Devils Lake
Infrastructure Protection Study

Prepared for

The U.S. Army Corps of Engineers
St. Paul District

by

Barr Engineering Company

January 10, 2003

BARR

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Executive Summary

Introduction

The Devils Lake Infrastructure Protection Study (Infrastructure Protection Study) identified the costs and benefits of flood protection measures for roads, railroads, state facilities, communities, and rural areas in and around Devils Lake. In addition, the study was used to develop flood protection summary tables— tables that interested parties may find useful in anticipating the costs and developing a schedule for the planning and implementation of these flood protection measures.

The Infrastructure Protection Study follows on the work of previous studies[1] concerned with flood protection in the Devils Lake area. Previous studies, however, focused on determining the costs and benefits of providing an outlet (pump station and pipeline to remove water) for Devils Lake. Flood protection measures in and around the Devils Lake area were important for those studies principally for determining the reduction in flood protection expense that an outlet would provide.

The Infrastructure Protection Study used the previous work as its base. For the Infrastructure Protection Study, a reexamination of the previous work was conducted to identify significant structures and infrastructure[2] needing protection, and to consolidate the information that had already been collected. A summary of the information collected previously is provided as a part of this report. The summary includes a compilation of the results of the economic evaluations that were completed for the flood protection measures.

However, the study extended the previous work by examining further the costs and benefits of flood protection measures that would need to be implemented in the near future. It also treated the flood protection measures as projects in themselves, without relating them to the potential effects of an outlet. In this way, the most critical flood protection measures could be evaluated directly, and the costs and benefits could be estimated for each of the flood protection measures.

Comparison of the costs and benefits gave an indication of whether or not each of the measures was economically justified. However, it should be noted that there are many uncertainties in the analysis – especially regarding the cost and damage assessments, and future lake levels. These uncertainties must be taken into account when attempting to draw conclusions from the study results. Furthermore, economic assessments are only a part of the data needed for decisions regarding flood protection in the Devils Lake area. Ultimately, flood protection decisions must be based on an in-

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[1] See *Economic Analysis of Devils Lake Alternatives,* (*Main Report, Tabular Data, and Technical Appendix),* Barr Engineering Company, 2001. The *Economic Analysis of Devils Lake Alternatives* built upon the previous Barr studies of flood protection efforts in the Devils Lake area. A complete listing of the references used for this report is provided in Appendix B.

[2] "Structures," as used in this report, refers generally to residential, agricultural, commercial, and municipal buildings. It includes accessory structures such as barns, sheds, garages, silos, etc. "Infrastructure" includes roads, railroads, utilities, and parklands.

depth assessment by local, state, and Federal officials to ensure that whichever plan is selected is technically, economically, environmentally, and socially sound.

The Infrastructure Protection Study was commissioned by the US Army Corps of Engineers (Corps), St. Paul District. Barr Engineering Company (Barr) conducted the study.

Process Used for the Study

In general, the Infrastructure Protection Study proceeded according to the following sequence:

1. The information from previous studies regarding flood protection for each of the 25 features[3] around Devils Lake was examined. Data from those studies was consolidated and summarized (see Section 2 of this report). Previously identified flood protection strategies and decision-making processes were noted and described. Tables showing the previous analysis' estimates of flood protection costs and flood damages were prepared. The results of the economic modeling were also collected and tabulated.

2. An analysis was conducted for the 17 features that would require action in the near future – prior to the lake level reaching 1454.

   For these 17 features, a more detailed and comprehensive examination of various flood protection measures and their comparative costs was made. The study took into account environmental costs, geological and geotechnical considerations, local hydrology and its effects on providing flood protection, and gave a more uniform assessment of the costs for planning and design, supervision and administration, and operations and maintenance. It also included a more detailed examination of costs related to real estate acquisition, and refined the determination of unit prices for construction materials.

   Flood damages were also examined in more detail for the 17 features. Potential flood-related damages to roads, railways, and structures (including residential, commercial, and park buildings, as well as some community infrastructure) were reassessed, and the listings of flood-related damages were updated to more accurately reflect the situation in 2002. The study identified the lake elevations at which the features would actually suffer flood-related damages.

   Assessments were also provided as to the time that would be required for planning and design, and for construction of the flood protection measures for each of the features. For levees, where failure would be catastrophic, these times were used in conjunction with probability-based lake elevation curves (showing lake elevation vs. time, in years) to allow identification

[3] A "feature" is defined as a physical entity or group of entities that would be susceptible to damage from the rising lake water.

of the lake levels at which levee construction activities must commence, and when the levee construction must be completed.

The results of the examination of the 17 features were compiled and are presented in Section 4 (and Appendix A) of this report.

3. Flood protection cost and flood damage information was entered in to a computerized economics model. Using a set of 10,000 stochastically generated[4] traces of projected lake levels over a 50-year period, the model generated average costs and benefits for flood protection measures for each of the 17 features. From these costs and benefits, the net benefits and benefit-cost ratio (BCR) for each flood protection measure could be calculated. This analysis indicated whether or not the flood protection measure appeared to be economically justified.

   In addition to producing the stochastic results, the economics model was also used to analyze the flood protection measures with reference to three single 50-year lake level traces. Each of these three traces represented one of three categories of climate and hydrologic futures for the Devils Lake area (and for the lake itself): the Wet Future, Moderate Future 1, and Moderate Future 2. Net benefits and BCRs for the flood protection measures under each of these climate futures could then be calculated.

   For each of the 17 features, economic analysis was conducted for the increment of flood protection effort that would be needed immediately (the "first action level" of flood protection), and for the remainder of the action levels up to the lake's "maximum"[5] elevation. The damages and costs for the first action level were examined to the level of detail described above. For the higher action levels, however, a similar level of detail was used for only three of the features. A simplified method of estimating costs was used when analyzing the higher action levels for the other 14 features.

4. The results of the analysis and the economics modeling were compiled for all features. Feature protection strategies that were economically justified, if any, were identified. Similarly, the target lake levels associated with flood protection project initiation and completion (identified in Step 2, above) were tabulated.

5. Based on the data collected, the determinations of target lake levels, and the results of the economics modeling, Flood Protection Summary were developed for the Devils Lake area.

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[4] Generated by using a hydrologic model for the basin and allowing certain climatological parameters to vary randomly within pre-set boundaries.

[5] There are many uncertainties with respect to the maximum lake level that the lake could or will achieve. However, several studies have used 1463 as the expected maximum water level for Devils Lake under prolonged wet climate conditions. Accordingly, 1463 has been used in the present study as the "maximum" lake level. It was assumed that flood protection measures would be designed accordingly.

For each feature, the summary tables identify the incremental flood protection strategy having the largest net benefits. They list the expected costs of providing flood protection at each of the features. They also give the lake elevations at which project activities—planning and design, and construction—should commence and/or be completed.

Flood Protection Summary Tables

The Flood Protection Summary Tables EX-1a and EX-1b provided at the end of the Executive Summary show the results of the analysis. Table EX-1a gives results for all action levels for all 25 features. Table EX-1b focuses on the first-action-level feature protection at the 17 Devils Lake features expected to first be affected by rising water. For those 17 features, it also provides the decision-critical elevations for the flood protection strategies. Both tables show economics results from the stochastic modeling, and from the analysis of the wet future trace. The tables allow comparison of economic results for flood protection at only the first action level with the economic results for flood protection up to the maximum lake level.

As was noted above, the Flood Protection Summary Tables provide information regarding the required costs and timing of providing flood protection for Devils Lake features. The information may be of value to those charged with making decisions regarding the flood protection for each of the features. If a decision is made to provide flood protection for a given feature, the tables supply an estimate of how much money should be set aside for the project. They also give an indication, for each of the features, of when planning and construction activities for the first phases of flood protection should commence and be completed. Timing for project activities is indicated by referring to lake levels, so that decision-makers would be able to estimate the urgency of the task by considering the elevation of Devils Lake at the time when flood protection decisions are being made.

Construction Material and Mitigation Requirements

Table EX-2 shows the primary construction material requirements, the number of structures requiring relocation, and the required environmental mitigation acreage for providing flood protection at the first action level for the 17 features. The table is provided so that an assessment can be made of the feasibility of providing flood protection for many features at once. It has been noted that concurrent initiation of construction on all 17 flood protection measures may make the acquisition of construction materials difficult.

