to Agricultural Properties are registered as flood damages when flow in the Sheyenne River exceeds the capacity of the channel. Damages include direct damage to property, and the expense incurred in post-flood cleanup and restoration.

Agricultural Property damage was computed using damage curves relating river stage to damage amount (in dollars) for each reach of the Sheyenne River. The damage curves were provided by the Corps, and provide estimates of aggregate damage to regional Agricultural Properties, including rural homes, farm outbuildings, farm equipment, fences, etc. Damage information was provided on a per-acre basis. The damage curves were based on data collected as part of the 1982 Sheyenne River flood control study; for the present study all the original dollar values were updated to 2001 dollars.

For each of the traces analyzed, the annual daily maximum flow was found for each reach of the Sheyenne River. This annual daily maximum flow was translated to river stage using the reach-specific discharge-stage relationship provided by the Corps. Then, the annual daily maximum stage was compared to the reach-specific stage-damage curve to provide the annual damage amount, by reach. The project damages for all the reaches of the Sheyenne River were later summed to give an annual damage amount for the flood management alternative. For each Devils Lake flood management alternative, annual flood damages were computed for both the with-project and without-project conditions. The damages attributable to the project were then determined by subtraction.

I.5.5.6 Urban Property

Project Costs

In the Economic Analysis, no project costs are registered for Urban Property.

Project Damages

Urban Property damages include the flood-related expenses that can be incurred at residential, commercial, industrial, and public properties. Damages to Urban Property are registered when flow in the Sheyenne River exceeds the capacity of the channel.

Urban Property damage is computed using damage curves relating river stage to damage amount (in dollars) for each of two cities—Valley City and Lisbon—along the Sheyenne River. (Urban centers further downstream were not included in the analysis because it was assumed that river flow increases resulting from Devils Lake outflows would be relatively insignificant for downstream areas.) The damage curves were provided by the Corps, and provide aggregate estimates of damage to Urban Property in Valley City and Lisbon. The Urban Property damage curves were based on data collected during the Sheyenne River flood control study referenced above; for the present study all the original dollar values were updated to 2001 dollars using the Engineering News Record (ENR) Building Index.

For each of the traces analyzed, the annual daily maximum flow is found for the reach of the Sheyenne River in which the city of concern is located. This annual daily maximum flow was translated to river stage using the reach-specific discharge-stage relationship provided by the Corps. This annual daily maximum stage was then compared to the city-specific stage-damage curve to provide the annual damage amount, by reach. For each Devils Lake flood management alternative, annual flood damages are computed for both the with-project and without-project cases. The damages attributable to the project are then determined by subtraction. The project damages for both cities were then summed to give an annual Urban Property damage amount for the alternative.

I.5.5.7 Transportation Infrastructure

Project Costs

In the Economic Analysis, no project costs are registered for Transportation Infrastructure.

Project Damages

Transportation Infrastructure damages include flood-related damages to roads, highways, bridges, and culverts, as well as traffic detour damages. Damages to Transportation Infrastructure are registered when flow in the Sheyenne River exceeds the capacity of the channel.

Transportation Infrastructure damage is computed using cost curves relating river stage to damage amount (in dollars) for each of the five reaches of the Sheyenne River. The Transportation Infrastructure stage-damage relationships developed for the Sheyenne River flood control study were used as the basis for the stage-damage relationships for Reaches 2 through 5. For Reach 1, the Corps developed a new stage-damage relationship by assuming that the per-acre damage characteristics for that reach would be comparable to those of Reach 2. All dollar values were updated to 2001 dollars using the ENR Construction Index.

For each of the traces analyzed, the annual daily maximum flow was found for each reach of the Sheyenne River. This annual daily maximum flow was translated to river stage using the reach-specific discharge-stage relationship provided by the Corps. Then, the annual daily maximum stage was compared to the reach-specific stage-damage curve to provide the annual damage amount, by reach. The project damages for all the reaches are later summed to give an annual damage amount for the flood management alternative. For each Devils Lake flood management alternative, annual flood damages are computed for both the with-project and without-project cases. The damages attributable to the project are then determined by subtraction.

I.5.6 Economic Modeling of Downstream Features

I.5.6.1 General Description of the Modeling Process

As was the case with the analysis of the features adjacent to Devils Lake, the analysis of the features downstream of Devils Lake was based on 50-year projections of future conditions. The projections, as was also the case with the adjacent features, were each founded on a specific set of climate assumptions.

For the downstream features, however, the potential effects of any flood control alternative at Devils Lake depend not on water level at the lake, but on water quantity and water quality in the rivers downstream of the lake.

As has been mentioned, effects on three of the downstream features—the MWTFs (a set of eight facilities), the Industrial Users (two facilities), and the Irrigation Operations (many)—were assumed to be primarily dependent on changes in water quality in the Sheyenne River and the Red River of the North. Effects on the other four downstream features—Crops, Agricultural Properties, Urban Property, and Transportation Infrastructure—were assumed to be dependent on flow in the rivers. The 50-year projections of flow and water quality were developed by the Corps, and depended on the specifics of the assumed weather conditions and of the flood control alternative in consideration.

Reach-Specific projections

Because the damage estimates for the downstream features were expected to vary by river reach (see Section I.5.5), it was necessary to have projections of water quality and water quantity that varied by river reach. As would be expected, water quality effects of Devils Lake discharges would be most pronounced furthest upstream, where dilution effects would be least. Similarly, any increased flooding attributable to Devils Lake discharges would be greatest at upstream points, because the additional water from Devils Lake would represent a larger percentage of the total flow. It was therefore necessary to identify the reach in which each feature was located. Computations of the costs and damages for a given feature were then based on reach-specific water quality and water-quantity projections.

Spreadsheet Model

The analyses of both the water quality and water quantity effects on downstream features were conducted by means of a computer model consisting of a set of inter-linked Excel spreadsheets.

For the water quality effects, feature-specific algorithms were developed based on research that had been conducted for the 1999 *Devils Lake ND Downstream Surface Water Users Study.* For each of the MWTFs, for example, a series of equations were developed that allowed calculation of water softening and alternative water supply costs. The weather-specific, reach-specific, and alternative-specific 50-year water quality projections were used as input to the model. These projections were supplied by the Corps for both with-project conditions and without-project conditions (using the HEC-5/5Q model). For each feature, the spreadsheet model estimated damages under both conditions, using the difference to arrive at a net damage amount resulting from (or prevented by) implementation of the alternative. (Detailed assumptions for the water quality modeling are provided in Attachment I.D)

The analysis of the water quantity effects was slightly less complicated. The spreadsheet models were based on research conducted by the Corps, and treated flood-related effects on each of the affected features—Crops, Agricultural Property, Urban Property, and Transportation Infrastructure—in aggregate. Agricultural property, for example, had its own cost curve relating damage to area flooded for each reach of the Sheyenne River. A separate reach-specific curve related Sheyenne River flow to area flooded. The weather-specific, reach-specific, and alternative-specific 50-year flow projections were used as input to

the model. Projections were supplied by the Corps for both with-project conditions and without-project conditions. For each feature, the spreadsheet model estimated damages under both conditions, using the difference to arrive at a net damage amount resulting from (or prevented by) implementation of the alternative.

The benefits summations for each feature were summed to produce a total for the downstream features. This total was added to results of the economic analysis of the adjacent features analysis and used in producing the overall economic indices for each alternative. Project costs were handled in similar fashion.

I.5.6.2 General Aspects of the Water Quality and Quantity Modeling Used for Analyzing Downstream Features

The 50-year water quality and water quantity projections required for analysis of the downstream features were produced through use of two computer models.

I.5.6.2.1 USGS 6-Box Model

To determine the potential impacts on water treatment facilities, methods were required to calculate future water quality constituent concentrations in the Sheyenne River and Red River of the North for two potential futures—without and with the project. Because Devils Lake is a landlocked lake, the range of future water level and water quality fluctuations is more difficult to calculate than for a simpler surface water system (such as a river basin). Future lake levels and quality are affected by a variety of climatic factors, by the lake level in previous years, and by the elevation of the surficial aquifers.

Potential future lake conditions—or "futures"—for the lake were produced from a "6-Box" lake level model developed by the United States Geological Survey (USGS) and described in Section I.4.5.2 above. The previous discussion of the 6-Box model highlighted its use in the analysis of features around the lake; below is described the manner in which output from the 6-Box model was used in the analysis of the downstream features.

The 50-year trace outputs from the 6-Box model include lake elevations and water quality, Devils Lake discharges and associated water quality, and Sheyenne River flows and associated water quality at the approximate point at which Devils Lake flows would join the Sheyenne River. To provide a "base case" for the subsequent downstream analysis, it was first assumed that no discharge would occur from the lake. In this way, a first set of 10,000 (without-project) traces of future lake levels and water quality parameters was created to represent the without-project (or without-overflow) condition.

This same set of 10,000 traces was then run assuming the project was in place. This produced corresponding pairs of with- and without-project traces and related lake elevations, discharge amounts, and water quality. Because the 6-Box model provides projections of water quality for any of the six major portions or bays of Devils Lake, it could be used to estimate the water quality that would be associated with discharge from any bay of the lake. The daily discharge rates and water quality

projections could be then be used to estimate Sheyenne River flows and water quality at the insertion point.

Combining water quality projections with outflow quantity resulted in 50-year projections that included the water quality for any lake discharge, resulting from either outlet construction or natural overflow. The outflow water quantity depended on the alternative in consideration, and was a function of several factors, including:

- Presence or absence of an outlet
- Location of the withdrawal from the lake
- Specified outlet pumping rate, or gravity outlet capacity
- Applicable constraints on pumping
- Assumptions regarding erosion at the natural outlet

I.5.6.2.2 HEC-5/5Q River and Reservoir Model

General

To assess the downstream water quality effects of discharges from Devils Lake into the Sheyenne River, the Corps developed a HEC-5/5Q river and reservoir model for the Sheyenne River and Red River of the North. For each alternative, the HEC-5/5Q model routes the 6-Box model's output down the Sheyenne River and Red River of the North to estimate daily downstream flow and water quality. The model takes into account the regional hydrology for the two river basins, and model results are based on climate assumptions matched with those used in developing the corresponding 6-Box/Devils Lake outflow results described above. Tributary and impoundment effects were also taken into account.

Combining the Devils Lake water quantity and water quality outflow projections (from the 6-Box model—see above) with the river projections provided by the HEC-5/5Q model, overall water quality and water quality projections could be made for both the Sheyenne River and the Red River of the North. Using output from the 6-Box model, the projections were made for both the without-project (or without-overflow) cases, and for the with-project (or with-overflow) cases. These projections were broken down by reach so that the reach-specific damage dependencies could be identified. In this way, reach-specific, climate assumption-specific, and alternative-specific daily 50-year projections were developed for both with-project and without-project conditions.

The HEC-5/5Q model was used to track TDS, sulfate, chloride, and hardness, which were assumed to be conservative substances and were modeled as such. A conservative constituent is one for which the concentration is directly related to the extent of dilution, i.e., the substance is not decomposed, altered chemically, or removed physically as a result of natural processes. The model was not used to track non-conservative substances, such as nitrogen, phosphorus, total organic carbon (TOC), dissolved oxygen, biochemical oxygen demand (BOD), and pH, whose pathways are far more complex. Output from the

HEC-5/5Q model allows determination of representative ranges, concentration duration, and concentration frequency of water quality constituents.

Traces Used

Note that although the stochastic analysis of the features adjacent to the lake uses 10,000 6-Box lake level traces to compute damage estimates, the computer analysis of the downstream damage estimates had been configured to use only a single HEC-5/5Q trace. This was problematic, in that a damage estimate based on 10,000 traces could reasonably be said to represent an average for potential future conditions. By contrast, an estimate based on a single trace would represent damages incurred only for one specific climate future. It was therefore necessary to find a way to make the downstream damage estimates compatible with the estimates of upstream damages.

Compatibility was achieved by using four representative traces for the analysis of the downstream features. Each of the four traces was held to be representative of a particular category (Wet, Moderate 1, Moderate 2, and Dry) of future conditions, and representative of a certain percentage (10, 30, 25, and 36 percent respectively) of all potential climate futures. For the alternatives, therefore, the four representative 6-Box model traces were used as input for the HEC-5/5Q model. In this way, four 50-year flow and water quality concentration projections were calculated for the Sheyenne River and Red River of the North downstream of the Devils Lake discharge.

Downstream feature damage estimates were then made for each alternative using all of the four HEC-5/5Q traces, and a weighted average (based on the above-listed percentages) of the damages was then made. These weighted average downstream feature damages could then be added to the adjacent features damages—based on 10,000 traces—to provide an overall estimate of the damages for the alternative.

For the Wet Future Scenario analysis, and for the portion of the sensitivity analysis that involved separate consideration of the Moderate or Dry climate futures, the analysis of the downstream features utilized only the HEC-5/5Q trace specific to the climate future under consideration for the alternative being considered.)

Model Output Stations

The complexity of the HEC-5/5Q model requires that the output only be produced at several predetermined locations (“stations”) along the two rivers. The river mile for each station was identified, with the furthest downstream point (Lake Winnipeg) being river mile 0.0. The junction of the Red River and the Sheyenne River is at river mile 427.5. For the purposes of this study, the Sheyenne River miles were combined with the Red River miles; the furthest upstream point (Devils Lake outflow insertion) being river mile 890.7. The stations at which model output was tabulated mark the endpoints of eleven river reaches described below:

Reach	From	To	River
1	Outlet* (RM 890.7)	Cooperstown (RM 744.5)	Sheyenne
2	Cooperstown (RM 744.5)	Valley City (RM 680.5)	Sheyenne
3	Valley City (RM 680.5)	Lisbon (RM 589.2)	Sheyenne
4	Lisbon (RM 589.2)	Kindred (RM 495.7)	Sheyenne
5	Kindred (RM 495.7)	Junction* (RM 427.5)	Sheyenne
6	Junction* (RM 427.5)	Halstad (RM 375.2)	Red
7	Halstad (RM 375.2)	Grand Forks (RM 298.1)	Red
8	Grand Forks (RM 298.1)	Oslo (RM 271.2)	Red
9	Oslo (RM 271.2)	Drayton (RM 206.7)	Red
10	Drayton (RM 206.7)	Emerson (RM 154.7)	Red
11	Emerson (RM 154.7)	Lake Winnipeg (RM 0.0)	Red

* "Outlet" refers to the approximate point at which any flows from Devils Lake reach the Sheyenne River; "Junction" refers to the point of confluence of the Sheyenne River and Red River of the North.

Figure I.9 shows the river reaches for the study area.

Locating the municipal, industrial, and other permitted users within one of the river reaches allowed a modeled water quality concentration to be assigned to that user. For example, a user located in Reach 2 was assumed to be subject to the modeled trace water quality data tabulated for Cooperstown. In this way, potential effects could be assessed more realistically, with consideration made for the dilution occurring as the Devils Lake water moves downstream.

I.5.6.3 Economics Calculations for Water Quality-dependent Downstream Features

Using input provided by the Corps' HEC-5/5Q model, economic analysis of the downstream features was done using inter-linked Excel spreadsheets and a set of small computer programs (macros) to automate the process. Each feature required a spreadsheet or set of spreadsheets for the analysis; input parameters and the approach to the economic analysis varied with each feature. As was mentioned above, the required input also included reach-specific, climate assumption-specific, and alternative-specific daily 50-year projections for both with-project and without-project conditions. The inter-linked spreadsheets allowed simultaneous analysis of all downstream features (and components of the features) for each 50-year projection used as input.

Specifics of the data handling and modeling are given below; see also Attachment I.D.

I.5.6.3.1 MWTF Modeling

Trace Data Management and Manipulation

The river water quality data used in this study were output from the HEC-5/5Q model, as explained in Section 5.6.2.2. The HEC-5/5Q model output showed fluctuations in five water quality parameters (total dissolved solids, sulfate, chloride, total hardness, and non-carbonate hardness) at eleven locations ("stations") along the Sheyenne River and the Red River of the North. Traces were developed for both "with-project" and "without-project" conditions. Through consideration of the location of the eleven stations with respect to the locations of the water treatment facilities to be analyzed, six stations were selected for evaluating the economic effects of the alternative on drinking water treatment facilities downstream. The table below lists each of the eight drinking water treatment facilities evaluated in this study, along with the corresponding HEC-5/5Q station that was used to represent the "with-project" and "without-project" water quality. Locations of the MWTFs are shown on Figure I.10. The trace without-project raw data were compared to the raw water quality data provided by each treatment facility to assure that projected without-project water quality was similar to existing water quality.

Drinking Water Treatment Facility	HEC-5/5Q Trace Data Station
Valley City	Valley City
Fargo	Kindred
Grand Forks	Halstad*
Grafton	Oslo
Drayton	Drayton
Pembina	Emerson
Letellier	Emerson
Morris	Emerson

* The water quality data for the station at Halstad, rather than that of the Grand Forks station, was used for the Grand Forks drinking water facility because the facility's intake is upstream of the confluence of the Red Lake River and Red River of the North. The HEC-5/5Q station at Grand Forks is downstream of this confluence.

It should be emphasized that the five water quality parameters modeled for each of the traces were chosen (by the Corps of Engineers) because they are commonly of interest with respect to water treatment and water use, and could be assumed to be conservative substances. However, non-conservative constituents that may also be of interest for water treatment investigations (e.g., pH, TOC, and BOD) were not investigated in this study.

Although sodium concentrations were not generated for the trace output, they were of interest when examining water treatment and water use. Therefore, a method was developed to provide estimates of sodium concentrations. It was assumed that sodium would pair with sulfate in solution. For each of the traces, sodium concentrations were then calculated as being 45 percent, by mass, of the modeled sulfate

concentration. The validity of this method of estimation was verified by examination of water treatment facilities records of raw water constituent concentrations. This relationship between sodium and sulfate was assumed to be accurate for the without- and with-project conditions.

Trace data were originally provided in ASCII text file format. For each alternative for which there was flow from Devils Lake, twelve daily trace data files were provided—two (one with- and one without-project) for each of the six stations pertinent to the municipal water treatment facility analysis. Each set of twelve trace data files corresponded to the particular climate future under consideration.

The daily trace data files were imported into Excel (Version 97 for Windows NT) for processing. Monthly averages for each water quality constituent were computed for each trace. Monthly averages dampen the effects of data outliers—short-lived spikes in water quality constituent concentrations—while still allowing accurate evaluation of longer-term changes in water quality. The use of monthly (rather than daily, or weekly) averages for estimating water treatment facility costs provided a means by which to more closely approximate a treatment facility's response to changing water quality. Short-term (daily or weekly) fluctuations in water quality would not be expected to occasion changes in chemical treatment dosages, which would be altered only after longer-term trends have been observed. In addition, the use of monthly averages allowed the use of a significantly smaller data set for mitigation cost estimating.

For each station, the with-project and without-project monthly averages were calculated from the daily trace data files and copied into separate tabs of a single Excel file. Within the Excel file, the difference in each of the water quality parameters (with-project minus without-project) was computed for each month and placed on a third tab. These tabulations of water quality constituent concentration differences, or "deltas," one set per station, served as the main data sets for the water treatment facility mitigation models.

The water quality deltas were used as data input for both the Phase I and Phase II mitigation models. They also served to allow assessment of impacts due to increased concentrations of water quality parameters that are not affected by existing treatment at the municipal water treatment facilities. The delta values for carbonate and non-carbonate hardness were used in the Phase I model to estimate the increased water treatment cost. This cost is that required for the removal of additional hardness (as indicated by the delta values) such that the municipal water treatment facilities' finished water total hardness would be the same as the without-outflow conditions. Because the treatment facilities were seen to be capable of handling the additional hardness (as indicated by the deltas) without plant modifications, the removal of additional hardness requires only increased chemical feed costs. As such, the removal is directly proportional to the delta value.

The delta values for total dissolved solids (TDS) **not** associated with hardness were used to estimate the additional cost for treatment under the Phase II model. For Phase II, it was assumed that the with-project municipal water treatment facilities' finished water TDS concentration must be treated so that it would be similar to the without-project concentration. Phase II, therefore, added further TDS removal (by ion exchange) costs to the hardness removal costs estimated in Phase I.

The delta values were generated for each trace for each water quality constituent, and at all six trace data stations. As such, the tables listing the deltas are quite voluminous and, therefore, were not printed for this report. The tables are contained in the Excel spreadsheets used to run both the Phase I and Phase II mitigation models.

Phase I (Softening) Model for MWTFs

As stated previously, the constituents included in the mitigation model were limited to those tracked by the HEC-5/5Q model: total hardness (both carbonate and non-carbonate), TDS, chloride, and sulfate. Review of the data obtained from each of the treatment facilities showed that for these constituents, only total hardness was used to measure facility performance. Equipment and processes were in place at each of the facilities to meet the current finished water hardness goal. It was assumed, therefore, for the Phase I evaluation that the treatment facilities would continue to remove hardness down to their current finished water concentration targets, no matter what raw water hardness concentration resulted from the Devils Lake outflow. The raw water hardness values were all within the range of conventional lime-soda limitations for hardness removal.

Through examination of the trace data, it was seen that, in all cases, the existing chemical feed capacity was sufficient to treat the additional hardness so that no capital improvements would be necessary. Costs for capital improvements were therefore assumed to be unnecessary for the Phase I portion of the mitigation model; no new unit processes were anticipated to be required as a result of the increased raw water hardness. Anticipated treatment costs were limited to those resulting from expected increases in chemical feed, and additional chemicals required were limited to those necessary for softening treatment only. Because it was assumed that additional treatment with lime and soda ash for softening would require additional pH adjustment, additional costs for recarbonation were also included in the Phase I cost evaluation.

The increase in chemical usage was determined by calculating the chemical feed rate currently required to remove one pound of hardness at each treatment facility. The same pound for pound dosage was used in calculating the increased chemical feed rates that would be required to treat the increased hardness caused by the outflow from Devils Lake. Because no capital improvements are required to accommodate the need for increased hardness removal (see above), hardness removal costs are dependent only on the chemical costs for treating the additional hardness. These costs are assumed to be linearly related to the hardness deltas described previously.

When possible, chemical costs were obtained from the treatment facilities. When this information was not available from a treatment facility, costs were estimated by using costs from similar facilities. All chemical costs were verified by comparison with cost data obtained from a local chemical supplier.

In addition to increased chemical costs, the need for increased softening will cause increases in sludge handling and disposal costs. For the Phase I model, the amount of additional sludge production was estimated based on current sludge production data from each facility. The cost of sludge disposal on a

per-pound basis was unknown in most cases. Therefore, sludge disposal costs generally had to be estimated based on what was known about the facilities' sludge handling processes.

Most of the water treatment facilities currently discharge their lime sludge to sludge lagoons located on site. The sludge is allowed to accumulate and thicken until the lagoon has reached its capacity. At that time the lagoon is emptied and a cost is incurred for both sludge removal and disposal. This manner of infrequent sludge disposal made it difficult to assign a per-pound or even an annual cost for sludge disposal. For the purpose of this study, the sludge production rate for each facility was used along with a known or estimated lagoon capacity to estimate the number of years required for the lagoon to reach capacity. Increased softening would result in increased sludge production and a faster rate of lagoon filling. Known or estimated lagoon-emptying and disposal costs would, thereby, be incurred more frequently. By comparing with modeled without-project sludge disposal costs, the difference in cost for the with-project scenarios could be established.

Each of the MWTFs was researched, and the facility operators interviewed if possible[9]. Although several of the water treatment facilities provided data related to several recent years of operation, those data were often incomplete. Data for 1997 were assumed to not be representative because of the severe flooding problems during the spring. However, examination of the treatment facilities' reports indicated that 1996 was a relatively average year with respect to water use in the study area. In addition, most of the facilities were able to supply fairly complete data for 1996. Therefore, most of the operations cost projections for this study were based on 1996 data for treatment facility water production, water quality concentrations, and chemical feed rates. All costs were updated to 2001 dollars for the present analysis.

Using the above-stated assumptions, the Phase I model calculates the cost of mitigation for each facility by the following method: The model first calculates the average delta (with-project minus without-project) for hardness for each month of the study. The delta is calculated using treatment facility flow data and trace data concentrations. The calculated delta is then multiplied by the pounds of chemical required per pound of total hardness removed, and with this result a chemical treatment cost is calculated. Similarly, the increased production of sludge is calculated from the monthly hardness deltas. Sludge disposal costs vary by treatment facility, and are calculated as described in the discussion for each facility. The total cost of the Phase I portion of the mitigation model consists of the sum of the increased chemical feed costs and sludge disposal costs. In all cases, the costs over the 50-year modeled period are brought back to present dollars and then annualized.

Phase II (Alternate Water Supply) Model for MWTFs

As has been described, the purpose of the Phase II model was to evaluate the available options and estimate the costs associated with providing a finished water to the consumer that would be similar in the water quality parameters analyzed to that available if there were no outflow from Devils Lake.

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9 See the *Devils Lake ND Downstream Surface Water Users Study* (March 1999; Barr) for details.

Only hardness (calcium and magnesium concentrations) would be reduced by current water treatment facility processes; other water quality parameters that increase due to the outflow will not be affected by current treatment facility processes. The water quality parameters not affected by conventional treatment processes in place at the treatment facilities include the ions sulfate (SO_4^{-2}), chloride (Cl^-), and sodium (Na^+). Although the increase in the concentration of these constituents due to Devils Lake outflows will not cause them to exceed SDWA Secondary Standards in most cases, Phase II evaluates options to remove these constituents through treatment. Phase II also investigates alternate water source options available to the treatment facilities as an option to mitigate the anticipated effects of the outflow from Devils Lake.

Development of Capital and O&M Costs for Ion Exchange

Because SO_4^{2-}, Cl^-, and Na^+ are not removed by lime-soda ash softening or the other treatment processes currently in place at the treatment facilities, ion exchange was selected as a likely treatment process to develop costs for treatment and compare treatment costs to alternative water supply options. To simplify the development of capital and additional operations and maintenance costs associated with ion exchange, it was assumed that the increase of the total dissolved solids due to the outflow could be accounted for solely by the increase of SO_4^{2-}, Cl^-, and Na^+ concentrations. Furthermore, it was assumed that by reducing TDS concentrations from with-project to without-project levels, a treated water quality similar to that of the without-outflow conditions would result.

Ion exchange almost completely removes the ions in the water and, therefore, only a portion of the total water supplied to the users would be required to undergo ion exchange treatment. The ion-free finished water stream from the process would then be blended with the stream from the existing treatment processes. In this manner, a blended finished water could be produced that would be similar to that of the without-outflow conditions.

Capital costs for ion exchange processes were developed using the USEPA document *Estimation of Small System Water Treatment Costs* (R.C. Gumerman, et. al., USEPA, 1984). This document gives curves for capital and O&M costs for various treatment technologies. The document focuses on treatment facility sizes ranging from 2,500 gallons per day (gpd) to 1 million gallons per day (MGD). The items included in the capital cost curves includes:

- Excavation and Site Work
- Manufactured Equipment
- Concrete
- Steel
- Labor
- Piping and Valves

- Electrical and Instrumentation
- Housing

A contingency is also included as part of the capital costs. To be able to input the capital cost curve into the mitigation model and allow for flexibility between treatment facilities and traces, a best-fit analysis was performed on the data used to develop the cost curve. The resulting equation from this line was programmed into the Phase II model.

The estimate of the size and capacity of the ion exchange unit required depends on the flow rate and the TDS concentration of the water fed to the unit. The amount of flow fed to the unit will be a fraction of the total treatment facility flow, but will be related to the overall demand at the plant. Therefore, the unit sizing and associated capital cost estimates were based on the maximum monthly water demand and the highest TDS concentration (as seen in the trace data) for that month. The estimated capital cost was updated from 1983 dollars to 2001 dollars by multiplying the result by the 2001 to 1983 ratio of the Construction Cost Index (CCI) published by Engineering News Record.

The same sources and methods were relied upon to develop the O&M costs for ion exchange. The items included in the O&M cost curves include:

- Energy
- Maintenance Material
- Regeneration Chemical Costs
- Labor

Costs are also associated with the disposal of the brine that results from regeneration of the ion-exchange resin. The EPA lists seven methods for disposal of brine waste in their document, *Management of Water Treatment Plant Residuals* (1996): (1) direct discharge to surface water, (2) deep well injection, (3) spray irrigation, (4) discharge to a drainfield or borehole, (5) discharge to sanitary sewer collection systems, (6) brine concentration, and (7) brine evaporation ponds. Preliminary investigations indicated that discharge to the sanitary sewer collection systems would be the least cost alternative for these water treatment facilities. NPDES permits would need to be revised for each facility to reflect the change in effluent quality. The cost for brine disposal was included in the economic analysis; brine disposal was assumed to cost $4.12 per gallon (1998 dollars). Brine disposal costs were included in O&M costs. Details of the brine disposal analysis can be found in an Appendix to a previous report: *Potential Impacts of a Stump Lake Spill on Downstream Water Users* (Barr, September 2000).

In 1998 dollars, the assumed labor cost was $40/hour and the energy cost was assumed to be $0.05/kw-hr. Sulfuric acid (H_2SO_4) was assumed to be used as the strong acid for regeneration. Local chemical feed suppliers give the cost of H_2SO_4 as either $0.19/lb for 330-gallon totes or $0.15/lb for bulk shipments (approximately 3,000 gallons). Sodium hydroxide (50 percent NaOH) was assumed to be used as the strong base for resin regeneration. The cost of NaOH was either $0.40/lb for 330-gallon totes or $0.36/lb

for bulk shipments (approximately 3,000 gallons). Initial calculations were performed using the 1998 dollar amounts; the totals were subsequently updated to 2001 dollars using the ENR Construction Index.

Because the amount of TDS needed to be removed varied month to month and from facility to facility, the O&M costs were developed on a per-pound-of-TDS-removed basis for the various treatment facilities. The values were plotted and a cost curve was developed for per-pound cost for TDS removed versus treatment facility system size. A best fit analysis of the curve was performed and the resulting equation was used in the Phase II model.

The capital cost for ion exchange was assumed to be incurred in the first year of operation. Replacement frequency will depend to some extent on the demands placed on the ion exchange unit, but two replacements were assumed to be required over the course of the 48-year cost projection. Therefore, full replacement of the ion exchange systems was assumed to be required in years 16 and 32. The O&M cost was estimated using the cost equation and the monthly pounds of TDS to be removed by each facility. The costs were brought to present worth values and annualized for the 50-year modeling period.

Development of Capital and O&M Costs for Alternative Water Supply Options

Groundwater was initially considered as the likeliest alternate source water for municipal users. To evaluate the possibility of using groundwater as an alternative municipal supply source, aquifer information was gathered separately for each state/province. In North Dakota, this information was obtained from county groundwater studies published by the North Dakota Geological Survey and through communications with Milton Lindvig (Director of Water Appropriations for the North Dakota State Water Commission). In Minnesota, aquifer information was obtained from *Designation of Principal Water-Supply Aquifers in Minnesota*, published by the U.S. Geological Survey. Manitoba aquifer information was obtained through communications with Eric Carlson of Manitoba Water Resources.

Investigation of the area aquifers revealed that the only usable groundwater was contained in surficial aquifers. Deeper aquifers represented by the Dakota Group and the Montana Group are also present throughout the study region. However, these aquifers are of poor water quality and water yields are small, making them virtually useless as a drinking water source.

Surficial aquifers, having acceptable water quality but variable yields, are scattered throughout the region. Those municipalities with possible access to groundwater are discussed in later sections. The area around Pembina, Drayton, and Grafton has virtually no surficial aquifers available on either the North Dakota or Minnesota side of the Red River of the North. As has been stated, the deep aquifers are of poor quality.

In addition to groundwater sources, other options were considered. Additional water supply options were investigated for each treatment facility to compare the cost associated with onsite treatment to that of obtaining water of better quality from an alternate source. These additional options included obtaining raw water from wells, rural water supply, or from nearby rivers not affected by the Devils Lake outflow.

The raw water quality of each alternate source was compared to the existing raw water source water quality. In most cases the hardness levels were expected to be similar to those of the raw water, and in no

case were these concentrations identified as being significantly lower in the alternate supply. In cases where the alternate supply had higher hardness, it was assumed that the existing facility would treat the alternate source water down to the facility target finished hardness concentration and an increase in operations cost would result. This increase in treatment cost was included in the Phase II mitigation model. It was also assumed that no modifications or additions to the existing water treatment processes would be necessary to treat water supplied from a source other than the Sheyenne River or Red River of the North. Lime-soda ash softening was assumed to be adequate for treating the alternate raw water source in order to produce water of the quality that would be obtained if there were no outflow from Devils Lake.

In cases where wells or a rural water supply were assumed to be the alternate water supply source, capital and annual O&M costs associated with constructing wells and conveying the water from the alternate source to the treatment facility were considered. Additional treatment costs, if necessary, were calculated as discussed above.

Cost assumptions used to develop cost estimates for wells or rural water as the alternative water supply are presented in Attachment I.D. A brief discussion on the assumptions used to develop cost estimates for the alternative water supply sources for each of the municipalities is also given in Attachment I.D.

I.5.6.3.2 Industrial Users Model

To develop damage estimates for the industrial users, a variation of the Phase I and Phase II mitigation models discussed in Section I.5.6.3.1 (above) was used. Because the beet processing facility treated the river water through lime softening for hardness removal, the Phase I mitigation model could be used to estimate the increase in operating cost for additional softening.

The power generating facility treated river water for TDS removal by means of an ion-exchange treatment system. Since the facility did not provide any existing operating cost data, the Phase II model was used to estimate the additional cost for TDS removal by ion-exchange treatment. No increases in capital costs were considered, because the facility currently already has an ion-exchange treatment system in place.

I.5.6.3.3 Irrigation Operations Model

A previous study[10] detailed the results of the preliminary research regarding the numbers and locations of Irrigation Operations, crops irrigated, salinity tolerance, and irrigation methods. Data was gathered through various means, including: review of the water use permits, examination of maps and planting records, interviews with local agency officials, and review of literature regarding the effects of salinity. Water supply alternatives were also investigated for the potentially affected uses. That research provided the basis for the economic modeling of the damages to Irrigation Operations.

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10 *Devils Lake ND Downstream Surface Water Users Study* (March 1999; Barr). This report contains background material on the effects of salinity on crops.

Research into the potential effects of increased salinity enabled computation of estimated "threshold" water quality levels for irrigation. Threshold levels are defined for this report as the levels above which impacts may be detrimental and, if severe enough, might warrant correction or compensation for losses. It was assumed that minor water quality changes below these threshold levels are not likely to be detrimental for water users. Exceedance of the threshold was evaluated by reach, and took into account crop type and soil type.

Soils types along the rivers can be generally characterized as sandy loams with pockets of sand and clay along most of the Sheyenne River, and mainly clays with pockets of sandy loams through the Red River Valley. Soils were characterized using information from the State Soil Geographic Database (STATSGO), and are based on Soil Conservation Service classifications.

Calculation of Threshold Levels Based on Study Data

The threshold levels of the various agricultural crops grown in the study area were computed based on the particular crop tolerance and the soil types. Tables in Attachment I.D list the range of threshold levels by soil type for the agricultural crops. For purposes of this study, it was assumed that the average value would be used as the threshold level.

Dry edible beans appear to be the agricultural crop most sensitive to salinity; even in well-drained sandy soil (soil type A), these plants can tolerate only approximately 900 mg/L before a reduction in yield is experienced. Corn, flax, and potato yields would be affected in soils with moderate permeability; in clay and loamy soils (soil types C and D), these crops can tolerate approximately 700 mg/L before a reduction in yield is experienced. All other agricultural crops had threshold levels that were greater than 1,800 mg/L for all soil types.

For purposes of this study, county-by-county agricultural use averages were used to estimate the number of users according to specific type of use. There are no data available from the counties that allowed differentiation of the amount of agricultural use from the amount of other uses (nurseries, golf courses, gardens, lawn, and domestic). Therefore, the information obtained from the user interviews was used to estimate the approximate percent of permittees that use the river water for agricultural use (50 percent) versus other uses (50 percent).

The agricultural use of river water was further subdivided between crops and livestock using county data that provided the average per-county acreage of each. Since the county data were available by average acreage and the permittees use the river for multiple uses, the total potentially affected acreage was estimated (rather than the total number of users). The potentially affected acreage per agricultural user was estimated based on conversations with the North Dakota Agricultural Extension Service. According to the Extension Service, the approximate maximum distance that irrigation equipment can draw from the river water is 1 mile. Therefore, irrigators were assumed to irrigate up to a maximum area encompassed by a 1-mile radius centered on the permit location.

The acreage that would be potentially affected was computed using the following data:

- Total acreage of crops and livestock (by county).
- Irrigated crops grown within each county (percent). The North Dakota and Minnesota Agricultural Statistics Service and Minnesota Department of Agriculture indicate that in counties within the Sheyenne and Red River of the North Basins, the following crops may be grown: barley, corn, dry edible beans, flax, hay, oat, potato, rye, soybean, sugar beets, sunflower, and wheat. The North Dakota statistics indicate that barley, corn, potatoes and wheat are the only irrigated crops in those counties. The percentage of irrigated crops was used for the determination of affected acreage in North Dakota. Minnesota statistics for irrigated crops are not available. For the analysis, it was assumed that the irrigated crops in Minnesota would be the same as in North Dakota (barley, corn, potatoes, and wheat). The percentages of each crop were based on the total agricultural crops grown.
- Soil types (based on the SCS hydrologic soil group) were estimated using the STATSGO soils database. Soil types were identified within the 1-mile radius of the location of each irrigative permit holder.

The determination of potentially affected acreage thus included consideration of soil type, crop salinity tolerance, land use, and typical crop distributions within one mile of the agricultural water use permit holders' locations. The determination was reach-specific; all calculations were made based on the modeled HEC-5/5Q indices for the water quality station for the reaches in which the permits existed.

For each month of the potential irrigation season (May through September), monthly averages for the daily HEC-5/5Q TDS values were computed. For each year of the 50-year modeled period, the highest of these monthly averages was used to compare with threshold values for each crop known to be grown in the reach. If threshold values were exceeded, the crop was listed as potentially affected. Using county agricultural service records to determine whether or not the potentially affected crop was actually grown in which county, the potentially affected acreage could be estimated for that crop.

In cases where TDS levels in the Sheyenne River and the Red River of the North exceed threshold values for irrigation, river water users may be able to utilize one of several alternative water supplies. Depending on the location of the Irrigation Operation, the alternative supplies may include rural water supply, other river sources, and private or cooperative wells. Irrigators may also simply continue to use the river water, under the expectation that rainfall and snowmelt water will mitigate any possible long-term effects on crops or soils.

Similarly, several schemes could be imagined for compensating irrigators for potential losses. Easements could be purchased for potentially-affected acres. Current crop land rental rates could be paid to farmers in years in which it was expected that high TDS levels would interfere with normal irrigation efforts. Potentially-affected acreage could even be purchased outright, under an assumption that the high TDS levels would have the effect of removing the land from service. Each of these compensation schemes would necessitate a different method of calculating damages.

For the Economics Analysis, it was assumed that damages for the Irrigation Operations would be assessed on the basis of reduced yields. If above-threshold TDS levels resulted from Devils Lake discharges, it was assumed that water users would simply discontinue irrigation for that year. Presumably this would result in reduced yields. The difference in yield was estimated by comparing county records for yields for each potentially-affected crop under both with-irrigation and without-irrigation conditions. The difference in yield was multiplied by current crop prices to arrive at a per-acre damage for potentially affected acres. For each crop and for each reach, the potentially affected acreage was multiplied by the per-acre damage amount to give a crop damage amount. These amounts were totaled for all crops and all reaches; the annual results were brought back to present worth and annualized to give a damage amount for the alternative in question.

The majority of the information used as the basis for the damage assessment was gathered from the North Dakota Agricultural Statistics Bulletin. See Attachment I.D for detailed information regarding crops, yields, and prices.

I.5.6.4 Economics Calculations for Water Quantity-Dependent Downstream Features

The methods used for calculating the water quantity-dependent downstream damages were relatively simple. A complete description of the methods used for calculating those damages was given previously in this Technical Appendix (Sections I.5.5.4 through I.5.5.7). Within Attachment I.D can be found the complete text of the documentation for the methodology, as provided by the Corps.

I.6.0 Economic Analysis

I.6.1 General Description

The interest rate used for the analysis was 6-3/8 percent, based on FY00 Corps guidelines. The cost and damage data for each feature adjacent to Devils Lake were used to determine the net benefits around the lake. As discussed in Section I.4.3.2, the set of most likely action strategies for adjacent lake features provided the baseline measure of net benefits from each project. In addition to the benefits from adjacent lake features were the benefits (or damages) to features downstream of Devils Lake along the Sheyenne River and the Red River of the North. The present worth values for total costs and benefits for each trace were used to determine annual net benefits of the project.

For the stochastic analysis, the present worth values for adjacent lake features were average values based on the 10,000 traces evaluated. For the downstream features, a weighted average was computed based on the results of the representative scenarios and used to estimate the downstream impacts on the net benefits and benefit-cost ratio (BCR).

For the Wet Future Scenario analysis, the present worth values for adjacent lake features were based on evaluation of a single trace that represented just one (the Wet Future) of the four categories of future lake levels. The downstream features were also evaluated using the concentrations and flows for the same trace to estimate the downstream impacts on the net benefits and benefit-cost ratio (BCR).

A more general description of the economic analysis is provided in the Main Report.

I.6.2 Project Evaluation

To analyze the economic feasibility of a project, the net benefit is computed as the project's benefits minus the project's costs. A project is considered to be economically justified if the net benefit is greater than zero. Another method of looking at the economic viability of a project is to determine the benefit-cost ratio (BCR), which shows the benefits compared to the costs. A BCR greater than one indicates that the benefits are greater than the costs, and the project is economically justified. A BCR less than one indicates that the costs are greater than the benefits, and the project is not economically justified.

The damages and costs of flood protection measures for the without-project future conditions were compared to the damages and costs of flood protection measures for the with-project future conditions. The benefits of the projects may include:

- The cost savings that occur as protection of infrastructure adjacent to Devils Lake would be reduced or eliminated by lower lake levels or flood protection measures.
- The reduction in damages to infrastructure adjacent to Devils Lake.

- The reduction in road restoration costs and the frequency and duration of detours from road closures around Devils Lake if the project would lower lake levels.
- The cost savings provided by a reduction in the number of years that the state's upper basin storage program is operated (assumed to be when the lake level is above 1440).
- The reduction in operating costs for downstream water treatment and industrial facilities.
- The reduction in flow-related damages to agricultural crops, transportation features, and urban sites that are within the floodplain adjacent to the Sheyenne River.
- The reduction in water quality-related damages to agricultural crops adjacent to the Sheyenne River and the Red River of the North.

The costs and benefits were computed at an interest rate of 6-3/8 percent and are presented as an annualized present worth value over a 50-year period starting on October 1, 2000. The benefit categories were defined to be consistent with National Economic Development (NED) criteria. For alternatives that include an outlet, the outlet was assumed to be operational on May 1, 2005, and therefore capable of operating for the last 45.5 years of the 50-year period of analysis.

A summary of the costs and benefits of the projects based on the set of most likely action strategies is included in Part II of this Technical Appendix for the stochastic and Wet Future Scenario analyses. Sensitivity analyses are also discussed in Part II of this Technical Appendix.

The Main Report for the Economics Analysis summarizes the economic analysis of the alternatives based on these analyses.

I.7.0 Methodology for Sensitivity Analyses

Because the results of the economic modeling are dependent upon the assumptions inherent in the model, the Economic Analysis includes examination of the modeling results when assumptions were altered. The method of investigation of the model's sensitivity to its modeling assumptions varied, and depended on which assumptions were under scrutiny and how those assumptions were incorporated in the modeling process. For each of the four sensitivity analyses included in this Economic Analysis, the manner in which the sensitivity analysis was conducted is described below.

I.7.1 Local Flood Protection Strategies Adjacent to the Lake

As has been mentioned, there is a range of flood protection strategies that might be employed for features adjacent to the lake. Four such strategies are detailed in the main report:

- **Set of Most Likely Actions Flood Protection Strategies**
  This set of strategies assumes that the types of emergency measures currently being pursued in the project area would continue to be implemented as necessary as the lake continues to rise.

- **Set of Cost-Effective Flood Protection Strategies**
  The most cost-effective strategy for each feature, with cost-effectiveness based on the maximum net benefits, i.e., benefits minus costs. The most cost-effective flood protection strategy may be different for the with- and the without-project futures. Since this study provided a reconnaissance-level investigation of flood protection measures, the strategy net benefits for each feature was assumed to be accurate within 1 percent. Therefore, if a strategy for a given a feature provided more protection than the strategy with the highest net benefit and had a net benefit within 1 percent of the highest net benefit, that strategy was selected for this set of strategies.

- **Set of Maximum Flood Protection Strategies (at the First Decision/Action Level)**
  The strategy for each feature that provides flood protection to the maximum lake level at the first decision/action level, i.e., no further flood protection measures would be necessary to protect the features. Where more than one maximum protection strategy was analyzed for a particular feature, the strategy with the least cost was used for this set of strategies.

- **Set of No Flood Protection Strategies**
  The strategy for each feature that provides no flood protection, i.e., it is assumed that no action is taken to protect the feature.

The economic modeling generally assumes that whichever set of strategies is adopted, it will be employed under both without-project and with-project conditions. However, the choice of a strategy will affect the modeling results.

The economic indices presented in the Main Report are underlain with the assumption that the *most likely action* strategy is the one that will actually be implemented for the features adjacent to the lake. However, the Features Analysis Model (FAM) used to produce these indices also generates economic results for each of the three other sets of strategies every time the model is run. Sensitivity results, therefore, are generated automatically each time an alternative is evaluated. The analysis of the sensitivity to these modeling assumptions can therefore be conducted simply by examination of the model output.

I.7.2 Maximum Infrastructure Protection Adjacent to the Lake

The Maximum Infrastructure Protection sensitivity analysis involves an examination of the economic results when it is assumed that the **project itself** will contain the infrastructure protection measures adjacent to the lake that are otherwise assumed to be undertaken independently. The analysis involved an examination of alternatives that included the Maximum Infrastructure Protection approach (see Main Report) to protecting infrastructure adjacent to the lake. The alternatives included:

- **Maximum Infrastructure Protection (with no other flood management effort)**
  This alternative evaluates the economic feasibility of implementing the set of most likely action strategies for all of the features adjacent to the lake, assuming this is the comprehensive plan for flood protection at Devils Lake. The cost of the project is the cost to implement the set of most likely action strategies: building levees, raising roads and rail lines, relocating homes, etc. For this alternative, the with-project condition assumes that the types of emergency measures currently being pursued in the basin would continue to be implemented as the project, whenever they are necessary as the lake continues to rise. The only modification to the existing protection strategies would be to ensure safe protection of all areas, including the Expanded Infrastructures Measures that are described in Section I.3.1.2 (raising several roads as dams and constructing perimeter dams as noted on Figure I.2).

- **Combination of Upper Basin Management and Maximum Infrastructure Protection**
  This alternative combines the Upper Basin Management project with the Maximum Infrastructure Protection project. The alternative assumes that the existing flood protection strategies would be combined with storage in the upper basin to protect the primary features around the lake. The project costs include the implementation of upper basin storage and the combined costs for feature protection around the lake (as described above).

- **Combination of West Bay Outlet with Upper Basin Management and Maximum Infrastructure Protection**
  This alternative combines the West Bay outlet with the Upper Basin Management project and the Maximum Infrastructure Protection project. In addition to construction of an outlet that releases flow from the West Bay, the alternative assumes that the existing flood protection strategies and upper basin storage would be implemented to protect the primary features around the lake. The project

costs include the construction of the West Bay outlet, implementation of upper basin storage, and the combined costs for feature protection around the lake.

The Maximum Infrastructure Protection alternatives are the only alternatives where the without-project condition assumes no protection for the features adjacent to the lake. (This is the case because these alternatives are the only ones for which the alternatives themselves are considered as including infrastructure protection.) This fact makes the examination of these alternatives useful in assessing the value of infrastructure protection.

The Maximum Infrastructure Protection alternatives were evaluated in exactly the same fashion as all the other alternatives. The sensitivity analysis with respect to the alternatives, then, consisted of examining economic results for these alternatives, and comparing those results to the alternatives for which the without-project conditions included infrastructure protection.

I.7.3 Moderate and Dry Future Scenarios

The stochastic analysis provided an estimate of average economic indices for each of the alternatives, and the Wet Future Scenario analysis provided estimates for those indices under that particular (Wet Future) climate assumption. A further comparison of results was made possible by using the economics model to determine results when other climate futures (Moderate I, Moderate II, and Dry) were assumed.

The sensitivity analysis for these climate futures, therefore, consisted of generating model results for features both adjacent to the lake and downstream of the lake using three specific climate future traces. For each climate future and each alternative to be evaluated, it was necessary to obtain additional lake level and HEC-5/5Q traces from the Corps. Once these traces were available, however, the economic evaluation involved exactly the same procedures as those used to generate results for the Wet Future Scenario analysis.

Only five of the eleven alternatives were evaluated for the Moderate and Dry Future sensitivity analysis. The selection of the five alternatives was made by the Corps, and are listed below:

- West Bay 300 cfs Constrained Outlet
- West Bay 480 cfs Unconstrained Outlet
- Pelican Lake 300 cfs Constrained Outlet
- Pelican Lake 480 cfs Unconstrained Outlet
- Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures

I.7.4 Erosion at Natural Outlet

For the Economic Analysis, it was generally assumed that the stability of the natural outlet would be maintained (under both without-project and with-project conditions) so that outflow from Stump Lake would not erode the natural outlet and change its discharge characteristics. There is some reason to question this assumption, however, so this sensitivity analysis was conducted for certain alternatives using the assumption that no erosion protection was in place.

In preparation for the erosion sensitivity analysis, Barr conducted an analysis of the mechanics of how the natural outlet would be cut down by outflow from Stump Lake. The details of the analysis of how the natural outlet would erode—including evaluation of local soils, flow rates, and changing discharge rates—are discussed in Attachment I.F. The results of this analysis were provided to the USGS, which used the results to estimate new lake levels and overflow rates, creating new 6-Box model results. The 6-Box lake level and outflow traces were in turn passed to the Corps, which used them as model input to create new HEC-5/5Q traces. The 6-Box traces and the HEC-5/5Q traces were then used in the economics model to estimate costs and benefits for selected alternatives with erosion of the outlet, in accord with the methods used for the evaluation of alternatives for which erosion was assumed to be prevented. The sensitivity analysis therefore consisted of comparing the results of the with-erosion analysis with those obtained when no erosion was assumed.

Note that erosion at the natural outlet only comes into play for those climate futures that result in an overflow from Stump Lake. As a result, the results of the erosion analysis are most significant for those alternatives that are capable of preventing an overflow. The sensitivity analysis for the erosion assumptions was thus conducted for only the following three alternatives, selected by the Corps:

- West Bay 300 cfs Constrained Outlet
- West Bay 480 cfs Unconstrained Outlet
- Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures

It should also be noted that an additional with-erosion analysis was conducted for an “alternative” that included a West Bay 300 cfs Constrained Outlet, Upper Basin Storage, and Maximum Infrastructure Protection. This allowed an analysis of the model’s sensitivity to the combined effects of erosion and Maximum Infrastructure Protection.

I.8.0 Glossary

action level – an elevation at which a feature protection action is taken (costs are incurred to construct or implement a flood protection measure) based on a decision made at a prior, lower decision/action level. No decision is required.

Alternative – an overall approach to flood control and management, consisting of a single project or combination of projects. Each alternative is evaluated to determine its economic feasibility and compare its net benefit to that of other alternatives.

Analysis – economic evaluation of various alternatives using either a stochastic (quantitative) or scenario (qualitative) based approach.

BCR (benefit-cost ratio) – a measure of the economic feasibility of a project. The BCR is defined as the benefits divided by the costs. A BCR greater than one indicates that the benefits are greater than costs, which implies that the project is economically justified.

benefit – the value of protection that is provided by a project or a feature protection measure, including the reduction of damages and the cost savings. Benefits are negative in cases where project implementation increases the damages to a particular feature. In some analyses, negative benefits are tallied as costs; for this Economic Analysis they are recorded in the benefits column along with any positive benefits.

cost – an amount paid to construct a project that will prevent potential damages, or an amount paid to mitigate future damages. The term is also sometimes used to refer to damages induced by a project.

Cost-effective – designation for a set of feature protection strategies that are based on the maximum net benefits, i.e., benefits minus costs.

Cost-effectiveness – a term used to compare alternatives in which not all of the benefits are quantifiable. The alternative that provides the most benefits for the investment of Federal dollars refers to the plan with the highest cost-effectiveness.

damage – loss of value to infrastructure or features due to flooding or increased concentrations in the water.

decision level – an elevation at which a decision is required for protection of a feature, but no action is taken as a result of the decision (no decision levels were identified in this study).

decision/action level – an elevation at which a decision is made for protection of a feature and an action may be taken (depending on the decision made). In some cases, later actions may also be taken at subsequent, higher action levels based on the decision made at the original decision/action level.

decision tree – a graphical representation that indicates the lake elevations at which decisions and actions would be required for each feature and the options at those levels.

economically justified / economically feasible – an alternative is said to be economically justified or economically feasible if it has a positive net benefit—the benefits of a project minus the costs for construction and operation of the project are greater than zero.

Features – physical entities or groups of entities that would be susceptible to damage from the rising lake or from flows released from the lake (for example, Community of St. Michael, Highway 20 between Highway 57 and Tokio, Grahams Island State Park, Rural Areas adjacent to Stump Lake, downstream municipal water treatment facilities, etc.).

future – refers to an event that will happen in a time period that is to follow the current situation.

Future – one of four categories of the stochastically generated traces. These Futures each center around an average peak lake level. For example, the Wet Future comprises 10% of the stochastically generated traces and has an average peak lake level of 1461.1. For the purposes of this study, each of these Futures is represented by one trace.

Infrastructure – individual structures and transportation, communication, and utility networks. Infrastructure may include roads, rail lines, homes, businesses, utilities, etc.

Natural outlet – the waterway through which water naturally flows out of the Devils Lake basin, through the Tolna Coulee, and to the Sheyenne River. The term is at times used to refer to the location at the rim of the Devils Lake basin over which flow would first occur from the basin.

Natural overflow – flow that leaves the Devils Lake basin through the natural outlet.

Net benefit – the benefits of a project minus the costs for construction and operation of the project. Project selection will typically favor the project with the largest net benefit, although risk and effectiveness must also be considered.

Outlet – a flood control project that removes water from Devils Lake and directs it into the Sheyenne River (for example, West Bay 300 cfs constrained pumped outlet or East End 480 cfs unconstrained gravity outlet).

project – a flood control measure that reduces the regional damages that would otherwise be caused from the rising lake—either by reducing the lake level, reducing the downstream impacts, or protecting the features adjacent to the lake. For example, upper basin storage, infrastructure protection, a pumped or gravity outlet, or an Raise the Natural Outlet are each referred to as a project.

project cost – the costs related to installation, operation, and maintenance of a project, including costs for induced damages, and for environmental monitoring and mitigation of environmental damages.

scenario – a conditional forecast based on certain climatic and hydrologic assumptions. The assumptions inherent in the forecast determine the lake levels and related downstream flows. The scenarios defined in this study include a wet future, two moderate futures, and a dry future.

set of strategies – a selection of flood response measures that is universally assumed for all features. The four sets of strategies include: set of most likely action strategies, set of cost-effective strategies, set of no flood protection strategies, and set of maximum protection strategies at the first action level. In most cases, the set of strategies will be implemented independent of a flood control project.

stochastic – a term used to describe the probabilistic determination of future lake levels, based on the assumption of a stationary climate. The stochastic analysis generates the 10,000 traces of 50-year future lake levels.

strategy – a flood response measure specific to a particular feature around the lake (for example, raise Highway 2 above the current flood level, or relocate homes in Churchs Ferry).

trace – a 50-year sequence of projected lake levels or river characteristics (concentrations, flows, etc.).

Tables

Table I.1

Project Costs : Expanded Infrastructure Measures Alternative

Lake Level (Top of Levee Elevation)	Incremental Perimeter Dam Project Costs	Annual Operation and Maintenance Costs
1447	$0	$0
1450 (1455)	$32,000,000	$320,000
1460 (1465)	$63,000,000	$630,000

NOTE: Annual operation and maintenance costs were assumed to equal 1% of the total construction costs.

Table I.2

Project Raise Costs : Raise Natural Outlet Alternative

Lake Level	Feature Number	Feature Description	Project Raise Costs
1461	6	Gilbert C. Grafton State Military Reservation	$12,993,000
1461	7	Grahams Island State Park	$6,300,000
1461	17	Highway 281 North of US Highway 2	$38,376,000
1461	22	Highway 20 Between Highway 57 and Tokio	$36,194,000
1463	24	BIA 6 Between Highway 20 and Fort Totten	$6,262,000

NOTE: These project raise costs were assumed to occur as necessary as the lake level rises.

Table I.3: Municipal Water Treatment Facility Project Costs [1]

Analysis	Valley City		Fargo		Grand Forks		Grafton		Drayton		Pembina		Letellier		Morris		Total
WF-4	$6,333,000	(W)	$641,000	(IE)	$1,289,000	(IE)	$0	(TP)	$150,000	(IE)	$101,000	(IE)	$3,240,000	(W)	$3,596,000	(W)	$15,350,000
WF-6	$6,333,000	(W)	$884,000	(IE)	$1,607,000	(IE)	$0	(TP)	$169,000	(IE)	$110,000	(IE)	$320,000	(IE)	$3,596,000	(W)	$13,019,000
WF-10	$6,333,000	(W)	$24,518,000	(W)	$1,692,000	(IE)	$0	(TP)	$157,000	(IE)	$109,000	(IE)	$3,240,000	(W)	$3,596,000	(W)	$39,645,000
WF-13	$6,333,000	(W)	$641,000	(IE)	$1,289,000	(IE)	$0	(TP)	$150,000	(IE)	$101,000	(IE)	$3,240,000	(W)	$3,596,000	(W)	$15,350,000
M1-2	$6,333,000	(W)	$888,000	(IE)	$1,904,000	(IE)	$0	(TP)	$166,000	(IE)	$111,000	(IE)	$3,240,000	(W)	$3,596,000	(W)	$16,238,000
M1-6	$6,333,000	(W)	$857,000	(IE)	$1,711,000	(IE)	$0	(TP)	$144,000	(IE)	$106,000	(IE)	$301,000	(IE)	$3,596,000	(W)	$13,048,000
M2-2	$6,333,000	(W)	$825,000	(IE)	$1,649,000	(IE)	$0	(TP)	$172,000	(IE)	$108,000	(IE)	$3,240,000	(W)	$3,596,000	(W)	$15,923,000
M2-6	$6,333,000	(W)	$796,000	(IE)	$1,772,000	(IE)	$0	(TP)	$172,000	(IE)	$111,000	(IE)	$3,240,000	(W)	$3,596,000	(W)	$16,020,000
DR-2	$6,333,000	(W)	$804,000	(IE)	$1,669,000	(IE)	$0	(TP)	$167,000	(IE)	$111,000	(IE)	$339,000	(IE)	$458,000	(IE)	$9,881,000
DR-6	$6,333,000	(W)	$662,000	(IE)	$1,504,000	(IE)	$0	(TP)	$150,000	(IE)	$108,000	(IE)	$309,000	(IE)	$415,000	(IE)	$9,481,000

[1]Costs are shown for the least expensive treatment technology or alternate water source for each municipality under each analysis.
In each case, the least expensive treatment technology or alternate water source (shown in parentheses to the right of the capital costs) was determined by comparing the sum of the capital cost and the annual operating expenses of each technology and alternate water source. Annual operating expenses were counted as damages (not shown here).

Key to Treatment Technologies and Alternate Water Supplies:

W: Wells[2]

IE: Ion Exchange[3]

TP: Treatment of the Park River[4]

[2]Capital costs for well installation do not vary with changes in water quality.
[3]Capital costs for ion exchange vary depending on the water quality constituents in the downstream flows. Therefore, they vary by analysis.
[4]Treatment of the Park River at Grafton was estimated to have a negligible associated capital cost.

Note: These capital costs are incurred in year 2001.
For each stochastic analysis, a weighted average of capital costs was computed. These weighted averages were based on the percent of traces (among the 10,000) that were within the categories for the wet, dry, moderate-1 and moderate -2 traces (9.5%, 35.6%, 29.9% and 25%, respectively).

Table I.4

Project Raise Costs : Pelican Lake Outlet Alternatives

Elevation of Raise	Construction Costs (Project Costs)	Revised Highway Raise Costs	
		Highway 281	Highway 19
1447.0	---	$3,829,000	---
1448.0	---	$31,867,000	---
1453.0	---	$37,695,000	---
1454.0	$13,388,000	---	$26,444,000
1458.0	---	$45,593,000	---
1459.0	$17,751,000	---	$41,410,000
1463.0	---	$42,134,000	---

Table I.5

List of Most Likely Action Strategies for Features Adjacent to Devils Lake

Feature Description	Most Likely Action Strategy
Communities and Cities (includes wastewater treatment facilities, hospitals and schools)	
Churchs Ferry	Incremental Relocations
City of Devils Lake	Incremental Levee Raises
Fort Totten	Incremental Relocations
City of Minnewaukan	Incremental Levee Raises
St. Michael	Incremental Relocations
State Facilities	
Gilbert C. Grafton State Military Reservation	Incremental Road and Levee Raises
Grahams Island State Park	Relocation of Structures and Raise Access Road
Rural Areas	
Devils Lake Rural Areas	Structure Relocation
Stump Lake Rural Areas	Structure Relocation
Rail Lines	
Red River Valley and Western Railroad: Minnewaukan South	N/A
Canadian Pacific Railroad: City of Devils Lake to Harlowe	Incremental Rail Raises
Burlington Northern Railroad: Along US Highway 2	Incremental Rail Raises
Burlington Northern Railroad: Churchs Ferry to Cando	Incremental Rail Raises
Roads	
US Highway 2	Incremental Road Raises
Highway 57 between Highway 20 and BIA 1	Incremental Road Raises
Highway 57 between BIA 1 and Highway 281	Incremental Road Raises
Highway 281 South of US Highway 2	Incremental Road Raises
Highway 281 North of US Highway 2	Incremental Road Raises
Highway 19 from the City of Devils Lake Levee to Highway 281	Incremental Road Raises
Highway 1	Relocate Road
Highway 20 North of the City of Devils Lake	Incremental Road Raises
Highway 20 from the City of Devils Lake Levee to Highway 57	Incremental Road Raises
Highway 20 between Highway 57 and Tokio	Incremental Road Raises
BIA 1 between Highway 57 and BIA 6	Incremental Road Raises
BIA 6 between Highway 20 and Fort Totten	Incremental Road Raises

Table I.6

List of Adjacent Lake Features

Communities and Cities (includes wastewater treatment facilities, hospitals and schools)

1. Churchs Ferry
2. City of Devils Lake
3. Fort Totten
4. City of Minnewaukan
5. St. Michael

State Facilities

5. Gilbert C. Grafton State Military Reservation
6. Grahams Island State Park

Rural Areas

8.1 Devils Lake Rural Areas
8.2 Stump Lake Rural Areas

Rail Lines

9. Red River Valley and Western Railroad: Minnewaukan South (note: this rail line has been abandoned)
10. Canadian Pacific Railroad: City of Devils Lake to Harlowe
11. Burlington Northern Railroad: Along US Highway 2
12. Burlington Northern Railroad: Churchs Ferry to Cando

Roads

13. US Highway 2
14. Highway 57 between Highway 20 and BIA 1
15. Highway 57 between BIA 1 and Highway 281
16. Highway 281 South of US Highway 2
17. Highway 281 North of US Highway 2
18. Highway 19 from the City of Devils Lake Levee to Highway 281
19. Highway 1
20. Highway 20 North of the City of Devils Lake
21. Highway 20 from the City of Devils Lake Levee to Highway 57
22. Highway 20 between Highway 57 and Tokio
23. BIA 1 between Highway 57 and BIA 6
24. BIA 6 between Highway 20 and Fort Totten

Table I.7

Economic Analysis of Devils Lake Alternatives

Cumulative Land and Structural Damages
(Assuming No Protection)
(Thousands)

	Cumulative Land and Structure Damages			
Lake Elevation	**Communities and Cities**	**Rural Areas**	**State facilities**	**Total**
1406	$0	$0	$0	$0
1407	$0	$0	$0	$0
1408	$0	$0	$0	$0
1409	$0	$418	$0	$418
1410	$0	$418	$0	$418
1411	$0	$418	$0	$418
1412	$0	$418	$0	$418
1413	$0	$418	$0	$418
1414	$0	$644	$0	$644
1415	$0	$644	$0	$644
1416	$0	$644	$0	$644
1417	$0	$644	$0	$644
1418	$0	$644	$0	$644
1419	$0	$915	$0	$915
1420	$0	$915	$0	$915
1421	$0	$915	$0	$915
1422	$0	$915	$0	$915
1423	$0	$915	$0	$915
1424	$0	$1,258	$0	$1,258
1425	$0	$1,258	$0	$1,258
1426	$0	$1,258	$0	$1,258
1427	$0	$1,258	$0	$1,258
1428	$0	$1,258	$0	$1,258
1429	$0	$1,688	$0	$1,688
1430	$0	$1,688	$0	$1,688
1431	$0	$1,688	$0	$1,688
1432	$0	$1,688	$0	$1,688
1433	$0	$1,688	$0	$1,688
1434	$0	$2,215	$0	$2,215
1435	$0	$2,215	$0	$2,215
1436	$0	$2,215	$0	$2,215
1437	$0	$2,215	$0	$2,215
1438	$0	$2,215	$0	$2,215
1439	$0	$2,841	$0	$2,841
1440	$0	$2,841	$0	$2,841
1441	$0	$2,841	$0	$2,841
1442	$0	$2,841	$0	$2,841
1443	$0	$2,841	$0	$2,841
1444	$0	$4,512	$0	$4,512
1445	$0	$4,512	$0	$4,512
1446	$0	$4,512	$0	$4,512
1447	$5,535	$23,186	$335	$29,056
1448	$5,535	$35,109	$335	$40,979
1449	$182,794	$38,426	$609	$221,829
1450	$187,853	$46,150	$609	$234,612
1451	$188,163	$52,871	$674	$241,708
1452	$238,625	$55,319	$674	$294,618
1453	$238,625	$66,295	$674	$305,594
1454	$238,625	$75,506	$685	$314,816
1455	$254,724	$78,104	$685	$333,513
1456	$255,220	$96,180	$771	$352,171
1457	$332,879	$96,180	$771	$429,830
1458	$332,879	$115,565	$771	$449,215
1459	$332,879	$116,485	$771	$450,135
1460	$332,879	$150,649	$771	$484,299
1461	$332,879	$150,649	$35,613	$519,141
1462	$332,879	$150,649	$35,613	$519,141
1463	$332,879	$150,649	$35,613	$519,141

NOTE: Damages to land and structures are assumed to be incurred once- when first affected by the rising lake.

Table I.8

Economic Analysis of Devils Lake Alternatives

CUMULATIVE ANNUAL DAMAGES
(Assuming Temporary Closure)
(Thousands)

	State Facilities Cumulative Total	Rail Line Cumulative Total	Roads Cumulative Total	
Lake Elevation	Lost Business	Trucking or Detour Damage	Detour Damage	Total
1406	$0	$0	$0	$0
1407	$0	$0	$0	$0
1408	$0	$0	$0	$0
1409	$0	$0	$0	$0
1410	$0	$0	$0	$0
1411	$0	$0	$0	$0
1412	$0	$0	$0	$0
1413	$0	$0	$0	$0
1414	$0	$0	$0	$0
1415	$0	$0	$0	$0
1416	$0	$0	$0	$0
1417	$0	$0	$0	$0
1418	$0	$0	$0	$0
1419	$0	$0	$0	$0
1420	$0	$0	$0	$0
1421	$0	$0	$0	$0
1422	$0	$0	$0	$0
1423	$0	$0	$0	$0
1424	$0	$0	$0	$0
1425	$0	$0	$0	$0
1426	$0	$0	$0	$0
1427	$0	$0	$0	$0
1428	$0	$0	$0	$0
1429	$0	$0	$0	$0
1430	$0	$0	$0	$0
1431	$0	$0	$0	$0
1432	$0	$0	$0	$0
1433	$0	$0	$0	$0
1434	$0	$0	$0	$0
1435	$0	$0	$0	$0
1436	$0	$0	$0	$0
1437	$0	$0	$0	$0
1438	$0	$0	$0	$0
1439	$0	$0	$0	$0
1440	$0	$0	$0	$0
1441	$0	$0	$0	$0
1442	$0	$0	$0	$0
1443	$0	$0	$13,073	$13,073
1444	$0	$0	$13,073	$13,073
1445	$0	$0	$13,073	$13,073
1446	$0	$0	$13,649	$13,649
1447	$516	$0	$18,863	$19,379
1448	$516	$0	$18,863	$19,379
1449	$516	$509	$19,818	$20,843
1450	$516	$509	$19,818	$20,843
1451	$516	$509	$21,140	$22,165
1452	$516	$4,650	$21,140	$26,306
1453	$516	$4,650	$21,140	$26,306
1454	$516	$5,159	$70,021	$75,696
1455	$516	$5,159	$70,021	$75,696
1456	$516	$5,159	$70,021	$75,696
1457	$516	$5,159	$70,021	$75,696
1458	$516	$5,159	$70,021	$75,696
1459	$516	$5,159	$73,396	$79,071
1460	$516	$5,159	$73,396	$79,071
1461	$516	$5,159	$73,396	$79,071
1462	$516	$5,159	$73,396	$79,071
1463	$516	$5,159	$73,396	$79,071

NOTES: Annual damages are incurred every year that the lake is higher than the lowest elevation in each feature. Therefore, higher annual da
that more features are affected by the lake.

Table I.9

Economic Analysis of Devils Lake Alternatives

Road and Rail Line Restoration Damages
(Assuming No Protection)
(Thousands)

Lake Elevation	Rail Line Cumulative Total	Roads Cumulative Total	Total
1409	$0	$0	$0
1410	$0	$0	$0
1411	$0	$0	$0
1412	$0	$0	$0
1413	$0	$0	$0
1414	$0	$0	$0
1415	$0	$0	$0
1416	$0	$0	$0
1417	$0	$0	$0
1418	$0	$0	$0
1419	$0	$0	$0
1420	$0	$0	$0
1421	$0	$0	$0
1422	$0	$0	$0
1423	$0	$0	$0
1424	$0	$0	$0
1425	$0	$0	$0
1426	$0	$0	$0
1427	$0	$0	$0
1428	$0	$0	$0
1429	$0	$0	$0
1430	$0	$0	$0
1431	$0	$0	$0
1432	$0	$0	$0
1433	$0	$0	$0
1434	$0	$0	$0
1435	$0	$0	$0
1436	$0	$0	$0
1437	$0	$0	$0
1438	$0	$0	$0
1439	$0	$0	$0
1440	$0	$0	$0
1441	$0	$0	$0
1442	$0	$0	$0
1443	$0	$0	$0
1444	$0	$31	$31
1445	$0	$31	$31
1446	$0	$31	$31
1447	$0	$6,867	$6,867
1448	$0	$9,434	$9,434
1449	$0	$9,434	$9,434
1450	$4,963	$10,176	$15,139
1451	$4,963	$15,484	$20,447
1452	$4,963	$20,184	$25,147
1453	$7,860	$20,959	$28,819
1454	$9,517	$23,655	$33,172
1455	$13,238	$46,420	$59,658
1456	$14,444	$49,188	$63,632
1457	$16,790	$61,475	$78,265
1458	$20,328	$64,701	$85,029
1459	$22,007	$69,714	$91,721
1460	$24,383	$75,897	$100,280
1461	$31,158	$82,635	$113,793
1462	$34,431	$88,142	$122,573
1463	$39,924	$90,911	$130,835

NOTE: Restoration damages are incurred once per event, when the lake level recedes from a given elevation (shown in the table) to below the lowest elevation of the road or rail line.

Restoration damages are dependent on the length of the road and rail lines that are under water- they increase with the lak
The total damage incurred by a rise in lake level is the cumulative total damage at the peak of the rise-fall event.

Table I.10

Interdependence of Features

Feature That Could Be Temporarily Closed During Flooding	Features Affected by Temporary Closure During Flooding																				
	1	2	3	4	5	6	7	8.1	8.2	13	14	15	16	17	18	19	20	21	22	23	24
	Churchs Ferry	City of Devils Lake	Fort Totten	City of Minnewaukan	St. Michael	Gilbert C. Grafton State Military Reservation	Grahams Island State Park	Devils Lake Rural Areas	Stump Lake Rural Areas	US Hwy 2	Hwy 57: Hwy 20 to BIA 1	Hwy 57: BIA 1 to Hwy 281	Hwy 281 South of US Hwy 2	Hwy 281 North of US Hwy 2	Hwy 19 from the Devils Lake Levee to Hwy 281	Hwy 1	Hwy 20 North of the City of Devils Lake	Hwy 20 from the Devils Lake Levee to Hwy 57	Hwy 20: Hwy 57 to Tokio	BIA 1: Hwy 57 to BIA 6	BIA 6: Hwy 20 to Fort Totten
Burlington Northern Railroad: Along US Highway 2	?	?																			
Burlington Northern Railroad: Churchs Ferry to Cando	?																				
US Highway 2	?	?						?	?		+	+	+		+		+		+		+
Highway 57 between Highway 20 and BIA 1			?							+		+	+		+						+
Highway 57 between BIA 1 and Highway 281		?	?							+									+		+
Highway 281 South of Highway 2				?						+	+	+						+		+	+
Highway 281 North of Highway 2	?																+				
Highway 19							?				+	+	+					+			
Highway 1									?												
Highway 20 North of City of Devils Lake Levee		?								+				+							
Highway 20: City of Devils Lake Levee to Highway 57		?	?		?	?				+		+	+		+						+
Highway 20 from Highway 57 to Tokio		?	?		?							+								+	+
BIA 1 from Highway 57 to BIA 6					?														+		
BIA 6 from Highway 20 to Fort Totten			?		?																

A feature's dependency on itself was not considered a legitimate dependency.

\+ Indicates an increase in road traffic on the detour route due to temporary closure of a road feature.

? Indicates a functional dependence of the feature on the transportation feature that would be temporarily closed.

Figures

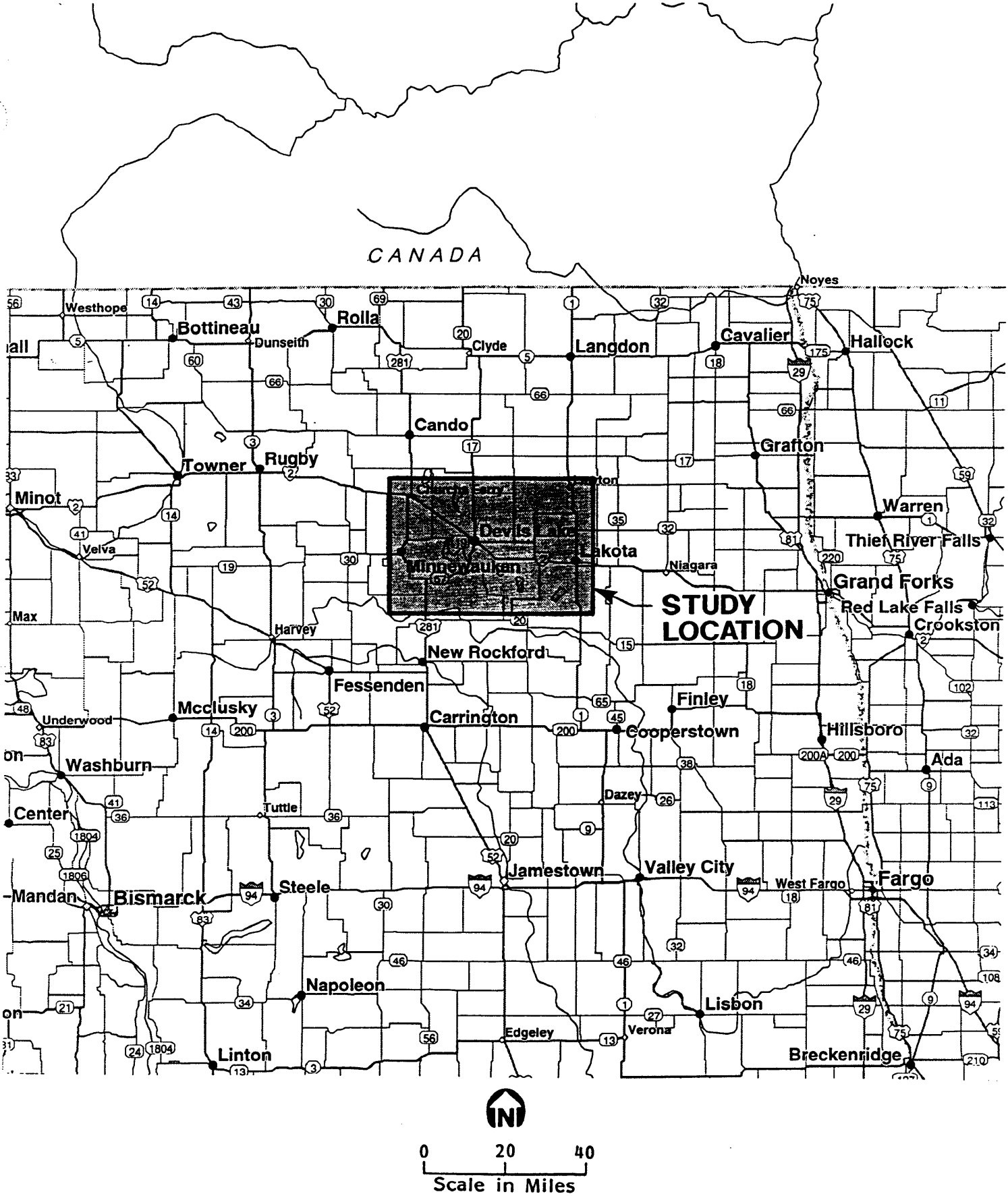


Figure I.1

STUDY LOCATION MAP
Economic Analysis of Devils Lake Alternatives

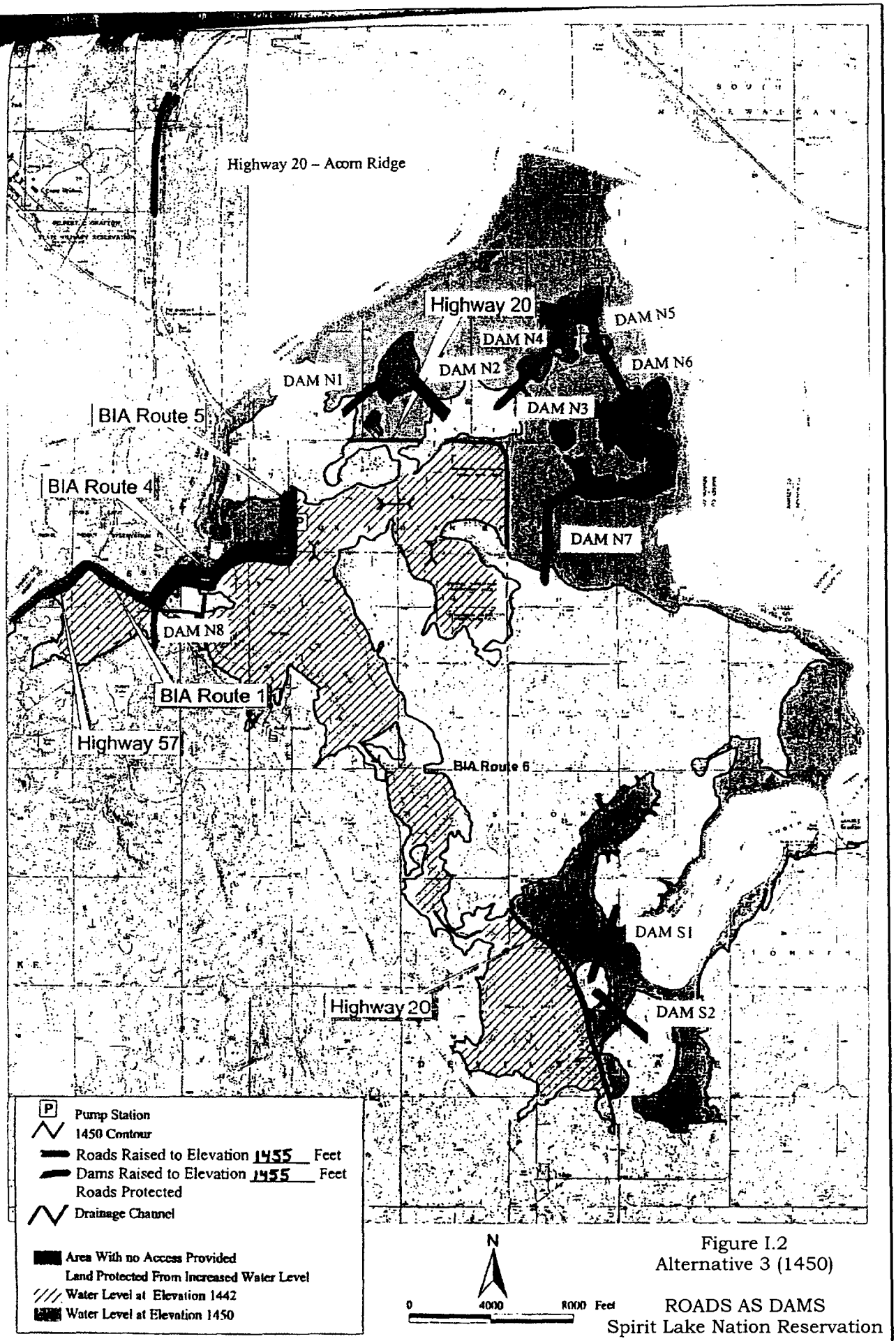
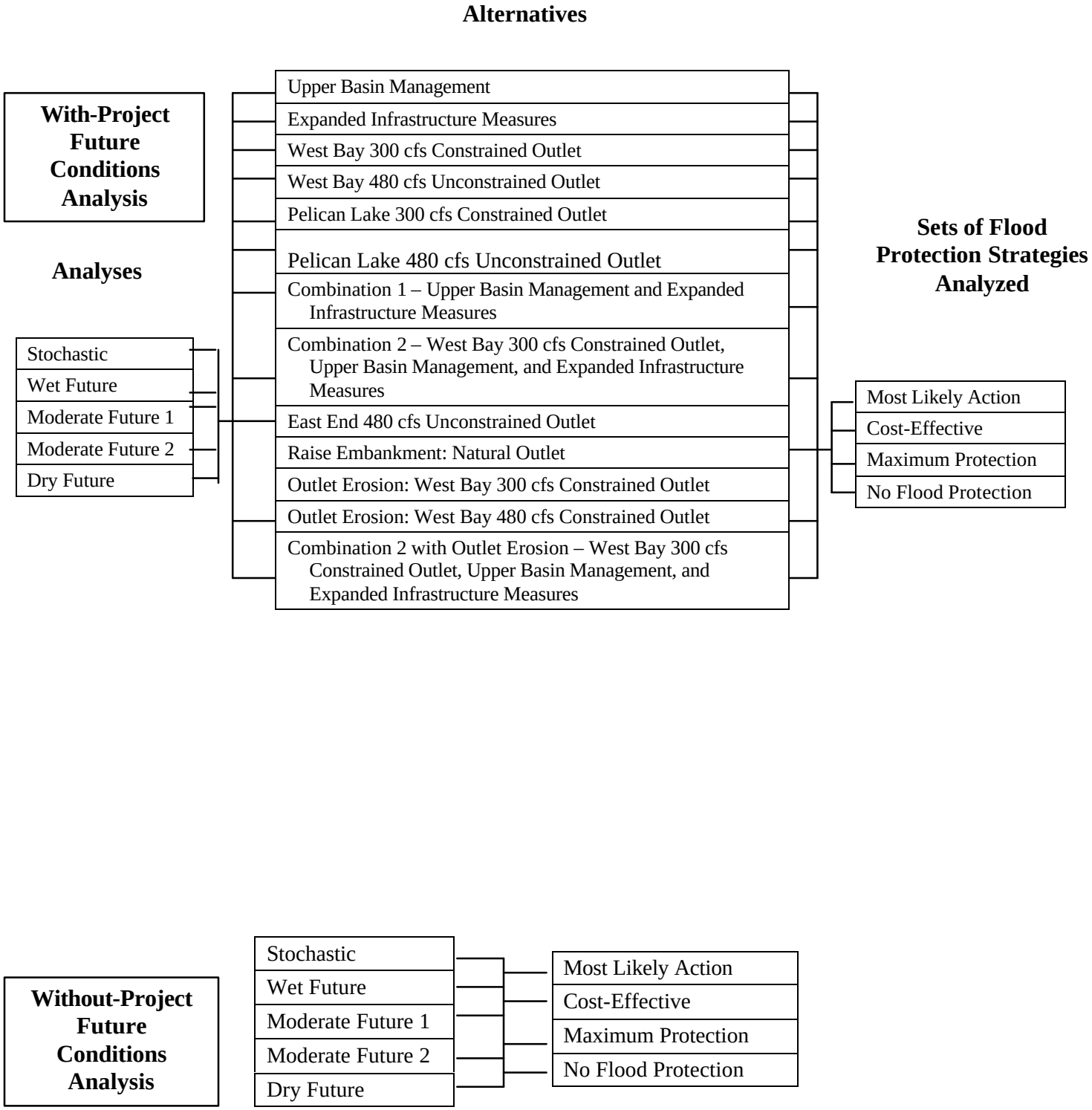


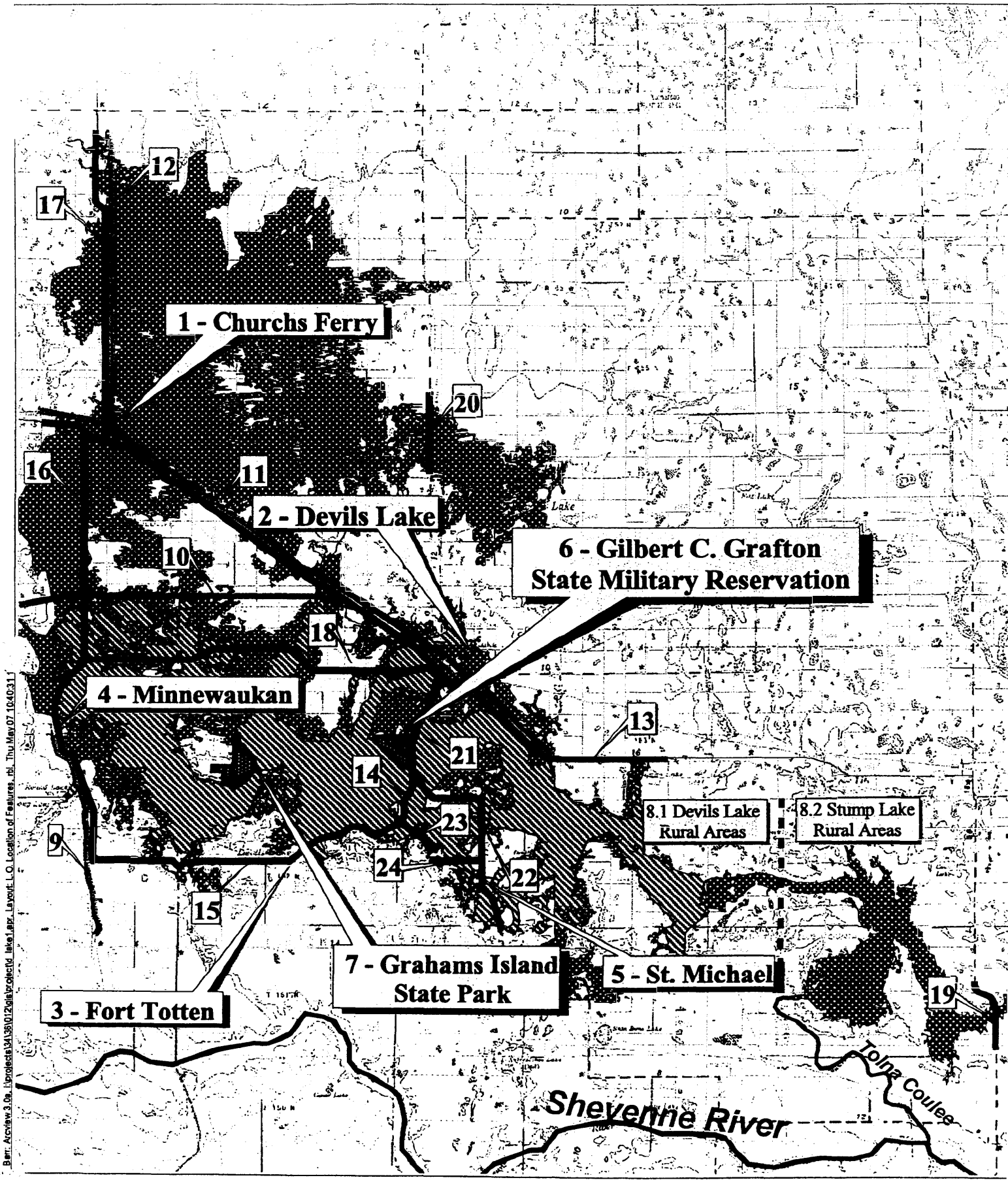
Figure I.2
Alternative 3 (1450)

ROADS AS DAMS
Spirit Lake Nation Reservation
and Acorn Ridge

Figure I.3

Schematic of Analyses, Alternatives, and Sets of Flood Protection Strategies For Features Adjacent to Devils Lake



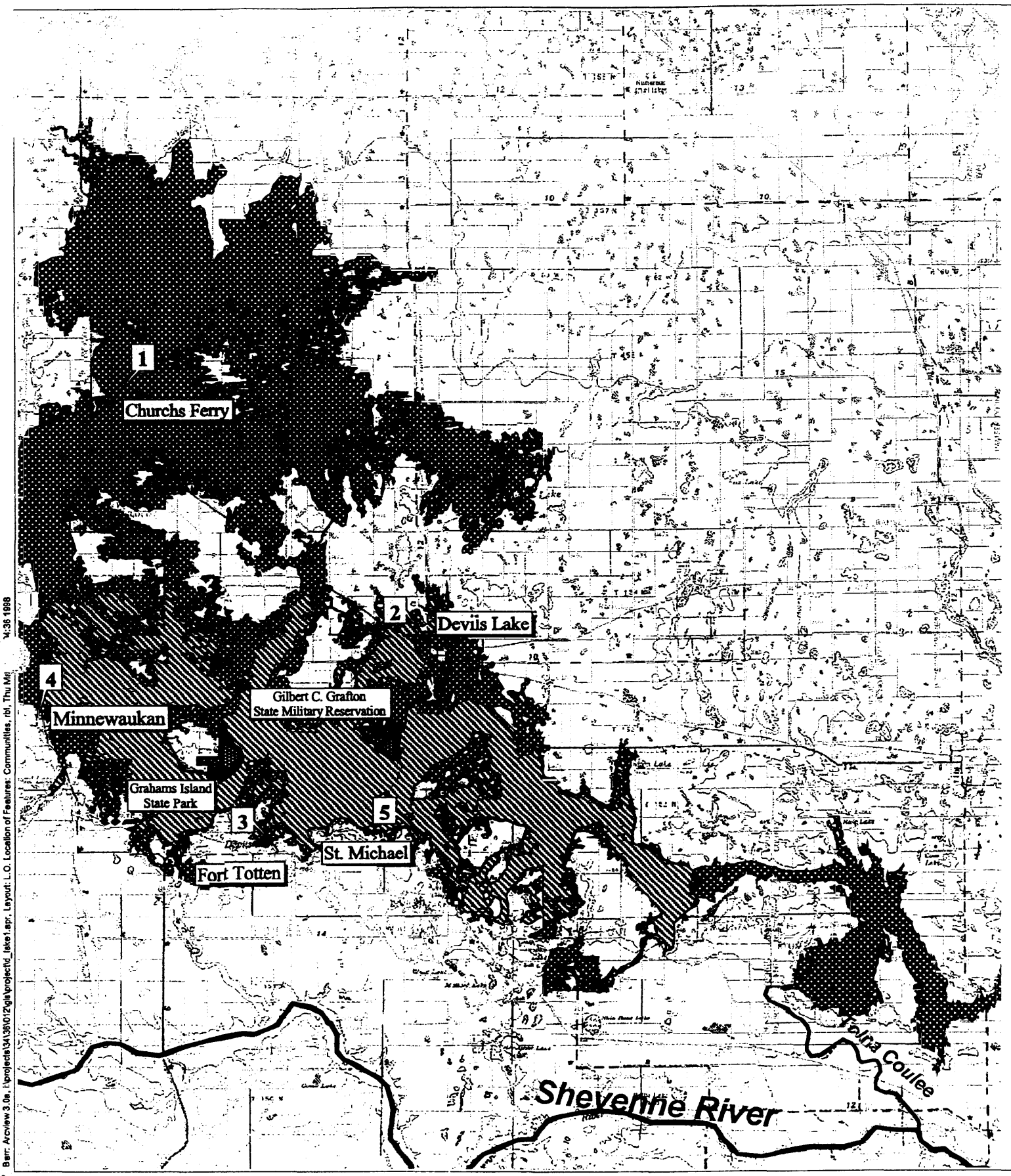


8 Rural Areas
Devils Lake Elevation at 1443 feet above MSL
Devils Lake Elevation at 1463 feet above MSL
Roads
Railroad

0 2 4 6 8 Miles

Figure I.4

LOCATION OF FEATURES

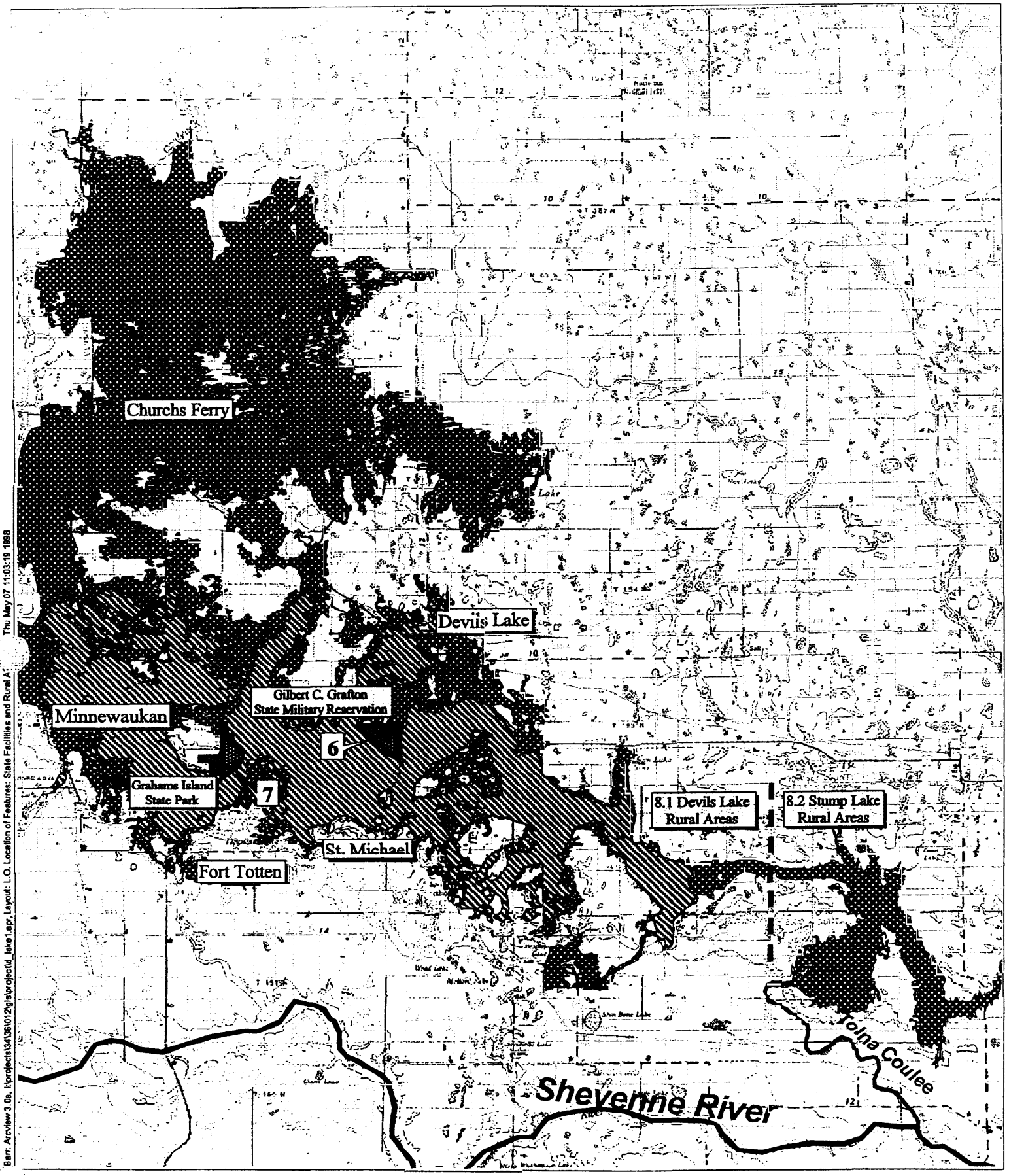


Devils Lake Elevation at 1443 feet above MSL
Devils Lake Elevation at 1463 feet above MSL