Discussion

The many differences between the previous Economic Analysis and the Infrastructure Protection Study are reflected in the results tables (2.0-2, and 5.0-1) for the two studies. Under the Infrastructure Protection Study, flood protection costs are generally higher, and flood damages are lower. This can be seen by comparing net benefits for the stochastic analysis, which dropped from $13 million (Economic Analysis) to $0.8 million (Infrastructure Protection Study). Similarly, the overall BCR dropped from 2.27 in the Economic Analysis to 1.07 in the Infrastructure Protection Study (stochastic analysis results).

In some cases, the costs for feature protection changed markedly from those identified in the Economic Analysis. Some costs increased and others were reduced. The changes resulted primarily from the more detailed data used in evaluating relocations, more detailed analysis of road plans, and accounting for recent raises. For similar reasons, estimates of damage (if flood protection were not provided) also changed dramatically for some features. Overall, the aggregate feature protection costs of the Economic Analysis decreased slightly when computed for the Infrastructure Protection Study (dropping from $1,150 million to $912 million). The aggregate structure and infrastructure damage estimates were also reduced, from $519 million to $403 million. Aggregate annual detour damage estimates were the same ($79 million), but the per event aggregate restoration damages rose slightly (from $131 million to $145 million).

The results of the Economic Analysis indicated that the protection of infrastructure up to the maximum lake level, for all features in aggregate, was economically justified (BCR = 2.27). The Infrastructure Protection Study also indicated economic justification for feature protection in aggregate (BCR = 1.07), but the benefits were more nearly equal to the damages prevented. This reduction can be at least partially explained by noting that especially in the case of the Economic Analysis, large benefits are derived from flood protection at just two features: the City of Devils Lake and BIA Highway 6. Flood protection for the City of Devils Lake showed large benefits because of the density of structures and infrastructure there. The large benefits (damages prevented) shown for flood protection at BIA Highway 6 are a consequence of the assumption that if BIA Highway 6 were closed due to flooding, ND Highway 20 would also be under water. As discussed previously, this assumption results in large damages for BIA Highway 6, because it means that long detours would be required.

Under the Infrastructure Protection Study, the estimates of the benefits of flood protection at these two features were reduced significantly. The City of Devils Lake benefits were reduced mainly as a consequence of registering costs and damages at different elevations. As explained above, this can make a large difference in the economic results. In the case of BIA Highway 6, the main reason for the reduction in benefits was the fact that the road had already been raised. This eliminated a significant portion of the detour damages that are prevented when this highway is kept from flooding.

Overall, the Economic Analysis showed that 11 of the 25 features had net benefits that were greater than zero (under the stochastic analysis). By contrast, the Infrastructure Protection Study showed that only eight of the feature protection strategies have net benefits that are greater than zero. The three features for which flood protection is no longer shown to be economically justified are:

1. Feature 4: City of Minnewaukan – The Economic Analysis assumed that flood protection would involve the construction of a road/levee to protect portions of the city. It was assumed that some of the construction expense would be borne by the ND DOT. Under the Infrastructure Protection Study, however, this assumption was determined to be invalid. As a result, the Infrastructure Protection Study assumed a different and higher-priced levee configuration, without any funding support from other agencies. Costs therefore increased significantly, and the BCR fell.

2. Feature 8: Rural Areas – In the Economic Analysis, land damages for rural areas were included in the overall analysis. This inclusion could not be made under the terms of the Infrastructure Protection Study, which evaluated all features individually. As a result, prevention of land damages could not be registered, and the economic results showed a decline in the BCR.

3. Feature 11: Burlington Northern Railroad – The Economic Analysis' assumptions regarding flood protection for this feature were significantly different from those of the Infrastructure Protection Study. The Economic Analysis assumed that there would be two incremental rail raises for the Burlington Northern Railroad. However, more recent conversations with railroad personnel made it clear that the only flood protection strategy that would be implemented would be raising the road all at once to the maximum level. Economic modeling shows that this strategy compares unfavorably with the two-step raise contemplated previously.

However, even without reference and comparison to the previously conducted Economic Analysis, several results of the economic analysis conducted for the Infrastructure Protection Study deserve mention:

- The four features showing the largest net benefits are all roads – ND Highway 57 (two features, two different segments), ND Highway 20 (City of Devils Lake to ND Highway 57), and BIA Highway 6. The large net benefits for these features result primarily from the detour damages that are prevented when the road is raised. (These roads also showed similarly large net benefits under the Economic Analysis.) As was mentioned previously, because of interdependencies among these roads, summing the benefits of flood protection for these features may result in artificial inflation of the aggregate BCR.

- First costs for feature protection show wide variation – from approximately $2 million to $152 million. In general, the higher costs are registered in cases where road, railroad, or levee raises involve wide cross-sections and long segments.
- The economic analysis of the Wet Future climate scenario generally showed larger net benefits and BCRs than those for the stochastic analysis. Under the Wet Future scenario, lake levels rise quickly and stay high. Consequently, the benefits of flood protection are large, and are registered early in the 50-year modeling period. Relatively large net benefits and BCRs are generally the result. This also points to the fact that the modeling results are quite sensitive to climate assumptions.
- The Infrastructure Protection Study showed that although the net benefits are negative for constructing a levee for the City of Minnewaukan, this strategy provides the largest net benefits of any flood protection strategy for that feature. Construction of a levee would be less expensive than relocation of the entire community. A sensitivity analysis conducted for this feature indicated that the annual net benefits would be positive ($29,500) if relocation was assumed as the base (without-project) condition for this feature. Under the terms of that analysis, the levee raise is economically justified.
- Because some of the interior roads have now been raised, the Infrastructure Protection Study indicated that the benefits for the Roads Acting as Dams feature were less than those shown in previous analyses. Having the interior roads already raised decreases the dollar value of damages prevented by construction of the perimeter levees. The use of Roads Acting as Dams was not shown to be economically justified previously (BCR of 0.99 in the Economic Analysis), and is shown to have an even smaller BCR of 0.61 under the Infrastructure Protection Study (stochastic results).
- Of the 17 selected features, the three that are economically justified for the first action level are the three that are economically justified for all action levels (stochastic analysis) – Feature 2: City of Devils Lake, Feature 16: US Highway 281 (South of US Highway 2), and Feature 23: BIA Highway 1. Under the Wet Future analysis for the first action level, two additional features are economically justified for the first action level – Feature 7: Grahams Island State Park and Feature 11: Burlington Northern Railroad.
- The results of the stochastic analysis for flood protection up to the maximum lake level are slightly different than the results under the wet future analysis. Eight features are shown to be economically justified under the stochastic analysis, while ten are shown to be economically justified under Wet Future conditions. The two additional features showing economic justification under Wet Future conditions are Feature 4: City of Minnewaukan, and Feature 11: Burlington Northern Railroad.

Finally, it bears mentioning that the economic results presented in this report should be used with caution. For this study, some components of the flood protection strategies – for example, the Devils Lake levees – were analyzed relatively thoroughly. However, it should also be noted that due to limitations on time and resources, it was in general impossible to conduct exhaustive investigations regarding the flood protection measures at the many features. The investigations did not include, for example, detailed design analysis or field investigations. In addition, because of time constraints it was not possible to coordinate fully with local officials regarding ongoing and planned flood protection efforts.

Further study would be necessary before actually proceeding with flood protection projects. Similarly, the damage and cost estimates provided can be considered to be adequate for planning purposes. However, more detailed project or mitigation costs must be determined if and when the projects proceed. Ultimately, flood protection decisions must be based on an in-depth assessment by local, state, and Federal officials to ensure that whichever plan is selected is technically, economically, environmentally, and socially sound.

Table EX-1a

Flood Protection Summary Table
Economic Results: All Action Levels -- to Lake Level 1463
Devils Lake Infrastructure Protection Study

			Present Worth[1]			Stochastic Analysis		Wet Future Scenario		
Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Total First Costs	Total Damages Prevented	Annual Damages Prevented[2]	Average Annual Net Benefits[3]	Benefit- Cost Ratio	Average Annual Net Benefits[3]	Benefit- Cost Ratio	Lake Level of First Damages
1	Churchs Ferry	Relocation of All Structures	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (22,400)	0.76	1451
2	City of Devils Lake	Incremental Levee Raises	$ 78,174,000	$ 305,380,000	--	$ 365,200	1.30	$ 6,972,700	2.84	1454.5
3	Fort Totten	Incremental Relocations	$ 5,367,000	$ 4,086,000	--	$ (20,500)	0.76	$ (65,600)	0.76	1448
4	City of Minnewaukan	Incremental Levee Raises	$ 17,605,000	$ 25,042,000	--	$ (25,300)	0.88	$ 149,700	1.17	1451
5	St. Michael	Incremental Relocations	$ 1,720,000	$ 1,224,000	--	$ (11,700)	0.71	$ (21,200)	0.71	Current[4]
6	Gilbert C. Grafton Military Reservation	Relocation of Munitions Facility	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,100)	0.64	Current
7	Grahams Island State Park	Incremental Road Raises and Structure Relocations	$ 23,764,000	$ 2,718,000	$ 516,000	$ (66,400)	0.86	$ (414,400)	0.59	Current
8.1	Devils Lake Rural Areas	Incremental Relocations	$ 79,764,000	$ 58,670,000	--	$ (273,700)	0.72	$ (831,300)	0.73	Current
8.2	Stump Lake Rural Areas	Incremental Relocations	$ 5,457,000	$ 3,547,000	--	$ (28,700)	0.65	$ (87,700)	0.65	1413
9	Red River Valley and Western Railroad	N/A	--	--	--	--	--	--	--	N/A
10	Canadian Pacific Railroad	Incremental Rail Raises	$ 67,260,000	--	$ 533,000	$ (895,900)	0.48	$ (2,646,700)	0.17	Current
11	Burlington Northern Railroad (along US	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ 1,060,300	1.48	1452
12	Burlington Northern Railroad (Churchs Ferry to	Incremental Rail Raises	$ 69,394,000	--	$ 509,000	$ (179,100)	0.19	$ (1,595,500)	0.20	1451
13	US Highway 2	Incremental Road Raises	$ 152,738,000	--	$ 11,863,000	$ 88,200	1.15	$ 2,298,800	1.47	1452
14	ND Highway 57 (between ND Highway 20 and BIA Highway 1)	Incremental Road Raises	$ 14,274,000	--	$ 13,104,000	$ 646,100	11.57	$ 7,251,000	16.25	1452
15	ND Highway 57 (between BIA Highway 1 and US Highway 281)	Incremental Road Raises	$ 42,667,000	--	$ 9,488,000	$ 353,400	3.05	$ 4,250,500	4.05	1452
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 2,733,000	1.98	Current
17	US Highway 281 (North of US Highway 2)	Incremental Road Raises	$ 38,459,000	--	$ 1,403,000	$ (35,200)	0.85	$ (198,300)	0.86	1451
18	ND Highway 19	Incremental Road Raises	$ 101,252,000	--	$ 1,322,000	$ (289,000)	0.29	$ (2,379,100)	0.28	1452
19	ND Highway 1	- NA -	--	--	--	--	--	--	--	1462
20	ND Highway 20 (North of City of Devils Lake)	Incremental Road Raises	$ 33,382,000	--	$ 3,375,000	$ (26,200)	0.66	$ (29,100)	0.97	1457
21	ND Highway 20 (City of Devils Lake Levee to ND Highway 57)	Incremental Road Raises	$ 24,859,000	--	$ 13,104,000	$ 606,900	6.71	$ 6,915,500	9.35	1452
22	ND Highway 20 (ND Highway 57 to Tokio)	Incremental Road Raises	$ 37,987,000	--	$ 611,000	$ (592,300)	0.50	$ (1,210,800)	0.34	Current
23	BIA Highway 1	Incremental Road Raises	$ 11,382,000	--	$ 1,012,000	$ 188,400	2.08	$ 469,100	1.97	1448
24	BIA Highway 6[5]	Incremental Road Raises	$ 4,538,000	--	$ 13,873,000	$ 740,900	35.46	$ 8,016,700	52.59	1453.9
		CUMULATIVE TOTAL	**$ 908,117,000**	**$ 403,116,000**	**$ 78,907,000**	**$ 759,000**	**1.07**	**$ 30,582,100**	**1.86**	

Summary Including Roads Acting as Dams

5	St. Michael	Protected by Roads Acting as Dams	--	$ 1,224,000	--	$ -	--	$ -	--	Current[4]
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	$ 611,000	$ -	--	$ -	--	Current
24	BIA Highway 6[5]	Protected by Roads Acting as Dams	--	--	$ 13,873,000	$ -	--	$ -	--	1453.9
25.1	Roads Acting as Dams (Acorn Ridge Area)	Incremental Levee Raises	$ 15,209,000	$ 3,098,000	$ -	$ (468,500)	0.12	$ (193,400)	0.21	Current[4]
25.2	Roads Acting as Dams (Mission Township Area)[6]	Incremental Levee Raises	$ 87,509,000	$ 7,220,000	$ -	$ (1,410,200)	0.61	$ (166,100)	0.93	Current[4]
		CUMULATIVE TOTAL WITH ROADS ACTING AS DAMS	**$ 966,590,000**	**$ 413,434,000**	**$ 78,907,000**	**$ (1,256,600)**	**0.91**	**$ 23,437,900**	**1.65**	

Notes

1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2 Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented in this table.
3 The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.
4 Currently protected by temporary dikes and roads that are acting as dams.
5 Currently protected by tempoary dikes and roads that are acting as dams, and is being raised to a minimum elevation of 1456.9.

Table EX-1b

Flood Protection Summary Table
Economic Results: First Action Level
Devils Lake Infrastructure Protection Study