0 2 4 6 8 Miles

Figure I.5

LOCATION OF FEATURES:
Communities



8 Rural Areas

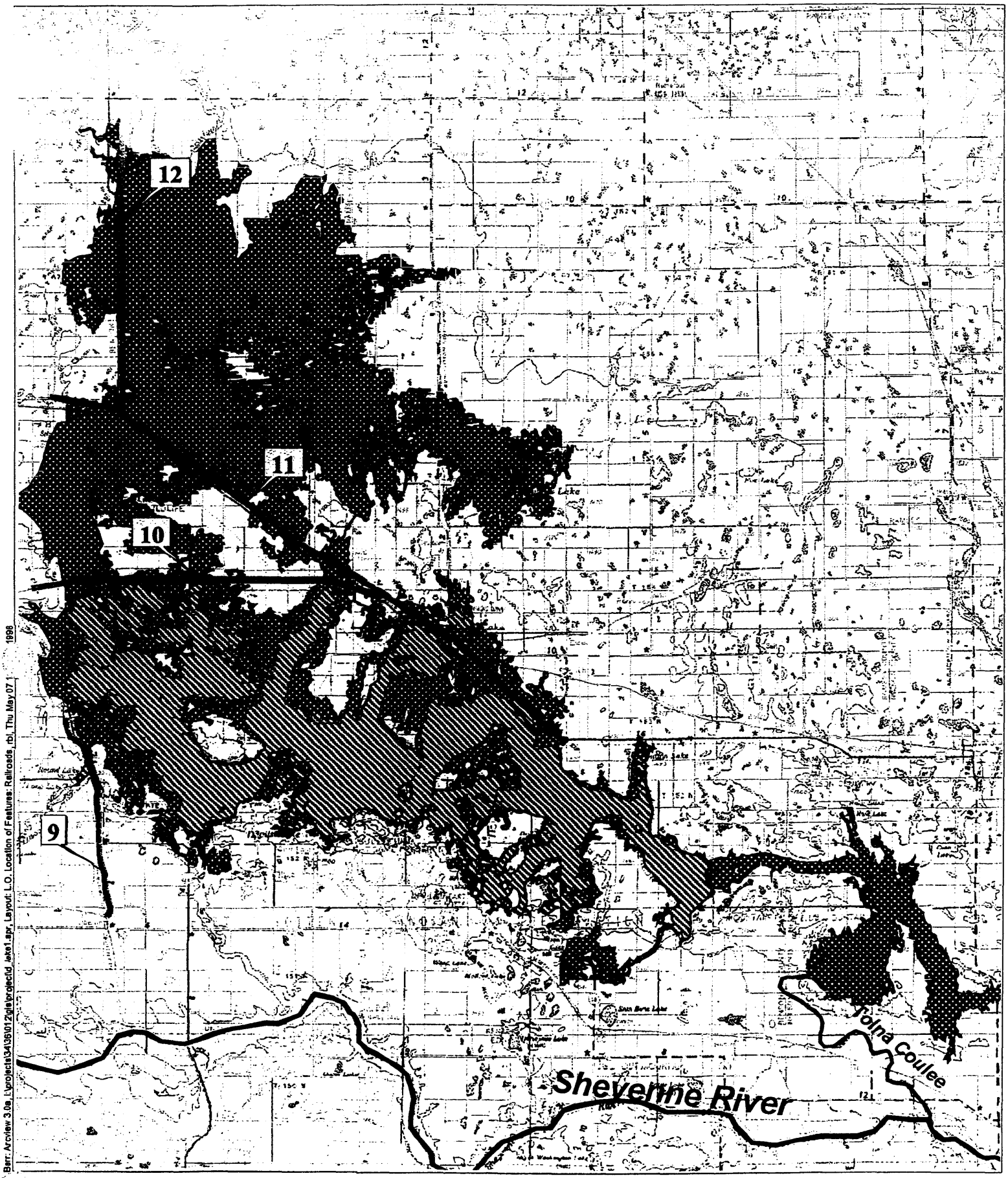
Devils Lake Elevation at 1443 feet above MSL

Devils Lake Elevation at 1463 feet above MSL

0 2 4 6 8 Miles

Figure I.6

LOCATION OF FEATURES:
State Facilities and Rural Areas



Devils Lake Elevation at 1443 feet above MSL
Devils Lake Elevation at 1463 feet above MSL
Railroad

0 2 4 6 8 Miles

Figure I.7

LOCATION OF FEATURES:
Railroads

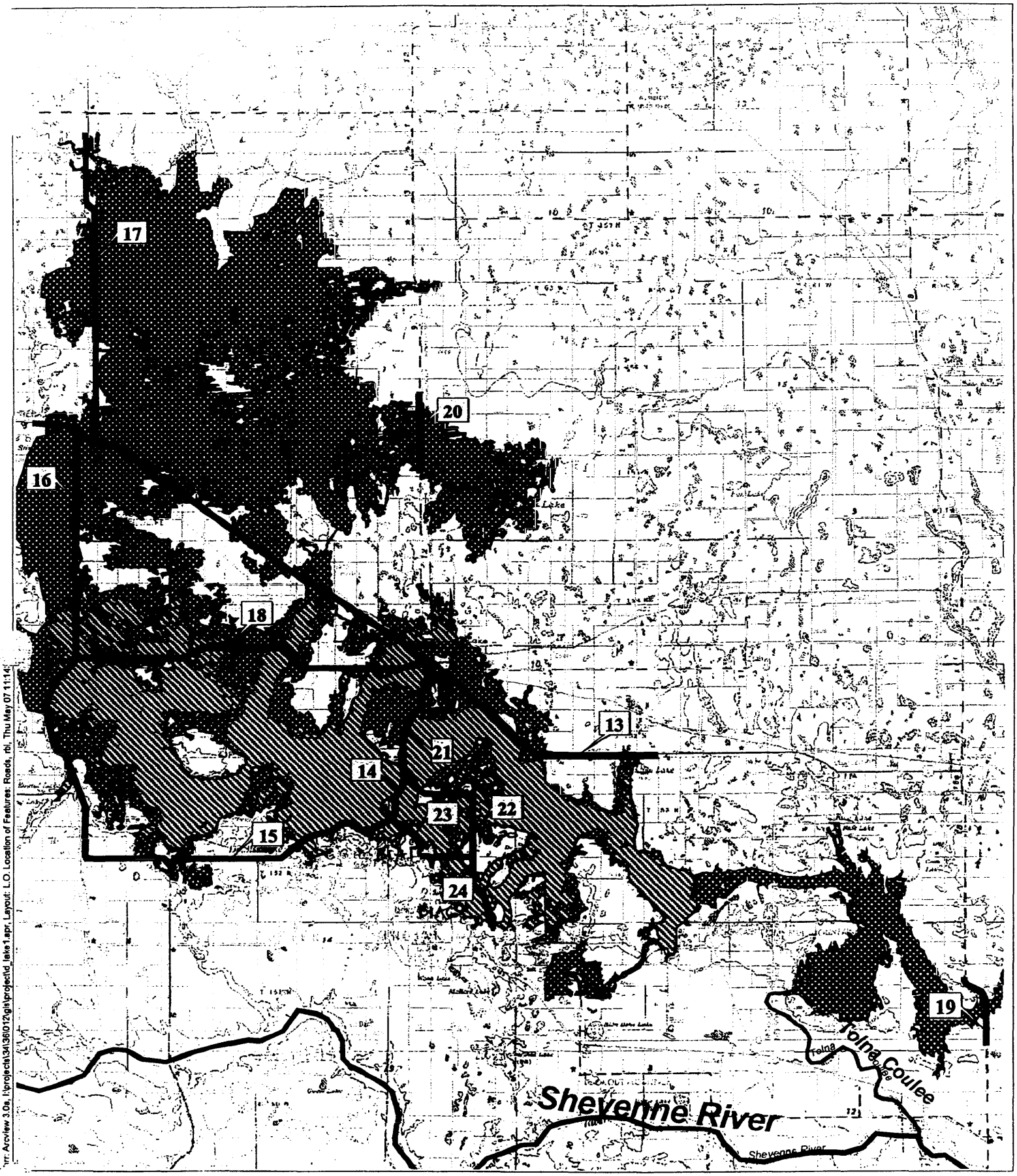


Figure I.8

LOCATION OF FEATURES:
Roads

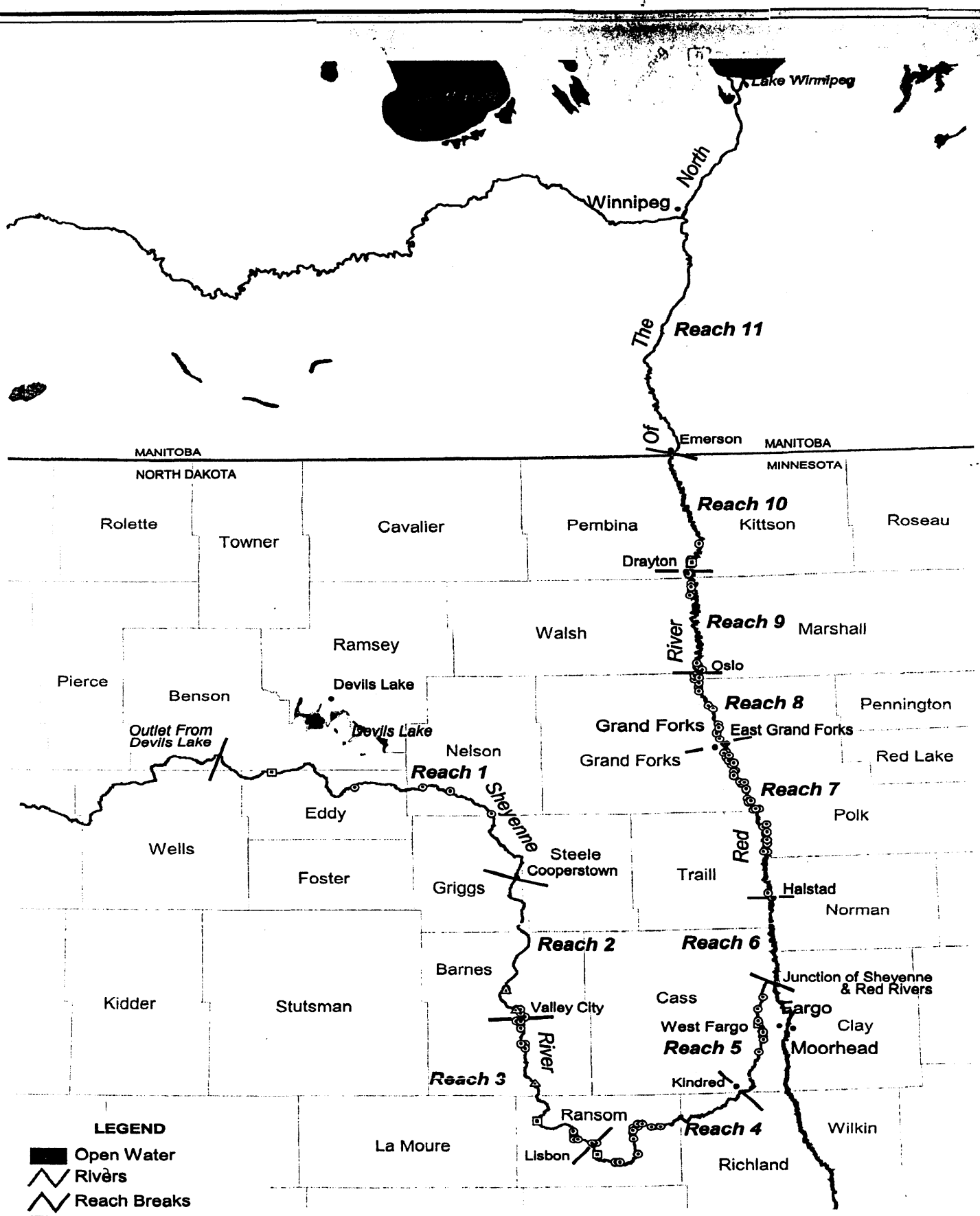
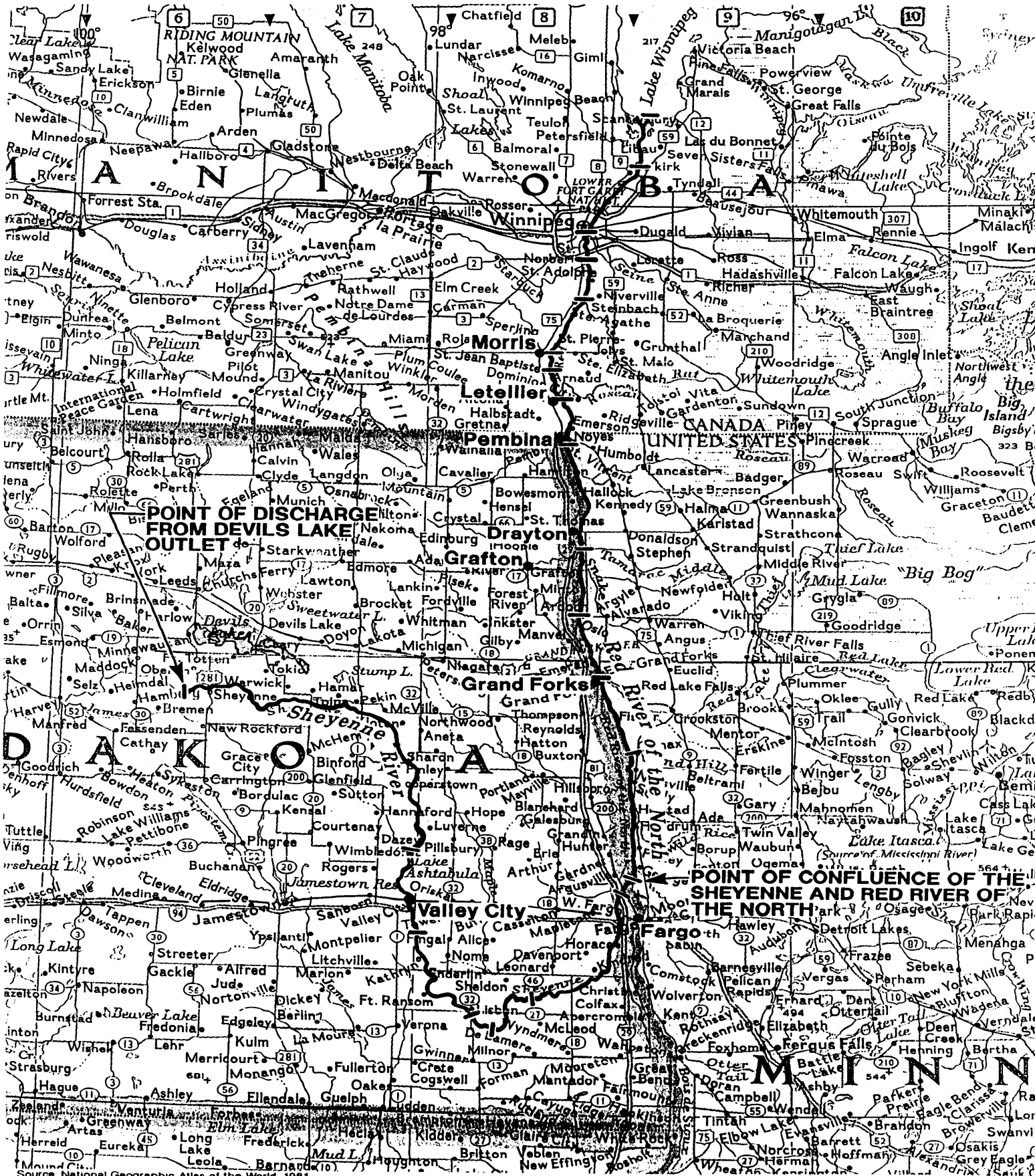


Figure I.9

LOCATION OF REACHES AND RIVER WATER APPROPRIATION PERMITS



Location of Confluence with Major Tributaries

Water Treatment Facilities Using Red or Sheyenne River Water

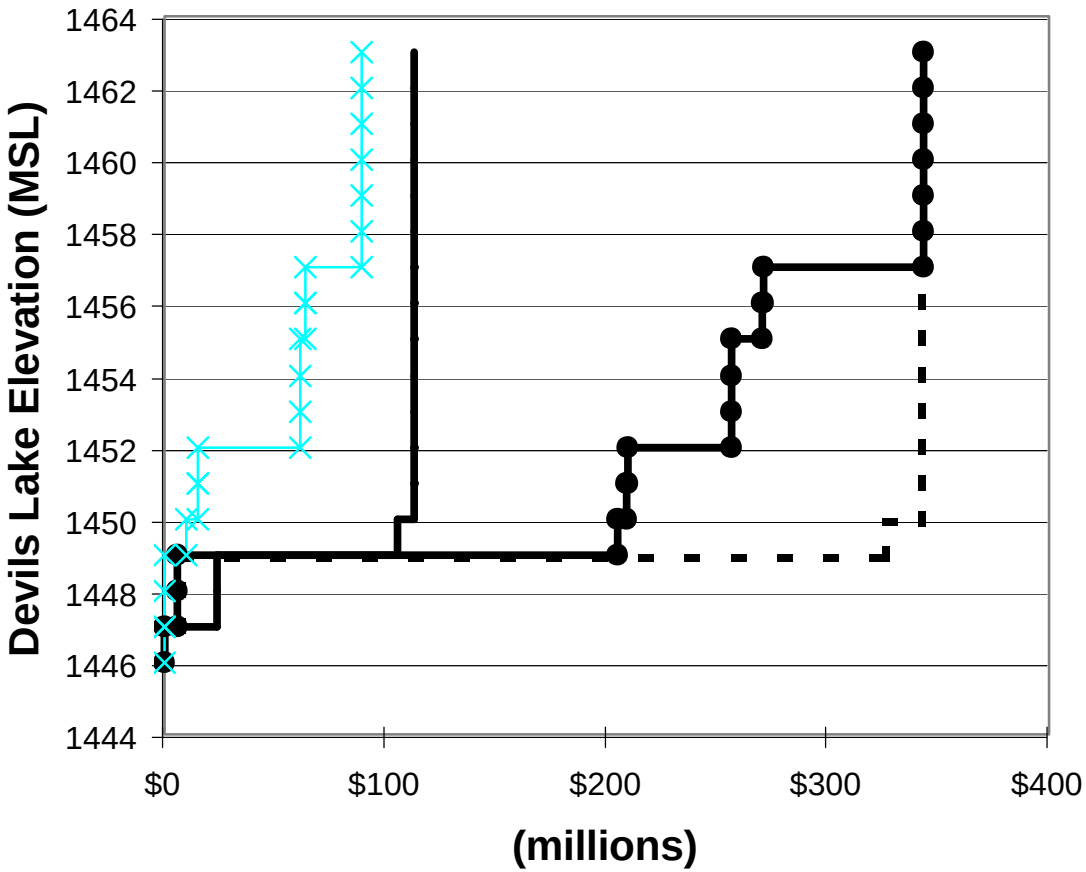
0 25 50
Scale in Miles

Figure I.10

LOCATION OF WATER TREATMENT FACILITIES

Graphs

GRAPH I.1
Cumulative Costs:
COMMUNITIES AND CITIES



Maximum Structure Relocation at the First Action Level

Incremental Structure Relocation

Maximum Levee Raise at the First Action Level

Incremental Levee Raise

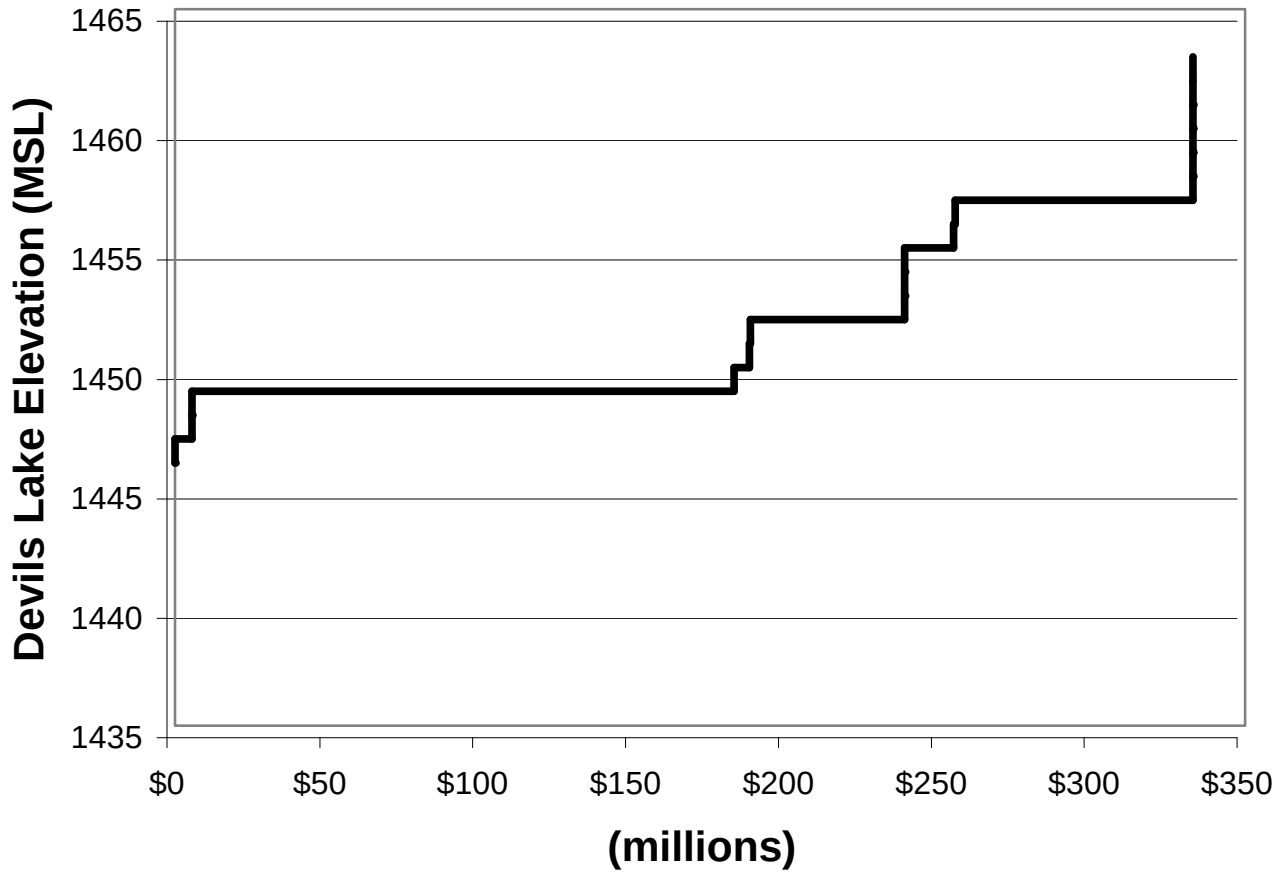
NOTES:

Although maximum levee raise data was collected for Fort Totten and St. Michael, these cities do not have incremental levee raise data because levee raises were not considered a viable strategy. Therefore, the incremental levee raise costs do not equal the maximum levee raise costs at lake elevation 1463.

Levee costs do not include Operation and Maintenance costs.

Costs are presented in steps due to the way that data was collected in this study.

GRAPH I.2
Cumulative Damages:
COMMUNITIES AND CITIES



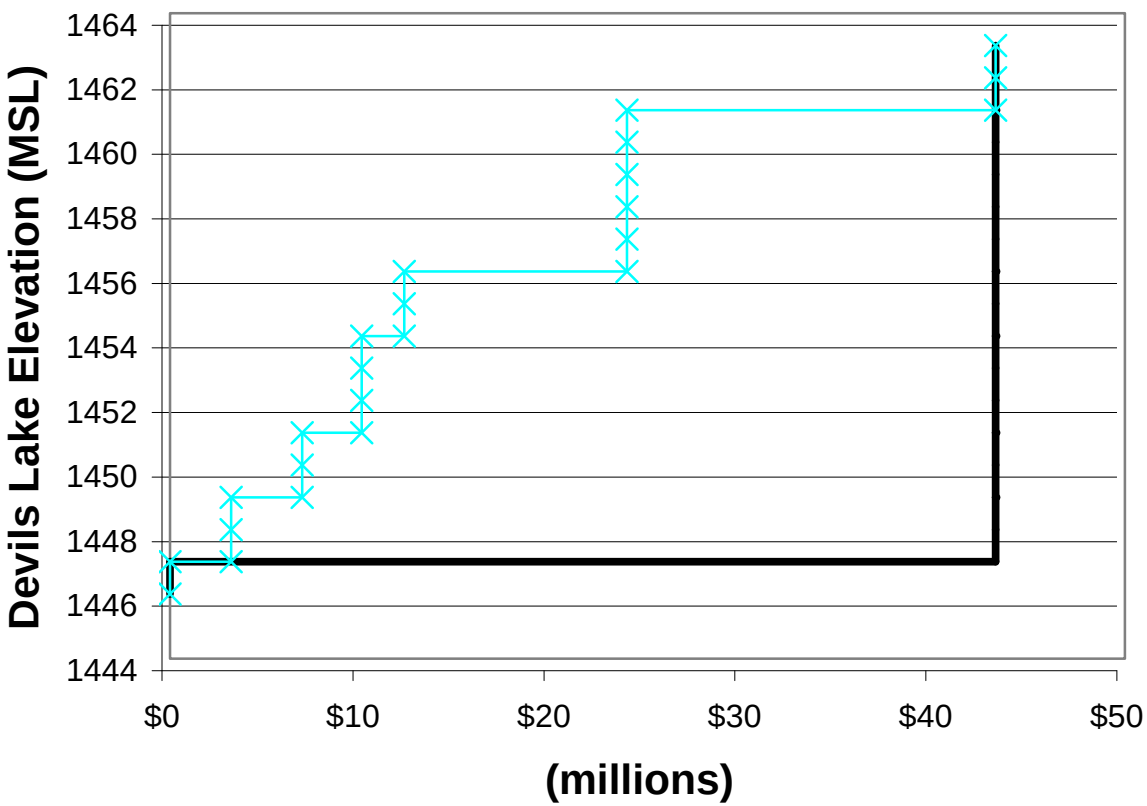
Structural Damages

NOTES:

These damages are incurred when no action is taken to protect the communties and cities in this study.

Damages are presented in steps due to the way that data was collected in this study.

GRAPH I.3
Cumulative Costs:
STATE FACILITIES
Camp Grafton and Grahams Island State Park



Maximum Road and Munitions Levee Road Raise, Maximum Structure Relocation at the First Action Level

Incremental Road and Munitions Levee Raise, Incremental Structure Relocation

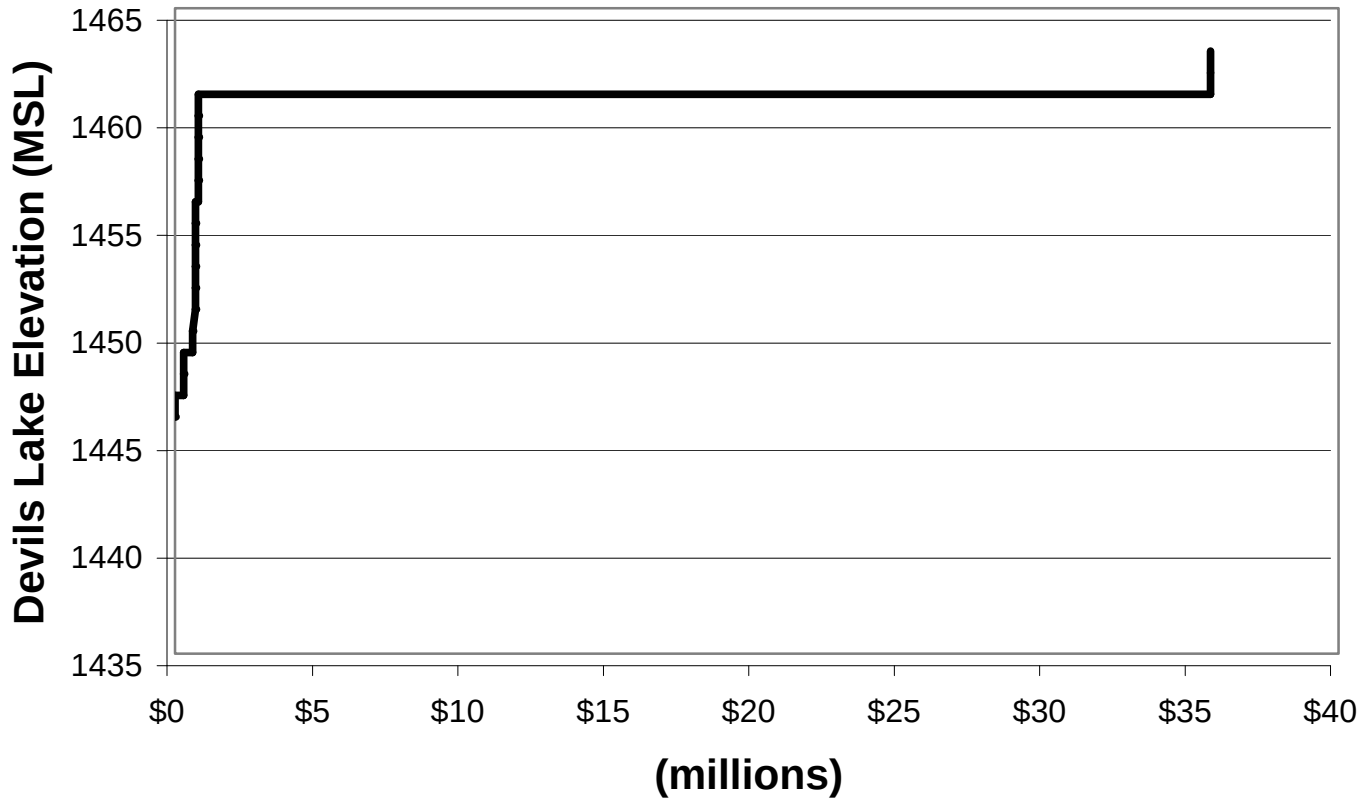
NOTES:

Levee costs do not include Operations and Maintenance costs.

Strategies that assume temporary closure of roads have no associated costs.

Costs are presented in steps due to the way that data was collected in this study.

GRAPH I.4
Cumulative Damages:
STATE FACILITIES
Camp Grafton and Grahams Island State Park



Total Damages

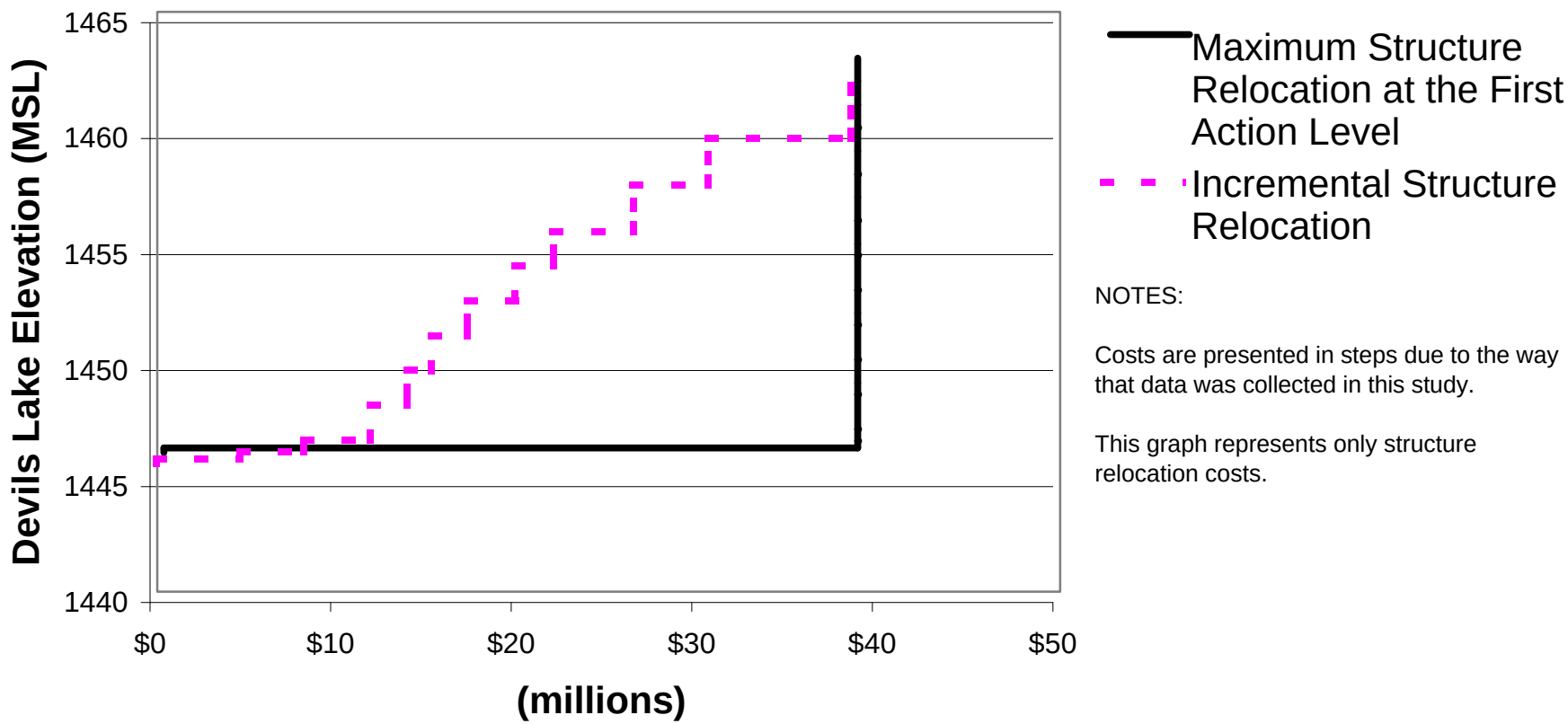
NOTES:

These damages are incurred when no action is taken to protect the state facilities in this study.

These damages do not include annual recreational losses due to closure of Grahams Island State Park.

Damages are presented in steps due to the way that data was collected in this study.

GRAPH I.5
Cumulative Costs:
RURAL AREAS
Devils Lake and Stump Lake

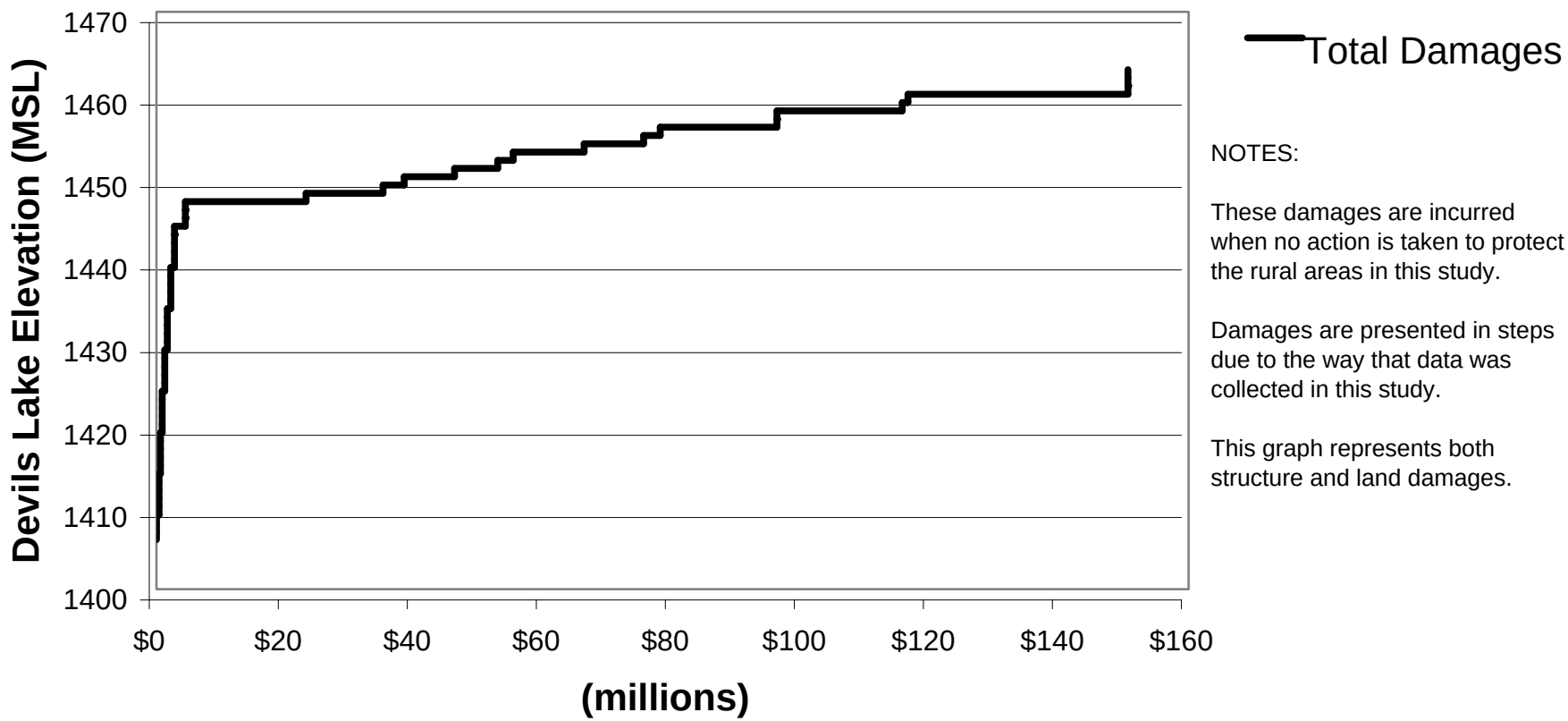


NOTES:

Costs are presented in steps due to the way that data was collected in this study.

This graph represents only structure relocation costs.

GRAPH I.6
Cumulative Damages:
RURAL AREAS
Devils Lake and Stump Lake



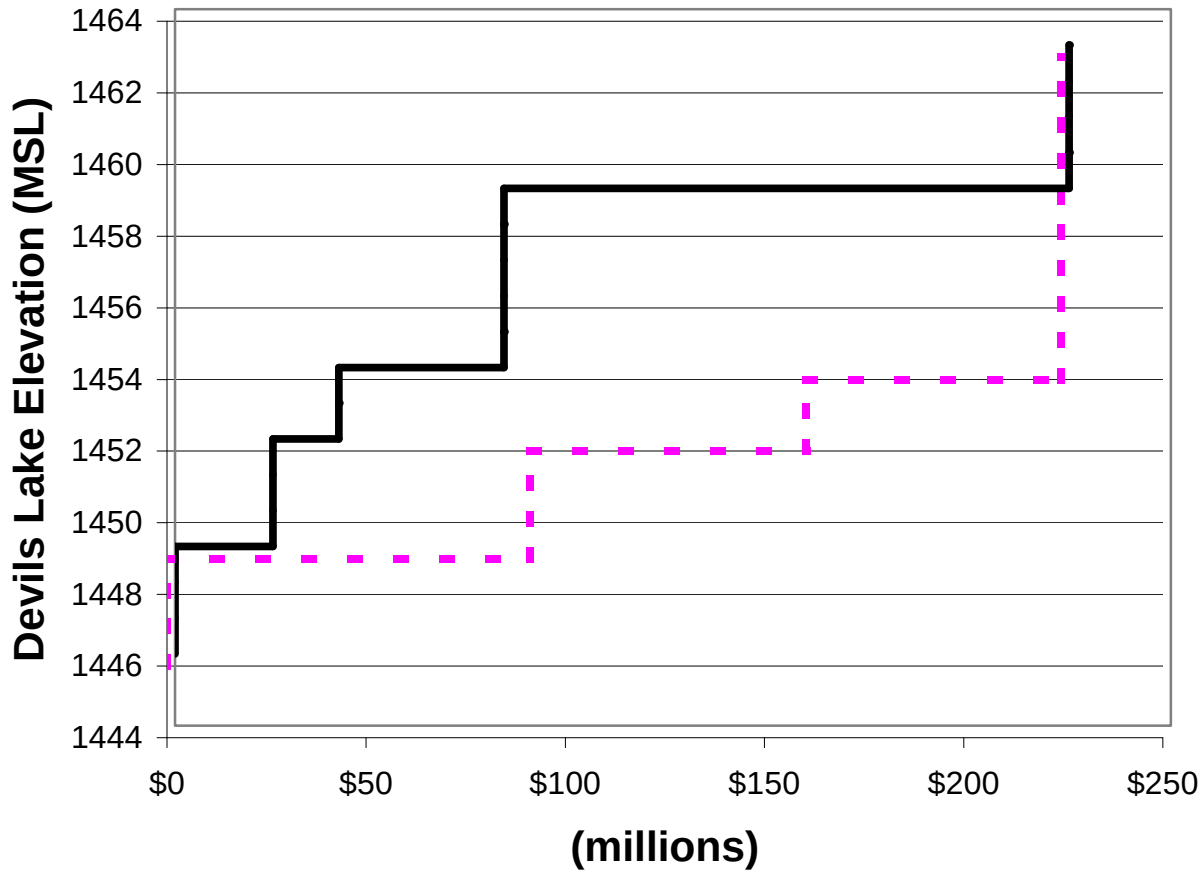
NOTES:

These damages are incurred when no action is taken to protect the rural areas in this study.

Damages are presented in steps due to the way that data was collected in this study.

This graph represents both structure and land damages.

GRAPH I.7
Cumulative Costs:
RAIL LINES



Maximum Raise at the First Action Level

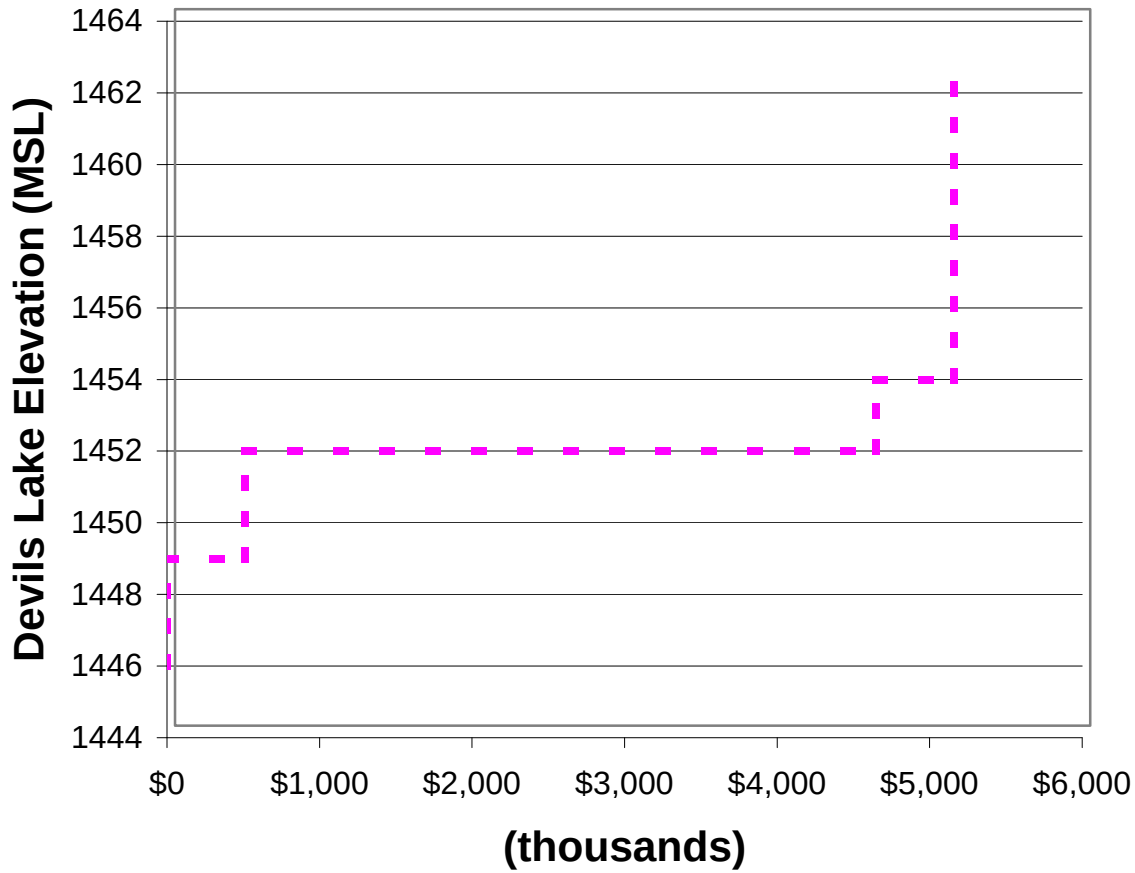
Incremental Raise

NOTES:

Strategies that assume temporary closure of a rail line at the first action level have no associated costs.

Costs are presented in steps due to the way that data was collected in this study.

GRAPH I.8
Cumulative Annual Damages:
RAIL LINES



Annual Trucking/Detour Damages

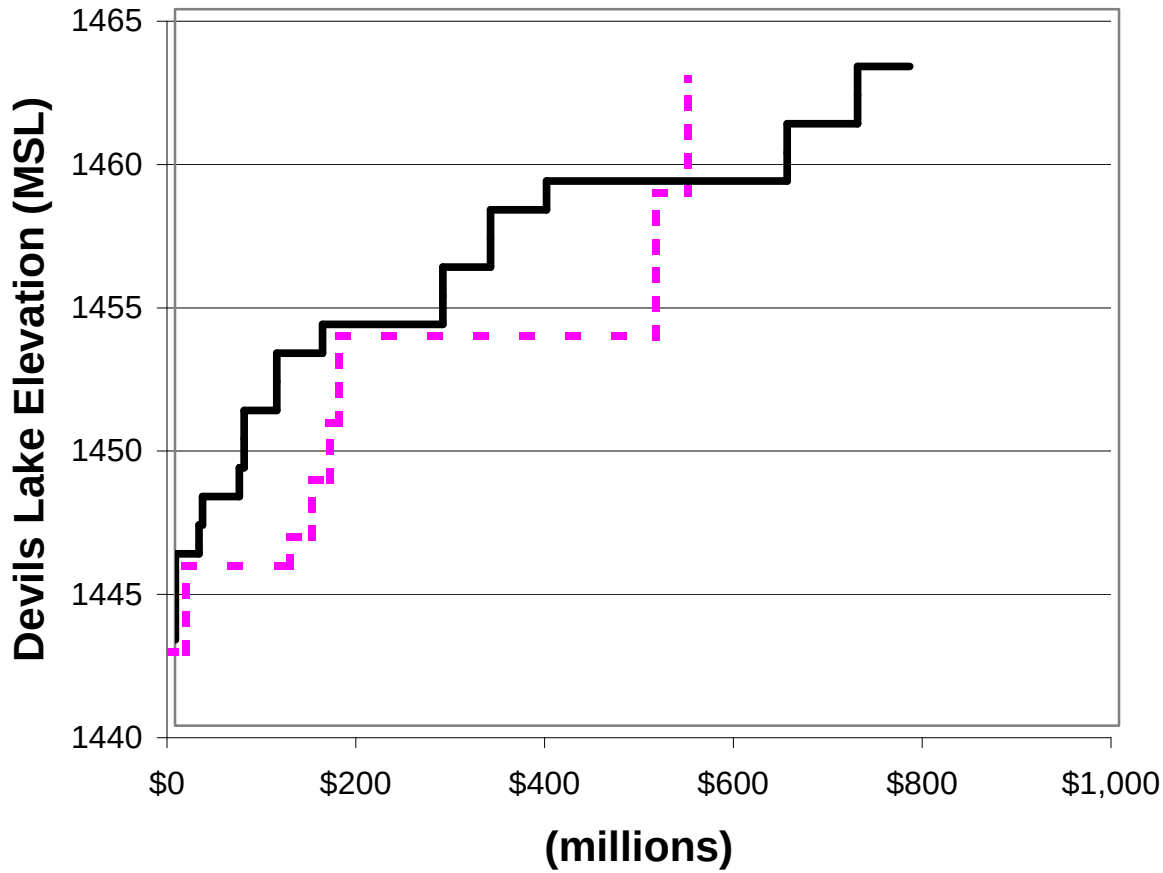
NOTES:

NOTE THAT DAMAGES ARE IN THOUSANDS

These trucking damages are incurred in the temporary closure strategy every year that the rail line is closed due to flooding.

Damages are presented in steps due to the way that data was collected in this study.

GRAPH I.9
Cumulative Costs:
ROADS



Reroute* or Maximum Raise at the First Action Level

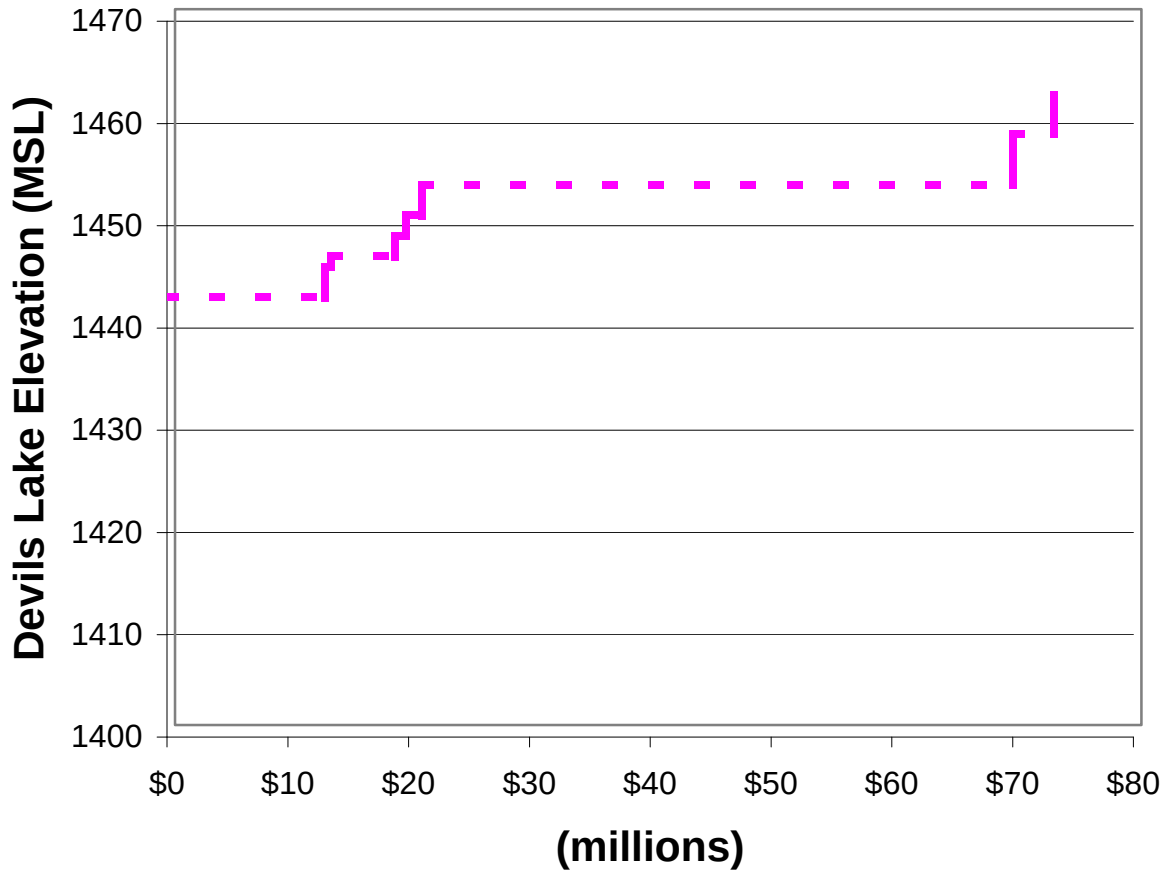
Incremental Raise

NOTES:

* Road reroute costs are only included when rerouting is a viable option for a feature. For features where reroute is not a viable option, costs to raise the road to 1468 at the first action level is included instead.

Costs are presented in steps due to the way that data was collected in this study.

GRAPH I.10
Cumulative Annual Damages:
ROADS



Annual Detour Damages

NOTES:

These detour damages are incurred in the temporary closure strategy every year that the road is closed due to flooding. These detour damages reflect recent decisions by the NDDOT regarding the future protection strategy for these features.

Damages are presented in steps due to the way that data was collected in this study.

8 May 2001

DEVILS LAKE OUTLET ALTERNATIVES SCREENING
(Step 1 of the Alternative Re-Evaluation)

Introduction

General

The purpose of this report is to summarize previous evaluation and present conclusions regarding alternatives for an outlet for Devils Lake for Step 1 of the design development process. For this screening process, eight basic alternatives have been selected as potential outlets from previous outlet studies. All of the proposed outlets discharge water from Devils Lake into the Sheyenne River. The selected alternatives were considered to have the greatest potential for being effective in drawing down the lake levels, while meeting objectives for downstream channel capacities, water quality criteria, and the ability to implement them. The proposed outlets have been developed to various extents in the past, some with extensive design performed. Although as much existing information was used as possible, some of the information presented here was developed recently for this study. The alternatives presented will be grouped by location of the intake in Devils Lake. The alternatives are described in the first part of this write-up. They are discussed and selections are made for carrying forward to Step 2 in the second portion of the write-up.

Previous Studies

Over the past ten years, the Corps of Engineers has performed numerous studies on Devil Lake and many different outlet schemes have been considered in these studies. Information used for determining alternatives came primarily from five reports. The reports used are the "Devils Lake, North Dakota, Contingency Plan, 12 August 1996", the "Devils Lake, North Dakota, Emergency Outlet Plan, 12 August 1996", the "Devils Lake Emergency Outlet, Independent Assessment, Phase I, October 30, 1997", a memorandum for record dated 14 April 1999 with the subject "Devils Lake Emergency Outlet, Alternative Cost Comparisons", and "Devils Lake Basin, North Dakota, Integrated Draft Feasibility Report and Environmental Impact Statement, April 1988".

Outlet Assumptions

There are various configurations that can be used for each alternative. Pipe materials, pump types, pump station configurations, and pipes verses open channels are a few of the choices that can be made when developing an outlet along a particular alignment. For the screening process the most logical and most developed alternatives from past work will be investigated for discussion and cost estimating.

For Step 1 of the alternative re-evaluation, to treat all outlet alternatives equally, several constraining assumptions have been made: 1) The maximum capacity of the outlet will be 300 cfs at a lake elevation of 1445 msl. 2) Flow through the outlet will be constrained by water

quality and quantity of the Sheyenne River. 3) Flow through the outlet will be controllable to increments of 10 cfs. 4) Screens will prevent fish passage through the outlet. 5) Operation of the outlet is to be limited to seven months of the year. Consideration was also given to effects of the outlet on the Sheyenne and Red Rivers if it was operated with flows unconstrained by water quality because of lake level rises that threatened a natural overflow from Stump Lake.

Outlet Descriptions.

Outlet Intake Location: West Bay Devils Lake

Most outlet alternatives that have been seriously developed in the past have started in the West Bay of Devils Lake. This area has the best water quality in the lake that is located relatively near the Sheyenne River. However, even an outlet with flows constrained by sulfate concentration on the Sheyenne River will have water quality impacts on the Sheyenne and Red Rivers. Three different basic outlets could be feasible to draw water from the West Bay.

Alternative 1. Pump Along Twin Lakes Route from West Bay This alternative has been investigated extensively in the past because it is the shortest and lowest route for pumping water from the West Bay of Devils Lake to the Sheyenne River. A design is summarized in the 12 August, 1996 report titled "Emergency Outlet Plan, Devils Lake, North Dakota". This outlet brings water approximately 13 miles from Devils Lake to the Sheyenne River. It uses a series of three pump stations and impoundments to bring water in steps to the top of the divide between Devils Lake and the Sheyenne River. The top of the divide is at approximately elevation 1495 feet msl. Existing natural lakes would be taken advantage of to form the impoundments. From the top of the divide to the Sheyenne River water would flow in an open channel along an existing coulee. See Table 1 for estimated costs for this alternative.

Alternative 2. Pump Along Peterson Coulee Route from West Bay Because of opposition from the Spirit Lake Nation over the Twin Lakes Route, an outlet from West Bay that incorporates the Peterson Coulee was substantially developed and designed in 1998. With a total length of about 14 miles and a divide elevation of 1570 feet msl, this route is slightly longer and much higher than the Twin Lakes Route. However, only the northernmost 1½ to 2 miles of this route lie within the Spirit Lake Reservation and no Tribal trust lands are impacted because affected reservation lands are all in private ownership.

The Twin Lakes outlet design developed in 1996 proposed to convert several natural lakes and wetlands, as well as an existing coulee, into storage basins and channels for the outlet. The effort for the Emergency Outlet Plan emphasized low construction cost. Environmental and social impacts were not fully considered. The opposition that outlet plans were receiving from the Spirit Lake Nation and other landowners led to greater emphasis on environmental and social impacts when making decisions regarding the configuration of the Peterson Coulee outlet. The Peterson Coulee route was therefore developed using a pipeline to convey water from Devils Lake to the Sheyenne River. This configuration minimizes impacts along the outlet route in exchange for moderate increases in estimated construction costs.

The Peterson Coulee alternative requires a high head pump station to convey water through the pipeline. The pump station would be constructed east of Round Lake and Highway 281 to draw water from Devils Lake and convey it under the highway and over the divide to the Sheyenne River. The underground pipeline would extend from the pump station on Devils Lake to the Sheyenne River and is approximately 70,100 feet (13.3 miles) long. The first approximately 14,000-foot long high-pressure section would be either ductile iron pipe or steel pipe and the remainder would be reinforced concrete pipe. See Table 1 for costs for this alternative. The section of pipeline that runs down Peterson Coulee could be replaced by open channel flow over a series of drop structure. However, past evaluations of this feature have concluded that the pipeline is preferred over the open channel.

In order to satisfy water quality constraints on the Sheyenne River and still pump at maximum efficiency for drawing down Devils Lake, a pumping system is required that can provide highly variable quantities of flow. For the 1998 design, a pumping station was designed that combined many small (10 cfs) and medium (50 cfs) sized pumps in order to be able to provide the increment of flow desired. This is the design reflected in Table 1. It is recognized now that a much less costly pump station could be constructed using just a few large pumps, such as three-100 cfs pumps. The flow from each of these pumps can only be varied by a small percentage from its rated capacity though. Constructing a small reservoir area just before the pipeline enters Peterson Coulee could provide variable flow desired. A gate on the outlet of the reservoir would allow water to be metered into the pipeline to the Sheyenne River. The level of water in the reservoir would be maintained within a set range by cycling the pumps in the pump station off and on.

Alternative 3. Gravity Flow Pipelines From West Bay. For this alternative, a gravity flow tunnel would be constructed from Devils Lake to the Sheyenne River. The invert of the pipe at its inlet would be at approximately an elevation of 1415. This outlet method is attractive because the costs for operation are minimal after it is completed and impacts along the outlet route are minimized. A tunnel was sized that would run directly south from the pump station location identified for the Peterson Coulee pump outlet. The tunnel along this alignment would be about 14.2 miles long and would have an interior diameter of 11-feet. Approximately seven access shafts would be required along the length of the concrete lined tunnel for construction and future maintenance. A control structure would be needed at the mouth of the tunnel to control the quantity of flow allowed into the Sheyenne River.

This plan has never been extensively pursued in the past though because of the high cost of implementing it. Several experienced tunneling contractors were contacted to help determine costs for the tunnel during the 1999 alternative study though. See Table 1 for estimated costs for this alternative.

Outlet Intake Location: Pelican Lake

The largest inflows into Devils Lake come from Mauvais Coulee and enter Devils Lake through Pelican Lake, which is on the north side of the West Bay. Water quality in Mauvais Coulee is similar to the Sheyenne River making Pelican Lake water much fresher than the rest of the Devils Lake, particularly after high runoff events. Therefore, an outlet that intakes water in

Pelican Lake is attractive because it is the freshest water available in Devils Lake. This would allow the outlet to be more effective in drawing down the lake with flows constrained for water quality than could be expected at other outlet locations. It would also have the least impacts on the Sheyenne and Red Rivers if used in an unconstrained mode to reduce the potential for a natural overflow. This intake location was briefly considered in the 1988 feasibility study. More serious consideration and conceptual designs and for an outlet from Pelican Lake were investigated in the winter of 1999 after it was found that the effectiveness of constrained flow West Bay outlets was less than desired.

Alternative 4. Outlet from Pelican Lake Pump over Peterson Coulee. The distance between a potential inlet on Pelican Lake to the Sheyenne River is a little over 22 miles. The water must be transported south across the flat Devils Lake Basin and then up and over the divide to the Sheyenne River. Peterson Coulee lies within the direct route and would be used similarly to the West Bay outlet alternative.

Based on the 1999 conceptual studies, the first step in outletting water from Pelican Lake would be along a 6.1-mile long open channel to a pump station located on the north side of Minnewauken. The channel would run from Pelican Lake through low ground and then cross Highway 281. It then would follow Highway 281 to the north side of Minnewaukan. Portions of the channel alignment are at or below elevation 1435 feet and wide enough that excavation would not be required.

From the end of the channel on the north side of Minnewauken, water would be pumped through a pipeline about 16.1 miles long to the Sheyenne River. Initial design work indicated that about 24,000 feet of the pipeline would be ductile iron or steel pipe and remainder would be reinforced concrete. The pump station and pipeline would be similar to that required for the West Bay outlet through Peterson Coulee, but would have higher head requirements due to the longer length of the pipeline.

As an alternate configuration, the Alternative 2 outlet could be constructed and Pelican Lake water could be brought to this pump station. Initial indications from concepts studied in 1999 were that this would be far more costly and have greater impacts than the concept presented above. However, there may be advantages to a staged outlet construction and this concept should be further investigated if an outlet from Pelican Lake appears to be feasible.

More fresh water would be available from Mauvais Coulee into Pelican Lake if the historical drainage route from Dry Lake to Mauvais Coulee was restored. Drainage From Dry Lake was diverted directly to Devils Lake through Channel A in 1979. Therefore, a control structure could be built at the head of channel A and a new channel would be constructed west of Dry Lake to allow flow to reach Mauvais Coulee. This feature is included in the cost estimate for this alternative.

Embankments would be needed to keep the fresher water in Pelican Lake and the gravity channel separated from the West Bay of Devils Lake. For the most part, the existing embankments for Highways 281 and 19 would be used to do this. In response to Devils Lake rises to date, Highway 281 and County Road 19 have been raised to minimum elevations of 1451.3 and

1448.8, respectively. Culverts under Highway 281 and County Road 19 would be plugged so that the road embankments would separate the freshwater channel from the higher salinity water in the West Bay. A tieback dike would be needed along the section road on the north side of Minnewaukan from Highway 281 to high ground.

A control structure would be needed where County Road 19 crosses the Big Coulee below Pelican Lake to control flow between the area north of County Road 19 and the West Bay. As presently conceived, the structure would be on the East Side of the existing bridge crossing on the centerline of the existing highway. The structure would consist of an earth embankment to block the coulee, and used gated, concrete pipes to control flow through the structure.
In addition to the control structure on Highway 19, a control structure comprising a gatewell and pipes would probably be constructed in the vicinity of the pump station. This structure would be somewhat similar to the Highway 19 control structure. This structure could have two purposes. One would be to allow West Bay water into the pump station when there is insufficient inflow from Big Coulee (in lieu of West Bay backflow to the intake at Pelican Lake). The other purpose would be to allow runoff from the west side of Highway 281 to flow into Devils Lake in case of major local precipitation or snowmelt runoff events (in lieu of backflow up the freshwater channel to Pelican Lake).

See Table 1 for estimated costs for this alternative.

Outlet Intake Location: East Devils Lake

East Devils Lake is the closest point of Devils Lake to the Sheyenne River and also has the lowest divide elevation, 1465 feet msl, between Devils Lake itself and the Sheyenne River basin. There is a naturally formed channel along the divide that undoubtedly was an outlet from the lake during high water level periods in the distant past. The path over the divide flows naturally down a circuitous route along Tolna Coulee to the Sheyenne River. The total distance along this route is approximately 22 miles. The closest straight-line distance from East Devils Lake to the Sheyenne River is approximately 8.6 miles.

Water quality is much worse in East Devils Lake than in the western part of the lake where most runoff enters though. For this reason, outlet alternatives from this end of the lake have not been developed beyond conceptual levels in the past. Outlet alternatives from this end of the lake are considered here though because if operated in an unconstrained manner, they: 1) are low cost outlets; 2) are as effective as other alternatives in controlling further rises in lake levels; 3) avoid impacts to the U.S. Fish and Wildlife Refuge in Stump Lake; 4) significantly enhance the water quality in the entire Devils Lake, thereby creating a recreational resource for the region; and 5) provide and economic basis for quantifying the additional cost for releasing better water quality by selecting alternatives from western locations. Relatively more alternatives are presented here than for other locations on the lake because outlets from the east end of the lake have not been examined extensively enough in the past to be able to predetermine the most efficient outlet configuration.

<u>Alternative 5. Gravity Flow Along Tolna Coulee from East Devils Lake</u> For this alternative, an approximately 14 mile long channel would be dug from East Devils Lake to a daylight point in

Tolna Coulee. The existing channel would be used to minimize depths of excavation. Water would then flow down Tolna Coulee to the Sheyenne River. As currently envisioned, the new channel invert would be at approximately elevation 1439 at East Devils Lake and the channel would slope at 0.0001 on 1 until it daylighted in Tolna coulee. The average depth of the channel would be about 20 feet with maximum cuts of approximately 30 feet. It is assumed that the channel would be grass lined but that some maintenance would be required because grass would not live long below the waterline of a frequently used channel. The concept design attempted to keep velocities in the channel low enough to prevent major erosion. A gated control structure would be required at the channel inlet (lake outlet) to control the amount of flow in the channel. Several four to seven feet high drop structures will be needed where the new channel daylights into the existing Tolna coulee and at the lower part of the coulee and where it drops into the Sheyenne River below the Tolna Dam. See Table 1 for estimated costs for this alternative.

Alternative 6. Pump from East Devils Lake to Tolna Coulee This alternative is virtually the same as Alternative 5 in alignment and for most of the concept. The only difference is that a pump station would be used to lift Devils Lake water up to a higher channel across the divide between East Devils Lake and Tolna Coulee. Alternatives 5 and 6 were both conceptually designed and presented here because neither had been extensively developed in the past. The channel invert for this alternative would by 1455 at the pump station and be sloped at 0.0001 on 1 until it daylighted in Tolna Coulee. Compared to Alternative 5, this alternative requires far less excavation, but it does require a pump station. This pump station would be similar in sized to the East Ditch Pump Station on the Devils Lake Levee project and would require much smaller motors for the pumps than is required for the full pipeline alternatives such as Alternative 2. One disadvantage of this plan compared to Alternative 5 is that it would not provide a large channel that could be used as an emergency spillway out of Devils Lake. The outlet would be limited to the capacity of the pump station up to very high lake levels. Estimated costs are shown on Table 1.

Alternative 7. Gravity Flow Tunnel from East Devils Lake For this alternative, a gravity flow tunnel would be constructed from Devils Lake to the Sheyenne River. A tunnel was sized that would run from the southernmost point of East Devils Lake directly south to the Sheyenne River. The tunnel along this alignment would be about 8.5 miles long and would have an interior diameter of 7-feet. Four or five access shafts would be required along the length of the concrete lined tunnel for construction and for future maintenance. A control structure would be needed at the mouth of the tunnel to control flow into the Sheyenne River.

Costs developed for the tunnel from the West Bay of Devils Lake were used to estimate costs for this alternative. See Table 1 for estimated costs for this alternative.

Alternative 8. Gravity Flow Channel from East Devils Lake to Stump Lake Outlet. For this alternative, the outlet from the east end of Devils Lake would be a grass lined gravity flow channel that initially would follow the natural overflow channel between Devils Lake and Stump Lake. At Stump Lake, the channel would follow the west side of the lake until it reached the natural outlet from Stump Lake. From there it would continue along the natural Stump Lake outlet route until the channel invert intersected natural ground in Tolna Coulee. From there, Devils Lake water would flow down Tolna Coulee into the Sheyenne River. The initial,

excavated, portion of the channel is about 16 miles long. The total length of the outlet from Devils Lake to the Sheyenne River is about 28 miles long.

A channel was designed that could allow 300 cfs to flow out of Devils Lake when the Lake elevation is 1446 or more. The channel as currently designed has a bottom width of 24 feet, side slopes of 4 on 1, and a bottom slope of 0.00005. The invert at the beginning of the channel would be about 1439 and daylights in Tolna Coulee at about elevation 1434. Most of the channel excavation is 5 to 12 feet deep, but through the Stump Lake outlet the required excavation depths exceed thirty feet. Below Tolna Dam, drop structures would be required to control erosion. A drop structure might also be required where the channel daylights into Tolna Coulee because the natural channel is rather steep there.

A gate structure would be needed at a road crossing on the divide between Devils Lake and Stump Lake in order to control outflows within the operational constraints of the project. However, very large inflows into Devils Lake may exceed the operationally constrained outflow limitations. This would require that excess water be passed into Stump Lake to prevent project created damages around Devils Lake. The gate structure therefore would need to be designed to pass excess flows into Stump Lake as well as control flows into the channel.

The current design incorporates features to prevent Stump Lake from inundating the channel even if Stump Lake fills to an elevation of 1459. The channel around Stump Lake follows approximately the 1448 contour and excavation from the channel would be used to construct an embankment on the Stump Lake side of the channel that would keep channel water separate from Stump Lake water. Riprap has been included in the design and cost estimate to prevent erosion of the embankment under high lake levels. If this plan was implemented, installation of the riprap could be delayed until Stump Lake actually filled.

Outlet Intake Location: West Stump Lake

An outlet from West Stump Lake into Tolna coulee requires the least amount of construction of any outlet plan. The divide elevation between West Stump Lake and Tolna Coulee is just 1459.0. As with East Devils Lake, the low point is in an existing channel that obviously formed an outlet for the Devils Lake basin in some historical period. A complete hydraulic design for a West Stump Lake outlet has not been completed at this time, although a channel for the outlet has been conceptually sized. An outlet from West Stump Lake would require that Devils Lake water flow several miles over the divide between Devils Lake and Stump Lake and fill Stump Lake before it could operate. Stump Lake is currently about 35 feet lower than Devils Lake. The divide between Stump Lake and Devils Lake is approximately at elevation 1446.5 feet msl. The need to get water over the divide between the two lakes before the Stump Lake outlet would become effective may require that a higher level would need to be produced in Devils Lake compared with other plans.

After Stump Lake is filled from Devils Lake, the water in Stump Lake will still contain approximately twice the dissolved solids as in East Devils Lake. It would therefore be even less effective than East Devils Lake in lowering the lake level with a constrained flow plan. In

addition, this plan would be ineffective in averting some of the great impacts on the Sheyenne and Red Rivers due to poor water quality from a natural spill. The outlet could be used as a control structure to control outflows from the lake under a natural spill condition though.

Alternative 9. Gravity Flow Along Tolna Coulee from West Stump Lake For this alternative, an approximately 5.6 mile long channel would be dug from West Stump Lake to a daylight point in Tolna Coulee. The new channel would be similar in design to the channel conceived for East Devils Lake and would follow the existing outlet channel out of Stump Lake. The channel invert would be at approximately elevation 1440 at Stump Lake and the channel would slope at 0.00034 on 1 as presently conceived. The average depth of the channel would be about 10 feet with maximum cuts of approximately 20 feet. Existing wetlands, lakes, ponds, and a dam along the current channel would complicate construction. A gated control structure would be required at the channel inlet (lake outlet) to control the amount of flow in the channel. Several five to fourteen feet high drop structures will be needed where the new channel daylights into Tolna coulee and at the lower part of the Coulee and where it drops into the Sheyenne River below the Tolna dam. See Table 1 for estimated costs for this alternative.

Water Treatment

Treatment of outlet water from Devils Lake has been briefly investigated in past reports. Treating lake water to reduce the total dissolved solids would allow much more water to be added to the Sheyenne River without exceeding water quality standards. There are several technologies being used today to desalinate water, all of them are very costly. Water treatment has been considered in all studies of the lake, most recently for the 1996 Emergency Outlet Plan report. For this report, it was found that there is a reverse osmosis plant in Yuma, Arizona that would be similar in size to what would be needed at Devils Lake. This plant is the second largest desalinization plant in the world, producing an outflow equivalent to 130 cubic feet per second (cfs) of treated water. According to information in the 1996 Emergency Outlet Plan, this plant cost over $211,000,000 to build and costs about $26,000,000 per year just to operate. Updated from 1996 to 2001 costs using the factors in Table 1, today's first cost is $240,000,000. Annualized costs using the above numbers updated to 2001 for first cost plus operation costs using the factors from Table 1 are $44,000,000 per year.

Other sources list similarly high costs for desalinating water. In its web page, the USGS indicates that costs for desalinization of seawater can range from $1300-$2200 per acre-foot (total costs). Desalinating 150 cfs for seven months per year would result in an annual cost of $82,000,000-$140,000,000 using the USGS estimates. World Bank estimates for desalinated water are $1.60 to $2.70 per cubic meter. These unit costs would result in yearly cost of $124,000,000 to $210,000,000 at 150 cfs for seven months. Optimistic planners for desalinating seawater in the Middle East hope to get costs as low as $0.50 per cubic meter. If this could be achieved in Devils Lake, it would still result in an annual cost of $39,000,000. It seems likely that a very large desalination plant at Devils Lake would approach the lower end of estimated costs per volume of water treated. Energy costs would be extremely high. The absolute minimum energy required to recover 1,000 gallons of fresh water is 2.98 kwh.

There are concerns with operating a large desalinization plant besides cost. One is finding a source for the large amount of power that would be required to run the plant. Another is finding a disposal location for the large quantities of sludge and brine that would be produced by the plant

Cost Estimates

Table 1 lists estimates for initial construction costs and average annual costs for the eight alternatives. The cost estimates for the alternatives were developed at different times and to different levels of detail. They are intended only to show general relative costs between the alternatives and therefore can be compared only at a very rough level. The level of design that was used for the estimates is described as follows:

a) The estimate for Alternative 1 was developed for the Emergency Outlet Plan in 1996 based on conceptual design for all features.
b) The estimate for Alternative 2 is based on extensive design development that was conducted in 1998.
c) The estimate for Alternative 3 was developed from rough estimates from tunneling contractors. No design was performed on this alternative besides sizing the require tunnel diameter. Estimates for features such as the inlet structure were based on the cost expected for a similar type structure. The environmental and real estate costs shown are rough estimates. No development work has been done at this time.
d) The estimate for Alternative 4 was developed in an alternative study conducted in the winter of 1999. The estimate is based on the Alternative 2 estimate for similar features where possible. Much of it is based on very rough, conceptual designs though. Major features were identified and roughly sized. However, not enough development was performed to verify all of the components that would be needed to get water from Pelican Lake to the Sheyenne River and operate the outlet over a range of lake levels. The environmental and real estate costs shown are rough guesses. No development work has been done at this time
e) The estimates for Alternatives 5, 6, 7, 8, and 9 were developed in January, 2001 based on conceptual designs. The sizes of the channels and the number and height of drop structures was estimated, but costs for all other components for these plans are based only on rough estimates of what similar features might be expected to cost. The environmental and real estate costs shown are rough estimates. No development work has been done at this time.
f) The estimate for Alternative 7 was based on the rough tunneling costs developed for Alternative 3.

Some assumptions were made to develop the total and annual costs in Table 1. It is assumed that all costs are based on 2001 prices. For the annual costs, it is assumed that the initial cost is amortized over 50 years and that the interest rate will be 6 3/8%. Annual costs were computed assuming that the outlet is operated every year for 50 years. Less operation would decrease the annual cost for the pumping alternatives, but the comparison would not likely change significantly

The monitoring costs shown are rough, preliminary estimate. This cost will be refined under Step 2 and 3. This cost does not include any mitigation proposals and associated costs that would arise from the monitoring. They are unknown at this time.

The annual downstream water users cost were estimated from the Barr Engineering downstream water users report for municipalities and industry. Costs to mitigate affects on irrigators and other small users are not included. For all alternatives except the outlet from Pelican Lake, it is assumed that all municipalities downstream of the outlet would require major infrastructure upgrades to be able to treat river water. For the Pelican Lake outlet plan, it is assumed that only Valley City would require major infrastructure upgrades to treat water and that all other municipal users could accommodate water from the outlet with occasion extra softening. At this time, it is difficult to determine just what treatment the downstream water users would need. The assumption of whether new water treatment infrastructure and processes are needed or whether the existing treatment plants can be used to treat the lower quality water greatly impacts expected costs.

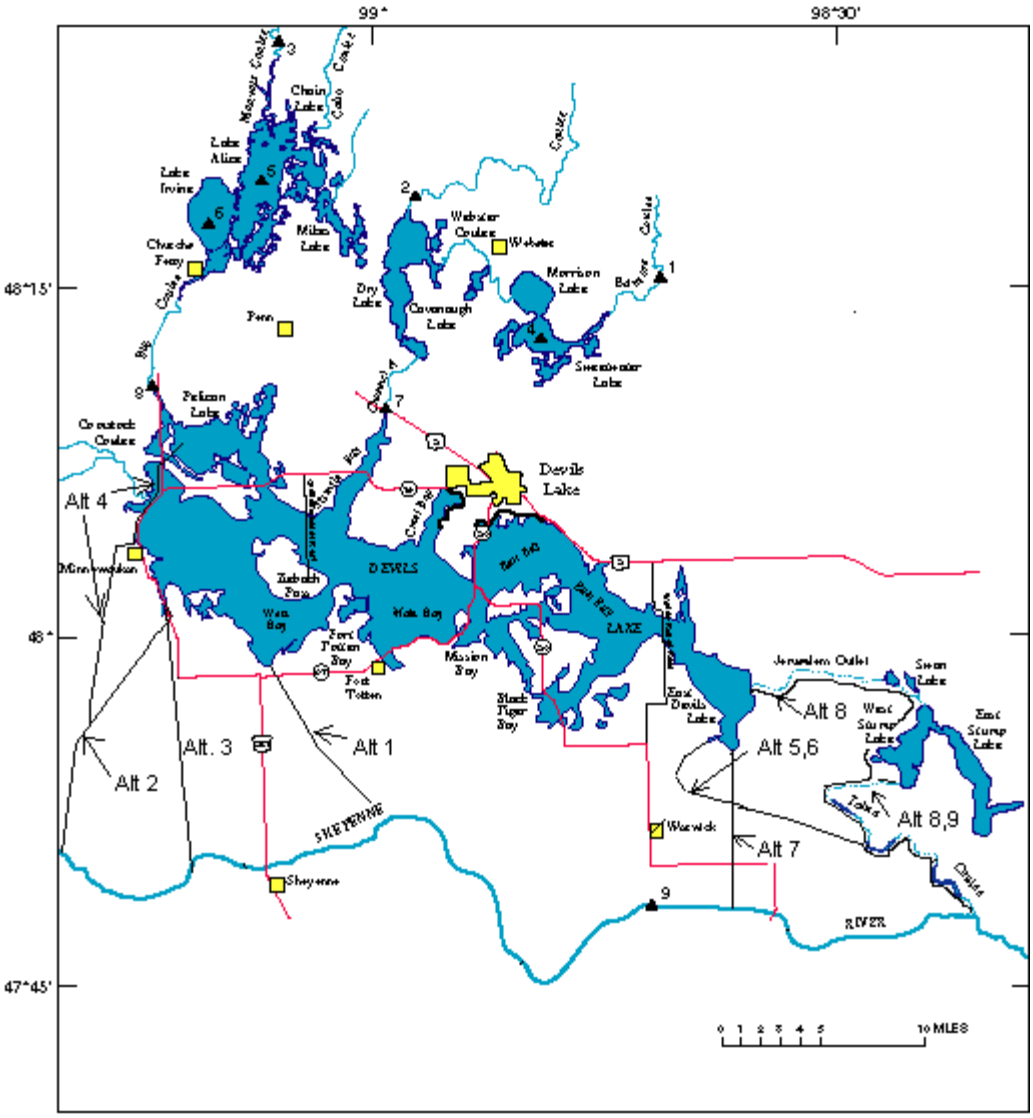


Table 1

Item Description	Outlet Intake Location >>	West Bay Devils Lake			Pelican Lake	East Devils Lake				W. Stump Lake
	Alignment >>	Twin Lakes	Peterson Coulee		Peterson Coulee	Tolna Coulee				Outlet Channel
	Main Feature >>	Pumped Storage	PS W Pipeline	Tunnel	PS W Pipeline	Gravity Flow	Gravity W/ PS	Tunnel	Gravity/ Stump	Gravity Flow
	Alternative No. >>	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Estimated Construction Cost		13,336,000	50,189,000	94,355,000	note 6	36,224,000	20,521,000	61,327,000	27,541,000	12,391,000
Estimated Contingencies		5,624,000	6,250,000	33,024,000	note 6	15,856,000	6,976,000	21,039,000	10,559,000	5,455,000
Contingencies Percentage		42%	12%	35%	note 6	44%	34%	34%	38%	44%
Estimated Construction + Contingencies Cost		18,960,000	56,439,000	127,379,000	101,478,000	52,080,000	27,497,000	82,366,000	38,100,000	17,846,000
Date of Estimate		July-96	Aug-96	note 4	Aug-96	note 4	note 4	note 4	note 4	note 4
CWCCIS Factor		445.58	459.40	note 4	459.40	note 4	note 4	note 4	note 4	note 4
Current CWCCIS Factor		485.19	485.19	note 4	485.19	note 4	note 4	note 4	note 4	note 4
Update Index		1.09	1.06	note 4	1.06	note 4	note 4	note 4	note 4	note 4
Updated Estimated Construction Cost W/ Contingencies		20,645,000	59,607,000	127,379,000	107,175,000	52,080,000	27,497,000	82,366,000	38,100,000	17,846,000
Engineering & Design		3,545,000	3,000,000	23,820,000	note 1	6,249,600	3,300,000	9,884,000	4,571,880	2,142,000
Supervision and Administration		1,243,000	3,758,000	8,407,000	note 1	3,395,200	1,787,000	5,354,000	2,476,435	1,160,000
Environmental Restoration/Mitigation[5]		note 1	note 3	600,000	note 1	4,000,000	4,000,000	250,000	4,943,000	3,000,000
Real Estate		293,000	218,000	218,000	note 1	1,500,000	1,500,000	250,000	1,983,000	1,100,000
Total First Costs		25,726,000	66,583,000	160,424,000	126,508,000	67,214,800	38,084,000	98,104,000	52,074,000	25,248,000
Annual Maintenance Cost Percentage			0.50%	0.17%	0.50%	0.50%	0.75%	0.35%	0.50%	0.50%
Annual Maintenance, Percentage of Estimated Construction Cost		182,000	298,000	217,000	536,000	260,000	206,000	288,000	191,000	89,000
Annual Operation Cost Percentage			1.72%	0.00%	1.20%	0.00%	2.00%	0.00%	0.00%	0.00%
Annual Operation, Percentage of Estimated Construction Cost[6]		490,000	1,025,000	0	1,286,000	0	250,000	0	0	0
Annual Monitoring Costs		700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000
Annual Downstream Water Users Cost - Municipal		3,300,000	3,300,000	3,300,000	450,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000
Annual Downstream Water Users Cost- Industrial		32,000	32,000	32,000	1,500	32,000	32,000	32,000	32,000	32,000
Annual Cost of Total First Costs	Term 50 Years Interest 6.375%	1,718,000	4,447,000	10,715,000	8,583,000	4,489,000	2,544,000	6,552,000	3,478,000	1,686,000
Total Annual Cost		6,422,000	9,802,000	14,964,000	11,556,500	9,481,000	7,732,000	11,572,000	8,401,000	6,507,000

Alternatives Description
1 Pump and Storage along Twin Lakes route from West Bay
2 Pump and Pipeline along Peterson Coulee route from West Bay
3 Gravity flow pipelines from West Bay
4 Outlet Channel from Pelican Lake, pump over Peterson Coulee
5 Gravity Open Channel along Tolna Coulee from East Devils Lake
6 Gravity Open Channel along Tolna Coulee from East Devils Lake with PS
7 Gravity flow tunnel from East Devils Lake
8 Gravity Open Channel from East Devils lake around Stump Lake to natural outlet and Tolna Coulee
9 Gravity Open Channel along Tolna Coulee from West Stump Lake

Notes
1 Included in construction cost.
2 E&D costs for alt 2 include only A/E fees for Phases 1,2, & 3.
3 Costs not determined. Assumed to be minimal
4 Not applicable due to level of detail
5 Costs for mitigation of adverse affects downstream not included.
6 Assumes Operation for 25 of 50 years

Summary

Alternative 1. Pump Along Twin Lakes Route from West Bay

Estimated First Cost: $ 25.7 million
Estimated Annualized Cost: $ 6.2 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Fair, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake itself if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake.
Social/Political Considerations: This outlet would pass through Tribal Trust Lands of the Spirit Lake nation. Opposition to the plan by the Spirit Lake Nation led to its abandonment as a feasible outlet scheme in 1996. Meetings with the Tribe held in December 2000 indicated that it is still opposed to a permanent outlet constructed on Trust Lands. There would be great impacts to land used along the route from the open channels and three permanent pump stations.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands along the direct path of the outlet. Environmental considerations in the Sheyenne and Red River in this and all other alternatives are assumed to be directly linked to water quality.
Design/Construction Considerations: Rough design has been completed. North Dakota Water Commission also is working on a design for this route.
Conclusion: Drop from further study due to opposition from Tribe.

Alternative 2. Pump Along Peterson Coulee Route from West Bay

Estimated First Cost: $ 66.6 million
Estimated Annualized Cost: $ 9.3 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Fair, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake itself if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake. At high lake levels, water from this location may not seriously affect water quality standards on the Red River (?).
Social/Political Considerations: The final plan would not greatly affect land use along the route of the outlet, but a group of local landowners have organized to prevent it. There will be high costs for operating the pump station. A large power line will need to be brought into the pump station.
Environmental Considerations: There will be some impact to wetlands along the pipe route during construction. All areas affected will be restored after completion of the project so that long-term impacts would be expected to be minimal.
Design/Construction Considerations: This plan was extensively designed in 1998. Some redesign may be desired to reduce costs, but the overall scheme and alignment is set.
Conclusion: This plan will be retained for further study.

Alternative 3. Gravity Flow Pipelines From West Bay

Estimated First Cost: $ 160.4 million
Estimated Annualized Cost: $ 15.0 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Fair, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake itself if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake.
Social/Political Considerations: Because it is mostly underground, the final plan would not greatly affect land use along the route of the outlet. There would be opposition from groups sensitive to potential uses of any plan as an inlet into Devils Lake since this plan could most easily reversed. The local sponsor would be in favor the low operating costs of this proposal.
Environmental Considerations: Environmental impacts along the outlet route are expected to be very minimal.
Design/Construction Considerations: Only conceptual designs regarding sizing of the tunnel have been completed to date. No environmental or cultural studies in potential construction areas have been completed.
Conclusion: Drop from study due to very high costs and potential political opposition due to the perception that it could be used as an inlet.

Alternative 4. Outlet from Pelican Lake, Pump over Peterson Coulee

Estimated First Cost: $ 128.5 million
Estimated Annualized Cost: $ 10.5 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Good, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will very minimally exceed standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake. It is like that some West Bay water would be still need to be used under an unconstrained flow plan though since there most likely would not be enough inflow.
Social/Political Considerations: The final plan would not greatly affect land use from the pump station to the river. The present concept does require several miles of open channel north of Minnewaukan though. This plan would benefit by raising Highways 19 and 281 near Minnewaukan, which would be a benefit to Minnewaukan and areas south and west of it. Rerouting flow out of Dry Lake may cause concern with landowner between Dry Lake and Mauvais Coulee. This plan would be the most palatable to interests downstream of the insertion point because the water quality could be relatively good.
Environmental Considerations: Environmental impacts along the pipeline route are expected to be minimal after construction. Impacts to the Pelican Lake area, in areas identified for open channels between Pelican Lake and the pump station, or affected by the rerouting of Dry Lake outflow have not been studied. Most of these areas are currently under water.

Design/Construction Considerations: Conceptual design has been performed. Some of the alignment would be the same as Alternative 2. The many features and the operation plan for holding water in Pelican Bay and moving it to a pump station will require much more extensive analysis. In addition, cultural and environmental impacts along much of the proposed route have not been studied.
Conclusion: Carry forward for further study because of high water quality and potential effectiveness for lowering the lake.

Alternative 5. Gravity Flow Along Tolna Coulee from East Devils Lake

Estimated First Cost: $ 67.2 million
Estimated Annualized Cost: $ 9.5 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. Impacts if operated under unconstrained flows to reduce the potential for a natural spill would not my much better than a natural spill from Stump Lake. A natural spill is expected to have significant water quality impacts.
Social/Political Considerations: This plan does cross some portions of the Spirit Lake Nation Reservation. There would be great impacts from the open channels on land use along the route. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location. The local sponsor would be in favor the low operating costs of this proposal.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands along the direct path of the outlet
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Alternative 6. Pump from East Devils Lake to Tolna Coulee

Estimated First Cost: $ 38.1 million
Estimated Annualized Cost: $ 7.7 million
All considerations are the same as Alternative 5 except that there would be somewhat greater operating costs in exchange for much lower first costs.
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Alternative 7. Gravity Flow Tunnel from East Devils Lake

Estimated First Cost: $ 98.1 million
Estimated Annualized Cost: $ 11.6 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. Impacts if operated under unconstrained flows to reduce the potential for a natural spill would not my much better than a natural spill from Stump Lake. A natural spill is expected to have significant water quality impacts.

Social/Political Considerations**:** This plan does cross some portions of the Spirit Lake Nation Reservation. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location. The local sponsor would be in favor the low operating costs of this proposal.
Environmental Considerations: This plan would be expected to have very minimal environmental impacts along the outlet route. Most of those would occur only during construction.
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Alternative 8. Gravity Flow from East Devils Lake to Stump Lake and Out Natural Outlet

Estimated First Cost: $ 52.1 million
Estimated Annualized Cost: $ 8.4 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Same as Alternative 5.
Social/Political Considerations: This plan was proposed and by residents of Devils Lake and has support from the community there that thinks this would be a cheap, low operation cost alternative. There would be great impacts from the open channels on land use along the route. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands in the 28-mile long direct path of the outlet
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Carry forward to Step 2 because this is the locally preferred plan. Greater analysis in Step 2 will better quantify impacts of an East End outlet. However, outlets from east end of the lake only can be effective if they are operated without constraint for water quality on the Sheyenne River.

Alternative 9. Gravity Flow Along Tolna Coulee from West Stump Lake

Estimated First Cost: $ 25.3 million
Estimated Annualized Cost: $ 6.5 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. Impacts if operated under unconstrained flows to reduce the potential for a natural spill are same as a natural spill. A natural spill is expected to have significant water quality impacts.
Social/Political Considerations: This plan does cross some portions of the Spirit Lake Nation Reservation. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location. The requirement to fill Stump Lake before operation of this plan is also a negative factor. This plan would be the cheapest for locals to cost share with, would have low operating costs, and is similar to plans conceived by people in Devils Lake.

Environmental Considerations: This plan would greatly impact many natural lakes and wetlands along the direct path of the outlet
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Water Treatment

Estimated First Cost: $+230 million
Estimated Annualized Cost: $ +44 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Good
Water Quality Impacts: Water treatment would permit good quality water to be discharged from Devils Lake to the Sheyenne River. However, handling of the brine is a major concern that would need to be addressed.
Social/Political Considerations: Water treatment would require a very large plant to be built covering many acres. A very large amount of power would be needed to run the plant. There would be a great amount of resistance to dealing with the brine and other waste products produced by the plant. Downstream interests would be very much in favor of the plant. It is possible that the plant could partially resolve Canada's concern with biota. The plant would employ many people in the Devils Lake Basin. As an understatement, the great cost of operating the plant would put a great strain on financial resources in North Dakota.
Environmental Considerations: The plant and its operations would undoubtedly have a negative affect on the area that they were constructed in.
Design/Construction Considerations: No design has been performed.
Conclusion. Because of the great cost, water treatment is not considered feasible for a Devils Lake outlet.

Sensitivity of Alternative Selection for Step 2 as Affected by the Operating Plan

From the evaluation to this point, using a 300 cfs constrained operating plan, Alternatives 2 (Peterson Coulee Pump with Pipeline) and 4 (Pelican Lake Pump with Pipeline) will be the ones to be carried forward for further analysis and development in Step 2. However, besides the 300 cfs constrained release operating plan used as a base condition in Step 1, these alternatives will also be evaluated for an alternative operating plan that could release up to 480 cfs unconstrained for seven months in Step 2. Alternative 8 will also be evaluated for the 480 cfs unconstrained condition because it is a locally preferred plan and is one of the least expensive methods of building an outlet for Devils Lake. Since this additional operating plan will be included in the formulation of alternatives from this point forward, it is appropriate to review those plans that have been eliminated from consideration in light of the unconstrained operating plan to assure that the reasons for not being carried forward would not change.

From a downstream user perspective and politically, it is reasonable to assume that any outlet operation plan which degrades water quality will be considered unacceptable. All the outlet operation plans (300 constrained or 480 unconstrained) will do this to some extent. West Bay clearly provides the best outlet water quality between the West Bay, East Devils Lake, and

Stump Lake options. Pelican Lake, has the capability of providing a higher quality release water than West Bay, however the supply of water may be limited, requiring West Bay water to be pumped in addition

The initial concentrations of sulfate and TDS vary throughout the lake, generally increasing from west to east through the Devils Lake Chain. Under a scenario assuming a wet future condition, the sulfate distribution between the bays at the onset of pumping is anticipated to be 300 mg/l in West Bay, 1180 mg/l in East Devils Lake, and 2670 mg/l in Stump Lake. In essence this represents a four-fold increase in concentration from West Bay to East Devils Lake and a nine fold increase between West Bay and Stump Lake. Initial TDS concentrations are approximated to be 760 mg/l in West Bay, 2300 mg/l in East Devils Lake, and 5180 mg/l in Stump Lake resulting in a three fold and seven fold increase in the relative TDS concentrations between West Bay and East Devils Lake and West Bay and Stump Lake.

Under this scenario and simplified lake model, the operation of an unconstrained 480cfs West Bay outlet would not exceed the sulfate standard on the Sheyenne River. However, it would substantially degrade existing water quality on the Sheyenne River. It would also increase the magnitude and duration of TDS and sulfate standard exceedances on the Red River of the North. The extent of the impact would depend on local flows available for dilution.

An East Devils Lake outlet alternative with a 480 cfs unconstrained outlet operation would continually exceed the sulfate standard on the upper Sheyenne River, often times more than doubling it. At Kindred it is anticipated that the sulfate standard would be exceeded at flows less than 1200 cfs. Sulfate concentrations would peak at concentrations near 900 mg/l for flows near 200 cfs. On the Red River at Emerson the sulfate standard would be exceeded whenever the flow at Emerson (not including DL releases) is less than about 3000 cfs. Sulfate standard exceedances on the Red River upstream of the confluence of the Red Lake River would be more prevalent. Exceedances of the TDS standard on the Red River at Emerson would occur at natural flows of about 16,000 cfs or less. Some years there would be continued excursions of the TDS standard at Emerson. TDS concentrations are expected to peak at over 1000 mg/l TDS for natural flows less than 1000 cfs and over 700 mg/l TDS at flows less than 3000 cfs. The mean monthly flow at Emerson is less than 3000 cfs from July through March. TDS concentrations upstream of the confluence with the Red Lake River will tend to be much higher than those experienced at Emerson.

A 480cfs unconstrained Stump Lake Outlet operation would create even larger excursions in the duration and magnitude of the sulfate and TDS standards than an East Devils Lake Outlet. On the Sheyenne River at Kindred the sulfate standard would likely be exceeded for all flows less than about 3500 cfs. This corresponds to a near 100% sulfate standard exceedance at all locations on the Sheyenne River. At Emerson the TDS standard would also be exceeded nearly 100% of the time and the sulfate standard would likely be exceeded at flows of 7000 cfs or less. TDS concentrations would likely exceed 1000 mg/l at flows equal to or less than 3000 cfs and exceed 2000 mg/l at flows less than 1000 cfs.

Individually, consideration of the alternatives that would be dropped from further consideration in light of a 480 cfs unconstrained operating plan is summarized as follows:

Alternative 1 (Twin Lakes Pumped Storage) - Since the downstream water quality impacts would be very similar to the Peterson Coulee alternative and the Peterson Coulee route is considered more implementable (not crossing Tribal Trust lands), it is only necessary to carry forward the Peterson Coulee plan (alternative 2).

Alternative 3 (Gravity Flow from West Bay) - The incremental increase in first and average annual cost for increasing the capacity to 480 cfs would be less for this alternative in comparison to a pumped outlet at the same location. However, it would still be significantly more costly. Among alternative configurations along the Peterson Coulee alignment, this route is best represented by Alternative 2.

Alternative 5 (Gravity Flow along Tolna Coulee from East Devils Lake) - This alternative becomes more effective in controlling stages in Devils Lake if not constrained by conditions in the Sheyenne River. However, with the TDS concentrations in East Devils Lake being approximately five times that of the West Bay concentrations, outlet alternatives from this portion of the lake are considered much more difficult to implement. Reasons for dropping from consideration earlier (greater water quality impacts downstream, as compared to Alternatives 2 or 4, and political opposition) remain major obstacles and likely to make such a plan non-implementable. Alternative 8, a lower cost plan, will be carried forward to more fully evaluate these factors.