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Present Worth[1] Total First Costs for First Action Level	Present Worth[1] Damages Prevented	Present Worth[1] Annual Damages Prevented[2]	Stochastic Analysis First Action Level Average Annual Net Benefits[3]	Stochastic Analysis First Action Level Benefit-Cost Ratio	Stochastic Analysis All Action Levels Average Annual Net Benefits[3]	Stochastic Analysis All Action Levels Benefit-Cost Ratio	Wet Future Scenario Analysis First Action Level Average Annual Net Benefits[3]	Wet Future Scenario Analysis First Action Level Benefit-Cost Ratio	Wet Future Scenario Analysis All Action Levels Average Annual Net Benefits[3]	Wet Future Scenario Analysis All Action Levels Benefit-Cost Ratio	Decision-Critical Lake Elevations[4] Current	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	Notes
1	Churchs Ferry	Relocation of All Structures Below 1468	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (6,100)	0.76	$ (22,400)	0.76	$ (22,400)	0.76					PC, LD, CI	LS						
2	City of Devils Lake	One Incremental Levee Raise	$ 6,327,000	$ 223,729,000	--	$ 1,294,000	5.74	$ 365,200	1.30	$ 10,392,400	29.46	$ 6,972,700	2.84	PI	CI				PC		LD			LS	
3	Fort Totten	One Incremental Relocation	$ 4,753,000	$ 3,638,000	--	$ (19,900)	0.77	$ (20,500)	0.76	$ (60,200)	0.77	$ (65,600)	0.76		LD, CI	LS									
4	City of Minnewaukan	One Incremental Levee Raise	$ 11,298,000	$ 10,493,000	--	$ (23,600)	0.85	$ (25,300)	0.88	$ (62,000)	0.89	$ 149,700	1.17		PI			CI, LD	LS	PC					Temporary Protection of Low Homes
5	St. Michael	One Incremental Relocation	$ 582,000	$ 409,000	--	$ (10,500)	0.70	$ (11,700)	0.71	$ (10,500)	0.70	$ (21,200)	0.71	PI, CI, PC, LD				LS							
6	Gilbert C. Grafton Military Reservation	Relocation of All Structures	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,000)	0.64	$ (33,100)	0.64	$ (33,100)	0.64	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS=1444
7	Grahams Island State Park	One Incremental Road Raise	$ 5,668,000	$ 531,000	$ 516,000	$ (67,500)	0.80	$ (66,400)	0.86	$ 173,000	1.50	$ (414,400)	0.59	PI, CI, PC, LD				LS							
8.1	Devils Lake Rural Areas	Five Incremental Relocations	$ 23,511,000	$ 17,055,000	--	$ (218,500)	0.72	$ (273,700)	0.72	$ (359,500)	0.72	$ (831,300)	0.73												Broad Range of Elevations
8.2	Stump Lake Rural Areas	Eight Incremental Relocations	$ 2,982,000	$ 1,960,000	--	$ (22,900)	0.66	$ (28,700)	0.65	$ (53,100)	0.66	$ (87,700)	0.65												Broad Range of Elevations
10	Canadian Pacific Railroad	One Incremental Rail Raise	$ 23,234,000	--	$ 533,000	$ (654,500)	0.54	$ (895,900)	0.48	$ (1,193,600)	0.16	$ (2,646,700)	0.17	PI, CI, PC, LD			LS								
11	Burlington Northern Railroad (along US Highway 2)	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ (62,600)	0.87	$ 1,060,300	1.48	$ 1,060,300	1.48				PI		CI, LD				LS		
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 315,600	1.11	$ 2,733,000	1.98	$ 2,733,000	1.98	PI, CI, LD			LS								
17	US Highway 281 (North of US Highway 2)	One Incremental Road Raise	$ 9,953,000	--	$ 1,403,000	$ (15,300)	0.88	$ (35,200)	0.85	$ (207,000)	0.57	$ (198,300)	0.86		PI			CI, LD			LS				
19	ND Highway 1	- NA -	--	--	--	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -												LS=1465, Has been relocated
22	ND Highway 20 (ND Highway 57 to Tokio)	One Incremental Road Raise	$ 17,858,000	--	$ 611,000	$ (532,300)	0.51	$ (592,300)	0.50	$ (826,000)	0.24	$ (1,210,800)	0.34	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS=1445
23	BIA Highway 1	One Incremental Road Raise	$ 3,004,000	--	$ 1,012,000	$ 161,900	2.27	$ 188,400	2.08	$ 125,300	1.73	$ 469,100	1.97	PI	CI, LD			LS							
24	BIA Highway 6	- NA -	--	--	--	- NA -	- NA -	$ 740,900	35.46	- NA -	- NA -	$ 8,016,700	52.59												Being raised to LS=1457

Roads Acting as Dams

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Total First Costs for First Action Level	Damages Prevented	Annual Damages Prevented[2]	Stochastic First Action Level Average Annual Net Benefits[3]	Stochastic First Action Level Benefit-Cost Ratio	Stochastic All Action Levels Average Annual Net Benefits[3]	Stochastic All Action Levels Benefit-Cost Ratio	Wet Future First Action Level Average Annual Net Benefits[3]	Wet Future First Action Level Benefit-Cost Ratio	Wet Future All Action Levels Average Annual Net Benefits[3]	Wet Future All Action Levels Benefit-Cost Ratio	Current	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	Notes
5	St. Michael	Protected by Roads Acting as Dams	--	--	--	--	- NA -	--	- NA -	--	- NA -	--	- NA -	PI, CI, PC, LD				LS							
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	--	--	- NA -	--	- NA -	--	- NA -	--	- NA -	PI, CI, PC, LD, LS											LS = 1445
25.1	Roads Acting as Dams (Acorn Ridge Area)	One Incremental Levee Raise	$ 3,404,000	$ 853,000	--	$ (172,300)	0.23	$ (468,500)	0.12	$ (160,800)	0.24	$ (193,400)	0.21	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS =
25.2	Roads Acting as Dams (Mission Township Area)	One Incremental Levee Raise	$ 35,674,000	$ 20,763,000	--	$ (1,047,500)	0.55	$ (1,410,200)	0.61	$ (945,700)	0.57	$ (166,100)	0.93	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS =

LS = Low Structure, LD = Lake Damage, PC = Project Completion, CI = Construction Initiation, PI = Project Initiation. For further description of decision-critical lake elevations, see Section 3.2.1.

Notes
1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2 Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented in this table.
3 The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.
4 Decision-critical elevations are rounded to the nearest foot.

Figure 1.01

LOCATION MAP
DEVILS LAKE FEATURES
Devils Lake Infrastructure Protection Study

Table EX-2

Construction Material and Mitigation Requirements for First Action Level

Devils Lake Infrastructure Protection Study

Feature Number	Feature Name	Flood Protection Strategy	Total Mitigation Required[1] (Acres)	Construction Quantities: Fill Material (CY)	Bedding (CY)	Riprap (CY)	Number of Structures Relocated[2]
1	Churchs Ferry	Relocation of All Structures	--	--	--	--	16
2	City of Devils Lake[3]	One Incremental Levee Raise	1.2	19,018	2,826	3,327	--
3	Fort Totten	One Incremental Relocation	--	--	--	--	5
4	City of Minnewaukan	One Incremental Levee Raise	50.0	95,900	16,100	22,700	6
5	St. Michael	One Incremental Relocation	--	--	--	--	1
6	Gilbert C. Grafton Military Reservation	Relocation of Munitions Facility	--	--	--	--	6
7	Grahams Island State Park	One Incremental Road Raise and Relocation of Structures	84.7	329,000	0	14,000	1
8.1	Devils Lake Rural Areas	Five Incremental Relocations (total up to 1454)	--	--	--	--	257
8.2	Stump Lake Rural Areas	Eight Incremental Relocations (total up to 1454)	--	--	--	--	35
10	Canadian Pacific Railroad	One Incremental Rail Raise	83.2	305,700	0	129,000	--
11	Burlington Northern Railroad (along US Highway 2)	One Incremental Rail Raise	250.7	518,700	0	182,200	--
16	US Highway 281 (South of US Highway 2)	One Incremental Road Raise	235.4	2,643,300	0	25,000	--
17	US Highway 281 (North of US Highway 2)	One Incremental Road Raise	178.2	670,000	0	300	--
19	ND Highway 1	- NA -	--	--	--	--	--
22	ND Highway 20 (between ND Highway 57 and Tokio)	One Incremental Road Raise	65.1	1,018,000	0	77,000	--
23	BIA Highway 1	One Incremental Road Raise	17.5	118,500	0	15,000	--
24	BIA Highway 6	- NA -	--	--	--	--	--
CUMULATIVE TOTAL			**966.0**	**5,718,118**	**18,926**	**468,527**	**327**

Summary Including Roads Acting as Dams (Expanded Infrastructure Protection)

5	St. Michael	Protected by Roads Acting as Dams	--	--	--	--	--
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	--	--	--
25.1	Roads Acting as Dams (Acorn Ridge Area)	One Incremental Levee Raise	0	85,000	5,700	8,500	1
25.2	Roads Acting as Dams (Mission Township Area)	One Incremental Levee Raise	6,789	677,000	60,000	90,000	15
CUMULATIVE TOTAL WITH ROADS ACTING AS DAMS			**7,689.9**	**5,462,118**	**84,626**	**490,027**	**342**

Notes

1 Required mitigation for wildlife habitat impacted by flood protection measures.

2 Structures include all residences, barns, sheds, and commercial/industrial buildings.

3 Wildlife habitat mitigation estimate for the City of Devils Lake levee was obtained from the Alternatives Alignment Study, 2001.

1. Introduction

1.0 Brief History of Devils Lake Flooding and Approaches to Mitigation

Devils Lake is a closed basin in northeastern North Dakota that receives runoff from a 3,814 square mile watershed. Figure 1.0-1 shows the Devils Lake area. (All tables and figures in this report are provided at the end of the section in which they are referenced.) In the seven years between 1993 and 1999, the lake rose approximately 25 feet, from 1422.5[6] in 1993 to a peak elevation of 1447.2 in 1999. In 2001, the lake peaked at 1448.0. 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 1459, it would be combined with Stump Lake and overflow into the Sheyenne River. The Sheyenne River flows to the Red River of the North.

Rising lake levels have affected communities, transportation routes, and rural lands. Federal, state, and local agencies have generally 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. Several studies have been conducted regarding the potential for using upstream storage to slow the lake's rise. Upstream areas are currently being used to retain water and help mitigate Devils Lake flooding.