Alternative 6 (Pump from East Devils Lake to Tolna Coulee) - same reasons for dropping as stated for Alternative 5.

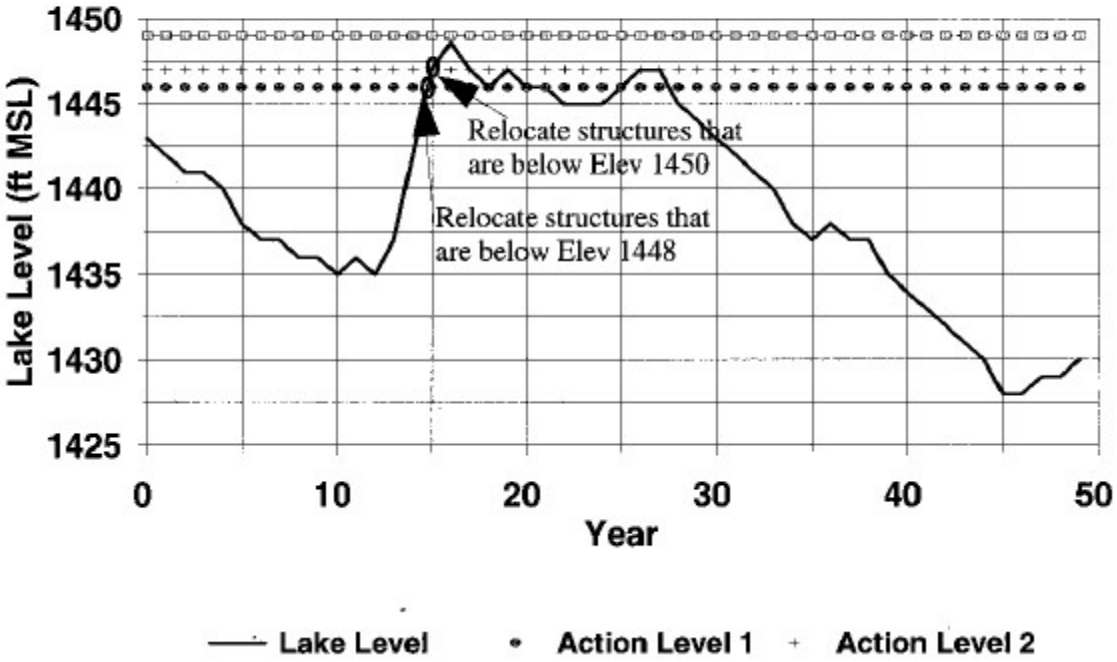
Alternative 7 (Gravity Flow Tunnel from East Devils Lake) - same reasons for dropping as stated for Alternative 5.

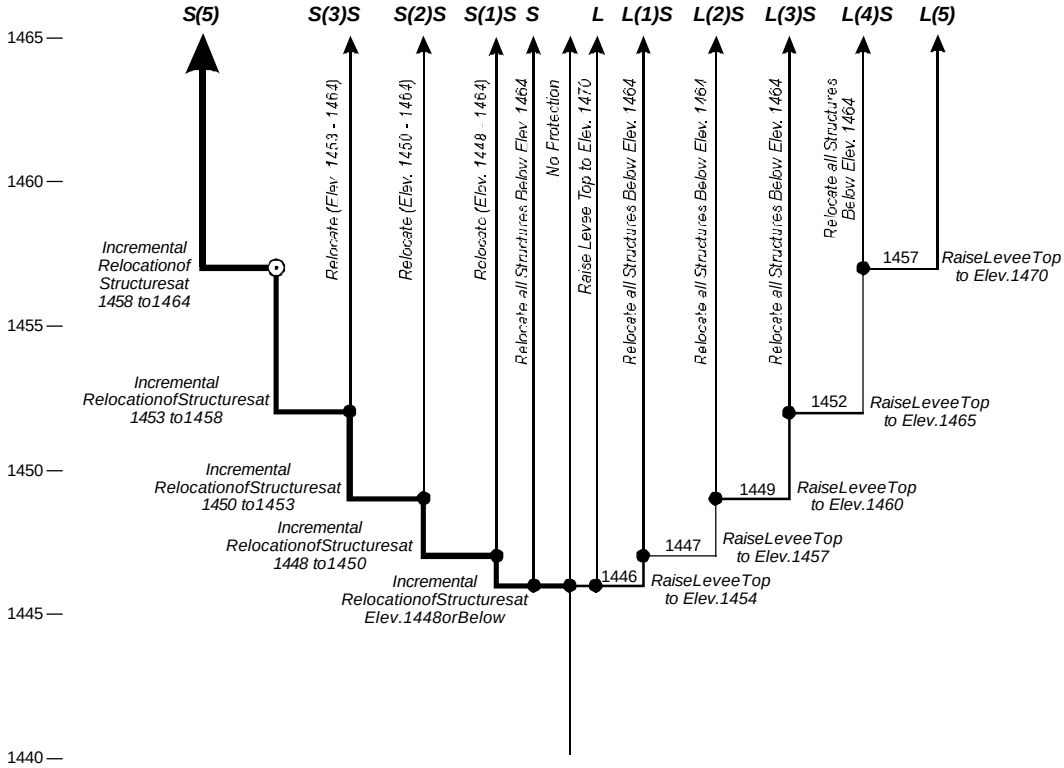
Alternative 9 (Gravity Flow Along Tolna Coulee from West Stump Lake) - same reasons for dropping as stated for Alternative 5.

Alternatives Carried Forward to Step 2

It appears reasonable from a water quality perspective to only carry forward Alternatives 2 and 4 for further analysis and development in Step 2. Alternative 8 will be carried forward as the locally preferred plan so that the effects of an East Devils plan can be more formally evaluated. Alternative 8 will only be evaluated with outflows unconstrained by water quality in the Sheyenne and Red Rivers.

City of Devils Lake
Incremental Relocation





NOTES: 1. For this trace,thelakelevelneverreacheselevation1449andtherefore, thedecision trace is only followed for the first twoactionlevels.Theselectionofastrategyat elevation 1449 would not be required for this trace.
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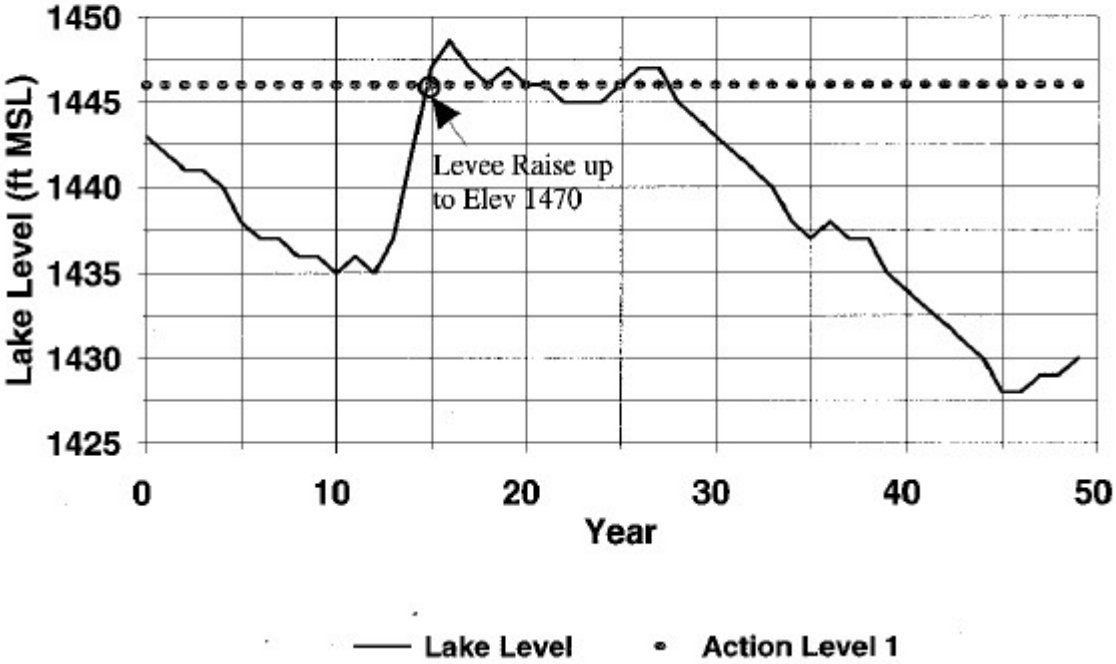
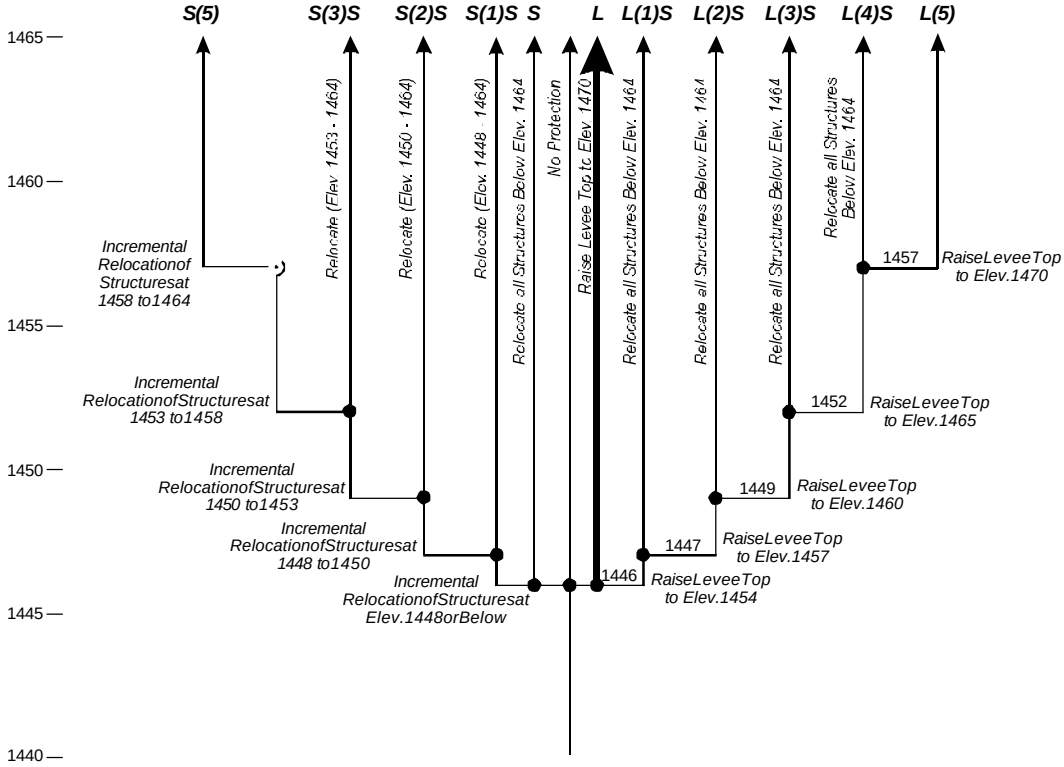
City of Devils Lake

Maximum Levee Raise at First Action Level





NOTE: 1. Thisdecision treeisshownasaexampleonly.Thedecisiontreefor this feature has been updated (See Communities Feature2).

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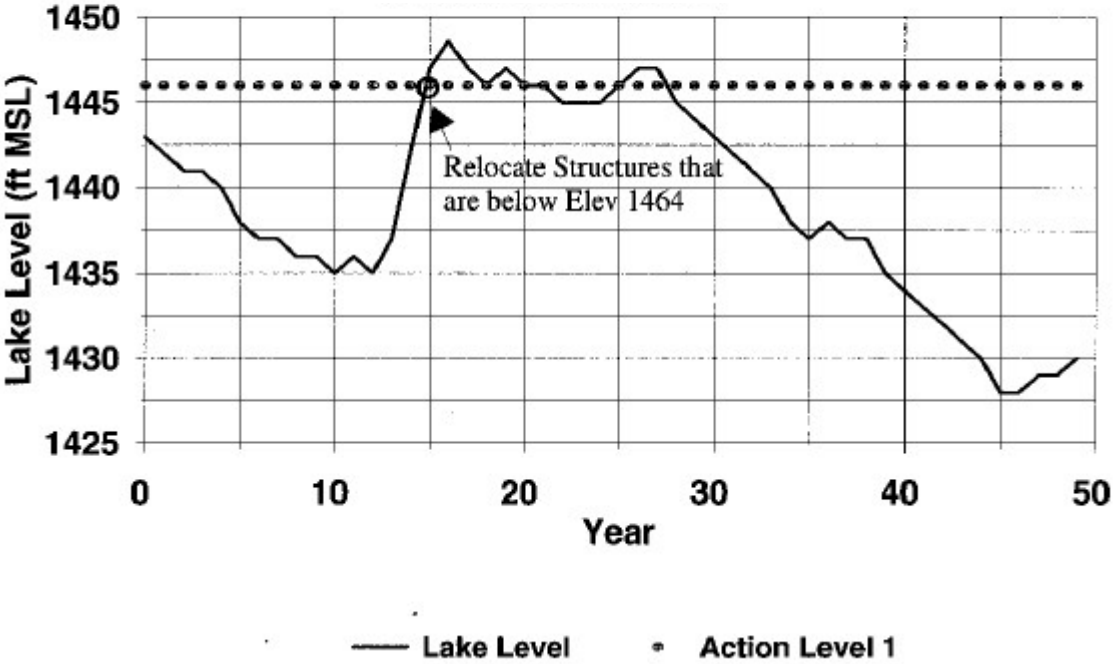
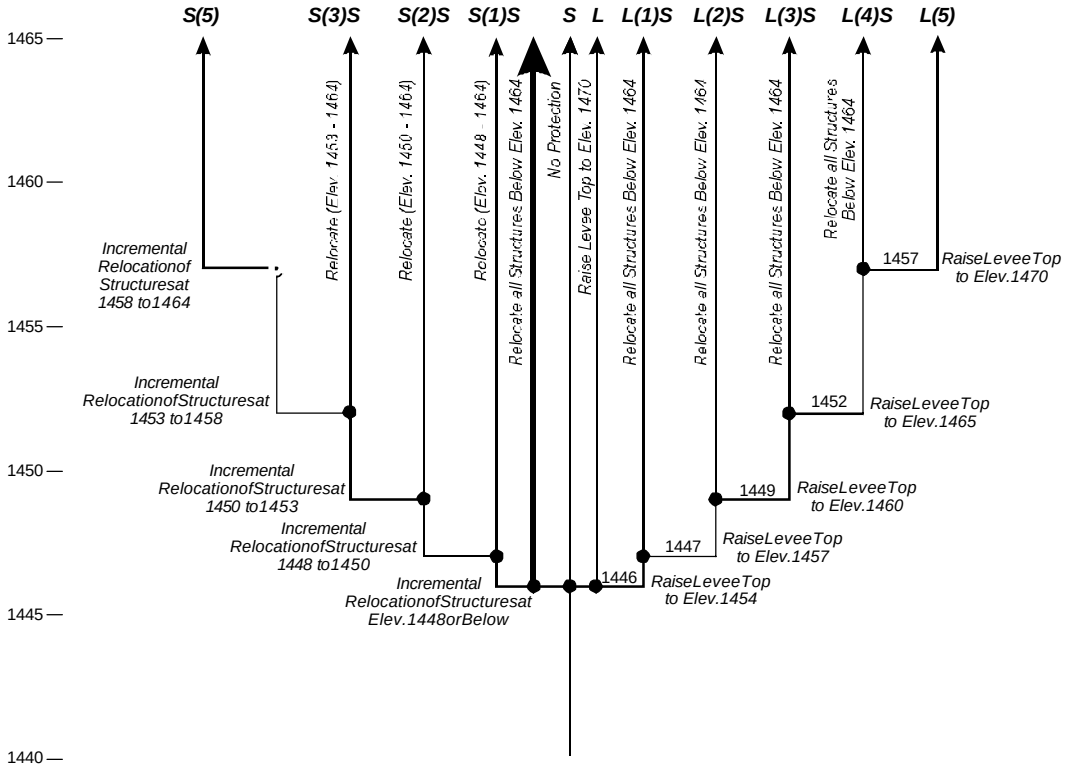
City of Devils Lake
Relocation of All Affected Structures
At First Action Level





NOTE: 1. Thisdecision treeisshownasaexampleonly.Thedecisiontreefor this feature has been updated (See Communities Feature2).

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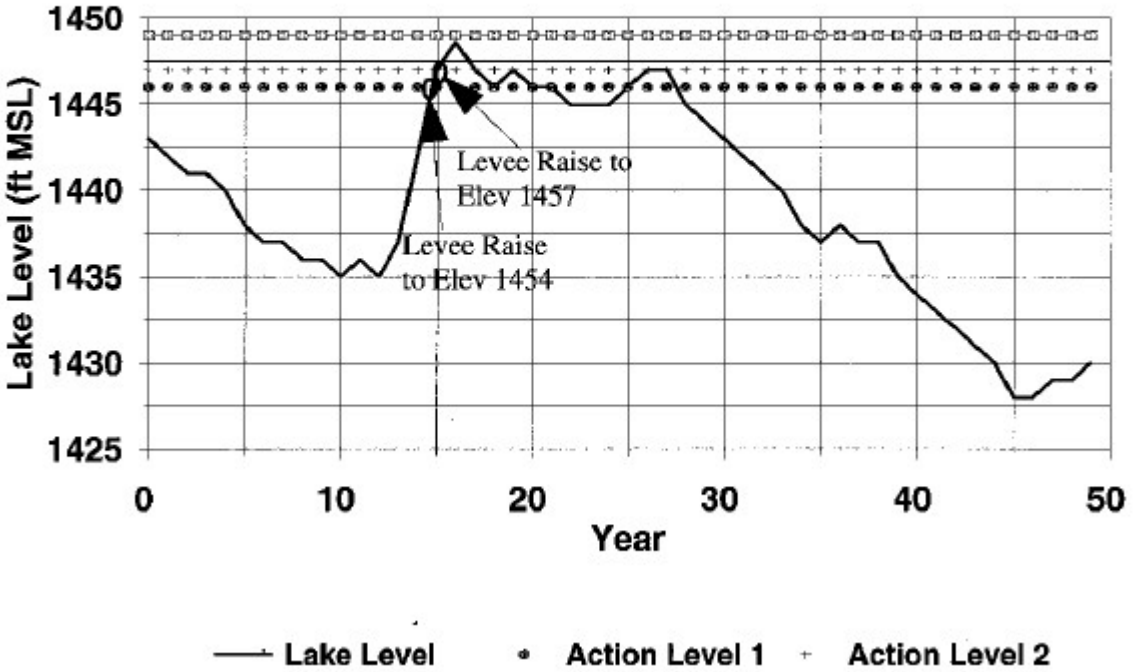
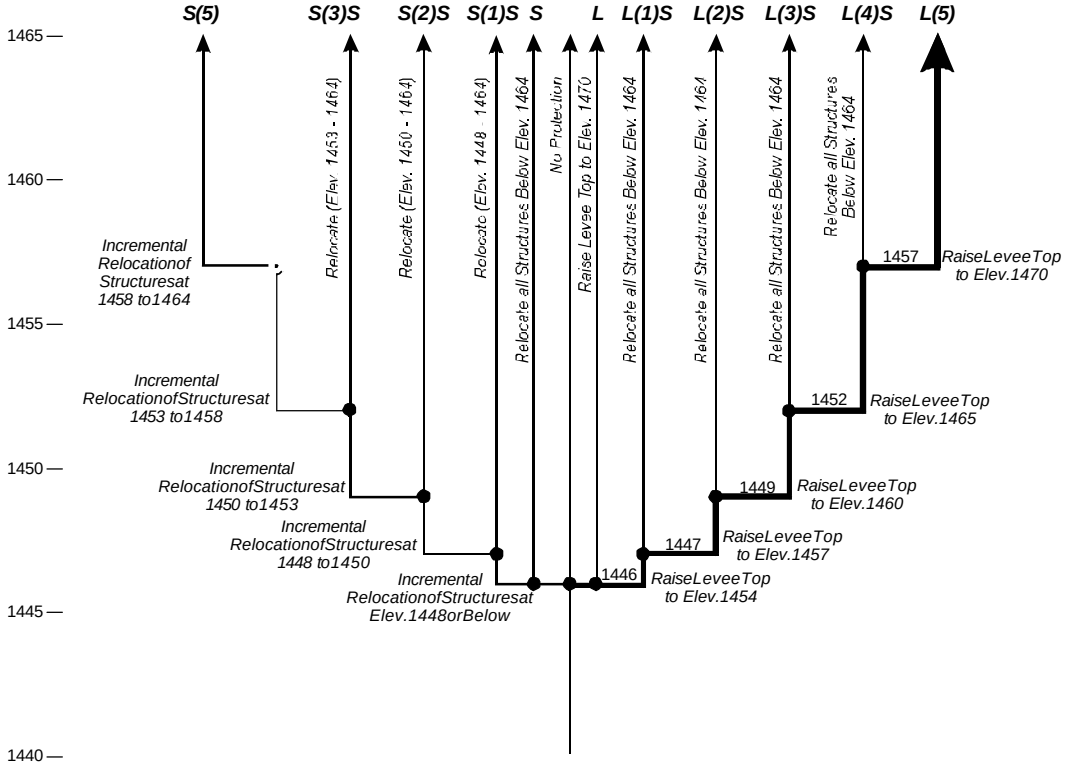
City of Devils Lake
Incremental Levee Raise





NOTES: 1. For this trace,thelakelevelneverreacheselevation1449andtherefore, thedecision trace is only followed for the first twoactionlevels.Theselectionofastrategyat elevation 1449 would not be required for this trace.
2. Thisdecision treeisshownasaexampleonly.Thedecisiontreefor this feature has been updated (See Communities Feature2).

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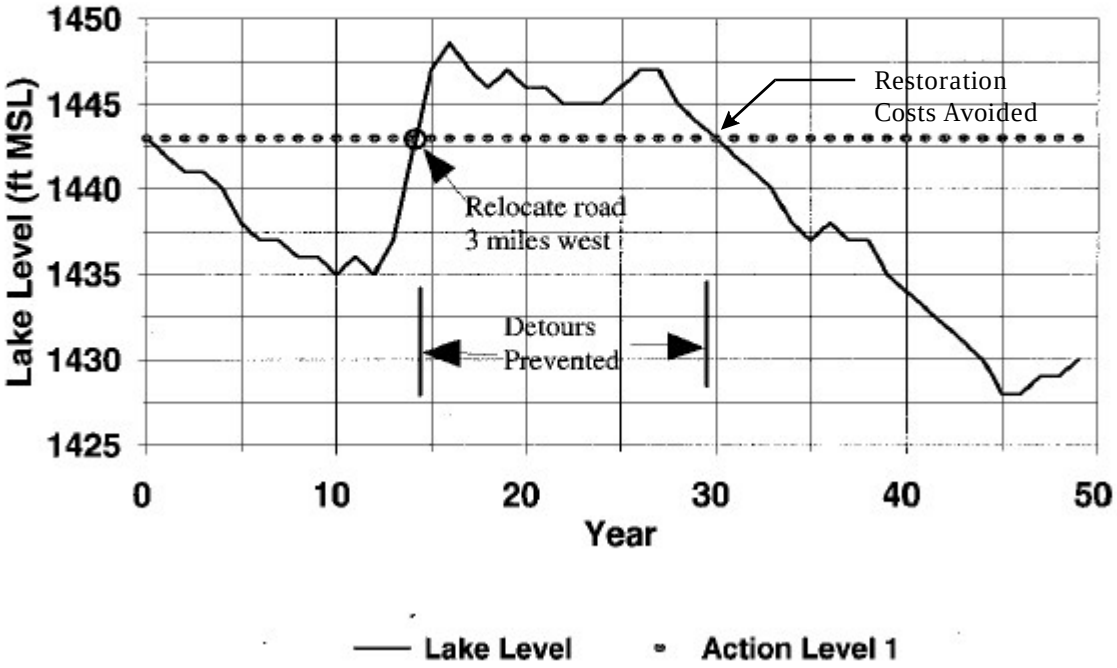
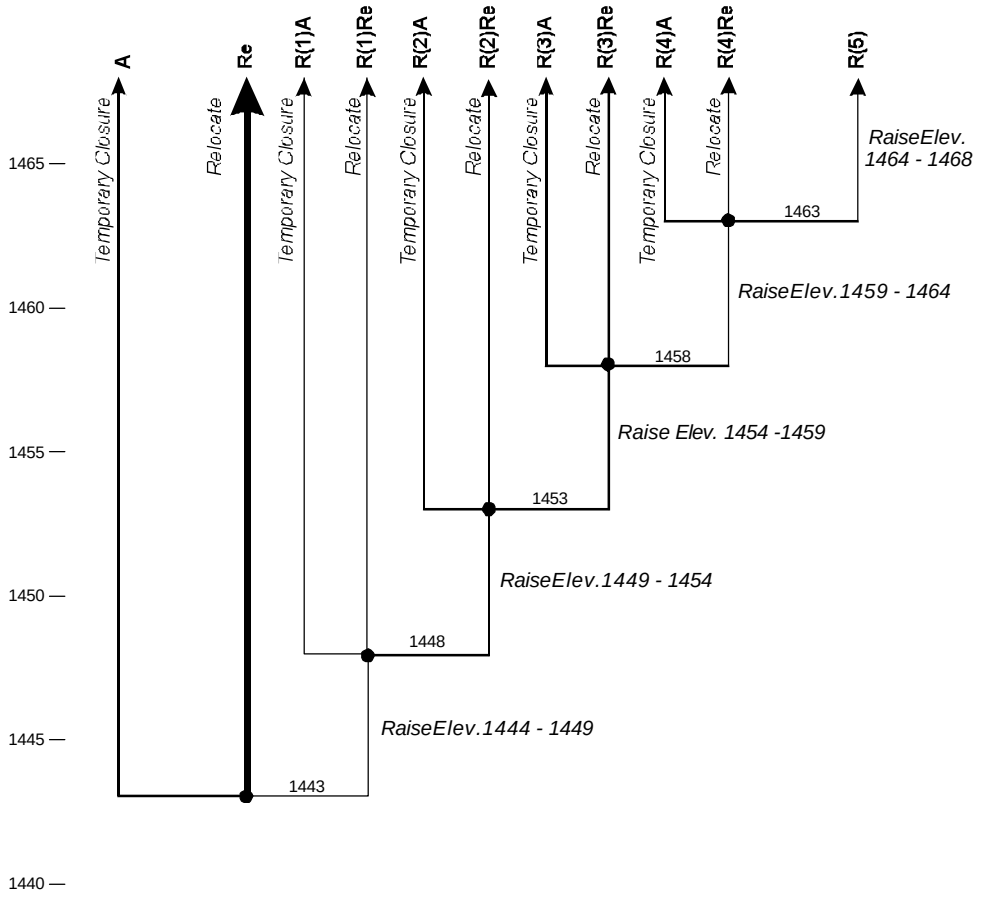
Highway 281
Relocate Road at First Action Level





LowestRoadElevation: 1444

NOTE: 1. Thisdecision treeisshownasaexampleonly.Thedecisiontreefor this feature has been updated (See Roads Feature16).

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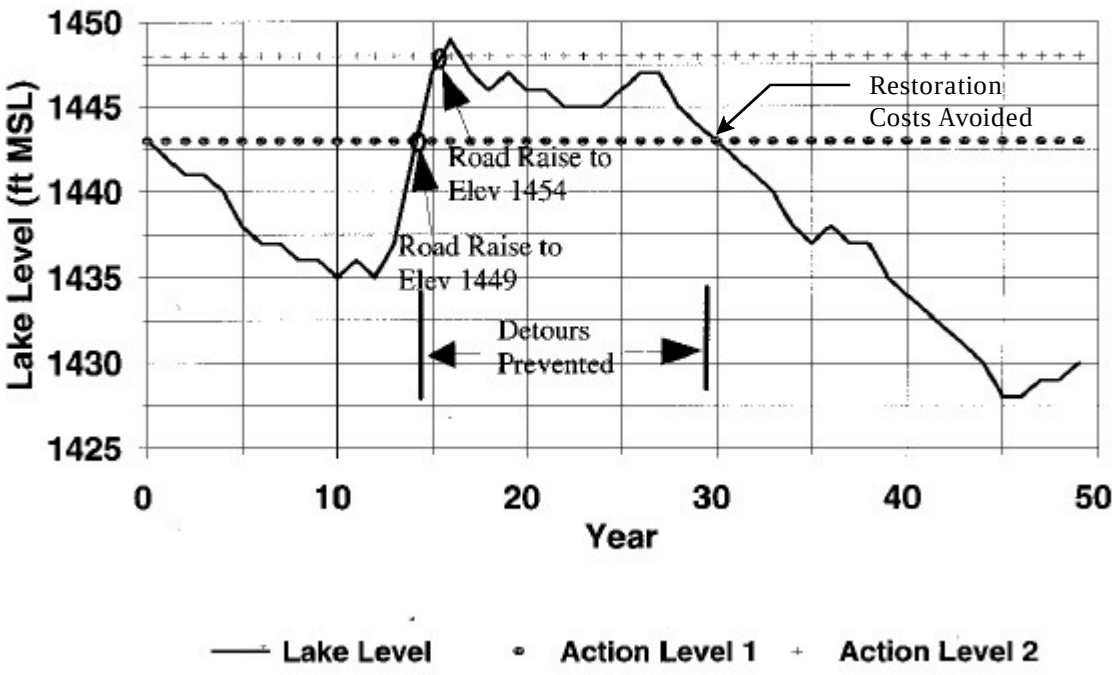
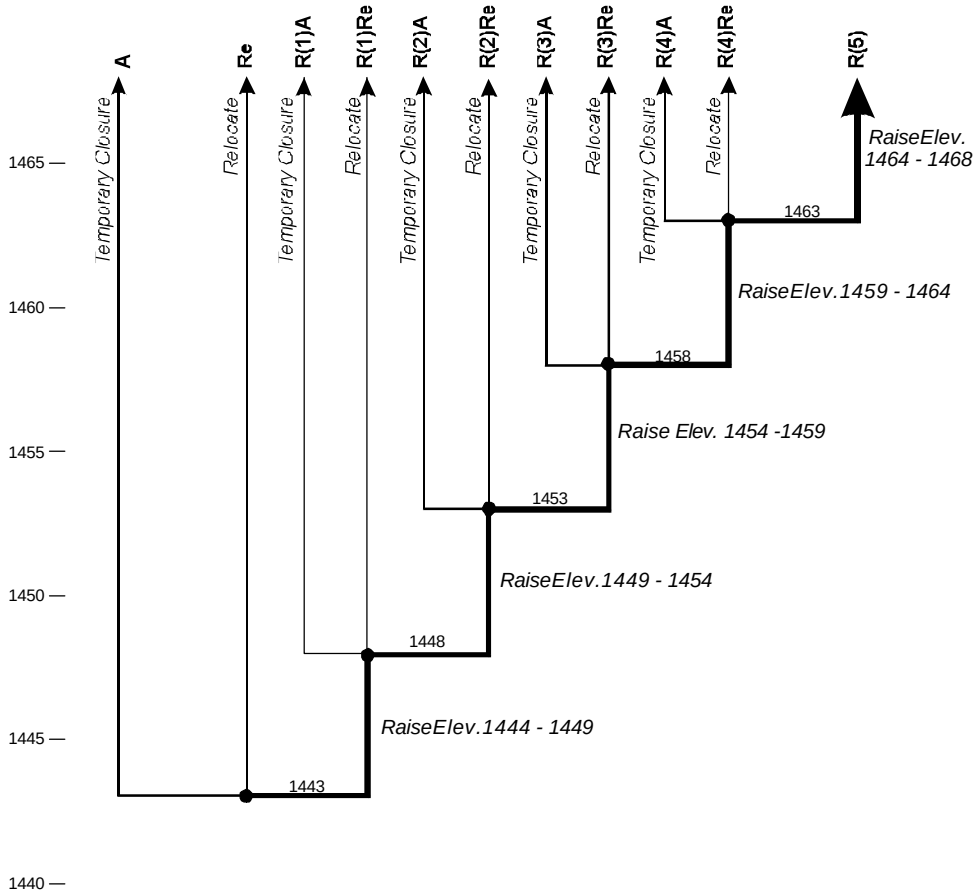
Highway 281
Incremental Road Raise





LowestRoadElevation: 1444

NOTES: 1. For this trace,thelakelevelneverreacheselevation1449andtherefore, thedecision trace is only followed for the first twoactionlevels.Theselectionofastrategyat elevation 1449 would not be required for this trace.
2. Thisdecision treeisshownasaexampleonly.Thedecisiontreefor this feature has been updated (See Roads Feature16).

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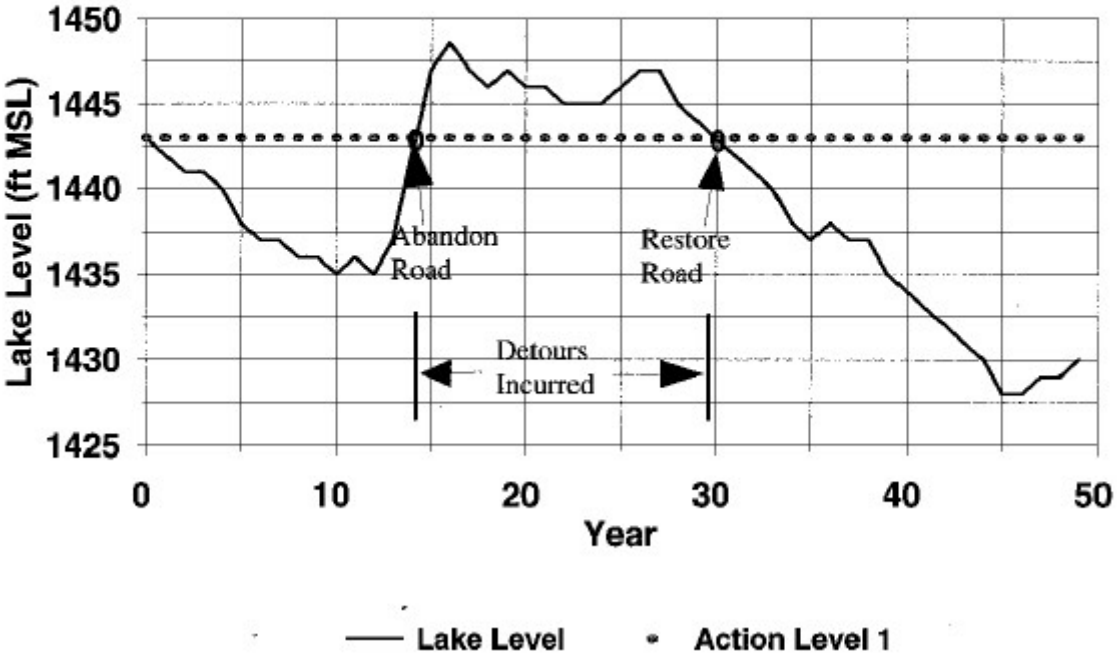
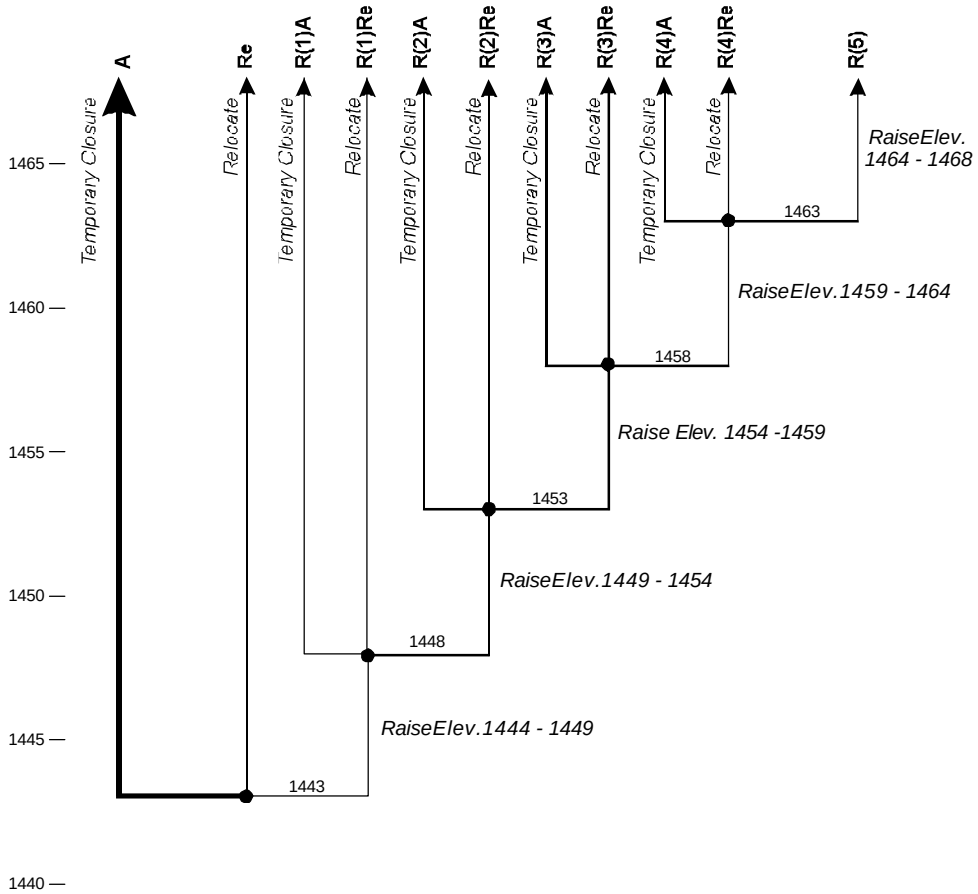
Highway 281
Temporary Road Closure During Flooding





LowestRoadElevation: 1444

NOTE: 1. Thisdecision treeisshownasaexampleonly.Thedecisiontreefor this feature has been updated (See Roads Feature16).

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Technical Appendix
Part I
Economic Analysis of Devils Lake Alternatives
Attachment I.C

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Communities

Overall Description

This section lists the major assumptions for each city or community analyzed. The large number of features and possible strategies required the use of approximate data for evaluation of costs and benefits. While this is appropriate for evaluation of the overall project, it is important to make the assumptions and approximations clear. With this information, local authorities will understand the level of accuracy of the analysis of individual features and will be able to judge the need for additional study for any given feature.

Section I.2.3.2 of Part I includes a detailed discussion of the viability of levees as a community flood protection measure at high lake levels. Seepage problems would be expected in isolated areas, where structures are in contact with a permeable granular soil. These seepage issues could typically be alleviated by installation of draintile systems and sump pumps.

Algorithms used to calculate costs and damages for each feature have not been included in this attachment. The algorithms can be found in the *Devils Lake Limits Study: An Economic Evaluation of the Emergency Outlet* by Barr Engineering Company (July, 1998).

Note: Much of the data used in this analysis was obtained in 1998 for the *Devils Lake Limits Study: An Economic Evaluation of the Emergency Outlet*. In the following pages of this attachment, ”in 1998” refers to this data.

Feature 1. Churchs Ferry

A. General Assumptions

1. Farmland losses were not included in this feature. These losses were included in Feature 8.1: Devils Lake Rural Areas.

B. Levees

1. It was assumed that the existing levee would not be raised because the cost of raising it would greatly exceed the value of the few structures that it would protect.

2. The top of the existing levee is at elevation 1451.5.

C. Residential And Commercial Property

1. For relocation strategies, a decision was assumed to be made when the lake is 1 foot below the level of the low structure. This was based on the existing process which is influenced by the availability of movers, the estimated lake rise each spring, and the restrictions of funding programs. Depending on the slope of the land, wave action may affect structures several feet above the lake's level.

2. The average relocation cost for a house is $68,000. This cost was obtained from the North Dakota - North Central Planning Council and represents the average cost to relocate a residence during the buyout program conducted in Churchs Ferry last year (2000). The $68,000 includes the following costs: demolition of the existing house, purchase of an equivalent house in a nearby community, purchase of a lot, and legal, appraisal, and management fees. Only 3 residents decided to forego the buyout offer, all of which are located between 1456 and 1464.

3. The cost for relocation/rebuilding of commercial and public facilities was assumed to be 100% of the value of the structure and property.

4. In 1998, the grain elevator had an insured value of $5.1 million according to Jarvis Haugeberg, grain elevator operator. This value was updated for inflation by multiplying it by the ENR Building Cost Index of 1.042. This accounts for 4.2% inflation during the period from 1998 to February 2001. The updated value is $5.3 million.

5. The 1998 average depreciated replacement value of a house was estimated to be $24,000 (*Economics Database Update for the Lands and Developments Feasibility Study, Devils Lake,* Watts & Associates, Inc., October, 1997). According to the Ramsey County Assessor, the remaining houses in Churchs Ferry are worth ½ of their 1998 value. Therefore, the average value of the 3 remaining houses in Churchs Ferry was estimated to be $12,000.

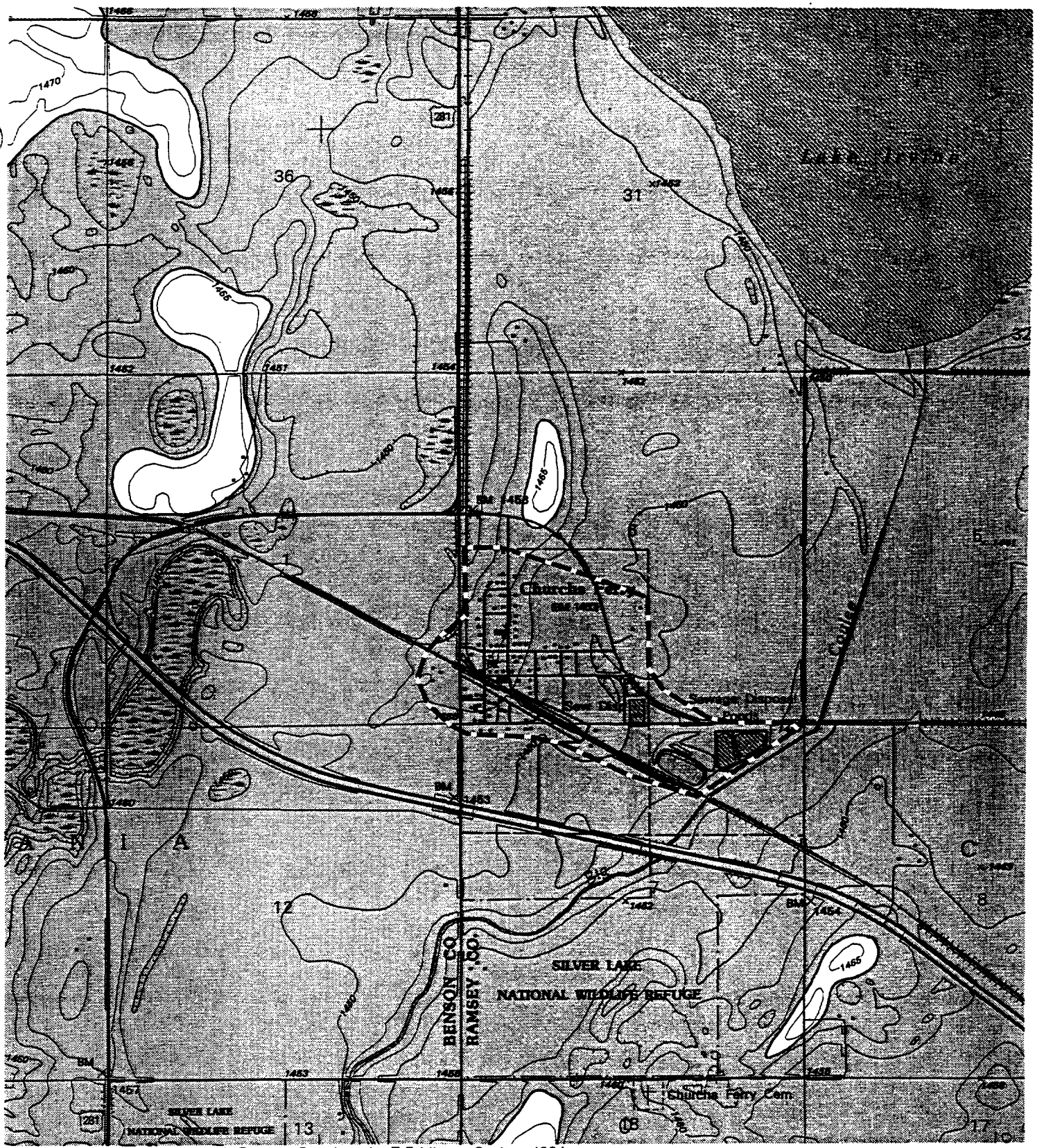
6. In 1998, the value of the church was estimated to be $100,000, including the value of the parcel. This value was updated for inflation by multiplying it by the ENR Building Cost Index of 1.042. This

accounts for 4.2% inflation during the period from 1998 to February 2001. The updated value is $104,000.

7. The existing Sewage lagoons are serving only the 3 remaining residences. The cost to protect the lagoons is $150,000, which is greater than the value of these 3 homes. Therefore, it was assumed that if the lake rose to the level of the lagoons, they would be abandoned and damages would be ignored.

Feature 1 Figures and Tables

Figure I.C.1.A Churchs Ferry Map
Figure I.C.1.B Feature 1: Decision Tree
Table I.C.1.A Feature 1: Cost and Damage Table
Table I.C.1.B Feature 1: Inventory Sheet



Source: Churchs Ferry, North Dakota Quadrangle, 7.5 Minute Series, 1994.

N

0 2000 4000

Scale in Feet

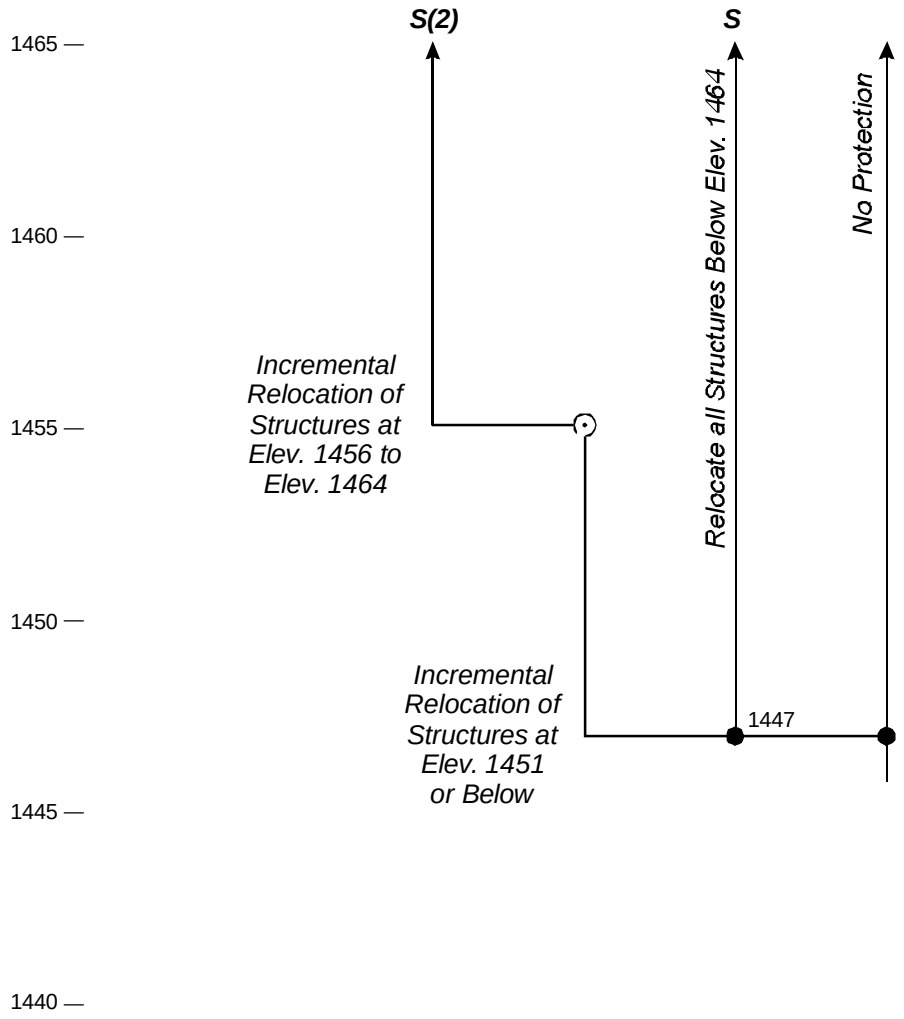
Area Inundated at Elevation 1463

Alignment of Potential Levee

CHURCHS FERRY

Feature No. 1

CHURCHS FERRY



- ● Decision required at this point
- ⊙ Trigger point for action, no decision needed
- ***L(1)*** Incremental levee raise (number of times)
- ***L*** Levee raise to Elev. 1468
- ***S(1)*** Structure relocation (number of times)
- ***S*** Relocate all structures below Elev. 1464
- — — — Strategy not analyzed

Feature No. 1

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.1.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 1 - Churchs Ferry

COSTS

Lake Elevation (MSL)	S(2) Incremental Relocation at AL1, AL2	S Relocate All Structures at AL1
	THOUSANDS	
1445	$0	$0
1446	$0	$0
1447	$5,314	$5,591
1448	$0	$0
1449	$0	$0
1450	$0	$0
1451	$0	$0
1452	$0	$0
1453	$0	$0
1454	$0	$0
1455	$277	$0
1456	$0	$0
1457	$0	$0
1458	$0	$0
1459	$0	$0
1460	$0	$0
1461	$0	$0
1462	$0	$0
1463	$0	$0

Note: AL = Decision/Action Level

DAMAGES

Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy.

Lake Elevation (MSL)	Structures and Infrastructure (THOUSANDS)
1445	$0
1446	$0
1447	$5,314
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$140
1456	$0
1457	$0
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.1.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 1 - Churchs Ferry

Decision/Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1447	Incremental Relocation	Grain Elevator		$5,314,000		$5,314,000
			Total	**$5,314,000**	**Total**	**$5,314,000**
1455	Incremental Relocation	House	3 @ $68,000 each	$204,000	3 @ $12,000 each	$36,000
		Church	1 @ 70% of $104,000	$73,000	1 @ $104,000	$104,000
			Total	**$277,000**	**Total**	**$140,000**

The maximum protection strategy cost for this feature (relocation of all structures at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

Feature 2. City of Devils Lake

A. General Assumptions

1. The area included in the City of Devils Lake feature is the land currently protected by the levees and the area within the Devils Lake city limits.

2. For relocation strategies, structures were assumed to be relocated to high ground north and/or east of the existing city (as discussed in Part I, Section I.2.4.1). A precise location was not determined, since the cost of relocation would not be significantly different.

3. Existing levees were assumed to be built to elevation 1452, based on plans for work performed in 1998 (*Devils Lake, ND Bi-Weekly Report*, St. Paul District Corps of Engineers, January 22, 1998).

4. The value of land outside of the Devils Lake city limits was estimated to be $400 per acre (*Corps of Engineers,* April, 2001)

5. The values of the properties described below were determined in 1998. These values were updated for inflation by multiplying them by 1.09, which accounts for an inflation rate of 3% per year from 1998 to February 2001. This inflation rate was obtained from the Devils Lake City Assessor.

   a. The value of land for airport relocation was estimated at $500 per acre in 1998. The updated value is $545 per acre.

   b. The estimated value of commercial property within the Devils Lake city limits was $10,000 per acre in 1998. The updated value is $10,900 per acre.

   c. The estimated value of parkland within the Devils Lake city limits was $5,000 per acre in 1998. The updated value is $5,450.

6. The cost of rebuilding or relocating utility systems and associated features was included in relocation strategies. These costs do not address the costs of demolition of the existing features. Detailed review of demolition costs was beyond the scope of this study.

7. For all relocation strategies, raising portions of both Highway 20 and US Highway 2 behind the levee to the maximum level was included in the relocation costs at the first action level when a relocation strategy was chosen. The analysis assumed the section of highways behind the existing levees was raised in one increment up to elevation 1468. US Highway 2 was assumed to be relocated to higher land adjacent to the Burlington Northern Railroad tracks, for close proximity to the high ground in the downtown area.

B. Levees

1. A decision was assumed to be made when the lake is 1 foot below the design level of protection (i.e., 1 foot below the lower limit of the required freeboard of a levee).

2. It was assumed that the existing levees are built with adequate base to raise the levee to elevation 1460. The parameters used to design the existing levees allow for a 15-foot top width at elevation 1460, with a 6H:1V lakeward slope and 3H:1V landward slope.

3. Proposed incremental levee raises to elevation 1460 were based on plans by the Corps of Engineers.

4. The freeboard for the existing levee is 7 feet with the top of levee at 1457.

5. The levee raise from elevation 1460 to 1470 will require filling on the landward side of the existing levee. The estimated costs of a levee raise from elevation 1460 to 1465 included adequate overbuild for a future raise to elevation 1470. The top width of the levee at elevation 1465 would be 60 feet.

6. The cost of stripping additional topsoil between each levee raise was considered to be incidental. The cost of stripping topsoil to extend the levee on undisturbed ground was included.

7. Based on a brief review of an air photo, 9,000 linear feet of tree removal was estimated to be required above elevation 1460. The costs for the levee raise from elevation 1460 to 1465 included the cost of clearing 20 acres to widen the levee base to the maximum width and extend the levee over previously undisturbed areas. The costs for the levee raise from elevation 1465 to 1470 included the cost of clearing 10 acres to extend the levee over previously undisturbed areas.

8. The costs of incremental levee raises and pump modifications were determined in 1998. These costs were updated for inflation by multiplying it by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

C. Residential and Commercial Properties

1. In 1998, the assessed values of residential and commercial structures were obtained from the municipal GIS database. These values were increased based on data from the City of Devils Lake Assessor for the period from 1998 to February 2001. Values were multiplied by a factor of 1.075 (to account for new development of 2.5% per year) and a factor of 1.09 (to account for inflation of 3% per year).

2. For relocation strategies, a decision was assumed to be made when the lake is 1 foot below the level of the low structure. This was based on the existing process which is influenced by the availability of movers, the estimated lake rise each spring, and the restrictions of funding programs. Depending on the slope of the land, wave action may affect structures several feet above the lake's level.

3. On the 1994 USGS quadrangle map, small buildings outside the Devils Lake city limits were assumed to denote single residential dwellings. Each square was counted as a single residence, unless field investigation indicated otherwise (i.e., structure was already gone or abandoned or the structure was a garage instead of residential dwelling). Additional residences that were not indicated on the quadrangle map were counted based on visits to the city.

4. Subdivision boundaries in the Creel Township area were identified based on visits to the city (*Devils Lake Creel Township Levee Assessment*, Barr Engineering Company, August 20, 1997). Average values of residences within these boundaries were obtained from the 1997 report. These values were multiplied by a factor of 1.075 (to account for new development of 2.5% per year) and a factor of 1.09 (to account for inflation of 3% per year) for the increase during the period from 1998 to February 2001.

5. The value of residences outside of the Devils Lake city limits (described in item number 3 above) were estimated based on the 1998 residential average within the city (from the municipal GIS database). These values were multiplied by a factor of 1.075 (to account for new development of 2.5% per year) and a factor of 1.09 (to account for inflation of 3% per year) for the increase during the period from 1998 to February 2001. Specific assumptions for the 1998 values included:

   a. If a residence was part of "small tracts of land" in the Midland Atlas, the average value used for the residential dwelling was $41,950 (lot value and improvement value). The updated value is $49,950.

   b. If a residence was on land with an identified owner in the Midland Atlas, the lot value was estimated by multiplying the parcel size shown in the Midland Atlas by $300 per acre (the agricultural land value). This lot value was added to $34,664 per residential dwelling, the estimated average improvement value, to give a total value for lot and improvements. The updated values are $400 per acre for lots and $40,620 for improvements.

   c. In the absence of flood protection measures, damages were assumed to occur at the lowest elevation at which a residential structure was affected by rising lake levels. Land could d be affected at lower elevation but this land loss was not included until the dwelling was affected. Seepage into basements was not considered.

6. On the 1994 quadrangle map, larger plain rectangles (not small squares) outside the Devils Lake city limits were assumed to denote commercial buildings. Each rectangle was counted as a single commercial building.

7. Commercial buildings outside of the Devils Lake city limits were assumed to have average values based on the 1998 commercial average within the city (from the municipal GIS database). These values were multiplied by a factor of 1.075 (to account for new development of 2.5% per year) and a factor of 1.09 (to account for inflation of 3% per year) for the increase during the period from 1998 to February 2001. Specific assumptions for the 1998 values included:

   a. If a commercial building was part of "small tracts of land" in the Midland Atlas, the average value of the commercial building used was $94,785 (lot value plus improvement value). The updated value is $111,060.

   b. If a commercial building was on land with an identified owner in the Midland Atlas, the lot value was estimated by multiplying the parcel size shown in the Midland Atlas by $300 per acre (the

agricultural land value). This lot value was added to $74,743 per commercial building (the estimated average improvement value) to give an estimated total value of lot and improvement. The updated values are $400 per acre for lots and $87,580 for improvements.

c. In the absence of flood protection measures, damages were assumed to occur at the lowest elevation at which a structure was affected by rising lake levels. Land could be affected at lower elevations but these losses were only included at the elevation at which the structure began to be affected.

8. The area identified as "Bible Camp" on the 1994 quadrangle map was outlined based on field observation (Lakewood Bible Camp). The structures within the Lakewood Bible Camp boundaries were not included in the above residential or commercial values.

   a. All but one small building (small square on topo) was at an elevation greater than 1465. Although the buildings in the Camp are on high ground, the Bible Camp would be surrounded by the lake without the existing levee and it would not have access. Therefore, for all relocation strategies, the entire camp was assumed to be damaged at the first relocation action level, with damages assumed to occur at that level.

   b. The replacement cost of the Bible Camp was assumed to be the insured value of the structures. In 1998, the insured value was $2,462,000. This value was multiplied by a factor of 1.09, to account for inflation of 3% per year, during the period from 1998 to February 2001. The updated value is $2,683,580.

9. The value of the golf course was assumed to be $2,300,000 (*Devils Lake Creel Township Levee Assessment*, Barr Engineering Company, August 20, 1997). This value is in 1998 dollars; therefore it was multiplied by a factor of 1.09, to account for inflation of 3% per year, during the period from 1998 to February 2001. The updated value is $2,500,000.

10. Land in the Midland Atlas that had a total acreage, but did not have structures noted on the quadrangle map, was valued at $400 per acre (the agricultural land value as stated above).

11. In the absence of flood protection measures, damages to structures were assumed to occur at the lowest elevation at which structures were affected, except as follows:

   a. Damages to the golf course were assumed to occur at the first action level where the levee is not raised. The golf course is protected by the city levee and damages would only happen if the levee was abandoned; the first potential abandonment would be at action level 1450. Assuming there was no levee at elevation 1450, a large portion of the golf course would be inundated by the lake, and the golf course was assumed to be inoperable.

   b. Damages to land that contains no structures or improvements were estimated to occur at the lowest elevation at which the land was affected. Damages to land were grouped between action levels, and were assumed to occur when the water surface is 1 foot below the action level. This

may ‘front-end load’ the damages; however, only small parcels of land were analyzed for this feature, and the effects of this assumption are not expected to be significant. Conversely, wave action could affect land several feet above the lake’s level and, therefore, actual damages might occur before the lake reaches the parcel’s lowest elevation.

c. The Bible Camp is excepted as noted in item 7 above.

12. Land outside the city limits that is within the assumed levee alignment and above the maximum lake level would become isolated and inaccessible if the levee is not raised and the lake rises to 1463. The values for the land and structures in these isolated areas were calculated and included as damages for relocation strategies. Conversely, for strategies where levees remain in place, these amounts were included as damages prevented.

13. In the absence of the existing levee, the subdivision located southwest of the intersection of Highway 20 and Ramsey County 1 would become isolated and surrounded by the lake above elevation 1440. However, the access road is relatively short and the costs of raising the access would be minimal compared to the costs of relocating the subdivision. Because Highway 20 within the levee is assumed to remain open with or without the levee in place, the area was assumed to have access even if the existing levee was removed. For relocation strategies, relocation of these houses was assumed to occur at the elevation of the structure (not the elevation at which the area becomes isolated). Similarly, for levee strategies, damages prevented for this area were assumed to occur at the elevation of the structures.

14. All structures and property below elevation 1450 were grouped to compute damages in the absence of flood protection measures. For relocation strategies, when the lake reaches action level 1449 (1 foot below the level of protection of the existing levee), all structures within the current levee alignment that are below elevation 1450 would be relocated.

15. In the absence of flood protection measures, damages to structures and property were assumed to be equal to the depreciated replacement values discussed above. Conversely, if protection is provided, all or a portion of the potential damages would be treated as damages prevented.

16. The costs for relocating or rebuilding commercial structures were estimated to be 100% of the assessed value of the improvement and 100% of the assessed value of the lot.

17. The costs for relocation of residential structures were estimated to be 70% of the assessed value of the improvement and 100% of the assessed value of the lot.

D. Public Properties

1. **The values and costs for the public property described below in items 2 – 6, were determined in 1998. These 1998 dollars were multiplied by a factor of 1.09 to account for inflation of 3% per year during the period from 1998 to February 2001. This inflation rate was obtained in conversations with the Ramsey County Assessor and the City of Devils Lake Assessor.**

2. Estimated values for property owned by Ramsey County were based on telephone conversations with staff at the County Assessor's office.

3. Estimated values for properties owned by the City of Devils Lake were based on telephone conversations with Gary Martinson, City Assessor.

4. The value of public properties was based on the estimated insured replacement values of the structures.

5. In the absence of flood protection measures, relocation or rebuild costs were assumed to equal the value of the structure.

6. Relocation costs for the cemetery are based on telephone conversation with the City Assessor. The cemetery charges $300 to move a burial. Assuming that relocating the cemetery would result in further moving distances, $500 was used for moving each burial. Relocation included the cost to purchase 80 acres of new land at $300 per acre and relocating 8,000 burials at $500 each. The updated values are $400 per acre for land and $545 per burial for relocating. In the absence of flood protection measures, damages to the cemetery included 80 acres at $1,000 per acre and 8,000 burials at $500 each. The updated values are $1,090 per acre for land and $545 per burial for relocating.

E. School and Churches

1. **All costs and values described below in items 2 – 6 were determined in 1998. These 1998 dollars were multiplied by a factor of 1.075 (to account for new development of 2.5% per year) and a factor of 1.09 (to account for inflation of 3% per year) for the increase during the period from 1998 to February 2001. These inflation rates were obtained in conversations with the City of Devils Lake Assessor.**

2. For schools and churches, insured values of the structure were used when available. According to the City Assessor, insured replacement values are typically much greater than assessed values. Therefore, land values were not added to determine the total value. Insured values for several schools were obtained from telephone conversations with the Devils Lake school administrator. Insured values for several churches were obtained from telephone conversations with church administrators. All other school and church values were estimated using *RS Means Building Construction Cost Data, 56th Annual Edition*, 1998. If only total insured values were provided, the structure was assumed to have a value of 75% of the total insured value.

3. Insured values included the value of only the structures. The insured value of contents was not included in the insured value.

4. Several institutions between elevation 1460 and 1462 were assumed to be relocated or rebuilt for the relocation strategies. It appears likely that several of these facilities could be protected with a ring dike or levee more economically than they could be relocated, provided that access is maintained. However, this study did not analyze this option.

5. The relocation or rebuild cost was assumed to be 100% of insured value of the structure.

6. In the absence of flood protection measures, damages were assumed to be 100% of insured value of the structure.

F. Utilities

1. **The costs of relocating utilities described below in items 2 – 9 were obtained in 1998. These 1998 dollars were updated for inflation by multiplying it by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.**

2. Individual utility service connections were included with assessed lot values. However, the cost to replace utility infrastructure was calculated separately for relocation strategies and to determine the benefit provided for flood protection measures.

3. Gas main costs associated with relocation strategies were based on discussions with Montana Dakota Utilities (MDU) staff. In the absence of flood protection measures, damages were assumed to equal the relocation or rebuild cost. Costs were distributed on a per-user basis.

4. Relocation costs for electrical infrastructure were based on conversations with Otter Tail Power staff. In the absence of flood protection measures, damages were assumed to equal the relocation cost.

5. Relocation costs for telephone infrastructure were based on conversations with North Dakota Telephone Company staff. In the absence of flood protection measures, damages were assumed to equal the relocation cost. The costs did not include the cost of fiber optic cables. Costs were distributed on a per-user basis.

6. For relocation strategies, costs for the wastewater treatment system were based on conversations with the City Engineer and the City Assessor and on Environmental Protection Agency (EPA) construction costs. The cost includes construction of a new wastewater treatment plant and distribution system and the closing of the existing lagoons. In the absence of flood protection measures, damages were assumed to be 75% of the rebuild cost, due to depreciation of the existing system. Although land application disposal was assumed in this study, the City Engineer indicated that a lagoon system may be required.

7. For strategies that include levee protection, it was assumed that the lagoons would continue to function as the lake continues to rise. A brief analysis of groundwater in the area indicates that it would not affect the operation of lagoons in the area *(Hydrogeology of the Shallow Water Table at the City of Devils Lake, North Dakota*, North Dakota State Water Commission, 1998).

8. For relocation strategies, costs for the water treatment system were based on conversations with the City Engineer and the City Assessor and on EPA construction costs. The cost includes construction of a new plant, a 500,000-gallon water tower, a 3,000,000-gallon reservoir, four supply wells, and a distribution system. The actual system may include tapping into and treating surface water.

However, the scope of the study did not include review of specific treatment system alternatives. In the absence of flood protection measures, advance replacement of infrastructure was assumed to be 75% of the rebuild cost to factor in the effects of depreciation.

9. For relocation strategies, costs for the storm sewer system were based on a conversation with the City Engineer. The cost was based on converting the $7,000,000 upgrade performed in 1978 to 1998 costs using historical cost indexes (*RS Means Building Construction Cost Data, 56th Annual Edition*, 1998). The estimated cost to rebuild the system was $14,968,000. The updated cost is $15,866,080. In the absence of flood protection measures, damages were assumed to be 75% of the rebuild cost due to depreciation. The costs were distributed on a per-user basis.

G. Devils Lake Airport

1. **The costs to relocate the airport and build a runway extension, described below in items 2 – 6, were determined in 1998. These costs were updated for inflation by multiplying the airport by a factor of 1.09 (to account for an inflation rate of 3% per year) and the runway extension was multiplied by the ENR Construction Cost Index of 1.06 (to account for 6% inflation from 1998 to February 2001). The inflation rate was obtained from the City of Devils Lake Assessor.**

2. Airport relocation costs were developed based on telephone conversations with the Airport District Engineer and the airport consultant at the firm of Kadrmis, Lee & Jackson.

3. Airport relocation costs included 15% for various engineering, administrative, and environmental review costs. In addition to engineering design, the relocation of the new airport would require detailed studies including preparation of an Environmental Impact Statement (EIS) to assess the social, economic and environmental effects of the project.

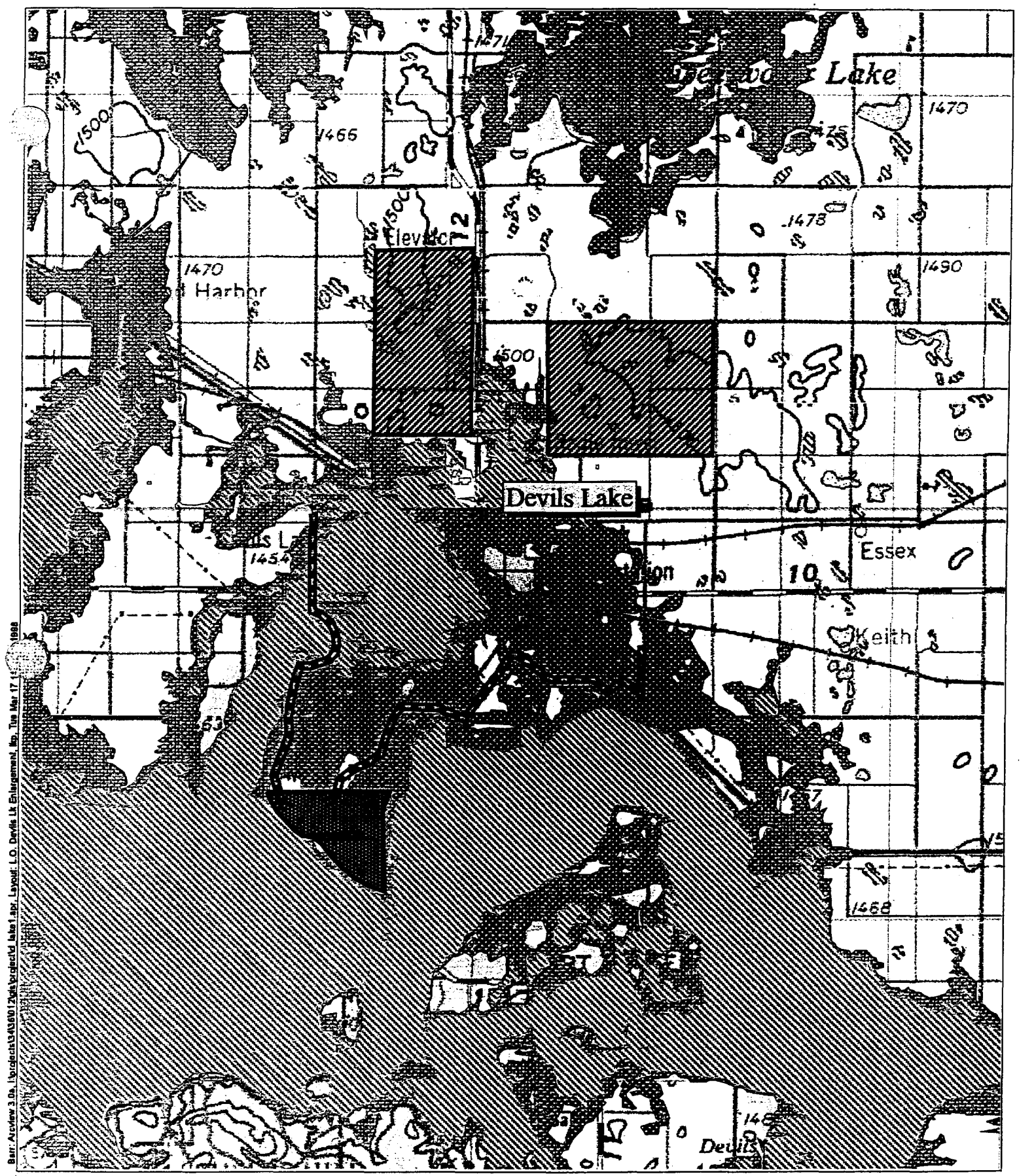
4. Due to depreciation, the value of the existing airport ("damages prevented") was assumed to be 75% of the value to relocate/rebuild.

5. Raising the existing levee to elevation 1457 would require extending Runway 321 by 170 feet due to FAA clearance regulations. The runway extension cost of $261,000 was included in the levee cost at action level 1449. The updated cost is $276,660. This cost does not include the cost to demolish sections of the existing runway that would no longer be useable.

6. Raising the levee to elevation 1465 would require additional expansion of the runway. The estimated cost of $500,000 was assumed to occur at action level 1452. The updated cost is $530,000. Extending the runway in smaller increments was not feasible due to disruption of air traffic. This cost does not include the cost to demolish sections of the existing runway that would no longer be useable.

Feature 2 Figures and Tables

Figure I.C.2.A City of Devils Lake Map
Figure I.C.2.B Feature 2: Decision Tree
Table I.C.2.A Feature 2: Cost and Damage Table
Table I.C.2.B Feature 2: Inventory Sheet



Levee Alignment

Possible Relocation Areas

Devils Lake Elevation at 1443 feet above MSL

Devils Lake Elevation at 1463 feet above MSL

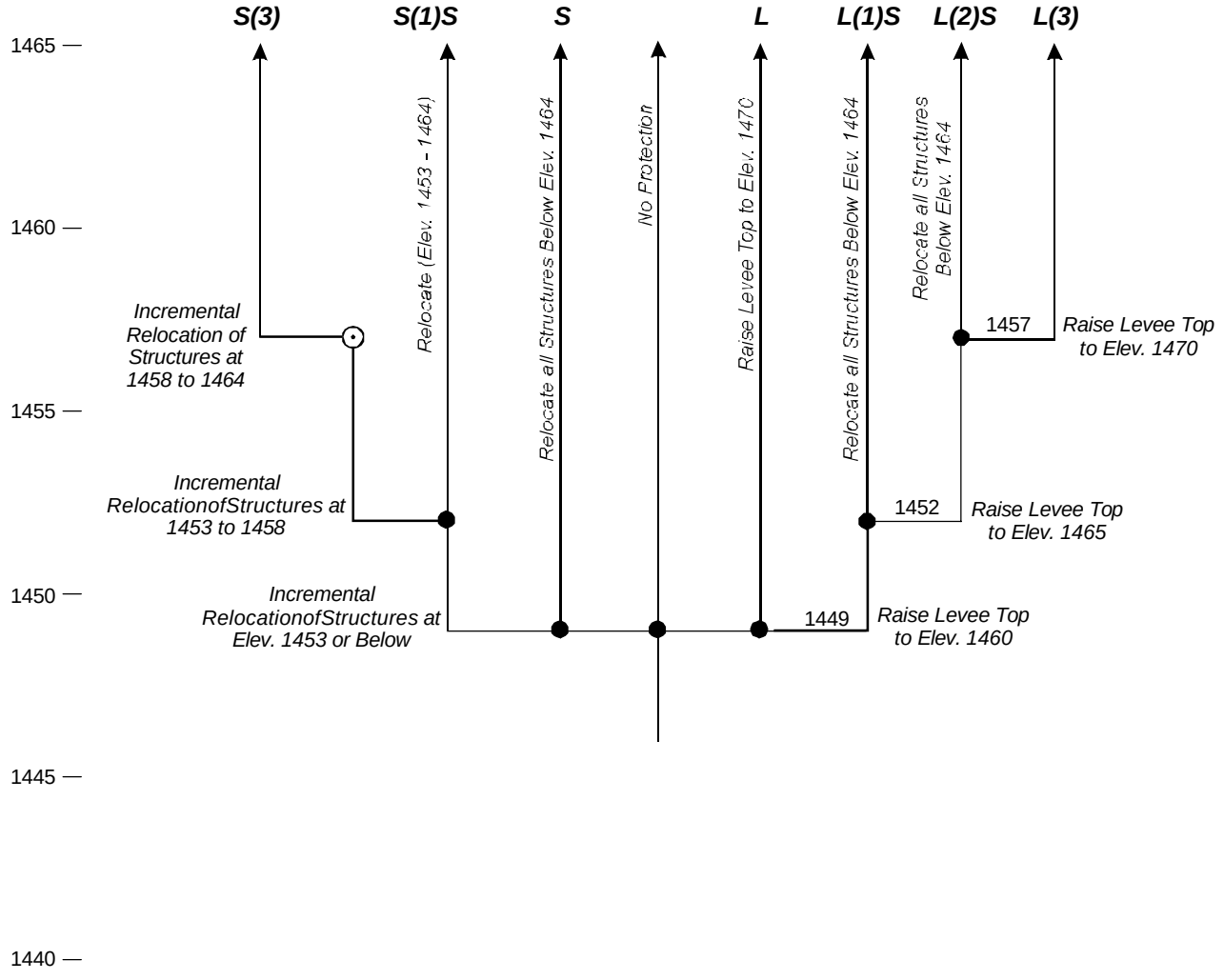
0 1 2 3 Miles

City of Devils Lake

Bar: Arcview 3.0a, I:\projects\3493\6901\2\dls\projectd_lake1.apr, Layout: L.O. Devils Lk Enlargement, Mp, Tue Mar 17 1 1998

Feature No. 2

CITY OF DEVILS LAKE



● Decision required at this point

⊙ Trigger point for action, no decision needed

L(1) Incremental levee raise (number of times)

L Levee raise to Elev. 1470

S(1) Structure relocation (number of times)

S Relocate all structures below Elev. 1464

Feature No. 2

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.2.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 2 - City of Devils Lake

COSTS

Lake Elevation (MSL)	S(3) Incremental Relocation at AL1, AL2, AL3	S(1)S Incremental Relocation at AL1; Relocate All Structures at AL2	S Relocate All Structures at AL1	L Maximum Protection Levee Raise at AL1	L(1)S Raise Levee at AL1; Relocate All Structures at AL2	L(2)S Raise Levee at AL1, AL2; Relocate All Structures at AL3	L(3) Raise Levee at AL1, AL2, AL3
	THOUSANDS						
1445	$0	$0	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0	$0	$0
1447	$0	$0	$0	$0	$0	$0	$0
1448	$0	$0	$0	$0	$0	$0	$0
1449	$199,536	$199,536	$318,597	$81,442	$9,595	$9,595	$9,595
1450	$0	$0	$0	$0	$0	$0	$0
1451	$0	$0	$0	$0	$0	$0	$0
1452	$46,681	$119,061	$0	$0	$318,597	$46,476	$46,476
1453	$0	$0	$0	$0	$0	$0	$0
1454	$0	$0	$0	$0	$0	$0	$0
1455	$0	$0	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$0	$0	$0
1457	$72,380	$0	$0	$0	$0	$318,597	$25,371
1458	$0	$0	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0	$0	$0
1462	$0	$0	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL OPERATION AND MAINTENANCE COSTS

Operation and maintenance costs apply to levee strategies, and include operation and maintenance of pumping stations and levee embankments. These costs are incurred annually, each year that the levee remains in place. This table shows operation and maintenance costs for incremental levee construction. If the maximum protection levee is constructed at the first decision/action level, operation and maintenance costs will be $40,000 from lake elevation 1443 to 1445 and $50,000 from 1445 to 1463.

Lake Elevation (MSL)	Operation and Maintenance (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$6
1450	$6
1451	$6
1452	$7
1453	$7
1454	$7
1455	$7
1456	$7
1457	$11
1458	$11
1459	$11
1460	$11
1461	$11
1462	$11
1463	$11

DAMAGES

Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy.

Lake Elevation (MSL)	Structures and Infrastructure (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$177,259
1450	$0
1451	$0
1452	$50,462
1453	$0
1454	$0
1455	$0
1456	$0
1457	$77,659
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.2.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 2 - City of Devils Lake

Decision/Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1449	Incremental Relocation	Road Raise		$23,979,000		
		Assessed Residential & Commercial		$109,668,000		$124,065,000
		Churches and Schools		$7,403,000		$7,540,000
		Utilities		$42,153,000		$33,160,000
		Airport		$15,712,000		$11,837,000
		City Property		$608,000		$613,000
		Cemetary		$13,000		$44,000
			Total	**$199,536,000**	**Total**	**$177,259,000**
	Incremental Levee Raise	Levee	Length = 48,800 Feet Average Height = 3 Feet	$9,595,000		
			Total	**$9,595,000**	Same as for Incremental Relocation	
1452	Incremental Relocation	Assessed Residential & Commercial		$27,385,000		$34,373,000
		Utilities		$12,974,000		$9,769,000
		City Property		$1,949,000		$1,916,000
		Cemetary		$4,373,000		$4,404,000
			Total	**$46,681,000**	**Total**	**$50,462,000**
	Incremental Levee Raise	Levee	Length = 57,300 Feet Average Height = 5 Feet	$45,925,000		
		Pump Modifications		$21,000		
		Runway Extensions		$530,000		
			Total	**$46,476,000**	Same as for Incremental Relocation	
1457	Incremental Relocation	Assessed Residential & Commercial		$59,430,000		$67,083,000
		Utilities		$11,126,000		$8,782,000
		City Property		$1,824,000		$1,794,000
			Total	**$72,380,000**	**Total**	**$77,659,000**
	Incremental Levee Raise	Levee	Length = 65,800 Feet Average Height = 5 Feet	$22,427,000		
		Pump Modifications		$2,944,000		
			Total	**$25,371,000**	Same as for Incremental Relocation	

The first maximum protection strategy cost for this feature (relocation of all structures at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

The second maximum protection strategy for this feature (maximum protection levee raise at the first decision/action level) is obtained by adding the incremental levee raise costs at each decision/action level shown in this table.

Feature 3. Fort Totten

A. General Assumptions

1. Estimated damages included only the homes in the immediate area of Fort Totten. According to the League of Cities office in Bismarck, the area is not incorporated. The few homes outside of the immediate area were included in computations for Feature 8.1: Devils Lake Rural Areas.

B. Levee

1. A decision was assumed to be made when the lake is 1 foot below the design level of protection (i.e., 1 foot below the lower limit of the required freeboard of a levee).

2. In Fort Totten, most of the houses to be protected are arranged linearly and parallel to the land contours. The levees required to protect the homes would therefore be extremely long. A preliminary cost estimate (1998 dollars) indicated that the cost of construction and maintenance of these levees would be approximately $14 million to protect to the maximum lake level. The cost of incremental levee raises would be $2.5 and $8.5 million at action levels 1446 and 1451, respectively. Since the cost of these levees would be far in excess of the estimated value of the structures at each action level, the levee protection strategy was not pursued further. Therefore, only relocation strategies were analyzed for Fort Totten.

3. For levee protection, it was assumed that 5 feet of freeboard would be required at action levels 1447 and 1451, and that 7 feet of freeboard would be required at the maximum lake level. The assumed freeboard was based on the proposed freeboard for the City of Devils Lake and the high waves predicted for this area.

C. Residential and Commercial Properties

1. For relocation strategies, a decision was assumed to be made when the lake is 1 foot below the level of the low structure. This was based on the existing process which is influenced by the availability of movers, the estimated lake rise each spring, and the restrictions of funding programs. Depending on the slope of the land, wave action may affect structures several feet above the lake's level.

2. The average value of a house in Fort Totten was estimated to be $62,000. This figure was obtained from the Federal Emergency Management Agency (FEMA) and represents the average value of a house located on the Spirit Lake Nation Reservation. The value for each house was determined for FEMA by certified flood insurance adjusters and was based on total habitable square footage of the buildings and standardized real estate appraisals (*FEMA*, personal communication, March, 2001). These values did not include the value of land on which the houses were located.

3. Relocation cost for a house was estimated to be $68,000. This cost was obtained from the North Dakota-North Central Planning Council and represents the average cost to relocate a residence during the buyout program conducted in Churchs Ferry (2000). The $68,000 includes the following costs: demolition of the existing house, purchase of an equivalent house in a nearby community, purchase of

a lot, and legal, appraisal, and management fees. It was assumed relocation costs would be approximately the same in Fort Totten as they were in Churchs Ferry.

4. The disposal ponds located near the lake in the Fort Totten area are no longer in use. New disposal ponds were constructed on higher ground west of this location. The old ponds near the lake had a majority of the wastewater removed by pumping into the new disposal ponds, according to Neil Austin of the Spirit Lake Nation Indian Health Service. There is still a direct pumping pipeline from the old disposal ponds to the new ponds. The pipeline serves two purposes:

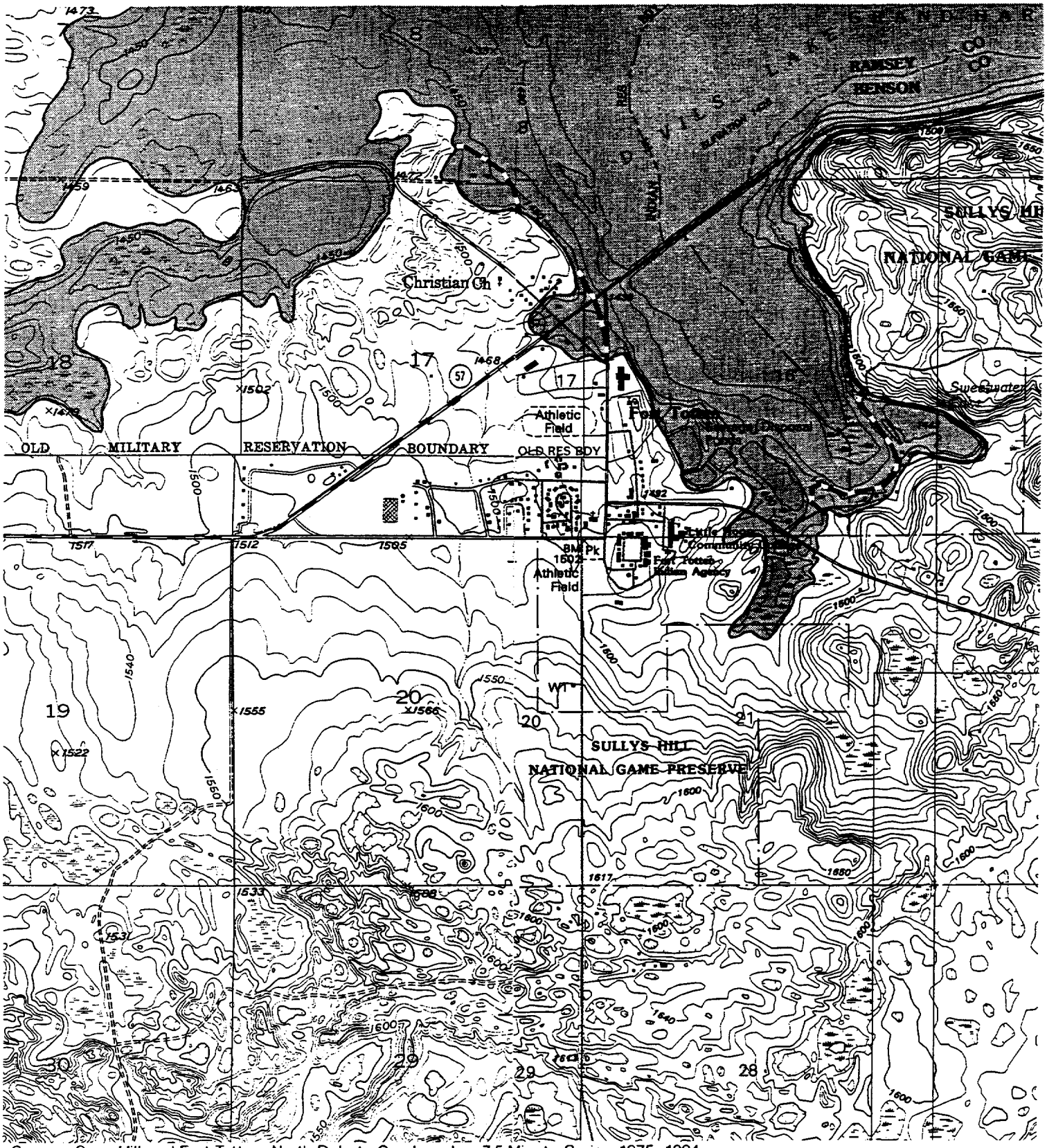
   a. To pump the remaining wastewater from the old eastern ponds to the new western ponds.

   b. To be used in case of an emergency where the new western ponds would be unusable.

   Therefore, it was assumed that the eastern ponds will not be needed during flooding events and can be abandoned if necessary.

Feature 3 Figures and Tables

Figure I.C.3.A Fort Totten Map
Figure I.C.3.B Feature 3: Decision Tree
Table I.C.3.A Feature 3: Cost and Damage Table
Table I.C.3.B Feature 3: Inventory Sheet



Source: Crow Hill and Fort Totten, North Dakota Quadrangles, 7.5 Minute Series, 1975, 1994.

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0 2000 4000

Scale in Feet

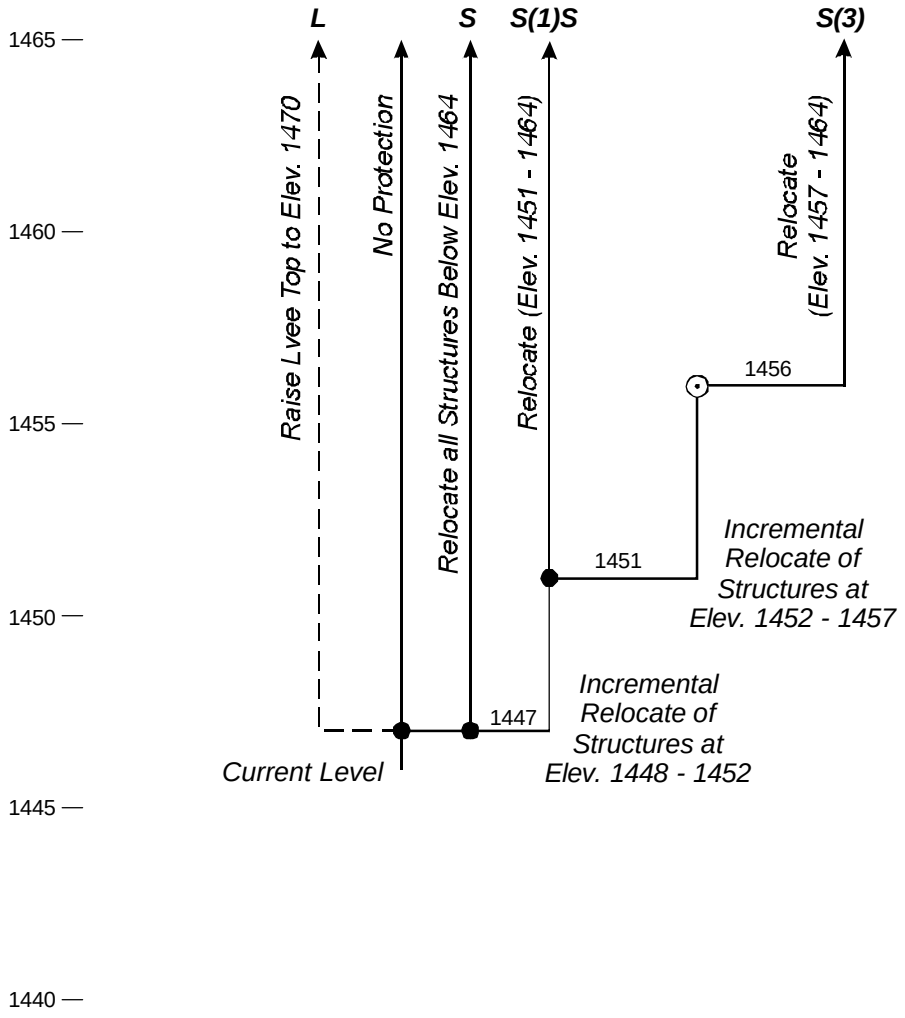
Area Inundated at Elevation 1463

Location of Potential Levees

FORT TOTTEN

Feature No. 3

FORT TOTTEN



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- ● Decision required at this point
- ⊙ Trigger point for action, no decision needed
- ***L(1)*** Incremental levee raise (number of times)
- ***L*** Levee raise to Elev. 1470
- ***S(1)*** Structure relocation (number of times)
- ***S*** Relocate all structures below Elev. 1464
- — — — Strategy not analyzed

Feature No. 3

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

Table I.C.3.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 3 - Fort Totten

COSTS

Lake Elevation (MSL)	S Relocate All Structures at AL1	S(1)S Incremental Relocation at AL1; Relocate All Structures at AL2	S(3) Incremental Relocation at AL1, AL2, AL3
	THOUSANDS		
1445	$0	$0	$0
1446	$0	$0	$0
1447	$952	$68	$68
1448	$0	$0	$0
1449	$0	$0	$0
1450	$0	$0	$0
1451	$0	$884	$340
1452	$0	$0	$0
1453	$0	$0	$0
1454	$0	$0	$0
1455	$0	$0	$0
1456	$0	$0	$544
1457	$0	$0	$0
1458	$0	$0	$0
1459	$0	$0	$0
1460	$0	$0	$0
1461	$0	$0	$0
1462	$0	$0	$0
1463	$0	$0	$0

Note: AL = Decision/Action Level

DAMAGES
Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy.

Lake Elevation (MSL)	Structures and Infrastructure (THOUSANDS)
1445	$0
1446	$0
1447	$62
1448	$0
1449	$0
1450	$0
1451	$310
1452	$0
1453	$0
1454	$0
1455	$0
1456	$496
1457	$0
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.3.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 3 - Fort Totten

Decision/Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1447	Incremental Relocation	House	1 @ $68,000	$68,000	1 @ $62,000 each	$62,000
			Total	**$68,000**	**Total**	**$62,000**
	Maximum Protection Levee Raise *	Levee	Length = 7,000 Feet Average Height = 21 Feet	$14,190,000		
		Pump Station	3 @ $283,000	$849,000		
			Total	**$15,039,000**	Same as for Incremental Relocation	
1451	Incremental Relocation	House	5 @ $68,000 each	$340,000	5 @ $62,000 each	$310,000
			Total	**$340,000**	**Total**	**$310,000**
1456	Incremental Relocation	House	8 @ $68,000 each	$544,000	8 @ $62,000 each	$496,000
			Total	**$544,000**	**Total**	**$496,000**

The maximum protection strategy cost for this feature (relocation of all structures at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

* This maximum protection levee raise cost was not analyzed in our conceptual model due to its excessive cost.

Feature 4. City of Minnewaukan

A. General Assumptions

1. It was assumed that the low structure in the city lies at elevation 1448, based on maps supplied by the city staff showing curb and gutter elevations, selected survey points, and personal conversations with the County Assessor.

B. Levees

1. A decision was assumed to be made when the lake is 1 foot below the design level of protection (i.e., 1 foot below the lower limit of the required freeboard of a levee).

2. The costs of levee protection did not consider the cost of undefined supplemental protection for higher levels along an unnamed coulee along the northwest city limits during runoff events.

3. Levees were assumed to require 5 feet of freeboard.

4. The levee design was obtained from the *Devils Lake, Minnewaukan Federal Interest Study*, Barr Engineering Company, September 29, 1998. That report provided two options for structural protection: a levee and a road/levee. Continued viability of the City is dependent on not only the levee but also on keeping Highway 281 open to provide access. If the levee option is chosen, Highway 281 south of US Highway 2 will be raised.

5. The analysis of incremental levee raises would not allow a relocation of structures prior to construction of the first levee raise. Therefore, the first relocation at elevation 1447.0 was not included in the analysis. The value of this relocation ($0.3 million) is minimal when compared to the total values at higher elevations ($4.0 to $12.3 million).

C. Residential and Commercial Buildings

1. For relocation strategies, a decision was assumed to be made when the lake is 1 foot below the level of the low structure. This was based on the existing process which is influenced by the availability of movers, the estimated lake rise each spring, and the restrictions of funding programs. Depending on the slope of the land, wave action may affect structures several feet above the lake's level.

2. The average value of a house in Minnewaukan is estimated to be $88,000. This figure was obtained from the Federal Emergency Management Agency (FEMA) and represents the average value of rural houses located around Devils Lake, excluding houses on the Spirit Lake Nation Reservation. The value for each house was determined for FEMA by certified flood insurance adjusters and was based on total habitable square footage of the buildings and standardized real estate appraisals (*FEMA*, personal communication, March, 2001). These values did not include the value of the land on which the houses were located. The $88,000 average was based on rural houses only, therefore houses in the Cities of Minnewaukan and Devils Lake were not included in the analysis. However, the analysis

did include many houses in the area surrounding Minnewaukan. Therefore, it was assumed that the average value of a residence in Minnewaukan was same as in the surrounding area.

3. The values and relocation costs for the structures and properties described below are in 1998 dollars. These values and costs were updated for inflation by multiplying them by the ENR Building Cost Index of 1.042. This accounts for 4.2% inflation during the period from 1998 to February 2001. Specific assumptions for the 1998 values included:

   a. For the park and the athletic fields, the same values were used as in the ongoing study for the city. A value of $25,000 was used for the park as well as the athletic fields. The updated value is $26,050.

   b. The value of all churches was approximated using the $275,000 insured value of the structure only for Trinity Lutheran Church. The updated value is $286,550.

   c. The value of the Courthouse was estimated using the 1997 Swift and Marshall Book replacement value for a good Class C building, at $100 per square foot for the top three floors and $74 per square foot for the basement. The courthouse has approximately 14,403 square feet on the top three floors. The basement was assumed to be 4,000 square feet. Therefore, the estimate replacement value of the Courthouse was $1,736,000. The updated value is $1,808,912.

   d. The value of the Museum was estimated at $100,000, based on a conversation with Garvin Plumber, Museum operator, and increased to $120,000 to reflect the depreciated replacement value. The updated value is $125,040.

   e. Costs for the swimming pool, school, and library were estimated using a value of 25% of the low end of the 1997 Means Cost Estimate. The low-end estimates were used based on the comparatively low values of structures in a small city. Since only the square footage for the school was available, the square footage was assumed for the other structures at:

      i. Swimming pool building = 450 square feet

      ii. Library = 2,000 square feet

   f. The estimated values for the structures mentioned above include the value of the lots. According to the City Assessor, each lot had an assessed value of $300. The updated value is $312. The lot sizes of some larger structures were determined from the city map as follows:

      i. West Bay Housing (Individual HUD home) = 16 lots

      ii. Trailer court = 20 lots

4. For relocation strategies, it was assumed that the pool and park were not relocated. The pool is in very poor condition, and has not been used in recent years because of its poor condition.

5. Relocation costs were assumed to be 70% of the assessed value of trailer courts and HUD homes (West Bay units) plus 100% of the assessed values of the lot.