2. Protection to structures and infrastructure in case the lake continues to rise. Efforts to protect local structures and infrastructure are ongoing. These efforts are the focus of this report.

3. An outlet[7] to release excess water from the lake. Several options for providing a pump station and pipeline to remove water from the lake have been explored. Both the state and the Federal government have completed preliminary designs for a Devils Lake outlet.

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[6] For convenience, all elevations in this report are given simply as the number of feet above mean sea level. It should be pointed out that there are likely to be discrepancies within the set of reported elevations. This results from the fact that the agencies providing data (regarding local topography, road elevations, levee elevations, etc.) may base their reported elevations on either of two reference datums (NAVD29 or NAVD88). However, use of the different datums is likely to result in a maximum discrepancy of only about one foot. Therefore, it was assumed that any inconsistencies in reported elevations would be of relatively small magnitude and would not materially affect the conclusions of this study.

[7] Defined as a flood control project that removes water from Devils Lake and directs it to the Sheyenne River.

1.1 History of Economic Analysis of the Outlet

The flooding at Devils Lake has been the subject of several studies, each concerned with identifying viable options for preventing further damage from the rising waters. Because of the wide extent of the damage, flood protection efforts have been and will continue to be costly. Due to the large expenses involved with providing flood protection—in the form of upstream storage, structure and infrastructure protection, and/or construction of an outlet—a principal focus of the studies has been the evaluation of the economic justification of any of the proposed approaches to flood protection.

Two major efforts have already been undertaken to determine the relative costs and benefits of providing a Devils Lake outlet:

In 1998, the Devils Lake Limits Study[8] (Limits Study) was completed. That study provided an economic evaluation of several proposed outlet configurations for Devils Lake, taking into account the ongoing efforts to protect "features"[9] in and around the Devils Lake area. (See Figure 1.0-1; Section 1.3 below gives a listing of the features originally identified in the 1998 report.) Taking into account possible climate variations as well as the various options that were available for protection of features near the lake, the Devils Lake Limits Study provided an estimate of the likely costs and benefits of outlet construction. Benefit-cost ratios (BCRs) were thus computed for the outlet under a variety of climate assumptions, and under a variety of operating assumptions for the outlet.

In 2001, the work of the Limits Study was expanded in the Economic Analysis of Devils Lake Alternatives[10] (referred to as the Economic Analysis in this report). The original study was expanded for several reasons. Water quality concerns had resulted in a re-evaluation of the proposed location and pumping rates for the outlet. Several alternative outlets, each extracting water of varying water quality from different parts of the lake, had been proposed and needed evaluation. Water quality concerns had also motivated an effort to include the potential downstream effects (on riparian areas, agricultural and industrial operations, and water treatment facilities) of an outlet in the economic analysis. The Economic Analysis therefore used the basic approach developed earlier in the Limits Study, but adapted it and extended it to evaluate the economics of new outlet options while taking downstream water quality effects into account. BCRs were developed for each of the outlet alternatives[11].

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[8] *Devils Lake Limits Study: An Economic Evaluation of the Emergency Outlet*, Barr Engineering Company, July 20, 1998.
[9] Defined as a physical entity or group of entities that would be susceptible to damage from the rising lake water
[10] *Economic Analysis of Devils Lake Alternatives,* (*Main Report, Tabular Data, and Technical Appendix)*, Barr Engineering Company, 2001.
[11] In the context of the Economic Analysis, "alternative" meant a specific outlet configuration – including the outlet's location, its pumping rate, and the water quality constraints to which the pumping was subject.

1.2 Why Further Analysis was Needed

The previous economic analyses related to flood protection efforts at Devils Lake have centered on the costs and benefits of construction of an outlet. For these analyses, however, it has always been necessary to take into account the ongoing and potential flood protection efforts for the Devils Lake features. Providing an outlet and thereby lowering the water level in Devils Lake would result in a reduction of damages in the basin and a reduction in costs for protecting Devils Lake features. Road raises or structure relocations, for example, might become unnecessary if the outlet serves to keep the lake from flooding the roads or damaging the structures.

For the previous analyses, therefore, much information regarding the protection of Devils Lake features was collected and analyzed. Local officials were contacted regarding plans and options for flood protection. The most likely flood protection strategies were identified. Construction cost estimates were developed based on then-current plans and unit prices. Estimates of the damages that would result from the rising water—for example, damages to homes and businesses, croplands, and infrastructure—were also developed for each of the features. These evaluations and cost/damage assessments were integral to the previous economic analyses.

However, because the previous economic analyses had focused on the costs and benefits of providing an outlet for Devils Lake, the economics of feature protection strategies for individual features had not been examined closely. Feature protection had been considered, but only in the context of the examination of economics of the outlet proposals[12]. The economic justification for continuing to raise an individual feature – US Highway 2, for example – had not been thoroughly evaluated. Similarly, the economic justification for flood protection at the other Devils Lake features had not been examined closely. Nevertheless, the previous analyses had given indication that protection of infrastructure around the lake would be economically justified[13] for the features in aggregate.

The US Army Corps of Engineers St. Paul District (Corps) is currently working to complete an Integrated Planning Report and Environmental Impact Statement (IPR/EIS) to address flooding around the lake and a potential natural spill into the Sheyenne River. The IPR/EIS was originally intended to focus mainly on the construction and operation of an outlet for Devils Lake, with feature protection continuing to be integral to the outlet analysis. However, comments were received from higher authority stating that infrastructure protection should be treated as a separate alternative for flood protection at Devils Lake. In addition, full National Environmental Protection Act (NEPA) documentation should be provided to allow feature protection to be implemented if it were selected as the preferred plan.

[12] The only exception was the Maximum Infrastructure Protection analysis (see the Economic Analysis report), which did consider overall feature protection separately from outlet considerations.

[13] Defined as having positive net benefits

The time allowed to complete the IPR/EIS did not allow a feasibility-level analysis to be completed for the infrastructure protection measures. Therefore, in lieu of a full feasibility-level analysis, the Devils Lake Infrastructure Protection Study (Infrastructure Protection Study) was intended to:

- Review and summarize the results of the analysis that had been conducted previously for 25 Devils Lake features
- Add description as necessary to provide a clearer picture of the 25 features, and the feature protection strategies that had been envisioned
- Perform additional analysis of 17 selected features—features that would be impacted at lake elevations not significantly above the recent peak (1448)—to bring the analysis of those features to a higher level of development
- Provide NEPA documentation for the current City of Devils Lake levee raise to 1460
- Use the analysis of the selected features to develop Flood Protection Summary Tables—guidance that could be used for Federal, state, and local officials in planning for the feature protection measures needed at Devils Lake

1.3 Features Analyzed

In accordance with the rationale for the study explained above, the Infrastructure Protection Study involved a review and investigation of the 25 Devils Lake features that had been identified in the Economic Analysis[14]. Additional analysis was conducted for 17 of these features that had been identified by the Corps as being subject to imminent impact from rising lake levels. The 25 features are listed below; the 17 features singled out for additional analysis are shown in bold text.

Devils Lake Features

1. **Churchs Ferry**
2. **City of Devils Lake**
3. **Fort Totten**
4. **City of Minnewaukan**
5. **St. Michael**
6. **Gilbert C. Grafton Military Reservation**
7. **Grahams Island State Park**
8. **Rural Areas**

[14] See the Economic Analysis for information on which features were included, and why.