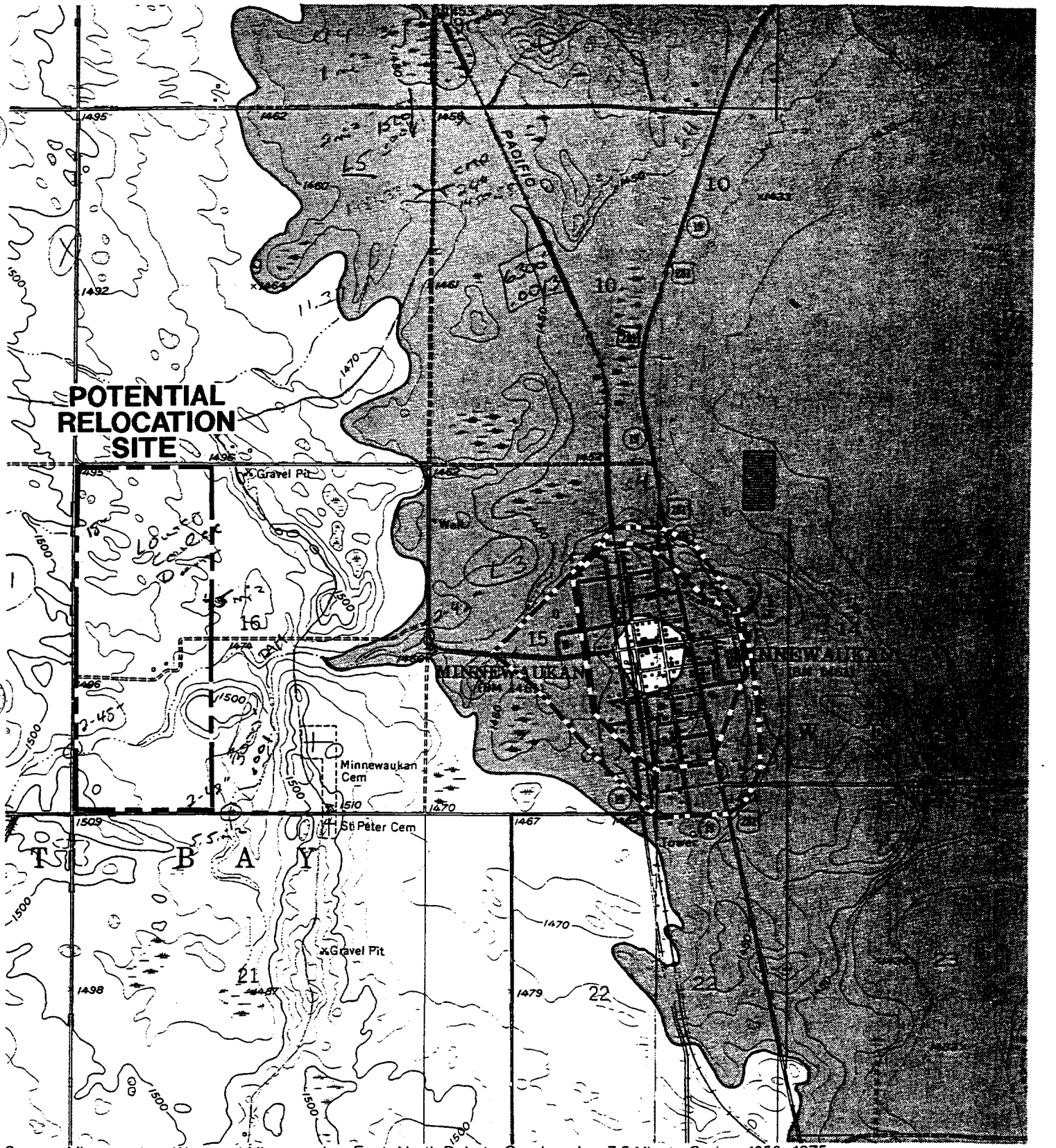
6. Relocation costs for homes were estimated to be $68,000. This cost was obtained from the North Dakota-North Central Planning Council and represents the average cost to relocate a residence during the buyout program conducted in Churchs Ferry (2000). The $68,000 includes the following costs: demolition of the existing house, purchase of an equivalent house in a nearby community, purchase of a lot, and legal, appraisal, and management fees. It was assumed relocation costs would be approximately the same in Minnewaukan as they were in Churchs Ferry.

7. The cost for relocation/rebuilding of commercial and public facilities was assumed to be 100% of the value of the structure and property.

8. The land value for Minnewaukan is estimated to be $400/acre. This value was provided by the Corps of Engineers (April, 2001) and is an estimate of the average value of all land surrounding Devils Lake.

Feature 4 Figures and Tables

Figure I.C.4.A City of Minnewaukan Map
Figure I.C.4.B Feature 4: Decision Tree
Table I.C.4.A Feature 4: Cost and Damage Table
Table I.C.4.B Feature 4: Inventory Sheet



Source: Minnewaukan West and Minnewaukan East, North Dakota Quadrangles, 7.5 Minute Series, 1958, 1975.

N

0 2000 4000

Scale in Feet

Area Inundated at Elevation 1463

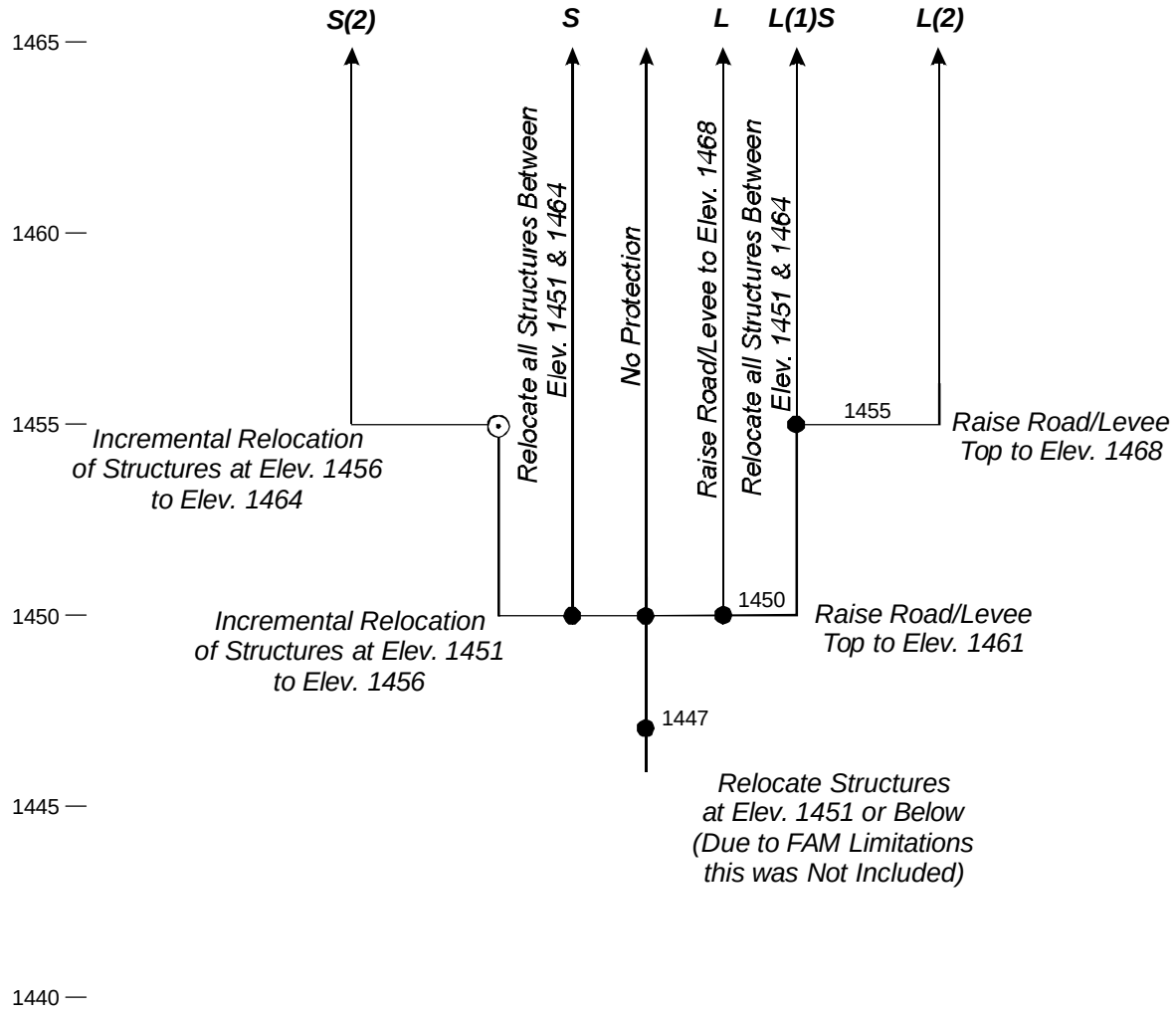
Alignment of Incremental Levee

Alignment of Potential Full Levee

CITY OF MINNEWAUKAN

Feature No. 4

CITY OF MINNEWAUKAN



- ● Decision required at this point
- ⊙ Trigger point for action, no decision needed
- ***L(1)*** Incremental levee raise (number of times)
- ***L*** Levee raise to Elev. 1468
- ***S(1)*** Structure relocation (number of times)
- ***S*** Relocate all structures below Elev. 1464
- — — — Strategy not analyzed

Feature No. 4

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.4.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 4 - City of Minnewaukan

COSTS

Lake Elevation (MSL)	S(2) Incremental Relocation at AL1, AL2	S Relocate All Structures at AL1	L Maximum Protection Levee at AL1	L(1)S Raise Levee at AL1; Relocate All Structures at AL2	L(2) Raise Levee at AL1, AL2
	THOUSANDS				
1445	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0
1447	$0	$0	$0	$0	$0
1448	$0	$0	$0	$0	$0
1449	$0	$0	$0	$0	$0
1450	$4,031	$16,342	$7,802	$5,349	$5,349
1451	$0	$0	$0	$0	$0
1452	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0
1454	$0	$0	$0	$0	$0
1455	$12,311	$0	$0	$16,342	$2,453
1456	$0	$0	$0	$0	$0
1457	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0
1462	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL OPERATION AND MAINTENANCE COSTS
Operation and maintenance costs apply to Levee strategies, and include operation and maintenance of pumping stations and Levee embankments. These costs are incurred annually, each year that the Levee remains in place.

Lake Elevation (MSL)	Operation and Maintenance (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$7
1451	$7
1452	$7
1453	$7
1454	$7
1455	$7
1456	$8
1457	$8
1458	$8
1459	$8
1460	$8
1461	$8
1462	$8
1463	$8

DAMAGES
Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy.

Lake Elevation (MSL)	Structures and Infrastructure (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$4,997
1451	$0
1452	$0
1453	$0
1454	$0
1455	$14,471
1456	$0
1457	$0
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.4.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 4 - City of Minnewaukan

Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1447	Incremental Relocation	Church	1 @ $287,000	$287,000	1 @ $287,000	$287,000
			Total	**$287,000**	**Total**	**$287,000**
1450	Incremental Relocation	House	45 @ $68,000 each	$3,060,000	45 @ $88,000 each	$3,960,000
		HUD Unit	1 @ 70% of $219,070 + 16 Lots @ $313 Ea.	$158,000	1 @ $219,070 + 16 Lots @ $313 Ea..	$224,000
		Apartments/Senior Residences	1 @ Individual Assessed Values	$46,000	1 @ Individual Assessed Values	$46,000
		Business	3 @ $42,500 each	$127,500	3 @ $42,500 each	$127,500
		School		$550,000		$550,000
		Lots	194 @ $313	$60,700	194 @ $313	$60,700
		Land	21.5 ac. @ $400/ac.	$8,600	21.5 ac. @ $400/ac.	$8,600
		Trailer Court		$19,800		$19,800
			Total	**$4,030,600**	**Total**	**$4,996,600**
	Incremental Levee Raise	Levee		$2,605,300		
		Interior Drainage		$2,163,400		
		House	Relocated 7 @ $68,000 each (38 protected by levee)	$476,000	45 @ $88,000 each	$3,960,000
		Lots	Protected by Levee	$0	194 @ $313	$60,700
		Land	Protected by Levee	$0	21.5 ac. @ $400/ac.	$8,600
		HUD Unit	Protected by Levee	$0	1 @ $219,070 + 16 Lots @ $313 Ea..	$224,000
		Apartments/Senior Residences	Protected by Levee	$0	1 @ Individual Assessed Values	$46,000
		Business	Relocate 2 @ $42,500 (1 protected by levee)	$85,000	3 @ $42,500 each	$127,500
		School	Protected by Levee	$0		$550,000
		Trailer Court	Relocate 1 @ $19,800	$19,800	1 @ $19,760	$19,800
			Total	**$5,349,500**	**Total**	**$4,996,600**
1455	Incremental Relocation	House	108 @ $68,000 each	$7,344,000	108 @ $88,000 each	$9,504,000
		Business	23 @ $42,500 each	$977,500	23 @ $42,500 each	$977,500
		Minnewaukan Residences	2 @ Individual Assessed Values	$203,000		$203,000
		Church	3 @ $287,000	$861,000	3 @ $287,000	$861,000
		Library		$43,800		$43,800
		Courthouse		$1,808,900		$1,808,900
		Lots	391 @ $313	$122,400	391 @ $313	$122,400
		Land	109.4 ac. @ $400/ac.	$44,000	109.4 ac. @ $400/ac.	$44,000
		Grain Elevator		$750,200		$750,200
		Museum		$125,000		$125,000
		Park		$31,200		$31,200
			Total	**$12,311,000**	**Total**	**$14,471,000**
	Incremental Road/Levee Raise	Levee		$2,453,000		
		House	Protected by Road/Levee	$0	108 @ $88,000 each	$9,504,000
		Business	Protected by Road/Levee	$0	23 @ $42,500 each	$977,500
		Minnewaukan Residences	Protected by Road/Levee	$0		$203,000
		Church	Protected by Road/Levee	$0	3 @ $287,000	$861,000
		Library	Protected by Road/Levee	$0		$43,800
		Courthouse	Protected by Road/Levee	$0		$1,808,900
		Lots	Protected by Road/Levee	$0	391 @ $313	$122,400
		Land	Protected by Road/Levee	$0	109.4 ac. @ $400/ac.	$44,000
		Grain Elevator	Protected by Road/Levee	$0		$750,200
		Museum	Protected by Road/Levee	$0		$125,000
		Park	Protected by Road/Levee	$0		$31,200
			Total	**$2,453,000**	**Total**	**$14,471,000**

The maximum protection strategy cost for this feature (relocation of all structures at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

* This maximum protection levee raise cost was not analyzed in our conceptual model due to its excessive cost.

** 248 lots were assumed to be saved by the levee in our conceptual model. However, up to 52 lots may actually be under the footprint of the levee or outside of the levee. For this reason, the damages prevented for this strategy may be slightly less than those used in our analysis.

Feature 5. St. Michael

A. Levees

1. It was assumed that 7 feet of freeboard would be required for levee protection at the maximum lake level, based on the proposed freeboard for the City of Devils Lake and the high waves predicted for this area.

2. A decision was assumed to be made when the lake is 1 foot below the design level of protection (i.e., 1 foot below the lower limit of the required freeboard of a levee).

3. It was assumed that any levee constructed for the community would protect the sewage lagoons. The top of the existing sewage lagoons is at elevation 1451. The lagoons were assumed to be affected at action level 1447 because of potential wave damage.

4. For strategies that include levee protection, it was assumed that the lagoons would continue to function as the lake continues to rise (as discussed in Part I, Section I.2.3.2). A brief analysis of groundwater in the area indicates that it would not affect the operation of lagoons in the area *(Hydrogeology of the Shallow Water Table at the City of Devils Lake, North Dakota*, North Dakota State Water Commission, 1998).

5. Construction costs for pump stations to remove interior drainage behind the levee were estimated to be $350,000. This cost is in 1998 dollars, therefore it was updated for inflation by multiplying it by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. The updated cost is $371,000.

6. A preliminary cost estimate (1998 dollars) indicated that the cost of a levee would be approximately $8 million to protect to the maximum lake level. The cost of incremental levee raises would be $4.0 and $5.0 million at elevations 1447 and 1450, respectively. Since the cost of the levees would be far in excess of the estimated value of the structures at each action level, the levee protection strategy was not pursued further. Therefore, only relocation strategies were analyzed for St. Michael.

B. Residential and Commercial Properties

1. For relocation strategies, a decision was assumed to be made when the lake is 1 foot below the level of the low structure. This was based on the existing process which is influenced by the availability of movers, the estimated lake rise each spring, and the restrictions of funding programs. Depending on the slope of the land, wave action may affect structures several feet above the lake's level.

2. The average value of a house in St. Michael was estimated to be $62,000. This figure was obtained from the Federal Emergency Management Agency (FEMA) and represents the average value of a house located on the Spirit Lake Nation Reservation. The value for each house was determined for FEMA by certified flood insurance adjusters and was based on total habitable square footage of the buildings and standardized real estate appraisals (*FEMA*, personal communication, March, 2001). These values did not include the value of land on which the houses were located.

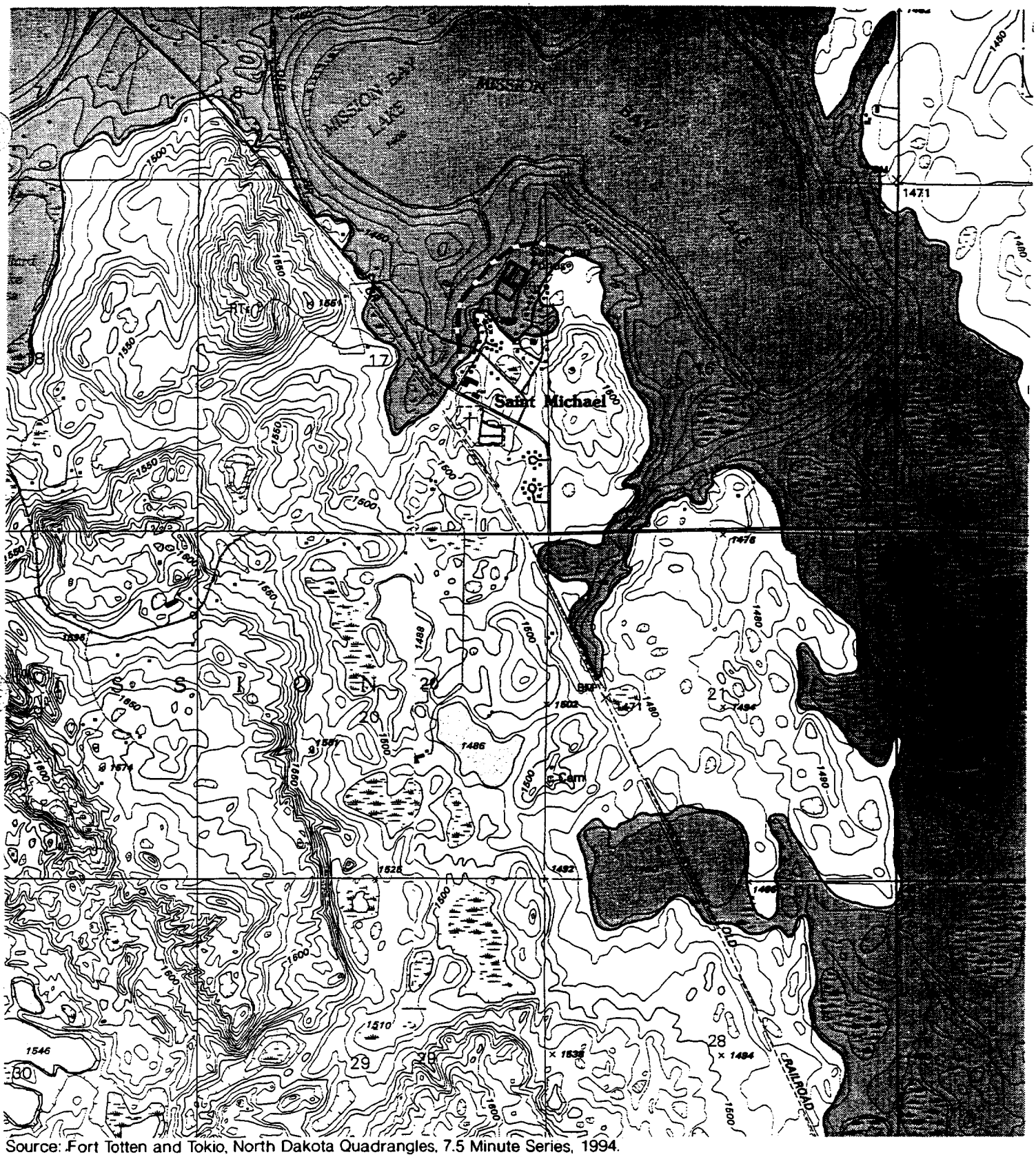
3. Relocation costs for homes were estimated to be $68,000. This cost was obtained from the North Dakota-North Central Planning Council and represents the average cost to relocate a residence during the buyout program conducted in Churchs Ferry (2000). The $68,000 includes the following costs: demolition of the existing house, purchase of an equivalent house in a nearby community, purchase of a lot, and legal, appraisal, and management fees. It was assumed relocation costs would be the approximately the same in St. Michael as they were in Churchs Ferry.

4. The cost for relocation/rebuilding of commercial and public facilities was assumed to be 100% of the value of the structure and property.

5. For relocation strategies, the advanced replacement of the lagoon was estimated at $150,000 (*Devils Lake Spirit Lake Nation Reservation Alternatives Assessment*, Barr Engineering Company, October, 1997). This cost is in 1998 dollars, therefore it was updated for inflation by multiplying it by the ENR Construction Cost Index of 1.06. The updated cost is $159,000.

Feature 5 Figures and Tables

Figure I.C.5.A City of St. Michael Map
Figure I.C.5.B Feature 5: Decision Tree
Table I.C.5.A Feature 5: Cost and Damage Table
Table I.C.5.B Feature 5: Inventory Sheet



Source: Fort Totten and Tokio, North Dakota Quadrangles, 7.5 Minute Series, 1994.

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Scale in Feet

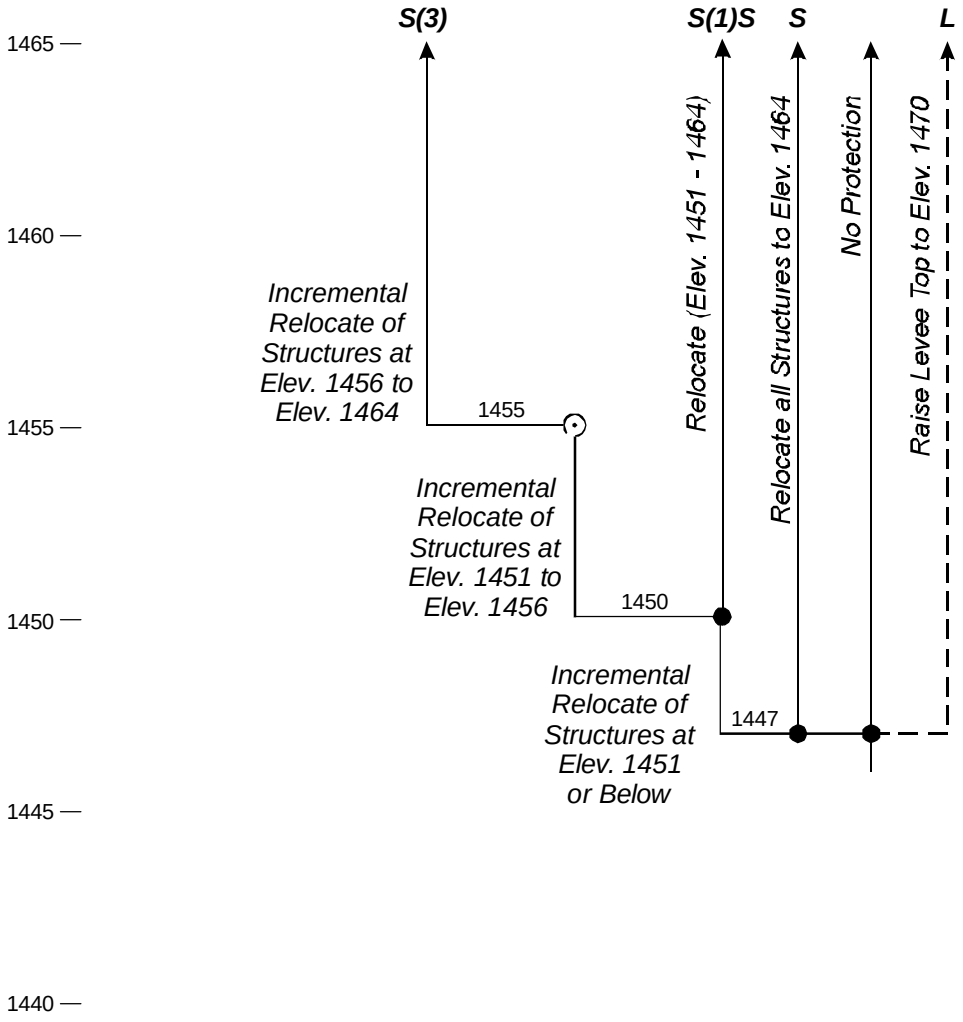
Area inundated at Elevation 1463

Location of Potential Levee

ST. MICHAEL

Feature No. 5

ST. MICHAEL



● Decision required at this point

⊙ Trigger point for action, no decision needed

L(1) Incremental levee raise (number of times)

L Levee raise to Elev. 1470

S(1) Structure relocation (number of times)

S Relocate all structures below Elev. 1464

— — — Strategy notAnalyzed

Feature No. 5

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.5.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 5 - St. Michael

COSTS

Lake Elevation (MSL)	S(3) Incremental Relocation at AL1, AL2, AL3	S(1)S Incremental Relocation at AL1; Relocate All Structures at AL2	S Relocate All Structures at AL1
	THOUSANDS		
1445	$0	$0	$0
1446	$0	$0	$0
1447	$159	$159	$1,859
1448	$0	$0	$0
1449	$0	$0	$0
1450	$68	$1,700	$0
1451	$0	$0	$0
1452	$0	$0	$0
1453	$0	$0	$0
1454	$0	$0	$0
1455	$1,632	$0	$0
1456	$0	$0	$0
1457	$0	$0	$0
1458	$0	$0	$0
1459	$0	$0	$0
1460	$0	$0	$0
1461	$0	$0	$0
1462	$0	$0	$0
1463	$0	$0	$0

Note: AL = Decision/Action Level

DAMAGES
Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy.

Lake Elevation (MSL)	Structures and Infrastructure (THOUSANDS)
1445	$0
1446	$0
1447	$159
1448	$0
1449	$0
1450	$62
1451	$0
1452	$0
1453	$0
1454	$0
1455	$1,488
1456	$0
1457	$0
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.5.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 5 - St. Michael

Decision/Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1447	Incremental Relocation	Sewage Treatment Lagoon		$159,000		$159,000
			Total	**$159,000**	**Total**	**$150,000**
	Maximum Protection Levee Raise *	Levee	Length = 3,200 Feet Average Height = 23 Feet	$8,271,000		
		Pump Station	1 @ $350,000	$371,000		
			Total	**$8,642,000**	Same as for Incremental Relocation	
1450	Incremental Relocation	House	1 @ $68,000 each	$68,000	1 @ $62,000	$62,000
			Total	**$68,000**	**Total**	**$62,000**
1455	Incremental Relocation	House	24 @ $68,000 each	$1,632,000	24 @ $62,000	$1,488,000
			Total	**$1,632,000**	**Total**	**$1,488,000**

The maximum protection strategy cost for this feature (relocation of all structures at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

* This maximum protection levee raise cost was not analyzed in our conceptual model due to its excessive cost.

Feature 6. Gilbert C. Grafton State Military Reservation

A. General Assumptions

1. It was assumed that Highway 20 access would be kept open to provide access to the Camp roads. These costs are not included in this feature and are analyzed separately in Feature 21: Highway 20 from the City of Devils Lake Levee to Highway 57.

2. Camp Grafton is valued at approximately $35 million, not including land. These capitalized costs were provided by Captain Clark Johnson, Civil Engineer, Camp Grafton.

3. It was assumed that during high water conditions, the main gate (Gate #6 with access from Highway 20) would be the only access route that would be maintained and raised (based on conversations with Captain Clark Johnson).

4. It was assumed that the Camp would not close, even if the lake reaches its maximum level. A significant portion of the land area and all of the structures are above elevation 1463. Camp Grafton South (30 miles south) would be unaffected and could be used for maneuvers and activities that require a larger area.

5. It was assumed that the sewer system would be fully converted to the Ramsey County Rural Sewer system before lagoons were inundated (State Flood Coordination Center, Staff meeting, November 18, 1997).

6. There are currently no open culverts located under Highway 20 near Camp Grafton, and the area west of Highway 20 has been kept dry in recent years with pumping. It was assumed that culverts would be installed under Highway 20 to relieve pressure, resulting in flooding of the low areas west of Highway 20. It was assumed this would occur at the first action level (elevation 1447) and, thereafter, all lands west of Highway 20 would be inundated by lake levels higher than the elevations of those lands.

B. Levees and Roads

1. The maximum road and levee elevation was assumed to be elevation 1468, assuming a 5-foot freeboard above the maximum lake level of 1463.

2. Roads were assumed to be raised when the water surface elevation is within 1 foot of the low point of the road.

3. It was assumed that a levee would be constructed to protect the munitions storage area from flooding (based on conversations with Captain Clark Johnson, Civil Engineer, Camp Grafton).

4. Riprap protection was assumed to be required to protect the lakeward side of Avenue A (conversation with Captain Clark Johnson, Civil Engineer, Camp Grafton). It was assumed that the riprap would extend from elevation 1452.5 to 1461 (based on the May 1997 3-foot contour map) and would be 2 feet thick.

5. It was assumed that a dike would be constructed along Avenue A if the water surface reached an elevation of 1461.5 to protect against wave action.

C. Structures

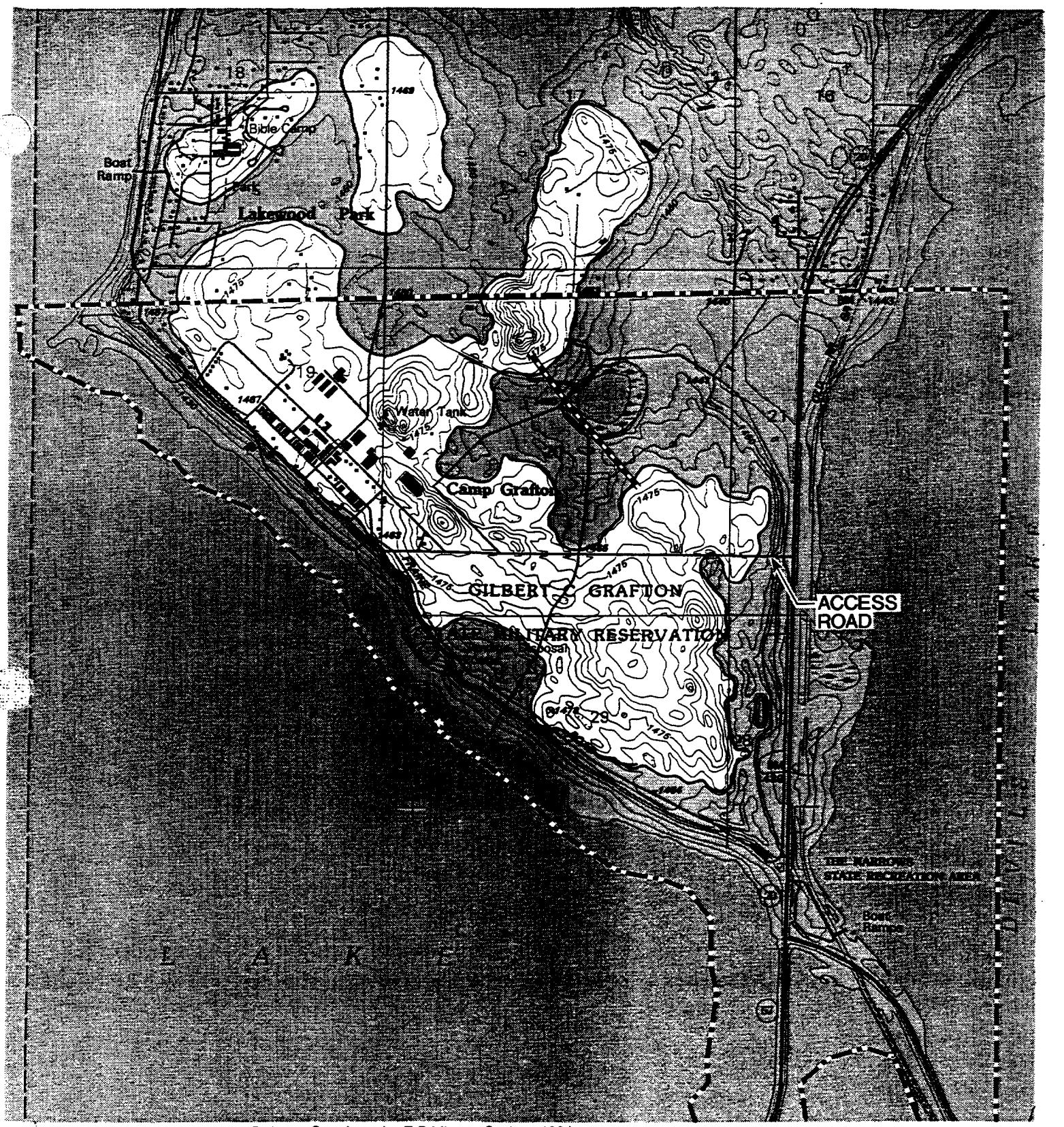
1. Buildings were not assumed to be moved, because most buildings are above elevation 1464 (based on conversations with Lieutenant Colonel Gary Doll, Camp Grafton).

2. Building values were based on the capitalized cost, which was computed as the original cost plus improvements. This is probably a low estimate, as some buildings were constructed in the 1940s and the replacement value would be much higher (based on conversations with Captain Clark Johnson, Civil Engineer, Camp Grafton).

3. The land value for Camp Grafton is estimated to be $400/acre. This value was provided by the Corps of Engineers (personal communication, April, 2001) and is an estimate of the average value of all land surrounding Devils Lake.

Feature 6 Figures and Tables

Figure I.C.6.A Gilbert C. Grafton State Military Reservation Map
Figure I.C.6.B Feature 6: Decision Tree
Table I.C.6.A Feature 6: Cost and Damage Table
Table I.C.6.B Feature 6: Inventory Sheet



Source: Camp Grafton, North Dakota Quadrangle, 7.5 Minute Series, 1994.

Note: The area inundated at elevation 1463 does not reflect protection to areas inside the City of Devils Lake levee system.

N

0 2000 4000

Scale in Feet

Munitions Levee

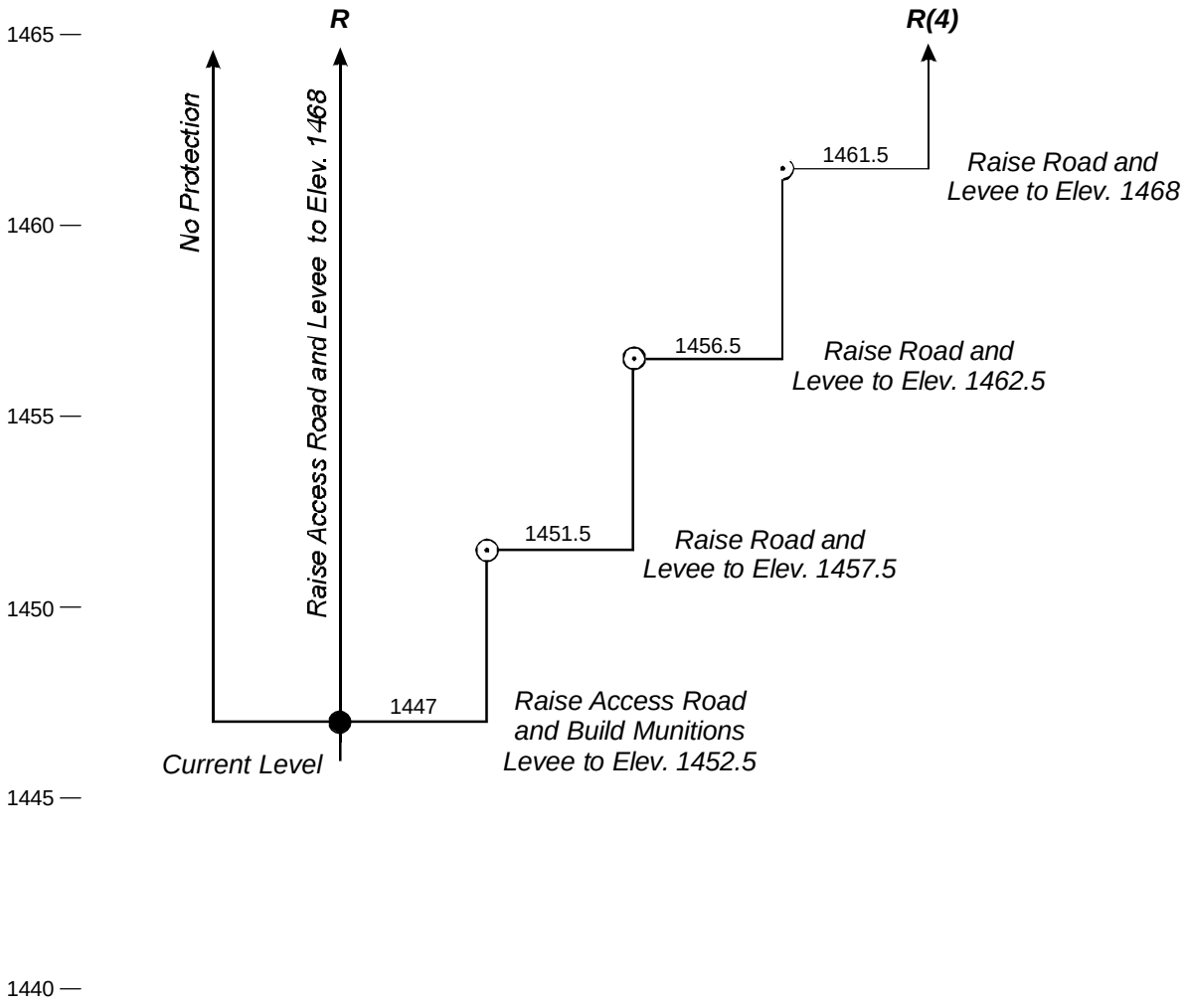
Area Inundated at Elevation 1463

Military Reservation Boundary

GILBERT C. GRAFTON
STATE MILITARY RESERVATION

Feature No. 6

GILBERT C. GRAFTON
STATE MILITARY RESERVATION



● Decision required at this point

⊙ Trigger point for action, no decision needed

R(1) Incremental road raise(number of times)

R Raise road to elev. 1468

Feature No. 6

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.6.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 6 - Gilbert C. Grafton State Military Reservation

COSTS

Lake Elevation (MSL)	R Raise Access Road and Build Munitions Levee at AL1	R(4) Raise Access Road and Build Munitions Levee at AL1, AL2, AL3, AL4
	THOUSANDS	
1443	$0	$0
1444	$0	$0
1445	$0	$0
1446	$0	$0
1447	$25,226	$3,151
1448	$0	$0
1449	$0	$0
1450	$0	$0
1451	$0	$3,124
1452	$0	$0
1453	$0	$0
1454	$0	$0
1455	$0	$0
1456	$0	$5,958
1457	$0	$0
1458	$0	$0
1459	$0	$0
1460	$0	$0
1461	$0	$12,993
1462	$0	$0
1463	$0	$0

Note: AL = Decision/Action Level

DAMAGES

Damages to structures and infrastructure are a one time damage, incurred only under the no protection or temporary closure of access road strategies. Damages to land are a one time damage incurred under all strate

Lake Elevation (MSL)	Structures and Infrastructure	Land
	THOUSANDS	
1443	$0	$0
1444	$0	$0
1445	$0	$0
1446	$0	$0
1447	$45	$58
1448	$0	$0
1449	$0	$0
1450	$0	$0
1451	$0	$65
1452	$0	$0
1453	$0	$0
1454	$0	$0
1455	$0	$0
1456	$0	$65
1457	$0	$0
1458	$0	$0
1459	$0	$0
1460	$0	$0
1461	$34,732	$72
1462	$0	$0
1463	$0	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.6.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 6 - Gilbert C. Grafton State Military Reservation

Decision/Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1447	Incremental Raise	Road Raise	Length = 430 Feet	$56,000	Munitions Area Buildings (Includes Ammo Storage Office and 4 Ammo Storage Bunkers)	
		Levee Raise	Length = 3,600 Feet	$3,095,000		
			Average Height = 6 Feet			
			Includes Pump (1 @ $1,000,000)			$45,000
			Total	**$3,151,000**	**Total**	**$45,000**
1451	Incremental Raise	Road Raise	Length = 690 Feet	$108,000		
		Levee Raise	Length = 5,100 Feet	$2,692,000		
		Avenue A Riprap		$324,000		
			Total	**$3,124,000**	**Total**	**$0**
1456	Incremental Raise	Road Raise	Length = 1,300 Feet	$239,000		
		Levee Raise	Length = 5,200 Feet	$5,395,000		
		Avenue A Riprap		$324,000		
			Total	**$5,958,000**	**Total**	**$0**
1461	Incremental Raise	Road Raise	Length = 2,600 Feet	$604,000	Total Buildings (Less Camp Grafton South)	$25,155,000
		Levee Raise	Length = 5,200 Feet	$8,722,000		
		Avenue A Levee	Length = 4,200 Feet	$3,667,000	Infrastructure	$9,577,000
			Average Height = 7 Feet			
			Total	**$12,993,000**	**Total**	**$34,732,000**

The maximum protection strategy cost for this feature (maximum road raise and levee raise at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

Feature 7. Grahams Island State Park

A. General Assumptions

1. Access to Grahams Island State Park is dependent on Highway 19 remaining open. It was assumed that Highway 19 access would be kept open to provide access to the park road. The costs for Highway 19 are not included in this feature and are analyzed separately in Feature 18: Highway 19 from the City of Devils Lake Levee to Highway 281. Costs for the park access road from Highway 19 to the park were included in the costs of protection for this feature.

B. Roads

1. For the incremental road raise strategies, it was assumed that county roads being used as park access would be raised to the same elevation as Highway 19, starting with the first raise at elevation 1449.5 (1 foot below the existing road elevation).

2. For the incremental road raise strategies, it was assumed that the access road would be raised when the lake level is within 1 foot of the low road elevation.

3. The estimated maximum road elevation was elevation 1468, based on a 5-foot freeboard above the maximum lake level of 1463.

4. Road raises within the park boundary were not included because roads within the park are, for the most part, above elevation 1468.

5. If the selected strategy is temporary closure during flooding, restoration costs for the access road were included when the lake drops 1 foot below the lowest point on the access road.

6. If the county access road is not raised and access to the park is temporarily lost, the value lost was assumed to equal the unit day value of time lost. The unit day value of time lost was computed as $7 per day (Corps of Engineers, personal communication, March, 2001) times the average annual number of park visitors. In 1999 the park had 73,770 visitors, which is representative of a typical year (based on conversations with Dick Horner, Park Superintendent). This number was used to compute the unit day value of time lost, for a total of $516,000 per year.

C. Structures

1. It was assumed that if access was maintained to the park, structures within the park that would be affected by the lake would be moved to high ground (above elevation 1464.) Structures were assumed to be moved when the lake level was within 1 foot of the structure.

2. The estimated value of structures was full replacement value, since all structures have been built since 1989 (based on conversations with Dick Horner, Park Superintendent).

3. If the park was temporarily closed because of lack of access, buildings at elevations greater than the maximum lake level were assumed to be unaffected. The buildings are primarily used by park staff, and could be temporarily closed while access is unavailable.

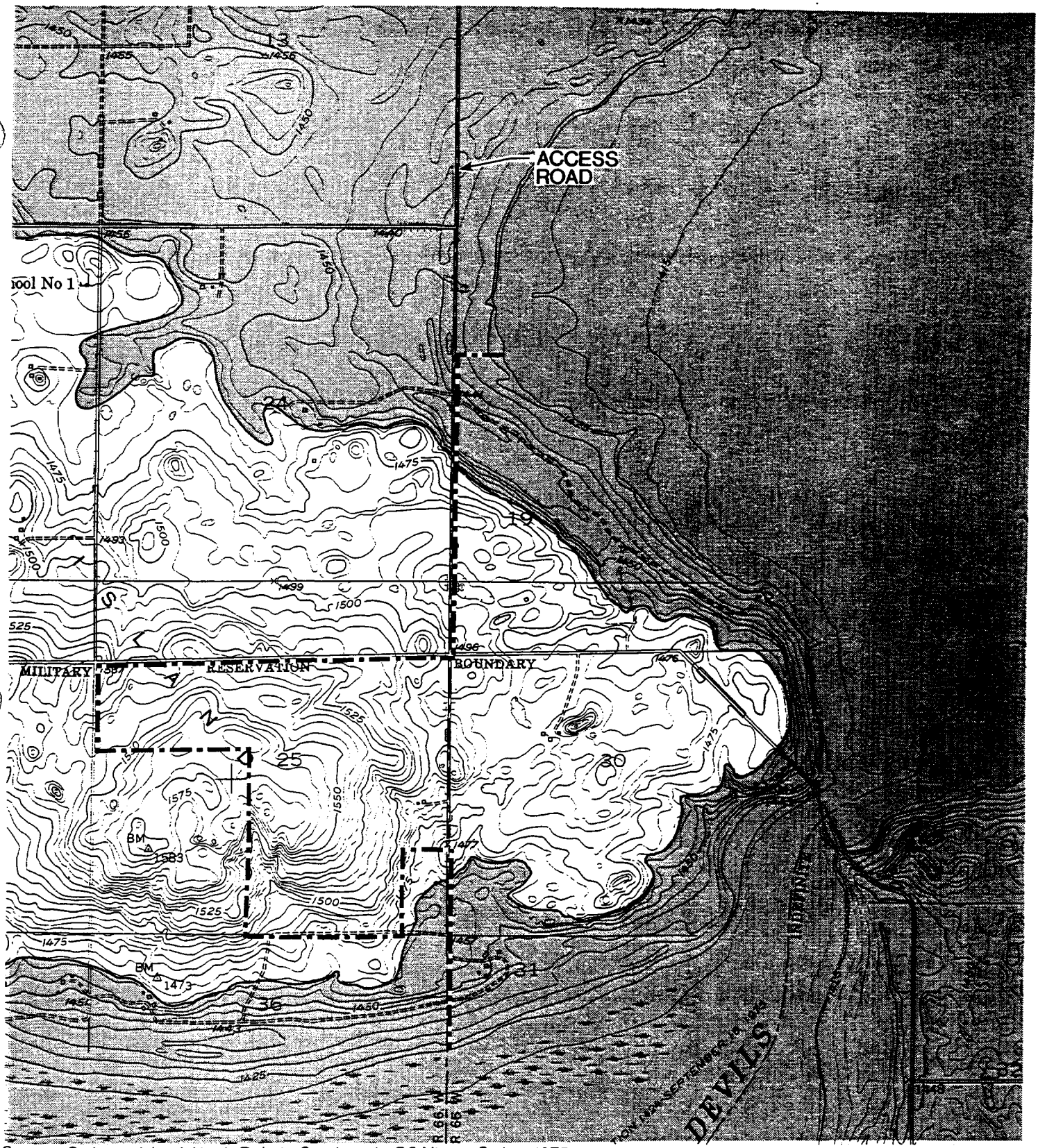
4. The land value for Grahams Island State Park is estimated to be $400/acre. This value was provided by the Corps of Engineers (personal communication, April, 2001) and is an estimate of the average value of all land surrounding Devils Lake.

5. Structure relocation costs were estimated to be 75% of the structure value for residential structures (including garages, barns, etc.) and 100% for commercial structures (lift stations, comfort stations, etc.).

6. If the park was temporarily closed because of lack of access, damages to land and structures were assumed to occur as they are affected by the rising lake level.

Feature 7 Figures and Tables

Figure I.C.7.A Grahams Island State Park Map
Figure I.C.7.B Feature 7: Decision Tree
Table I.C.7.A Feature 7: Cost and Damage Table
Table I.C.7.B Feature 7: Inventory Sheet



Source: Grahams Island, North Dakota Quadrangle, 7.5 Minute Series, 1975.

N

0 2000 4000

Scale in Feet

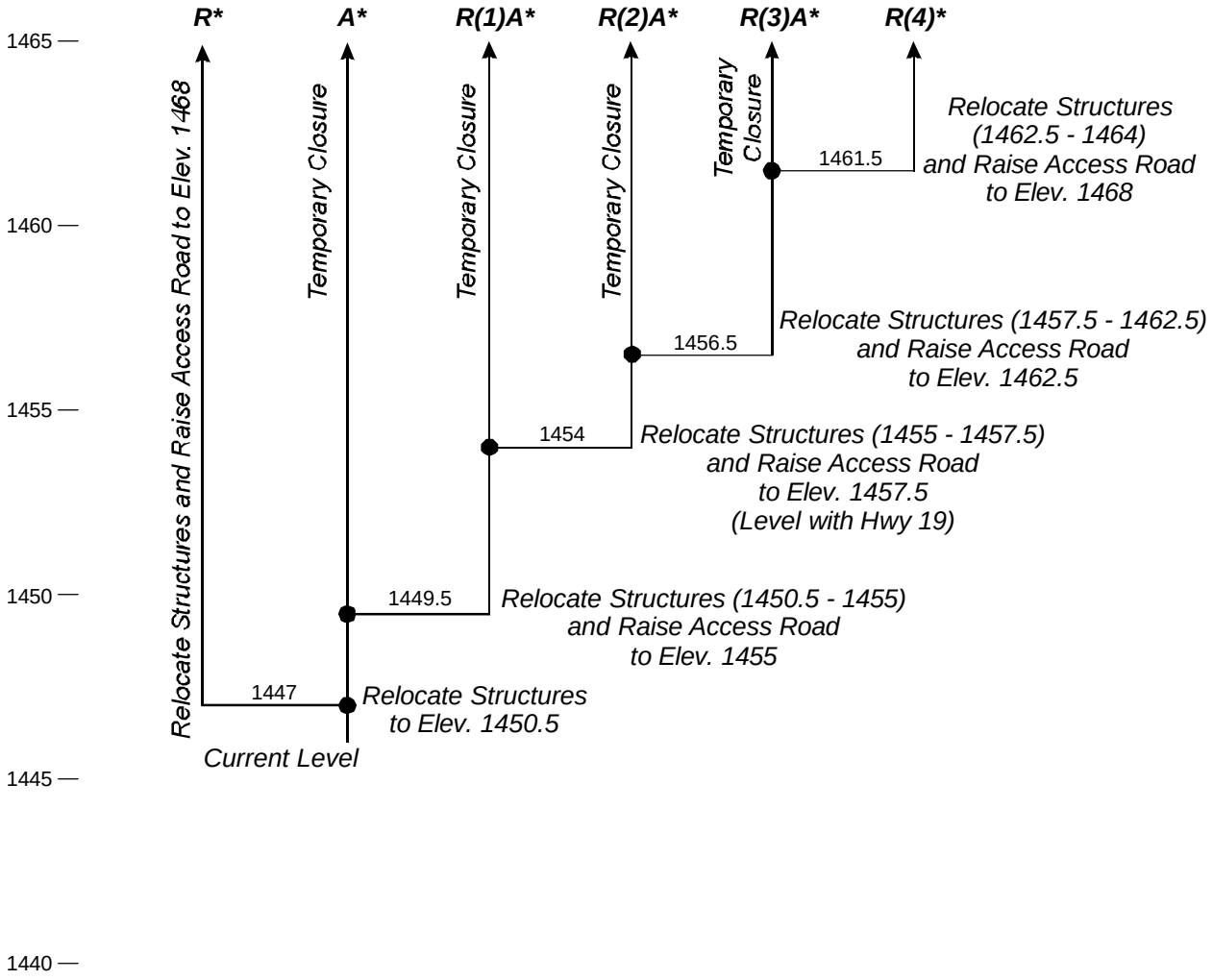
Area Inundated at Elevation 1463

Park Boundary

GRAHAMS ISLAND STATE PARK

Feature No. 7

GRAHAMS ISLAND STATE PARK



● Decision required at this point

⊙ Trigger point for action, no decision needed

A Temporary closure of park

R(1) Incremental road raise(number of times)

***** In addition to road raises or temporary closure there are also structure relocations

Feature No. 7

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.7.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 7 - Grahams Island State Park

COSTS

Lake Elevation (MSL)	R* Relocate Structures and Raise Road at AL1	A* Relocate Structures at AL1; Temporary Closureof Park at AL2	R(1)A* Relocate Structures at AL1; Raise Road and Relocate Structures at AL2; Temporary Closure of Park at AL3	R(2)A* Relocate Structures at AL1; Raise Road and Relocate Structures at AL2, AL3; Temporary Closure of Park at AL4	R(3)A* Relocate Structures at AL1; Raise Road and Relocate Structures at AL2, AL3, AL4; Temporary Closure of Park at AL5	R(4)* Relocate Structures at AL1; Raise Road and Relocate Structures at AL2, AL3, AL4, AL5
	THOUSANDS					
1445	$0	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0	$0
1447	$18,002	$56	$56	$56	$56	$56
1448	$0	$0	$0	$0	$0	$0
1449	$0	$0	$3,713	$3,713	$3,713	$3,713
1450	$0	$0	$0	$0	$0	$0
1451	$0	$0	$0	$0	$0	$0
1452	$0	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0	$0
1454	$0	$0	$0	$2,229	$2,229	$2,229
1455	$0	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$5,704	$5,704
1457	$0	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0	$6,300
1462	$0	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level
* In addition to a road raise or temporary closure there are also structure relocations.

ANNUAL DAMAGES
Annual damages refer to loss of recreational value resulting from temporarily closing the park (incurred during

portions of strategies A*, R(1)A*, R(2)A*, and R(3)A*).

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)	Annual Damage (THOUSANDS)
1445	$0	$0
1446	$0	$0
1447	$0	$516
1448	$0	$516
1449	$0	$516
1449.6	$794	$516
1450	$794	$516
1451	$794	$516
1452	$794	$516
1453	$794	$516
1454	$794	$516
1455	$794	$516
1455.1	$1,013	$516
1456	$1,013	$516
1457	$1,013	$516
1458	$1,013	$516
1459	$1,013	$516
1460	$1,013	$516
1461	$1,013	$516
1462	$1,013	$516
1463	$1,013	$516

DAMAGES
Damages to structures and infrastructure are a one time damage, incurred only under the no protection or temporary closure of access road strategies. Damages to land are a one time damage incurred under all strategies.

Lake Elevation (MSL)	Structures and Infrastructure	Land
	THOUSANDS	
1445	$0	$0
1446	$0	$0
1447	$75	$157
1448	$0	$0
1449	$255	$19
1450	$0	$0
1451	$0	$0
1452	$0	$0
1453	$0	$0
1454	$0	$11
1455	$0	$0
1456	$0	$21
1457	$0	$0
1458	$0	$0
1459	$0	$0
1460	$0	$0
1461	$15	$23
1462	$0	$0
1463	$0	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table I.C.7.B

Economic Analysis of Devils Lake Alternatives
Inventory Sheet

Feature 7 - Grahams Island State Park

Decision/Action Level	Strategy	Item	Cost		Damages Prevented	
			Description	Value	Description	Value
1447	Incremental Raise	Move	South Employee Residence	$56,300	South Employee Residence	$75,000
			Total	**$56,300**	**Total**	**$75,000**
1449	Incremental Raise	Move	Loop A Comfort Station	$110,000	Loop A Comfort Station	$110,000
			Loop A Lift Station	$30,000	Loop A Lift Station	$30,000
			South Residence Barn	$75,000	South Residence Barn	$100,000
			South Residence Garage	$11,300	South Residence Garage	$15,000
		Road Raise	County Road # 1020	$2,759,500		
			County Road # 1021	$726,900		
			Total	**$3,713,000**	**Total**	**$255,000**
1454	Incremental Raise	Road Raise	County Road # 838	$795,000		
			County Road # 1020	$1,135,300		
			County Road # 1021	$298,900		
			Total	**$2,229,000**	**Total**	**$0**
1456	Incremental Raise	Road Raise	County Road # 838	$905,200		
			County Road # 1020	$4,110,700		
			County Road # 1021	$687,900		
			Total	**$5,704,000**	**Total**	**$0**
1461	Incremental Raise	Move	Picnic Shelter West	$15,000	Picnic Shelter West	$15,000
		Road Raise	County Road # 838	$1,211,600		
			County Road # 1020	$4,178,500		
			County Road # 1021	$894,600		
			Total	**$6,300,000**	**Total**	**$15,000**

The maximum protection strategy cost for this feature (maximum road raise and relocation of all structures at the first decision/action level) is obtained by adding the incremental relocation costs at each decision/action level shown in this table.

Feature 8. Rural Areas

A. General Assumptions

1. The only viable strategy for the rural areas was to relocate residences, abandon public and private property, and relocate public utilities. The density of structures does not justify the cost for protection by a levee, and access is a potential problem if the structures were somehow protected.

2. The cost of road raises or road restoration was not considered for the rural areas in this report. Major roads in the region were analyzed as separate features, Features 13 through 24.

3. Areas that are protected by levees were not considered in the value of rural areas—these were included in the feature for the respective community or city.

4. The average value of rural houses located around Devils Lake, but not on the reservation, was $88,000. The average value for rural houses located on the Spirit Lake Nation Reservation was $62,000. These figures were obtained from the Federal Emergency Management Agency (FEMA). The average values for off-reservation and on-reservation houses were based upon 1,219 and 88 houses, respectively. The value for each house was determined for FEMA by certified flood insurance adjusters and was based on total habitable square footage of the buildings and standardized real estate appraisals. These values did not include the value of land on which the houses were located. FEMA has been using these average values for planning purposes only (*FEMA*, March, 2001). The number of houses and their elevations were also provided by FEMA. This data was used for only Feature 8.1: Devils Lake Rural Areas.

   For Feature 8.2: Stump Lake Rural Areas, the values of rural structures were assumed to be the values presented in the 1997 Depreciated Replacement Cost (*Economics Database Update for the Lands and Developments Feasibility Study, Devils Lake,* Watts & Associates, Inc., October, 1997). FEMA data was not available for the Stump Lake area. These values were updated for inflation by multiplying them by 1.09 to account for inflation of 3% per year during the period from 1998 to February 2001.

5. For Feature 8.1, within each increment it was assumed that structures would be relocated and land would be damaged when the water surface is 1 foot below the elevation of the lowest structure or land. For example, at action level 1448.5, structures between elevations 1449.5 to 1451 would be relocated and land between elevation 1449.5 to 1451 would be damaged. There are two exceptions to this for Feature 8.1: at decision/action level 1446.2, structures at elevations between 1446.2 and 1446.5 are relocated, and at decision/action level 1446.5, structures at elevations between 1446.5 and 1448 are relocated. This assumption front-end loads the costs and damages for each increment. However, wave action could affect land and structures several feet above the lake's level and, therefore, actual damages might occur well before the lake reaches the land or structure elevation.

For Feature 8.2, there are only 7 structures that are located between elevation 1445 and 1450. Therefore, all structures were assumed to be relocated at the first action/decision level of 1444. Ten additional action levels were selected for this feature to compute the damages to land. Within these elevation increments, it was assumed that land and structures would be damaged when the water surface is 1 foot below the action level, as in Feature 8.1.

6. Land value in rural areas was assumed to be $400/acre. This value was provided by the Corps of Engineers (personal communication, April, 2001) and is an estimate of the average value of all land surrounding Devils Lake.

7. The majority of Spirit Lake Nation Reservation residences are in Fort Totten and St. Michael and were considered separately in those features.

8. All structures and land in Nelson County are part of the Stump Lake watershed and would not be affected until Devils Lake overflows at elevation 1446.6. Therefore, the Stump Lake rural areas were analyzed separately from the Devils Lake rural areas. The relocation costs and damages for the Stump Lake rural areas were calculated with reference to Stump Lake water surface elevations, not Devils Lake water surface elevations.

9. All seven residences in the Nelson County portion of the study area are located between elevation 1445 and 1450 in the Stump Lake Rural Areas (*Reconnaissance Report: Devils Lake Basin, North Dakota,* St. Paul District U.S. Army Corps of Engineers, 1992).

10. In the 1998 study, costs for relocating rural utilities and damages to rural parks and boat ramps were included in the total damage values for structures and infrastructure. The total damage values were obtained from the *Economics Database Update for the Lands and Developments Feasibility Study, Devils Lake* by Watts & Associates, Inc. (October, 1997). However, relocation costs for utilities and damages to rural parks and boat ramps were not itemized in the Watts study and these data were not available elsewhere. Therefore, for the 2001 analysis these additional costs were not included in the total damages.

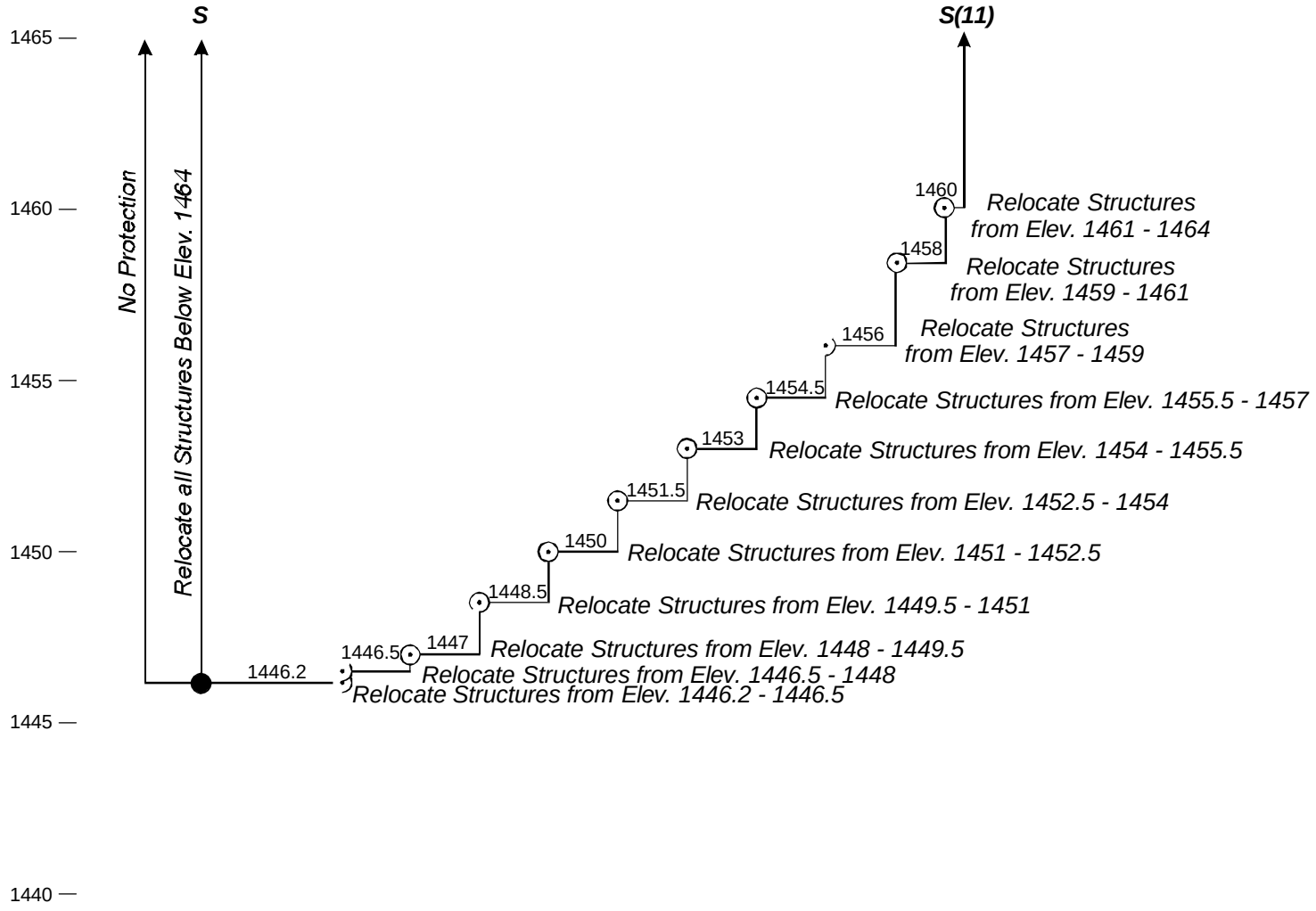
11. Land areas adjacent to Devils Lake and Stump Lake that would be affected by rising lake levels were obtained from the USGS (5-Box Model) elevation-volume-area relationships. Areas above elevation 1463 were extrapolated to elevation 1465.

Feature 8 Figures and Tables

Figure I.C.8.1 Feature 8.1: Decision Tree
Table I.C.8.A Feature 8.1: Cost and Damage Table
Figure I.C.8.2 Feature 8.2: Decision Tree
Table I.C.8.B Feature 8.2: Cost and Damage Table

Feature No. 8.1

DEVILS LAKE RURAL AREAS



● Decision required at this point

⊙ Trigger point for action, no decision needed

S(1) Incremental structure relocation (number of times)

S Relocate all structures below Elev. 1464

Feature No. 8.1

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.8.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 8.1 - Devils Lake Rural Areas

COSTS

Lake Elevation (MSL)	S Relocate All Structures at AL1	S(11) Relocate Structures at AL1, AL2, AL3, AL4, AL5, AL6, AL7, AL8, AL9, AL10, AL11
	THOUSANDS	
1445	$0	$0
1446	$0	$0
1446.2	$38,420	$4,624
1446.5	$0	$3,536
1447	$0	$3,672
1448.5	$0	$2,040
1449	$0	$0
1450	$0	$1,360
1451.5	$0	$1,972
1452	$0	$0
1453	$0	$2,652
1454.5	$0	$2,108
1455	$0	$0
1456	$0	$4,420
1457	$0	$0
1458	$0	$4,148
1459	$0	$0
1460	$0	$7,888
1461	$0	$0
1462	$0	$0
1463	$0	$0

Note: AL = Decision/Action Level

DAMAGES

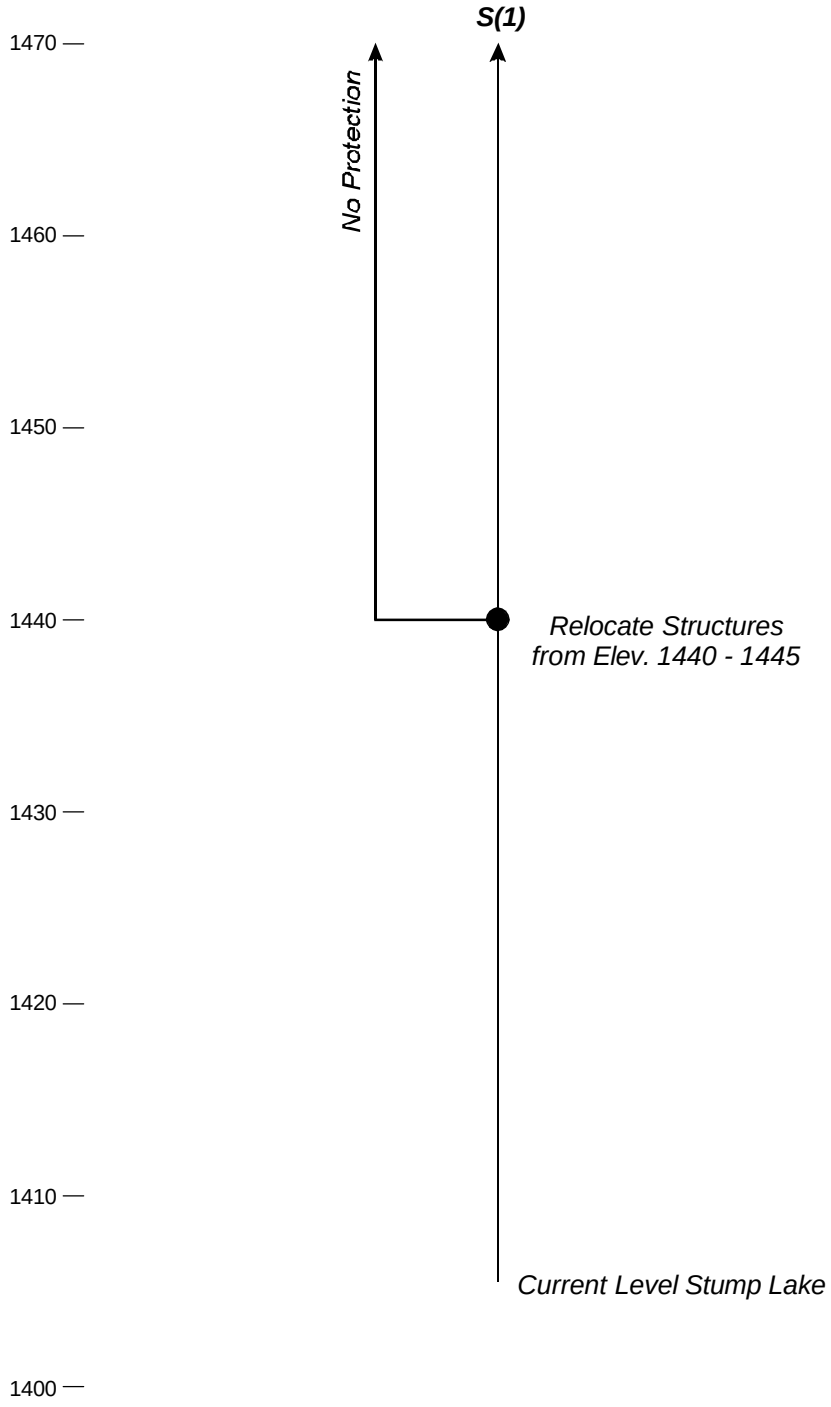
Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy. Damages to land are a one time damage incurred under all strategies.

Lake Elevation (MSL)	Structures and Infrastructure	Land
	THOUSANDS	
1445	$0	$0
1446	$0	$0
1446.2	$4,840	$0
1446.5	$4,446	$0
1447	$4,622	$4,766
1448	$0	$11,923
1448.5	$2,510	$0
1449	$0	$0
1450	$1,656	$6,068
1451	$0	$6,721
1451.5	$2,448	$0
1452	$0	$0
1453	$3,380	$7,596
1454	$0	$8,335
1454.5	$2,598	$0
1455	$0	$0
1456	$5,512	$12,564
1457	$0	$0
1458	$5,134	$14,251
1459	$0	$0
1460	$9,896	$24,268
1461	$0	$0
1462	$0	$0
1463	$0	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature No. 8.2

STUMP LAKE RURAL AREAS



● Decision required at this point

S(1) Incremental structure relocation (number of times)

S Relocate all structures below Elev. 1464

Feature No. 8.2

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.8.B

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 8.2 - Stump Lake Rural Areas

COSTS

Lake Elevation (MSL)	S(1) Relocate Structures at AL1 (THOUSANDS)
1443	$0
1444	$363
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$0
1456	$0
1457	$0
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: AL = Decision/Action Level

DAMAGES
Damages to structures and infrastructure are a one time damage, incurred only under the no protection strategy.
Damages to land are a one time damage incurred under all strategies.

Lake Elevation (MSL)	Structures and Infrastructure	Land
	THOUSANDS	
1409	$0	$418
1410	$0	$0
1411	$0	$0
1412	$0	$0
1413	$0	$0
1414	$0	$226
1415	$0	$0
1416	$0	$0
1417	$0	$0
1418	$0	$0
1419	$0	$271
1420	$0	$0
1421	$0	$0
1422	$0	$0
1423	$0	$0
1424	$0	$343
1425	$0	$0
1426	$0	$0
1427	$0	$0
1428	$0	$0
1429	$0	$430
1430	$0	$0
1431	$0	$0
1432	$0	$0
1433	$0	$0
1434	$0	$527
1435	$0	$0
1436	$0	$0
1437	$0	$0
1438	$0	$0
1439	$0	$626
1440	$0	$0
1441	$0	$0
1442	$0	$0
1443	$0	$0
1444	$518	$1,153
1445	$0	$0
1446	$0	$0
1447	$0	$0
1448	$0	$0
1449	$0	$807
1450	$0	$0
1451	$0	$0
1452	$0	$0
1453	$0	$0
1454	$0	$876
1455	$0	$0
1456	$0	$0
1457	$0	$0
1458	$0	$0
1459	$0	$920
1460	$0	$0
1461	$0	$0
1462	$0	$0
1463	$0	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Rail Lines

General Assumptions

1. Costs of railroad raises and restorations were obtained from *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. These costs were updated for 2001 based on conversations with area railroad companies as follows:

    a. Filter fabric will no longer be placed under rip rap for railroad raises; therefore, filter fabric costs were not included in the analysis.

    b. Rip rap costs have increased from $20 per cubic yard to $30 per cubic yard due to inflation and scarcity of materials in the area.

    c. Fill costs have increased from $4.50 per cubic yard to $9 per cubic yard based on current costs in the area.

    d. Costs to install rails, ties and ballast were estimated at $135 per linear foot, which is representative of the cost of current installation methods in the area.

    e. Estimated railroad bridge raise costs were decreased from $500,000 per 100-foot bridge to $212,000 per 100-foot bridge based on new information on construction methods.

    f. Side slopes for raises and repair of rail beds were assumed to be 2:1 instead of 3:1,based on new information on construction methods. This revised assumption was also made for the side slopes of existing rail beds.

    g. Detour damages for rail abandonment were inflated to 2001 dollars.

2. It was assumed that decisions on protection would occur when the lake level is 1 foot below the top of the lowest rail bed.

3. If the railroad feature has a bridge with a low chord below the lowest rail bed, no decision will occur until the lake level is within 1 foot of the top of the lowest rail bed.

4. If railroads are temporarily closed during flooding, they were assumed to be restored—except for Feature 9 which was assumed to be permanently abandoned. Although some spur lines have been abandoned in recent years due to a loss of profitability of the lines, representatives of the respective railroads have indicated that they have no plans to abandon these specific spur lines and have indicated they would restore them if they were temporarily flooded. Burlington Northern Railroad does have a legal commitment to limit the total miles of tracks abandoned in the state, but can abandon a line if it is out of service for 2 years or more (based on a conversation with Don Laschkewitsch, Transportation Senior Manager, Railroads, NDDOT). For this study, it was assumed that the tracks would not be abandoned, but may be temporarily closed during flooding and restored

when the lake recedes to 1 foot below the top of the lowest rail bed (again, with the exception of Feature 9).

Feature 9. Red River Valley and Western Railroad: Minnewaukan South

1. Upon investigation it was found that this feature has been permanently abandoned, with no plans for future restoration. No decision trees and no costs are included for this feature.

Feature 10. Canadian Pacific Railroad: City of Devils Lake to Harlowe

1. Based on conversation with Greg Haug of Northern Plains Railroad, lessee of Canadian Pacific Railroad (CPR) tracks, CPR would not reroute rails to higher ground. Rerouting the track would be extremely costly. Even rebuilding a portion of the track within the railroad's right-of-way has proven to be an expensive effort. The railroad would likely raise the tracks to keep the line open as the lake level rises.

2. This railroad has been closed since 1998. The current lake level is 4 feet below the lowest elevation of the tracks (1450 MSL); however, wave action has caused erosion damage to the sides of the rail bed, making the railroad too dangerous to use. The tracks between the City of Devils Lake and Harlowe were predominantly used for grain shipments. Grain is now trucked to a BNSF line instead of being shipped by rail. This increases shipment costs by approximately $480,000 per year (based on conversations with Greg Haug- Northern Plains Railroad, lessee of CPR tracks).

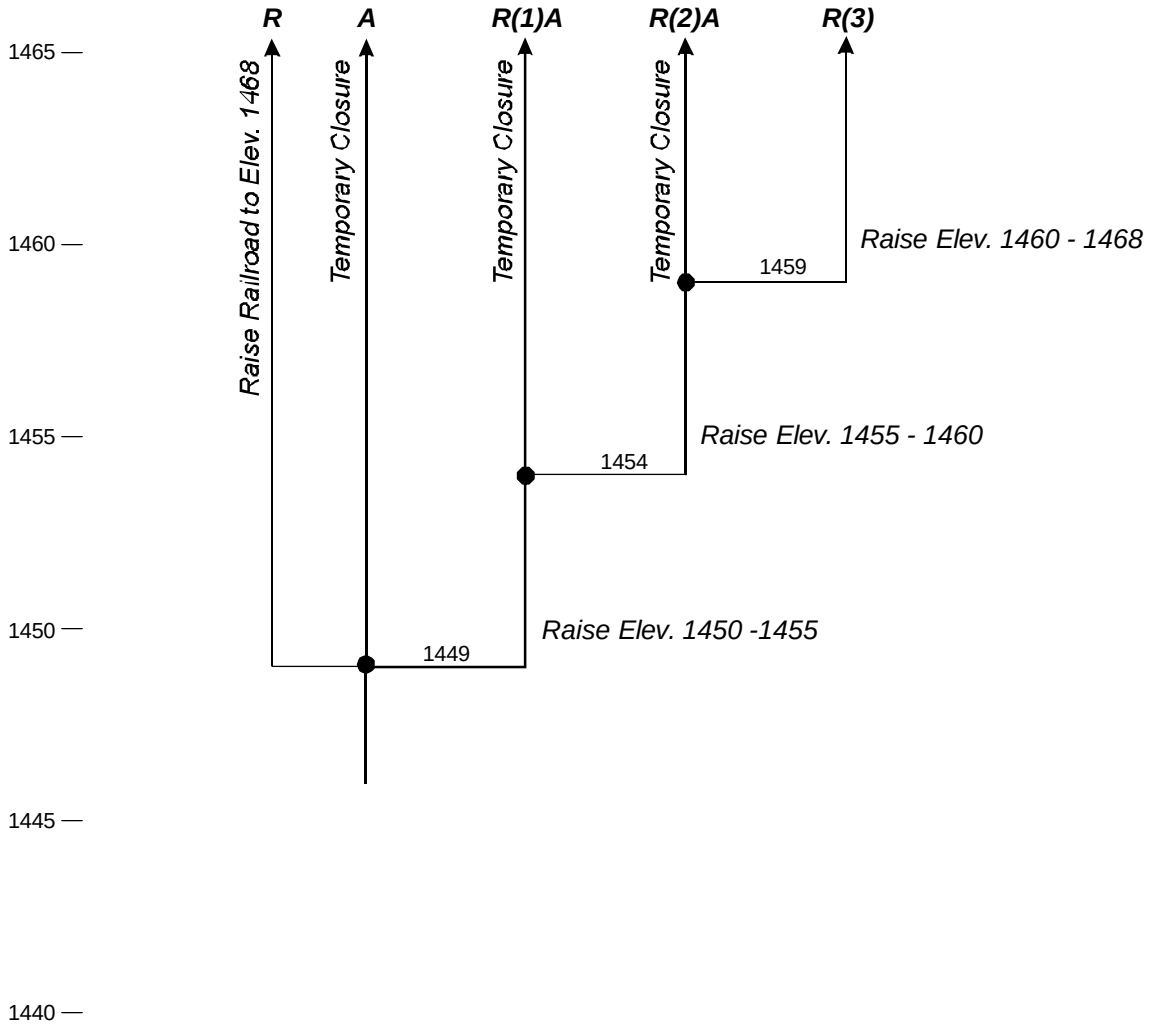
3. Northern Plains Railroad does not consider the railroad "abandoned" because they intend to reopen the tracks if they receive funding from the US Congress for repair and raises. Instead the railroad is considered "embargoed". For this analysis, it was assumed that the funding will become available and the railroad will be reopened.

Feature 10 Figures and Tables

Figure I.C.10 Feature 10: Decision Tree
Table I.C.10.A Feature 10: Cost and Damage Table

Feature No. 10

CANADIAN PACIFIC RAILROAD
CITY OF DEVILS LAKE TO HARLOWE



Lowest Rail Elevation: 1450

- ● Decision required at this point
- ◐ Trigger point for action, no decision needed
- ***R(1)*** Incremental railroad raise (number of times)
- ***R*** Railroad raise to 1468
- ***A*** Temporary closure of railroad

Feature No. 10

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.10.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 10 - Canadian Pacific Railroad: City of Devils Lake to Harlowe

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2)A Raise at AL1, AL2 Temporary Closure at AL3	R(3) Raise at AL1, AL2, AL3
	THOUSANDS				
1443	$0	$0	$0	$0	$0
1444	$0	$0	$0	$0	$0
1445	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0
1447	$0	$0	$0	$0	$0
1448	$0	$0	$0	$0	$0
1449	$91,146	$0	$24,597	$24,597	$24,597
1450	$0	$0	$0	$0	$0
1451	$0	$0	$0	$0	$0
1452	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0
1454	$0	$0	$0	$25,009	$25,009
1455	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$0
1457	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$41,540
1460	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0
1462	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a rail line is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1449	$509
Raise at AL1, Temporary Closure at AL2	1454	$509
Raise at AL1, AL2, Temporary Closure at AL3	1459	$509
Raise at AL1, AL2, AL3	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below the rail bed after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the rail line that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$4,963
1451	$4,963
1452	$4,963
1453	$4,963
1454	$6,620
1455	$9,123
1456	$10,314
1457	$10,314
1458	$12,563
1459	$12,563
1460	$12,563
1461	$12,563
1462	$12,563
1463	$13,499

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 11. Burlington Northern Railroad: Along US Highway 2

1. The track along US Highway 2 is a transcontinental freight route that extends from the State of New York to the State of Washington (through Devils Lake). Amtrack passenger routes use the track and many other companies use the track for shipping a variety of products across the country. Burlington Northern Railroad (BNR) has no plans to temporarily close this line because it would affect so many train routes (conversation with Cliff Inman, Burlington Northern). Therefore, the cost-effective strategy assumes this track remains open. During rapid rises in the lake level, this line might experience inadvertent closure(s) due to wave action damages or subbase failure from long-term submergence of the rail bed. As with CPR, rerouting the BNR tracks is not considered a feasible option. Therefore, rerouting tracks was not considered as a strategy in this study. Consequently, the only protection strategy evaluated for this feature is rail raises. For the no protection strategy, detour damages were estimated based on assumptions described in the following paragraphs (a – m). **These detour damages were estimated in 1998, therefore they were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. The 1998 assumptions are as follows:**

   a. In general, the train traffic that runs through Devils Lake along U.S. Highway 2 consists of two Amtrak trains per day; two merchandise trains per day, six times per week (100 cars per train); and four grain trains per week (104 cars per train). The merchandise and grain trains make stops in Devils Lake to pick up/drop off cargo and then continue on in the same direction.

   b. The detour costs for Amtrak trains were based on a conversation with Gary Erford, Produce Line Director, Amtrak. If the rail line along U.S. Highway 2 were closed, Amtrak trains would be rerouted from Fargo, northwest to Minot (along Highway 52... hereafter called the lower track). Consequently, there would be no Amtrak service for Grand Forks, Devils Lake and Rugby.

   c. The lost service to the three cities for Amtrak was estimated to result in approximately $100,000 per year revenue to Amtrak. Although bus service could be used to transport passengers from Grand Forks, Devils Lake, and Rugby to Minot or Fargo at a cost of $365,000 per year, it was assumed that service would be stopped to these three cities. The updated value for lost train service is $106,000.

   d. The other Amtrak damage involved in abandoning the track along U.S. Highway 2 is the lost time due to congestion on the Fargo-Minot line (the lower track). When Amtrak first switched over to the lower track during the 1997 floods, their trains had delays of 1 to 2 hours per trip. However, after the fleeting was better organized, the delay was down to 30 minutes. This is considered a better estimate of a typical Amtrak delay along this line. This delay does not take into account those times that bad weather or mechanical failure cause extreme hold-ups along the line. The cost associated with delay is $155 per minute, based on Amtrak computations. This 30-minute delay at $155 per minute was assumed for this study, and incorporates passenger time, crew over time and fuel. The updated cost associated with the delay is $164 per minute.

e. Data for the grain and merchandise train detour costs are based on conversation with Doug Chapel, Train Master of North Dakota in Fargo—in charge of the Burlington Northern line between Minot and Grand Forks and with Chuck Wendt, Superintendent of Operations in Fargo.

f. Doug Chapel stressed the issue of congestion on the would-be detour line from Fargo to Minot (the lower track). Amtrak trains are on the upper Devils Lake line because of the difficulties of congestion on the lower line, not because Amtrak business is booming in Devils Lake. Routing trains on the lower line would be more of a short term fix rather than an easy solution to an abandoned track through Devils Lake.

g. John Quiltey, the BNR Head of the Locomotive Engineers in Forth Worth, TX and Skip Trader, also of the BNR Fort Worth Office, were contacted regarding detour costs.

h. The detour costs for merchandise and grain trains were based on fuel costs and crew overtime using Amtrak's 30-minute delay and assuming the detoured trains travel at 70 mph. An equivalent detour mileage for the time delay is then 35 miles.

i. Fuel costs for 1997 of $0.684/gal were assumed, based on conversations with Mr. Skip Trader (BNSF Fort Worth). Fuel efficiency is based on a Gross Ton Mile/Gal figure, at 711 ton mile/gal for 1997. In other words, 711 gross tons (material plus car weight) were transported 1 mile using 1 gallon of diesel fuel. The updated fuel cost is $0.725/gal.

j. The average capacity of grain and merchandise cars was obtained from the BNSF Railroad web site—an average agricultural car capacity of 134 gross tons and an average boxcar capacity of 120 gross tons.

k. The average crew required to operate a train was assumed to be three, plus one more person for switch operation. Dennis Mead (BNSF Payroll) stated that the crew members get paid on a mileage basis until a certain limit is reached. After that, a lot of other add-ons occur and that no general assumptions could be made for the 30 additional minutes of crew delay time. Therefore, the crew was assumed to be paid at an average hourly rate of $25/hr/person and that delays would be paid at 1.5 the normal rate. The updated average hourly rate is $26.50/hr/person.

l. The detour costs do not account for trucking of merchandise and grain to/from Devils Lake. However, if the track along U.S. Highway 2 is under water, the viability of commerce in Devils Lake is questionable and there may not be as great a need for merchandise and grain shipment to/from Devils Lake.

m. The detour costs also do not address the possibility of additional delays that other existing trains would experience due to the additional traffic from the upper track. However, five more trains per day on the lower track may not make much difference to the trains already there, especially if fleeting is well coordinated.

2. Recent surveys (2001) indicate that this segment of the BNR has 3 signaling stations that would need to be replaced if the railroad is raised. The replacement cost for the signaling network (i.e. all 3 signaling stations) is estimated to be $850,000. The signaling network would need to be replaced for each incremental railroad raise.

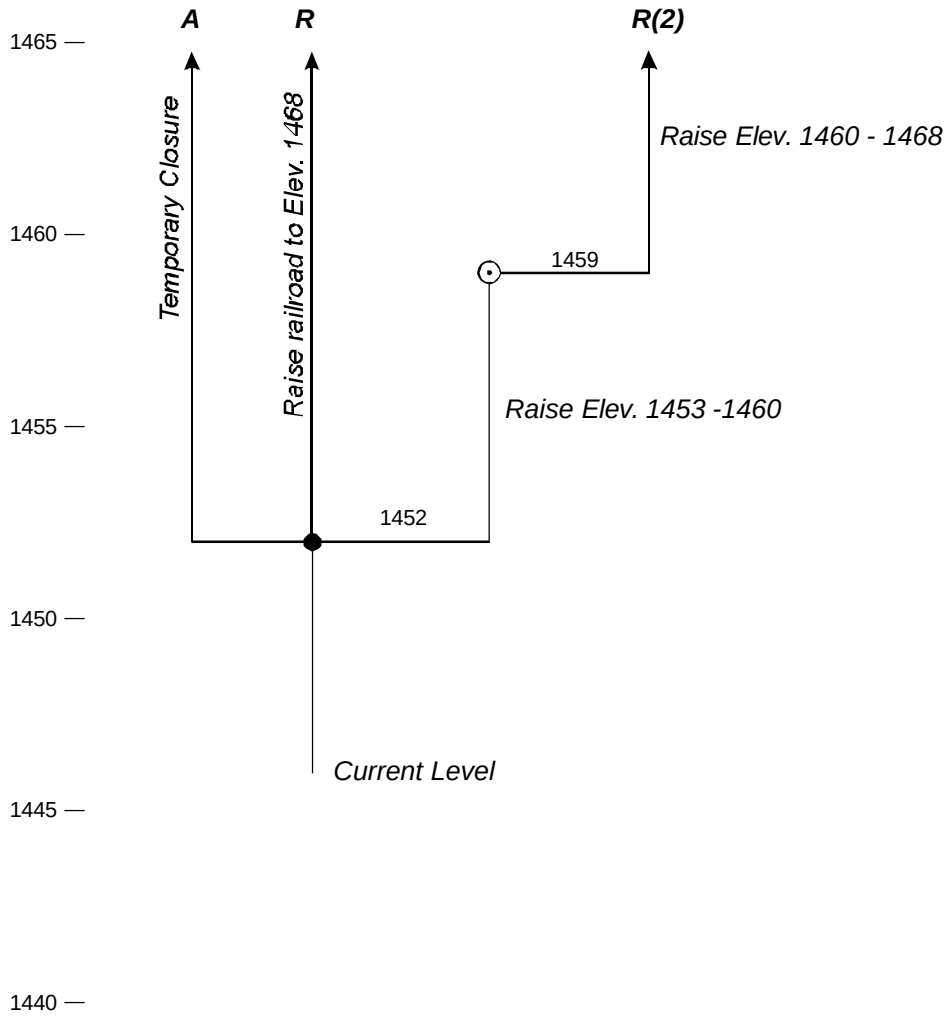
3. Recent surveys (2001) indicate that railroad raises would affect 3 road crossings. The cost to rebuild each crossing is estimated to be $1,000 per track-foot and the typical track-foot length is 30 feet; therefore, the total estimated rebuild cost would be $30,000.

Feature 11 Figures and Tables

Figure I.C.11 Feature 11: Decision Tree
Table I.C.11.A Feature 11: Cost and Damage Table

Feature No. 11

BURLINGTON NORTHERN RAILROAD ALONG US HIGHWAY 2



Lowest Rail Elevation: 1453

- ● Decision required at this point
- ◉ Trigger point for action, no decision needed
- ***R(1)*** Incremental railroad raise (number of times)
- ***R*** Railroad raise to 1468
- ***A*** Temporary Closure

Feature No. 11

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.11.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 11 - Burlington Northern Railroad: Along US Highway 2

COSTS

Lake Elevation (MSL)	A Temporary Closure at AL1	R Maximum Raise at AL1	R(2) Raise at AL1, AL2
	THOUSANDS		
1443	$0	$0	$0
1444	$0	$0	$0
1445	$0	$0	$0
1446	$0	$0	$0
1447	$0	$0	$0
1448	$0	$0	$0
1449	$0	$0	$0
1450	$0	$0	$0
1451	$0	$0	$0
1452	$0	$69,394	$16,561
1453	$0	$0	$0
1454	$0	$0	$0
1455	$0	$0	$0
1456	$0	$0	$0
1457	$0	$0	$0
1458	$0	$0	$0
1459	$0	$0	$52,833
1460	$0	$0	$0
1461	$0	$0	$0
1462	$0	$0	$0
1463	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a rail line is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1452	$4,141
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below the rail bed after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the rail line that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$2,897
1454	$2,897
1455	$2,897
1456	$2,912
1457	$2,912
1458	$4,201
1459	$5,093
1460	$5,093
1461	$9,230
1462	$10,032
1463	$12,205

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 12. Burlington Northern Railroad: Churchs Ferry to Cando

1. According to John Heizman, Burlington Northern Railroad, this track carries an average of approximately 100 cars per month. It is difficult to estimate how much trucking would cost because the material shipped changes significantly throughout the year and involves both fertilizer and grain. It was assumed that the cost for trucking fertilizer and other commodities would be comparable to the trucking cost for grain at $400 per carload. Therefore, if the tracks were temporarily closed, annual damages would be $480,000. These annual damages were determined in 1998, therefore they were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. The inflated damages are $509,000.

2. Rerouting of the rail is not logical for this rail feature, as discussed in Features 10 and 11. Therefore, only temporary closure during flooding and rail raise scenarios is evaluated for this track.

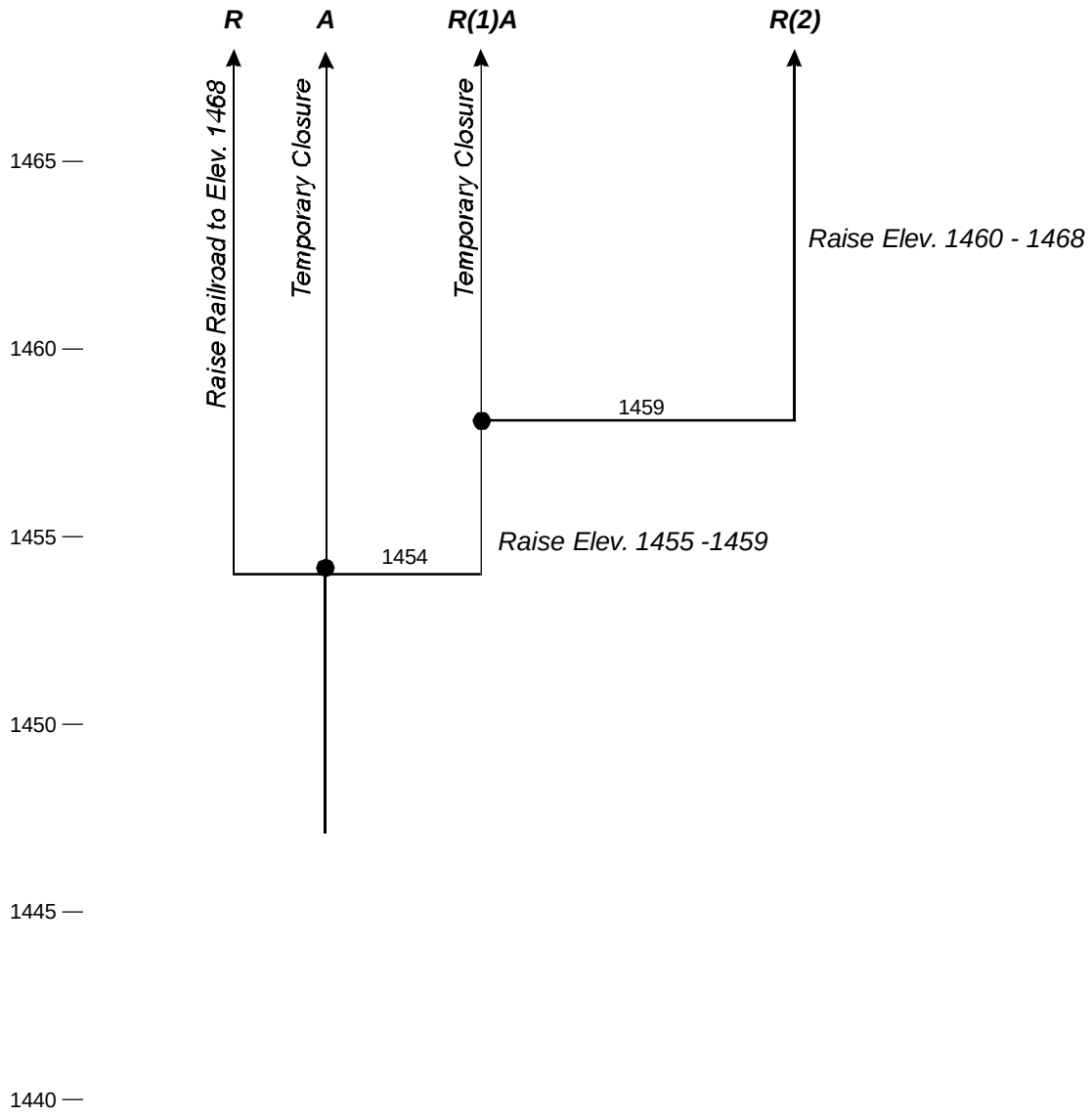
3. Recent surveys indicate that railroad raises would affect 2 road crossings. The cost to rebuild each crossing is estimated to be $1,000 per track-foot and the typical track-foot length is 30 feet; therefore, the total estimated rebuild cost would be $30,000.

Feature 12 Figures and Tables

Figure I.C.12 Feature 12: Decision Tree
Table I.C.12.A Feature 12: Cost and Damage Table

Feature No. 12

BURLINGTON NORTHERN RAILROAD
CHURCHS FERRY TO CANDO



Lowest Rail Elevation: 1455

● Decision required at this point

Trigger point for action, no decision needed

R(1) Incremental railroad raise (number of times)

R Railroad raise to 1468

A Temporary closure of railroad

Feature No. 12

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.12.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 12 - Burlington Northern Railroad: Churchs Ferry to Cando

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2) Raise at AL1, AL2
	THOUSANDS			
1443	$0	$0	$0	$0
1444	$0	$0	$0	$0
1445	$0	$0	$0	$0
1446	$0	$0	$0	$0
1447	$0	$0	$0	$0
1448	$0	$0	$0	$0
1449	$0	$0	$0	$0
1450	$0	$0	$0	$0
1451	$0	$0	$0	$0
1452	$0	$0	$0	$0
1453	$0	$0	$0	$0
1454	$63,879	$0	$16,452	$16,452
1455	$0	$0	$0	$0
1456	$0	$0	$0	$0
1457	$0	$0	$0	$0
1458	$0	$0	$0	$0
1459	$0	$0	$0	$47,427
1460	$0	$0	$0	$0
1461	$0	$0	$0	$0
1462	$0	$0	$0	$0
1463	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a rail line is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1454	$509
Raise at AL1, Temporary Closure at AL2	1459	$509
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below the rail bed after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the rail line that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$1,218
1456	$1,218
1457	$3,564
1458	$3,564
1459	$4,351
1460	$6,727
1461	$9,365
1462	$11,836
1463	$14,220

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Introduction

Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions will be described in general terms with exceptions as appropriate for specific features.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been available until the National Weather Service predicts on February 15th that the road will go under water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

4. Bureau of Indian Affairs (BIA) roads were assumed to be raised in 5-foot increments (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998).

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding, assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. There is more commitment on the part of the North Dakota Department of Transportation (NDDOT) to the Highway 57 causeway than to the Highway 20 causeway through The Narrows. Therefore, Highway 57 was assumed to be the detour route for the Highway 20 causeway. If the Highway 57 causeway was temporarily closed during flooding, it was assumed that the Highway 20 causeway would also be temporarily closed.

7. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

8. Detour paths were determined assuming that all other featured roads would be open (with three exceptions: the Highway 57 detour assumes that Highway 20 across The Narrows is closed and both the BIA 1 and the BIA 6 detours assume that Highway 20 from Highway 57 to Tokio is closed). No effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an ? interdependency? was noted.

9. The analysis of Features 23 (BIA 1 between Highway 57 and BIA 6) and Feature 24 (BIA 6 between Highway 20 and Fort Totten) assumed that Feature 22 (Highway 20 between Highway 57 and Tokio) is temporarily closed during high lake levels. BIA 1 and BIA 6 are part of the north-south detour for Highway 20 and the preliminary analysis indicated that Feature 22 would likely be temporarily closed during high lake levels.

10. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. It was assumed that if a road was permanently rerouted, the old route for that road would never be restored. Rerouting a road is an expensive option, so it was assumed that once this investment was made, the old road would not be considered usable. However, detour damages (reflecting the longer distance on the new alignment) will continue to be incurred for every year that the rerouted road is in use. This detour damage is estimated with same model output from the QRS II model described in the assumptions regarding temporary closure during flooding.

2. It was assumed that the rerouted path for any feature would be upgraded to the same level (road width and speed limit) as the existing feature.

3. Road reroutes do not necessarily have to be onto roads that are currently at or above the maximum elevation 1468. If there is a logical reroute path that would require a minor road lift (<10 feet), this reroute path could still be acceptable.

4. The only features that have reroute strategies are Highway 281 north of US Highway 2, and Highway 281 south of US Highway 2. All other strategies either have no logical reroute or have routes that would require more than 10-foot raises.

5. Highway 1 is located near Stump Lake, which is currently at about elevation 1409. If Devils Lake overtops into Stump Lake, the lake level would rise to about elevation 1447 and become one lake with Devils Lake. It was found to be considerably less expensive to reroute Highway 1 than to raise it from 1410 to 1452. The rerouting of Highway 1 is planned for 2001. For this analysis, the reroute was assumed complete and therefore no costs or damages were associated with this feature.

Feature 13. US Highway 2

Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

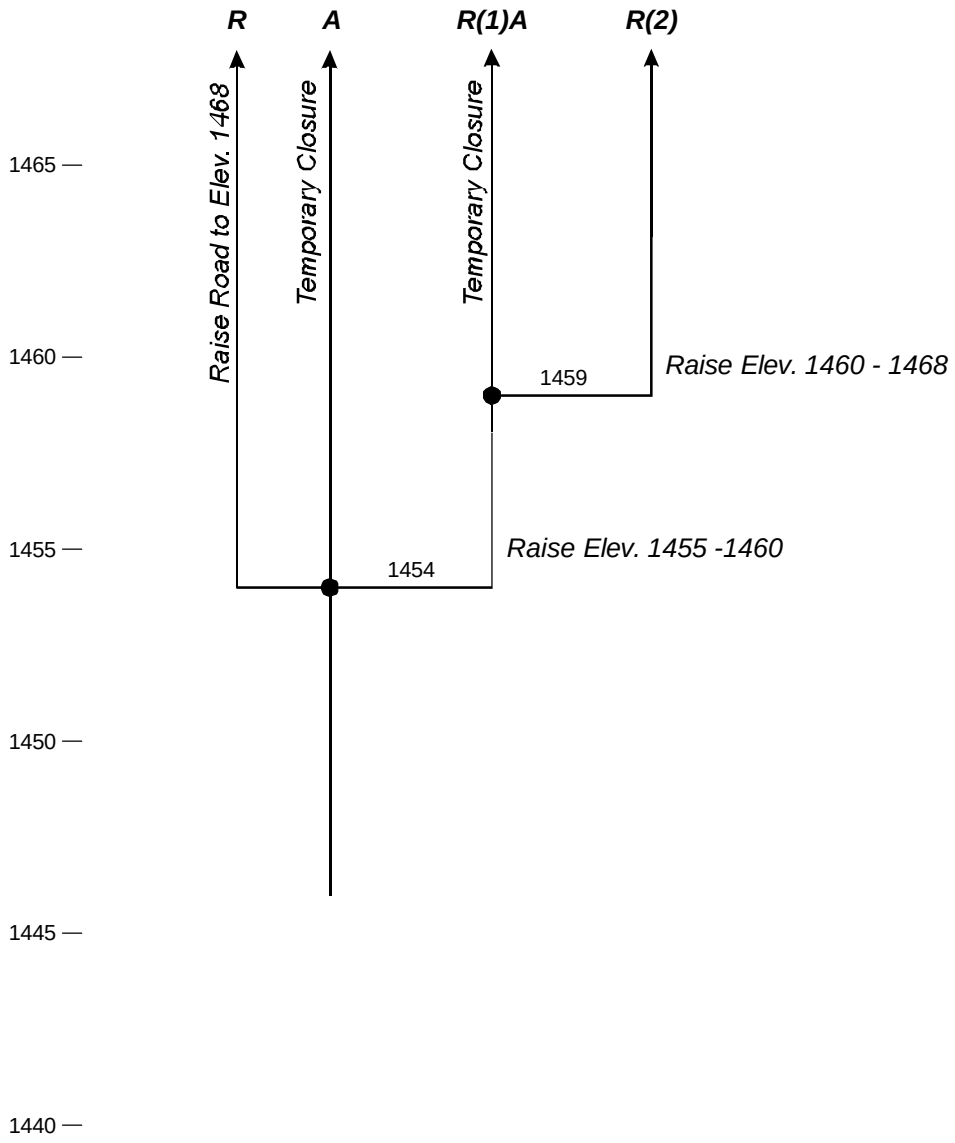
1. Plans for 2001 include raising Highway 2 from a minimum elevation of 1454 to 1455 and the bridges at Mauvais Coulee and Channel A from 1452 to 1461 (low chord). For this analysis, the work was assumed completed and the new elevations were used.

Feature 13 Figures and Tables

Figure I.C.13 Feature 13: Decision Tree
Table I.C.13.A Feature 13: Cost and Damage Table

Feature No. 13

US HIGHWAY 2



Lowest Road Elevation: 1455

- ● Decision required at this point
- ◐ Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 13

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.13.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 13 - US Highway 2

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2) Raise at AL1, AL2
	THOUSANDS			
1443	$0	$0	$0	$0
1444	$0	$0	$0	$0
1445	$0	$0	$0	$0
1446	$0	$0	$0	$0
1447	$0	$0	$0	$0
1448	$0	$0	$0	$0
1449	$0	$0	$0	$0
1450	$0	$0	$0	$0
1451	$0	$0	$0	$0
1452	$0	$0	$0	$0
1453	$0	$0	$0	$0
1454	$152,738	$0	$50,648	$50,648
1455	$0	$0	$0	$0
1456	$0	$0	$0	$0
1457	$0	$0	$0	$0
1458	$0	$0	$0	$0
1459	$0	$0	$0	$102,090
1460	$0	$0	$0	$0
1461	$0	$0	$0	$0
1462	$0	$0	$0	$0
1463	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1454	$11,863
Raise at AL1, Temporary Closure at AL2	1459	$11,863
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$1,679
1456	$1,679
1457	$11,830
1458	$14,097
1459	$16,823
1460	$16,823
1461	$18,330
1462	$20,323
1463	$22,260

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 14. Highway 57 Between Highway 20 and BIA 1

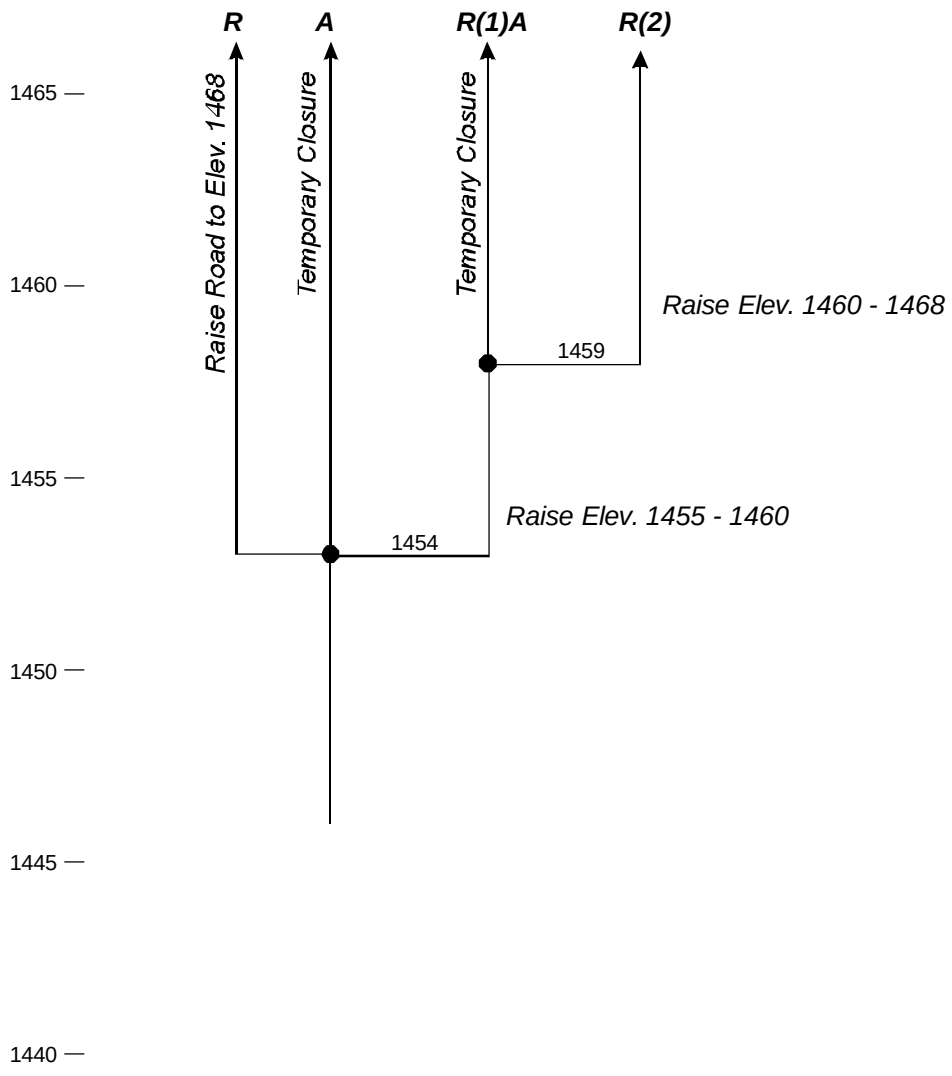
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 14 Figures and Tables

Figure I.C.14 Feature 14: Decision Tree
Table I.C.14.A Feature 14: Cost and Damage Table

Feature No. 14

HIGHWAY 57
BETWEEN HIGHWAY 20 AND BIA 1



Lowest Road Elevation: 1455

- ● Decision required at this point
- ·) Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 14

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.14.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 14 - Highway 57 between Highway 20 and BIA 1

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2) Raise at AL1, AL2
	THOUSANDS			
1443	$0	$0	$0	$0
1444	$0	$0	$0	$0
1445	$0	$0	$0	$0
1446	$0	$0	$0	$0
1447	$0	$0	$0	$0
1448	$0	$0	$0	$0
1449	$0	$0	$0	$0
1450	$0	$0	$0	$0
1451	$0	$0	$0	$0
1452	$0	$0	$0	$0
1453	$0	$0	$0	$0
1454	$14,274	$0	$6,203	$6,203
1455	$0	$0	$0	$0
1456	$0	$0	$0	$0
1457	$0	$0	$0	$0
1458	$0	$0	$0	$0
1459	$0	$0	$0	$8,071
1460	$0	$0	$0	$0
1461	$0	$0	$0	$0
1462	$0	$0	$0	$0
1463	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1454	$13,104
Raise at AL1, Temporary Closure at AL2	1459	$13,104
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$1,693
1456	$1,693
1457	$1,693
1458	$1,693
1459	$1,693
1460	$1,693
1461	$1,693
1462	$1,693
1463	$1,693

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 15. Highway 57 Between BIA 1 and Highway 281

Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

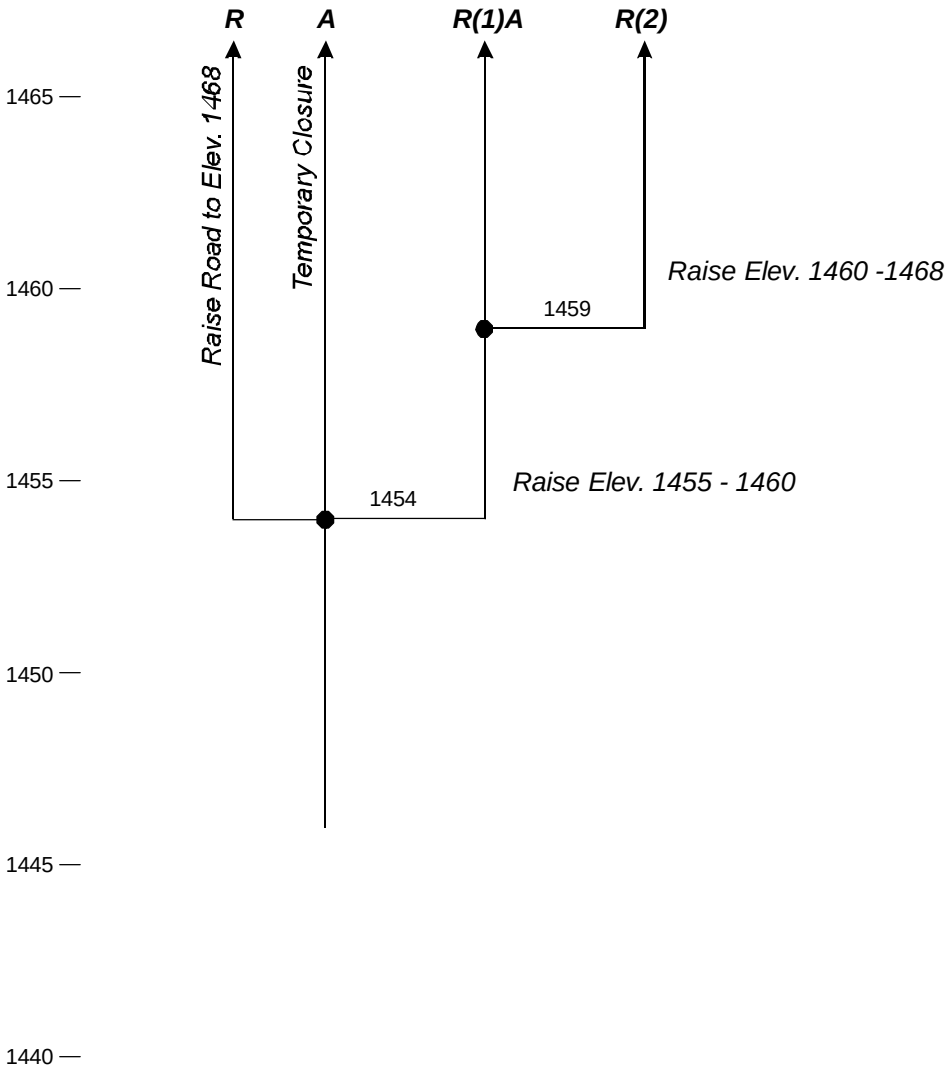
1. Plans for 2002 include raising Highway 57 from a minimum elevation of 1447.5 to 1455. For this analysis, the work was assumed completed and the new elevations were used.

Feature 15 Figures and Tables

Figure I.C.15 Feature 15: Decision Tree
Table I.C.15.A Feature 15: Cost and Damage Table

Feature No. 15

HIGHWAY 57
BETWEEN BIA 1 AND HIGHWAY 281



Lowest Road Elevation: 1455

● Decision required at this point

Trigger point for action, no decision needed

R(1) Incremental road raise (number of times)

R Road raise to 1468

A Temporary closure of road

Feature No. 15

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.15.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 15 - Highway 57 between BIA 1 and Highway 281

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2) Raise at AL1, AL2
	THOUSANDS			
1443	$0	$0	$0	$0
1444	$0	$0	$0	$0
1445	$0	$0	$0	$0
1446	$0	$0	$0	$0
1447	$0	$0	$0	$0
1448	$0	$0	$0	$0
1449	$0	$0	$0	$0
1450	$0	$0	$0	$0
1451	$0	$0	$0	$0
1452	$0	$0	$0	$0
1453	$0	$0	$0	$0
1454	$42,667	$0	$16,380	$16,380
1455	$0	$0	$0	$0
1456	$0	$0	$0	$0
1457	$0	$0	$0	$0
1458	$0	$0	$0	$0
1459	$0	$0	$0	$26,287
1460	$0	$0	$0	$0
1461	$0	$0	$0	$0
1462	$0	$0	$0	$0
1463	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES

Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1454	$9,488
Raise at AL1, Temporary Closure at AL2	1459	$9,488
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES

Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$3,644
1456	$3,644
1457	$4,599
1458	$4,599
1459	$4,599
1460	$4,599
1461	$5,460
1462	$5,460
1463	$5,460

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 16. Highway 281 South of US Highway 2

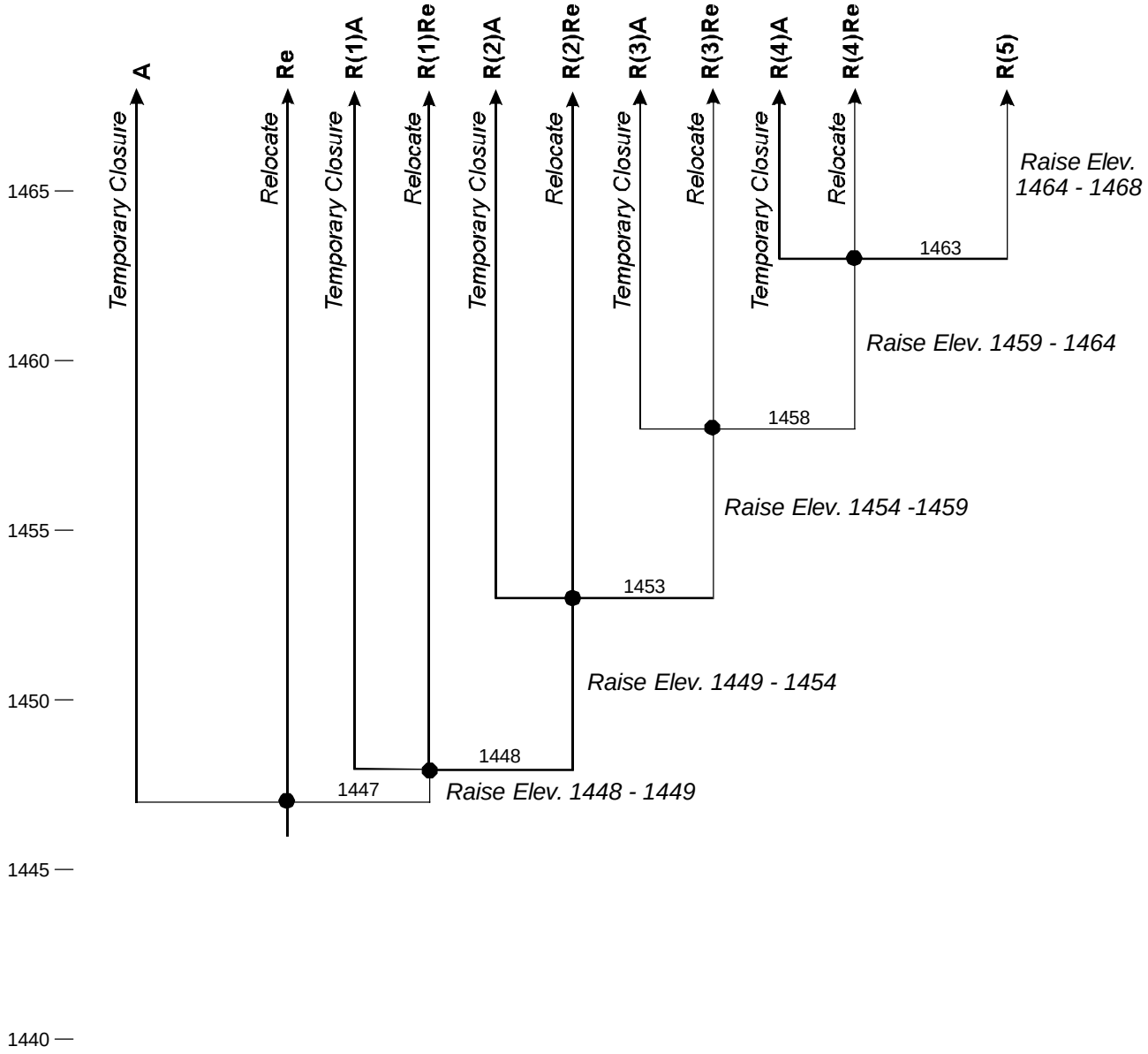
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 16 Figures and Tables

Figure I.C.16 Feature 16: Decision Tree
Table I.C.16.A Feature 16: Cost and Damage Table

Feature No. 16

HIGHWAY 281
SOUTH OF US HIGHWAY 2



Lowest Road Elevation: 1448

- ⬢ Decision required at this point
- ⊙ Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***A*** Temporary closure of road
- ***Re*** Relocate

Feature No. 16

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.16.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 16 - Highway 281 South of US Highway 2

COSTS

Lake Elevation (MSL)	A Temporary Closure at AL1	Re Relocate at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(1)Re Raise at AL1; Relocate at AL2	R(2)A Raise at AL1, AL2; Temporary Closure at AL3	R(2)Re Raise at AL1, AL2; Relocate at AL3	R(3)A Raise at AL1, AL2, AL3; Temporary Closure at AL4	R(3)Re Raise at AL1, AL2, AL3; Relocate at AL4	R(4)A Raise at AL1, AL2, AL3, AL4; Temporary Closure at AL5	R(4)Re Raise at AL1, AL2, AL3, AL4; Relocate at AL5	R(5) Raise at AL1, AL2, AL3, AL4, AL5
	THOUSANDS										
1443	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1444	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1445	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1447	$0	$23,718	$3,829	$3,829	$3,829	$3,829	$3,829	$3,829	$3,829	$3,829	$3,829
1448	$0	$0	$0	$23,718	$37,471	$37,471	$37,471	$37,471	$37,471	$37,471	$37,471
1449	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1450	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1451	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1452	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0	$23,718	$43,464	$43,464	$43,464	$43,464	$43,464
1454	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1455	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1457	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0	$0	$0	$23,718	$52,807	$52,807	$52,807
1459	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1462	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0	$0	$0	$0	$0	$23,718	$48,947

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES

Annual detour damages are based on each strategy. They are independent of lake elevation.
They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1447	$5,214
Relocate at AL1	1447	$1,575
Raise at AL1, Temporary Closure at AL2	1448	$5,214
Raise at AL1, Relocate at AL2	1448	$1,575
Raise at AL1, AL2, Temporary Closure at AL3	1453	$5,214
Raise at AL1, AL2, Relocate at AL3	1453	$1,575
Raise at AL1, AL2, AL3, Temporary Closure at AL4	1458	$5,214
Raise at AL1, AL2, AL3, Relocate at AL4	1458	$1,575
Raise at AL1, AL2, AL3, AL4, Temporary Closure at	1463	$5,214
Raise at AL1, AL2, AL3, AL4, Relocate at AL5	1463	$1,575
Raise at AL1, AL2, AL3, AL4, AL5	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$2,567
1449	$2,567
1450	$2,567
1451	$7,875
1452	$11,678
1453	$12,453
1454	$14,634
1455	$14,634
1456	$16,154
1457	$16,154
1458	$16,693
1459	$17,180
1460	$17,180
1461	$17,762
1462	$17,762
1463	$17,762

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 17. Highway 281 North of US Highway 2

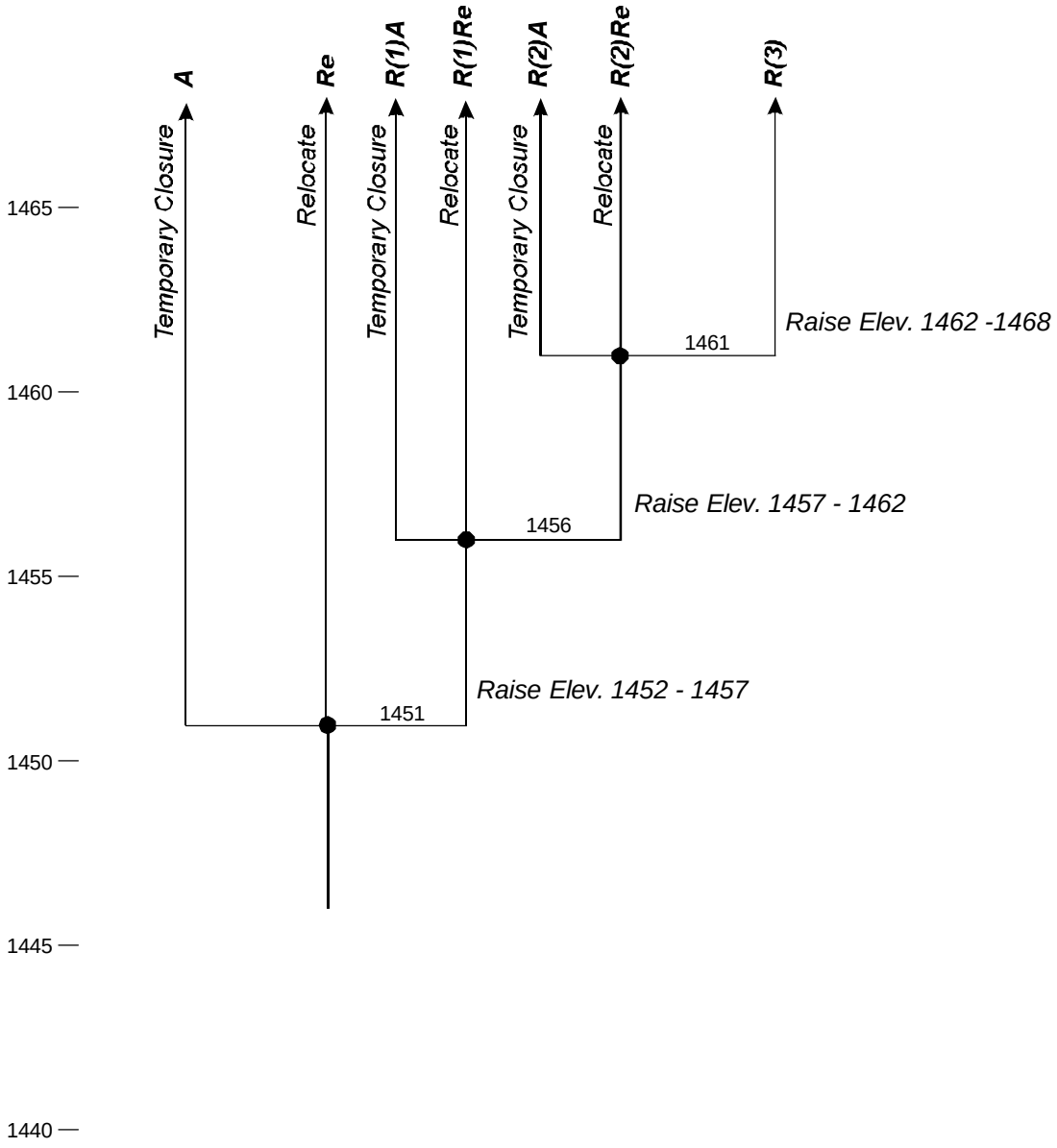
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 17 Figures and Tables

Figure I.C.17 Feature 17: Decision Tree
Table I.C.17.A Feature 17: Cost and Damage Table

Feature No. 17

HIGHWAY 281
NORTH OF US HIGHWAY 2



Lowest Road Elevation: 1452

- ⬢ Decision required at this point
- ⊙ Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***A*** Temporary closure of road
- ***Re*** Relocate

Feature No. 17

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.17.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 17 - Highway 281 North of US Highway 2

COSTS

Lake Elevation (MSL)	A Temporary Closure at AL1	Re Relocate at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(1)Re Raise at AL1 Relocate at AL2	R(2)A Raise at AL1, AL2 Temporary Closure at AL3	R(2)Re Raise at AL1, AL2 Relocate at AL3	R(3) Raise at AL1, AL2, AL3
	THOUSANDS						
1443	$0	$0	$0	$0	$0	$0	$0
1444	$0	$0	$0	$0	$0	$0	$0
1445	$0	$0	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0	$0	$0
1447	$0	$0	$0	$0	$0	$0	$0
1448	$0	$0	$0	$0	$0	$0	$0
1449	$0	$0	$0	$0	$0	$0	$0
1450	$0	$0	$0	$0	$0	$0	$0
1451	$0	$10,067	$12,126	$12,126	$12,126	$12,126	$12,126
1452	$0	$0	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0	$0	$0
1454	$0	$0	$0	$0	$0	$0	$0
1455	$0	$0	$0	$0	$0	$0	$0
1456	$0	$0	$0	$10,067	$23,537	$23,537	$23,537
1457	$0	$0	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0	$10,067	$38,376
1462	$0	$0	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1451	$1,322
Relocate at AL1	1451	$1,326
Raise at AL1, Temporary Closure at AL2	1456	$1,322
Raise at AL1, Relocate at AL2	1456	$1,326
Raise at AL1, AL2, Temporary Closure at AL3	1461	$1,322
Raise at AL1, AL2, Relocate at AL3	1461	$1,326
Raise at AL1, AL2, AL3	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$897
1453	$897
1454	$897
1455	$3,774
1456	$3,774
1457	$4,834
1458	$4,834
1459	$6,634
1460	$6,634
1461	$9,665
1462	$9,665
1463	$10,224

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 18. Highway 19 from the City of Devils Lake Levee to Highway 281

Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

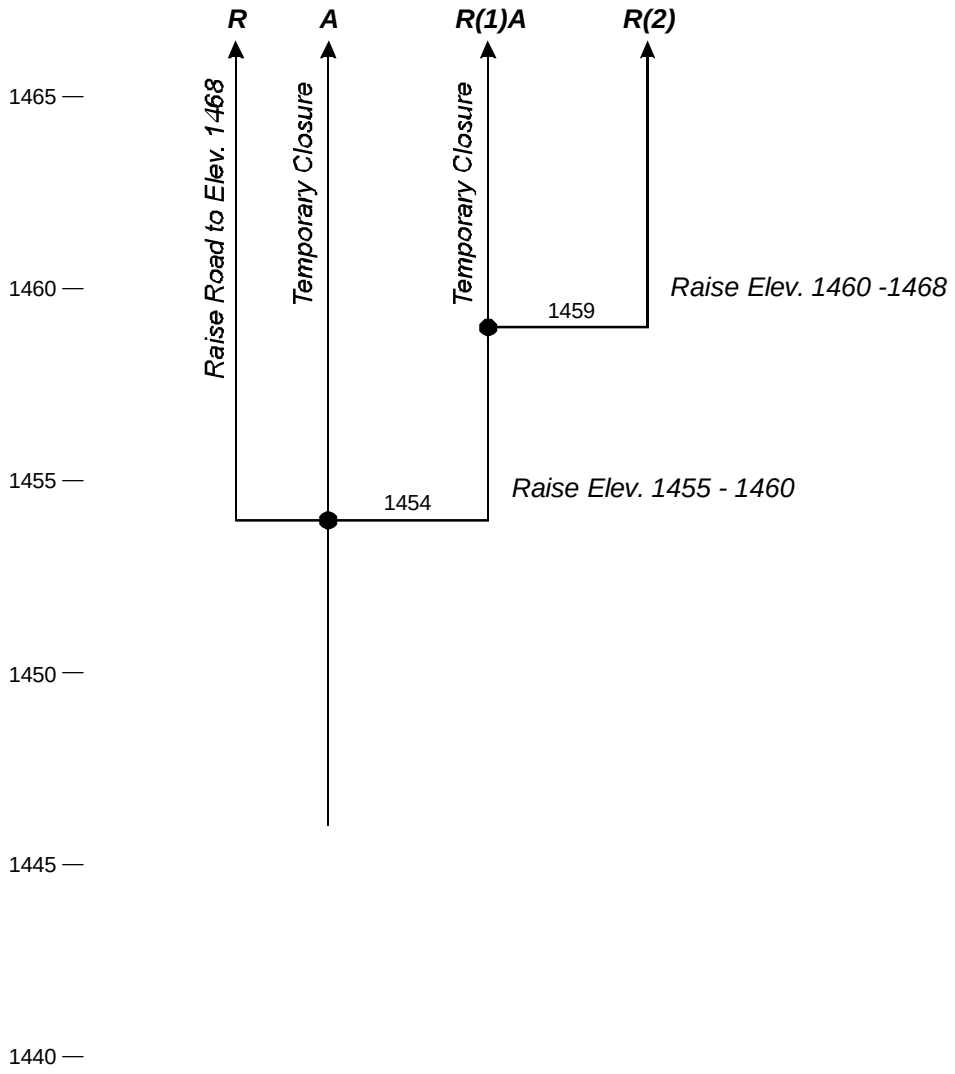
1. Plans for 2001 include raising Highway 19 to a minimum elevation of 1455 and the bridges at Mauvais Coulee and Six Mile Bay to a minimum elevation of 1461 (low chord). For this analysis, the work was assumed completed and the new elevations were used.

Feature 18 Figures and Tables

Figure I.C.18 Feature 18: Decision Tree
Table I.C.18.A Feature 18: Cost and Damage Table

Feature No. 18

HIGHWAY 19
CITY OF DEVILS LAKE LEVEE
TO HIGHWAY 281



Lowest Road Elevation: 1455

- ● Decision required at this point
- ·) Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 18

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.18.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 18 - Highway 19 from the City of Devils Lake Levee to Highway 281

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2) Raise at AL1, AL2
	THOUSANDS			
1443	$0	$0	$0	$0
1444	$0	$0	$0	$0
1445	$0	$0	$0	$0
1446	$0	$0	$0	$0
1447	$0	$0	$0	$0
1448	$0	$0	$0	$0
1449	$0	$0	$0	$0
1450	$0	$0	$0	$0
1451	$0	$0	$0	$0
1452	$0	$0	$0	$0
1453	$0	$0	$0	$0
1454	$101,252	$0	$38,810	$38,810
1455	$0	$0	$0	$0
1456	$0	$0	$0	$0
1457	$0	$0	$0	$0
1458	$0	$0	$0	$0
1459	$0	$0	$0	$62,442
1460	$0	$0	$0	$0
1461	$0	$0	$0	$0
1462	$0	$0	$0	$0
1463	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES

Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1454	$1,322
Raise at AL1, Temporary Closure at AL2	1459	$1,322
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$9,923
1456	$9,923
1457	$9,923
1458	$9,923
1459	$9,923
1460	$11,258
1461	$12,015
1462	$14,999
1463	$15,272

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 19. Highway 1

Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

1. Plans for 2001 include relocating Highway 1 to the east. For this analysis, the work was assumed completed and no costs or damages were associated with this feature.

Feature 19 Figures and Tables

Figure I.C.19 Feature 19: Decision Tree
Table I.C.19.A Feature 19: Cost and Damage Table

Feature No. 19

HIGHWAY 1

Lowest Road Elevation: 1410

- ⬢ Decision required at this point
- ⊙ Trigger point for action, no decision needed
- ***Re*** Relocate
- ***A*** Temporary closure of road

Feature No. 19

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.19.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 19 - Highway 1

COSTS

Lake Elevation (MSL)	Re Relocation at AL1
1409	$0
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$0
1456	$0
1457	$0
1458	$0
1459	$0
1460	$0
1461	$0
1462	$0
1463	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Relocate at AL1	1409	$0

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 20. Highway 20 North of the City of Devils Lake

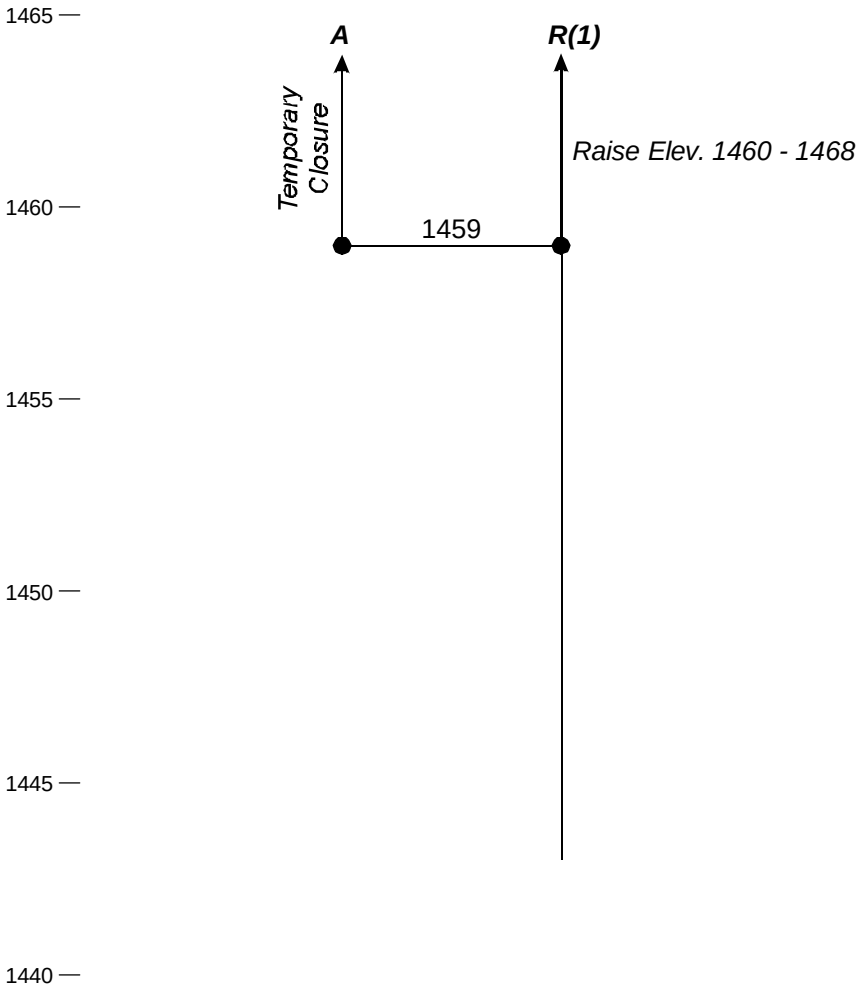
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 20 Figures and Tables

Figure I.C.20 Feature 20: Decision Tree
Table I.C.20.A Feature 20: Cost and Damage Table

Feature No. 20

HIGHWAY 20
NORTH OF CITY OF DEVILS LAKE



Lowest Road Elevation: 1460

- ● Decision required at this point
- Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 20

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.20.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 20 - Highway 20 North of the City of Devils Lake

COSTS

Lake Elevation (MSL)	A Temporary Closure at AL1	R(1) Raise at AL1
	THOUSANDS	
1443	$0	$0
1444	$0	$0
1445	$0	$0
1446	$0	$0
1447	$0	$0
1448	$0	$0
1449	$0	$0
1450	$0	$0
1451	$0	$0
1452	$0	$0
1453	$0	$0
1454	$0	$0
1455	$0	$0
1456	$0	$0
1457	$0	$0
1458	$0	$0
1459	$0	$33,382
1460	$0	$0
1461	$0	$0
1462	$0	$0
1463	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1459	$3,375
Raise at AL1	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$0
1456	$0
1457	$0
1458	$0
1459	$0
1460	$4,848
1461	$4,848
1462	$4,848
1463	$4,848

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 21. Highway 20 from the City of Devils Lake Levee to Highway 57

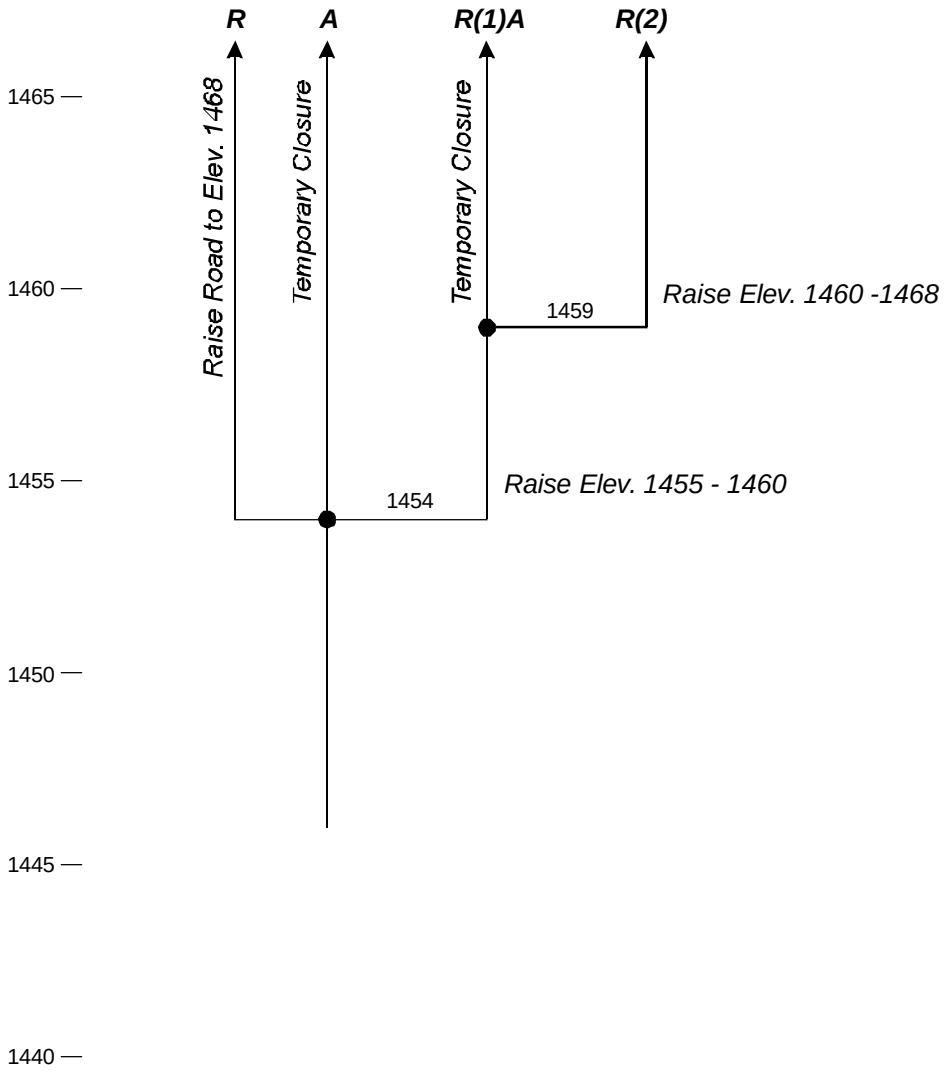
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 21 Figures and Tables

Figure I.C.21 Feature 21: Decision Tree
Table I.C.21.A Feature 21: Cost and Damage Table

Feature No. 21

HIGHWAY 20
FROM THE CITY OF DEVILS LAKE LEVEE
TO HIGHWAY 57



Lowest Road Elevation: 1455

- ● Decision required at this point
- ◐ Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 21

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.21.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 21 - Highway 20 from the City of Devils Lake Levee to Highway 57

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2) Raise at AL1, AL2
	THOUSANDS			
1443	$0	$0	$0	$0
1444	$0	$0	$0	$0
1445	$0	$0	$0	$0
1446	$0	$0	$0	$0
1447	$0	$0	$0	$0
1448	$0	$0	$0	$0
1449	$0	$0	$0	$0
1450	$0	$0	$0	$0
1451	$0	$0	$0	$0
1452	$0	$0	$0	$0
1453	$0	$0	$0	$0
1454	$24,859	$0	$10,803	$10,803
1455	$0	$0	$0	$0
1456	$0	$0	$0	$0
1457	$0	$0	$0	$0
1458	$0	$0	$0	$0
1459	$0	$0	$0	$14,056
1460	$0	$0	$0	$0
1461	$0	$0	$0	$0
1462	$0	$0	$0	$0
1463	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES

Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1454	$13,104
Raise at AL1, Temporary Closure at AL2	1459	$13,104
Raise at AL1, AL2	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$0
1451	$0
1452	$0
1453	$0
1454	$0
1455	$2,949
1456	$2,949
1457	$2,949
1458	$2,949
1459	$2,949
1460	$2,949
1461	$2,949
1462	$2,949
1463	$2,949

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 22. Highway 20 Between Highway 57 and Tokio

Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

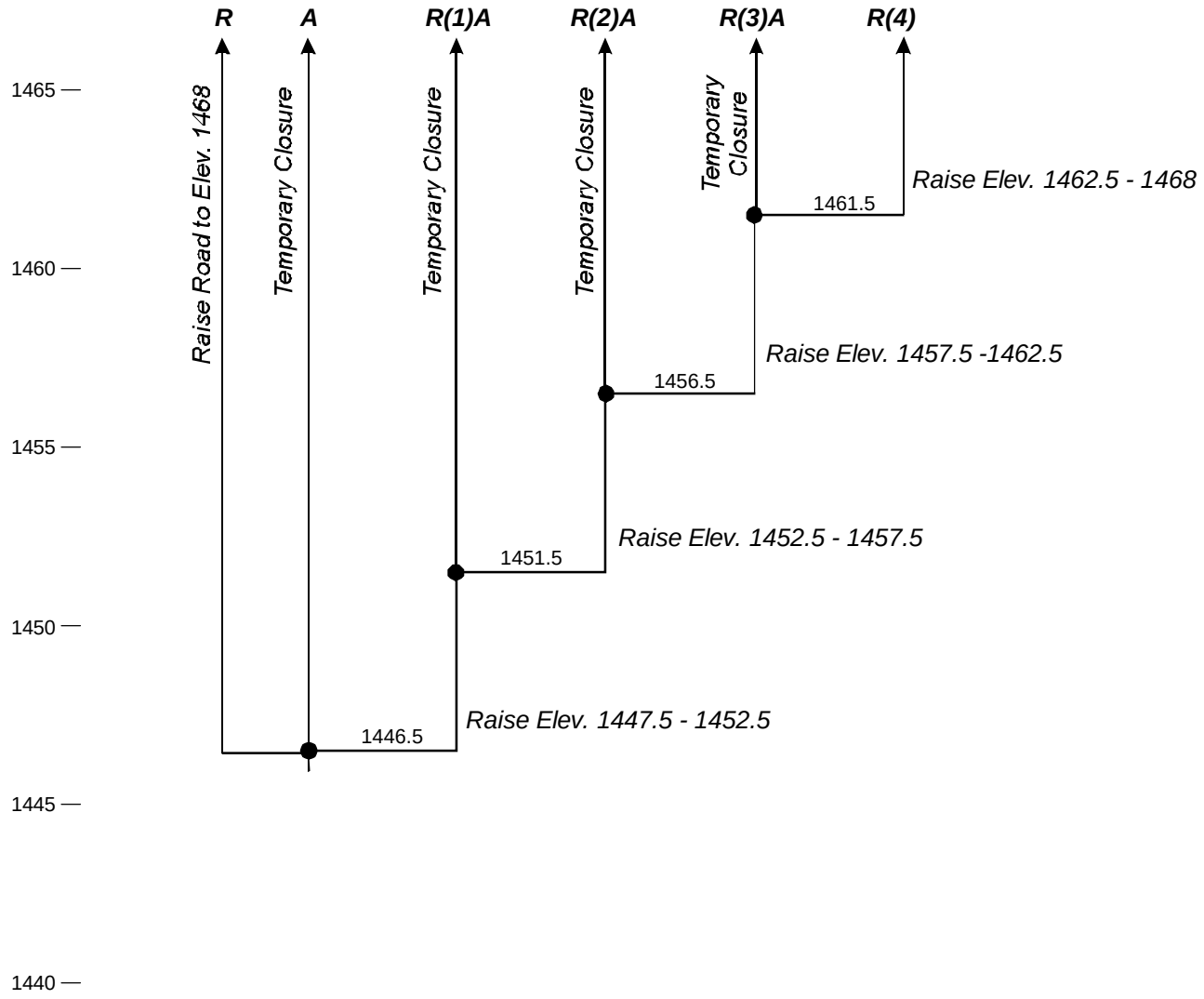
1. Plans for 2001 include raising Highway 20 from a minimum elevation of 1447.5 to 1455 and the bridge across Devils Lake from 1443.5 to 1461 (low chord). For this analysis, the work was assumed completed and the new elevations were used.

Feature 22 Figures and Tables

Figure I.C.22 Feature 22: Decision Tree
Table I.C.22.A Feature 22: Cost and Damage Table

Feature No. 22

HIGHWAY 20
BETWEEN HIGHWAY 57 AND TOKIO



Lowest Road Elevation: 1447.5

● Decision required at this point

Trigger point for action, no decision needed

R(1) Incremental road raise (number of times)

R Road raise to 1468

A Temporary closure of road

Feature No. 22

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.22.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 22 - Highway 20 between Highway 57 and Tokio

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2)A Raise at AL1, AL2; Temporary Closure at AL3	R(3)A Raise at AL1, AL2, AL3; Temporary Closure at AL4	R(4) Raise at AL1, AL2, AL3, AL4
	THOUSANDS					
1443	$0	$0	$0	$0	$0	$0
1444	$0	$0	$0	$0	$0	$0
1445	$0	$0	$0	$0	$0	$0
1446	$110,322	$0	$25,045	$25,045	$25,045	$25,045
1447	$0	$0	$0	$0	$0	$0
1448	$0	$0	$0	$0	$0	$0
1449	$0	$0	$0	$0	$0	$0
1450	$0	$0	$0	$0	$0	$0
1451	$0	$0	$0	$22,269	$22,269	$22,269
1452	$0	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0	$0
1454	$0	$0	$0	$0	$0	$0
1455	$0	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$26,814	$26,814
1457	$0	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0	$36,194
1462	$0	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1446	$576
Raise at AL1, Temporary Closure at AL2	1451	$576
Raise at AL1, AL2, Temporary Closure at AL3	1456	$576
Raise at AL1, AL2, AL3, Temporary Closure at AL4	1461	$576
Raise at AL1, AL2, AL3, AL4	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$6,836
1448	$6,836
1449	$6,836
1450	$6,836
1451	$6,836
1452	$6,836
1453	$6,836
1454	$6,836
1455	$6,836
1456	$8,084
1457	$8,084
1458	$8,084
1459	$8,084
1460	$8,084
1461	$8,084
1462	$8,614
1463	$8,614

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 23. BIA 1 Between Highway 57 and BIA 6

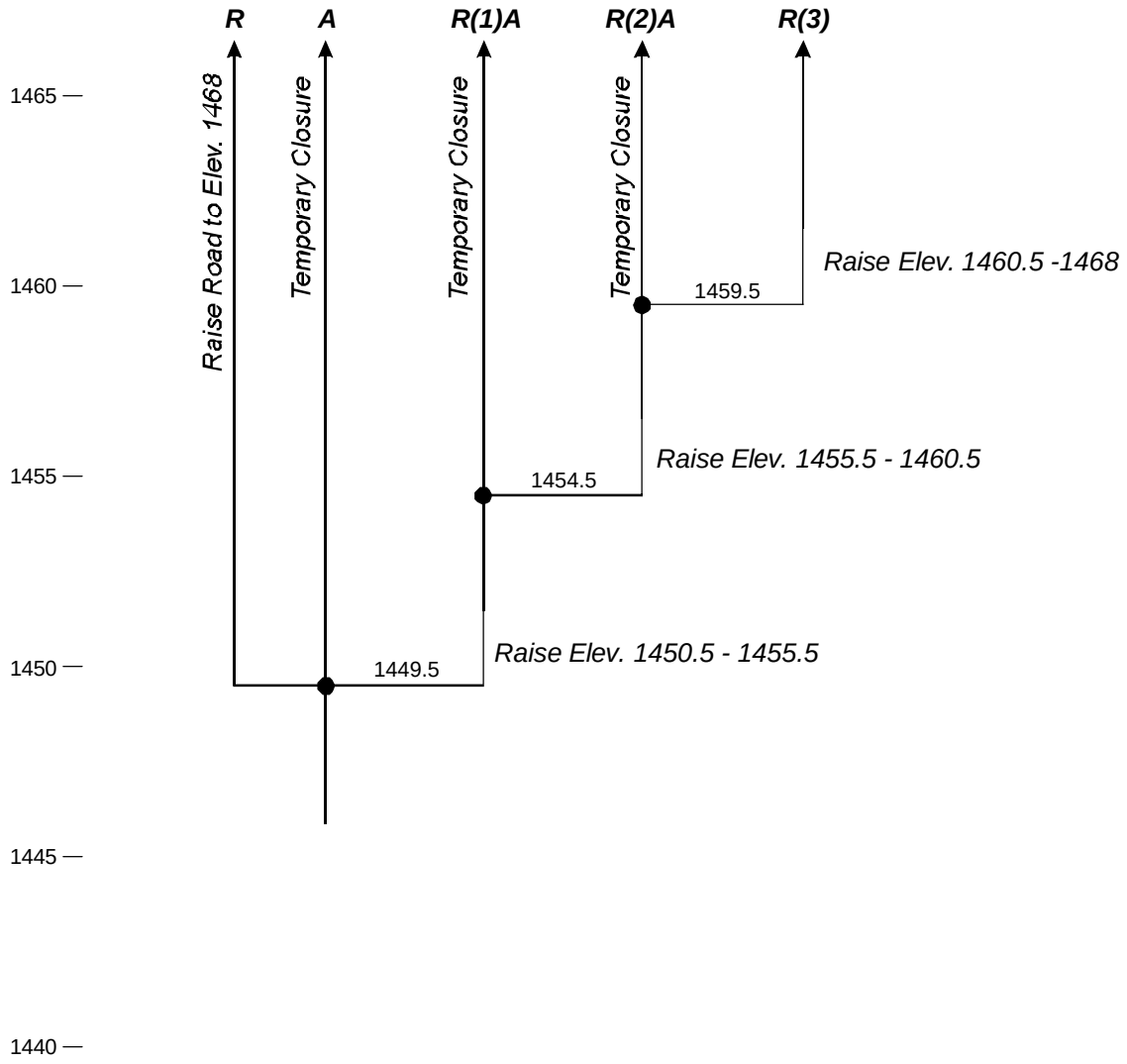
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 23 Figures and Tables

Figure I.C.23 Feature 23: Decision Tree
Table I.C.23.A Feature 23: Cost and Damage Table

Feature No. 23

BIA 1
BETWEEN HIGHWAY 57 AND BIA 6



Lowest Road Elevation: 1450.5

- ● Decision required at this point
- ◐ Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 23

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.23.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 23 - BIA 1 between Highway 57 and BIA 6

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2)A Raise at AL1, AL2; Temporary Closure at AL3	R(3) Raise at AL1, AL2, AL3
	THOUSANDS				
1443	$0	$0	$0	$0	$0
1444	$0	$0	$0	$0	$0
1445	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0
1447	$0	$0	$0	$0	$0
1448	$0	$0	$0	$0	$0
1449	$18,430	$0	$5,119	$5,119	$5,119
1450	$0	$0	$0	$0	$0
1451	$0	$0	$0	$0	$0
1452	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$0
1454	$0	$0	$0	$4,607	$4,607
1455	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$0
1457	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0
1459	$0	$0	$0	$0	$8,704
1460	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0
1462	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1449	$955
Raise at AL1, Temporary Closure at AL2	1454	$955
Raise at AL1, AL2, Temporary Closure at AL3	1459	$955
Raise at AL1, AL2, AL3	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation (MSL)	Restoration Damage (THOUSANDS)
1443	$0
1444	$0
1445	$0
1446	$0
1447	$0
1448	$0
1449	$0
1450	$742
1451	$742
1452	$742
1453	$742
1454	$742
1455	$742
1456	$742
1457	$742
1458	$742
1459	$742
1460	$742
1461	$742
1462	$742
1463	$742

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Feature 24. BIA 6 Between Highway 20 and Fort Totten

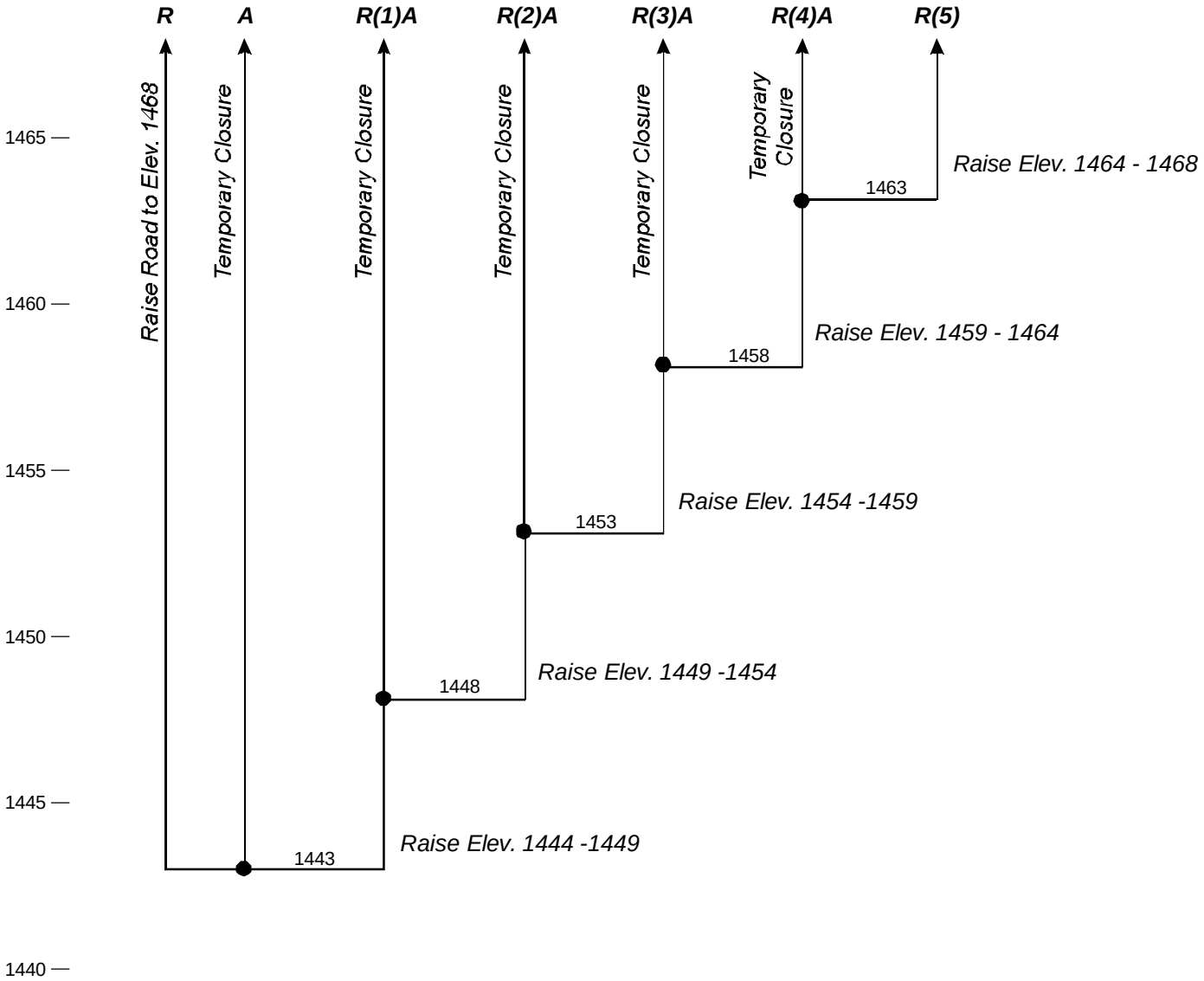
Assumptions for roads are common to all road features. Therefore, instead of describing the same assumptions repetitively for each road feature, the assumptions were described in the Roads section in general terms with exceptions as appropriate for specific features.

Feature 24 Figures and Tables

Figure I.C.24 Feature 24: Decision Tree
Table I.C.24.A Feature 24: Cost and Damage Table

Feature No. 24

BIA 6
BETWEEN HIGHWAY 20 AND FORT TOTTEN



Lowest Road Elevation: 1444

- ● Decision required at this point
- ·) Trigger point for action, no decision needed
- ***R(1)*** Incremental road raise (number of times)
- ***R*** Road raise to 1468
- ***A*** Temporary closure of road

Feature No. 24

ECONOMIC ANALYSIS OF
DEVILS LAKEALTERNATIVES

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Table I.C.24.A

Economic Analysis of Devils Lake Alternatives
Cost and Damage Table

Feature 24 - BIA 6 between Highway 20 and Fort Totten

COSTS

Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1 Temporary Closure at AL2	R(2)A Raise at AL1, AL2 Temporary Closure at AL3	R(3)A Raise at AL1, AL2, AL3 Temporary Closure at AL4	R(4)A Raise at AL1, AL2, AL3, AL4 Temporary Closure at AL5	R(5) Raise at AL1, AL2, AL3, AL4, AL5
	THOUSANDS						
1443	$19,773	$0	$214	$214	$214	$214	$214
1444	$0	$0	$0	$0	$0	$0	$0
1445	$0	$0	$0	$0	$0	$0	$0
1446	$0	$0	$0	$0	$0	$0	$0
1447	$0	$0	$0	$0	$0	$0	$0
1448	$0	$0	$0	$1,664	$1,664	$1,664	$1,664
1449	$0	$0	$0	$0	$0	$0	$0
1450	$0	$0	$0	$0	$0	$0	$0
1451	$0	$0	$0	$0	$0	$0	$0
1452	$0	$0	$0	$0	$0	$0	$0
1453	$0	$0	$0	$0	$5,065	$5,065	$5,065
1454	$0	$0	$0	$0	$0	$0	$0
1455	$0	$0	$0	$0	$0	$0	$0
1456	$0	$0	$0	$0	$0	$0	$0
1457	$0	$0	$0	$0	$0	$0	$0
1458	$0	$0	$0	$0	$0	$6,568	$6,568
1459	$0	$0	$0	$0	$0	$0	$0
1460	$0	$0	$0	$0	$0	$0	$0
1461	$0	$0	$0	$0	$0	$0	$0
1462	$0	$0	$0	$0	$0	$0	$0
1463	$0	$0	$0	$0	$0	$0	$6,262

Note: AL = Decision/Action Level

ANNUAL DETOUR DAMAGES
Annual detour damages are based on each strategy. They are independent of lake elevation. They are only incurred when a road is temporarily closed or permanently relocated.

Strategy	Lake Elevation at Which Annual Detour Damages Begin	Annual Detour Damages (THOUSANDS)
Temporary Closure at AL1	1443	$13,073
Raise at AL1, Temporary Closure at AL2	1448	$13,073
Raise at AL1, AL2, Temporary Closure at AL3	1453	$13,073
Raise at AL1, AL2, AL3, Temporary Closure at AL4	1458	$13,073
Raise at AL1, AL2, AL3, AL4, Temporary Closure at AL5	1463	$13,073
Raise at AL1, AL2, AL3, AL4, AL5	---	$0

RESTORATION DAMAGES
Restoration damages are a per event damage. They are only incurred when and if the lake recedes below a road after a period of flooding. Restoration damages depend on the maximum lake level during the period of flooding because the extent of the road that needs restoration depends on the extent of flooding.

Lake Elevation	Restoration Damage (THOUSANDS)
1443	$0
1444	$31
1445	$31
1446	$31
1447	$31
1448	$31
1449	$31
1450	$31
1451	$31
1452	$31
1453	$31
1454	$546
1455	$546
1456	$546
1457	$667
1458	$1,087
1459	$1,087
1460	$1,087
1461	$1,087
1462	$1,087
1463	$1,087

Note: Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Attachment I.D: Features Downstream of Devils Lake

This Attachment I.D provides supplementary information regarding the economic analysis of the downstream features. Included is information regarding the research that was conducted as a part of the downstream features information, and the particulars of the modeling assumptions used in the analysis.

The modeling of the costs and damages for the water quality-dependent features was based on investigations conducted in preparing the *Devils Lake ND Downstream Surface Water Users Study* (Barr, March 1999) and the *Potential Impacts of a Stump Lake Spill on Downstream Water Users* (Barr, September 2000). Further details regarding the water quality-dependent features may be found by consulting that report. The modeling of the damage estimates for the water quantity-dependent features was based on information provided by the Corps of Engineers, St. Paul District.

Municipal Water Treatment Facilities

Treatment Facility Identification and Investigation

To identify the water treatment facilities that may be affected by the operation of the outlet, permitted municipal users along the Sheyenne River and Red River of the North were identified. The agencies responsible for permitting were contacted: North Dakota State Water Commission, Minnesota Department of Natural Resources, and Manitoba Water Resources. A listing of the municipal water-use permittees was obtained from each of the three agencies for the portions of the rivers that could potentially be impacted by Devils Lake outflows. North Dakota listed a total of 14 permits for water treatment facilities along the Sheyenne River and Red River of the North, Minnesota listed 1 permit along the Red River of the North, and Manitoba listed 3 permits along the Red River of the North.

Each of the permit holders were then contacted and interviewed. Several cities had obtained permits for withdrawal of water but had never constructed a surface water treatment facility and had no intention of using the river as a raw water source in the future. Other cities had at one time operated a surface water treatment facility but had discontinued operations at the facility with no intentions of constructing another. The water treatment facilities in McVille, Lisbon, Oslo, and Selkirk were eliminated from the impact study because their source of water was neither the Sheyenne River nor the Red River of the North. The City of East Grand Forks (located on the Red River of the North) does not currently have a permit for withdrawing water from the Red River. However, East Grand Forks has expressed an interest in using the river in the future and has concern over the future river water quality. Therefore, information regarding the East Grand Forks water treatment facility was also obtained (but cost estimates were not developed for this study for the East Grand Forks facility). The City of Winnipeg, although located on the Red River of the North, withdraws water from Shoal Lake chain and, therefore, is not influenced by Red River water quality.

Eight water treatment facilities were retained for further analysis. From farthest upstream on the Sheyenne River to farthest downstream on the Red River of the North, those facilities were: Valley City, Fargo, Grand Forks, Grafton, Drayton, and Pembina; all located in North Dakota; and Letellier and Morris, located in Canada.

To collect necessary information regarding facility operations, interviews were conducted in person at each water treatment facility. From these interviews, as well as from several follow-up telephone conversations with operators at each facility, an information sheet was developed for each facility. (These information sheets are included in Appendix A of the *Devils Lake ND Downstream Surface Water Users Study;* Barr, March 1999.) Information listed includes: facility permit number, contact person, intake location, chemicals used for treatment of hardness, type of treatment processes, contingency plans, water usage, treatment efficiency, finished water quality, cost of operation, and treatment capacity. In some cases, treatment facility operators were unable or unwilling to supply certain information; the information sheets show these data as N/A (not available). The listings of chemicals used (Appendix A) vary from one treatment facility to the next; these variations reflect differing modes of treatment and

differing treatment objectives for the individual facilities. Monthly raw water usage for the North Dakota facilities for the years of 1996 and 1997 were obtained from the North Dakota State Water Commission.

Because of the difficulty in obtaining complete data for each of the treatment facilities, data-gathering efforts were focused on high-volume users furthest upstream. These users are Valley City, Grand Forks, and Fargo. Examination of the water quality traces showed that these users would be affected most by the proposed outlet from Devils Lake, so the overall treatment facility cost increases resulting from the Devils Lake outlet depends heavily on how these users are affected. Development of accurate cost estimates for these users was, therefore, felt to be most important, so that gathering accurate operations data for these facilities was most critical. By contrast, any cost increases projected for the lower-volume facilities further downstream (Pembina, Letellier, and Morris) would have less effect on the overall treatment facility costs. For expediency, therefore, cost and operations assumptions (such as using similar cost and operational data supplied by the high-volume users) were made when necessary to supplement operator-supplied data for developing mitigation costs for the lower-volume facilities further downstream.

Phase I Modeling Assumptions

In the following paragraphs, the treatment facilities are described, along with the unique assumptions used in the Phase I model for the particular facility. The water treatment facilities are discussed from upstream to downstream along the Sheyenne River and the Red River of the North.

1 Phase I Modeling Assumptions for Valley City

Valley City is the treatment facility closest to the outlet and is therefore most likely to experience the greatest impact on its raw water quality due to Devils Lake outflows. The Valley City Public Works Water Treatment Facility was built in 1972 and has a capacity of 4.0 million gallons per day (MGD). The facility serves a population of 7,400 people with an average water usage of 1.0 MGD. During most of the year, the raw water is taken directly from the Sheyenne River. During summer months, taste and odor problems resulting from elevated algae levels in the Sheyenne make that water undesirable. As a substitute, during periods of high algae levels, raw water is instead obtained from wells located adjacent to the river. The wells are shallow and only 48 feet from the river. (Based on the well proximity to the river, it was assumed that the well water quality, in terms of the parameters modeled, was identical to that of the river water.)

Because the facility capacity is twice the current demand, it was assumed that the existing chemical feed equipment is sized at twice capacity and would be able to meet any increased demand caused by increased hardness concentrations. This assumption was verified with the facility operator.

With the exception of polymer costs, the costs of softening-related chemicals were not available directly from the staff at the Valley City treatment facility. Therefore, Valley City's costs were assumed to be similar to those provided by the Grand Forks treatment facility as confirmed by the local chemical feed supplier.

The additional sludge production that would result due to Devils Lake outflows was estimated based on cost data provided by Valley City for emptying the sludge lagoons. The city estimated that the lagoons reach capacity approximately every 23 years, and the cost of emptying and disposing of the sludge is approximately $75,000. Because the sludge lagoon is currently near maximum capacity, it was assumed that it would be empty at the start of Devils Lake outflow.

Based on information received from the facility, the following estimates were used in the Phase I mitigation model for Valley City:

Flow, annual average (MGD)	1.0
Target finished water hardness (mg/L)	120
Pounds of lime used per pound of hardness removed	2.64
Pounds of CO_2 used per pound of hardness removed	0.24
Pounds of sodium aluminate used per pound of hardness removed	0.018
Pounds of polymer used per pound of hardness removed	0.0013
Pounds of sludge produced per pound of hardness removed	3.15

2 Phase I Modeling Assumptions for Fargo

The Fargo Water Treatment Facility was constructed in 1997 and currently serves a population of approximately 85,000 people. Fargo has a primary intake source on the Red River of the North and a secondary intake source on the Sheyenne River. The intake on the Red River of the North is located upstream of the confluence with the Sheyenne River and, therefore, it was assumed that Devils Lake outflows would not have an effect on the raw water drawn from the Red River of the North. The Fargo treatment facility also has a permit to withdraw water from Lake Ashtabula should it be necessary due to emergency conditions. The facility has a peak rated capacity of 30 MGD and an average rated capacity of 14 MGD. The average daily water use rate has been approximately 11.5 MGD.

Since only a portion of Fargo's raw water supply would be affected by Devils Lake outflows, the portion of flow typically taken from the Sheyenne had to be estimated. Fargo uses the intake on the Red River of the North as its primary raw water source due to the Sheyenne River's water quality generally being worse. The exception is when water quality in the Red River is worse than the water quality on the Sheyenne River; on these occasions, Fargo switches to the Sheyenne River as its primary source. Because there appears to be no means of accurately predicting the timing or amount of Sheyenne River withdrawals for the Phase I model, these withdrawals were estimated by averaging the last 10 years of Sheyenne River withdrawal data.

Since Fargo's treatment facility is relatively new, the capacity of the chemical feed equipment was determined to be more than adequate for the anticipated increased hardness concentrations resulting from Devils Lake outflows.

Although the Fargo staff was able to provide the approximate cost of softening chemicals on a per-gallon-of-water-treated basis, the cost range provided by the facility was too wide to be of use for the cost model. Therefore, it was assumed that all chemical costs, except polymer costs, would be similar to those of Grand Forks. Grand Forks data were used since it is the next largest facility, and the cost data provided by Grand Forks were more readily usable for modeling purposes. The polymer cost was assumed to be equivalent to that obtained for Valley City.

Fargo indicated that they dispose of their dewatered sludge on a daily basis by hauling it to the landfill as daily cover. The cost of additional sludge disposal was estimated by assuming a monthly cost for landfill disposal (based on "tipping" fees). Estimates of tipping fees were based on information obtained from the City of Fargo.

The following estimates were used in the Phase I mitigation model for Fargo:

Flow, annual average (MGD)	11.5 Total 0.83 Sheyenne
Target finished water hardness (mg/L)	110
Pounds of lime used per pound of hardness removed	1.05
Pounds of soda ash used per pound of hardness removed	0.32
Pounds of CO_2 used per pound of hardness removed	0.24
Pounds of sodium aluminate used per pound of hardness removed	0.053
Pounds of polymer used per pound of hardness removed	0.011
Pounds of sludge produced per pound of hardness removed	8.25

3 Phase I Modeling Assumptions for Grand Forks

The City of Grand Forks Water Treatment Facility, installed in 1897, has undergone several upgrades over the years. The facility has a capacity of 16.5 MGD but produces an average of approximately 8.0 MGD and serves approximately 55,000 people. Grand Forks obtains approximately 60 percent of their raw water from the Red Lake River and approximately 40 percent from the Red River of the North. Water from the two sources is blended, with the exact proportions depending on the water quality in each river. The Red River of the North is normally a little harder, but lower in TOC than the Red Lake River. Therefore, although Grand Forks has an alternate raw water supply (the Red Lake River) should the water from Red River of the North water quality be greatly degraded, the elevated TOC concentrations in the Red Lake River make it an undesirable source at certain times of the year. For purposes of this study, it was assumed that the city would continue to withdraw water from its two sources at the current proportions.

The capacity of the Grand Forks water treatment facility is approximately twice the current average daily demand. It was, therefore, assumed that the capacity of the chemical feed equipment would be adequate

to handle the increased dosages required by Devils Lake outflow effects. This assumption was verified with the facility operator. The city provided detailed information on the cost of their chemicals and these data were used in the mitigation model for Grand Forks.

The city also provided sludge production data. The Grand Forks water treatment facility dewaters its sludge using vacuum filtration, and then hauls it to the city-owned landfill for final disposal. Although the water treatment facility is not billed directly for the landfill disposal, costs for disposal nevertheless exist and were included in the Phase I model. A sludge disposal fee of $25 per ton was assumed to represent landfill tipping fees.

The following estimates were used in the Phase I mitigation model for Grand Forks:

Flow, annual average (MGD)	8.0 Total 3.2 Red Lake
Target finished water hardness (mg/L)	145
Pounds of lime used per pound of hardness removed	1.66
Pounds of soda ash used per pound of hardness removed	0.1
Pounds of CO_2 used per pound of hardness removed	0.44
Pounds of sludge produced per pound of hardness removed	11.0

4 Phase I Modeling Assumptions for Grafton

The Grafton Water Treatment Facility, installed in 1954, serves 5000 people and has a facility capacity of 3.0 MGD. The daily average water usage was 0.7 MGD in 1997 with approximately 90 percent of the facility's raw water coming from the Red River of the North and 10 percent from the Park River. According to reports received from the City of Grafton, the Park River has a substantially higher total hardness concentration than the Red River of the North, so that the Red River of the North is the raw water source of choice. The Park River is used as a water source for Grafton during spring runoff or during periods when the water from the Red River of the North is less desirable. The Park River is also used as a backup supply in cases where mechanical or electrical malfunctions interrupt operations at the Red River. Similarly, the Park River is used when electrical suppliers restrict electrical use at the Red River of the North pumping station.

In evaluating the need for capital improvements required to treat additional hardness at Grafton, Trace 6262 raw water with- and without-outlet hardness concentrations were compared. The trace data showed that the with-outlet hardness was only elevated by an average of 5 mg/L over the average without-outlet concentration of approximately 250 mg/L. Based on this average increase of only 2 percent, it was assumed that the existing chemical feed equipment would be adequate to handle the increased chemical feed rates required due to Devils Lake outflows.

Chemical costs were obtained directly from water treatment facility staff.

Sludge production data were not available from the Grafton facility and were estimated based on data from other facilities. Specifically, the sludge production rate on a per-pound-of-hardness-removed basis was assumed to be similar to that at Valley City. Similarly, the per-pound sludge disposal cost was assumed to be equal to that of Valley City. Grafton supplied an estimated cost of $90,000 every eight years for sludge disposal, and this cost was used in the model.

The following estimates were used in the Phase I mitigation model for Grafton:

Flow, annual average (MGD)	0.7
Target finished water hardness (mg/L)	127
Pounds of lime used per pound of hardness removed	0.98
Pounds of soda ash used per pound of hardness removed	0.26
Pounds of CO_2 used per pound of hardness removed	0.27
Pounds of sodium aluminate used per pound of hardness removed	0.036
Pounds of polymer used per pound of hardness removed	0.00094
Pounds of sludge produced per pound of hardness removed	3.15

5 Phase I Modeling Assumptions for Drayton

The Drayton Water Treatment Facility was installed in 1962, with expansions and upgrades occurring in 1994, 1995, and 1996. The city uses the Red River as its raw water source and serves a population of approximately 1,000 people. The maximum capacity of the facility is 0.72 MGD and the average raw water intake is 0.25 MGD. The Red River of the North is the sole raw water source for the Drayton Water Treatment Facility.

In evaluating the need for capital improvements required to allow softening to continue at Drayton, Trace 6262 raw water with- and without-outlet hardness concentrations were compared. The trace data showed that the with-outlet hardness was only elevated by an average of 5 mg/L over the average without-outlet concentration of approximately 250 mg/L. Based on this average increase of only 2 percent, it was assumed that the existing chemical feed equipment would be adequate to handle the increased chemical feed rates required due to Devils Lake outflows.

Drayton city staff provided the cost of lime and soda ash used in their softening process. The cost for polymer was assumed to be equal to that for Valley City, and the carbon dioxide cost was assumed to be equal to that of Grand Forks.

Sludge production data were unavailable from the city, so sludge production and cost data were assumed to be equivalent to that of Valley City on a pounds of sludge produced per pound of hardness removed basis. Sludge disposal cost data were provided by Drayton and used in model development.

The following estimates were used in the Phase I mitigation model for Drayton:

Flow, annual average (MGD)	0.25
Target finished water hardness (mg/L)	130
Pounds of lime used per pound of hardness removed	4.03
Pounds of soda ash used per pound of hardness removed	0.52
Pounds of CO_2 used per pound of hardness removed	0.35
Pounds of polymer used per pound of hardness removed	0.0013
Pounds of sludge produced per pound of hardness removed	3.15

6 Phase I Modeling Assumptions for Pembina

The City of Pembina currently serves approximately 650 people, and uses the Red River of the North as its raw water source. The facility was constructed in 1970 and has a maximum capacity of 0.58 MGD. The average daily water usage is 0.17 MGD. In emergency situations, Pembina can obtain water from a rural water supplier.

In evaluating the need for capital improvements required to treat additional hardness at Pembina, Trace 6262 raw water with- and without-outlet hardness concentrations were compared. The trace data showed that the with-outlet hardness was only elevated by an average of 4 mg/L over the average without-outlet concentration of approximately 256 mg/L. Based on this average increase of less than 2 percent, it was assumed that the existing chemical feed equipment would be adequate to handle the increased chemical feed rates required due to Devils Lake outflows.

Sludge disposal information was not available from the water treatment facility personnel and was estimated from per-pound-of-hardness-removed averages obtained from other facilities. The cost of sludge disposal was estimated using data from the Drayton facility.

The following estimates were used in the Phase I mitigation model for Pembina:

Flow, annual average (MGD)	0.07
Target finished water hardness (mg/L)	120
Pounds of lime used per pound of hardness removed	2.53
Pounds of soda ash used per pound of hardness removed	0.22
Pounds of CO_2 used per pound of hardness removed	0.43
Pounds of sludge produced per pound of hardness removed	3.15

7 Phase I Modeling Assumptions for Letellier

Letellier is located in Manitoba, Canada, approximately 10 miles north of the United States-Canadian border. The City of Letellier's water treatment facility is operated by a private Canadian company. Several attempts were made to obtain information from the facility staff and operator in Letellier and from the general manager of the private operating company in Altona, Manitoba, but were unsuccessful. Therefore, all Phase I modeling parameters for Letellier were estimated using data from other facilities. It is not anticipated that using estimated data at this location will significantly affect the overall mitigation cost estimates. The difference between with- and without-outlet constituent concentrations for Trace 6262 near Letellier appear to be minimal.

The Letellier treatment facility currently serves the entire surrounding county, and treatment facility staff stated that the facility's average daily finished water output is approximately 1.0 MGD. Monthly withdrawal rates from the Red River were not available as input for the mitigation model. To compensate for this data gap, annual average flow was scaled from the Pembina data, and it was assumed that the treatment processes for the two facilities were identical. The chemical feed rates and sludge production rates were also assumed to be equivalent to those for Pembina.

The following estimates were used in the Phase I mitigation model for Letellier:

Flow, annual average (MGD)	1.0
Target finished water hardness (mg/L)	120
Pounds of lime used per pound of hardness removed	2.53
Pounds of soda ash used per pound of hardness removed	0.22
Pounds of CO_2 used per pound of hardness removed	0.43
Pounds of sludge produced per pound of hardness removed	3.15

8 Phase I Modeling Assumptions for Morris

The City of Morris, located in the province of Manitoba, uses raw water from the Red River to serve a population of approximately 1,700 people. The average water use reported was 0.73 MGD. Lime, soda ash, and polymer are the chemicals used in the treatment processes. Beyond this information, no other data were available at the time this report was prepared. The City of Morris water treatment facility is operated by the same private Canadian company as Letellier's and the company declined to provide any further information. Therefore, costs associated with mitigation of Devils Lake outflows were estimated based on the data received from other treatment facilities.

Because the average annual flows are approximately equal to those of Grafton, monthly average flow data for each month were estimated based on the Grafton data. Chemical usage and sludge production, as well as the costs associated with each, were also estimated from Grafton data.

Because no trace data were available beyond the United States-Canadian border, the raw water data from Emerson were used. Morris is approximately 12 miles downstream from the Emerson station, and there are several tributaries that flow into the Red River of the North between Emerson and Morris. Therefore, the resultant mitigation cost estimated for Morris is likely to be higher than would actually occur.

The following estimates were used in the Phase I mitigation model for Morris:

Flow, annual average (MGD)	0.73
Target finished water hardness (mg/L)*	127
Pounds of lime used per pound of hardness removed	0.98
Pounds of soda ash used per pound of hardness removed	0.26
Pounds of CO_2 used per pound of hardness removed	0.27
Pounds of polymer used per pound of hardness removed	0.00094
Pounds of sludge produced per pound of hardness removed	3.15

* Estimated from Grafton data

Phase II Modeling Assumptions

For the Phase II modeling, it was necessary to develop cost estimates for the development of alternate source water supplies for each of the potentially affected municipalities. The cost of development of alternate source water supplies could then be compared to the cost of using ion exchange technology to provide additional treatment for the river water. Using this comparison, the model selects the least cost choice, and uses that in assigning capital costs and O&M costs (registered as damages) to the alternative.

The cost assumptions that were used to develop cost estimates for the development of alternate source water supplies – wells or rural water – are detailed in the table and text below.

Municipal Permitted User	Alternate Source			Pipeline Length (miles)	Capital Costs	Annual Operation Costs	Maintenance Costs
	Number of Wells	Capacity of Each Well (gpm)	Rural Water Supply				
Valley City	2	800	NA	18	$5,702,000	$24,500	$30,000/ten years
Fargo	10	750	NA	50	$23,130,000	$35,200	$30,000/five years
Grand Forks1	NA	NA	NA	NA	NA	NA	NA
Grafton2	NA	NA	Yes	27	$5,955,000	$945,400	$10,000/ten years
Drayton	NA	NA	Yes	Unknown	$2,442,000	$88,000	None
Pembina	NA	NA	Yes	Unknown	$800,000	$40,500	None
Morris	2	300	NA	13	$3,056,000	$19,700	$4,000/ten years
Letellier	2	800	NA	10	$3,393,000	$19,500	$30,000/ten years

Notes:

1. Rural water and/or wells are not available for Grand Forks
2. Grafton has the capability to withdraw raw water from the Park River

NA Not Applicable, or Not Available as an alternate water source.
All amounts are in 1998 dollars.

A brief discussion on the assumptions used to develop cost estimates for the alternative water supply sources for each of the municipalities is given in the following paragraphs.

1 Phase II Modeling Assumptions for Valley City

The alternative water supply source for Valley City was assumed to be two wells that would totally replace the Sheyenne River as the raw water supply source. Each well would be designed to meet the maximum average monthly demand, and both wells combined would meet the maximum demand. The nearest usable aquifer to meet Valley City's water demand is the Spiritwood Aquifer. To convey the water to Valley City would require the construction of an 18-mile pipeline. (A rural water supplier in the area was contacted but did not have the capacity to serve a city the size of Valley City.)

2 Phase II Modeling Assumptions for Fargo

Fargo currently draws approximately 10 percent of its total water supply from the Sheyenne River. Fargo uses its Sheyenne River intake when the water quality of the Red River of the North is poor. It was assumed that under with-outlet conditions Fargo would need to draw water from a source other than the Sheyenne River for such periods, and that wells could replace the water currently obtained from the Sheyenne River intake. The nearest groundwater source with sufficient yield to supply Fargo is the Sheyenne Delta Aquifer situated approximately 40 to 50 miles from Fargo. Construction of the wells and a 40- to 50-mile pipeline would be required to supply Fargo with an alternate raw water source. (Area rural water suppliers are unable to meet the water demands of Fargo.)

3 Phase II Modeling Assumptions for Grand Forks

Grand Forks currently blends raw water from the Red River of the North with water from the Red Lake River prior to treatment and distribution. Approximately 40 percent of the water supply currently comes from the Red River of the North. To replace the water withdrawn from the Red River of the North, construction of two groundwater wells would be required. The wells would not be used to meet peak demands; the facility is assumed to be capable of meeting peak demands by increased withdrawals from the Red Lake River. The nearest surficial aquifer to Grand Forks is the West Larimore Aquifer, which is approximately 20 miles west of Grand Forks. Based upon discussions with the North Dakota State Water Commission, this aquifer is heavily appropriated and is not likely to be a good alternative for Grand Forks. Wells as an alternative raw water supply was not available to Grand Forks and an alternate water supply cost was not developed. (An area rural water supplier provides water to neighboring towns and to rural houses right up to the Grand Forks city limits. However, the supplier does not have the capacity to replace the amount of water drawn from the Red River of the North.)

4 Phase II Modeling Assumptions for Grafton

Grafton currently is able to withdraw water from the Park River as an alternate water supply, although the Park River water is very hard, and is known to be periodically tainted with organic compounds. The Park River is generally considered as an emergency alternative for the Grafton MWTF. Nevertheless, for this analysis, it was assumed that the Grafton facility would be able to meet its demands by withdrawing water solely from the Park River. However, the hardness levels in the Park River water are significantly greater than those of the Red River of the North. Therefore, the cost for using the Park River as an alternate supply was assumed to consist of the additional cost associated with removal of the additional hardness. Unit costs developed under Phase I for hardness removal on a per-pound basis were used to estimate this additional cost.

5 Phase II Modeling Assumptions for Drayton

Drayton is in an area of the state with virtually no usable groundwater, so wells are not an alternative. One feasible alternate for Drayton is to hook up to rural water. North Kittson Rural Water, based out of Lake Bronson, Minnesota, has already performed a feasibility study to estimate the cost estimate for Drayton to use North Kittson Rural Water as their water supply.

6 Phase II Modeling Assumptions for Pembina

Pembina is in an area of the state with virtually no usable groundwater, so wells are not an alternative. A more feasible alternative is for Pembina to connect to rural water supplier. North Valley Water Association provides rural water in the area and already has a pipeline to Pembina.

7 Phase II Modeling Assumptions for Letellier

The alternative water supply source for Letellier was assumed to be two wells that would be constructed to totally replace the Red River of the North as the city's raw water supply source. Each well was designed to meet the maximum average monthly demand, and both wells combined would meet the maximum demand. The nearest usable aquifer is approximately 10 miles east of Letellier. This would require the construction of 10 miles of pipeline. Letellier supplies water to area towns so rural water is not an option; Letellier is in effect the rural water supplier in the area.

8 Phase II Modeling Assumptions for Morris

The alternative water supply source for Morris was assumed to be two wells that would be constructed to totally replace the Red River of the North as the city's raw water supply source. Each well was designed to meet the maximum average monthly demand, and both wells combined would meet the maximum demand. The nearest usable aquifer is a limestone aquifer approximately 13 miles east of Morris. This would require the construction of 13 miles of pipeline. (Information regarding the availability of rural water was not made available.)

Industrial Users

Industrial Users Identification and Investigation

In order to identify the industries that may be affected by the operation of the outlet, permitted industrial users along the Sheyenne River and Red River of the North were identified and sorted by reach. The agencies responsible for permitting were contacted: North Dakota State Water Commission, Minnesota Department of Natural Resources, and Manitoba Water Resources. A listing of the industrial water-use permittees was obtained from each of the three agencies for the portions of the rivers that could potentially be impacted by Devils Lake outflows.

After sorting out permittees holding multiple permits and permit holders reported by both North Dakota and Minnesota, 11 industries remained having permits to draw from the Sheyenne River or Red River of the North in the study region. In an early phase of this study, four of the industrial users were contacted to evaluate the extent of possible impacts of Devils Lake pumping on their operations. Summaries from these initial contacts are given in Appendix F of the *Devils Lake ND Downstream Surface Water Users Study;* Barr, March 1999.

To gain more complete information as the study proceeded, holders of all of the eleven industrial permits were contacted and interviewed to determine the types of use and to identify the industrial facility processes. The permitted users were interviewed to determine what processes at the facility use river water, the facility's water quality requirements, what treatment (if any) is presently required to use the river water, and the potential effects of with-outlet water quality on the industrial users.

Using the interview data, the industrial users were sorted according to which might potentially be affected by Devils Lake outflows. Those potentially affected were interviewed further to evaluate the likely effects.

Use of Preliminary Results

Based on interview data, most of the industrial users will not be affected by Devils Lake outflows:

- Five of the industrial permit holders do not currently use river water. Four of these permit holders have no plans to use the river in the future. The fifth may use the river to wash rocks in the future, but would not be affected by an increased hardness.
- Two permittees currently use the river water to wash sand and gravel, and would not be affected by a change in water quality.
- Another permit holder is a ski area that uses the river water to make snow. The ski area does not treat the water and believes the increased hardness would not adversely affect their snow-making. The impact on the grass in the ski area when the snow melts was not addressed, although grasses are relatively tolerant of TDS.

The three remaining permit holders include a paper mill, a sugar beet processing facility, and a coal-fired power plant. Uses and potential impacts are described below.

The paper mill uses the river water as part of their paper processing. The paper mill's chemist indicated that with-outlet water quality would not affect their current production of non-white paper. The paper mill has considered purchasing additional machinery to produce white paper, but it is not known if, or when, they will purchase the machinery necessary. If they were to begin making white paper, the chemist thought that an increased dissolved solids concentration might affect the process, but could not say with any certainty. Because it is not known if the paper mill is going to purchase the machinery to produce white paper and what the effect would be, mitigation cost estimates were not prepared for the paper mill for this study.

The two remaining permittees would potentially be affected by Devils Lake outflow water quality:

- A sugar beet processing facility on the Red River on the North uses the water to supplement their process water. The process water is treated for hardness, so the Devils Lake outflow water quality would result in increased hardness removal.
- A coal-fired power plant on the Red River of the North uses river water mainly as once-through cooling water and to transport fly ash. However, a small amount (less than one percent) is treated for hardness and used for boiler feed pump cooling and occasionally for boiler water makeup.

Development of Mitigation Model

1 General Considerations

To develop costs for mitigation due to Devils Lake outflow for the industrial users, a variation of the Phase I and Phase II mitigation model (as discussed in the main body of the Technical Appendix) was used. Because the beet processing facility treated the river water through lime softening for hardness removal, the Phase I mitigation model could be used to estimate the increase in operating cost for additional softening.

The power generating facility treated river water for TDS removal by means of an ion-exchange treatment system. Since the facility did not provide any existing operating cost data, the Phase II model was used to estimate the additional cost for TDS removal by ion-exchange treatment. No increases in capital costs were considered, because the facility currently operates an ion-exchange treatment system.

2 Modeling Assumptions for Sugar Beet Processing Facility

The sugar beet processing facility declined to provide detailed process information, stating that water usage is an integral part of their process and they did not want to reveal trade secrets. They did not provide the amount of river water they treat for hardness, but they did say that they withdraw water from the river in the fall (September, October, and November) and store it for year-round use in an onsite storage basin. Their monthly water usage for the last 10 years was obtained from the North Dakota State

Water Commission. Because they did not provide the amount of river water that they treat, it was assumed that they treat all of the water taken from the river.

The facility did indicate that they treat for hardness with lime. The cost was therefore estimated based upon additional softening with lime (as in Phase I of the municipal water treatment facilities model). The values for increased hardness were those for the months (September, October, and November) that the facility withdraws water from the river, using the facility's 10-year average flow for each month. Water use, and therefore softening of the supply water stored in the onsite basin, was assumed to occur throughout the year. All costs brought back to present worth and then annualized, as with Phase I.

3 Modeling Assumptions for Power Plant

The power plant declined to provide detailed information about the amount of river water they use. However, they did provide the size of their pumps and a flow diagram showing the relative percentage of water they treat. The majority of their water is not treated and is used only as cooling water. However, a small portion of the water withdrawn is demineralized and used for boiler make-up water. Ion exchange is currently used for demineralization. It was assumed that the power plant would be upgraded periodically and remain operational for the 50-year project life and that water needs and treatment requirements would remain unchanged.

Based upon the capacity of their pumps and the percent treated, it was estimated that they treat 195,000 gallons per day (gpd). Cost estimates were made for extra costs incurred to remove the increase in hardness and total dissolved solids. The O&M cost equation developed under Phase II of the municipal water treatment facilities model was used with the HEC-5/5Q trace water quality data. All costs were brought back to present worth and then annualized, as with Phase II.

Irrigation Operations

After identifying the non-municipal, non-industrial permittees along the Sheyenne River and the Red River of the North, approximately 20 percent of these permitted users were interviewed to determine the types and frequency of use, and the potential effects of the Devils Lake outflow. In addition, the intake locations for the permitted river water users were identified relative to river mile location and river reach.

A listing of the permitted users in Minnesota, North Dakota, and Manitoba was obtained from the permitting agencies: North Dakota State Water Commission (NDSWC), Minnesota Department of Natural Resources (MDNR), and Manitoba Water Resources. In North Dakota, a water-use permit is required for any water user irrigating more than one acre, or withdrawing more than 12.5 acre-feet of water per year (approximately 11,000 gallons per day) from the river. Minnesota requires a water-use permit if the daily water withdrawal is more than 10,000 gallons per day, or for domestic use serving more than 25 people. Manitoba requires a water-use permit for any users withdrawing more than 5,000 imperial gallons per day (approximately 6,000 U.S. gallons per day).

North Dakota listed 194 permittees along the Sheyenne River and Red River of the North, Minnesota listed 313 permittees along the Red River of the North, and Manitoba listed 80 permittees along the Red River of the North. These lists of permittees included water users along both of the entire rivers, and therefore, required screening to remove from the list all permittees that are not located along the affected reaches. The Minnesota list included all water-use permittees from all sources, including groundwater, lake, stream/river, ditch, dug pit, quarry/gravel pit, and wetland. The Minnesota list was, therefore, filtered to include only those permittees who were identified as stream/river users and showed the Red River of the North as their water source. This reduced the number of Minnesota permittees from 313 to 35.

These three lists were compiled in a single database to allow sorting and to facilitate printing and generation of sublists. Sorting allowed the elimination of duplicate entries and municipal treatment facilities. Other listed permittees were removed from the database when mapping showed that they were actually on tributaries to the Sheyenne River or Red River of the North, or were on reaches unaffected by the proposed outlet. After eliminating municipal, industrial, duplicate entries, and those not on the Red River of the North and Sheyenne reaches of concern, a total of 201 permittees remained. A listing of the permittees, sorted by reach between trace data stations, is presented in Appendix C of the *Devils Lake ND Downstream Surface Water Users Study;* Barr, March 1999. More complete database information for the permittees of river water, sorted by country and state, is provided in Appendix D of that report.

Identification by Reach

For this investigation, permittees were to be identified by river reach between trace data stations (described in the main body of the Technical Appendix). The starting location for measuring the river mile locations in Manitoba was Lake Winnipeg (river mile 0.00), with the intersection with the border between the United States and Canada taken as river mile 155.00. Table I.D-1 lists the number of

permitted users by trace data station reaches (all numbered tables and figures are located at the end of this Attachment).