8.1 Devils Lake Rural Areas

8.2 Stump Lake Rural Areas

9. Red River Valley and Western Railroad[15]

10. Canadian Pacific Railroad

11. Burlington Northern Railroad (Along US Highway 2)

12. Burlington Northern Railroad (Churchs Ferry to Cando)

13. US Highway 2

14. ND Highway 57 (between ND Highway 20 and BIA Highway 1)

15. ND Highway 57 (between BIA Highway 1 and US Highway 281)

16. US Highway 281 (South of US Highway 2)

17. US Highway 281 (North of US Highway 2)

18. ND Highway 19

19. ND Highway 1

20. ND Highway 20 (North of City of Devils Lake)

21. ND Highway 20 (City of Devils Lake Levee to ND Highway 57)

22. ND Highway 20 (ND Highway 57 to Tokio)

23. BIA Highway 1

24. BIA Highway 6

25. Roads Acting as Dams[16]

25.1 Acorn Ridge Area

25.2 Mission Township Area

1.4 Feature Analysis

As was mentioned above, 17 of the 25 features were singled out for more detailed analysis. An economic analysis of flood protection – at this more detailed level of investigation – was completed for the first action level for these 17 features. For four of the 17 features, an economic analysis of flood protection – at the more detailed level of investigation – for *all* action levels was also

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[15] The Red River Valley and Western Railroad, although included in the features listings, has been abandoned and so was not analyzed for either the Economic Analysis or the Infrastructure Protection Study.

[16] Note that while Roads Acting as Dams was not actually called out as a feature in earlier reports, these water-retaining structures were identified and analyzed (as “Expanded Infrastructure Measures”) in those reports. For the Infrastructure Protection Study, the Roads Acting as Dams feature was treated as two separate features – 25.1 and 25.2.

completed. For these four features, the more detailed investigation included analysis of more than one flood protection strategy.

As work on the analysis proceeded, it became clear that the study required analysis of all action levels for all 25 of the features. Limitations on time and budget, however, did not permit the additional action levels to be analyzed at the same level of detail as was provided for the first action level for the 17 selected features. An abbreviated method of providing cost estimates was therefore devised for the remainder of the 17 features needing additional analysis.

Finally, the study provided economic results for flood protection up to the maximum lake level for the features not part of the group of 17 originally scheduled for detailed analysis. The analysis for these remaining features was based on previous tallies of costs and damages, updated only through the use of current interest rates; providing results for these eight features did not involve additional investigations.

Table 1.4-1 identifies the methods for the analysis that was conducted for the various action levels for each of the features. The methodology for the various analyses is described in detail in Section 3.

1.5 Components of the Devils Lake Infrastructure Protection Study

To present the results of the analysis of the above-listed features, this report on the Infrastructure Protection Study has the following components:

- Executive Summary – provides a brief description of the study, its rationale and methodology, and results.
- Section 1 – introduces the report; gives background information and explains why it was commissioned.
- Section 2 – gives a description of the previous analysis of the Devils Lake features, and presents the summaries prepared for each of the 25 features listed above (because of the volume of pages involved, the 25 summaries of the previous features analysis are bound separately from this report).
- Section 3 – explains the methodology used for the analysis completed for the 17 selected features highlighted in Section 1.3. The limited analysis conducted for the remaining features is also described.
- Section 4 – presents the general results of the analysis of the 17 selected features (Section 4.0). In Sections 4.1 through 4.25, summaries of the analysis of each of the 17 features are provided for both the first action level and for all action levels. However, because of the

volume of pages involved, the 17 feature summaries are provided in an appendix to this report.

- Section 5 – presents and explains the Flood Protection Summary Tables (Tables 5.0-1a and 5.0-1b). Table 5.0-1a shows the results for all action levels for the complete set of 25 features; Table 5.0-1b shows the results of the more detailed analysis of the 17 selected features at the first action level only.

- Section 6 – discusses the salient components of the analysis and Flood Protection Summary Tables, and highlights important conclusions that may be drawn from the work.

To assist in clarifying the sometimes-confusing array of specialized terminology used in the report, a glossary of terms has been provided, and can be found at the end of the report.

Several appendices are also attached to the report. The appendices include the features summaries, a listing of references, additional information regarding the environmental assessment, and additional tables detailing economic results for features 12 through 15, 18, 20, and 21.

Table 1.4-1

Analysis of Flood Protection Strategies for Each Feature

Feature Number	Feature Description	Economic Analysis of Devils Lake Alternatives (2001)[1]	Infrastructure Protection Study			
			Detailed Analysis of First Action Level (AL1)[2]	Detailed Analysis of All Action Levels[3]	Limited Analysis Above First Action Level (AL1)[4]	Interest Rate Update Only[5]
1	Churchs Ferry	X	X[10]			
2	City of Devils Lake	X	X[6]	[7]		[7]
3	Fort Totten	X	X	X		
4	Minnewaukan	X	X	X		
5	St. Michael	X	X	X		
6	Gilbert C. Grafton Military Reservation	X	X[10]			
7	Graham's Island	X	X		X	
8	Rural Areas	X[8]	X	X		
9	Red River Valley and Western Railroad	[9]				
10	Canadian Pacific Railroad	X	X		X	
11	Burlington Northern Railroad (Along US Highway 2)	X	X[10]			
12	Burlington Northern Railroad (Churchs Ferry to Cando)	X				X
13	US Highway 2	X				X
14	ND Highway 57 (between ND Highway 20 and BIA Highway 1)	X				X
15	ND Highway 57 (between BIA Highway 1 and US Highway 281)	X				X
16	US Highway 281 (South of US Highway 2)	X	X[10]			
17	US Highway 281 (North of US Highway 2)	X	X		X	
18	ND Highway 19	X				X
19	ND Highway 1	[11]				
20	ND Highway 20 (North of the City of Devils Lake)	X				X
21	ND Highway 20 (City of Devils Lake levee to ND Highway 57)	X				X
22	ND Highway 20 (ND Highway 57 to Tokio)	X	X		X	
23	BIA Highway 1	X	X		X	
24	BIA Highway 6	X	X[12]		X	
25	Roads Acting as Dams	X[13]	X		X	

1 Data was taken directly from the Economic Analysis of Devils Lake Alternatives (2001) using the FY01 interest rate of 6 3/8%.

2 Cost and damage data for the first increment of flood protection (AL1) were reviewed and updated; the updates accounted for anticipated environmental, geotechnical, and real estate costs. The economic analysis was conducted using the FY02 interest rate of 6 1/8%.

3 Cost and damage data for the flood protection increments above the first action level (AL1) were reviewed and updated; the updates accounted for anticipated environmental, geotechnical, and real estate costs. The economic analysis was conducted using the FY02 interest rate of 6 1/8%.

4 Cost and damage data for the flood protection increments above the first action level (AL1) were reviewed and updated. However, environmental, geotechnical, and real estate costs were not evaluated. The economic analysis was conducted using the FY02 interest rate of 6 1/8%.

5 Cost and damage values were obtained from the Economic Analysis of Devils Lake Alternatives (2001), and the economic analysis was conducted using the FY02 interest rate of 6 1/8%.

6 The information for the first levee raise was obtained directly from the Devils Lake Levee Alternatives Assessment report (2001).

7 The costs and damages above Action Level 1 were obtained directly from the Economic Analysis of Devils Lake Alternatives (2001) for the City of Devils Lake.

8 Incremental analysis for the Rural Areas was included up to elevation 1454.

9 This feature was abandoned in recent years and so was not analyzed, but it is nevertheless included in the feature list for consistency with previous studies.

10 There is only one action level for this feature; Action Level 1 provides flood protection up to the maximum lake level.

11 ND Highway 1 was raised to a minimum elevation of 1465 in 2001, therefore it was not included in the analyses.

12 BIA Highway 6 is currently being raised to a minimum elevation of 1459.5, which was considered the first action level (AL1). No costs or damages were included in the economic results for AL1, because the project is already funded.

13 Roads Acting as Dams was not represented as a *feature* in the Economic Analysis of Devils Lake Alternatives (2001). It was, however, analyzed as Expanded Infrastructure Measures.

2. Results of Previous Analysis of Features

2.0 Summary of Methodology and General Results of Previous Studies

As has been mentioned, the previous studies[17] of the economics of flood protection at Devils Lake involved substantial investigation into the likely approach to flood protection for the Devils Lake features. For this Infrastructure Protection Study, therefore, the first step was to revisit the reports and files from the earlier reports. By re-examining the previous work, concise summaries of the earlier investigations and findings for each of the 25 features could be prepared. These summaries served as the foundation for the more comprehensive and updated investigations (see Sections 3 and 4) for the 17 features that were the primary focus of the Infrastructure Protection Study.

The nature of the previous investigation, and general results, are described in Section 2.0[18]. Sections 2.1 through 2.25 are compilations of the previous findings for each of features 1 through 25. Sections 2.1 through 2.25 are bound separately from this report.