For Minnesota and North Dakota, permittees within each river reach were located via GIS mapping using township, range, and section data provided in the Minnesota and North Dakota permit databases. The locations for the permitted users in Manitoba were identified based on the river lot number and parish name obtained from the Winnipeg Land Titles Office. Manitoba permit locations were then plotted manually on the maps provided by the Winnipeg Land Titles Office. Having located all the listed permittees on regional maps, each permittee was identified according to the appropriate Red River of the North or Sheyenne River reach.

Interviews of Users

Selecting Interviewees

A primary goal of the investigation was to interview users of all types in each affected Red River of the North and Sheyenne River reach. In addition, the interview process focused on the highest volume users, under the assumption that they would be affected the most. Therefore, the database was sorted according to location (Minnesota, North Dakota, or Manitoba), type of use, and quantity of use, if reported. Interviewees were then selected according to the state/province in which they are located and the type of use to obtain a diverse sample of uses along the entire reach of the study.

Based on the total of 201 permits, a representative sample of 39 permit holders (approximately 20 percent of the total) were to be interviewed. To determine how many of the users of each type would be interviewed, the number of interviewees within each user group was determined by multiplying the total number of interviews to be conducted (39 interviews) by the percentage of users that fall within each user type category. Table I.D-2 shows the relative percentages of each user type and the number of permittees who were selected for interviews.

It should be noted that further examination of the list of 201 permits indicated that the number of permit holders would actually be less than 201. In many cases, a single person, facility, or municipality held more than one permit, but often the multiple permits were actually for the same use. Canadian officials provided no permit numbers with their list of permittees, so it is possible that duplicate entries for persons or corporate entities were erroneous, or actually represented only a single use. Furthermore, in Minnesota and North Dakota, a single permit can be subdivided (among, for instance, family members) resulting in multiple permit numbers and permit holders for what is essentially one permit. Taking these issues into account, the number of potential interviewees would be reduced to only 185.

Once the number of interviewees was determined for each user group, those who use the highest volume of water were selected first for interviews. However, because water usage information was not available for Manitoba users, interviewees who live in Manitoba could not be selected using this criterion.

The permitted river water uses from North Dakota, Minnesota, and Manitoba were combined into the following use types: irrigation, fish and wildlife, domestic, and other.

Determination of Threshold Levels

Approach

The various types of permitted uses identified were analyzed to determine the potential effects of the Devils Lake outflows. Information on the potential effects on the uses was determined through available literature and contacts with agencies and/or specialists in each field. Research into the potential effects enabled computation of estimated "threshold" water quality levels for most uses, defined in this report as the level above which impacts may be detrimental and, if severe enough, might warrant correction or compensation for losses. It was assumed that minor water quality changes below these threshold levels are not likely to be detrimental for permitted users. Exceedance of the threshold was evaluated by use type. For each use, the trace data station reaches were evaluated as to its exceedance of the threshold by use type.

Definitions

There is some variability in the nomenclature and units used when discussing the effects of "saline" water—water containing dissolved minerals or "solutes"—on plants and animals. Salinity is often thought of as "saltiness" which implies consideration of a particular salt, sodium chloride. However, many other salts may be dissolved in water. And although it is true that both chloride and sodium can have their own particular toxic effects on plants and animals, the effects of solute-laden water on living creatures go beyond the potential damage that may be caused by sodium chloride. For this reason, the sum of all dissolved matter in the water is of primary concern in discussions of salinity with respect to its effects on organisms.

The sum of all dissolved matter in water is generally expressed in milligrams per liter (mg/L) of TDS. TDS may in some cases refer to "total dissolved **solids**," and in some cases refer to "total dissolved **salts**." Whereas total dissolved **solids** includes all dissolved matter, including organic compounds, total dissolved **salts** actually includes only dissolved inorganic (mineral) compounds. For purposes of this study, the organic content of the water is considered to be insignificant compared to dissolved salts, so that the HEC-5/5Q-modeled TDS concentrations are used directly as an index of salinity (total dissolved salts are assumed to be equal to total dissolved solids).

Electrical conductivity (EC) of the water (also known as specific conductance) is a measure of TDS. Water with higher concentrations of dissolved salts are more conductive of electricity, and purer water is less conductive. EC is typically expressed in micromhos per centimeter (µmhos/cm)[1]. The ratio, TDS/EC, typically ranges from 0.55 to 0.7 [in units of (mg/L)/(µmhos/cm)], depending on the ionic

[1]Alternately, mhos are also called Siemens, and µmho/cm is the same as µS/cm. The measurement of EC is usually standardized to 25°C, because conductivity changes with temperature.

composition of the water. The TDS/EC ratio for Devils Lake water was evaluated by examination of USGS gage station water quality data and was found to be approximately 0.65. Therefore, the value of 0.65 was used in this study to convert EC (µmho/cm) to TDS (in mg/L).

Threshold Levels for Agricultural Crops

Soil Salinity Relationship

The tolerance of crops, trees, shrubs, gardens, and grasses to TDS is directly related to the type of soil in which they are grown. Soil type affects the movement of water through the soil. Whether the water comes from rain or from irrigation sources, the pathways of the water are the same. Some of the water (the "leaching fraction") will percolate through the root zone and become part of the regional groundwater. Some of the water remains in the root zone as soil water. A portion of the water is taken up by the plant, where it either remains or is transferred back to the atmosphere via transpiration. Finally, a fraction of the water returns directly to the atmosphere via evaporation.

The leaching fraction for less-permeable (clayey) soils is lower than that for more-permeable (sandy) soils. Water passes slowly through clayey soils, so that it is exposed for longer periods of time to the warmest portion of the soil column. Evaporation effects are thus accentuated, and solutes tend to accumulate in the root zone as pure water is lost to evaporation. Another consequence of a lower leaching fraction is that the root zone is less easily "washed" by newly arriving water. The result is that the less-permeable soils are less likely to lose accumulated solutes.

Because of these considerations, less-permeable soils are considered to be less desirable when irrigation water is high in salinity. Other factors (irrigation amounts, timing of irrigation, climate, crop variety and growth stage, etc.) being equal, crops grown in such soils may be expected to be more susceptible to the potential adverse effects of saline water. In nature, some plant species have physiologically adapted to salinity in the root zone. Some of these species are grown in the horticulture industry and show higher-than-average tolerance for an accumulation of salts in the soil.

For this study, regional soil types were grouped according to the SCS hydrologic soil groups (A: high permeability soils, B: moderate permeability soils, C: low permeability soils, and D: very low permeability soils). Soil permeability data were required to estimate the leaching fraction of each soil type. The leaching fraction was assumed to be inversely related to permeability of the soil type—i.e., clayey soils would be expected to have a lower leaching fraction than sandy soils. Leaching fractions of SCS soil groups were assumed to range as follows:

- Soil Type A: 40 to 50%
- Soil Type B: 25 to 40%
- Soil Type C: 10 to 25%
- Soil Type D: 4 to 10%

Soils types along the rivers can be generally characterized as sandy loams with pockets of sand and clay along most of the Sheyenne River, and mainly clays with pockets of sandy loams through the Red River Valley. Soils were characterized using information from the State Soil Geographic Database (STATSGO), and are based on Soil Conservation Service classifications.

Limitations of Salinity Tolerance Level Estimates

Much of the available data regarding salt tolerance levels of crops, trees, shrubs, gardens, and grasses are based on studies conducted in arid climates with sandy soils (California, Middle East, etc.). The carefully controlled nature of these studies makes it difficult to directly apply their results to irrigation along the Sheyenne River and Red River of the North. Many of these studies are based on experiments simulating arid climate conditions, so that evaporation rates are high. Furthermore, the studies typically supply irrigation water as the only water source for the crops being studied. In this way, a steady-state[2] situation is eventually reached, wherein the salinity of the soil water in the root zone reaches a concentration plateau.

Clearly, this is not the situation for irrigated crops in Minnesota, North Dakota, and Manitoba, where irrigation is conducted only on an as-needed basis. During the (often long) periods when irrigation does not occur, salinity levels in the soils would be expected to decline because of the flushing effect of relatively ion-free rain and snowmelt water percolating through the root zone.

Unfortunately, crop salinity tolerance data derived for the conditions of midwestern irrigation are not available. Therefore, for this study, the threshold levels for salinity tolerance are based on data from the available studies—studies on plants subjected to high-evaporative environments with irrigation as the only water source. Similarly, the flushing effect of rain and snowmelt water was not taken into effect. As a result, the threshold levels presented below can be expected to be conservative—water of higher salinity could reasonably be expected to produce no ill effects on crops subjected to a typical irrigation regime in the study area.

The ionic composition of the TDS in the irrigation water used for the available studies is unknown. It is not known if the constituents of TDS would make a difference in the threshold level for the agricultural crops and cultivated plants. This information was not available.

Calculation of Threshold Levels Based on Study Data

The threshold levels of the various agricultural crops grown in the study area were computed based on the particular crop tolerance and the soil types. Table I.D-3 lists the range of threshold levels by soil type for

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[2] According to the United States Salinity Laboratory (USSL) in Riverside, California, a non-steady state model is being developed which will better address the dynamics of different field conditions, including the impact of intermittent rainfall on soil leaching. However, the model will not be available for several more months and may in any case be difficult to apply to the particular conditions in the study area.

the agricultural crops. For purposes of this study, it was assumed that the average value would be used as the threshold level. The potential damages to agricultural crops would decrease the crop yield.

Dry edible beans appear to be the agricultural crop most sensitive to salinity; even in well-drained sandy soil (soil type A), these plants can tolerate only approximately 900 mg/L before a reduction in yield is experienced. Corn, flax, and potato yields would be affected in soils with moderate permeability; in clay and loamy soils (soil types C and D), these crops can tolerate approximately 700 mg/L before a reduction in yield is experienced. All other agricultural crops had threshold levels that were greater than 1,800 mg/L for all soil types.

Assessment of Potentially Affected Irrigation Operations

The assessment of affected users requires a breakdown of the permit data by reach and specific type of use (type of crop grown, type of livestock raised, type of grass grown, etc.). The threshold levels (as defined in previous sections) can then be used to identify which permitted users would be affected by the Devils Lake outflows. However, the permit information lists only the general type of use (irrigation, recreation, fish and wildlife, etc.). The remaining permitted users had to be more specifically identified to compute the number of potentially affected users.

The potential effects on permitted river water users are presented according to the stations referred to previously. The river reaches are identified by their upstream and downstream boundaries. In each case, the upstream boundary is listed as the "Outlet," which for these purposes refers to point of discharge of the emergency outlet into the Sheyenne River. The downstream boundary is the trace data station downstream of which the threshold level is not exceeded. For example, "Outlet to Kindred" indicates that the threshold level is exceeded between the outlet's discharge point and some point upstream of Kindred (a point somewhere between Kindred and the next upstream station, Lisbon). "Outlet to Kindred" implies that nowhere downstream of Kindred would the threshold level be exceeded.

For purposes of this study, county-by-county agricultural use averages were used to estimate the number of users according to specific type of use. There are no data available from the counties that allowed differentiation of the amount of agricultural use from the amount of other uses (nurseries, golf courses, gardens, lawn, and domestic). Therefore, the information obtained from the user interviews was used to estimate the approximate percent of permittees that use the river water for agricultural use (50 percent) versus other uses (50 percent). The manner in which county data was used to further segregate use types is described below.

Agricultural Use

The agricultural use of river water was subdivided between crops and livestock using county data that provided the average per-county acreage of each. Since the county data were available by average acreage and the permittees use the river for multiple uses, the total potentially affected acreage was estimated (rather than the total number of users). The potentially affected acreage per agricultural user was estimated based on conversations with the North Dakota Agricultural Extension Service. According

to the Extension Service, the approximate maximum distance that irrigation equipment can draw from the river water is 1 mile. Therefore, irrigators were assumed to irrigate up to a maximum area encompassed by a 1-mile radius centered on the permit location.

The acreage that would be potentially affected was computed using the following data:

- Total acreage of crops and livestock (by county). The percentage of crops and livestock by county is listed in Table I.D-4.
- Irrigated crops grown within each county (percent). The North Dakota and Minnesota Agricultural Statistics Service and Minnesota Department of Agriculture indicate that in counties within the Sheyenne and Red River of the North Basins, the following crops may be grown: barley, corn, dry edible beans, flax, hay, oat, potato, rye, soybean, sugar beets, sunflower, and wheat. The North Dakota statistics indicate that barley, corn, and wheat are the only irrigated crops in those counties. The percentage of irrigated crops was used for the determination of affected acreage in North Dakota. Minnesota statistics for irrigated crops are not available. For the analysis, it was assumed that the irrigated crops in Minnesota would be the same as in North Dakota (barley, corn, and wheat). The percentages of each crop were based on the total agricultural crops grown. The maximum and minimum acreages of crops (in percent of total agricultural acreage) in these counties is listed in Table I.D-5.
- Soil types (based on the SCS hydrologic soil group) were estimated using the STATSGO soils database. Soil types were identified within the 1-mile radius of the location of each irrigative permit holder. The resulting acreage by soil type for irrigative users is listed in Table I.D-6.

Crops, Agricultural Property, Urban Areas, Transportation Systems

For the water quantity-dependent downstream features, the following information was provided by the St. Paul District Corps of Engineers:

Downstream Flood Damage Analysis

Much of the data used for analysis of downstream flood damages was collected during the course of the Sheyenne River flood control study of the early 1980s. The report documenting this analysis is entitled *General Reevaluation and Environmental Impact Statement for Flood Control and Related Purposes, Sheyenne River, North Dakota* (August 1982). Damage categories included in this analysis are crop, other agricultural property, transportation, and urban damage at Valley City and Lisbon. For purposes of evaluating flood damages, the flooded area along the Sheyenne River is divided into damage reaches. Reaches are divided based on hydraulic and/or economic characteristics. The reaches and reach boundaries are presented below. The downstream limit of the flood damage analysis is Horace, ND. It is assumed that the increased or decreased flows from the various with-project conditions would attenuate by the time they reached this part of the river and would not be significant in terms of flood damage impact.

Reach	Boundary
1	Outlet point to Lake Ashtabula
2	Baldhill Dam to Kathryn, ND
3	Kathryn, ND to Soo Line RR (River mile 125.8)
4	Soo Line RR to River mile 76.2 (near Kindred, ND)
5	Kindred, ND to Horace, ND

Crops – This category includes damage to crops and pasture. Flood damage may occur in different ways depending on the time of year flooding occurs. Spring flooding may delay planting beyond the optimum date resulting in lower yields and revenue. Or if the delay is long enough it may force a producer to plant an alternate crop with a shorter growing season and less income producing potential. Flooding later in the year during the growing season can partially or fully damage a standing crop directly depending on the depth and duration of flooding. Thus seasonality of flooding is a consideration in evaluating crop damage.

Crop damage is calculated by applying a crop damage per acre value to the area flooded for the particular flood event. Crop damage per acre will vary depending on time of year and type of crop flooded. The relationship that relates damage for a composite crop acre by date of flooding is the seasonal crop damage curve. Data collected to develop this curve includes types of crops grown in the study area, mix of crops grown as a percentage of land use, crop yields, crop prices, and the various farming operations and costs required for raising a crop. Seasonal crop damage curves were developed for each evaluation reach as

part of the 1982 Sheyenne River study. These were updated to reflect current crop prices and production costs. Figure I.D-1 is a sample of a seasonal crop damage curve.

Area flooded curves are also developed that relate flood flows (Reach 1) or stages (Reaches 2-5) with areal extent of flooding. These are generally based on historic flooding patterns. The area flooded curves for Reaches 2 through 5 were developed for the 1982 Sheyenne River study. The curve for Reach 1 was developed for the present study using USGS quad maps and selected cross sections within the reach. With the seasonal crop damage curve and the area flooded relationships, crop damages for a particular flood can be estimated. Given the date of the flood peak, the damage per acre can be derived from the seasonal crop damage curve. Peak flood stage is used to determine the number of acres flooded based on the stage-area flooded curve. Multiplying the two values results in the estimate for crop damage for the flood event. Figures I.D-2 to I.D-6 show the area flooded relationships for Reaches 1 through 5.

Other Agricultural Property – This category consists of all other property on a farm other than the crop in the fields including farm buildings, machinery and equipment, stored grain and hay, livestock, fences, and cleanup costs. Flood damage data was collected via survey for the Sheyenne River study and after historic flood events. Other agricultural damages are averaged over the flooded area and expressed on a per acre basis. Like agricultural damage, the per-acre damages are multiplied by the acres flooded to estimate other agricultural damage for the flood event. Damage values developed for the 1982 Sheyenne River study were updated to reflect current price levels. The flow-damage (Reach 1) and stage-damage (Reaches 2-5) relationships are shown on Figures I.D.-7 through I.D.-11.

Urban Areas – Urban damages represent the damage that may occur at Valley City and Lisbon located downstream on the Sheyenne River. Urban centers further downstream were not included in the analysis as it was judged that the impact of added flows would attenuate and not be significant. This category includes damage to residential, commercial/industrial and public properties. The elevation-damage relationships developed for the 1982 Sheyenne River study served as the basis for evaluating damages at Valley City and Lisbon for the current study. Damage values were updated to the current 2001 price level using the ENR Building index. Figures I.D-12 and I.D-13 show the damage curves for Valley City and Lisbon.

Transportation Infrastructure – This category includes damage to roads, highways, bridges, railroads, culverts, and traffic detour costs. The transportation damage relationships developed from the 1982 study serve as the basis for this analysis for Reaches 2 through 5. These are updated to reflect current 2001 price levels using the ENR Construction Index. The relationship for Reach 1 was estimated by assuming the damage characteristics, expressed on a per acre basis, are comparable to Reach 2. Figures I.D-14 through I.D-17 illustrate the stage-damage relationships for Reaches 1 through 4 for the transportation category. For Reach 5, Kindred ND to Horace ND, the transportation damages were assumed to be negligible; no stage-damage relationship is presented.

Table I.D-1
Permitted Uses
Listed Between Trace Data Stations

Use	State/Province	Number of Permitted Users	% of Grand Total
Red River of the North			
Between Lake Winnipeg and Emerson			
Irrigation	Manitoba	73	
Domestic	Manitoba	1	
Waterfowl Conservation	Manitoba	1	
Other	Manitoba	1	
	Subtotal:	**76**	**38%**
Between Emerson and Drayton			
Irrigation	North Dakota	15	
	Subtotal:	**15**	**7%**
Between Drayton and Oslo			
Irrigation	North Dakota	5	
	Subtotal:	**5**	**2%**
Between Oslo and Grand Forks			
Irrigation	North Dakota	9	
Major Crop Irrigation	Minnesota	7	
Golf Course	Minnesota	1	
	Subtotal:	**17**	**8%**
Between Grand Forks and Halstad			
Irrigation	North Dakota	20	
Major Crop Irrigation	Minnesota	15	
	Subtotal:	**35**	**17%**
Between Halstad and "Junction"			
There were no permitted users identified between Halstad and "Junction"			
Sheyenne River			
Between "Junction" and Kindred			
Irrigation	North Dakota	7	
	Subtotal:	**7**	**3%**
Between Kindred and Lisbon			
Irrigation	North Dakota	15	
	Subtotal:	**15**	**7%**
Between Lisbon and Valley City			
Irrigation	North Dakota	15	
Fish & Wildlife	North Dakota	1	
	Subtotal:	**16**	**8%**
Between Valley City and Cooperstown			
Irrigation	North Dakota	5	
Recreation	North Dakota	3	
Fish & Wildlife	North Dakota	2	
	Subtotal:	**10**	**5%**
Between Cooperstown and the proposed outlet			
Irrigation	North Dakota	5	
	Subtotal:	**5**	**2%**
	Grand Total:	**201**	**100%**

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Table I.D-2

Permitted Users by Permit Type and Location

Permit Location and Type	Percent of Permits	Number of Permittees Interviewed
Manitoba		
Irrigation	31%	12
Waterfowl Conservation	<1%	0
Domestic	<1%	0
Other	<1%	0
North Dakota		
Irrigation	54%	21
Fish & Wildlife	1%	1
Recreation	1%	1
Minnesota		
Irrigation	10%	4

(Note that while the total number of Permittees interviewed was 39, the number of interviews actually conducted was 37. Two of those interviewed were holders of two separate permits.)

Table I.D-3
TDS Threshold Levels for Agricultural Crops

CROPS	TDS Threshold Level (mg/L)			
	Soil Type A	Soil Type B	Soil Type C	Soil Type D
Barley	6753 - 7429	4906 - 6753	3852 - 4906	2889 - 3852
Corn	1435 - 1579	1042 - 1435	818 - 1042	614 - 818
Dry Edible Beans	844 - 929	613 - 844	481 - 613	360 - 481
Flax	1435 - 1579	1042 - 1435	818 - 1042	614 - 818
Hay*	4474 - 4921	3250 - 4474	2552 - 3250	1914 - 2552
Oats	N/A	N/A	N/A	N/A
Potato	1435 - 1579	1042 - 1435	818 - 1042	614 - 818
Rye	4726 - 5200	3434 - 4726	2696 - 3434	2022 - 2696
Soybean	4220 - 4643	3065 - 4220	2407 - 3065	1805 - 2407
Sugarbeet	5909 - 6500	4292 - 5909	3370 - 4292	2528 - 3370
Sunflower	N/A	N/A	N/A	N/A
Wheat	5064 - 5571	3679 - 5064	2889 - 3679	2166 - 2889

* Barley Hay

Notes: N/A denotes information not available for that crop.

Soil types are based on SCS hydrologic soil types as follows:

Type A Low runoff potential: high infiltration rates.
Type B Moderate infiltration rates.
Type C Slow infiltration rates.
Type D High runoff potential: slow infiltration rates.

Table I.D-4

Percent of Crops Grown and Livestock/Other Farmland Uses

County	Total Acres Farmed	Agricultural Crops		Livestock/Other	
		%	Acres	%	Acres
Red River of the North					
Minnesota					
Kittson	483,000	62.0%	299,400	38.0%	183,600
Marshall	744,700	64.3%	479,200	35.7%	265,500
Norman	457,700	71.5%	327,100	28.5%	130,600
Polk	1,042,900	61.6%	642,100	38.4%	400,800
North Dakota					
Grand Forks	769,200	86.9%	668,400	13.1%	100,800
Pembina	600,800	88.1%	529,300	11.9%	71,500
Traill	501,100	99.8%	500,100	0.2%	1,000
Walsh	737,300	76.4%	563,100	23.6%	174,200
Wells	750,900	71.3%	535,100	28.7%	215,800
Red River Subtotal	3,359,300	83.2%	2,796,000	16.8%	563,300
Sheyenne River					
Barnes	858,300	78.5%	673,900	21.5%	184,400
Benson	777,700	55.4%	430,800	38.2%	296,900
Cass	1,070,500	90.9%	973,200	9.1%	97,300
Eddy	369,100	57.3%	211,500	42.7%	157,600
Griggs	396,200	70.3%	278,600	29.7%	117,600
Nelson	552,700	68.1%	376,600	31.9%	176,100
Ransom	485,000	66.8%	323,800	33.2%	161,200
Richland	799,600	96.3%	770,000	3.7%	29,600
Steele	439,800	83.8%	368,400	16.2%	71,400
Sheyenne R. Subtota	5,748,900	76.7%	4,406,800	22.5%	1,292,100
Total	9,108,200	79.1%	7,202,800	20.4%	1,855,400

Based on 1992 Agriculture Census

Table I.D-5

Irrigated Agricultural Crops Acreage Planted in 1999

Minnesota		
Ag. Crop	**Min (%)**	**Max (%)**
Barley	11.4%	17.6%
Corn	1.8%	2.4%
Beans	0.0%	0.0%
Flax	0.0%	0.0%
Hay	0.0%	0.0%
Oats	0.0%	0.0%
Potato	0.0%	0.0%
Rye	0.0%	0.0%
Soybean	0.0%	0.0%
Sugarbeet	0.0%	0.0%
Sunflower	0.0%	0.0%
Wheat	80.0%	86.7%
North Dakota		
Ag. Crop	**Min (%)**	**Max (%)**
Barley	0.0%	0.0%
Corn	0.0%	80.3%
Beans	0.0%	0.0%
Flax	0.0%	0.0%
Hay	0.0%	0.0%
Oats	0.0%	0.0%
Potato	0.0%	19.9%
Rye	0.0%	0.0%
Soybean	0.0%	0.0%
Sugarbeet	0.0%	0.0%
Sunflower	0.0%	0.0%
Wheat	0.0%	100.0%

NOTES: North Dakota irrigated crop data for 1999 was obtained from the USDA National Agricultural Statistics Service
Minnesota irrigated crops were assumed to be limited to barley, corn and wheat.

Table I.D-6

Soil Types within 1 Mile of Permitted Users

River Reach by County	Soil Types (Acres)						
	A/D	A	B	C	CD	D	Total Acreage
Red River of the North							
Emerson to Drayton							
Pembina				2,829	1,492		4,321
Kittson				910			910
Drayton to Oslo							
Kittson				675			675
Marshall			949	2,656			3,605
Pembina				553	769		1,322
Walsh				5,260	1,819		7,079
Oslo to Grandforks							
Grand Forks			334	5,526	3,241		9,100
Marshall			421	818			1,239
Polk			5,269	2,641	150		8,059
Walsh				249			249
Grand Forks to Halstad							
Grand Forks			459		12,214		12,673
Norman				82		717	799
Polk			18,637		1,014		19,651
Traill			353	1,106	3,932	94	5,486
Sheyenne River							
Junction to Kindred							
Cass			5,420	4,021		3,011	12,452
Kindred to Lisbon							
Ransom		2,810	15,240		1,424		19,474
Lisbon to Valley City							
Barnes			270		1,380	6,837	8,488
Ransom			5,463	1,683			7,146
Valley City to Cooperstown							
Barnes	220		1,867		1,511	5,490	9,088
Cooperstown to Outlet							
Eddy			541		145	1,313	2,000
Griggs			201			180	381
Nelson			2,183			3,435	5,618
Total Acreage	220	2,810	57,608	29,008	29,092	21,077	139,816

NOTES:
Based on STATSGO soils database
Soil type A/D was grouped with soil type A.
Soil type C/D was grouped with soil type D.

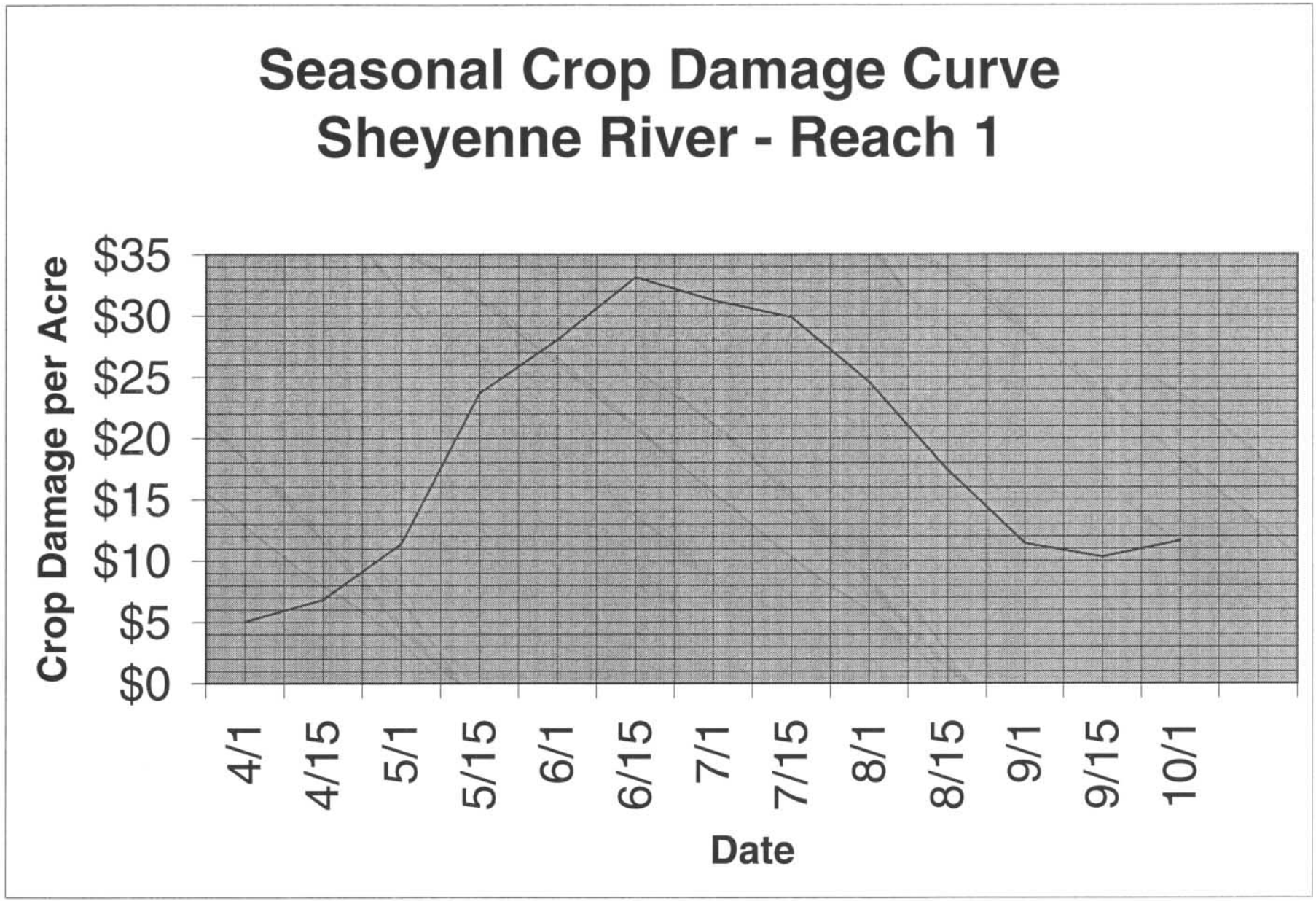
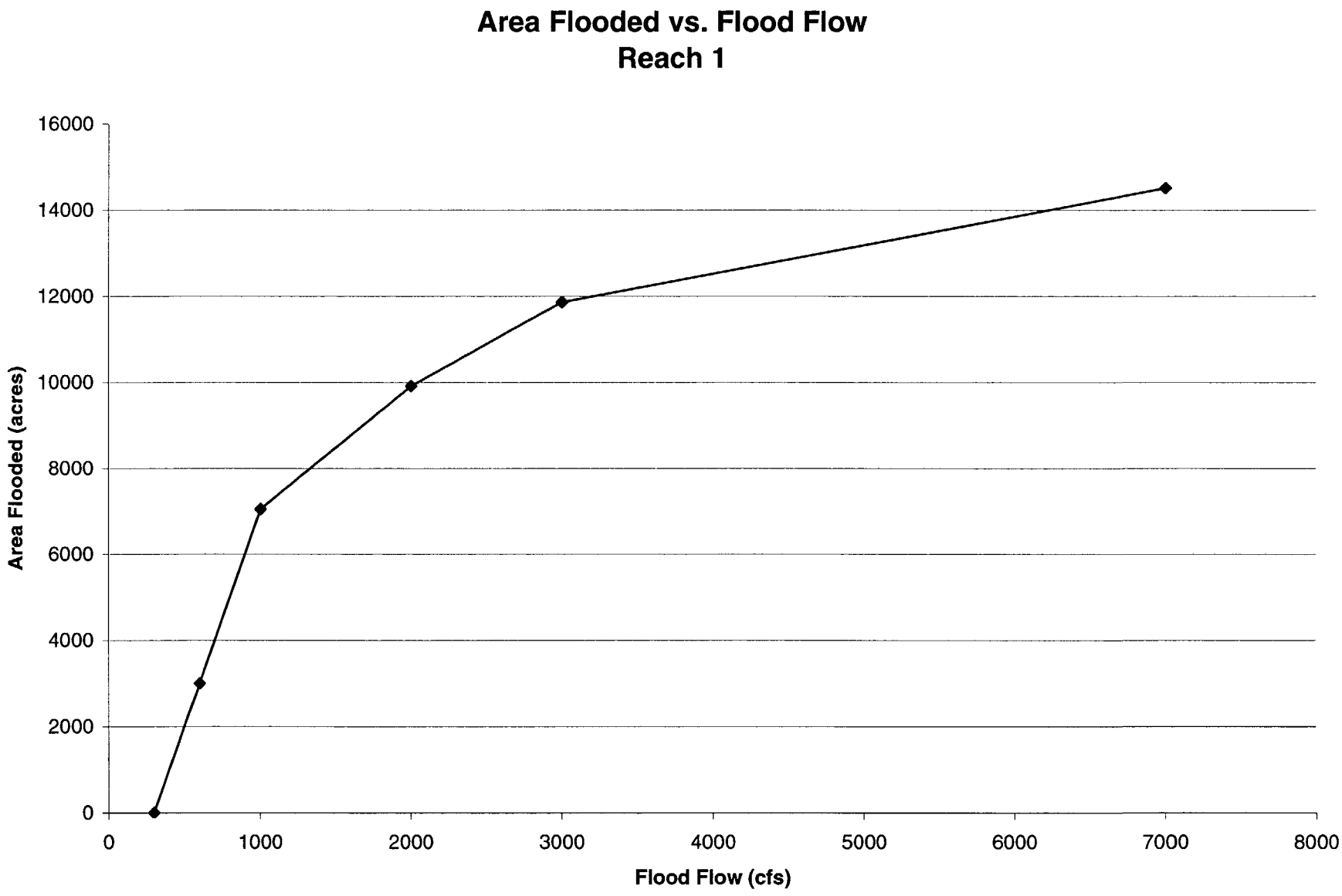

Seasonal Crop Damage Curve
Sheyenne River - Reach 1
Crop Damage per Acre
$35
$30
$25
$20
$15
$10
$5
$0
4/1
4/15
5/1
5/15
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
10/1
Date

Figure I.D-1



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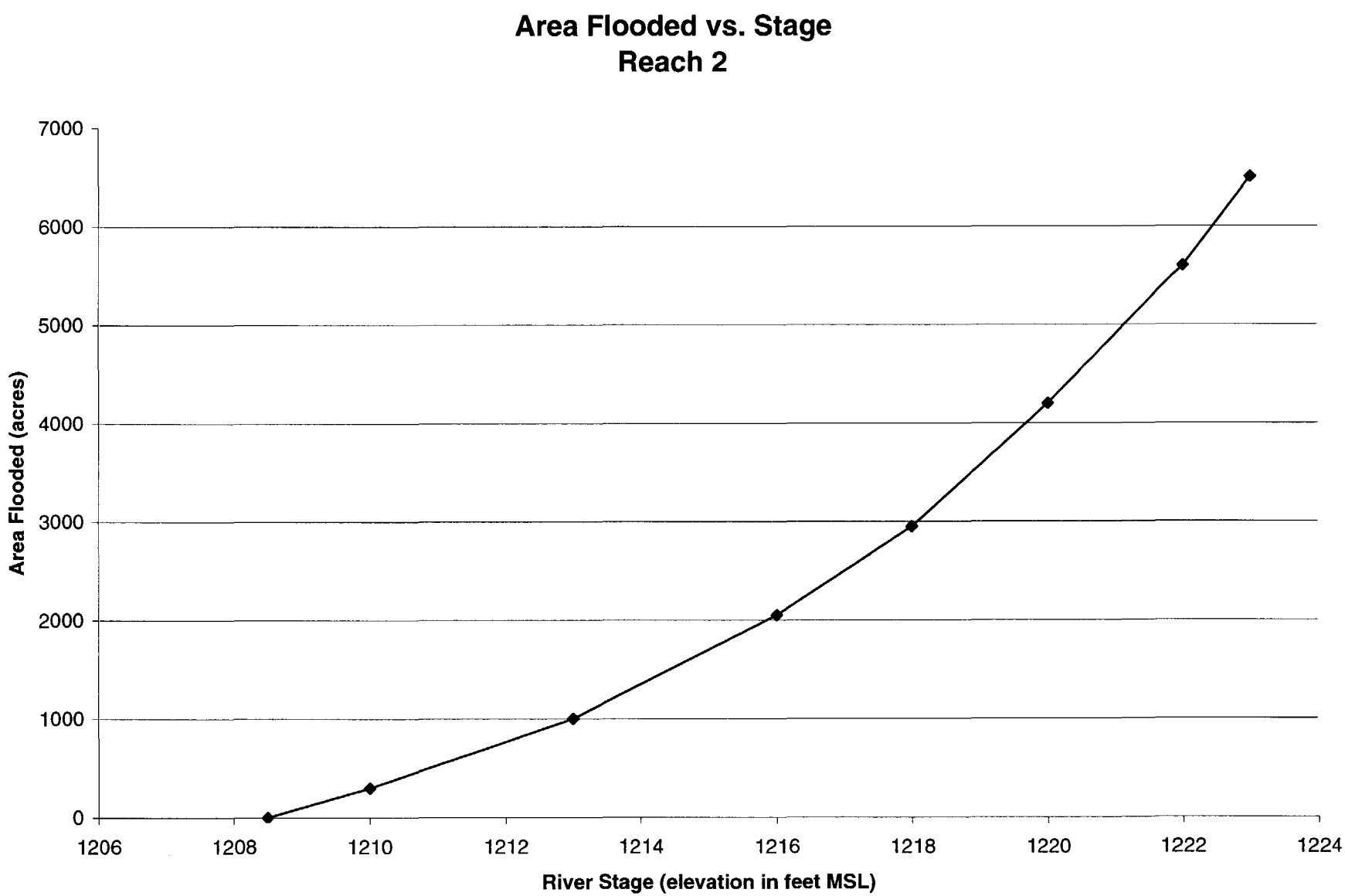

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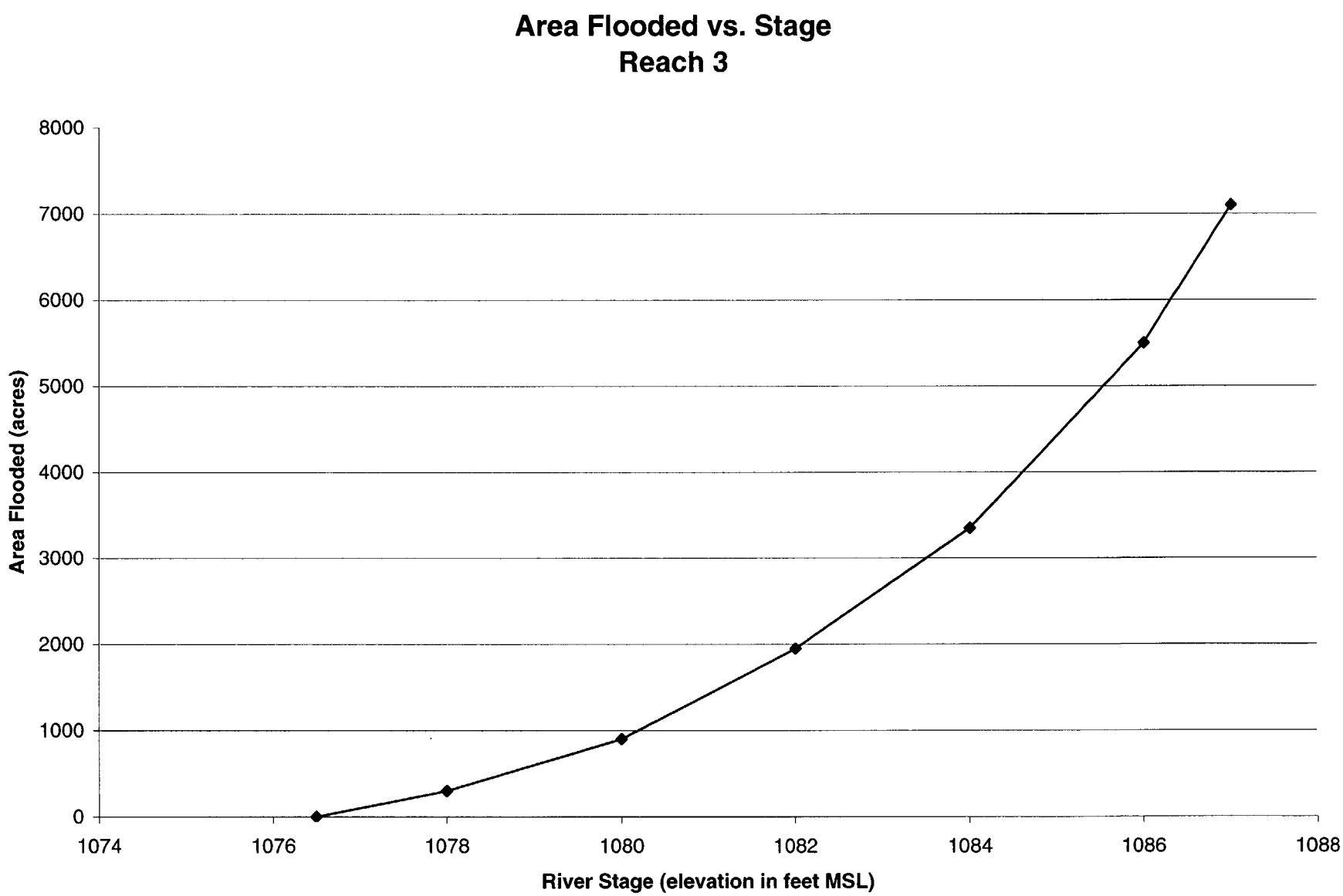

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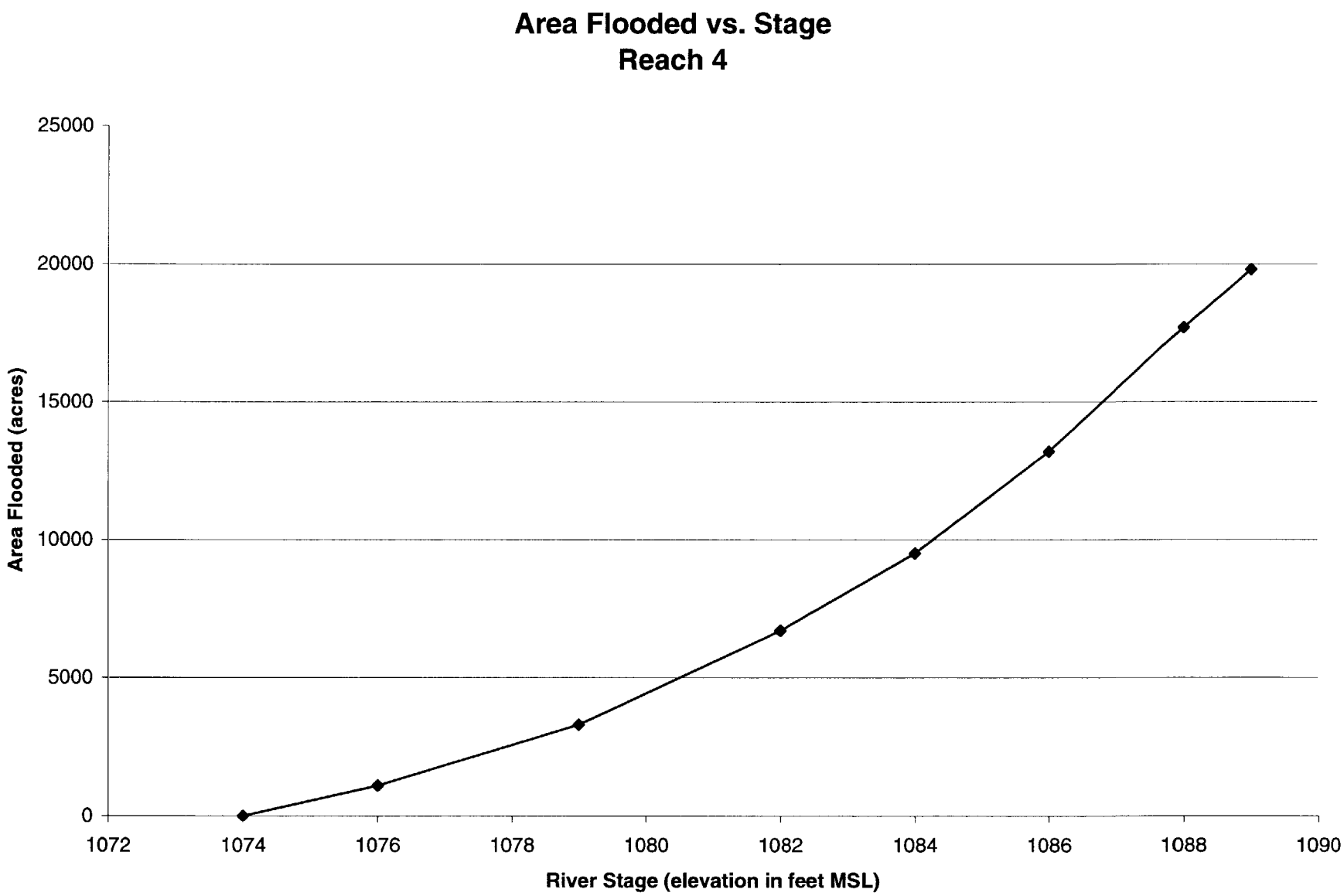

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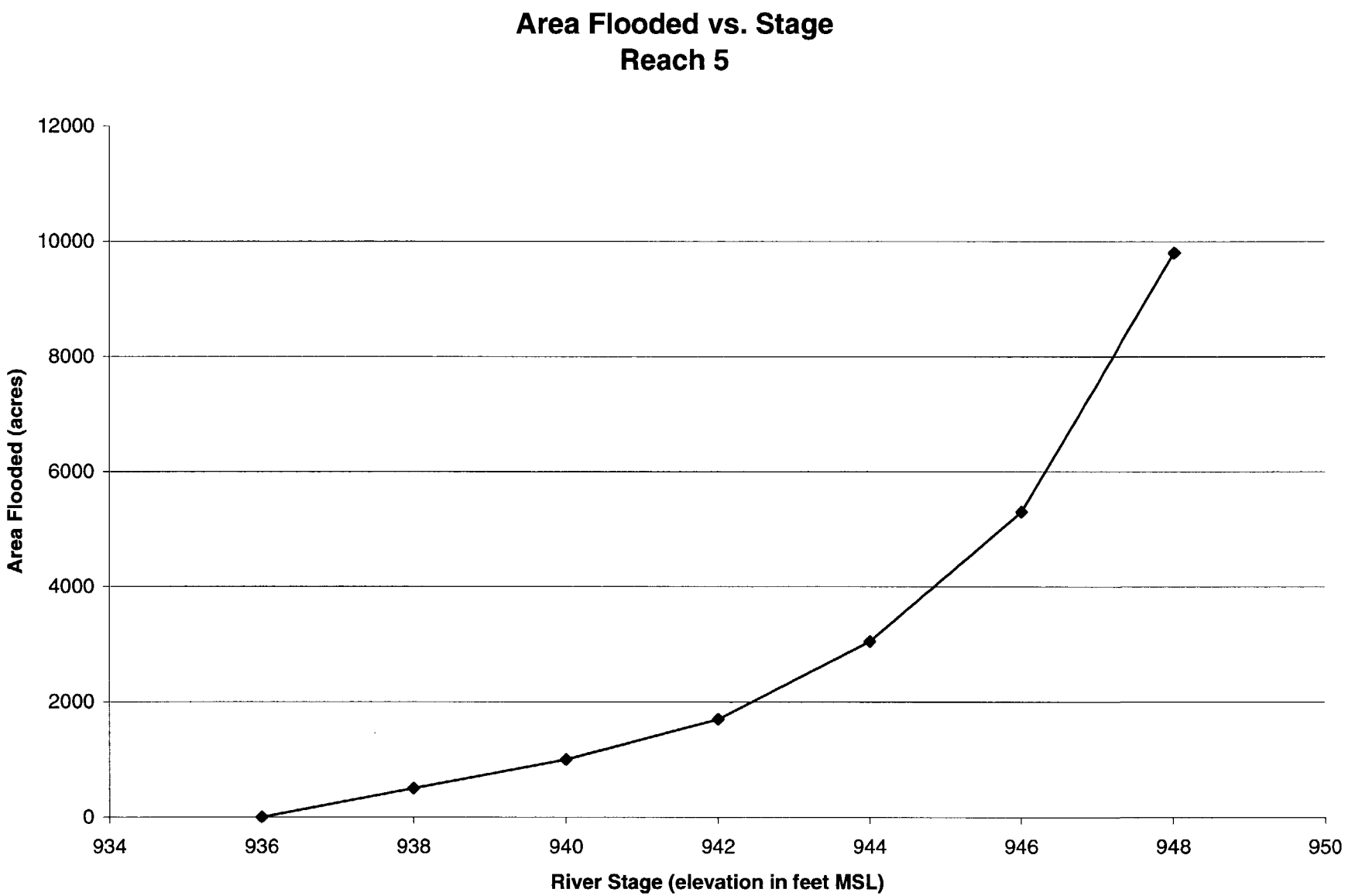

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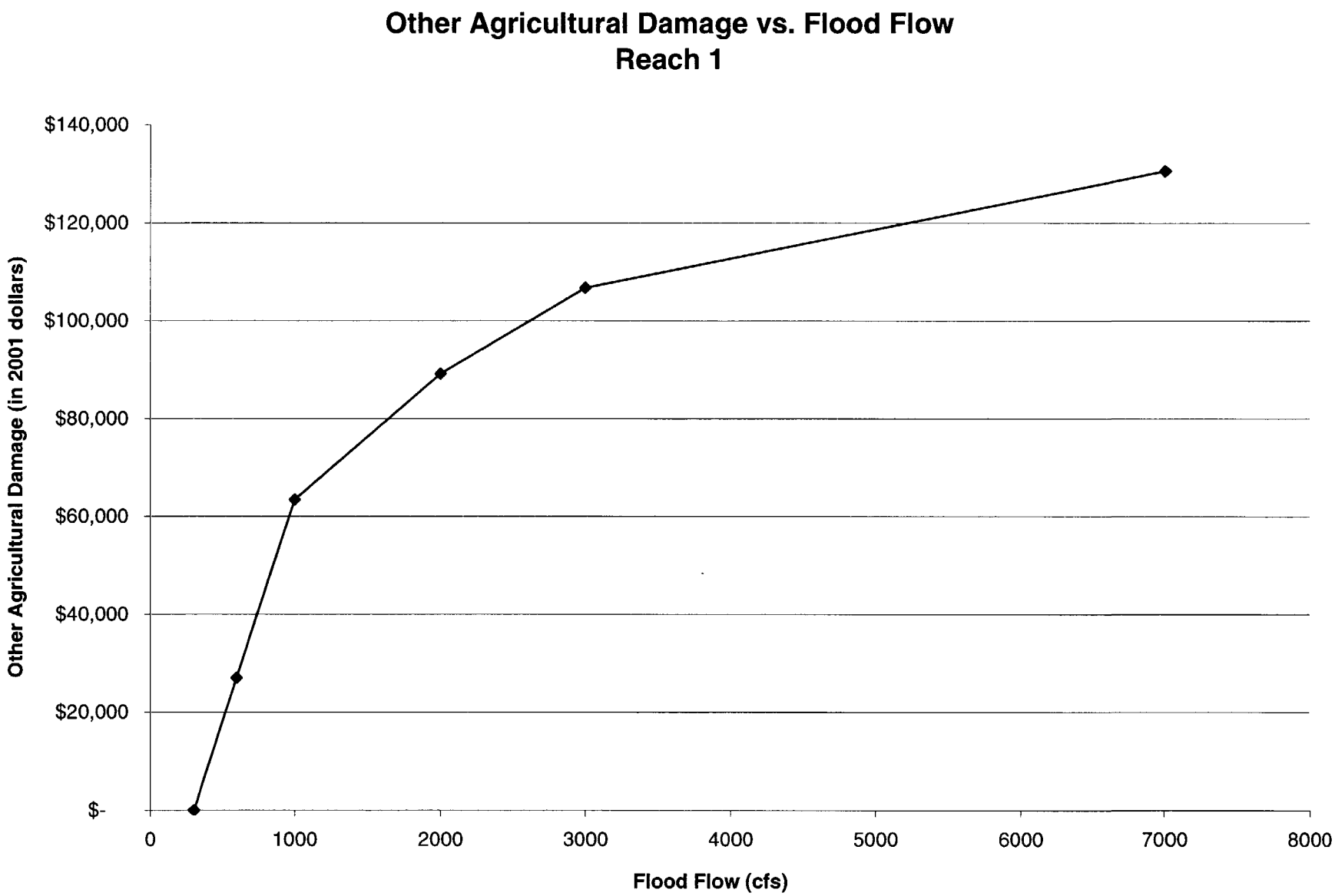

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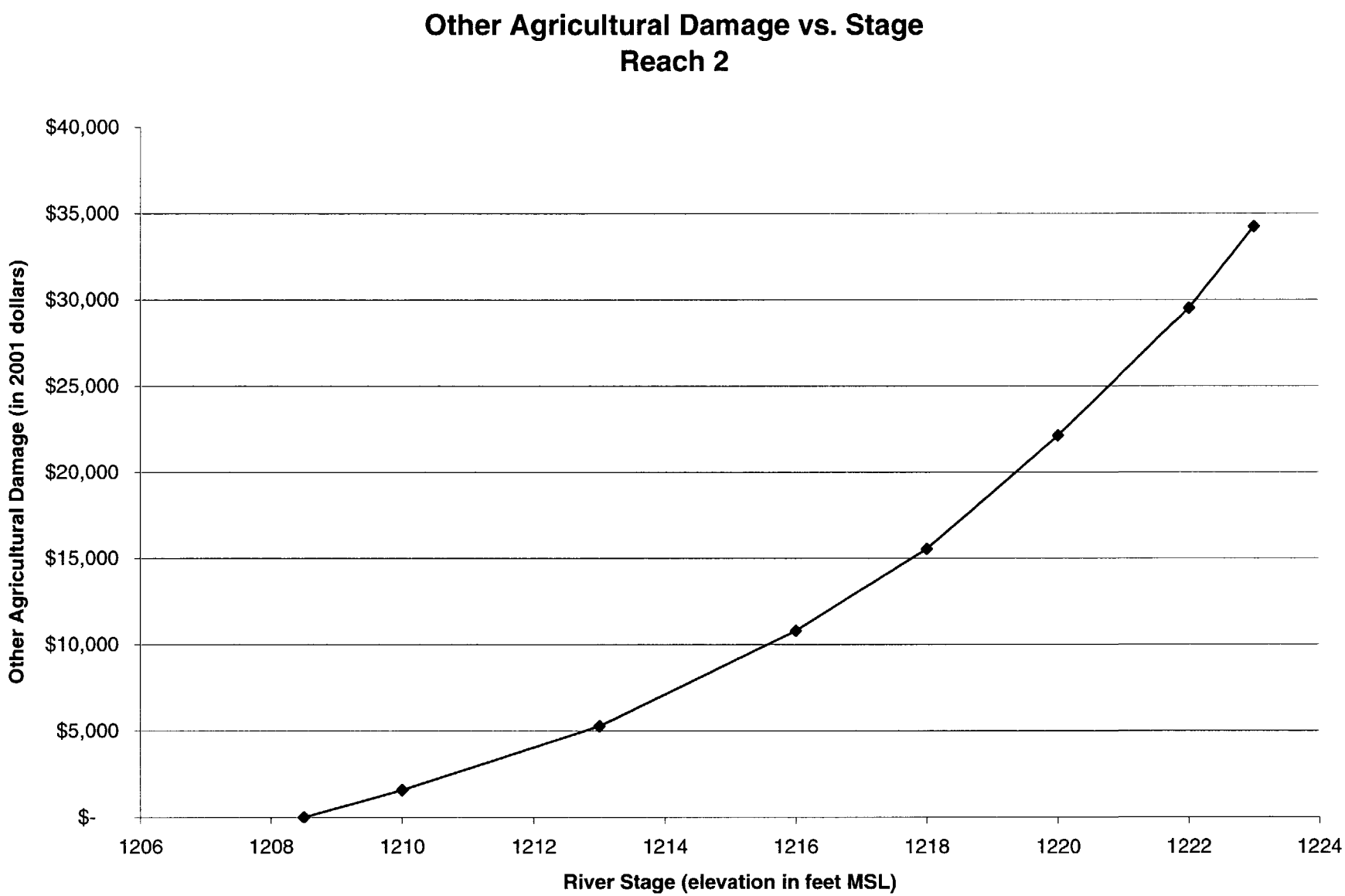

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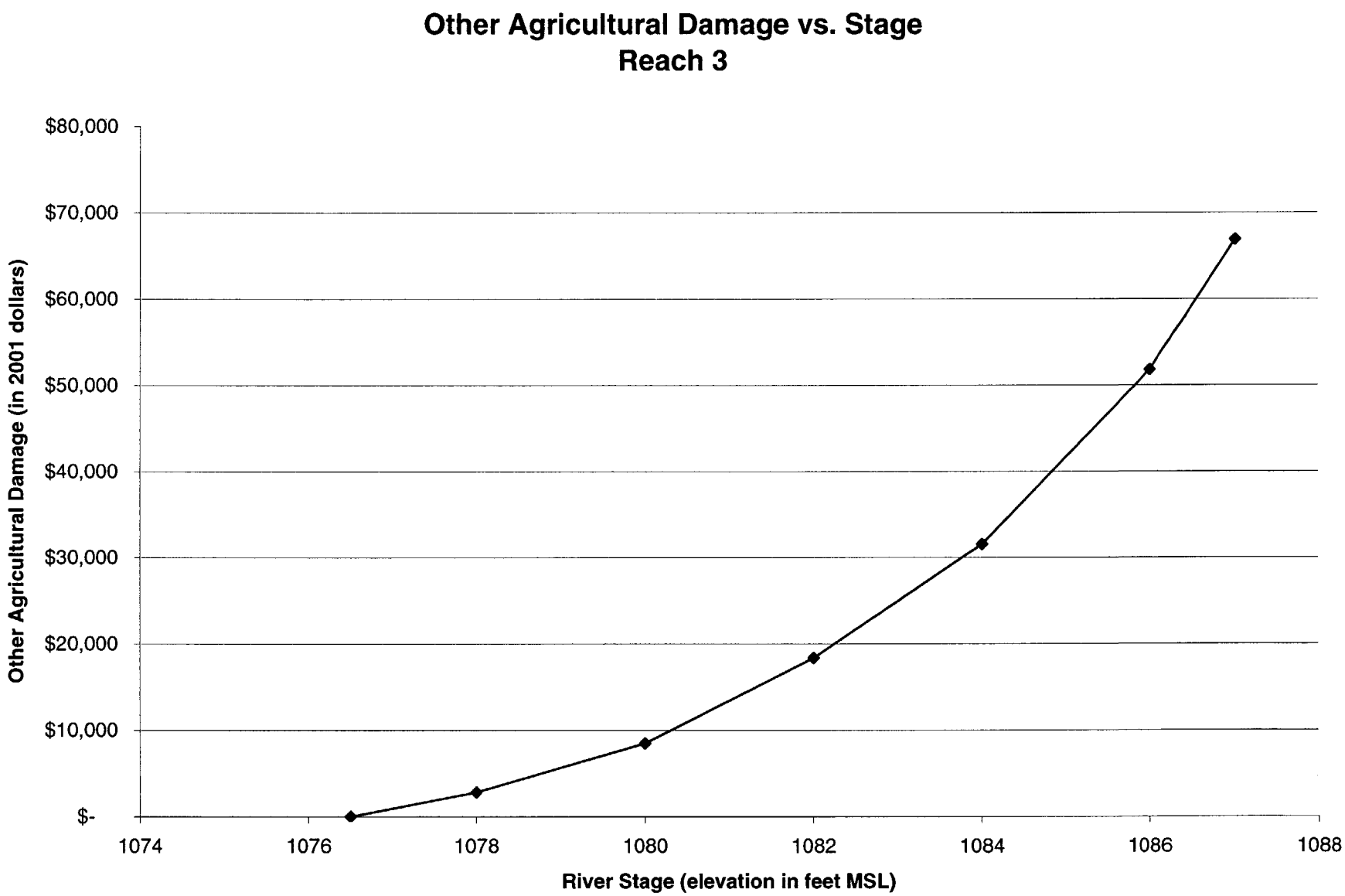

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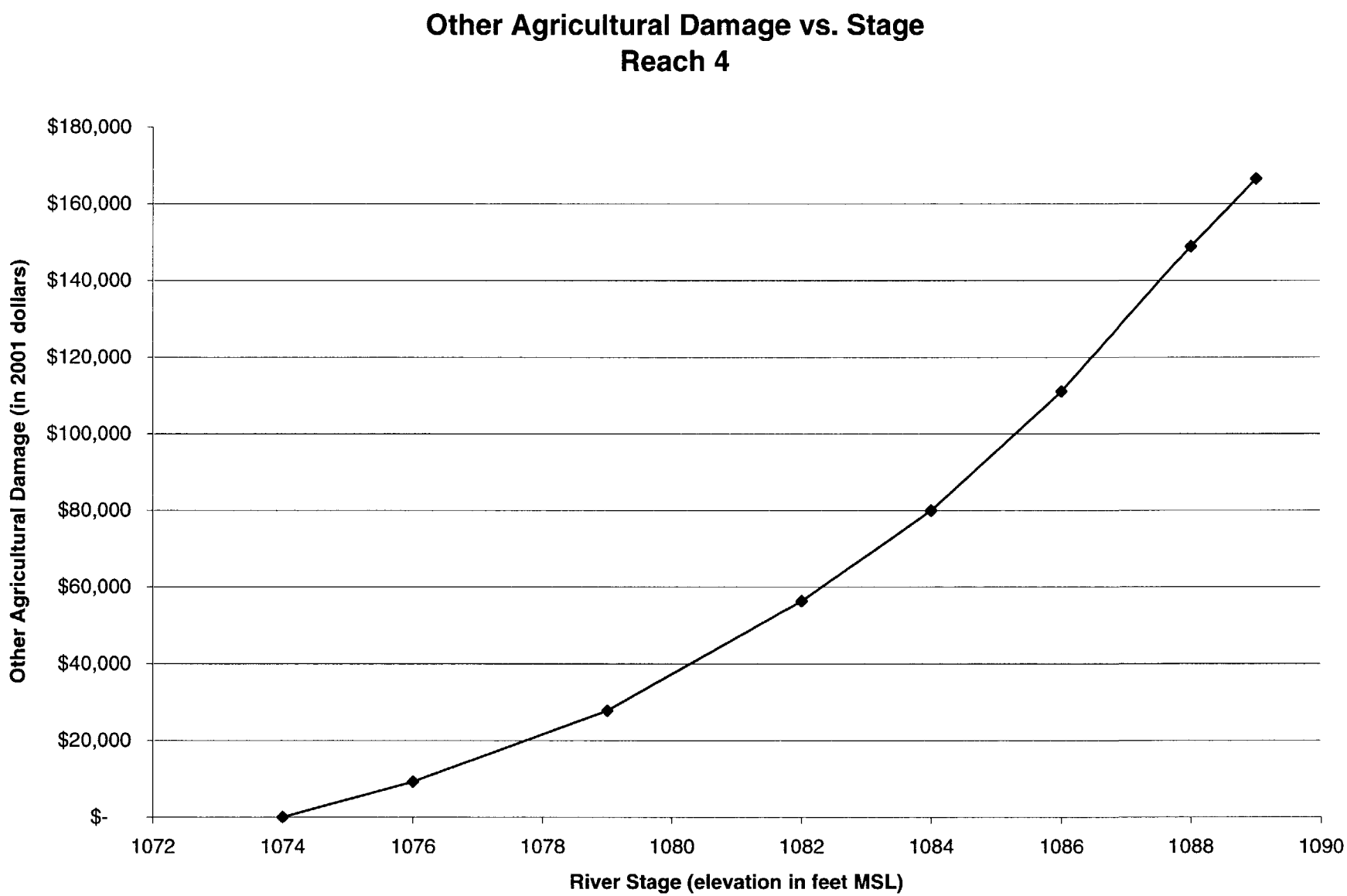

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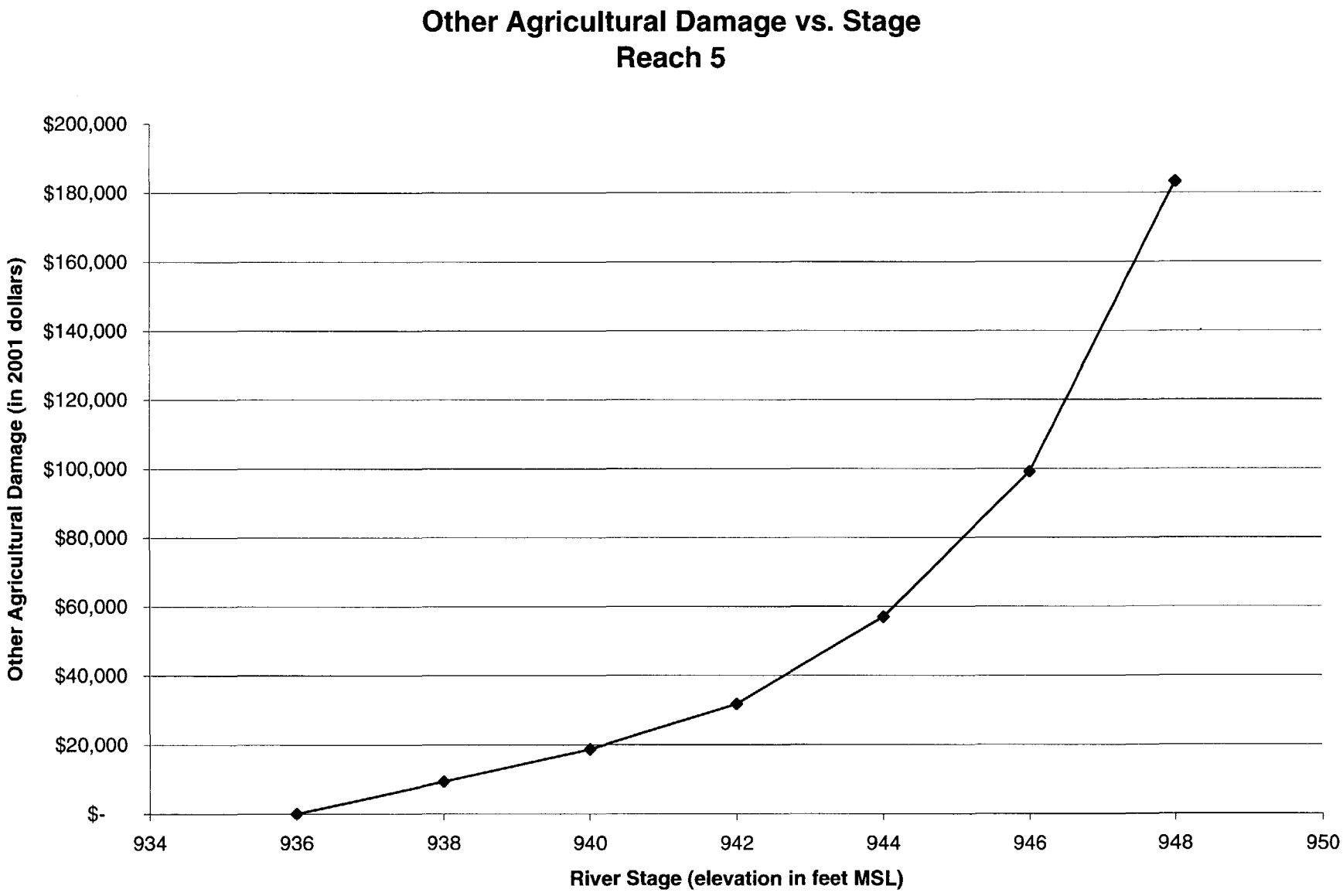

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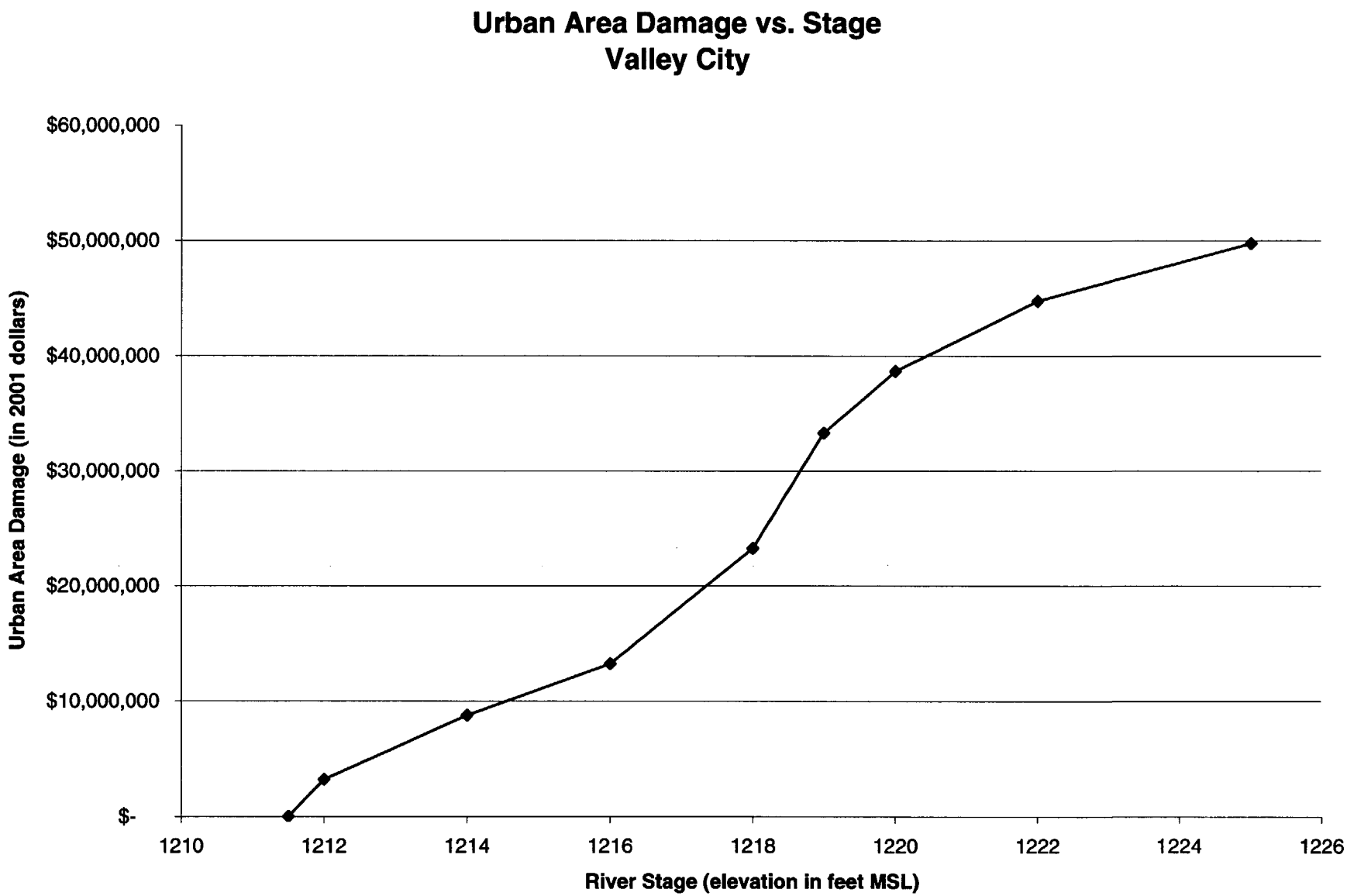

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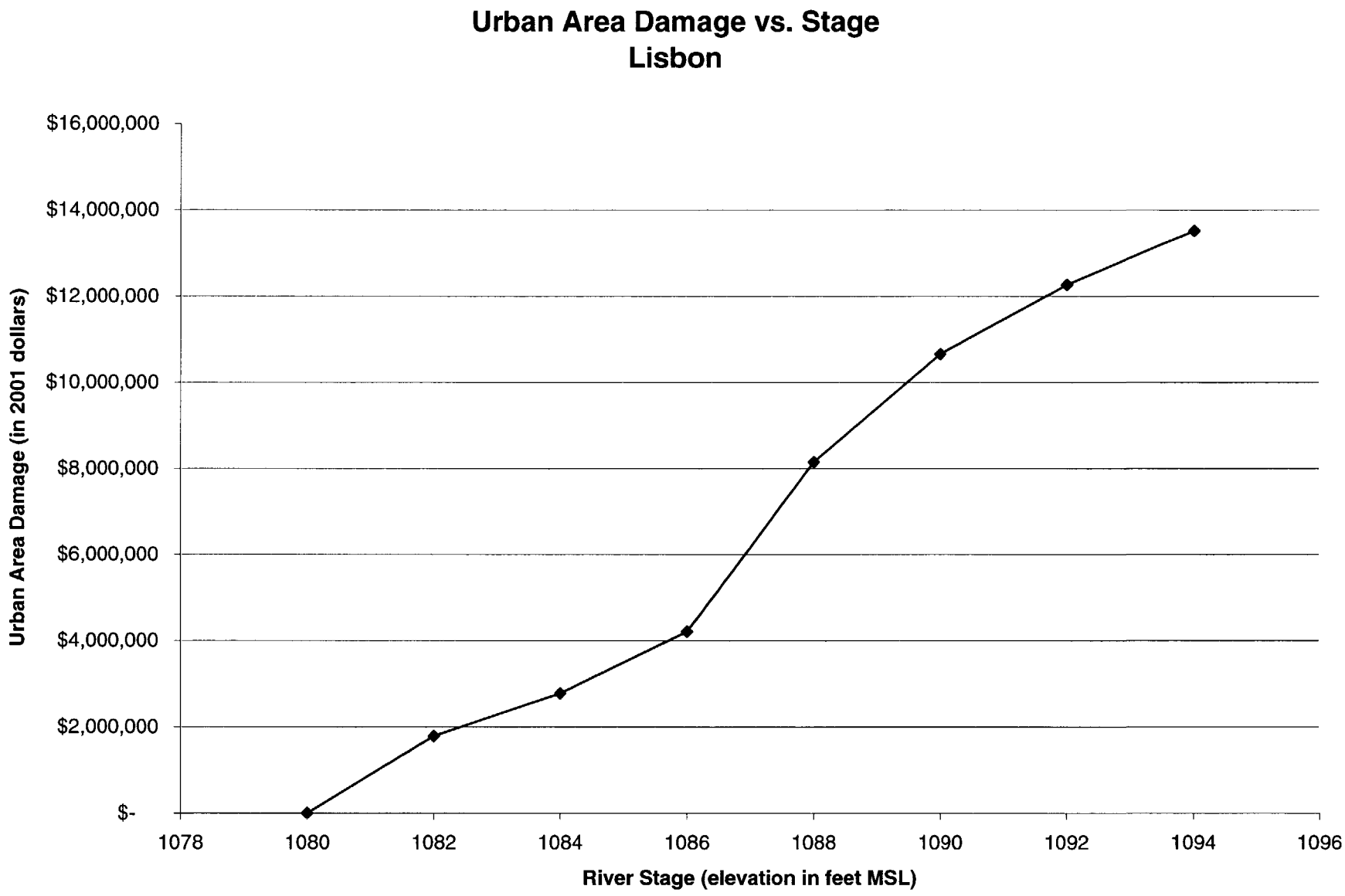

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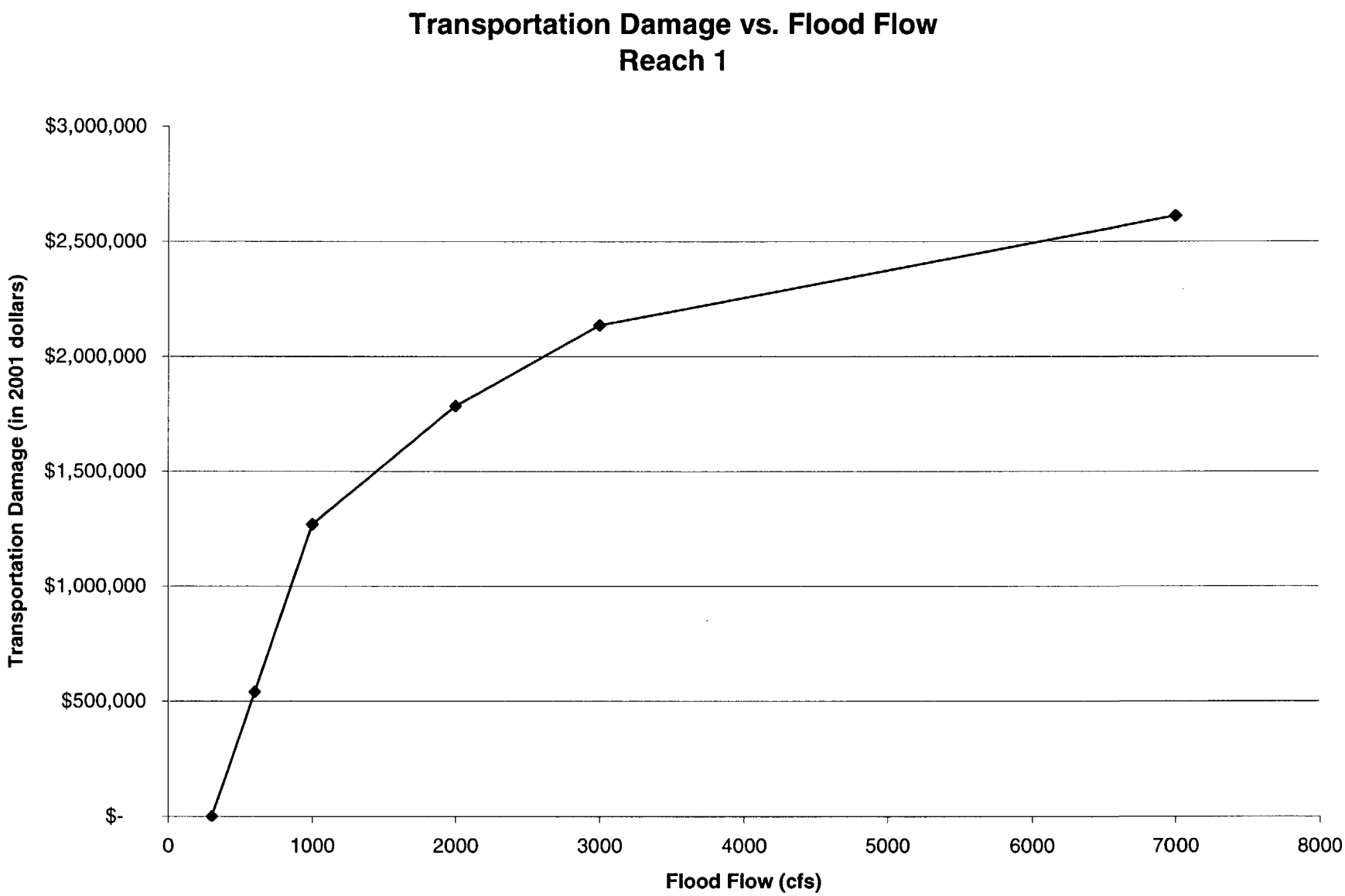

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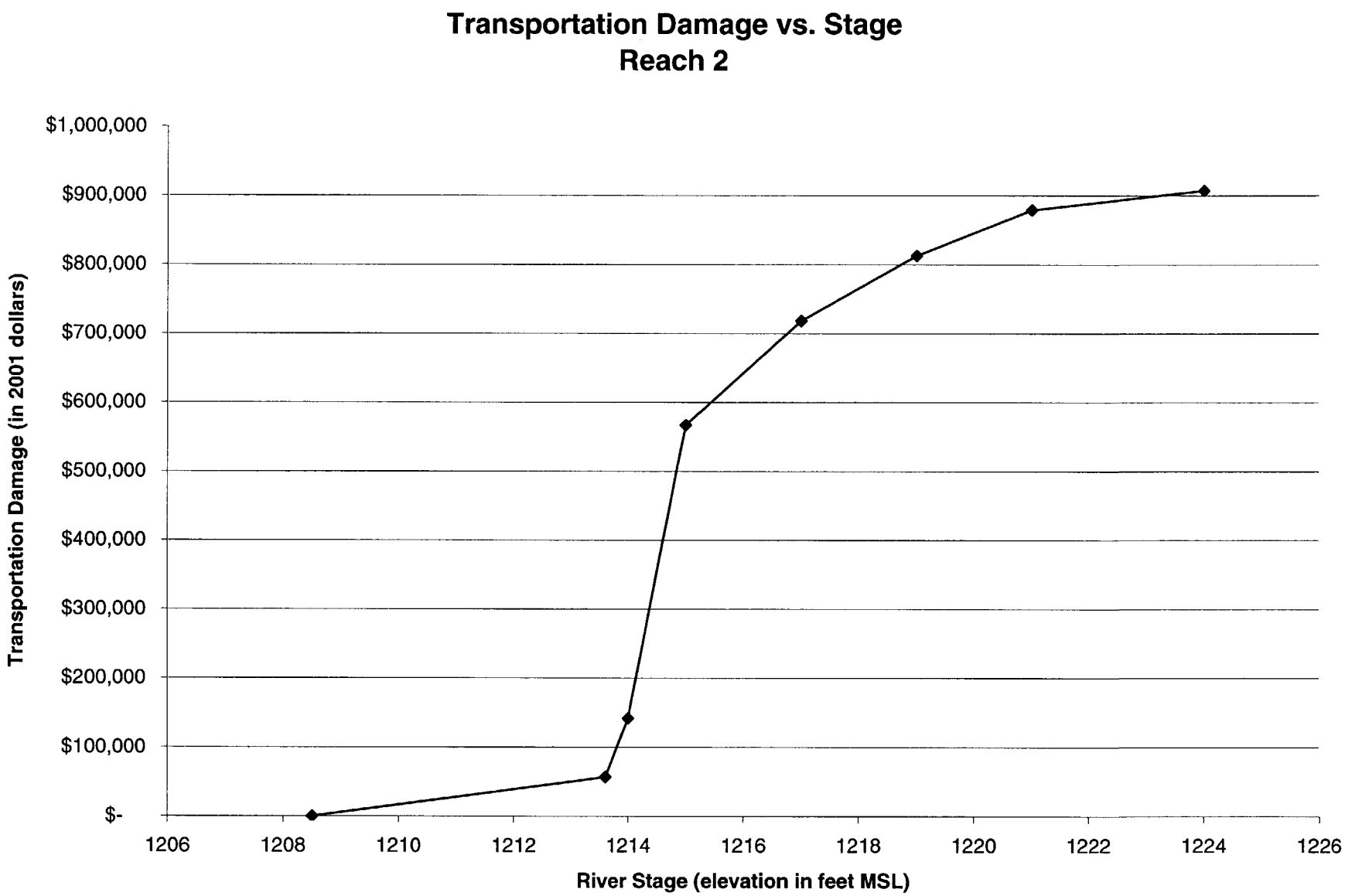

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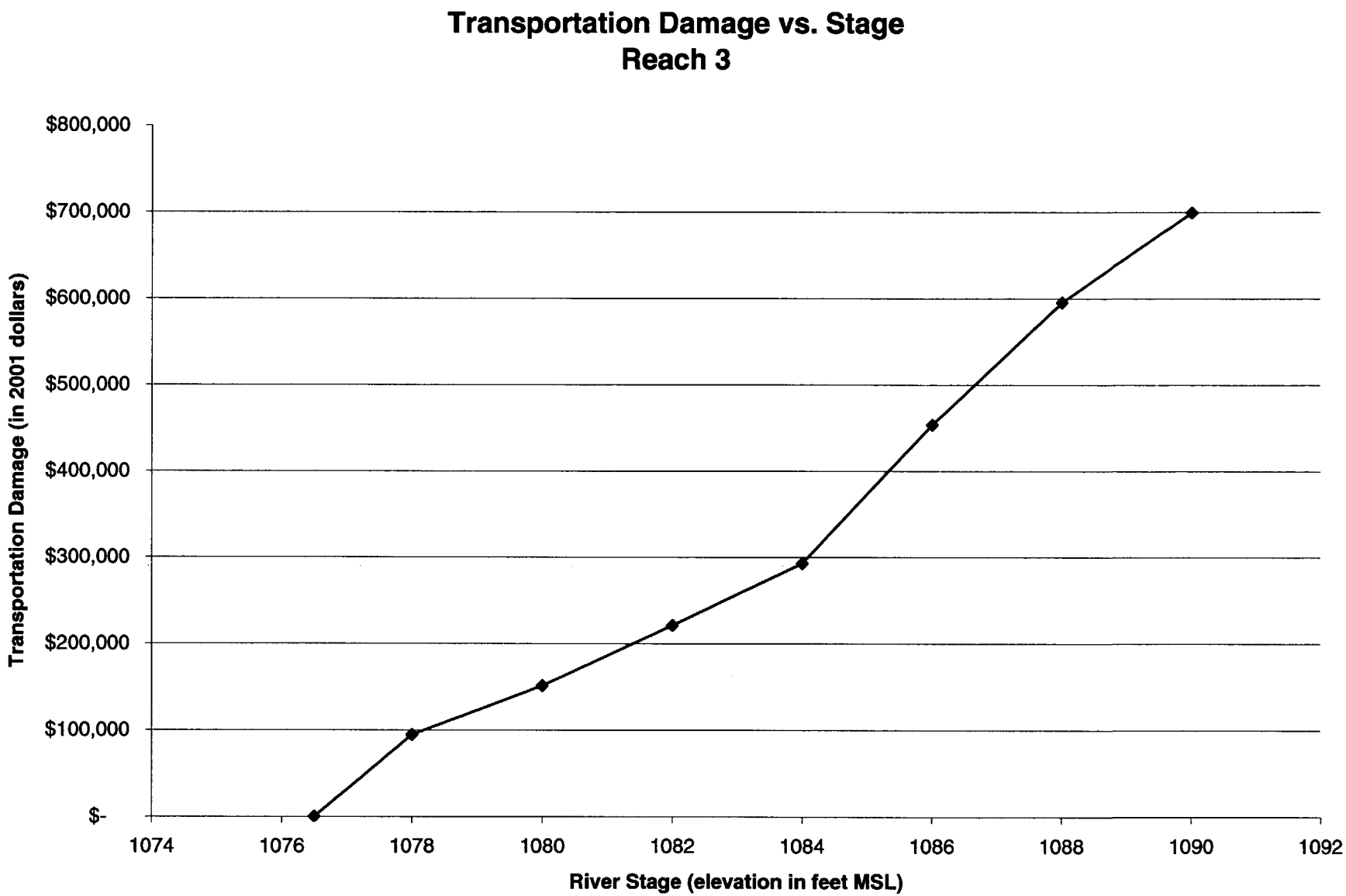

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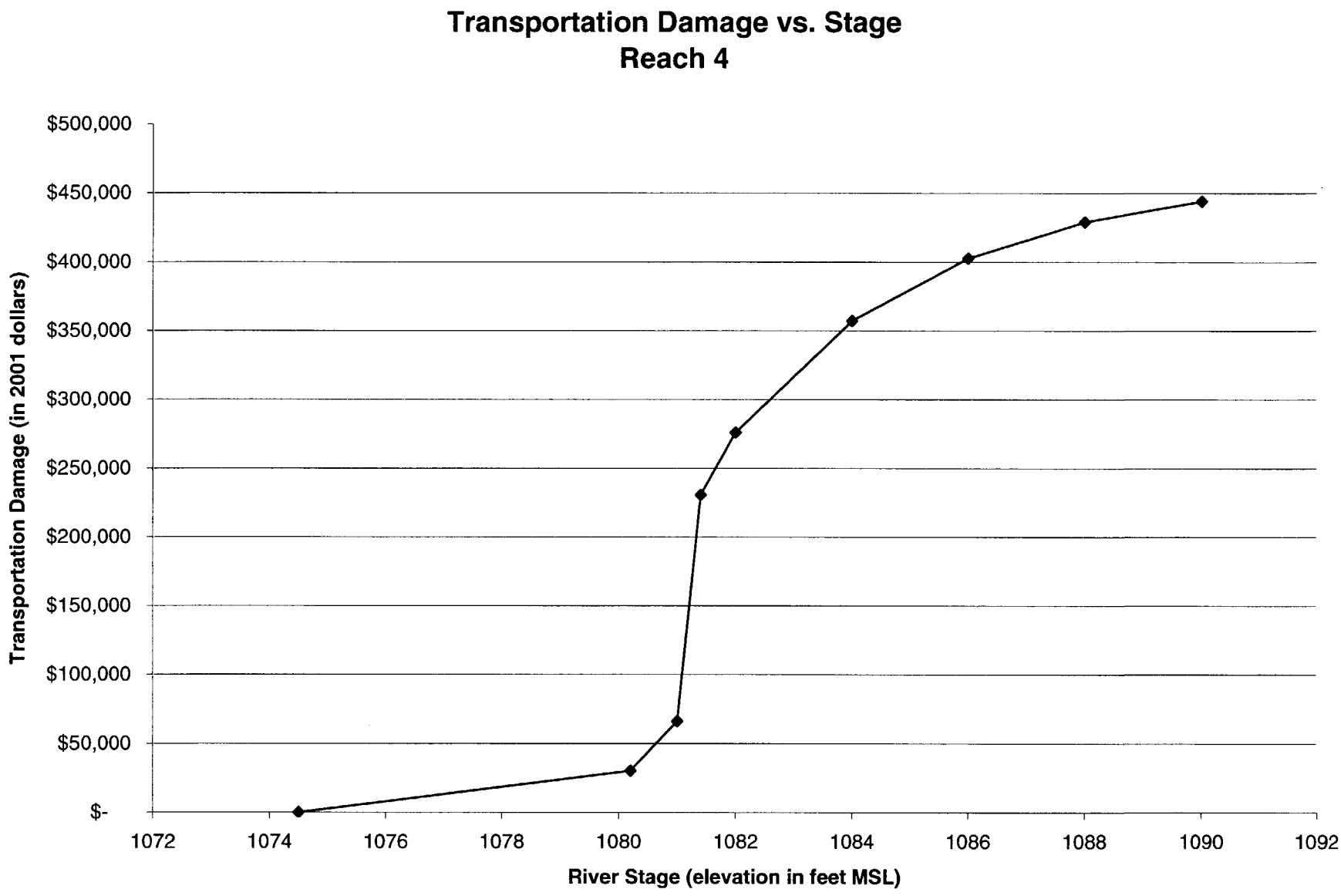

Figure I.D-17

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ESTIMATE OF MITIGATION COSTS FOR THE DEVILS LAKE OUTLET STUDY

Construction and operation of an outlet from Devils Lake would require the development and implementation of a mitigation plan to compensate for unavoidable losses. General geographic areas of potential impact would be: Devils Lake, the Outlet Route, the Sheyenne River, Lake Ashtabula, and the Red River. Investigations to date indicate the greatest potential for significant adverse impacts to natural and cultural resources are associated primarily with increased flows and water quality changes on the Sheyenne River. While detailed studies may identify some impacts in and around Devils Lake or along the Red River, it appears that these impacts may be of such minor magnitude or probability of occurrence, when compared to impacts along the Sheyenne River, as to constitute only a minor percentage of overall mitigation costs. The following provides a preliminary estimate for providing mitigation for losses to Natural and Cultural resources. The following assumptions were made in developing this estimate:

- The outlet design would be a buried pipeline along Peterson Coulee, with water being pumped from the west end of Devils Lake

- Operation of the outlet would not result in a change in the operation plan of Baldhill dam

- The primary downstream area affected would be those areas flooded when the flow on the upper Sheyenne River reach 1000 CFS.

- Operation of an outlet at 480 CFS would have limited effect on the extent or duration of flooded area along the upper Sheyenne River with flows exceeding 1000 CFS.

- Operation of a 480 CFS outlet would have negligible effects on out of bank flows on the Red River.

- The operation of an outlet would have limited effects on the aquatic habitat in Devils Lake.

- Based on limited studies to date, there is a low potential for biota transfer associated with the operation of an outlet and no mitigation, other than monitoring, would be required.

Potential Effects

Natural Resources

Increased flows on the Sheyenne River may result in changes in groundwater levels along the river. This could result in subtle changes in vegetation composition in the riparian corridor.

The operation of an outlet at 480 cfs discharge, unconstrained by channel capacity or water quality, would also increase the frequency of overbank flooding. An analysis of stream gauge information, for the time periods 1944-1998 and 1993-1998, at Warwick and Cooperstown was done in an effort to evaluate potential impacts of a 480 CFS discharge on the frequency and duration of selected flows (100 cfs to 4000 cfs). The analysis indicates potential impacts on the Upper Sheyenne River on the frequency and duration for flows up to 2000 cfs. Greater effects were noticed for the May-November timeframe for 93-98 time period than for the 44-98 time period. The greatest impact appeared to be on the frequency and duration of 1000 cfs flow event. Generally, the effect is to increase the frequency of occurrence by 2.5 times and to extend the duration of flooding by up to a week. The effects on flows of 2000 cfs or greater were negligible.

Based on the analysis of gauge information, the area flooded by the 1000 cfs discharge along the Upper Sheyenne River was used as a basis for estimating mitigation costs. Using digital ortho-quads and the DEM data for those quads, the potential acres inundated at different flow events were calculated. Flows up to 300 cfs were assumed to be contained within the channel in all areas. The acres of wetted area for the 300 cfs was calculated based on an average stream width of 100 feet and calculated for the length of stream from Peterson coulee to Cooperstown (approximately 100 miles). This was subtracted from the wetted area calculated for 1000 cfs, with the result being the number of acres inundated at the 1000 cfs flow event. This is estimated to be about 7,250 acres.

Similar information has not been developed for the lower Sheyenne River (below Baldhill Dam), which has a stream length of about 270 miles. It was assumed that the addition of 480 CFS would have similar effects on inundation in the downstream reaches and that the number of acres inundated would be proportional to stream length. There are several reaches along the lower Sheyenne River where the 2-5 year event is contained within the channel. For the purposes of this evaluation it was assumed to equal about 25% (70 miles) of the stream length of the lower Sheyenne River. Therefore, the number of acres inundated on the lower Sheyenne River was calculated at two times the estimated acres of the upper Sheyenne River (200 miles of river on the lower Sheyenne vs. 100 miles on the Upper Sheyenne), or about 14,500 acres. The total number of acres affected along the Sheyenne River would be about 21,750.

Aside from the induced overbank flooding associated with a 480 cfs discharge, outlet operation would result in substantial changes in aquatic habitat due to increased flows,

changes in channel geometry and water quality changes. The increase in flow would convert most of the habitat along the Sheyenne River to deep pool habitat. Changes in channel geometry and water quality could adversely affect the availability of critical habitat for the life stage requirements of many aquatic species. The effect of all these chronic changes would likely be a reduction the diversity and abundance of aquatic species in the Sheyenne River. Species more tolerant of wider fluctuation in water quality and flow would eventually dominate the system. In the absence of any mitigation measures, the re-establishment of existing species composition could take decades after the operation of the outlet has ceased.

Operation of an outlet at 300 cfs, constrained by water quality and channel capacity considerations, would result in negligible induced overbank flooding along the Sheyenne River. Subtle changes in riparian habitat quality may occur due to loss of bank vegetation associated with the higher flows. The primary effects on the terrestrial and aquatic communities may be slight shifts in species abundance and composition. The effects would likely be more noticeable along the upper Sheyenne River due to the more variable nature of this reach of the river.

Cultural Resources

Increased overbank flooding during storm events and the potential increase in diversity as the vegetation on the bank is lost, could result in an increased potential for the loss of cultural sites located along the Sheyenne River. Because the erosion effects of the increased flow would probably occur gradually, such sites could be protected or removed before they were lost. Based on surveys completed to date, it is estimated that at least 50 sites along the Sheyenne River would be affected by increased erosion associated with the operation of an outlet.

Potential Mitigation Costs

Many of the effects associated with the operation of an outlet cannot be readily quantified. Many of the potential effects involve long-term changes to existing ecosystems and may not be readily noticeable or quantified without extensive monitoring programs. Extensive monitoring programs for Devils Lake and along the Sheyenne and Red rivers are being designed and will be proposed for implementation prior to operation of the outlet. Potential monitoring programs include groundwater monitoring, water quality monitoring, soil salinity monitoring, establishment of long-term survey stations to assess aquatic ecosystem changes, including channel morphology, fish surveys, benthic/nektonic surveys and mussel surveys, and the establishment of vegetation survey transects along the Sheyenne River riparian corridor to monitor vegetation changes, monitoring known cultural sites to determine loss or changes in character due to erosion, and monitoring downstream water users to determine changes in treatment procedures or costs. The estimated annual cost for the monitoring program is $650,000 and a summary of proposed monitoring programs is presented in Table 1. Monitoring costs should be considered as part of the mitigation cost for the project.

The estimated total cost to provide mitigation for natural and cultural resources impacts associated with the operation of 480 cfs discharge outlet is $40.7 million. Estimated mitigation costs for a 300 cfs discharge outlet, constrained by water quality and channel capacity, is $12.9 million. An annual monitoring cost of $650,000 would be required for either alternative. A summary of the Preliminary Estimates for Mitigation costs is presented in Table 2.

Natural Resources

Precise cost estimates for fish and wildlife compensation features associated with the construction and operation of an outlet are not possible without the completion of detailed studies to identify; the type and extent of potential impacts, existing habitat quality, the potential for improving the quality of existing habitat through management and the availability and suitability of separable lands. However, a general guideline that can be used is to estimate mitigation costs is to calculate the acquisition/establishment cost of the replacement habitat on a 2-for-1 basis. This approach is often required on a regulatory level to provide mitigation for losses of wetlands, and would appear to be a reasonable approach for estimating mitigation costs to significant habitats along the Sheyenne River. In reality, the amount of lands required may be somewhat less but the estimated cost will usually reflect that management costs of acquired lands as well. This is the approach used for estimating mitigation costs for effects on terrestrial resources.

For this evaluation, an acquisition cost of $600 per acre was used. This cost reflects current average fee title acquisition costs in the Devils Lake/Sheyenne River basin. It is estimated that the operation of an outlet at 480 cfs discharge, unconstrained by water quality or channel capacity, would affect approximately 21,750 acres. The estimated cost of mitigation for the impacts to terrestrial resources is $26,100,000.

A similar approach for estimating mitigation costs for losses to the aquatic habitat is not appropriate. In the absence of similar guidelines for estimating aquatic mitigation costs, 5% of the total project cost is proposed as a preliminary cost estimate for aquatic mitigation features. At $92,200,000 for a 480 cfs outlet, the aquatic mitigation cost is estimated at $4.6 million. In reality, this may be extremely low. A brief evaluation of selected HREP projects indicates that of the cost/acre to restore or improve aquatic habitat on the Mississippi River is around $14K-$16K. The cost/mile to provide mitigation for the Rochester Flood Control Project was about $40K. While these are not directly applicable to the Sheyenne River, they do demonstrate that the cost of aquatic ecosystem restoration is extremely expensive. (Using the costs cited above, estimated mitigation costs could range from $10,000,000 - $55,000,000).

It is assumed that the operation of an outlet at 300 cfs, constrained by water quality and channel capacity, would have negligible effects on the riparian community corridor. It is assumed that monitoring would still be required to demonstrate that there were no terrestrial impacts occurring while the outlet was in operation. Outlet operation would

still have the potential to result in aquatic impacts, although presumably the impacts would be associated primarily with changes in flow and not water quality. The estimated cost of aquatic mitigation features for this alternative is $2.9 million, or 5% of the total project cost.

Cultural Resources

An estimate for Cultural Resources mitigation was based on the assumption that there are approximately 50 sites along the Sheyenne River that would be susceptible to loss or change in character due to erosion associated with the operation of the outlet. This assumption is the same for either a 480 cfs discharge or 300 cfs discharge outlet operation. Mitigation would be in the form of providing shoreline protection at these sites with riprap. The estimated cost is $10.1 million.

Table 1. Long Term Mitigation Monitoring

Resource	Baseline Information	Why Monitor	What Monitor	When Monitor	Annual Cost
Groundwater	Monitoring near Kindred, Kathryn, Cooperstown, and Sheyenne since 1998. Model of groundwater effects in Sheyenne Delta.	Potential effects to land use	Groundwater monitor wells to reflect changes in river stage and water quality. Monitoring wells	Yearly starting one month before operation starts and ending when influence no longer evident.	$100,000.00
Erosion / Sedimentation	River cross sections taken in past. In 1999, erosion sections established and baseline defined.	Potential effects to land use and aquatic resources	Monitor erosion and sedimentation. Measure loss of river bank and channel cross sections. Survey cross sections.	Every other year.	$100,000.00
Aquatic Habitat	Aquatic habitat cross sections established and baseline established in 1999. Nine representative sections along Sheyenne River.	Effect on physical habitat and aquatic species	Monitor river cross-sections to determine change in physical characteristics. Relate flow to habitat availability. Survey cross sections.	Every other year.	$100,000.00
Aquatic Species Composition	Algae survey 1996-1999. Macroinvertebrate survey 2001, in Sheyenne River, Lake Ashtabula, and Devils Lake. Literature review prepared in 1999. Baseline established.	Biota transfer concerns. Aquatic species composition.	Surveys for fish, invertebrates, algae, and bioassays for diseases. Species identification. Change in species composition and biota transfer from Devils Lake. Survey and literature review.	Every other year.	$50,000.00
Water Quality	Water quality information collected by NDDH, USGS, COE. Baseline established.	Effect on water users and aquatic resources	Monitor TDS and various parameters. Monitor flow and river stage. Surveys, gage data, etc.	Yearly starting one month before operation starts and ending when influence no longer evident.	$100,000.00
Riparian Vegetation	Baseline information consists of 1997 satellite imagery; 1999 partial Ikonos space imaging; DOQs.	Effect on vegetation composition, wetlands, grassland, etc.	Monitor riparian vegetation, wetlands, grassland, etc. for changes in composition and abundance. Aerial photography and/or remote imaging.	Every other year.	$50,000.00
Cultural Resources	Literature review for entire basin and Sheyenne River in 1997; field survey of Peterson Coulee in 1998; survey of potential erosion sites in 2001.	Effect on cultural resources.	Monitor sites to determine loss or changes in character due to erosion, inundation, or water quality. Monitor selected sites and conduct surveys.	Every other year.	$25,000.00
Soil Salinity	Baseline information consists of soil survey, SURGO, MUIR, etc.	Effect of alternatives on soil salinity and land uses	Monitor land use changes. User surveys, NRCS surveys, etc.	Every other year.	$25,000.00
Surface Water Users	Downstream Water Users Survey in 1997.	Effect of water quality changes on water users and uses.	Survey users to determine changes in treatment procedures or costs. User surveys.	Yearly starting one month before operation starts and ending when influence no longer evident.	$50,000.00
Sheyenne Delta Vegetation	Baseline information on species of special concern conducted in 2001. Location, species, abundance, etc.	Effect of changed river stages and water quality on unique vegetation.	Monitor sites to determine changes in composition or abundance. Monitor sites and vegetation surveys.	Every other year.	$50,000.00

Table 2. PRELIMINARY ESTIMATE OF MITIGATION COSTS

Mitigation Estimates - Peterson Coulee Alternative

ITEM	300 cfs proposal	480 cfs proposal
Project Total Cost	$58 Million	$92 Million
Estimated Mitigation Costs		
Cultural Resources	$10 million	$10 million
Vegetation/Wildlife/Wetland Resources	None, assume flow within channel	$26.1 million
Aquatic Resources	$2.9 million	$4.6 million
TOTAL COST	**$12.9 million**	**$40.7 million**
Monitoring	$650,000 annually	$650,000 annually

Note: all costs are first cost unless noted as annual; see narrative for additional discussion

- cultural costs based on erosion protection per typical site with construction assumptions; no specific site information available
- vegetation/wildlife/wetland cost based on twice the average fee title land value for acquisition and management of inundated area
- aquatic resource mitigation based on 5 percent of the projects first cost
- monitoring costs based on long-term resource monitoring after project is operational; see attached monitoring table

Tolna Coulee Outlet Erosion

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Appendix A Whartman Memo: Erosion of Tolna Coulee; June 5, 2001

Appendix B Tolna Coulee Soils Data – Murphy and Fritz, May 1997

1.0 Introduction

On May 17, 2001, the Corps requested that Contract Number DACW37-01-C-0008 regarding the re-evaluation of alternatives for Devils Lake be modified to include the evaluation of the expected erosion in the natural outlet of the combined Devils–Stump Lakes. This natural outlet is to the Sheyenne River via Tolna Coulee. As part of the study:

- The existing soils studies were to be reviewed.
- The Corps previous Tolna Coulee erosion estimates and methodologies were to be reviewed.
- The North Dakota United States Geological Survey (ND USGS) staff were to be contacted to determine an appropriate means to provide changing outlet rating curves.
- Outlet erosion was to be estimated and outlet rating curves were to be prepared for various erosion conditions.
- An economic analysis of impacts around the lakes and downstream impacts for three alternatives was to be completed using “Wet Future Trace” conditions.

This report presents the results of the erosion analysis.

2.0 Previous Investigations

2.1 Background

The natural outlet for the combined Devils–Stump Lake is to the Sheyenne River via Tolna Coulee. The overflow point is located in a broad, relatively flat marshy area that is about 300 feet wide and about 2,000 feet long. The overflow point is at Elevation 1459.1 based on 1986 Corps surveys. Immediately upstream and downstream of this broad marshy area the topography drops off comparatively fast to Elevation 1450. The total length along the Coulee above Elevation 1450 is about 4,000 feet. Figures 1 and 2 show the thalweg profile of Tolna Coulee. The overflow point is located about 75,000 feet above the mouth of Tolna Coulee. The overflow point (Elevation 1459.1) is about 100 feet above the thalweg of the Sheyenne River (Elevation 1360) at the mouth of Tolna Coulee. The average slope between the overflow point and the mouth is about 6.3 feet per mile, or approximately 0.1%. Many reaches of the Coulee are much steeper, as shown on Figures 1 and 2.

2.2 Previous Soil Investigations and Pertinent Conclusions

The Tolna Coulee outlet soils were previously investigated in 1997 and the results are presented in the report titled "Recent Sedimentation in the Jerusalem and Tolna Outlets, Devils Lake Basin." This report contains the best available information on soil types in the outlet. Since the report addresses another subject (sedimentation and historic overflows), the erodibility of the soils must be interpreted from basic information presented in the report.

The investigation included two test trenches and three borings all to a depth of about 18 feet. The trenches and borings are located in a 200 feet by 100 feet portion of the broad marshy overflow area. The report indicates about 20 feet of stratified combinations of silt, clay, sand, gravel, and paleosols overlie glacial till and outwash. The report and subsequent conversations with the author indicate that the test trench walls were fairly stable to a depth of 12 feet and sufficiently stable to allow excavation to 20 feet. Also, the inflow of groundwater into the test trench was quite slow.

Based on this investigation, the soils apparently do not pipe readily when excavated below the water table. Soils that have this characteristic tend to erode rapidly when scour cuts below the water table. It seems likely that a channel that erodes below the water table will be unstable and will slough into the channel resulting in a wide shallow cross section.

Various past investigations have characterized the soils as mildly to highly erodible. Additional soils information is presented in Appendices A and B.

2.3 Previous Hydraulic Investigations

During 1997, the Corps developed a rating curve for the Stump–Devils Lake outlet by performing a HEC-2 analysis of Tolna Coulee. The results of this analysis by the Corps are presented in a September 10, 1997, memo prepared by James Muegge. The developed rating curve for the outlet (named Sections 30 and 33 in the HEC-2 model) is presented as Figure 3. This analysis was based on existing conditions and does not include the impact of significant erosion.

During May 1999, Corps staff prepared a preliminary analysis of the erosion of the broad marshy area that controls the outlet from Stump Lake. This analysis was done for the standard project flood (SPF) and was performed using the HEC-RAS hydraulic model. The SPF peak discharge was about 6,500 cfs with a no erosion assumption. In this study, sediment transport rates were estimated using the methods proposed by Colby[1]. The results of the analysis indicated that the broad wide channel outlet control would erode in five to six months under SPF conditions. This erosion greatly increased the SPF peak discharge (to about 12,000 cfs), but only slightly reduced (by 0.2 feet) the SPF peak stage for Devils–Stump Lake, although the duration of flooding above Elevation 1952 was reduced by years.

---

[1] Colby, B. R., The Relationship of Sediment Discharge to Streamflow, U.S. Geological Survey Open File Report, 1955.

3.0 Outlet Erosion

3.1 Approach

The objective of the present study is to develop a series of rating curves for various progressive stages of the eroding Tolna Coulee outlet channel, and to develop a basis for transitioning between these rating curves. This information will be used by the North Dakota United States Geological Survey (ND-USGS) staff to refine their Devils Lake hydrologic model to incorporate the effects of Tolna Coulee erosion. Outlet erosion prediction is presented in this section. Section 4 presents the discharge rating curve development.

For determining the outlet channel erosion, there were two main tasks. The first task was to estimate the width and vertical alignment of progressive eroded coulee channels. The second task was to estimate sediment transport rates.

The erosion was subdivided into three phases. The initial erosion phase (see Section 3.2) will occur downstream of the outlet control point located at 74,950 feet above the mouth. The next phase or secondary erosion phase is when the overflow control point itself erodes. This is explained in greater detail in the Section 3.3. A final erosion phase was also considered; this phase would result from the ultimate stabilization of the upper coulee, and is described in Section 3.4.

3.2 Initial Erosion

Review of the Tolna Coulee profile and soils data indicated that initial significant erosion will likely start at the downstream end of the broad marshy overflow reach. This point of initial erosion is about 73,100 feet above the mouth of Tolna Coulee. Immediately downstream of this point (between about 68,500 and 73,100 feet above the mouth) is a relatively steep reach. Downstream of the steep reach is an essentially flat reach, which is located between about 61,000 and 68,500 feet above the mouth. It was assumed that the first impact to the outlet rating curve would come from erosion of this steep reach more than 68,500 feet above the mouth (see Figure 4).

For the initial erosion phase, the channel was assumed to erode until a trapezoidal channel of uniform gradient 150 feet wide with 1½ H to 1 V sideslope had developed between the overflow control point at 74,950 feet above the mouth in the upstream end of the flat reach (68,560 feet above the mouth).

The width of 150 feet was used because a channel of this width flowing at normal depth has about the same rating curve as computed for the existing condition in the Corpss' 1997 study.

The volume of the eroded material was computed using the survey information obtained by the Corps in 1986. This volume was computed using the average end area method.

3.3 Secondary Erosion

The secondary erosion phase begins upon completion of the initial erosion phase. For this secondary erosion phase, it was assumed that this upper coulee channel would progressively flatten to a slope of about 4.3 feet per mile, and the outlet control point would slowly be eroded away until it reached an existing ground point at Elevation 1450.8 and 76,250 feet above the mouth. This final slope was chosen because it is about the same as the slope of the relatively flat reach located between 61,000 and 68,500 feet above the mouth (see Figure 4).

The secondary erosion phase was divided into seven separate progressively flatter eroded channel steps that were selected based on the survey data and for computational convenience. These steps are for when the upstream channel invert has eroded to Elevation 1458, 1457, 1455.9, 1454, 1453, and 1451.9. The eroded volumes were computed as described above. The total volume of initial and secondary erosion is about 150,000 cubic yards. A summary of the eroded volumes is presented in Table 1.

3.4 Ultimate Erosion

The average thalweg slope for the entire coulee is 6.29 feet per mile. For the ultimate erosion condition, it was assumed that the upper coulee would continue to flatten (see Figure 4). It was assumed that this additional erosion would occur upstream of a point about 47,240 feet above the mouth. It was assumed that the channel invert would be a uniform grade of about 6.6 feet per mile, which is just slightly steeper than the average channel slope. With these assumptions, the total channel erosion would be approximately 940,000 cubic yards.

3.5 Sediment Concentration Estimate

Little research has been done on sediment transport in channels with primarily cohesive soils similar to those found in the Tolna Coulee. However, a review of the research on sediment transport in non-

cohesive channels was conducted for this report, with the expectation that the findings would have at least some application to Tolna Coulee.

Researchers have found that sediment transport is a function of depth, channel width, channel velocity, hydraulic radius, and velocity. Campbell and Bauder (1940) observed that the relation between the logarithm of sediment concentration and the logarithm of discharge was approximately linear. They suggested that this relationship could be used as a type of "rating curve" for sediment discharge estimates when discharge information is available.

Although the sediment rating curve remains an empirical result without direct physical justification, it has come into widespread use. It appears to be adequate for many purposes (Miller, 1951; Colby, 1955). The rating curve is simple and lends itself to the iterative nature of the process of determining the outflow of Devils Lake to an eroding Tolna Coulee. Computationally, it is also very convenient. This approach is also very similar to the approach used in the Corps' 1999 SPF analysis.

The historic sediment concentration measurements and discharge for selected North Dakota streams was reviewed. This data is presented in Figures 5 and 6. Based on review of this data, it is recommended that the average sediment concentration in the Devils Lake outflow in parts per million (ppm) be assumed to equal 20% of the mean daily discharge in cfs, except the sediment concentration should not exceed 400 ppm. For example, when the mean daily discharge is 100 cfs, the sediment concentration should be assumed to be equal to 20 ppm. This linear relationship was used because the more complex exponential relationship between sediment concentration and discharge was not likely to improve the quality of the estimates.

The assumptions regarding sediment capacity for the flows in Tolna Coulee were provided to ND-USGS staff for incorporation into their 6-Box modeling of Devils Lake and its outflows. Using this sediment concentration estimate method along with the ND-USGS hydrologic model, the cumulative volume of erosion can be computed. This cumulative volume can then be used to determine when to shift from one discharge rating curve to the next (see Table 1). The development of the rating curves is described in the following section of this report.

4.0 Discharge Rating Curves

4.1 Discharge Rating Curve Development

A set of rating curves for the Stump Lake outflow was developed by estimating flow rates in uniformly sloped channels. Rating curves were developed assuming normal flow in a channel that is 150 feet wide with sideslopes of 1.5 horizontal to 1 vertical. The slope of the energy grade line was assumed to be the slope of the channel invert, which varied depending on the erosion scenario under consideration. The normal flow discharge was estimated using Manning's equation, and assuming a Manning's "n" of 0.03. The Stump Lake water surface elevation was computed by summing the upstream channel invert elevation and the specific energy. The resulting rating curves are presented in Tables 2 through 9.

This information was also supplied to ND-USGS staff for incorporation into their hydrologic model. The discharge rating curves, along with the sediment transport estimates, allowed the staff to model the overflow from Stump Lake when it is assumed that no erosion protection is provided at the natural outlet.

These multiple curves were used for the initial run in the USGS model. Results from the initial run were smoothed to produce a composite rating curve, which was used for the final analysis. The analyses were bracketed using moderate and high erosion rate assumptions. In both cases, the outlet eroded quickly (within 2 years) down to 1450.8, at which the stable rating curve is reached.

Bibliography

Campbell, F. B. and Bauder, H.A., A Rating-Curve Method for Determining Silt-Discharge of Streams, EOS (Trans. Am. Geophys. Union), 21, 603-607, 1940.

Colby, B. R., The Relationship of Sediment Discharge to Streamflow, U.S. Geological Survey Open File Report, 1955.

Miller, C.R., Analysis of Flow-Duration, Sediment-Rating Curve Method of Computing Sediment Yield, U.S. Bureau of Reclamation, 1951.

Table 1

EROSION VOLUME SUMMARY		
Erosion Phase	**Cumulative Erosion Volume (cubic yards)**	**Rating Curve for this Phase**
Existing Conditions	0	Existing Conditions
Initial Erosion	15,949	Existing Conditions
Secondary to 1458	27,842	Initial
Secondary to 1457	40,657	Secondary - 1458
Secondary to 1455.7	67,130	Secondary - 1457
Secondary to 1455	78,271	Secondary - 1455.7
Secondary to 1454	96,075	Secondary - 1455
Secondary to 1453	114,539	Secondary - 1454
Secondary to 1451.9	150,505	Secondary - 1453
Upstream Stabilized	937,140	Stable - Secondary
Ultimate	Greater than 937,140	Ultimate

Table 2

Initial Rating Curve	
Assumed channel invert at Stump Lake	1459.1
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.00205 or 10.82 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1459.10
107	1459.63
340	1460.18
672	1460.73
1,089	1461.30
1,587	1461.86
2,160	1462.44
2,804	1463.01
3,518	1463.57
4,299	1464.18
5,145	1464.76
6,056	1465.35
7,030	1465.94

Table 3

Secondary — 1458 Rating Curve	
Assumed channel invert at Stump Lake	1458.0
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.001878 or 9.92 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1458.00
102	1458.53
326	1459.07
643	1459.62
1,043	1460.18
1,519	1460.74
2,067	1461.31
2,684	1461.88
3,367	1462.45
4,114	1463.03
4,925	1463.61
5,796	1464.19
6,729	1464.77

Table 4

Secondary — 1457 Rating Curve	
Assumed channel invert at Stump Lake	1457.0
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.00172 or 9.09 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1457.00
98	1457.53
312	1458.07
615	1458.61
998	1459.17
1,454	1459.72
1,979	1460.28
2,570	1460.85
3,224	1461.41
3,939	1461.98
4,715	1462.56
5,550	1463.13
6,442	1463.71

Table 5

Secondary — 1455.7 Rating Curve	
Assumed channel invert at Stump Lake	1455.7
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.00145 or 7.66 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1455.70
90	1456.22
285	1456.76
585	1457.29
916	1457.84
1,335	1458.39
1,816	1459.49
2,358	1459.49
2,958	1460.05
3,615	1460.61
4,327	1461.17
5,093	1461.73
5,912	1462.30

Table 6

Secondary — 1454 Rating Curve	
Assumed channel invert at Stump Lake	1454.0
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.00120 or 6.31 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1454.00
81	1454.52
260	1455.05
513	1455.58
832	1456.11
1,212	1456.65
1,649	1457.20
2,142	1457.74
2,687	1458.29
3,283	1458.84
3,930	1459.39
4,625	1459.94
5,369	1460.49

Table 7

Secondary — 1453 Rating Curve	
Assumed channel invert at Stump Lake	1453.0
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.001046 or 5.52 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1453.00
76	1453.52
243	1454.04
480	1454.57
778	1455.10
1,134	1455.64
1,543	1456.17
2,003	1456.71
2,513	1457.25
3,071	1457.79
3,676	1458.34
4,327	1458.88
5,023	1459.43

Table 8

Secondary — 1451.9 (Final/Stable) Rating Curve	
Assumed channel invert at Stump Lake	1451.9
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.000821 or 4.33 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1451.90
68	1452.41
215	1452.93
425	1453.45
689	1453.98
1,004	1454.51
1,366	1455.03
1,774	1455.57
2,226	1456.10
2,720	1456.63
3,255	1457.17
3,832	1457.70
4,448	1458.24

Table 9

Ultimate Rating Curve	
Assumed channel invert at Stump Lake	1450.8
Assumed channel bottom width	150 feet
Assumed channel sideslopes	1.5 H to 1 1V
Assumed Mannings "n"	0.03
Channel invert (EGL) slope	0.001136 or 6.00 feet/mile
Discharge (cfs)	**Stump Lake Elevation**
0	1450.80
83	1451.32
265	1451.85
523	1452.38
849	1452.92
1,236	1453.46
1,683	1454.00
2,185	1454.55
2,741	1455.10
3,349	1455.65
4,009	1456.20
4,718	1456.76
5,477	1457.31

Figures

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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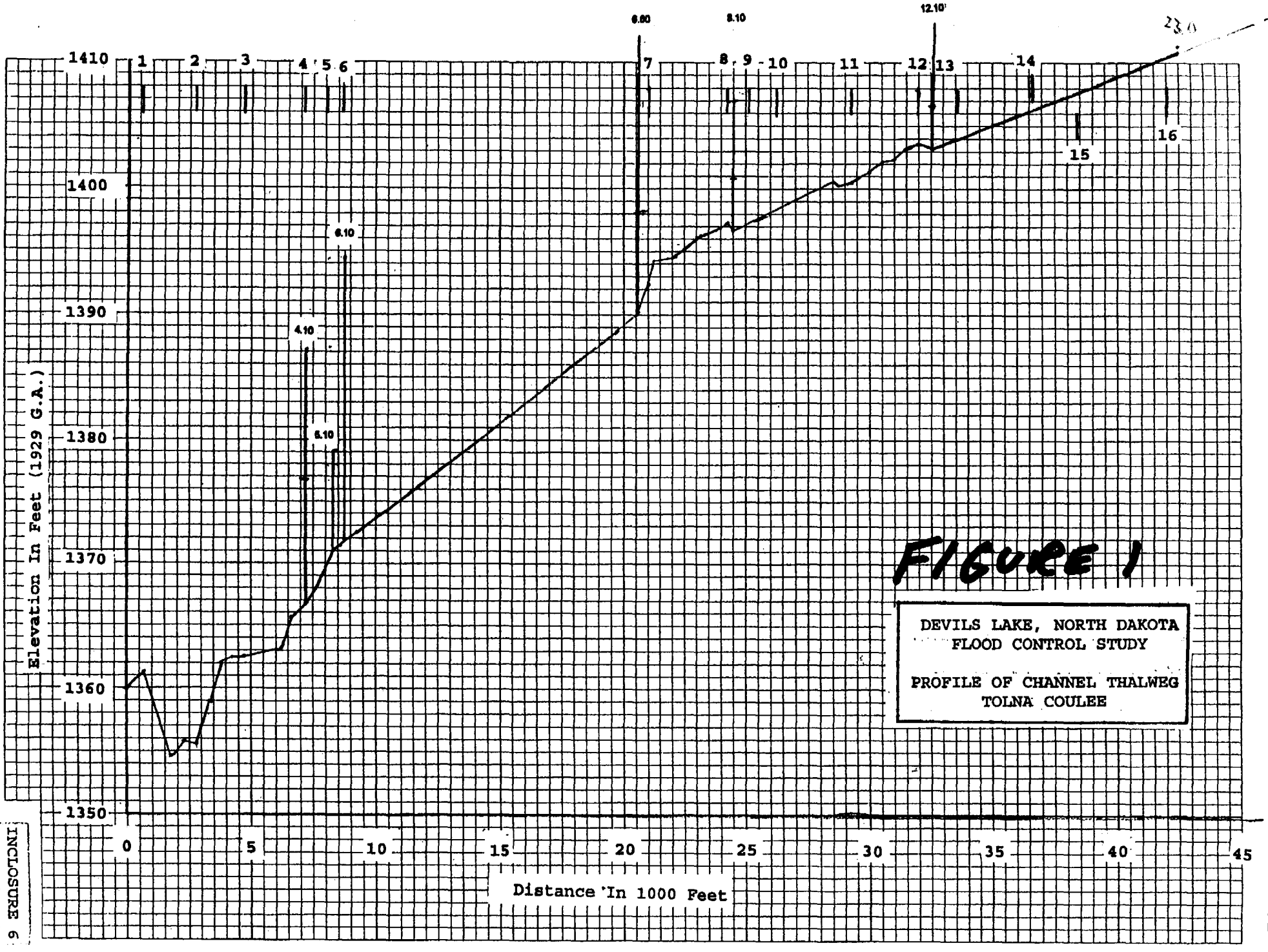

FIGURE 1

DEVILS LAKE, NORTH DAKOTA
FLOOD CONTROL STUDY

PROFILE OF CHANNEL THALWEG
TOLNA COULEE

INCLOSURE 6

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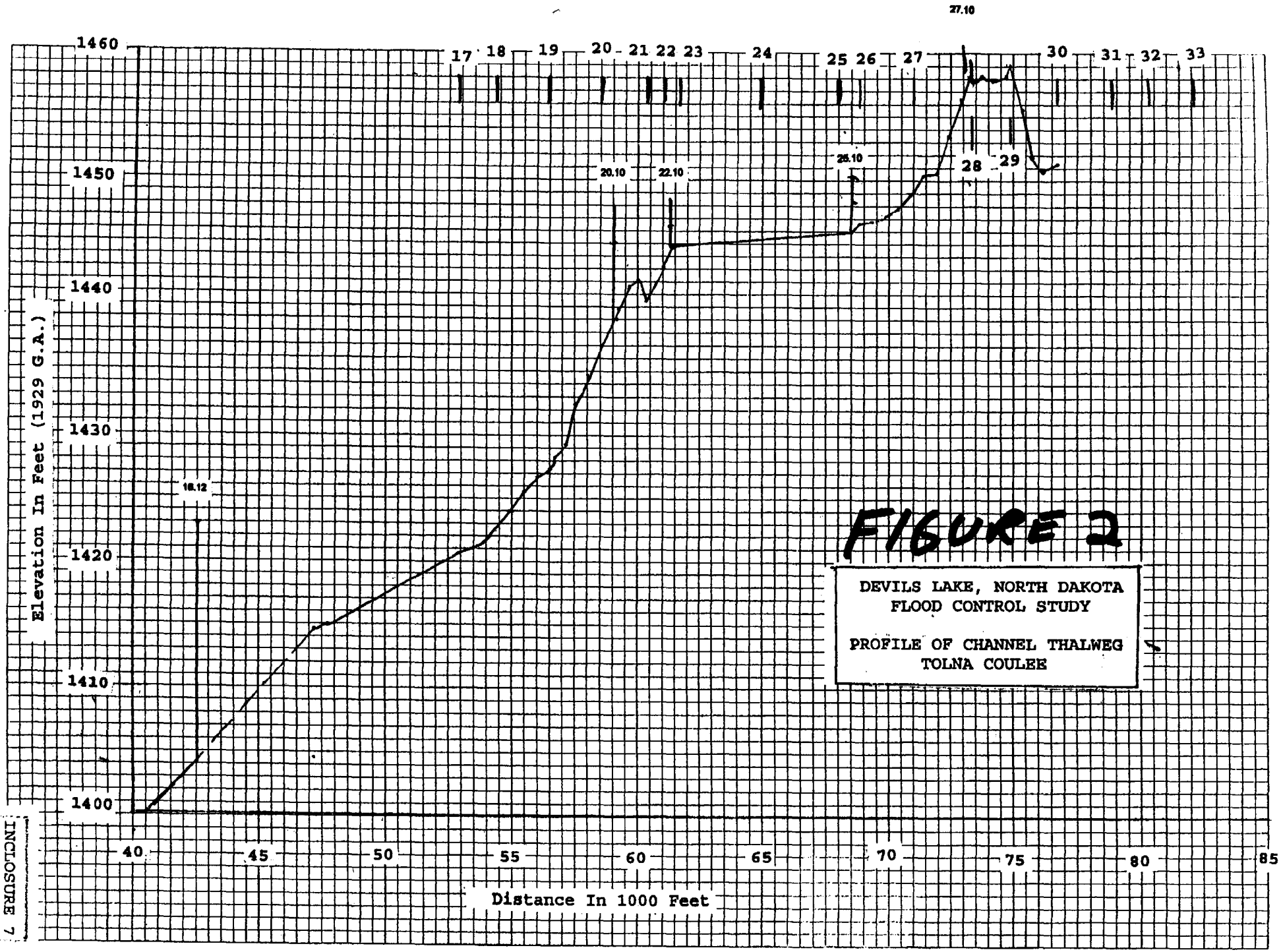
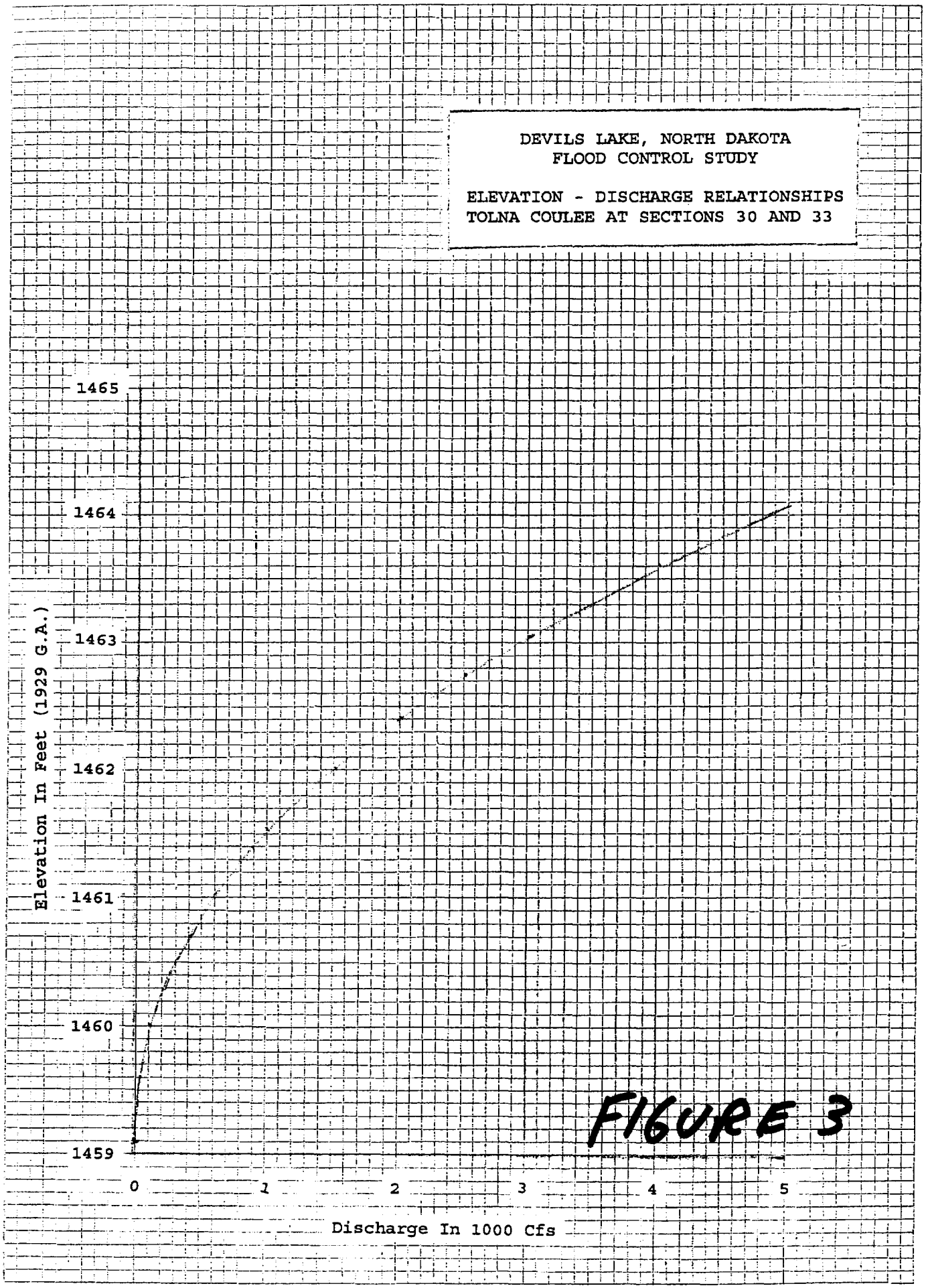


FIGURE 2

DEVILS LAKE, NORTH DAKOTA
FLOOD CONTROL STUDY

PROFILE OF CHANNEL THALWEG
TOLNA COULEE

INCLOSURE 7



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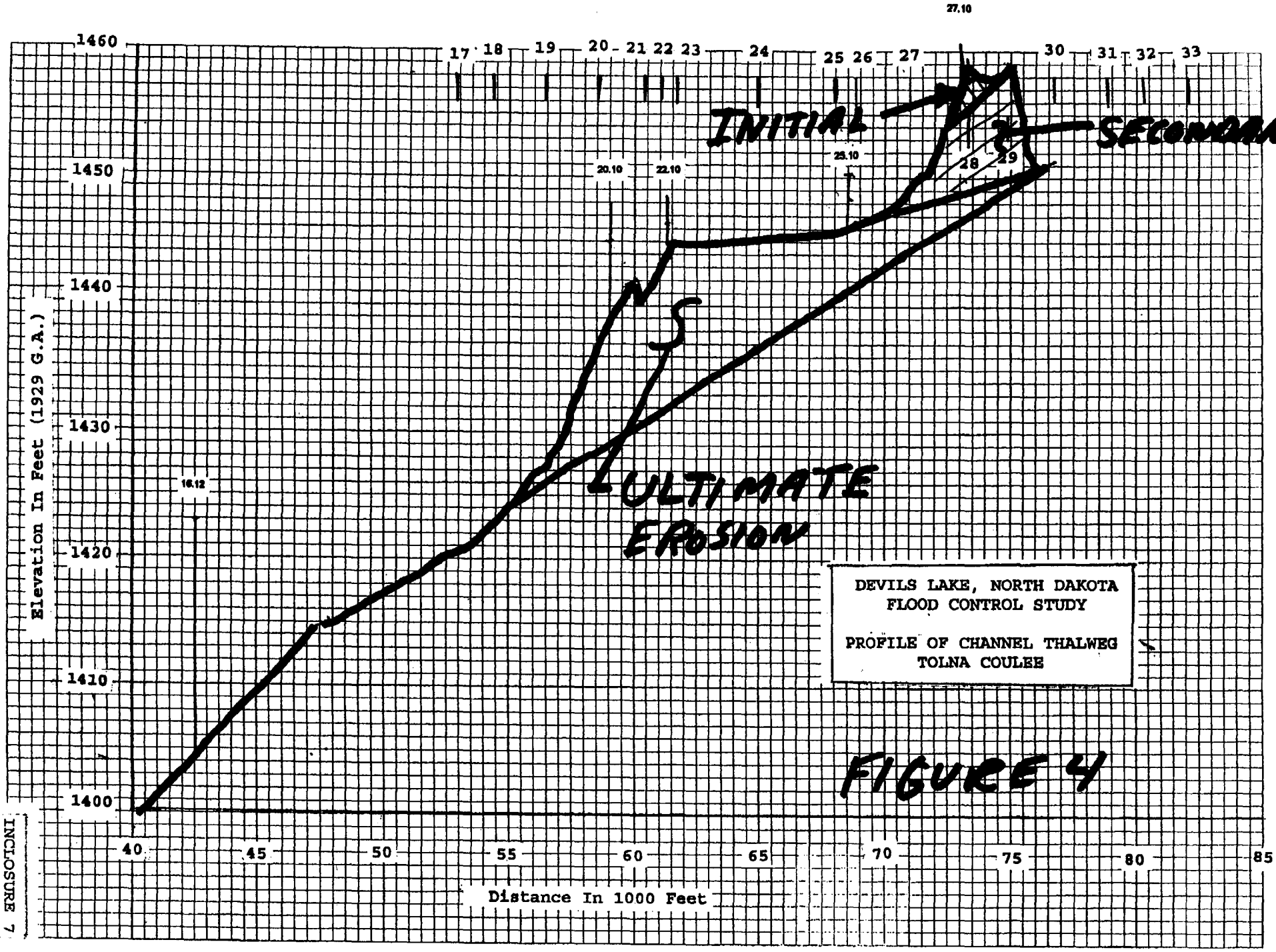

DEVILS LAKE, NORTH DAKOTA
FLOOD CONTROL STUDY

PROFILE OF CHANNEL THALWEG
TOLNA COULEE

FIGURE 4

INCLOSURE 7

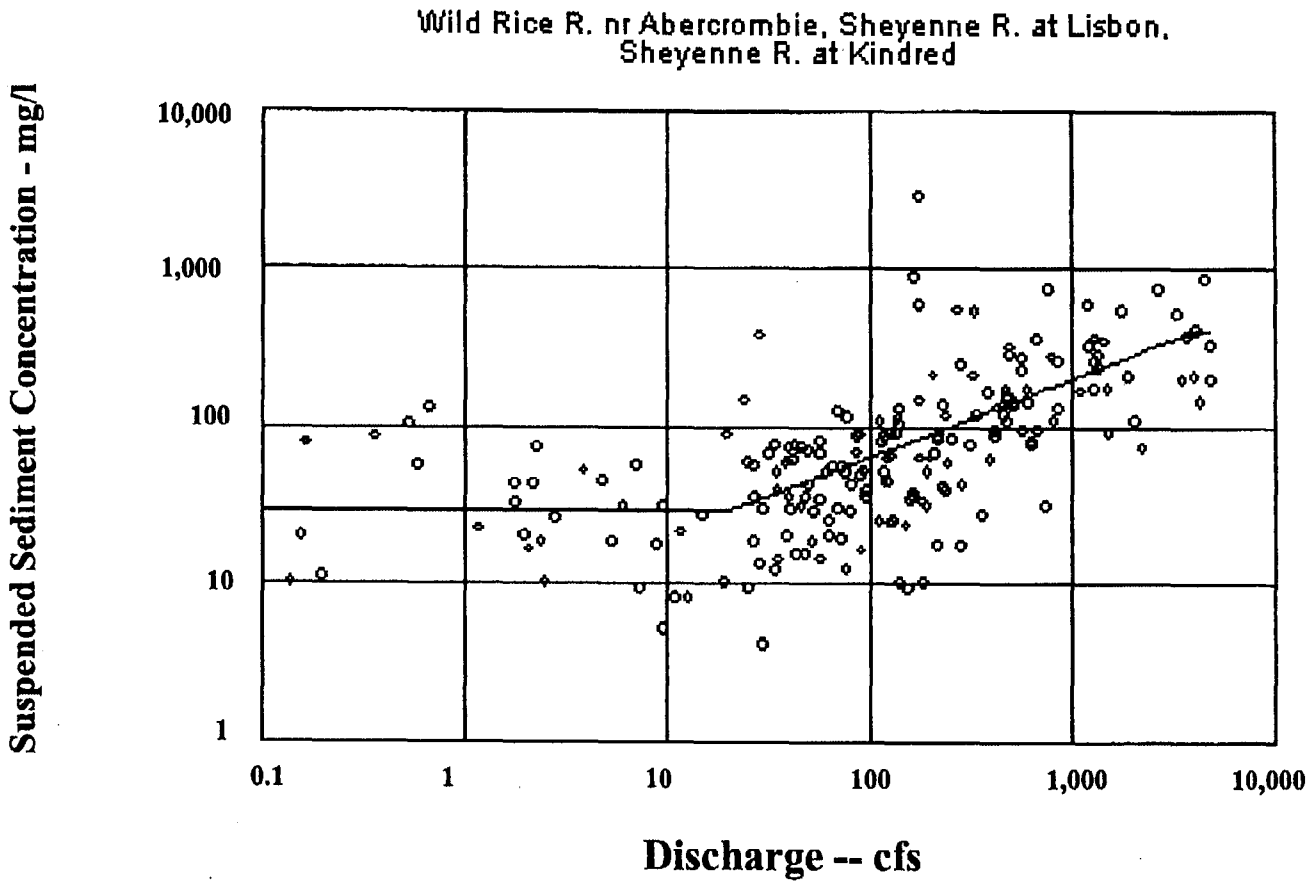
Wild Rice R. nr Abercrombie, Sheyenne R. at Lisbon,
Sheyenne R. at Kindred
Suspended Sediment Concentration - mg/l
10,000
1,000
100
10
1
0.1
1
10
100
1,000
10,000
Discharge -- cfs

Figure 5

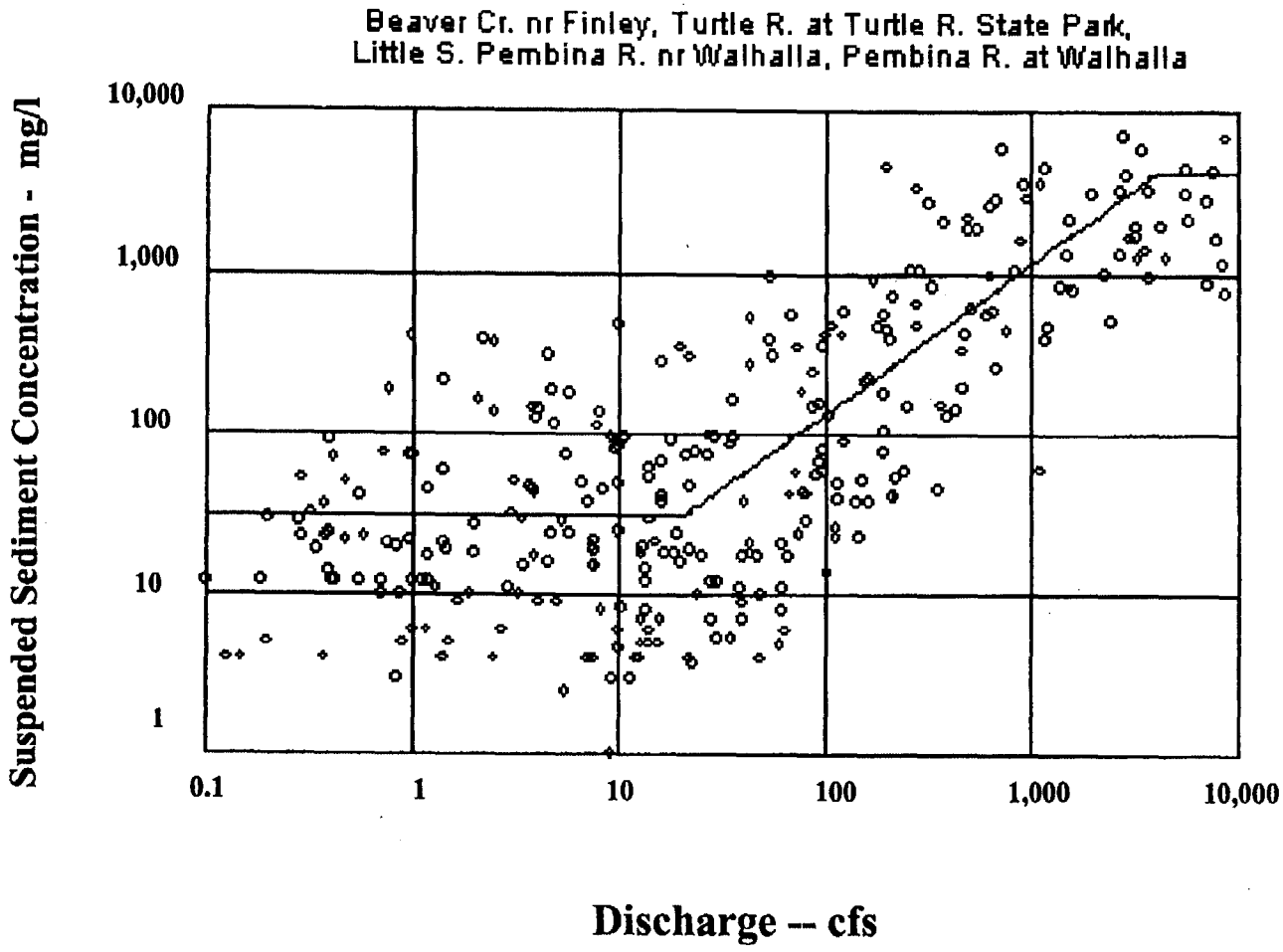
Beaver Cr. nr Finley, Turtle R. at Turtle R. State Park,
Little S. Pembina R. nr Walhalla, Pembina R. at Walhalla
Suspended Sediment Concentration - mg/l
10,000
1,000
100
10
1
0.1
1
10
100
1,000
10,000
Discharge -- cfs

Figure 6

Appendix A

BARR

Internal Memorandum

To: Al Fandrey

From: Robert Whartman

Subject: Erosion of Tolna Coulee Outlet from Stump Lake, North Dakota

Date: June 5, 2001

Project: 34/36-016

1.0 Introduction

In compliance with your request to assist in evaluating erosion that may occur from sustained discharge of 500 CFS in the Tolna Coulee outlet from Stump Lake, North Dakota, I have completed the following tasks.

a. Reviewed the report titled "Recent Sedimentation in the Jerusalem and Tolna Outlets, Devils Lake Basin" by Edward C. Murphy and Ann M. K. Fritz, a one-foot contour map of the area, and U.S.G.S. quadrangle maps.

b. Talked by phone with the following persons:

Terry Jorgenson - Corps of Engineers

Tim Fay - North Dakota State Water Commission

Bruce Inglehart - North Dakota State Water Commission

Edward Murphy - North Dakota State Geological Survey

The accompanying study notes outline my observations and my understanding of the conversations. The notes are brief and may need some additional explanation that I can provide upon request. The following paragraphs summarize my impression of the erosion situation based on the tasks performed. Some field investigation will be necessary to make more definite conclusions.

I will be pleased to answer any questions or provide additional information. The best way to reach me is through Barr's e-mail or at my home phone (651) 777-5211.

2.0 Previous Studies

The Corps of Engineers performed an evaluation of erosion in the outlet based on a discharge of 12000 CFS and concluded that the outlet would suffer about 7 feet of erosion in 3 to 4 months. The North Dakota State Water Commission evaluated the outlet for a total discharge of 2,000,000 acre feet and concluded that it would be eroded quite rapidly to Elevation 1447, or about 13 feet below the present ground surface.

3.0 Considerations for Predicting Erosion at the Outlet

My thoughts on some factors that will impact erosion of the outlet are presented briefly below.

a. The water discharging from Stump Lake will be nearly sediment free and will have a high capacity to carry additional suspended load.

b. The velocity of the discharge water will depend on whether it spreads out or is channelized. In this regard, I believe that no well developed channels presently exist and will have to be formed by the discharge.

c. The outlet floor is nearly planar and well vegetated so that headward erosion would likely have to start at the extreme downstream end of the 3000-foot-long high area that forms a low drainage divide at the outlet.

d. The dikes that exist in the outlet may act as small dams and release an additional surcharge of water if breached.

e. The erodibilty of the soils is extremely important. The soils are discussed in paragraph 4.0.

4.0 Erodibility of the Soils

The best information on soil types in the outlet is the report on sedimentation by Murphy and Fritz. Since the report addressed another subject, the erodibility of the soils must be interpreted from basic information presented. About 20 feet of stratified combinations of silt, clay, sand and gravel, and paleosols overlie glacial till and outwash. The area is marshy with a high water table. The report and conversation with Edward Murphy indicated that excavated trench walls were fairly stable to a depth of twelve feet and sufficiently stable to allow excavation to 20 feet. Also, the inflow of water was quite slow.

The soils apparently do not pipe readily when excavated below the water table. Soils that have this characteristic erode rapidly when scour cuts below the water table. Based on the behavior of the soils in the test trenches, I think that erosion of the site soils will not be severely aggravated by uplift and piping. I believe, however, that the channel side slopes will be unstable and slough resulting in channel widening. Thus, an eroded channel would have a wider, shallower cross section than if the material stood well with steep side slopes.

If one rates the erodibility for materials on a scale of 1 to 10 with 10 being the worst possible case, say a saturated loose silt, I would estimate the site soils to fall between 6.0 and 7.0.

TOLNA COULEE OUTLET EROSION

STUDY NOTES

R. L. WHARTMAN

(May 29 to June 5, 2001)

1.0 Nature of Project

Talked with Al Fandrey, May 29, 2001.

Corps has contracted with Barr Engineering to do an evaluation of possible erosion in the Tolna Coulee outlet to the Sheyenne River due to overflows from Devils Lake through Stump Lake, North Dakota.

Barr has to come up with estimated erosion and rating curves for Tolna Coulee outlet.

Corps evaluated the erosion problem for the Standard Project Flood (12,000 CFS Discharge). They concluded that a 3000-foot-long high reach would suffer about 7 feet of erosion in 3 to 4 months.

The discharge Barr is to study is 500 CFS.

Al requested that I try to get a feel for the soil types in the coulee by talking with persons associated with the project. He also sent a 1-ft contour map of the coulee, a report titled "Recent Sedimentation in the Jerusalem and Tolna Outlets, Devils Lake Basin" by Edward C Murphy and Ann M. K. Fritz, North Dakota Geological Survey, and USGS quadrangle maps of the area.

2.0 Notes From the Sedimentation Report

Page iii - One foot of sedimentation in last 100 years.

Page 5 - 15 to 20 feet of channel fill consisting of peat, clay, silt, sand, and gravel.

Channel fill is underlain by till and outwash sand capped by lag deposits.

Peat on top of lag deposits - 8700 to 8900 years Before Present (BP).

Page 15 - Two major flood events between 7820 and 8740 BP.

At least 2 more flood events occurred during the next 400 years (7820 to 7380).

Page 16- top foot deposited in last 100 years.

Page 19 - Sediments indicate 6 times in 10,000 years water has flowed from Devils Lake to the Sheyenne River.

Two major events 7820 to 8740.

Two more in next 440 years 7380 to 7830.

One more prior to 1080.

No fluvial events in last 1,100 years.

Little is known of period from 3000 to 7000 BP

3.0 One-Foot Contour Map

Outlet has a slightly flared shape - narrow at the outlet and becoming wider downstream.

Two dikes or roads bound a "marshy" area at the outlet.

No channel is evident on map.

Coulee has low gradient with flat floor - this is good in that "knick point" erosion appears unlikely near the Stump Lake end of the outlet.

4.0 Conversation with Terry Jorgenson (C of E) - May 30, 2001

(651) 290-5598

The Corps assumed the soils were alluvial and colluvial fine-grained soils for their analysis. The materials portion of the analysis was extremely cursory.

5.0 Conversation with Tm Fay (Nd St. Water Comm.) - May 31, 2001

(701) 328-4956

No detailed soils information is known to exist.

The "roads" on the 1-ft topog are not roads but are low dikes.

The east dike has a gap at the south end through which water could spill and erode from a pool formed behind the dike.

He considers the soils highly erodible.

They surveyed the area and probably have additional information.

They can send a survey crew out to get more information.

He believes the coulee has no channel but is "flat floored".

6.0 Conversation with Bruce Inglehart (Nd St Water Comm) June 1, 2001

(701) 328 -4958 (out of the office until June 4)

June 4, 2001

Did a study with the dikes washing out in study area. Their evaluation indicated that the Coulee could erode fairly rapidly to Elevation 1447 based on a total discharge of 2,000,000-acre feet of water.

Suggested looking at the USGS Fact Sheet on the subject available from the USGS web site.

They seem to think the dikes are extremely important and are pessimistic about the ability to control the situation if it becomes a reality. Control will be hampered by physical, political, and legal constraints.

Considers the soils highly erodible silts, clays and sands.

7.0 Conversation with Edward Murphy (Ndgs) June 1, 2001

(701) 328-8000

He was at the site in March and June of 1997.

He doesn't remember any channels. Coulee is flat-floored with "micro topography" (high density of 1-foot dimples) from cattle traffic.

Trench sidewalls were sufficiently stable to a depth of 12 feet to allow working in the trenches for at least an hour after excavation.

Silts and clays were cohesive and retained shape when dumped from backhoe bucket.

Water inflow at bottom of trench was about two garden hoses in volume.

He can't really say that the situation is one of continual aggradation after initial erosion to the lag gravel. If it were, erosion would not have been a significant factor during previous discharges.

Test pits may not represent soils across the valley floor. A channel that removed older sediments may exist.

The Coulee floor is well vegetated.

He thinks the dikes are access roads for farm use in crossing the marshy coulee.

Samples are available for testing if desired.

8.0 Nelson and Walsh County Geologic Report

No help.

9.0 U.S.G.S Quadrangle Maps

Indicate no existing discharge channels in the reach under consideration.

The area under consideration appears to be a 3000-foot-long drainage divide from which channels flow east to Stump Lake and west to Tolna Coulee.

"Flared" shape of outlet not evident with larger view offered by quads.

Appendix B

Tolna Coulee Soils Data from the Report "Recent Sedimentation in the Jerusalem and Tolna Outlets, Devils Lake Basin," May 1997 by E. Murphy and A. Fritz, North Dakota Geological Survey

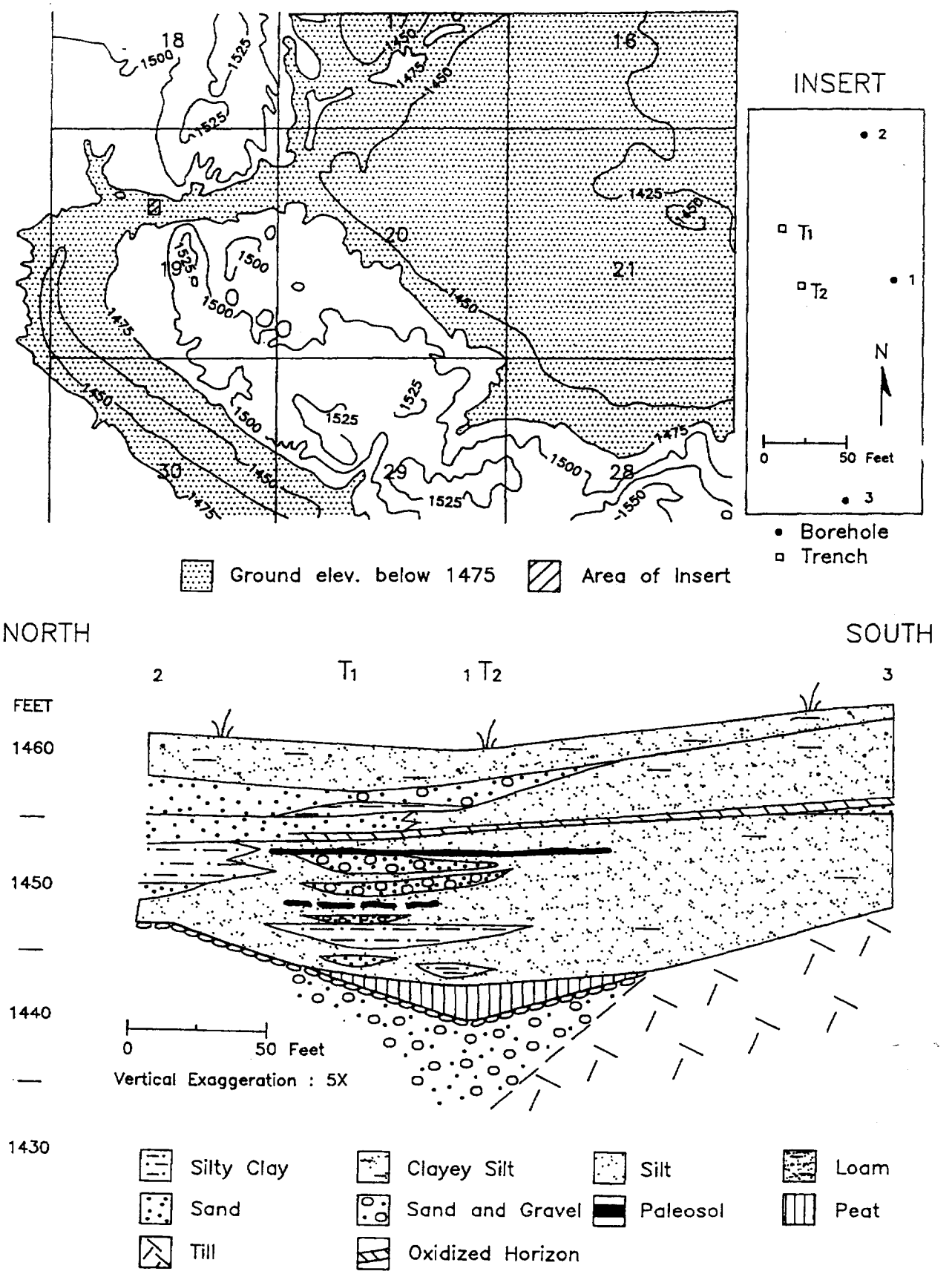

Figure 8. Topographic map and geologic cross-section of the Tolna outlet

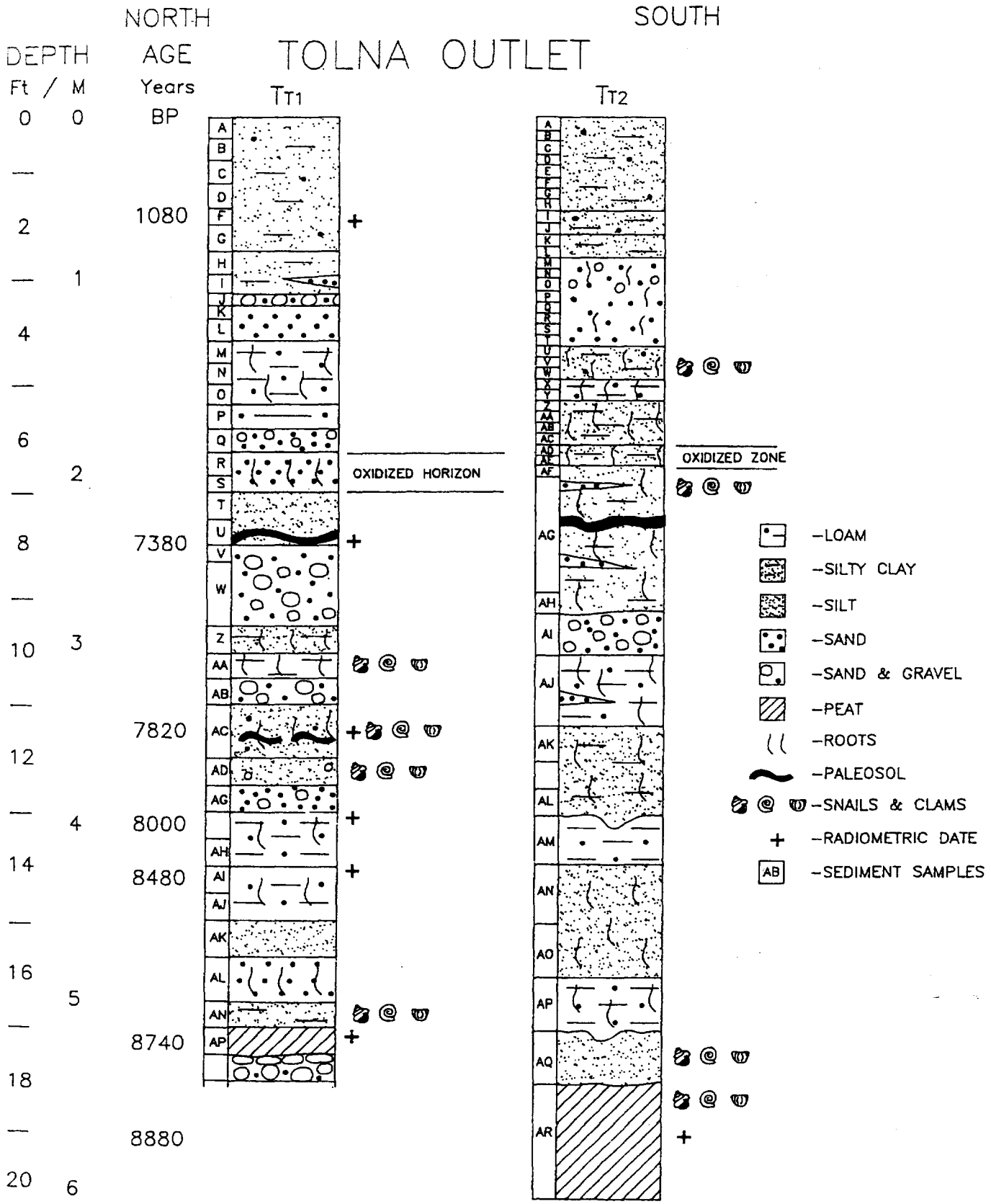

Figure 9. Stratigraphic columns for Tolna trenches TT1 and TT2.

Tolna Site
T151N, R61W, section 19

Hole 1
2845 fwl, 1700 fnl Elev. 1460.7

0-3.5	Loam, dark brown, roots.
3.5-4.5	Sand, brown, medium grained.
4.5-6	Clay, gray/brown, silty, pebbles.
6-8	Silt, green/gray, clayey.
8-9.5	Sand and gravel, gray.
9.5-13	Silt, gray to gray-green.
13-15	Clay, gray/brown, silty.
15-17	Silt, blue/gray, clayey.
17-20	Peat.
20-20.3	Rock.
20.3-26	Sand and gravel, gray, poor returns.

Hole 2
2870 fwl, 1805 fnl Elev. 1461

0-2	Loam, medium brown, pebbles.
2-3	Loam, light yellow brown, pebbles.
3-6	Sand, yellow/brown, medium grained, poor sorting, pebbles.
6-8	Sand, blue to blue/gray, medium grained, silty.
8-11	Clay, blue some black staining, silty, pebbles some shale pebbles, occasional roots.
11-12	Sand, green, fine grained, moderately sorted.
12-14	Silt, medium to dark gray, clayey, some pebbles.
14-14.2	Rock.

Hole 3
2840 fwl, 1970 fnl Elev. 1463.4

0-1	Loam, dark brown, pebbles.
1-4	Silt, light gray, clayey, pebbles.
4-7	Silt, yellow/brown, sandy, pebbles.
7-7.3	Oxidized zone, orange/brown, FeO stained.
7.3-8	Sand, green, medium grained, well sorted.
8-15	Silt, blue, very fine grained sand.
15-25	Till, blue/gray.

PROJECT: **Devils Lake**
LOCATION: NW 1/4 of SW 1/4 of NE 1/4 of Section 19, Township 151N, Range 61W
COUNTY: Nelson
OBSERVER(S): Ann Fritz and Ed Murphy
NOTES: No samples were submitted for pollen analysis from this trench.
SITE: **Tolna Trench 1**, Roger Johnson Farm

TT1 log - sheet 1 of 3

DEPTH (in feet)	DESCRIPTION	SEDIMENT SAMPLE ID	SAMPLE TYPE[1]
0 - 0.4	loam, dark brown; modern roots; organic rich	TT1-A	D
0.4 - 0.8	loam; as above	TT1-B	D
0.8 - 1.25	loam; as above	TT1-C	D
1.25 - 1.7	loam; as above	TT1-D	D
1.7 - 2.0	loam; as above	TT1-F	D
2.0 - 2.5	loam; as above	TT1-G	D †
2.5 - 2.9	clayey silt, gray brown; sand lense, organic horizons	TT1-H	D
2.9 - 3.3	clayey silt, gray brown; sand lense, organic horizons	TT1-I	D
3.3 - 3.5	sand and gravel, medium gray/brown; water seepage at this interval	TT1-J	D
3.5 - 3.75	sand, brown	TT1-K	D
3.75 - 4.2	sand, brown	TT1-L	D
4.2 - 4.6	silty clay, gray/brown; some iron oxide staining; root traces	TT1-M	D
4.6 - 5.0	silty clay, gray/brown;as above	TT1-N	D
5.0 - 5.4	silty clay, gray/brown mottled; some iron oxide staining; heavily rooted	TT1-O	D
5.4 - 5.8	silty clay, light brown; some pebbles	TT1-P	D
5.8 - 6.25	sand, green/gray; pebbles; black organic layers; iron oxide staining; top of oxidized interval	TT1-Q	D
6.25 - 6.7	sand, reddish orange; very fine grained; oxidized horizon; some black layers visible; rooted	TT1-R	D
6.7 - 7	sand, reddish orange; as above	TT1-S	D
7 - 7.5	clayey silt, green/gray; contains sand and gravel lenses; roots	TT1-T	D

TT1 log - sheet 2 of 3

DEPTH (in feet)	DESCRIPTION	SEDIMENT SAMPLE ID	SAMPLE TYPE[1]
7.5 - 8.0	clayey silt, green/gray; paleosol layer	TT1-U	D
8.0 - 8.3	sand and gravel; blue-gray; rootlets visible; shale pebbles numerous	TT1-V	D, S(8')†
8.3 - 8.5	sand and gravel, blue-gray; large cobbles of shale and limestone	TT1-W	D
8.5 - 9.0	sand and gravel; blue-gray; rootlets visible; shale pebbles numerous	TT1-X	D
9.0 - 9.5	sand and gravel; blue-gray; as above	TT1-Y	D
9.5 - 10.0	clayey silt, some shaley sand; root traces; shells	TT1-Z	D, W (9.5-10)
10.0 - 10.5	silty clay, dark brown ; pebbly; ribbons slightly; many roots distributed throughout peds; many poorly preserved shells and snails,	TT1-AA	D
10.5 - 11.0	sand and gravel; some silt; shale predominants sand fraction, largest pebbles are dolomite/limestone	TT1-AB	D
11.0 - 12.0	silt, light gray; more sandy than 10 - 10.5 interval; wood/plant fragments; shells and snails are abundant; thin paleosol	TT1-AC	D, S (11.5) W(11.5)†
12.0 - 12.75	silt, gray to gray-green; occasional pebble, fibrous wood/plant fragments common	TT1-AD	D, W(12.5)
	sandy clay, dark green; very fine grained sand	TT1-AE	D
	clayey silt, gray/brown; shell horizon; roots; some sand lenses	TT1-AF	D
12.75 -13.0	coarse sand layer, some cobbles	TT1-AG	D
13.5 - 14.0	silty clay, dark gray/black; roots and wood present	TT1-AH	D, W (13')†
14.0 - 14.5	silty clay, gray brown; contains medium to coarse roots, wood fragments	TT1-AI	D, W (14-14.5)†
14.5 - 15.0	silty clay, gray brown	TT1-AJ	D
15.0 - 15.7	silt; wood/plant fragments	TT1-AK	D
15.7 - 16.5	silty sand, blue gray; very fine grained sand; roots and wood fragments	TT1-AL	D

TT1 log - sheet 3 of 3

DEPTH (in feet)	DESCRIPTION	SEDIMENT SAMPLE ID	SAMPLE TYPE [1]
16.5	silty clay, dark blue-gray; wood and plant fibers; scattered shells and snails	TT1-AM	D W (16-17)
16.5 - 17.0	clayey silt, dark gray; wood and plant fibers; scattered shells and snails	TT1-AN	D, S
17.0 - 17.5	Peat, reddish-brown; wood, snails and shell fragments common	TT1-AO	P
	Peat; as above	TT1-AP	P †
17.5 - 18.0 bottom of trench	sand and gravel		

[1]SAMPLE TYPE: W = wood; S = paleosol; P = peat; D = grab sample of sediment.
Asterik (*) indicates sample was submitted for pollen analysis.
Cross (†) indicates sample was submitted for radiocarbon dating.

PROJECT: **Devils Lake**
LOCATION: NW 1/4 of NE 1/4 of SW 1/4 of Section 19, Township 151N, Range 61W
COUNTY: Nelson
OBSERVER(S): Ann Fritz and Ed Murphy
NOTES: Samples submitted for pollen and radiocarbon analysis are noted
SITE: **Tolna Trench 2**, Roger Johnson farm

TT2 log - sheet 1 of 3

DEPTH (in feet)	DESCRIPTION	SEDIMENT SAMPLE ID	SAMPLE TYPE[1]
0 - 0.21	loam, dark brown; organic rich	TT2-A	D *
0.21 - 0.42	loam,dark brown; organic rich	TT2-B	D *
0.42 - 0.63	loam,dark brown; organic rich	TT2-C	D *
0.63 - 0.83	loam,dark brown; organic rich	TT2-D	D *
0.83 - 1.04	loam,dark brown; organic rich	TT2-E	D *
1.04 - 1.25	silty clay loam; dark brown; organic rich	TT2-F	D *
1.25 - 1.46	silty clay loam, dark brown; organic rich	TT2-G	D *
1.46 - 1.67	silty clay loam, dark brown; organic rich	TT2-H	D *
1.67 - 1.88	silty clay loam, yellow brown	TT2-I	D *
1.88 - 2.08	silty clay loam, dark brown and tan, mottled; becoming sandier than above units	TT2-J	D *
2.08 - 2.29	clayey silt, light gray/brown; discontinuous boundary; inclusions of black silty clay loam	TT2-K	D
2.29 - 2.5	clayey silt, light gray/brown; as above	TT2-L	D
2.5 - 2.71	sand, light brown; medium to coarse grained sand, pebbles; roots	TT2-M	D
2.71 - 2.92	sand, light brown; as above	TT2-N	D
2.92 - 3.13	sand, light brown; as above	TT2-O	D
3.13 - 3.33	sand, light brown; as above	TT2-P	D
3.33 - 3.54	sand, light brown; as above	TT2-Q	D
3.54 - 3.75	sand, light brown; as above	TT2-R	D
3.75 - 3.96	sand, light brown; as above	TT2-S	D

DEPTH (in feet)	DESCRIPTION	SEDIMENT SAMPLE ID	SAMPLE TYPE[1]
3.96 - 4.17	silty sand, light gray brown; some clay horizons; sand sequence (from this point up to 2.5') is coarsening upwards	TT2-T	D
4.17 - 4.38	clayey silt; gray/brown; sandy; some thin organic layers; heavily rooted; some shell fragments	TT2-U	D
4.38 - 4.58	clayey silt, gray/brown; sandy; heavily rooted; snail shells	TT2-V	D
4.58 - 4.79	clayey silt, gray/brown; sandy; heavily rooted; some well preserved shell fragments	TT2-W	D
4.79 - 5.0	sandy clay, gray brown; iron staining, burrow fillings/root trails have manganese coats; some shell fragments	TT2-X	D *
5.0 - 5.21	silty clay; medium to coarse roots; oxidation occurring on root trails	TT2-Y	D
5.21 - 5.42	clayey silt; gray to brown; occasional pebbles; iron staining; medium to coarse roots	TT2-Z	D
5.42 - 5.625	clayey silt; as above	TT2-AA	D
5.625 - 5.83	clayey silt; as above	TT2-AB	D
5.83 - 6.04	silty clay, gray brown; sandy; heavily rooted; iron oxide staining	TT2-AC	D
6.04 - 6.25	clayey silt, dark green/gray to orange; silt lenses; iron oxide and mineralized root traces; iron oxide layers	TT2-AD	D
6.25 - 6.46	clayey silt, dark green/gray to orange; silt lenses; iron oxide and mineralized root traces; iron oxide layers	TT2-AE	D
6.46 - 6.67	clayey silt, dark green; occasional thin sand lense; root traces are abundant; woody root fragments; shells	TT2-AF	D*
6.67 - 8.8	clayey silt, dark green; some shells; occasional thin sand lense; paleosol layer	TT2-AG	D, S(7'9")
8.8 - 9.2	clayey silt, dark green; occasional thin sand lense	TT2-AH	D
9.2 - 10.0	sand and gravel, medium gray	TT2-AI	D
10.0 - 11.3	silty clay, gray; heavily rooted, some of the rooted zones have blue-green stains; intermittant sand lenses	TT2-AJ	D

TT2 log - sheet 3 of 3

DEPTH (in feet)	DESCRIPTION	SEDIMENT SAMPLE ID	SAMPLE TYPE[1]
11.3 - 12.0	clayey silt, dark brown to green-gray; some silty clay zones; some pebbles; roots and wood abundant	TT2-AK	D*
12.5 - 13.0	clayey silt, green-gray; contains wood fragments and roots	TT2-AL	D, W
13.0 - 14.0	silty clay, black-brown; irregular boundary between this unit and green-gray clayey silt from above; roots	TT2-AM	D
14.0 - 15.0	silt, black-brown; very coarse granular structure; contains plant fragments, roots and small pebbles; few shells	TT2-AN	D
15.0 - 16.0	silt, dark gray; contains plant fragments, roots	TT2-AO	D
16.0 - 17.0	silty clay, dark gray; contains plant fragments (horsetail {?}stem visible), roots	TT2-AP	D
17.0 - 18.0	silt, brownish gray to gray-green; contains fibrous plant matter and few seed pods; shells and snails are abundant but poorly preserved; irregular boundary with above unit	TT2-AQ	D*
18.0 - 20.0 bottom of trench	peat, reddish brown to black; shells and snails are abundant but poorly preserved; wood and plant fragments common.	TT2-AR	D* P(19'), W(19')†

[1]SAMPLE TYPE: W = wood; S = paleosol; P = peat; D = grab sample of sediment
Asterik (*) indicates sample was submitted for pollen analysis.
Cross (†) indicates sample was submitted for radiocarbon dating.

Technical Appendix
Part II
Economic Analysis of Devils Lake Alternatives

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Table II.ST-3 Stochastic Scenario Comparison of Benefits for Features Adjacent to Devils Lake

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Table II.WF-2 Wet Future Scenario Comparison of the Probability of Reaching Lake Levels

Table II.WF-3 Wet Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

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Table II.M1-2 Moderate Future 1 Scenario Comparison of the Probability of Reaching Lake Levels

Table II.M1-3 Moderate Future 1 Scenario Comparison of Benefits for Features Adjacent to Devils Lake

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Moderate Future 2 Scenario Tables

Table II.M2-1 Moderate Future 2 Scenario Cost and Benefit Comparison

Table II.M2-2 Moderate Future 2 Scenario Comparison of the Probability of Reaching Lake Levels

Table II.M2-3 Moderate Future 2 Scenario Comparison of Benefits for Features Adjacent to Devils Lake

Table II.M2-4 Moderate Future 2 Scenario Comparison of Benefits for Downstream Features

Dry Future Scenario Tables

Table II.DR-1 Dry Future Scenario Cost and Benefit Comparison

Table II.DR-2 Dry Future Scenario Comparison of the Probability of Reaching Lake Levels

Table II.DR-3 Dry Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

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Table II.ER-4 Erosion at Natural Outlet: Comparison of Benefits for Downstream Features

II.1.0 Stochastic Analysis Results

II.1.1 Stochastic Analysis Comparison

The comparison of the cost-effectiveness between alternatives considers these factors:

- The net benefits provided by the alternatives
- The effectiveness of the alternative in reducing the lake levels and thereby reducing the damages adjacent to the lake and the costs for protecting features
- The effectiveness of the alternative in reducing the downstream damages
- The financial risk for the investment of Federal funds that is associated with implementation of the alternative

II.1.1.1 Economic Benefit of Alternatives

Table II.ST-1 compares the costs and benefits of the various alternatives under the stochastic analysis. Economics indices were computed using two different computations of benefits: benefits without downstream impacts and benefits that include downstream impacts. The downstream impacts computed for the stochastic analysis are weighted averages, based on the results of the scenario analyses and the percentage of the lake level categories that they represent. However, because not all of the alternatives were analyzed under all of the scenarios, weighted average values for downstream impacts could not be computed for all of the alternatives. In general, this discussion will present the results that include the downstream impacts (it will be noted when results do not include downstream impacts).

The alternative with the largest net benefits is for the Expanded Infrastructure Measures alternative (ST-2b). There are no downstream impacts for this alternative, since the project does not significantly impact the lake levels.

Note that the computations for the ST-1 (Upper Basin Management) alternative do not include the downstream impacts. The net benefits of this Upper Basin Management alternative would likely increase slightly if downstream impacts were included, because the project reduces the overflows during wet futures (although overflows occur in less than 10% of the traces).

All of the alternatives that endeavor to reduce the peak lake level (outlets and upper basin storage) have negative net benefits, indicating that under the stochastic analysis these projects are not economically justified. Among these alternatives, the Upper Basin Management alternative (ST-1) has the largest average annual net benefits (-$1.9 million). The downstream impacts are a large portion of the negative net benefits for these alternatives, especially for the 480 cfs unconstrained outlets. Although the East End 480 cfs unconstrained outlet (ST-10) provides larger net benefits than other outlet alternatives, it also has greater environmental risks than an outlet from the West Bay or Pelican Lake (the poor water quality

from the East End may create many more damages than anticipated). Since the net benefits between the East End 480 cfs unconstrained (ST-10) and West Bay 300 cfs constrained (ST-3) outlets are within 10%, the cost-effectiveness of the West Bay outlet may be larger than for the East End outlet. However there is a greater financial risk for the West Bay outlet, the first costs are about 40% larger than the first costs for the East End outlet.

II.1.1.2 Lake Level Probabilities

Table II.ST-2 compares the effectiveness of the various alternatives on reducing the peak lake levels. As expected, the 480 cfs unconstrained outlets have the most impact on reduction of the lake levels—the 10% chance lake level is 1453. The results also indicate that the Pelican Lake 300 cfs constrained outlet is more effective at reducing lake levels than the West Bay 300 cfs outlet—10% chance lake levels of 1455 and 1456, respectively. This is due to the cleaner water that is captured at the Pelican Lake outlet.

The Upper Basin Management alternative is less effective at reducing the lake levels than any of the outlet alternatives. The Expanded Infrastructure Measures alternative does not impact the lake levels—the lake levels are the same as for the without-project conditions (within the accuracy of this model).

II.1.1.3 Economic Benefit of Alternatives on Features Adjacent to Devils Lake

All the alternatives are designed to reduce the flood protection measures that are required to protect features adjacent to the lake. As described in Part I, Section I.4.3.2, the set of most likely action strategies were assumed as protection measures under both without- and with-project conditions. Table II.ST-3 compares the effectiveness of the various alternatives on reducing the feature damages and the costs for feature protection adjacent to Devils Lake.

The alternatives with the largest reduction in feature damages (average 27% reduction) are the 480 cfs unconstrained outlets (ST-4, ST-6, and ST-10). These 480 cfs outlet alternatives also provide a reduction in feature protection costs of about 30%.

The Expanded Infrastructure Measures alternative (ST-2b) does not provide any additional reduction in damages (since the features are protected both with and without the project). However, the costs avoided by the project are increased by an average of 23%.

The Upper Basin Management alternative (ST-1) reduces average damages by about 6% and avoids about 7% of the average feature protection costs.

The combination of West Bay 300 cfs constrained outlet, Expanded Infrastructure Measures, and Upper Basin Management provides the most reduction in feature protection costs (38%), with a 14% reduction in feature damages.

II.1.1.4 Economic Benefit of Alternatives on Features Downstream of Devils Lake

Some of the alternatives modify the timing, quality, and/or volume of flows that are discharged to the downstream Sheyenne River and Red River of the North. The computed effect that these changes in

flows have on the downstream river water users is listed in Table II.ST-4. The downstream impacts computed under the stochastic analysis are weighted averages, based on the results of the scenario analyses (a wet, a dry, and two moderate traces). Therefore, values for downstream impacts are only available for the alternatives that completed these four scenario analyses.

The Percent of Downstream Damages Avoided was computed for comparison between alternatives. However, this number is computed based on the without-project condition damages (which are not always zero) and the assumptions for without-project condition damages vary depending on the damage category. Therefore, the percentages should be used for comparison purposes between alternatives, but not for an exact computation of reduction of downstream damages.

The Expanded Infrastructure Measures (ST-2b) alternatives have no impact on downstream features, since they do not alter the lake levels or the natural overflows.

The average downstream impacts were not analyzed for the Upper Basin Management alternative (ST-1).

The 480 cfs unconstrained outlet alternatives show large negative weighted benefits (about -$2 to -$3 million annually), which result primarily from the increase in municipal water treatment facility operation costs as a result of treating the increased total dissolved solids with the outlet. The 300 cfs constrained outlet alternatives show a reduction in municipal water treatment facility operation costs with the outlets—likely the result of a reduction in the natural overflows and their associated costs. The overall downstream benefits for the 300 cfs constrained outlets average about $0.2 million annually. Although these benefits are small, the Pelican Lake outlet (ST-5) has 24% more downstream benefits than the West Bay outlet (ST-3).

II.1.2 Stochastic Analysis : Alternatives within the Basin

This section includes a discussion of the results for each alternative within the basin under the set of most likely action strategies. A comparison of these results to those under various sets of flood protection strategies for features is also included in these sections. Although the other sets of flood protection strategies were conducted as a sensitivity analysis, the discussion fits in with the other results.

II.1.2.1 Economic Analysis of Upper Basin Management (ST-1)

The detailed results of the Upper Basin Management stochastic analysis are listed in the Tabular Data document, Tables TD.2.ST-1.1 through TD.2.ST-1.7.

II.1.2.1.1 Project Benefits

The Upper Basin Management alternative reduces the peak lake level by about one foot (based on data between the 100% and 10% probability levels[1]).

1 The “probability level” is defined as the percent chance that the lake will reach a certain level, based on the climate assumptions and project(s).

The benefits of Upper Basin Management (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated average annual cost savings of $0.7 million due to reduced flood protection measures using the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 7%.
- Damages Prevented to Features Adjacent to Devils Lake: The average annual reductions in infrastructure damages due to Upper Basin Management were computed to be $0.1 million. This is about a 6% decrease in total damages.
- Damages Prevented to Downstream Features: Although this alternative will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features was expected to be negligible and was therefore not computed.

The combined annual benefits (the sum of the individual benefits) of this Upper Basin Management alternative are $0.8 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are about 20% smaller—the reduction in damages under the cost-effective strategies is larger (fewer features are protected so more damages can be prevented) but the cost savings using the cost-effective strategies are smaller (there are fewer costs to prevent because only the cost-effective strategies are implemented).
- The set of maximum protection strategies increase the project benefits by about 6%, primarily by reducing the damages further (to features that cannot be protected—such as land and rural homes).
- If the set of no protection strategies were assumed, the project benefits would double. The project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.1.2.1.2 Project Costs

The project costs for the Upper Basin Management alternative are $39.7 million for construction of flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes (allowing water to flow into the lake unrestricted). The financial risk of this alternative should be considered in evaluation of its cost-effectiveness.

The present worth of the project is annualized for a total $2.7 million annual cost for the 50-year planning period.

II.1.2.1.3 Net Benefits

Using the set of most likely action strategies for the features adjacent to Devils Lake, the annual net benefit equals the benefits ($0.8 million) less the costs ($2.7 million), or -$1.9 million, i.e., the average annual costs exceed the average annual benefits. The BCR is $0.8 million/$1.9 million = 0.29. Because

the net benefits are negative, the Upper Basin Management alternative is not economically justified using the set of most likely action strategies under the stochastic analysis.

The net benefits for this alternative are generally around -$2.0 million, except under the set of no flood protection strategies ($1.1 million). The BCRs range from 0.23 to 0.59. This alternative is not economically justified under any of the sets of flood protection strategies (without downstream impacts considered).

II.1.2.1.4 Discussion of Results

The results indicate that this alternative is not economically feasible. Even if the project costs were cut to one-third of the assumed costs, the upper basin storage program appears to not be justifiable. The project may require coordination and negotiation with the upper basin landowners, which could be long-term because of the modification of flood control structures once the lake recedes. An evaluation of the cost-effectiveness of this alternative should consider downstream impacts.

This alternative assumes that 50% of the storage that is available in the upper watershed is placed into an upper basin storage program. Increasing the storage that is placed into this program would be more costly (since more prime farmland would be required). Therefore, it is unlikely that increasing the storage would make this alternative economically feasible. Decreasing the storage that is placed into this program would drop the effectiveness of reducing the damages to features adjacent to the lake, therefore the benefits would decrease along with the decreased costs.

II.1.2.2 Economic Analysis of Expanded Infrastructure Measures (ST-2b)

The detailed results of the Expanded Infrastructure Measures stochastic analysis are listed in the Tabular Data document, Tables TD.2.ST-2b.1 through TD.2.ST-2b.7.

II.1.2.2.1 Project Benefits

The Expanded Infrastructure Measures alternative has no computed effect on the peak lake levels. Similarly, this alternative will not reduce the natural overflows from Devils Lake. Therefore this alternative has no downstream impacts.

The benefits of the Expanded Infrastructure Measures alternative are primarily the reduction in the costs for flood protection measures using the set of most likely action strategies. The average annual cost savings (estimated to be $2.4 million) reduces the protection costs for the features adjacent to Devils Lake by about 23%. There is also a slight reduction in average annual infrastructure damages, computed to be about $0.01 million (less than 1% decrease in total damages).

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are more than 50% smaller—the reduction in damages under the cost-effective strategies is larger (fewer features are protected so more damages

can be prevented) but the cost savings using the cost-effective strategies are smaller (there are fewer costs to prevent because only the cost-effective strategies are implemented).

- The set of maximum protection strategies more than triple the project benefits by reducing the feature protection costs. The construction of the perimeter dikes and roads as levees has more net benefits than the protection measures that raise roads and flood the interior areas.

- If the set of no protection strategies were assumed, the project benefits would be reduced by 87%. The only benefit is the protection of several homes and land. Although some of the road features would be protected with the project, the damages to roads are not eliminated because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative, using the set of no protection strategies, is not a realistic solution to flooding in the basin.

II.1.2.2.2 Project Costs

The average present worth costs for implementation of the Expanded Infrastructure Measures alternative is $15.2 million for expansion of the existing flood protection measures to ensure safe protection of features adjacent to Devils Lake. Many of these costs would occur as necessary due to the rising lake, therefore the up-front costs for this alternative are not high and the financial risks are low.

Average operation and maintenance costs for interior drainage behind the new levees was computed to be $2.0 million present worth. The present worth of the project is annualized for a total $1.1 million annual cost for the 50-year planning period.

II.1.2.2.3 Net Benefit

The annual average net benefits of this alternative using the set of most likely action strategies equals the benefits ($2.4 million) less the costs ($1.1 million), or $1.3 million. The BCR is $2.4 million/$1.1 million = 2.10. Because the net benefits are positive, the Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies under the stochastic analysis.

The net benefits for this alternative range from -$0.8 to $7.5 million depending on the sets of flood protection strategies. The BCRs range from 0.27 to 7.50. The only set of flood protection strategies under which the alternative is not economically justified is for the set of no flood protection strategies (which is not a viable alternative—see discussion in Section II.1.2.2.1 above).

II.1.2.2.4 Discussion of Results

The Expanded Infrastructure Measures alternative is economically feasible as a plan for flood protection of the features that are currently being protected by roads that were not designed as dams. This is similar to the results shown in the *Spirit Lake Nation Report*, Barr Engineering Company, 1998. Further analysis of this alternative in 2000 confirmed the economic feasibility—*Roadways Serving as Water Barriers*, Devils Lake Transportation Task Force, May 2000.

II.1.2.3 Economic Analysis of Raise Natural Outlet

The Raise Natural Outlet alternative was not analyzed under the stochastic analysis. A discussion of this alternative can be found under the Wet Future Scenario analysis (Section II.2.2.3).

II.1.3 Stochastic Analysis : Outlet Alternatives

II.1.3.1 Economic Analysis of West Bay Outlets (ST-3 and ST-4)

The detailed results of the West Bay outlet stochastic analyses are listed in the Tabular Data document. Tables TD.2.ST-3.1 through TD.2.ST-3.7 list the data for the West Bay 300 cfs constrained outlet alternative. Tables TD.2.ST-4.1 through TD.2.ST-4.7 list the data for the West Bay 480 cfs unconstrained outlet alternative.

II.1.3.1.1 Project Benefits

The West Bay 480 cfs unconstrained outlet reduces the peak lake level almost 5 feet at the 10% probability level and about 2 feet at the 50% probability level. The West Bay 300 cfs constrained outlet has less effect, reducing the peak lake level by about 2 feet at the 10% probability level and by about 1 foot at the 50% probability level.

The benefits of the West Bay outlets (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated average annual cost savings of $1.4 and $3.1 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 13% (300 cfs) and 29% (480 cfs).

- Damages Prevented to Features Adjacent to Devils Lake: The average annual reductions in infrastructure damages were computed at $0.1 and $0.3 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This represents a decrease of about 10% and 26% for damages to adjacent lake features, respectively.

- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The 300 cfs constrained outlet reduces the average annual downstream damages by $0.2 million. This is about a 1% decrease in total damages. The 480 cfs unconstrained outlet increases the average annual downstream damages by $3.3 million. This is about a 29% increase in total damages, primarily due to the increased costs for municipal water treatment facilities to treat the increased concentration of total dissolved solids (which accounts for 87% of the total increase).

The combined annual benefit (the sum of the individual benefits) of the West Bay 300 cfs constrained outlet is $1.6 million. The West Bay 480 cfs unconstrained outlet has a much smaller combined annual benefit of $0.1 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are 15 to 22% smaller. The reduction in damages under the cost-effective strategies is larger (fewer features are protected so more damages can be prevented) but the cost savings using the cost-effective strategies are smaller (there are fewer costs to prevent because only the cost-effective strategies are implemented).
- The set of maximum protection strategies decrease the project benefits by 3 to 17%, primarily because the cost savings are less. The feature protection measures are implemented to the maximum level at the first action level, and most of these protection measures are necessary even with the outlet (whereas the most likely set of strategies are implemented incrementally, and some entire raises may be prevented by the outlet).
- If the set of no protection strategies were assumed, the project benefits would about double. The project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.1.3.1.2 Project Costs

The project costs for the West Bay outlets include:

- Construction costs, at $58.5 million for the 300 cfs constrained outlet or $92.2 million for the 480 cfs unconstrained outlet.
- Total present worth operation and maintenance costs for the West Bay outlets, at $6.4 million for the 300 cfs constrained outlet and $11.7 million for the 480 cfs unconstrained outlet. Average operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed, at $13.8 million present worth.
- Natural resource up-front mitigation costs along the downstream rivers, with a present worth cost of $12.9 million for the 300 cfs constrained outlet or $40.7 million for the 480 cfs unconstrained outlet.
- Annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts.

The total estimated present worth costs for the West Bay 300 cfs constrained outlet alternative are $87.5 million, and are annualized for a total of $5.9 million for the 50-year planning period. The total estimated present worth costs for the West Bay 480 cfs unconstrained outlet are much larger ($168.2 million) for a total of $11.2 million annual costs for the 50-year planning period.

II.1.3.1.3 Net Benefit

The net benefit equals the benefits of the alternative less the costs of the alternative. Using the set of most likely action strategies for local flood protection, the West Bay 300 cfs constrained outlet has an average net benefit of -$4.2 million, i.e., the average annual costs exceed the average annual benefits. The BCR is $1.6 million/$5.8 million = 0.28. Because the net benefits are negative, the West Bay 300 cfs constrained outlet alternative is not economically justified using the set of most likely action strategies according to the stochastic analysis.

The West Bay 480 cfs unconstrained outlet has significantly larger costs and much smaller benefits. The average net benefit is computed at -$11.1 million, i.e., the average annual costs exceed the average annual benefits. The BCR is $0.1 million/$11.2 million = 0.01. The West Bay 480 cfs unconstrained outlet alternative is not economically justified using the set of most likely action strategies according to the stochastic analysis.

The net benefits for these alternatives are essentially the same under all of the sets of flood protection strategies except under the set of no protection strategies. For the 300 cfs constrained outlet, the net benefits are typically about -$4.5 million and the BCR is about 0.22. Under the set of no protection strategies the net benefit is -$2.9 million and the BCR is 0.50. The 480 cfs unconstrained outlet net benefits are about -$11.6 million and the BCR is around zero. For the set of no protection strategies, it has net benefits of -$5.8 million and a BCR of 0.49. These alternatives are not economically justified under any of the sets of flood protection strategies.

II.1.3.1.4 Discussion of Results

The results indicate that neither of the West Bay outlet alternatives is economically feasible under the stochastic analysis. The 480 cfs unconstrained outlet has a relatively higher environmental risk to the downstream rivers than the 300 cfs constrained outlet, because the water that is released is not constrained by downstream water quality and quantity standards.

The cost-effectiveness of the outlet alternatives should consider the investment of Federal funds for these outlet alternatives and the non-quantifiable benefit to local agencies and residents that the highest degree of protection is being implemented to relieve the pressures of the prolonged flooding problems.

II.1.3.2 Economic Analysis of Pelican Lake Outlets (ST-5 and ST-6)

The detailed results of the Pelican Lake outlet stochastic analyses are listed in the Tabular Data document. Tables TD.2.ST-5.1 through TD.2.ST-5.7 list the data for the Pelican Lake 300 cfs constrained outlet alternative. Tables TD.2.ST-6.1 through TD.2.ST-6.7 list the data for the Pelican Lake 480 cfs unconstrained outlet alternative.

II.1.3.2.1 Project Benefits

The Pelican Lake 480 cfs unconstrained outlet reduces the peak lake level almost 5 feet at the 10% probability level and about 2 feet at the 50% probability level. The Pelican Lake 300 cfs constrained

outlet has slightly less effect, reducing the peak lake level by about 4 feet at the 10% probability level and by about 1 foot at the 50% probability level.

The benefits of the Pelican Lake outlets (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated average annual cost savings of $2.5 and $3.4 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. These outlets reduce the protection costs for the features adjacent to Devils Lake by 24% (300 cfs) and 32% (480 cfs).

- Damages Prevented to Features Adjacent to Devils Lake: The average annual reductions in infrastructure damages were computed at $0.2 and $0.3 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This represents a decrease of about 18% and 26% for damages to adjacent lake features, respectively.

- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The 300 cfs constrained outlet reduces the average annual downstream damages by $0.1 million. This is about a 1% decrease in total damages. The 480 cfs unconstrained outlet increases the average annual downstream damages by $2.3 million. This is about a 20% increase in total damages, primarily due to the increased costs for municipal water treatment facilities to treat the increased concentration of solids (which accounts for 87% of the total increase).

The combined annual benefit (the sum of the individual benefits) of the Pelican Lake 300 cfs constrained outlet is $2.9 million. The Pelican Lake 480 cfs unconstrained outlet has a much smaller combined annual benefit of $1.4 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are 26 to 57% smaller—the reduction in damages under the cost-effective strategies is larger (fewer features are protected so more damages can be prevented) but the cost savings using the cost-effective strategies are smaller (there are fewer costs to prevent because only the cost-effective strategies are implemented).

- The set of maximum protection strategies decrease the project benefits by 12 to 14%, primarily because the cost savings are less. The feature protection measures are implemented to the maximum level at the first action level, and most of these protection measures are necessary even with the outlet (whereas the most likely set of strategies are implemented incrementally, and some entire raises may be prevented by the outlet).

- If the set of no protection strategies were assumed, the project benefits double for the 300 cfs constrained outlet and quadruple for the 480 cfs unconstrained outlet. The project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.1.3.2.2 Project Costs

The project costs for the Pelican Lake outlets include:

- Construction costs, at $84.2 million for the 300 cfs constrained outlet or $129.2 million for the 480 cfs unconstrained outlet.
- Total present worth operation and maintenance costs for the Pelican Lake outlets, at $9.5 million for the 300 cfs constrained outlet and $14.0 million for the 480 cfs unconstrained outlet. Average operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.
- Construction costs to raise control structures along Highway 281 and Highway 19, at $1.1 million for the 300 cfs constrained outlet or $0.8 million for the 480 cfs unconstrained outlet.
- Total present worth operation and maintenance costs for the Pelican Lake Highway control structures, at $0.1 million for both the 300 cfs constrained and the 480 cfs unconstrained outlets. Annual maintenance costs were assumed to be 0.5% of the first costs.
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed, at $12.5 million present worth.
- Natural resource up-front mitigation costs along the downstream rivers, with a present worth cost of $12.9 million for the 300 cfs constrained outlet or $40.7 million for the 480 cfs unconstrained outlet.
- Annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts.

The total estimated present worth costs for the Pelican Lake 300 cfs constrained outlet alternative are $117.5 million, and are annualized for a total of $7.8 million for the 50-year planning period. The total estimated present worth costs for the Pelican Lake 480 cfs unconstrained outlet are much larger ($207.0 million) for a total of $13.8 million annual costs for the 50-year planning period.

II.1.3.2.3 Net Benefit

The net benefit equals the benefits of the alternative less the costs of the alternative. Using the set of most likely action strategies for local flood protection, the Pelican Lake 300 cfs constrained outlet has an average net benefit of -$4.9 million, i.e., the average annual costs exceed the average annual benefits. The BCR is $2.9 million/$7.8 million = 0.37. Because the net benefits are negative, the Pelican Lake 300 cfs constrained outlet alternative is not economically justified using the set of most likely action local protection strategies according to the stochastic analysis.