2.0.1 Methodology of Previous Analyses

2.0.1.1 Identification of Features

To evaluate flood protection strategies in the Devils Lake area, it was first necessary to develop a list of features for which flood protection efforts were likely. Developing the list required judgment as to which structure and infrastructure components might be grouped under a single feature. It also required an evaluation of the likely damages to the various roads, railroads, and other entities in the Devils Lake area. Discussions with local, state, and Federal officials provided essential information regarding which features were most critical, which could reasonably be protected, and which were more likely to be abandoned should the water continue rising.

Resulting from the previous investigations was a list of 24 features of five types: communities and cities, state facilities, rural areas, roads, and rail lines. A 25th feature—Roads Acting as Dams—has been added for the Infrastructure Protection Study. Roads Acting as Dams had been evaluated in the Economic Analysis[19] but had not been treated as a feature. The Infrastructure Protection Study treats Roads Acting as Dams as a feature and evaluates it accordingly.

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[17] *Devils Lake Limits Study: An Economic Evaluation of the Emergency Outlet*, Barr Engineering Company, July 20, 1998; and *Economic Analysis of Devils Lake Alternatives*, (*Main Report, Tabular Data, and Technical Appendix)*, Barr Engineering Company, 2001.

[18] The description of the methodology for previous studies given here is general, and does not touch on all aspects of the earlier studies. For greater detail, see the reports for the previous analyses.

[19] Roads Acting as Dams was considered under the analysis of "Expanded Infrastructure Measures"

Communities and Cities

Of the 24 selected independent features, five were communities or cities: Churchs Ferry, the City of Devils Lake, Fort Totten, Minnewaukan, and St. Michael. Each of these is home to local residents, and each has significant economic importance because of the relative density of infrastructure in this predominantly rural area of North Dakota. It was determined that all infrastructure (such as wastewater treatment facilities, schools, grain elevators, hospitals, schools, and airports) within the communities was dependent on the flood protection provided for the community. Therefore, such infrastructure was not treated separately; local infrastructure was considered simply as a part of the community or city feature.

State Facilities

Two of the selected features are state-owned facilities: Gilbert C. Grafton Military Reservation and Grahams Island State Park. The operation of the military base has a significant local economic impact. Rising lake levels were determined to have potential for substantial adverse impact on the access and use of the facility. A substantial amount of land formerly used for military maneuvers at the base has been inundated in recent years. The military base has also been forced to pump water from the west side of ND Highway 20 (just south of the City of Devils Lake levee) to protect several training areas.

Grahams Island State Park is a major tourist attraction in the Devils Lake 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 per-acre land values in these rural areas are not high, the total impact of rising lake levels on rural areas is significant. Because Stump Lake water levels could be significantly lower than those of Devils Lake, the rural areas around Stump Lake were treated separately from those adjacent to Devils Lake.

Rail Lines

Four rail lines in the area were initially selected as independent features because they would be impacted by the rising lake levels. However, the Red River Valley and Western spur line to Minnewaukan was subsequently closed so that further analysis was not necessary. 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 connect New York to the State of

Washington. Many local communities outside of the study area are also 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 local grain elevators, and to deliver fertilizer to the area. Because of flood damage, the Canadian Pacific Railroad line from the City of Devils Lake to Harlowe was closed in 1998, and was therefore considered "embargoed" by the Canadian Pacific Railroad company.

Roads

There were 12 sections of roads that were selected as independent features. The selection of road sections was based on the results of a 1998 study[20] of transportation patterns in the region. For the Economic Analysis, roads were selected as independent features if they had average daily traffic counts (ADTs) greater than 1,000 prior to the recent increases in lake level. The roads included as independent features are described below.

- US Highway 2 is an important regional transportation route. Both interstate travel and local communities outside of the study area would be adversely affected by the closing of this road. The low portions of US Highway 2 are currently protected by the City of Devils Lake levee.
- Two other roads that are heavily used for east-west travel in the area are ND Highway 57 and ND Highway 19. The lowest portions of both of these roads have been raised in recent years to maintain east-west travel. ND Highway 57 was recently improved by construction of a bridge carrying it across "The Narrows" – a constriction of the lake just south of the City of Devils Lake.
- There are three major highways used for north-south travel in the area: US Highway 281, ND Highway 20, and ND Highway 1. The lowest portions of US Highway 281 and ND Highway 20 have been raised in recent years to ensure uninterrupted north-south travel. ND Highway 1 is located near Stump Lake, and had been threatened by the rising water of Stump Lake until it was re-aligned in 2001.
- Two roads on the Spirit Lake Nation – BIA Highway 1 and BIA Highway 6 – were considered to be critical transportation routes, even though average daily traffic counts were not available for these BIA roads. The lowest portions of both of these roads have been raised in recent years to maintain travel in the area.
- Three of the highways (ND Highway 57, US Highway 281, and ND Highway 20) were subdivided into multiple sections, and each section was treated as a separate feature. Considering the sections individually allows economic modeling to account for different

[20] *Devils Lake Flood Control, Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998

traffic patterns, different potential reroute paths, and different lake elevations at which each of the road sections would be affected by flooding.

Roads Acting as Dams

In the Devils Lake area, several roads have been raised and the culverts plugged so that these roads themselves are currently holding back water. As a result, these roads act as dams and are providing flood protection for interior[21] land, roads, and structures. However, these "dams" have not been designed as such, and as a result could be prone to failure. Construction of a series of perimeter levees would reduce the danger of dam failure while maintaining flood protection for the area. The idea is that the new perimeter dams would take over the responsibility for holding back the lake water. New culverts placed under existing roads now acting as dams would allow water levels to equalize on each side of the road, thus removing unequal pressure and the likelihood of failure.

2.0.1.2 Identification of Feature Protection Strategies

For each feature, different strategies can be used to deal with the problem of flooding. One strategy might be to provide no protection – to abandon the feature either temporarily (until the lake water recedes) or permanently. Most features have at least one type of incremental flood protection strategy and maximum protection strategy. "Hybrid," or combination, strategies might also be implemented. All strategies evaluated flood protection costs and damages up to the maximum[22] lake level. The four general types of strategies that were analyzed for the features are described below.

- **No Protection**

  The no protection strategy implies that the feature would be abandoned, either temporarily or permanently.

  The planning, design, and construction of flood protection measures entails 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 expense of flood protection, the no protection strategy has been adopted for various features around the lake. Even if protection is not afforded, however, residential and commercial buildings have been and will continue to be relocated under current FEMA programs.

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[21] "Interior" refers to the land area protected by a levee (or dam). "Exterior," by contrast, refers to land areas or portions of the levee (or dam) on the lake side of the levee's centerline.

[22] There are many uncertainties with respect to the maximum lake level that the lake could or will achieve. However, several studies have used 1463 as the expected maximum water level for Devils Lake under prolonged wet climate conditions. Accordingly, 1463 has been used in the present study as the "maximum" lake level. It was assumed that flood protection measures would be designed accordingly.

- **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.

  For this stepwise approach to flood protection, the term "action level" was used in the Economic Analysis (and was carried over to the Infrastructure Protection Study). Action level refers to a lake level (or narrow range of lake levels) at which project planning and construction would be done for one of the flood protection increments.

  The incremental approach to flood protection has been used in the past for many of the features 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 total cost for implementation of incremental protection may be slightly larger than a one-time protection because of the additional project planning, management, and mobilization/demobilization costs. In addition, providing funding for incremental protection strategies requires repeated consideration and approval, which may exacerbate the stress of the flooding problem. The incremental approach is based to some extent on the hope that the lake level will soon decrease, eliminating the actions that might otherwise be required at the higher lake levels.

- **Maximum Protection**

  One-step flood protection 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 expected maximum elevation (1463). These strategies would include relocating sections of a community that would be threatened at 1463, raising a levee to protect a community, and raising or relocating a road (or rail line) to a new location above the expected maximum lake level.

  Maximum protection strategies for road raises, railroad raises, and levee raises were considered to be feasible strategies. Nevertheless, a "one-step" raise would be costly, might not receive full funding, and might not be a good investment if it turns out that the lake never reaches the maximum level. The one-step approach would, however, eliminate the need to continually revisit the decisions on funding.