The Pelican Lake 480 cfs unconstrained outlet has significantly larger costs and much smaller benefits. The average net benefit is computed at -$12.4 million, i.e., the average annual costs exceed the average annual benefits. The BCR is $1.4 million/$13.8 million = 0.10. The Pelican Lake 480 cfs unconstrained outlet alternative is not economically justified using the set of most likely action strategies according to the stochastic analysis.

The net benefits for these alternatives are essentially the same under all of the sets of flood protection strategies except under the set of no protection strategies. For the 300 cfs constrained outlet, the net benefits are typically about -$5.0 million and the BCR is about 0.3. Under the set of no protection strategies the net benefit is -$2.5 million and the BCR is 0.68. The 480 cfs unconstrained outlet net benefits range from -$7.4 to -$13.2 million and the BCR is between -0.04 to 0.47. Under the set of no protection strategies, it has net benefits of -$7.4 million and a BCR of 0.47. These alternatives are not economically justified under any of the sets of flood protection strategies.

II.1.3.2.4 Discussion of Results

The results indicate that neither of the Pelican Lake outlet alternatives is economically feasible under the stochastic analysis. However, the Pelican Lake outlets have the least environmental risk to downstream constituents, because the water is generally taken from the cleaner Big Coulee and not from Devils Lake. The 480 cfs unconstrained outlet has a relatively higher environmental risk to the downstream rivers than the 300 cfs constrained outlet, because the water that is released is not constrained by downstream water quality and quantity standards.

The financial investment of the Pelican Lake outlets is the highest of the outlet alternatives. The cost-effectiveness of the outlet alternatives should consider the benefit that the outlets provide to local agencies and residents in the knowledge that the highest degree of protection is being implemented to relieve the pressures of the prolonged flooding problems.

II.1.3.3 Economic Analysis of East End Outlet (ST-10)

The detailed results of the East End stochastic analyses are listed in the Tabular Data document. Tables TD.2.ST-10.1 through TD.2.ST-10.7 list the data for the East End 480 cfs unconstrained outlet alternative.

II.1.3.3.1 Project Benefits

The East End outlet reduces the peak lake level almost 5 feet at the 10% probability level and about 2 feet at the 50% probability level.

The benefits of the East End outlet (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated average annual cost savings of $3.1 million under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 29%.

- Damages Prevented to Features Adjacent to Devils Lake: The average annual reductions in infrastructure damages were computed at $0.3 million under the set of most likely action strategies. This represents a decrease of about 26% for damages to adjacent lake features.

- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The reduction in the average annual downstream damages was not computed for the East End 480 cfs unconstrained outlet.

The combined annual benefits (the sum of the individual benefits) of the East End 480 cfs unconstrained outlet are $3.4 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are 15% smaller—the reduction in damages under the cost-effective strategies is larger (fewer features are protected so more damages can be prevented) but the cost savings using the cost-effective strategies are smaller (there are fewer costs to prevent because only the cost-effective strategies are implemented).

- The set of maximum protection strategies increase the project benefits by 3%, primarily because more damages are prevented. The additional damages prevented are a function of the selection of the strategy measure for each feature, which is different than the strategy selected under the set of most likely action strategies.

- If the set of no protection strategies were assumed, the project benefits would more than double. The project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.1.3.3.2 Project Costs

The project costs for the East End 480 cfs unconstrained outlet include:

- Construction costs, at $57.4 million.

- Total present worth operation and maintenance costs for the East End outlet, at $0.5 million. Average operating and maintenance costs were assumed to be 1% of the first costs.

- Alternative water source or ion exchange unit installation at downstream municipal water treatment facilities. This project cost was not estimated for the stochastic analysis because it was not evaluated for the scenario analyses.

- Natural resource up-front mitigation costs along the downstream rivers, with a present worth cost of $40.7 million for the 480 cfs unconstrained outlet.

- Annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts.

The total estimated present worth costs for the East End 480 cfs unconstrained outlet alternative are $108.4 million, and are annualized for a total of $7.2 million for the 50-year planning period.

II.1.3.3.3 Net Benefit

Using the set of most likely action strategies for local flood protection, the net benefit equals the benefits ($3.4 million) less the costs ($7.2 million), or -$3.8 million, i.e., the average annual costs exceed the average annual benefits. The BCR is $3.4 million/$7.2 million = 0.88. Because the net benefits are negative, the East End 480 cfs unconstrained outlet is not economically justified using the set of most likely action strategies under the stochastic analysis. Inclusion of downstream damages and alternate water sources for municipal water treatment facilities would likely decrease the net benefits significantly and lower the BCR.

The net benefits for this alternative are essentially the same under all of the sets of flood protection strategies except the set of no protection strategies. The 480 cfs unconstrained outlet net benefits are about -$3.8 million and the BCR is between 0.75 and 0.91. These alternatives are not economically justified under most of the sets of flood protection strategies. The set of no protection strategies has net benefits of $1.5 million and a BCR of 2.26. The East End outlet is economically justified under the set of no protection strategies.

II.1.3.3.4 Discussion of Results

The results indicate that the East End outlet alternative is generally not economically feasible under the stochastic analysis. The 480 cfs unconstrained outlet has a higher environmental risk to the downstream rivers than the other outlets. The water that is released is not constrained by downstream water quality and quantity standards, and the East End of the lake typically has much higher TDS concentrations than other portions of the lake.

The up-front financial risks are relatively low compared to the other outlets analyzed. The cost-effectiveness of this outlet should consider the non-quantifiable benefit to local agencies and residents that the highest degree of protection is being implemented to relieve the pressures of the prolonged flooding problems.

II.1.4 Stochastic Analysis : Combination Alternatives

II.1.4.1 Economic Analysis of Upper Basin Management and Expanded Infrastructure Measures (ST-7b)

The detailed results of this stochastic analysis are listed in the Tabular Data document—Tables TD.2.ST-7b.1 through TD.2.ST-7b.7.

II.1.4.1.1 Project Benefits

This combination alternative reduces the peak lake level about 1 foot between the 100% and 10% probability levels. Although this alternative will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features was expected to be negligible and was therefore not computed.

The benefits of this combination alternative under the set of most likely action strategies are a function of:

- Costs Avoided: Estimated average annual cost savings of $3.1 million due to reduced flood protection measures under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 29%.
- Damages Prevented to Features Adjacent to Devils Lake: The average annual reductions in infrastructure damages were computed at $0.1 million under the set of most likely action strategies. This represents a decrease of about 6% for damages to adjacent lake features.

The combined annual benefits (the sum of the individual benefits) for this alternative are $3.2 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are about 50% smaller—the reduction in damages under the cost-effective strategies is larger (fewer features are protected so more damages can be prevented) but the cost savings using the cost-effective strategies are smaller (there are fewer costs to prevent because only the cost-effective strategies are implemented).
- The set of maximum protection strategies more than triple the project benefits by reducing the feature protection costs. The construction of the perimeter dikes and roads as levees has more net benefits than the protection measure that raises roads.
- If the set of no protection strategies were assumed, the project benefits would be reduced by 40%. Although some of the road features would be totally protected with the project, the damages to roads are not eliminated because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a consistent solution to flooding in the basin.

II.1.4.1.2 Project Costs

The project costs for the combination Upper Basin Management and Expanded Infrastructure Measures alternative include:

- Construction of upper basin flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes, at $39.7 million.

- Expansion of the existing flood protection measures to ensure safe protection of features adjacent to Devils Lake, at $14.1 million present worth value.
- Operation and maintenance costs for interior drainage behind the new levees, at $1.9 million present worth, based on estimated yearly costs.

The combined present worth cost of the project ($55.7 million) is annualized for a total $3.7 million annual cost for the 50-year planning period.

II.1.4.1.3 Net Benefit

Using the set of most likely action strategies the net benefits equal the benefits ($3.1 million) less the costs ($3.7 million), or $-0.6 million. The BCR is $3.1 million/$3.7 million = 0.84. The average annual costs exceed the average annual benefits, therefore the combination Upper Basin Management and Expanded Infrastructure Measures alternative is not economically justified using the set of most likely action strategies.

The net benefits for this alternative range from -$1.9 to $5.7 million depending on the sets of flood protection strategies. The BCRs range from 0.47 to 2.54. The only set of flood protection strategies under which the alternative is economically justified is the set of maximum protection strategies.

II.1.4.1.4 Discussion of Results

This combination Upper Basin Management and Expanded Infrastructure Measures alternative is generally not economically feasible. The inclusion of the Upper Basin Management project decreases the net benefits, which results in the combination not reaching economic feasibility. The net benefits of the Expanded Infrastructure Measures alternative alone are economically justifiable, and may be selected over this combination. However, the effectiveness of the combination alternative in reducing damages and costs is greater than the effectiveness of the Expanded Infrastructure Measures alternative. A comparison of the cost-effectiveness between alternatives should weigh all of these factors.

II.1.4.2 Economic Analysis of West Bay Lake Outlet with Upper Basin Management and Expanded Infrastructure Measures (ST-8b)

The detailed results of this stochastic analysis are listed in the Tabular Data document—Tables TD.2.ST-8b.1 through TD.2.ST-8b.7.

II.1.4.2.1 Project Benefits

This combination alternative reduces the peak lake level about 3 feet at the 10% probability level and about 1 foot at the 50% probability level.

The benefits of the alternative (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated average annual cost savings of $4.0 million under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 38%.

- Damages Prevented to Features Adjacent to Devils Lake: The average annual reductions in infrastructure damages were computed at $0.2 million under the set of most likely action strategies. This represents a decrease of about 14% for damages to adjacent lake features.

- Damages Prevented to Downstream Features: Reduction of the downstream damages because the increase in concentrations and flows during outlet operation is offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The average annual downstream damages are reduced by $0.2 million. This is about a 1% decrease in total downstream damages.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are about 36% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are significantly smaller.

- The set of maximum protection strategies more than double the project benefits by reducing the feature protection costs.

- If the set of no protection strategies were assumed, the project benefits would be reduced by 1%. Although some of the road features would be totally protected with the project, the damages to roads are not eliminated because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a consistent solution to flooding in the basin.

II.1.4.2.2 Project Costs

The project costs for the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures alternative include:

- Construction costs, at $58.5 million.

- Total present worth operation and maintenance costs for the West Bay outlet, at $6.0 million. Average operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.

- Construction of upper basin flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes, at $39.7 million.

- Expansion of the existing flood protection measures to ensure safe protection of features adjacent to Devils Lake, at $12.8 million present worth value.

- Operation and maintenance costs for interior drainage behind the levees, at $1.8 million present worth, based on estimated yearly costs.
- Natural resource monitoring and mitigation costs along the downstream rivers, a present worth cost of $22.6 million.

The combined present worth cost of the project ($141.4 million) is annualized for a total $9.5 million annual cost for the 50-year planning period.

II.1.4.2.3 Net Benefit

The combined annual net benefit (the sum of individual benefits) of this alternative using the set of most likely action strategies equals the benefits ($4.4 million) less the costs ($9.5 million), or –$5.1 million. The BCR is $4.4 million/$9.5 million = 0.46. The average annual costs exceed the average annual benefits, therefore the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures alternative is not economically justified using the set of most likely action strategies.

The net benefits for this alternative range from -$6.7 to $1.1 million depending on the sets of flood protection strategies. The BCRs range from 0.29 to 1.12. The only set of flood protection strategies under which the alternative is economically justified is the set of maximum protection strategies.

II.1.4.2.4 Discussion of Results

This combination of the West Bay outlet with Upper Basin Management and Expanded Infrastructure Measures alternative is generally not economically feasible as a combined plan for flood protection of features within the basin. The inclusion of the Upper Basin Management and West Bay outlet project decreases the net benefits, which results in the combination not reaching economic feasibility. The net benefits of the Expanded Infrastructure Measures alternative alone are economically justifiable, and may be selected over this combination. However, the effectiveness of the combination alternative in reducing the lake level and reducing the damages is greater than the effectiveness of the Expanded Infrastructure Measures alternative. A comparison of the cost-effectiveness between alternatives should weigh all of these factors.

II.2.0 Wet Future Scenario Analysis Results

II.2.1 Wet Future Scenario Analysis Comparison

A comparison of the net benefits between alternatives should consider these factors:

- The net benefits provided by the alternatives
- The effectiveness of the alternative in reducing the lake levels and thereby reducing the damages adjacent to the lake and the costs for protecting features
- The effectiveness of the alternative in reducing the downstream damages
- The financial risk for the investment of Federal funds that is associated with implementation of the alternative

II.2.1.1 Economic Benefit of Alternatives

Table II.WF-1 compares the costs and benefits of the various alternatives under the Wet Future Scenario analysis. All economics indices were computed using the same computations of benefits that include downstream impacts. Under the Wet Future Scenario analysis, all of the alternatives are economically feasible.

Under the Wet Future Scenario analysis, the 480 cfs unconstrained outlets provide the largest net benefits of the alternatives evaluated. These outlets are the most effective at reducing the lake levels, and provide a positive net benefit. The alternative with the largest net benefits is for the East End Outlet (WF-10)—at $18.3 million annually. The West Bay and Pelican Lake 480 cfs unconstrained outlets have annual net benefits similar to the East End 480 cfs unconstrained outlet. These unconstrained outlets also have relatively higher risks to the downstream rivers than the 300 cfs constrained outlets since the water that is released is not constrained by downstream water quality and quantity standards. The East End outlet poses the highest risk to downstream features, since the water quality is poorer at the East End of Devils Lake.

The West Bay and Pelican Lake 300 cfs constrained outlets have slightly smaller annual net benefits than the 480 cfs unconstrained outlets, although the benefits are still very high. The project costs are smaller than the 480 cfs unconstrained outlets, indicating a smaller financial risk for investment of Federal funds. These outlets may also have fewer risks to the downstream rivers than the 480 cfs outlet since the water that is released is constrained by downstream water quality and quantity standards.

The Expanded Infrastructure Measures alternative (WF-2b) and the Upper Basin Management alternative (WF-1) also produce a BCR that is greater than one, although the net benefits are much less (at $0.2 million and $0.5 million, respectively). The Raise Natural Outlet alternative (WF-11) shows net benefits of $2.4 million. However, the annual net benefits may not accurately represent the costs for

induced damages around the lake (which could be highly variable). There is also a risk associated with the additional environmental, social, and economic impacts within the basin.

II.2.1.2 Lake Level Probabilities

Table II.WF-2 compares the effectiveness of the various alternatives on reducing the peak lake levels. As expected, the 480 cfs unconstrained outlets have the most impact on the lake levels—to a peak elevation of 1452. The results also indicate that both the Pelican Lake and West Bay 300 cfs constrained outlets have the same effect of reducing the peak lake level to 1457. In both cases, the 300 cfs outlets can only reduce the peak lake level by 3 feet under this Wet Future Scenario.

The Expanded Infrastructure Measures and Upper Basin Management alternatives do not reduce the peak lake levels—the peak lake levels are the same as for the without-project conditions (within the accuracy of this model).

II.2.1.3 Economic Benefit of Alternatives on Features Adjacent to Devils Lake

All of the alternatives (except the Raise Natural Outlet alternative) are designed to reduce the flood protection measures that are required to protect features adjacent to the lake. The Raise Natural Outlet alternative reduces the downstream damages, at the expense of increasing the damages adjacent to the lake. Under this alternative, damages to adjacent lake features are increased. The increase in these damages was counted as a project cost.

As described in Part I, Section I.4.3.2, the set of most likely action strategies were assumed as protection measures under both without- and with-project conditions. Table II.WF-3 compares the effectiveness of the various alternatives on reducing the feature damages and the costs for feature protection adjacent to Devils Lake.

The alternatives with the largest reduction in feature damages (56% reduction) and cost savings (70% reduction) are the 480 cfs unconstrained outlets (WF-4, WF-6, WF-10). The 300 cfs constrained outlet alternatives provide about 33% reduction in feature damages and 40% cost savings. The Upper Basin Management alternative (WF-1) reduces average damages by about 5% and avoids about 6% of the feature protection costs.

The Expanded Infrastructure Measures alternative (WF-2b) provides 0.2% reduction in damages (the features are protected both with and without the project). However, the costs avoided by the project are increased by an average of 11%.

II.2.1.4 Economic Benefit of Alternatives on Features Downstream of Devils Lake

A natural overflow occurs during the Wet Future Scenario under without project conditions. Therefore, most of the alternatives modify the timing, water quality, and/or volume of flows that are discharged to the Sheyenne River and Red River of the North. The computed effect that these changes in flows have on the downstream river water users is listed in Table II.WF-4.

The Percent of Downstream Damages Avoided was computed for comparison between alternatives. However, this number is computed based on the without-project condition damages (which are not always zero) and the assumptions for without-project condition damages vary depending on the damage category. Therefore, the percentages should be used for comparison purposes between alternatives, but not for an exact computation of reduction of downstream damages.

The Expanded Infrastructure Measures (WF-2b) alternatives have no impact on downstream features, since they do not alter the lake levels or the natural overflows. The Upper Basin Management alternative (WF-1) does reduce the downstream impacts, but has less effect than the outlet alternatives. The Raise Natural Outlet alternative removes the overflow under the Wet Future Scenario, which essentially eliminates the downstream impacts.

The 300 cfs constrained outlet alternatives show the largest downstream benefits (19%) by eliminating the natural overflow and constraining the pumped outlet concentrations, thereby reducing the damages to downstream features. The largest increase comes from the reduction of municipal water treatment facility operation costs as a result of the decreased total dissolved solids.

The Pelican Lake 480 cfs unconstrained outlet is the only 480 cfs outlet that has positive impacts to downstream features. Both the West Bay and the East End 480 cfs unconstrained outlets have a net negative impact on downstream features. The East End Outlet may have the greatest potential impacts to the downstream rivers, because of the location on the East End of Devils Lake, where the water quality may be much worse than predicted.

II.2.2 Wet Future Scenario Analysis : Alternatives within the Basin

This section includes a discussion of the results for each alternative. A comparison of these results to those under various sets of flood protection strategies for features is also included in this section. Although this comparison was conducted as a sensitivity analysis, the discussion fits in with the other results.

II.2.2.1 Economic Analysis of Upper Basin Management (WF-1)

The detailed results of the Upper Basin Management Wet Future Scenario analysis are listed in the Tabular Data document, Tables TD.3.WF-1.1 through TD.3.WF-1.11.

II.2.2.1.1 Project Benefits

The Upper Basin Management alternative reduces the peak lake level by less than one foot under the wet future analysis.

The benefits of Upper Basin Management (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated annual cost savings of $2.4 million due to reduced flood protection measures using the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 6%.

- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages due to Upper Basin Management were computed to be $0.2 million. This is about a 5% decrease in total damages.

- Damages Prevented to Downstream Features: The reduction in natural overflows from Devils Lake prevents $0.6 million of damages to downstream features (4% of the total damages).

The combined annual benefits (the sum of the individual benefits) of this Upper Basin Management alternative are $3.2 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are about 20% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are smaller.

- The set of maximum protection strategies decrease the project benefits by about 45%, primarily because the costs for protection are high under both with- and without-project conditions.

- If the set of no protection strategies were assumed, the project benefits would increase by 16%. The project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.2.2.1.2 Project Costs

The project costs for the Upper Basin Management alternative are $39.7 million for construction of flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes. The present worth of the project is annualized for a total $2.7 million annual cost for the 50-year planning period.

II.2.2.1.3 Net Benefits

Using the set of most likely action strategies for the features adjacent to Devils Lake, the annual net benefit equals the benefits ($3.2 million) less the costs ($2.7 million), or $0.5 million, i.e., the annual benefits exceed the annual costs. The BCR is $3.2 million/$2.7 million = 1.20. Because the net benefits are positive, the Upper Basin Management alternative is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis.

The net benefits for this alternative are not changed significantly under the other sets of flood protection strategies. The net benefits range from -$0.7 to $1.0 million and the BCRs range from 0.74 to 1.39. This alternative is economically justified under the sets of no flood protection and most likely action strategies.

II.2.2.1.4 Discussion of Results

The results indicate that this alternative may be economically feasible under the Wet Future Scenario, depending on the set of feature strategies. The project would require coordination and negotiation with the upper basin landowners. This coordination would be long-term because of the modification of flood control structures once the lake recedes.

This alternative assumes that 50% of the storage that is available in the upper watershed is placed into an upper basin storage program. Increasing the storage that is placed into this program would be more costly (since more prime farmland would be required). Therefore, it is unlikely that increasing the storage would make this alternative economically feasible. Decreasing the storage that is placed into this program would drop the effectiveness of reducing the damages to features adjacent to the lake, therefore it is likely that the benefits would decrease along with the decreased costs, resulting in a project that is not economically justified.

II.2.2.2 Economic Analysis of Expanded Infrastructure Measures (WF-2b)

The detailed results of the Expanded Infrastructure Measures Wet Future Scenario analysis are listed in the Tabular Data document, Tables TD.3.WF-2b.1 through TD.3.WF-2b.11.

II.2.2.2.1 Project Benefits

The Expanded Infrastructure Measures alternative has no computed effect on the peak lake levels. Similarly, this alternative will not reduce the natural overflows from Devils Lake. Therefore this alternative has no downstream impacts.

The benefits of the Expanded Infrastructure Measures alternative are primarily the reduction in the costs for flood protection measures using the set of most likely action strategies. The annual cost savings (estimated to be $4.3 million) reduces the protection costs for the features adjacent to Devils Lake by about 11%. There is also a slight reduction in annual infrastructure damages, computed to be about $0.01 million (a 0.2% decrease in total damages adjacent to the lake).

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are more than 70% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are significantly smaller.
- The set of maximum protection strategies doubles the project benefits by reducing the feature protection costs. The construction of the perimeter dikes and roads as levees has more net benefits than the protection measure that raises roads.
- If the set of no protection strategies were assumed, the project benefits would be reduced by 90%. The only benefit is the protection of several homes and land. Although some of the road features would be protected with the project, the damages to roads are not eliminated because all other roads

in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a realistic solution to flooding in the basin.

II.2.2.2.2 Project Costs

The present worth costs for implementation of the Expanded Infrastructure Measures alternative is $54.8 million for expansion of the existing flood protection measures to ensure safe protection of features adjacent to Devils Lake. These costs would occur as necessary due to the rising lake, therefore the up-front costs for this alternative are not high and the financial risks are low.

Operation and maintenance costs for interior drainage behind the new levees was computed to be $6.0 million present worth. The present worth of the project is annualized for a total $4.1 million annual cost for the 50-year planning period.

II.2.2.2.3 Net Benefit

The annual net benefits of this alternative using the set of most likely action strategies equals the benefits ($4.3 million) less the costs ($4.1 million), or $0.2 million. The BCR is $4.3 million/$4.1 million = 1.06. Because the net benefits are positive, the Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis.

The net benefits for this alternative range from -$3.6 to $4.2 million depending on the sets of flood protection strategies. The BCRs range from 0.10 to 2.03. The alternative is not economically justified for the set of no flood protection and cost-effective strategies.

II.2.2.2.4 Discussion of Results

The Expanded Infrastructure Measures alternative is economically feasible as a plan for flood protection of the features that are currently being protected by roads that were not designed as dams. This is similar to the results computed by the *Spirit Lake Nation Report, Barr Engineering Company, 1998*. Further analysis of this alternative in 2000 confirmed the economic feasibility—*Roadways Serving as Water Barriers, Devils Lake Transportation Task Force, May 2000*.

II.2.2.3 Economic Analysis of Raise Natural Outlet (WF-11)

The detailed results of the Raise Natural Outlet alternative are listed in the Tabular Data document, Tables TD.3.WF-11.1 through TD.3.WF-11.11.

II.2.2.3.1 Project Benefits

The Raise Natural Outlet alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level. Since the Wet Future Scenario trace does overflow under without-project conditions, the peak lake level would rise higher under this alternative than for the without-project conditions.

The overall benefits of raising the natural outlet (using the set of most likely action strategies) are exclusively a function of damages prevented to downstream features. The natural overflows from Devils Lake would be eliminated under this alternative. The related prevention of damages to downstream features is about $3.4 million annually (a reduction of 22% of the downstream damages as computed by the model—in essence 100% of all downstream damages related to Devils Lake outflow are eliminated).

Compared to the benefits under the set of most likely action strategies, all of the other sets of strategies have nearly identical project benefits (within 3%)—the primary benefits are related to downstream features, which do not change with the sets of strategies for features adjacent to the lake.

II.2.2.3.2 Project Costs

The financial risks associated with this alternative are the total project costs ($15.9 million), which occur at project implementation. These costs include:

- Construction costs, at $1.1 million for the permanent weir.
- Total present worth operation and maintenance costs of $0.07 million for the weir. Operation and maintenance costs were computed as 1% of the first costs.
- Purchase of land between elevation 1460.8 (the without-project flood level) and 1463, at a cost of $27.7 million.
- Costs for incremental protection for features above the without-project flood level of 1460.8, on an as-needed basis. The total present worth cost for these protection measures was $100.1 million.

The total present worth of the project is annualized for a total $1.1 million annual cost for the 50-year planning period.

II.2.2.3.3 Net Benefits

The annual net benefits under the Wet Future Scenario analysis are $3.4 million. The BCR for this alternative is 3.24 under the Wet Future Scenario analysis.

Construction of the Raise Natural Outlet alternative is economically feasible under the Wet Future Scenario analysis (under the assumption that project costs would include damages between 1460.6 and 1463). The net benefits range from $2.4 to $2.5 million depending on the sets of flood protection strategies. The BCRs range from 3.2 to 3.7.

II.2.2.3.4 Discussion of Results

The Wet Future Scenario results indicate that the Raise Natural Outlet alternative is economically feasible under the Wet Future Scenario analysis. However, the annual net benefits may not accurately represent the costs for induced damages around the lake (which could be highly variable). There is also a risk associated with the additional environmental, social, and economic impacts within the basin.

II.2.3 Wet Future Scenario Analysis : Outlet Alternatives

II.2.3.1 Economic Analysis of West Bay Outlets (WF-3 and WF-4)

The detailed results of the West Bay outlet Wet Future Scenario analyses are listed in the Tabular Data document. Tables TD.3.WF-3.1 through TD.3.WF-3.11 list the data for the West Bay 300 cfs constrained outlet alternative. Tables TD.3.WF-4.1 through TD.3.WF-4.11 list the data for the West Bay 480 cfs unconstrained outlet alternative.

II.2.3.1.1 Project Benefits

The West Bay 480 cfs unconstrained outlet reduces the peak lake level by 8 feet and the West Bay 300 cfs constrained outlet reduces the peak lake level by 3 feet.

The benefits of the West Bay outlets (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated annual cost savings of $15.5 and $27.4 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 32% (300 cfs) and 56% (480 cfs).

- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages were computed at $1.3 and $2.3 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This represents a decrease of about 39% and 70% for damages to adjacent lake features, respectively.

- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The 300 cfs constrained outlet reduces the annual downstream damages by $3.0 million. This is about a 19% decrease in total damages. The 480 cfs unconstrained outlet increases the annual downstream damages by $0.9 million. This is about a 6% increase in total damages, primarily due to the increased costs for municipal water treatment facilities to treat the increased concentration of total dissolved solids (which accounts for 97% of the total increase).

The combined annual benefit (the sum of the individual benefits) of the West Bay 300 cfs constrained outlet is $19.7 million. The West Bay 480 cfs unconstrained outlet has a much larger combined annual benefit of $28.8 million (primarily because of the added protection to adjacent lake features).

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are 36 to 40% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are smaller.

- The set of maximum protection strategies decrease the project benefits by 41 to 79%, primarily because the cost savings are less.
- If the set of no protection strategies were assumed, the project benefits would decrease by 24% for the 300 cfs constrained outlet—the project cannot keep up with the rising lake, and more damages occur under the set of no protection strategies. The project benefits would increase by 41% for the 480 cfs unconstrained outlet under the set of no protection strategies—the 480 cfs outlet project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.2.3.1.2 Project Costs

The project costs for the West Bay outlets include:

- Construction costs, at $58.5 million for the 300 cfs constrained outlet or $92.2 million for the 480 cfs unconstrained outlet.
- Total present worth operation and maintenance costs for the West Bay outlets, at $14.3 million for the 300 cfs constrained outlet and $24.5 million for the 480 cfs unconstrained outlet. Operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed, at $15.4 million present worth.
- Natural resource monitoring and mitigation costs along the downstream rivers, a present worth cost of $22.6 million for the 300 cfs constrained outlet or $50.4 million for the 480 cfs unconstrained outlet.

The investment of Federal funds for these outlet alternatives results in a high financial risk. The total estimated present worth costs for the West Bay 300 cfs constrained outlet alternative are $95.5 million, and are annualized for a total of $6.4 million for the 50-year planning period. The total estimated present worth costs for the West Bay 480 cfs unconstrained outlet are much larger ($182.5 million) for a total of $12.2 million annual costs for the 50-year planning period.

II.2.3.1.3 Net Benefit

The net benefit equals the benefits of the alternative less the costs of the alternative. Using the set of most likely action strategies for local flood protection, the West Bay 300 cfs constrained outlet has a net benefit of $13.3 million, i.e., the annual benefits exceed the annual costs. The BCR is $19.7 million/$6.4 million = 3.09. Because the net benefits are positive, the West Bay 300 cfs constrained outlet alternative is economically justified using the set of most likely action strategies according to the Wet Future Scenario analysis.

The West Bay 480 cfs unconstrained outlet has significantly larger costs and benefits. The net benefit is computed at $16.6 million, i.e., the annual benefits exceed the annual costs. The net benefits for the

480 cfs unconstrained outlet are larger than the net benefits for the 300 cfs constrained outlet under the Wet Future Scenario analysis. The BCR is $28.8 million/$12.2 million = 2.37. The West Bay 480 cfs unconstrained outlet alternative is economically justified using the set of most likely action strategies according to the Wet Future Scenario analysis.

The net benefits for these alternatives vary greatly under all of the sets of flood protection strategies, all resulting in positive net benefits. For the 300 cfs constrained outlet, the net benefits range from $0.7 to $9.2 million and the BCR ranges from 1.1 to 2.5 for the other sets of flood protection strategies. The net benefits are the largest under the set of most likely action strategies. The 480 cfs unconstrained outlet net benefits range from $7.6 to $28.7 million and the BCR ranges from 1.5 to 3.4. The set of no protection strategies has the largest net benefits ($28.7 million) and a BCR of 3.4. The results indicate that both of these outlet alternatives are economically justified under any of the sets of flood protection strategies.

II.2.3.1.4 Discussion of Results

The results indicate that both of the West Bay outlet alternatives are economically feasible under the Wet Future Scenario analysis. The 480 cfs unconstrained outlet has a relatively higher environmental risk to the downstream rivers than the 300 cfs constrained outlet, because the water that is released is not constrained by downstream water quality and quantity standards. However, the 480 cfs unconstrained outlet is more effective at reducing damages that are adjacent to the lake.

The West Bay 480 cfs unconstrained outlet provides more net benefits than the 300 cfs constrained outlet, because it is able to have a greater impact on reducing the lake level under this Wet Future Scenario analysis.

II.2.3.2 Economic Analysis of Pelican Lake Outlets (WF-5 and WF-6)

The detailed results of the Pelican Lake outlet Wet Future Scenario analyses are listed in the Tabular Data document. Tables TD.3.WF-5.1 through TD.3.WF-5.11 list the data for the Pelican Lake 300 cfs constrained outlet alternative. Tables TD.3.WF-6.1 through TD.3.WF-6.11 list the data for the Pelican Lake 480 cfs unconstrained outlet alternative.

II.2.3.2.1 Project Benefits

The Pelican Lake 480 cfs unconstrained outlet reduces the peak lake level 8 feet. The Pelican Lake 300 cfs constrained outlet has slightly less effect, reducing the peak lake level by 3 feet.

The benefits of the Pelican Lake outlets (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated annual cost savings of $17.5 and $27.6 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 39% (300 cfs) and 70% (480 cfs).

- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages were computed at $1.4 and $2.3 million, respectively, for the 300 cfs constrained and the 480 cfs unconstrained outlets under the set of most likely action strategies. This represents a decrease of about 32% and 56% for damages to adjacent lake features, respectively.

- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The 300 cfs constrained outlet reduces the annual downstream damages by $3.0 million. This is about a 19% decrease in total damages. The 480 cfs unconstrained outlet decreases the annual downstream damages by $0.3 million. This is about a 2% decrease in total damages, primarily due to the decreased damages to irrigated crops.

The combined annual benefit (the sum of the individual benefits) of the Pelican Lake 300 cfs constrained outlet is $21.9 million. The Pelican Lake 480 cfs unconstrained outlet has a much larger combined annual benefit of $30.2 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are 35 to 37% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are smaller.

- The set of maximum protection strategies decrease the project benefits by 34 to 42%, primarily because the cost savings are less.

- If the set of no protection strategies were assumed, the project benefits are 10% smaller for the 300 cfs constrained outlet and are 40% larger for the 480 cfs unconstrained outlet.

II.2.3.2.2 Project Costs

The project costs for the Pelican Lake outlets include:

- Construction costs, at $84.2 million for the 300 cfs constrained outlet or $129.2 million for the 480 cfs unconstrained outlet.

- Total present worth operation and maintenance costs for the Pelican Lake outlets, at $17.2 million for the 300 cfs constrained outlet and $26.9 million for the 480 cfs unconstrained outlet. Operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.

- Construction costs to raise control structures along Highway 281 and Highway 19, at $6.4 million for the 300 cfs constrained outlet or $0.5 million for the 480 cfs unconstrained outlet.

- Total present worth operation and maintenance costs for the Pelican Lake Highway control structures, at $0.4 million for both the 300 cfs constrained and the 480 cfs unconstrained outlets. Annual maintenance costs were assumed to be 0.5% of the first costs.
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed, at $13.0 million present worth.
- Natural resource monitoring and mitigation costs along the downstream rivers, a present worth cost of $22.6 million for the 300 cfs constrained outlet or $50.4 million for the 480 cfs unconstrained outlet.

The total estimated present worth costs for the Pelican Lake 300 cfs constrained outlet alternative are $130.7 million, and are annualized for a total of $8.7 million for the 50-year planning period. The total estimated present worth costs for the Pelican Lake 480 cfs unconstrained outlet are much larger ($219.6 million) for a total of $14.7 million annual costs for the 50-year planning period.

II.2.3.2.3 Net Benefit

The net benefit equals the benefits of the alternative less the costs of the alternative. Using the set of most likely action strategies for local flood protection, the Pelican Lake 300 cfs constrained outlet has a net benefit of $13.2 million, i.e., the annual benefits exceed the annual costs. The BCR is $21.9 million/$8.7 million = 2.51. Because the net benefits are positive, the Pelican Lake 300 cfs constrained outlet alternative is economically justified using the set of most likely action local protection strategies according to the Wet Future Scenario analysis.

The Pelican Lake 480 cfs unconstrained outlet has significantly larger costs and benefits. The net benefit is computed at $15.5 million, i.e., the annual benefits exceed the annual costs. The net benefits for the 480 cfs unconstrained outlet are larger than the net benefits for the 300 cfs constrained outlet under the Wet Future Scenario analysis. The BCR is $30.2 million/$14.7 million = 2.06. The Pelican Lake 480 cfs unconstrained outlet alternative is economically justified using the set of most likely action strategies according to the Wet Future Scenario analysis.

The net benefits for these alternatives vary greatly under all of the sets of flood protection strategies, all resulting in positive net benefits. For the 300 cfs constrained outlet, the net benefits range from $1.8 to $12.2 million and the BCR ranges from 1.2 to 2.4 for the other sets of flood protection strategies. The net benefits are the largest under the set of most likely action strategies. The 480 cfs unconstrained outlet net benefits range from $4.7 to $27.1 million and the BCR ranges from 1.3 to 2.9. The set of no protection strategies has the largest net benefits ($27.1 million) and a BCR of 2.9. The results indicate that both of these outlet alternatives are economically justified under any of the sets of flood protection strategies.

II.2.3.2.4 Discussion of Results

The results indicate that both of the Pelican Lake outlet alternatives are economically feasible under the Wet Future Scenario analysis. The Pelican Lake outlets have the least environmental risk to downstream features (of the outlets analyzed), because the water is generally taken from the Big Coulee and not from

Devils Lake. The 480 cfs unconstrained outlet has a relatively higher environmental risk to the downstream rivers than the 300 cfs constrained outlet, because the water that is released is not constrained by downstream water quality and quantity standards. However, the 480 cfs unconstrained outlet is more effective at reducing damages for features that are adjacent to the lake.

The financial risks of the Pelican Lake outlets are the largest of the outlet alternatives (the costs are the largest).

II.2.3.3 Economic Analysis of East End Outlet (WF-10)

The detailed results of the East End Wet Future Scenario analyses are listed in the Tabular Data document. Tables TD.3.WF-10.1 through TD.3.WF-10.11 list the data for the East End 480 cfs unconstrained outlet alternative.

II.2.3.3.1 Project Benefits

The East End outlet reduces the peak lake level by 8 feet.

The benefits of the East End outlet (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated annual cost savings of $27.4 million under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 70%.
- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages were computed at $2.3 million under the set of most likely action strategies. This represents a decrease of about 56% for damages to adjacent lake features.
- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The annual downstream damages are increased under the 480 cfs unconstrained outlet by $1.5 million. This is about a 10% increase in total damages, primarily due to the increased damages to municipal water treatment facilities to treat the increased concentration of solids.

The combined annual benefit (the sum of the individual benefits) of the East End 480 cfs unconstrained outlet is $28.2 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are 37% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are smaller.

- The set of maximum protection strategies decrease the project benefits by 44%, primarily because fewer costs are avoided (the outlet cannot delay the costs for maximum protection at the first action level).
- If the set of no protection strategies were assumed, the project benefits would increase by 43%. The project is able to reduce more damages adjacent to the lake because nothing is protected by other measures.

II.2.3.3.2 Project Costs

The project costs for the East End 480 cfs unconstrained outlet include:

- Construction costs at $57.4 million.
- Total present worth operation and maintenance costs for the East End outlet, at $0.5 million. Operating and maintenance costs were assumed to be 1% of the first costs.
- Alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480 cfs unconstrained outlet is installed, at $39.6 million present worth.
- Natural resource monitoring and mitigation costs along the downstream rivers, a present worth cost of $50.4 million.

The total estimated present worth costs for the East End 480 cfs unconstrained outlet alternative are $148.0 million, and are annualized for a total of $9.9 million for the 50-year planning period.

II.2.3.3.3 Net Benefit

Using the set of most likely action strategies for local flood protection, the net benefit equals the benefits ($28.2 million) less the costs ($9.9 million), or $18.3 million, i.e., the annual benefits exceed the annual costs. The BCR is $28.2 million/$9.9 million = 2.85. Because the net benefits are positive, the East End 480 cfs unconstrained outlet is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis.

The net benefits for this alternative range from $6.0 to $33.6 million under the other sets of flood protection strategies and the BCR ranges from 1.6 to 4.4. This alternative is economically justified under all of the sets of flood protection strategies.

II.2.3.3.4 Discussion of Results

The results indicate that the East End outlet alternative is economically feasible under the Wet Future Scenario analysis. The 480 cfs unconstrained outlet has a very high environmental risk to the downstream rivers because the water that is released is not constrained by downstream water quality and quantity standards. Water released from this end of the lake typically has much higher TDS concentrations than other portions of the lake.

The up-front financial risks for this alternative are relatively low compared to the other outlets analyzed (the costs are smaller than other outlet costs).

II.2.4 Wet Future Scenario Analysis : Combination Alternatives

II.2.4.1 Economic Analysis of Upper Basin Management and Expanded Infrastructure Measures (WF-7b)

The detailed results of this Wet Future Scenario analysis are listed in the Tabular Data document—Tables TD.3.WF-7b.1 through TD.3.WF-7b.11.

II.2.4.1.1 Project Benefits

This combination alternative reduces the peak lake level by less than one foot.

The benefits of this combination alternative under the set of most likely action strategies are a function of:

- Costs Avoided: Estimated annual cost savings of $6.5 million due to reduced flood protection measures under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 16%.
- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages were computed at $0.2 million under the set of most likely action strategies. This represents a decrease of about 6% for damages to adjacent lake features.
- Damages Prevented to Downstream Features: Modification to the downstream damages due to the increase in concentrations and flows during outlet operation, which can be offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The annual downstream damages are decreased by $0.6 million. This is about a 4% decrease in total damages, primarily due to the decreased damages to municipal water treatment facilities to treat the increased concentration of solids.

The combined annual benefits (the sum of the individual benefits) for this alternative are $7.3 million.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are about 50% smaller—the damages prevented under the cost-effective strategies are smaller (in fact they are negative, indicating increased damages with the project) and the cost savings using the cost-effective strategies are smaller.
- The set of maximum protection strategies increase the project benefits by 38% by reducing the feature protection costs. The construction of the perimeter dikes and roads as levees has more net benefits than the protection measure that raises roads.

- If the set of no protection strategies were assumed, the project benefits would be reduced by 44%. Although some of the road features would be totally protected with the project, the damages to roads are not eliminated because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a consistent solution to flooding in the basin.

II.2.4.1.2 Project Costs

The project costs for the combination Upper Basin Management and Expanded Infrastructure Measures alternative include:

- Construction of upper basin flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes, at $39.7 million.
- Expansion of the existing flood protection measures to ensure safe protection of features adjacent to Devils Lake, at $51.7 million present worth value.
- Operation and maintenance costs for interior drainage behind the new levees, at $5.8 million present worth, based on estimated yearly costs.

The combined present worth cost of the project ($97.2 million) is annualized for a total $6.5 million annual cost for the 50-year planning period.

II.2.4.1.3 Net Benefit

Using the set of most likely action strategies the net benefit equals the benefits ($7.3 million) less the costs ($6.5 million), or $0.8 million. The BCR is $7.3 million/$6.5 million = 1.13. The annual benefits exceed the annual costs, therefore the combination Upper Basin Management and Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies.

The net benefits for this alternative range from -$2.7 to $3.8 million depending on the sets of flood protection strategies. The BCRs range from 0.59 to 1.58 for the other sets of flood protection strategies. The alternative is not economically justified under the sets of no flood protection and the set of cost-effective strategies.

II.2.4.1.4 Discussion of Results

This combination Upper Basin Management and Expanded Infrastructure Measures alternative is economically feasible as a combined plan for flood protection of features within the basin. Each of the component projects is also economically feasible as a standalone alternative. The effectiveness of the combination alternative in reducing damages and costs is greater than the projects alone.

II.2.4.2 Economic Analysis of West Bay Lake Outlet with Upper Basin Management and Expanded Infrastructure Measures (WF-8b)

The detailed results of this Wet Future Scenario analysis are listed in the Tabular Data document—Tables TD.3.WF-8b.1 through TD.3.WF-8b.11.

II.2.4.2.1 Project Benefits

This combination alternative reduces the peak lake level by 4 feet.

The benefits of the alternative (using the set of most likely action strategies) are a function of:

- Costs Avoided: Estimated annual cost savings of $21.1 million under the set of most likely action strategies. This reduces the protection costs for the features adjacent to Devils Lake by 54%.
- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages were computed at $1.5 million under the set of most likely action strategies. This represents a decrease of about 35% for damages to adjacent lake features.
- Damages Prevented to Downstream Features: Reduction of the downstream damages because the increase in concentrations and flows during outlet operation are offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The annual downstream damages are reduced by $3.0 million. This is about a 19% decrease in total downstream damages.

Compared to the benefits under the set of most likely action strategies, the other sets of strategies provide the following results:

- Project benefits under the set of cost-effective strategies are about 39% smaller—the reduction in damages under the cost-effective strategies is greater but the cost savings using the cost-effective strategies are significantly smaller.
- The set of maximum protection strategies lower the project benefits by 33% by reducing the feature protection costs.
- If the set of no protection strategies were assumed, the project benefits would be reduced by 7%. Although some of the road features would be totally protected with the project, the damages to roads are not eliminated because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a consistent solution to flooding in the basin.

II.2.4.2.2 Project Costs

The project costs for the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures alternative include:

- Construction costs of the West Bay 300 cfs constrained outlet, at $58.5 million.

- Total present worth operation and maintenance costs for the West Bay outlet, at $13.8 million. Operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.
- Construction of upper basin flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes, at $39.7 million.
- Expansion of the existing flood protection measures to ensure safe protection of features adjacent to Devils Lake, at $28.3 million present worth value.
- Operation and maintenance costs for interior drainage behind the levees, at $4.2 million present worth, based on estimated yearly costs.
- Natural resource monitoring and mitigation costs along the downstream rivers, a present worth cost of $22.6 million.

The combined present worth cost of the project ($167.2 million) is annualized for a total $11.2 million annual cost for the 50-year planning period.

II.2.4.2.3 Net Benefit

The combined annual net benefit (the sum of individual benefits) of this alternative using the set of most likely action strategies equals the benefits ($25.5 million) less the costs ($11.2 million), or $14.3 million. The BCR is $25.5 million/$11.2 million = 2.28. The annual benefits exceed the annual costs, therefore the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies.

The net benefits for this alternative range from $4.4 to $12.7 million for the other sets of flood protection strategies. The BCRs range from 1.40 to 2.14. The alternative is economically justified under all of the sets of flood protection strategies.

II.2.4.2.4 Discussion of Results

This combination of the West Bay outlet with Upper Basin Management and Expanded Infrastructure Measures alternative is economically feasible as a combined plan for flood protection of features within the basin. The inclusion of each component project increases the net benefits. The net benefit of each component project alone indicates that each is economically justifiable.

II.3.0 Sensitivity Results

II.3.1 Local Flood Protection Strategies Adjacent to the Lake

The tables in Tabular Data document list the detailed results for the local flood protection strategies adjacent to the lake.

II.3.1.1 Economic Benefit of Alternatives Using Other Flood Protection Strategies

The comparison of the BCR and net benefits by using other local flood protection strategies was discussed in Sections II.2.0 under the results for each of the various alternatives.

In general, the set of cost-effective strategies provides approximately the same benefits as the set of most likely action strategies. This is expected, because the feature protection measures for the two sets of strategies are the same for many of the features.

Although the set of maximum protection strategies at the first action level could provide similar benefits as the sets of most likely action strategies, the maximum protection strategy is not likely to be implemented for any or all features. These large benefits require very large investments in local flood protection at a fairly low lake level. If the project can avoid or delay these expenditures, it may produce slightly larger benefits than if a smaller expenditure (i.e., a more cost-effective strategy) would have been planned. However, it could be extremely difficult to find the funding required for implementation of the maximum protection strategies.

The set of no flood protection strategies almost always provides the largest project benefit among the set of feature protection strategies. This is because the set of no protection strategies represents the minimum level of local flood protection effort. Therefore, the alternatives can prevent the most benefits (because nothing else is protecting the features around the lake). However, without the project, it appears that this set of strategies is unlikely to be implemented. Recent experience shows that local officials will likely locate funds for some flood protection projects and that these will probably be carefully selected to maximize damage reduction.

However, for the set of Expanded Infrastructure Measures alternatives, the set of no flood protection strategies provides minimal benefits. The only benefit is the protection of several homes and land. Although some of the road features would be protected with the project, the damages to roads are not reduced because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a realistic solution to flooding in the basin.

II.3.1.2 Effect of Using Other Flood Protection Strategies on Features Adjacent to Devils Lake

The effects of other local flood protection strategies on the features adjacent to Devils Lake was discussed in Sections II.2.0 under the results for each of the various alternatives.

II.3.2 Maximum Infrastructure Protection

The Maximum Infrastructure Protection sensitivity analysis indicates that all of the alternatives that include Maximum Infrastructure Protection provide positive annual net benefits (under both the stochastic and Wet Future Scenario analyses). When Maximum Infrastructure Protection alone is considered, the net benefits are larger than those of any other alternative. This is true both for the stochastic and the Wet Future Scenario analysis. The implementation of the Maximum Infrastructure Protection measures within the basin is therefore economically justified.

Combining Maximum Infrastructure Protection measures with other projects within the basin provides a larger net benefit under the Wet Future Scenario. This implies that the wetter the future, the more that multiple types of projects are required in the basin to relieve the flooding. By contrast, under the more moderate climate assumptions of the stochastic analysis, adding other projects to Maximum Infrastructure Protection results in a reduction of net benefits, suggesting that such additions to Maximum Infrastructure Protection are economically infeasible.

There is little financial risk with the Maximum Infrastructure Protection measures: the incremental protection measures are completed as required and the total project costs are spread over a several-year duration.

A shortcoming of implementing the Maximum Infrastructure Protection measures alone is that the measures do nothing to relieve the prolonged flooding problems while the wet period continues. This condition can be expected to be stressful for local agencies and residents.

II.3.2.1 Economic Analysis of Maximum Infrastructure Protection (ST-2a and WF-2a)

The detailed results of the Maximum Infrastructure Protection analyses are listed in the Tabular Data document, stochastic analysis results are listed in Tables TD.3.ST-2a.1 through TD.3.ST-2a.4 and Wet Future Scenario analysis results are listed in Tables TD.3.WF-2a.1 through TD.3.WF-2a.8.

II.3.2.1.1 Project Benefits

The Maximum Infrastructure Protection alternative has no computed effect on the peak lake levels. Similarly, this alternative will not reduce the natural overflows from Devils Lake. Therefore this alternative has no downstream impacts.

The benefits of the Maximum Infrastructure Protection alternative are limited to the reductions in infrastructure damages, which were computed to be $23.8 million under the stochastic analysis and

$73.6 million under the Wet Future Scenario analysis (using the set of most likely action strategies). These benefits represent a 95% decrease in total damages as a result of the flood protection measures, which are defined as the project.

The Maximum Infrastructure Protection alternative provides a comprehensive evaluation of the most likely actions for flood protection in the basin—the types of emergency measures that are currently being pursued in the basin were assumed to be the project. The without-project condition assumes no flood protection for the features. Therefore, no other sets of flood protection strategies were analyzed.

II.3.2.1.2 Project Costs

The costs for implementation of the Maximum Infrastructure Protection alternative vary, depending on the lake levels and corresponding protection measure that are required for the features. Under the stochastic analysis, the present worth costs are $136.7 million for construction of most likely action flood protection measures and Expanded Infrastructure Measures adjacent to Devils Lake. These costs increase to about $579.5 million under the Wet Future Scenario analysis. The costs would occur as necessary due to the rising lake, therefore there are no up-front costs for this alternative. Therefore, the financial risks are very low because the projects are constructed only when needed.

Operation and maintenance costs for interior drainage behind the levees were computed to be $2.0 million (present worth) under the stochastic analysis and $6.0 million (present worth) for the Wet Future Scenario analysis. The present worth of the project under the stochastic analysis is annualized for a total $9.3 million cost for the 50-year planning period. The annual costs expected under the Wet Future Scenario analysis are $39.1 million.

II.3.2.1.3 Net Benefit

The annual net benefit of this alternative, using the set of most likely action strategies and the Expanded Infrastructure Measures as the Maximum Infrastructure Protection, equals the benefits less the costs, or $14.6 million under the stochastic analysis and $34.5 million under the Wet Future Scenario analysis. The BCR is 2.57 for the stochastic analysis and 1.88 for the Wet Future Scenario analysis. Because the net benefits are positive, the Maximum Infrastructure Protection alternative is economically justified using the set of most likely action strategies under both the stochastic and Wet Future Scenario analyses.

II.3.2.1.4 Discussion of Results

As expected, the Maximum Infrastructure Protection alternative is economically feasible as a comprehensive plan for flood protection of features within the basin. However, it would be extremely difficult to provide centralized administration for a Maximum Infrastructure Protection effort. The complicated and difficult decision-making regarding individual features—currently accomplished autonomously and at a local level—would become the responsibility of a Federal agency. This responsibility would extend through many years, or perhaps indefinitely.

II.3.2.2 Economic Analysis of Upper Basin Management and Maximum Infrastructure Protection (ST-7a and WF-7a)

The detailed results of these analyses are listed in the Tabular Data document —Tables TD.3.ST-7a.1 through TD.3.ST-7a.4 list the stochastic analysis results: Tables TD.3.WF-7a.1 through TD.3.WF-7a.8 list the Wet Future Scenario results.

II.3.2.2.1 Project Benefits

This combination alternative has limited effect on reducing the peak lake level. Under the stochastic analysis of this alternative, the lake level drops about 1 foot between the 100% and 10% probability levels. Under the Wet Future Scenario analysis, the peak lake level drops 2 feet below the without-project conditions. Although this alternative will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features would occur only during traces that overflow (and the alternative does not prevent overflows from occurring). Under the stochastic analysis, less than 10% of the traces create an overflow. Therefore, the expected damages were assumed to be negligible and were therefore not computed under the stochastic analysis. The downstream damages are reduced by $0.6 million under the Wet Future Scenario analysis.

The benefits of this combination alternative are primarily a result of the reductions in infrastructure damages adjacent to the lake, which were computed to be $23.9 million under the stochastic analysis and $73.8 million under the Wet Future Scenario analysis (using the set of most likely action strategies). This is a 95% decrease in total damages as a result of the flood protection measures, which are defined as the Maximum Infrastructure Protection portion of the alternative.

This alternative includes Maximum Infrastructure Protection, which contains a comprehensive evaluation of the most likely actions for flood protection in the basin—the types of emergency measures that are currently being pursued in the basin were assumed to be the project. The without-project condition assumes no flood protection for the features. Therefore, no other sets of flood protection strategies were analyzed.

II.3.2.2.2 Project Costs

The project costs for the combination Upper Basin Management and Maximum Infrastructure Protection alternative include:

- Construction of upper basin flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes, at $39.7 million.
- Construction of most likely action flood protection measures and Expanded Infrastructure Measures for the features adjacent to Devils Lake, at $125.9 million present worth under the stochastic analysis and $543.8 million under the Wet Future Scenario analysis.

- Operation and maintenance costs for interior drainage behind the levees, at $1.9 million present worth under the stochastic analysis and $5.8 million under the Wet Future Scenario analysis (based on estimated yearly costs).

The combined present worth cost of the project under the stochastic analysis ($167.5 million) is annualized for a total $11.2 million annual cost for the 50-year planning period. The combined present worth cost of the project under the Wet Future Scenario analysis ($589.3 million) is annualized for a total $39.4 million annual cost for the 50-year planning period.

II.3.2.2.3 Net Benefit

The annual net benefit of this alternative using the set of most likely action strategies equals the benefits less the costs, or $12.7 million under the stochastic analysis and $35.1 million under the Wet Future Scenario analysis. The BCR under the stochastic analysis is 2.14, and under the Wet Future Scenario analysis is 1.89. Because the net benefits are positive, the combination Upper Basin Management and Maximum Infrastructure Protection alternative is economically justified using the set of most likely action strategies under both the analyses.

II.3.2.2.4 Discussion of Results

This combination Upper Basin Management and Maximum Infrastructure Protection alternative is economically feasible as a combined plan for flood protection of features within the basin. However, under the stochastic analysis the net benefits of the Maximum Infrastructure Protection alternative are greater than this combination and the inclusion of the Upper Basin Management project actually decreases the net benefits. Therefore, under the stochastic analysis the Maximum Infrastructure Protection alternative may be selected over this combination. This is not true under the Wet Future Scenario analysis, where both of these projects are economically feasible as stand-alone projects and when combined result in a larger net benefit than that for the component projects taken individually.

The effectiveness of the combination in reducing the lake level and potential downstream damages is greater than the effectiveness of the Maximum Infrastructure Protection alternative as a stand-alone project. A comparison of the cost-effectiveness between alternatives should consider all of these factors.

However, it would be extremely difficult to provide centralized administration for a Maximum Infrastructure Protection effort. The complicated and difficult decision-making regarding individual features—currently accomplished autonomously and at a local level—would become the responsibility of a Federal agency. This responsibility would extend through many years, or perhaps indefinitely.

II.3.2.3 Economic Analysis of West Bay Lake Outlet with Upper Basin Management and Maximum Infrastructure Protection (ST-8a and WF-8a)

The detailed results of these analyses are listed in the Tabular Data document—Tables TD.3.ST-8a.1 through TD.3.ST-8a.4 list the stochastic analysis results: Tables TD.3.WF-8a.1 through TD.3.WF-8a.8 list the Wet Future Scenario results.

II.3.2.3.1 Project Benefits

This combination alternative reduces the peak lake level about 3 feet at the 10% probability level and about 1 foot at the 50% probability level under the stochastic analysis. Under the Wet Future Scenario analysis, the peak lake level drops 6 feet below the without-project conditions.

The benefits of the alternative (using the set of most likely action strategies) are a function of:

- Damages Prevented to Features Adjacent to Devils Lake: The annual reductions in infrastructure damages were computed at $24.0 million under the stochastic analysis and $75.0 under the Wet Future Scenario analysis (under the set of most likely action strategies). This represents a decrease of about 96 to 97% for damages to adjacent lake features: the large reduction in damages is due to the Maximum Infrastructure Protection portion of the alternative.

- Damages Prevented to Downstream Features: Reduction of the downstream damages because the increase in concentrations and flows during outlet operation are offset by the outlet's capability to reduce flows (and therefore concentrations) during the natural overflows from Devils Lake. The annual downstream damages are reduced by $0.2 million under the stochastic analysis and $3.0 million under the Wet Future Scenario analysis. This is about a 1% decrease in downstream damages under the stochastic analysis and 19% decrease under the Wet Future Scenario analysis.

This alternative includes Maximum Infrastructure Protection, which contains a comprehensive evaluation of the most likely actions for flood protection in the basin—the types of emergency measures that are currently being pursued in the basin were assumed to be the project. The without-project condition assumes no flood protection for the features. Therefore, no other sets of flood protection strategies were analyzed.

II.3.2.3.2 Project Costs

The project costs for the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Maximum Infrastructure Protection alternative include:

- Construction costs of the West Bay 300 cfs constrained outlet, at $58.5 million.

- Total present worth operation and maintenance costs for the West Bay outlet, at $6.0 million under the stochastic analysis and $13.8 million under the Wet Future Scenario analysis. Operating costs were computed on the basis of the yearly volume of water pumped. Annual maintenance costs were assumed to be 1% of the first costs during years that the outlet is operating and 0.5% of the first costs during the years that the outlet is not operating.

- Construction of upper basin flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes, at $39.7 million.

- Construction of most likely action flood protection measures and Expanded Infrastructure Measures adjacent to Devils Lake, at $110.2 million present worth value under the stochastic analysis and $301.4 million under the Wet Future Scenario analysis.

- Operation and maintenance costs for interior drainage behind the levees, at $1.8 million present worth under the stochastic analysis and $4.2 million under the Wet Future Scenario analysis (based on estimated yearly costs).
- Natural resource monitoring and mitigation costs along the downstream rivers, a present worth cost of $22.6 million.

The combined present worth cost of the project under the stochastic analysis ($238.8 million) is annualized for a total $15.9 million annual cost for the 50-year planning period. The combined present worth cost of the project under the Wet Future Scenario analysis ($440.3 million) is annualized for a total $29.4 million annual cost for the 50-year planning period.

II.3.2.3.3 Net Benefit

The combined annual benefit (the sum of the individual benefits) of this alternative using the set of most likely action strategies equals the benefits less the costs, or $8.2 million under the stochastic analysis and $48.6 million under the Wet Future Scenario analysis. The BCR is 1.52 under the stochastic analysis and 2.65 under the Wet Future Scenario analysis. Because the net benefits are positive, the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Maximum Infrastructure Protection alternative is economically justified using the set of most likely action strategies under both of the analyses.

II.3.2.3.4 Discussion of Results

This combination of the West Bay outlet with Upper Basin Management and Maximum Infrastructure Protection alternative is economically feasible as a combined plan for flood protection of features within the basin. However under the stochastic analysis, the net benefits of the Maximum Infrastructure Protection alternative are greater than this combination. The inclusion of the Upper Basin Management project and the West Bay outlet actually decrease the net benefits under the stochastic analysis. Therefore, the Maximum Infrastructure Protection alternative may be preferred over this combination. Conversely, under the Wet Future Scenario analysis, all of the projects are economically justified as stand-alone projects and the combination provides a larger net benefit.

The effectiveness of the combination alternative in reducing the lake level and reducing the damages is greater than the effectiveness of the Maximum Infrastructure Protection alternative. A comparison of the cost-effectiveness between alternatives should consider all of these factors.

However, it would be extremely difficult to provide centralized administration for a Maximum Infrastructure Protection effort. The complicated and difficult decision-making regarding individual features—currently accomplished autonomously and at a local level—would become the responsibility of a Federal agency. This responsibility would extend through many years, or perhaps indefinitely.

II.3.3 Moderate and Dry Future Scenarios

II.3.3.1 Economic Benefit of Alternatives Based on Moderate and Future Scenarios

The costs and benefits for the Moderate and Dry Future Scenarios are listed in Tables II.M1-1, II.M2-1, and II.DR-1. In general, when the future is wetter, the net benefits and benefit-cost ratios (BCR) of the alternatives increase. This is because there are more potential damages and the project can prevent more damages and avoid more costs.

For example, the following table compares the BCRs and net benefits for the West Bay 300 cfs constrained outlet alternative. The results for other alternatives show a similar pattern between the analyses.

Economic Indices	West Bay 300 cfs Constrained Outlet Results (dollars in millions)				
	Stochastic Analysis	Wet Future Scenario	Moderate Future 2 Scenario (Peak Lake Level 1455)	Moderate Future 1 Scenario (Peak Lake Level 1450)	Dry Future Scenario
Net Benefit	-$4.2	$13.3	-$0.4	-$5.3	-$6.0
BCR	0.28	3.09	0.92	0.10	-0.04

However, the relative positioning of the alternatives based on the net benefits and BCRs appears to fluctuate, depending on the scenario. For example between the outlet alternatives, the West Bay 300 cfs constrained outlet has the highest BCR under the wet future scenario (3.09) but the East End 480 cfs unconstrained outlet has the highest net benefit under the wet future scenario ($18 million annually). Whereas for the Moderate Future 2, the Pelican Lake 300 cfs constrained outlet has both the highest BCR and net benefit of the outlet alternatives (1.38 and $3 million annually, respectively).

Therefore, the selection of the recommended plan must consider the scenario from which the decision will be based. The wet future scenario provides an estimate of the potential economic effects of prolonged wet climatic conditions.

II.3.3.2 Lake Level Probabilities Based on Moderate and Future Scenarios

Tables II.M1-2, II.M2-2, and II.DR-2 compare the effectiveness of the five alternatives on reducing the peak lake levels under the Moderate and Dry Future Scenarios. Under the Dry Future Scenario, all of the alternatives have nearly identical impact on reducing the peak lake levels. This is expected, since even under the without-project conditions the peak lake level only increases to 1448 (about two feet above the existing lake level).

Under the two Moderate Future Scenarios, the 480 cfs unconstrained outlets have the largest effect on reducing the peak lake level (a reduction from without-project conditions of 3 feet for Moderate Future 2 and 6 feet for Moderate Future 1). Under Moderate Future 1, the Pelican Lake 300 cfs constrained outlet has an effect on peak lake levels similar to that of the 480 cfs unconstrained outlet (because the water is

cleaner and its operation can keep up with the precipitation experienced under this future climatic condition.

II.3.3.3 Effect of Moderate and Future Scenarios on Features Adjacent to Devils Lake

Tables II.M1-3, II.M2-3, and II.DR-3 compare the effectiveness of Moderate and Dry Future Scenarios on reducing the feature damages and the costs for feature protection adjacent to Devils Lake. As expected, the wetter the future the more potential damages, therefore the alternatives can prevent more damages and avoid more costs adjacent to the lake.

The alternatives evaluated under the Moderate Future 2 Scenario show a greater reduction in adjacent lake damages than those same alternatives evaluated under the Moderate Future 1 or the Dry Future Scenarios. Similar to the effect on the lake levels, the 480 cfs unconstrained outlets have the largest effect on reducing the damages to adjacent lake features and the costs to protect these features.

II.3.3.4 Effect of Moderate and Dry Future Scenarios on Features Downstream of Devils Lake

Tables II.M1-4, II.M2-4, and II.DR-4 compare the effectiveness of Moderate and Dry Future Scenarios on reducing the damages to features downstream of Devils Lake. None of these lake level futures under without-project conditions result in an overflow from Devils Lake. Therefore, the implementation of any outlet project will show increased damages to downstream features.

All of the outlet alternatives that were analyzed show an increase in downstream damages, ranging from 1% to 44% increase above those under without-project conditions. The 480 cfs unconstrained outlets have the largest impacts on downstream features.

II.3.4 Erosion at Natural Outlet

The detailed results of this sensitivity analysis are listed in Tables II.ER-1 through II.ER-4.

II.3.4.1 Effects of Outlet Erosion on the Lake Level Probability

With erosion at the outlet, the peak lake level is reduced by only 0.17 feet under without-project conditions. However, the duration of high lake levels is much shorter; the analysis does show that lands adjacent to the lake would be relieved of flooding sooner if erosion occurs. A somewhat intangible benefit of this, and one that is not accounted for in the Economic Analysis, is that property owners would be able to return to their lands sooner. Conversely, if the natural outlet is prevented from eroding, access by property owners would be restricted for longer periods.

Under with-project conditions that prevent the overflow, the erosion of the outlet is not a consideration. Analysis of alternatives that do not prevent overflow was not completed for the erosion sensitivity analysis.

II.3.4.2 Effect of Outlet Erosion on the Economic Benefit of Alternatives

The results of this sensitivity analysis indicate that if erosion is considered, the net benefits of the alternatives are larger. The erosion of the natural outlet does not significantly change the economic results for the features adjacent to the lake. This is to be expected, because the modeling shows that the peak lake levels are only 0.17 feet lower than they would be if no erosion were assumed.

Downstream damages, however, increase significantly when erosion of the natural outlet occurs during overflows. If it were assumed, therefore, that there was no erosion protection in place at the outlet, alternatives that prevent an overflow would show larger net benefits. These alternatives would prevent the larger downstream damages. This suggests that the net benefits of all the alternatives that prevent an overflow may have been somewhat underrated in this Economic Analysis. The without-project condition was always assumed to include erosion protection at the natural outlet, so the benefits of preventing erosion (by preventing an overflow) were hidden.

The primary increase in damages due to erosion is flow-related in urban areas during the year that the overflow takes place (increasing by more than $4 million). The industrial water treatment and the urban flow-related damages increase by nearly 50%, municipal water treatment damages increase by about 8%, and other flow-related damages increase by 5% to 10%. The increase in damages occurs primarily during the first three years that the overflow takes place. By contrast, irrigation-related damages are decreased by nearly 60%. This decrease in damages is a result of fewer years of irrigated crop damage.

It should also be noted that the erosion of the natural outlet without-project analysis does not include the additional damages that would occur due to the displacement and transport of the eroded material (approximately 937,000 cubic yards). This eroded material may cause additional physical and environmental damages in the downstream channel (in addition to those damages tabulated in this analysis). Including those additional damages in the analysis would increase the net benefits of the alternatives.

Tables

Economic Analysis of Devils Lake Alternatives
Table II.ST-1

Stochastic Scenario Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
ST-1	Upper Basin Management	$2,650	$773	-$1,877	0.29	NA	NA	NA
ST-2b	Expanded Infrastructure Measures	$1,149	$2,410	$1,261	2.10	$2,410	$1,261	2.10
ST-3	West Bay 300 cfs Constrained Outlet	$5,847	$1,477	-$2,858	0.34	$1,641	-$4,205	0.28
ST-4	West Bay 480 cfs Unconstrained Outlet	$11,232	$3,414	-$3,527	0.49	$119	-$11,113	0.01
ST-5	Pelican Lake 300 cfs Constrained Outlet	$7,844	$2,771	-$3,562	0.44	$2,905	-$4,940	0.37
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	$13,824	$3,718	-$5,901	0.39	$1,428	-$12,396	0.10
ST-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$3,717	$3,131	-$586	0.84	NA	NA	NA
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$9,446	$4,197	-$3,738	0.53	$4,363	-$5,083	0.46
ST-10	East End 480 cfs Unconstrained Outlet	$7,238	$3,414	-$455	0.88	NA	NA	NA

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives
Table II.ST-2

Stochastic Scenario Comparison of the Probability of Reaching Lake Levels

Lake Level (msl)	Without Project	Alternative								
		ST-1	ST-2b	ST-3	ST-4	ST-5	ST-6	ST-7b	ST-8b	ST-10
1447	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1448	83%	80%	83%	81%	71%	76%	71%	80%	79%	71%
1449	64%	60%	64%	61%	44%	51%	44%	60%	57%	44%
1450	51%	46%	51%	45%	29%	36%	29%	46%	41%	29%
1451	41%	36%	41%	35%	20%	26%	20%	36%	32%	20%
1452	34%	30%	34%	28%	15%	21%	15%	30%	25%	15%
1453	29%	25%	29%	22%	11%	16%	11%	25%	20%	11%
1454	25%	21%	25%	18%	9%	13%	9%	21%	16%	9%
1455	20%	17%	20%	14%	7%	11%	7%	17%	13%	7%
1456	17%	14%	17%	11%	6%	8%	6%	14%	10%	6%
1457	14%	12%	14%	9%	4%	7%	4%	12%	8%	4%
1458	12%	10%	12%	7%	3%	5%	3%	10%	6%	3%
1459	9%	8%	9%	5%	3%	4%	3%	8%	5%	3%
1460	7%	6%	7%	4%	2%	3%	2%	6%	3%	2%
1461	4%	4%	4%	3%	1%	2%	1%	4%	2%	1%
1462	2%	2%	2%	1%	1%	1%	1%	2%	1%	1%
1463	1%	1%	1%	1%	0%	1%	0%	1%	1%	0%

Economic Analysis of Devils Lake Alternatives
Table II.ST-3

Stochastic Scenario Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
ST-1	Upper Basin Management	Without-Project	$1,285	95%		$10,521		
		With-Project	$1,209	95%		$9,824		
		Total Benefits	$75		6%	$697	7%	$773
ST-2b	Expanded Infrastructure Measures	Without-Project	$1,285	95%		$10,521		
		With-Project	$1,279	95%		$8,117		
		Total Benefits	$5		0.42%	$2,405	23%	$2,410
ST-3	West Bay 300 cfs Constrained Outlet	Without-Project	$1,285	95%		$10,521		
		With-Project	$1,159	95%		$9,170		
		Total Benefits	$125		10%	$1,352	13%	$1,477
ST-4	West Bay 480 cfs Unconstrained Outlet	Without-Project	$1,285	95%		$10,521		
		With-Project	$953	94%		$7,440		
		Total Benefits	$331		26%	$3,081	29%	$3,412
ST-5	Pelican Lake 300 cfs Constrained Outlet	Without-Project	$1,285	95%		$10,521		
		With-Project	$1,054	96%		$7,983		
		Total Benefits	$231		18%	$2,539	24%	$2,770
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	Without-Project	$1,285	95%		$10,521		
		With-Project	$953	96%		$7,137		
		Total Benefits	$331		26%	$3,385	32%	$3,716
ST-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	Without-Project	$1,285	95%		$10,521		
		With-Project	$1,204	95%		$7,471		
		Total Benefits	$81		6%	$3,050	29%	$3,131
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Without-Project	$1,285	95%		$10,521		
		With-Project	$1,106	95%		$6,504		
		Total Benefits	$178		14%	$4,018	38%	$4,196
ST-10	East End 480 cfs Unconstrained Outlet	Without-Project	$1,285	95%		$10,521		
		With-Project	$953	94%		$7,440		
		Total Benefits	$331		26%	$3,081	29%	$3,412

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives

Table II.ST-4

Stochastic Scenario Comparison of Benefits for Downstream Features (Weighted Average)[1]

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits[2]	Percent of Downstream Damages Avoided[3]
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation			
ST-1	Without Project	NA	NA	NA	NA	NA	NA	NA		
	With Project	NA	NA	NA	NA	NA	NA	NA		
	Total Benefits	NA	NA	NA	NA	NA	NA	NA	NA	NA
ST-2b	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	With Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	Total Benefits	$0	$0	$0	$0	$0	$0	$0	$0	0%
ST-3	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	With Project	$22	$13	$446	$158	$8,639	$1,826	$27		
	Total Benefits	$237	-$9	-$11	$0	-$72	-$2	$22	$164	1%
ST-4	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	With Project	$3,124	$55	$471	$160	$8,676	$1,837	$267		
	Total Benefits	-$2,865	-$51	-$36	-$2	-$109	-$13	-$219	-$3,295	-29%
ST-5	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	With Project	$26	$17	$458	$159	$8,649	$1,828	$24		
	Total Benefits	$233	-$13	-$23	-$1	-$82	-$4	$24	$134	1%
ST-6	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	With Project	$2,221	$38	$472	$160	$8,676	$1,838	$180		
	Total Benefits	-$1,962	-$34	-$37	-$2	-$109	-$14	-$131	-$2,290	-20%
ST-7b	Without Project	NA	NA	NA	NA	NA	NA	NA		
	With Project	NA	NA	NA	NA	NA	NA	NA		
	Total Benefits	NA	NA	NA	NA	NA	NA	NA	NA	NA
ST-8b	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49		
	With Project	$21	$13	$445	$158	$8,638	$1,825	$28		
	Total Benefits	$238	-$9	-$10	$0	-$71	-$2	$21	$166	1%
ST-10	Without Project	NA	NA	NA	NA	NA	NA	NA		
	With Project	NA	NA	NA	NA	NA	NA	NA		
	Total Benefits	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1]For the purposes of including the impact of downstream features on the overall BCR of the stochastic traces, these values are a weighted average of the annualized damages and benefits for the downstream features during wet (WF), moderate-wet (M1), moderate-dry (M2) and dry (DR) based on the percentage of the 10,000 traces that fall into these four categories. If the weighted average is "NA", there was no data to compute the weighted average.

[2]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

[3]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the damage category.

Economic Analysis of Devils Lake Alternatives
Table II.WF-1

Wet Future Scenario Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
WF-1	Upper Basin Management	$2,650	$2,584	-$66	0.98	$3,191	$541	1.20
WF-2b	Expanded Infrastructure Measures	$4,063	$4,301	$238	1.06	$4,301	$238	1.06
WF-3	West Bay 300 cfs Constrained Outlet	$6,376	$16,760	$11,896	3.45	$19,718	$13,341	3.09
WF-4	West Bay 480 cfs Unconstrained Outlet	$12,188	$29,732	$21,938	3.81	$28,828	$16,640	2.37
WF-5	Pelican Lake 300 cfs Constrained Outlet	$8,731	$18,884	$11,665	2.62	$21,912	$13,181	2.51
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	$14,668	$29,943	$19,512	2.87	$30,198	$15,530	2.06
WF-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$6,491	$6,706	$214	1.03	$7,313	$821	1.13
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$11,165	$22,537	$12,883	2.33	$25,489	$14,324	2.28
WF-9	NOTE: WF-9 is the base condition – without project future condition.							
WF-10	East End 480 cfs Unconstrained Outlet	$9,885	$29,732	$25,863	7.68	$28,201	$18,315	2.85
WF-11	Raise Natural Outlet	$1,064	$0	$0	0.00	$3,441	$2,377	3.24

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Economic Analysis of Devils Lake Alternatives
Table II.WF-2

Wet Future Scenario Comparison of the Probability of Reaching Lake Levels

Lake Level (msl)	Without Project	Scenario									
		WF-1	WF-2b	WF-3	WF-4	WF-5	WF-6	WF-7b	WF-8b	WF-10	WF-11
1447	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1448	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1449	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1450	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1451	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1452	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1453	100%	100%	100%	100%	0%	100%	0%	100%	100%	0%	100%
1454	100%	100%	100%	100%	0%	100%	0%	100%	100%	0%	100%
1455	100%	100%	100%	100%	0%	100%	0%	100%	100%	0%	100%
1456	100%	100%	100%	100%	0%	100%	0%	100%	100%	0%	100%
1457	100%	100%	100%	100%	0%	100%	0%	100%	0%	0%	100%
1458	100%	100%	100%	0%	0%	0%	0%	100%	0%	0%	100%
1459	100%	100%	100%	0%	0%	0%	0%	100%	0%	0%	100%
1460	100%	100%	100%	0%	0%	0%	0%	100%	0%	0%	100%
1461	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
1462	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
1463	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Economic Analysis of Devils Lake Alternatives

Table II.WF-3

Wet Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
		Without-Project	$4,141	95%		$39,335		
		With-Project	$3,915	95%		$36,977		
WF-1	Upper Basin Management	Total Benefits	$226		5%	$2,358	6%	$2,584
		Without-Project	$4,141	95%		$39,335		
	Expanded Infrastructure	With-Project	$4,133	95%		$35,042		
WF-2b	Measures	Total Benefits	$9		0.21%	$4,293	11%	$4,301
		Without-Project	$4,141	95%		$39,335		
	West Bay 300 cfs Constrained	With-Project	$2,835	96%		$23,881		
WF-3	Outlet	Total Benefits	$1,307		32%	$15,454	39%	$16,760
		Without-Project	$4,141	95%		$39,335		
	West Bay480 cfs	With-Project	$1,810	95%		$11,935		
WF-4	Unconstrained Outlet	Total Benefits	$2,331		56%	$27,400	70%	$29,731
		Without-Project	$4,141	95%		$39,335		
	Pelican Lake 300 cfs	With-Project	$2,777	95%		$21,815		
WF-5	Constrained Outlet	Total Benefits	$1,364		33%	$17,520	45%	$18,884
		Without-Project	$4,141	95%		$39,335		
	Pelican Lake 480 cfs	With-Project	$1,810	95%		$11,724		
WF-6	Unconstrained Outlet	Total Benefits	$2,331		56%	$27,611	70%	$29,942
	Combination 1 – Upper Basin	Without-Project	$4,141	95%		$39,335		
	Management and Expanded	With-Project	$3,907	95%		$32,864		
WF-7b	Infrastructure Measures	Total Benefits	$235		6%	$6,471	16%	$6,706
	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure	Without-Project	$4,141	95%		$39,335		
		With-Project	$2,696	95%		$18,244		
WF-8b	Measures	Total Benefits	$1,445		35%	$21,091	54%	$22,537
WF-9	NOTE: WF-9 is the base condition – without project future condition.							
		Without-Project	$4,141	95%		$39,335		
	East End 480 cfs	With-Project	$1,810	95%		$11,935		
WF-10	Unconstrained Outlet	Total Benefits	$2,331		56%	$27,400	70%	$29,731
		Without-Project	$4,141	95%		$39,335		
		With-Project	$4,141	95%		$39,335		
WF-11	Raise Natural Outlet	Total Benefits	$0		0%	$0	0%	$0

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Economic Analysis of Devils Lake Alternatives

Table II.WF-4

Wet Future Scenario Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages Municipal	Water Treatment Damages Industrial	Flow Related Damages Ag-Crop	Flow Related Damages Ag-Other	Flow Related Damages Urban	Flow Related Damages Transportation	Irrigation	Overall Benefits[1]	Percent of Downstream Damages Avoided[2]
WF-1	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$2,283	$32	$509	$207	$9,264	$2,350	$421		
	Total Benefits	$443	$10	$6	$1	$83	$6	$58	$607	4%
WF-2b	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	Total Benefits	$0	$0	$0	$0	$0	$0	$0	$0	0%
WF-3	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$54	$39	$550	$208	$9,470	$2,358	$37		
	Total Benefits	$2,672	$4	-$35	$0	-$123	-$3	$442	$2,957	19%
WF-4	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$3,599	$69	$592	$210	$9,546	$2,382	$179		
	Total Benefits	-$873	-$27	-$78	-$2	-$199	-$26	$300	-$904	-6%
WF-5	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$29	$22	$550	$208	$9,463	$2,357	$16		
	Total Benefits	$2,697	$21	-$35	$1	-$116	-$2	$463	$3,028	19%
WF-6	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$2,545	$46	$591	$210	$9,546	$2,378	$101		
	Total Benefits	$181	-$4	-$77	-$1	-$199	-$22	$378	$256	2%
WF-7a	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$2,283	$32	$509	$207	$9,264	$2,350	$421		
	Total Benefits	$443	$10	$6	$1	$83	$6	$58	$607	4%
WF-7b	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$2,283	$32	$509	$207	$9,264	$2,350	$421		
	Total Benefits	$443	$10	$6	$1	$83	$6	$58	$607	4%
WF-8a	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$53	$38	$549	$208	$9,464	$2,358	$51		
	Total Benefits	$2,673	$4	-$34	$1	-$117	-$2	$428	$2,953	19%
WF-8b	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$53	$38	$549	$208	$9,464	$2,358	$51		
	Total Benefits	$2,673	$4	-$34	$1	-$117	-$2	$428	$2,953	19%
WF-10	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$3,707	$109	$592	$210	$9,546	$2,382	$658		
	Total Benefits	-$981	-$67	-$78	-$2	-$199	-$26	-$180	-$1,531	-10%
WF-11	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479		
	With Project	$0	$0	$500	$206	$9,184	$2,338	$3		
	Total Benefits	$2,726	$42	$15	$2	$163	$17	$475	$3,441	22%[3]

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

[2]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

[3]Downstream damages would theoretically be reduced by 100% for this alternative. However, this computation of damages avoided includes remaining flow-related damages that are due to local precipitation events.

Economic Analysis of Devils Lake Alternatives
Table II.M1-1

Moderate Future 1 Scenario (1450 Peak Lake Level) Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
M1-1	West Bay 300 cfs Constrained Outlet	$5,839	$644	-$3,683	0.15	$568	-$5,271	0.10
M1-2	West Bay 480 cfs Unconstrained Outlet	$11,357	$3,123	-$3,781	0.45	-$728	-$12,085	-0.06
M1-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$8,476	$3,557	-$3,408	0.51	$3,482	-$4,994	0.41
M1-5	Pelican Lake 300 cfs Constrained Outlet	$7,831	$3,122	-$3,197	0.49	$2,990	-$4,841	0.38
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	$13,791	$3,123	-$6,428	0.33	-$179	-$13,970	-0.01

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features aer not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives
Table II.M1-2

Moderate Future 1 Scenario (1450 Peak Lake Level)
Comparison of the Probability of Reaching Lake Levels

Lake Level (msl)	Without Project	Alternative				
		M1-1	M1-2	M1-3b	M1-5	M1-6
1447	100%	100%	100%	100%	100%	100%
1448	100%	100%	0%	100%	0%	0%
1449	100%	100%	0%	0%	0%	0%
1450	100%	100%	0%	0%	0%	0%
1451	0%	0%	0%	0%	0%	0%
1452	0%	0%	0%	0%	0%	0%
1453	0%	0%	0%	0%	0%	0%
1454	0%	0%	0%	0%	0%	0%
1455	0%	0%	0%	0%	0%	0%
1456	0%	0%	0%	0%	0%	0%
1457	0%	0%	0%	0%	0%	0%
1458	0%	0%	0%	0%	0%	0%
1459	0%	0%	0%	0%	0%	0%
1460	0%	0%	0%	0%	0%	0%
1461	0%	0%	0%	0%	0%	0%
1462	0%	0%	0%	0%	0%	0%
1463	0%	0%	0%	0%	0%	0%

Economic Analysis of Devils Lake Alternatives
Table II.M1-3

Moderate Future 1 Scenario (1450 Peak Lake Level) Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
M1-1	West Bay 300 cfs Constrained Outlet	Without-Project	$917	96%		$5,681		
		With-Project	$715	97%		$5,240		
		Total Benefits	$202		22%	$442	8%	$644
M1-2	West Bay 480 cfs Unconstrained Outlet	Without-Project	$917	96%		$5,681		
		With-Project	$358	96%		$3,119		
		Total Benefits	$559		61%	$2,563	45%	$3,122
M1-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Without-Project	$917	96%		$5,681		
		With-Project	$698	95%		$2,344		
		Total Benefits	$219		24%	$3,338	59%	$3,557
M1-5	Pelican Lake 300 cfs Constrained Outlet	Without-Project	$917	96%		$5,681		
		With-Project	$358	97%		$3,119		
		Total Benefits	$559		61%	$2,563	45%	$3,122
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	Without-Project	$917	96%		$5,681		
		With-Project	$358	96%		$3,119		
		Total Benefits	$559		61%	$2,563	45%	$3,122

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives

Table II.M1-4

Moderate Future 1 Scenario (1450 Peak Lake Level) Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits[1]	Percent of Downstream Damages Avoided[2]
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation			
M1-1	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2		
	With Project	$22	$12	$499	$179	$12,099	$1,909	$36		
	Total Benefits	-$22	-$12	-$6	$0	-$2	$0	-$34	-$76	-1%
M1-2	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2		
	With Project	$3,343	$56	$530	$182	$12,125	$1,930	$365		
	Total Benefits	-$3,343	-$56	-$37	-$3	-$28	-$21	-$363	-$3,851	-26%
M1-3b	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2		
	With Project	$21	$12	$499	$179	$12,099	$1,909	$36		
	Total Benefits	-$21	-$12	-$5	$0	-$2	$0	-$34	-$75	-1%
M1-5	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2		
	With Project	$31	$19	$516	$180	$12,114	$1,914	$37		
	Total Benefits	-$31	-$19	-$23	-$1	-$17	-$6	-$35	-$132	-1%
M1-6	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2		
	With Project	$2,764	$43	$534	$182	$12,125	$1,936	$399		
	Total Benefits	-$2,764	-$43	-$41	-$3	-$28	-$27	-$397	-$3,303	-22%

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

[2]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

Economic Analysis of Devils Lake Alternatives
Table II.M2-1

Moderate Future 2 Scenario (1455 Peak Lake Level) Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
M2-1	West Bay 300 cfs Constrained Outlet	$5,936	$5,564	$1,139	1.26	$5,489	-$447	0.92
M2-2	West Bay 480 cfs Unconstrained Outlet	$11,721	$13,167	$5,878	1.81	$8,910	-$2,810	0.76
M2-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$10,246	$10,112	$1,378	1.16	$10,043	-$202	0.98
M2-5	Pelican Lake 300 cfs Constrained Outlet	$8,005	$11,196	$4,702	1.72	$11,081	$3,076	1.38
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	$14,351	$13,498	$3,585	1.36	$10,504	-$3,846	0.73

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives
Table II.M2-2

Moderate Future 2 Scenario (1455 Peak Lake Level)
Comparison of the Probability of Reaching Lake Levels

Lake Level (msl)	Without Project	Alternative				
		M2-1	M2-2	M2-3b	M2-5	M2-6
1447	100%	100%	100%	100%	100%	100%
1448	100%	100%	100%	100%	100%	100%
1449	100%	100%	0%	100%	100%	0%
1450	100%	100%	0%	100%	100%	0%
1451	100%	100%	0%	100%	0%	0%
1452	100%	100%	0%	100%	0%	0%
1453	100%	100%	0%	0%	0%	0%
1454	100%	0%	0%	0%	0%	0%
1455	0%	0%	0%	0%	0%	0%
1456	0%	0%	0%	0%	0%	0%
1457	0%	0%	0%	0%	0%	0%
1458	0%	0%	0%	0%	0%	0%
1459	0%	0%	0%	0%	0%	0%
1460	0%	0%	0%	0%	0%	0%
1461	0%	0%	0%	0%	0%	0%
1462	0%	0%	0%	0%	0%	0%
1463	0%	0%	0%	0%	0%	0%

Economic Analysis of Devils Lake Alternatives
Table II.M2-3

Moderate Future 2 Scenario (1455 Peak Lake Level) Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
M2-1	West Bay 300 cfs Constrained Outlet	Without-Project	$2,015	95%		$17,635		
		With-Project	$1,736	94%		$12,349		
		Total Benefits	$279		14%	$5,285	30%	$5,564
M2-2	West Bay 480 cfs Unconstrained Outlet	Without-Project	$2,015	95%		$17,635		
		With-Project	$963	94%		$5,523		
		Total Benefits	$1,052		52%	$12,112	69%	$13,164
M2-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Without-Project	$2,015	95%		$17,635		
		With-Project	$1,418	95%		$8,120		
		Total Benefits	$597		30%	$9,515	54%	$10,112
M2-5	Pelican Lake 300 cfs Constrained Outlet	Without-Project	$2,015	95%		$17,635		
		With-Project	$1,208	95%		$7,246		
		Total Benefits	$807		40%	$10,388	59%	$11,195
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	Without-Project	$2,015	95%		$17,635		
		With-Project	$963	94%		$5,192		
		Total Benefits	$1,052		52%	$12,443	71%	$13,495

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives

Table II.M2-4

Moderate Future 2 Scenario (1455 Peak Lake Level) Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits[1]	Percent of Downstream Damages Avoided[2]
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation			
M2-1	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1		
	With Project	$24	$14	$430	$147	$7,293	$1,804	$18		
	Total Benefits	-$24	-$14	-$11	-$1	-$5	-$2	-$17	-$74	-1%
M2-2	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1		
	With Project	$3,816	$73	$468	$148	$7,310	$1,806	$291		
	Total Benefits	-$3,816	-$73	-$49	-$1	-$23	-$4	-$290	-$4,256	-44%
M2-3b	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1		
	With Project	$22	$12	$429	$147	$7,292	$1,804	$18		
	Total Benefits	-$22	-$12	-$10	-$1	-$5	-$2	-$17	-$69	-1%
M2-5	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1		
	With Project	$33	$23	$443	$147	$7,301	$1,805	$19		
	Total Benefits	-$33	-$23	-$24	-$1	-$13	-$3	-$18	-$115	-1%
M2-6	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1		
	With Project	$2,739	$54	$468	$148	$7,310	$1,806	$125		
	Total Benefits	-$2,739	-$54	-$49	-$1	-$23	-$4	-$124	-$2,993	-31%

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

[2]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

Economic Analysis of Devils Lake Alternatives
Table II.DR-1

Dry Future Scenario Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
DR-1	West Bay 300 cfs Constrained Outlet	$5,796	$0	-$4,284	0.00	-$212	-$6,008	-0.04
DR-2	West Bay 480 cfs Unconstrained Outlet	$10,821	$0	-$6,792	0.00	-$2,791	-$13,612	-0.26
DR-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$8,435	$2,754	-$4,169	0.40	$2,545	-$5,890	0.30
DR-5	Pelican Lake 300 cfs Constrained Outlet	$7,748	$331	-$5,905	0.05	$91	-$7,657	0.01
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	$13,420	$331	-$9,087	0.04	-$1,295	-$14,715	-0.10

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives
Table II.DR-2

Dry Future Scenario Comparison of the Probability of Reaching Lake Levels

Lake Level (msl)	Without Project	Alternative				
		DR-1	DR-2	DR-3b	DR-5	DR-6
1447	100%	100%	100%	100%	100%	100%
1448	100%	100%	100%	100%	100%	100%
1449	0%	0%	0%	0%	0%	0%
1450	0%	0%	0%	0%	0%	0%
1451	0%	0%	0%	0%	0%	0%
1452	0%	0%	0%	0%	0%	0%
1453	0%	0%	0%	0%	0%	0%
1454	0%	0%	0%	0%	0%	0%
1455	0%	0%	0%	0%	0%	0%
1456	0%	0%	0%	0%	0%	0%
1457	0%	0%	0%	0%	0%	0%
1458	0%	0%	0%	0%	0%	0%
1459	0%	0%	0%	0%	0%	0%
1460	0%	0%	0%	0%	0%	0%
1461	0%	0%	0%	0%	0%	0%
1462	0%	0%	0%	0%	0%	0%
1463	0%	0%	0%	0%	0%	0%

Economic Analysis of Devils Lake Alternatives
Table II.DR-3

Dry Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
DR-1	West Bay 300 cfs Constrained Outlet	Without-Project	$1,048	93%		$5,542		
		With-Project	$1,048	93%		$5,542		
		Total Benefits	$0		0%	$0	0%	$0
DR-2	West Bay 480 cfs Unconstrained Outlet	Without-Project	$1,048	93%		$5,542		
		With-Project	$1,048	89%		$5,542		
		Total Benefits	$0		0%	$0	0%	$0
DR-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Without-Project	$1,048	93%		$5,542		
		With-Project	$375	97%		$3,461		
		Total Benefits	$673		64%	$2,081	38%	$2,754
DR-5	Pelican Lake 300 cfs Constrained Outlet	Without-Project	$1,048	93%		$5,542		
		With-Project	$1,048	90%		$5,211		
		Total Benefits	$0		0%	$331	6%	$331
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	Without-Project	$1,048	93%		$5,542		
		With-Project	$1,048	89%		$5,211		
		Total Benefits	$0		0%	$331	6%	$331

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives

Table II.DR-4

Dry Future Scenario (1455 Peak Lake Level) Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits[1]	Percent of Downstream Damages Avoided[2]
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation			
DR-1	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6		
	With Project	$12	$7	$384	$136	$6,457	$1,628	$23		
	Total Benefits	-$12	-$7	-$8	-$1	-$165	-$2	-$16	-$212	-3%
DR-2	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6		
	With Project	$2,328	$38	$391	$137	$6,506	$1,635	$192		
	Total Benefits	-$2,328	-$38	-$16	-$2	-$214	-$9	-$185	-$2,792	-33%
DR-3b	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6		
	With Project	$12	$7	$384	$136	$6,456	$1,628	$23		
	Total Benefits	-$12	-$7	-$8	-$1	-$164	-$2	-$16	-$210	-2%
DR-5	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6		
	With Project	$17	$11	$394	$136	$6,468	$1,629	$20		
	Total Benefits	-$17	-$11	-$18	-$1	-$176	-$3	-$14	-$240	-3%
DR-6	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6		
	With Project	$1,316	$21	$391	$137	$6,506	$1,635	$55		
	Total Benefits	-$1,316	-$21	-$15	-$2	-$214	-$9	-$49	-$1,626	-19%

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

[2]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

Economic Analysis of Devils Lake Alternatives
Table II.ER-1

Erosion at the Natural Outlet : Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Annual Project Costs	Without Downstream Impacts			Including Downstream Impacts		
			Annual Benefits	Net Benefit	BCR	Annual Benefits	Net Benefit	BCR
WF-12	Outlet Erosion: West Bay 300 cfs Constrained Outlet	$6,376	$16,760	$11,896	3.45	$24,390	$18,014	3.83
WF-13	Outlet Erosion: West Bay 480 cfs Constrained Outlet	$12,188	$29,732	$21,938	3.81	$33,501	$21,312	2.75
WF-14b	Combination 2 with Outlet Erosion – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$11,165	$22,537	$12,883	2.33	$30,162	$18,997	2.70

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Economic Analysis of Devils Lake Alternatives
Table II.ER-2

Erosion at the Natural Outlet
Comparison of the Probability of Reaching Lake Levels

Lake Level (msl)	Without Project	Scenario		
		WF-12	WF-13	WF-14b
1447	100%	100%	100%	100%
1448	100%	100%	100%	100%
1449	100%	100%	100%	100%
1450	100%	100%	100%	100%
1451	100%	100%	100%	100%
1452	100%	100%	100%	100%
1453	100%	100%	0%	100%
1454	100%	100%	0%	100%
1455	100%	100%	0%	100%
1456	100%	100%	0%	100%
1457	100%	100%	0%	0%
1458	100%	0%	0%	0%
1459	100%	0%	0%	0%
1460	100%	0%	0%	0%
1461	0%	0%	0%	0%
1462	0%	0%	0%	0%
1463	0%	0%	0%	0%

Economic Analysis of Devils Lake Alternatives

Table II.ER-3

Erosion at Natural Outlet : Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Percent of Damages Prevented by Strategies	Percent of Damages Prevented by Project	Set of Feature Strategy Costs	Percent of Costs Avoided by Project	Benefits To Adjacent Lake Features
		Without-Project	$4,141	94%		$39,335		
	Outlet Erosion: West Bay 300	With-Project	$2,835	96%		$23,881		
WF-12	cfs Constrained Outlet	Total Benefits	$1,307		32%	$15,454	39%	$16,760
		Without-Project	$4,141	94%		$39,335		
	Outlet Erosion: West Bay 480	With-Project	$1,810	95%		$11,935		
WF-13	cfs Constrained Outlet	Total Benefits	$2,331		56%	$27,400	70%	$29,731
	Combination 2 with Outlet	Without-Project	$4,141	94%		$39,335		
	Erosion – West Bay 300 cfs	With-Project	$2,696	95%		$18,244		
WF-14b	Constrained Outlet, Upper	Total Benefits	$1,445		35%	$21,091	54%	$22,537

Economic Analysis of Devils Lake Alternatives
Table II.ER-4
Wet Future Scenario Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages Municipal	Water Treatment Damages Industrial	Flow Related Damages Ag-Crop	Flow Related Damages Ag-Other	Flow Related Damages Urban	Flow Related Damages Transportation	Irrigation	Overall Benefits[1]	Percent of Downstream Damages Avoided[2]
WF-12	Without Project	$2,963	$62	$558	$228	$13,860	$2,478	$197		
	With Project	$54	$39	$550	$208	$9,470	$2,358	$37		
	Total Benefits	$2,909	$23	$8	$20	$4,390	$120	$160	$7,630	38%
WF-13	Without Project	$2,963	$62	$558	$228	$13,860	$2,478	$197		
	With Project	$3,599	$69	$592	$210	$9,546	$2,382	$179		
	Total Benefits	-$636	-$8	-$34	$18	$4,314	$96	$18	$3,768	19%
WF-14b	Without Project	$2,963	$62	$558	$228	$13,860	$2,478	$197		
	With Project	$53	$38	$549	$208	$9,464	$2,358	$51		
	Total Benefits	$2,910	$24	$9	$20	$4,396	$120	$146	$7,625	37%

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

[2]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.