- **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 relocating the road (maximum protection strategy).

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.

The Economic Analysis provided a preliminary evaluation of all these strategies for each feature. The study focused on incremental protection strategies (and in so doing set the stage for the analysis of these same incremental strategies conducted for the Infrastructure Protection Study). This preliminary evaluation was needed as a first step in evaluating the economic effect of each flood protection project. It did not, however, constitute a complete study of all possible strategies for flood protection in the Devils Lake area.

2.0.1.3 Decision Trees

The strategies for each feature can be graphically represented on "decision trees" that show the choices that would arise at various critical lake elevations. A decision tree was developed for each feature. The decision trees indicated the lake elevations at which decisions and actions would be required, and showed the options that were analyzed at those levels.

For the Economic Analysis, 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 was defined separately for each feature and for each of the various flood protection measures. When the Economic Analysis was conducted in 2001, Devils Lake was at approximately 1446. The lowest action level was therefore 1446.2.

The decision/action levels for each feature were based on the flood protection measures that had been completed during the past several years, and on then-current plans to increase protection as the lake level rises. Decision trees for all 25 features are included with the feature summaries provided as Sections 2.1 through 2.25. The decision trees indicate which strategies were analyzed and give elevations of 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. The incremental protection strategies having the largest net benefits (see below) are highlighted in bold on the decision trees.

2.0.1.4 Interdependencies

Decisions made regarding flood protection for some of the features will in some cases depend on the decisions made regarding flood protection for other features. For instance, raising a levee to protect a community without raising the road to provide access to the community would not make sense. Similarly, relocating buildings within a community would not make sense if the only road providing access to the community were abandoned. Such relationships between features are referred to as "interdependencies," and were identified as a part of the investigations of the Economic Analysis. Despite any interdependencies, the costs of protecting a particular feature were always treated separately from the costs of protecting its interdependent feature or features.

The situation with respect to the interdependencies among the highway features is especially complex. The highways have many interdependencies – closing one road is almost certain to affect other roads, either by forcing traffic elsewhere, or by causing a reduction in travel on a connecting highway. When a flood protection strategy is successful in keeping water from closing any roads, detour damages never occur. In that case, these interdependencies become moot and the economic modeling is straightforward. However, scenarios can be envisioned in which rising waters close portions of several highways simultaneously. Accounting for the many possibilities for the resultant detour damages – and modeling them – would have been extremely complicated and laborious. Consequently, in most cases, it was assumed for the modeling that when rising waters forced closure of one road, all others would remain open. The modeling of detour damages is discussed further in Section 2.01.5.

Note that the Economic Analysis (and its successor, the Infrastructure Protection Study) did not attempt to account for what might be described as large-scale interdependencies. If the City of Devils Lake, for example, had to be relocated, significant economic damage to the entire region would result. Similarly, relocation of the City of Minnewaukan would cause considerable hardship to those who rely on that community's presence for commerce and government transactions. Such interdependencies, while real, could not be represented in the costs and benefits of flood protection as defined for the study.

2.0.1.5 Study of Benefits and Costs

It should be noted that, in general for the Economic Analysis, feature protection was not treated as a separate flood protection approach—it was assumed to be ongoing, with or without any efforts to reduce lake levels by means of an outlet or upstream storage. (As noted previously, an exception was the Economic Analysis' evaluation of "Maximum Infrastructure Protection".) The primary intent of the Economic Analysis was to evaluate the potential for an outlet or upstream storage to reduce flood protection costs and prevent damages. In estimating net costs and net benefits for any particular flood protection strategy, therefore, the absolute costs of feature protection were relatively unimportant.

The following description of the analysis of benefits and costs focuses on feature protection. For further information regarding upstream storage or outlet alternatives, the reader should consult earlier reports.

Benefits and costs were computed between the then-current lake level and the expected maximum of 1463.

Benefits – The calculation of benefits for flood protection is more complicated than the calculation of the costs. This section explains some of the reasons for the complication, and explains in general terms how the benefit calculations were conducted.

The benefits for the flood protection strategies consisted of *damages prevented* as a result of implementation of a particular strategy. The Economic Analysis investigated each feature adjacent to Devils Lake to determine the damages that would occur if the lake continues to rise. Damages were then computed both without and with each flood protection strategy. However, under some strategies, a portion of the damages may still occur with the project (such as detour damages when a road is relocated). Therefore, the evaluation of benefits consisted of tabulating damages both with and without flood protection. If the damages for a particular feature without flood protection exceed those when flood protection is provided, the flood protection measure shows a benefit for protection of that feature.

The benefits of the various flood protection strategies included such items as avoided damages to homes and roads, cost savings for postponed or avoided flood protection, and avoided losses of revenue for recreational facilities.

In the Economic Analysis, both direct and indirect[23] benefits were considered. For the Roads Acting as Dams feature, a portion of the benefits are actually *costs avoided* – costs that would otherwise be required but are avoided because the water-retaining perimeter dams serve to protect interior structures and infrastructure. If the costs to protect these structures and infrastructure when the perimeter dams are not in place exceeded the costs when the perimeter dams are in place, Roads Acting As Dams registered a benefit as a result of the cost savings.

Note that there are three categories of potential flood damages for features adjacent to the lake:

- Continuously-occurring damages (e.g., detours for vehicles caused by closed roads)
- One-time-only damages (e.g., damages to structures)

[23] "Direct" benefits of flood protection measures refer to the benefits of protection from, prevention of, or delay of flood damages to a feature or features. By contrast, "indirect" benefits are those that accrue to a feature by means of avoided costs, or as a consequence of measures taken to protect other features.

- Once-per-event damages, occurring each time the lake rises and falls (e.g., damages to roadways – roadways that would have to be restored when the lake level falls)

These damages all increase as the lake level rises. The Economic Analysis indicated that "continuously occurring" damages (detour, trucking, and lost recreational use damages when roads are closed and access is denied) for each year of closure would total over $79 million at the maximum lake level. The one-time-only damages to land and infrastructure would total $520 million at the maximum lake level. The once-per-event restoration damages to roads and rail lines would total just over $131 million at the maximum lake level.

As was mentioned previously, in general the detour damages for a particular highway were computed assuming that all other roads would remain open. However, there were two exceptions.

1. When computing detour damages when ND Highway 57 (feature 14) was closed, it was assumed that ND Highway 20 (feature 22) across the Narrows was also closed. This assumption was made because history and discussions with the North Dakota Department of Transportation (NDDOT) indicated that protecting ND Highway 57 was of higher priority than protecting ND Highway 20. Therefore, if it had been impossible to protect ND Highway 57 and it was in fact under water, it would almost certainly be the case that ND Highway 20 would also be flooded and closed. It should be noted, however, that this assumption results in high detour damages for ND Highway 57. The simultaneous closure of ND Highway 20 means that long detours would be required for those traveling from the south to the City of Devils Lake, or from the City of Devils Lake to the south.

   (Conversely, however, when computing detour damages for ND Highway 20, it was not assumed ND Highway 57 was closed simultaneously. The estimated detour damages for ND Highway 20 are consequently much lower than those for ND Highway 57.)

2. When computing damages for BIA Highway 6 (feature 24), it was assumed that when BIA Highway 6 was closed due to flooding, ND Highway 20 (feature 22) would also be closed. This assumption was made because analysis showed that although both roads are susceptible to flooding at approximately the same lake level, it would be more expensive to keep ND Highway 20 open. The simultaneous closure of both these roads would cause considerable inconvenience for those traveling to the City of Devils Lake from the southeast (and vice versa), so that the estimates of detour damages for BIA Highway 6 are relatively high.

   (Conversely, however, when computing detour damages for ND Highway 20, it was not assumed BIA Highway 6 was closed simultaneously. The estimated detour damages for ND Highway 20 are consequently much lower than those for BIA Highway 6.)

The detour damages for all roads are computed individually, so that the benefits (damages prevented) for flood protection measures are assigned wholly and exclusively to the road being evaluated. It should be noted that in fact, however, flooding might cause several roads along a well-traveled route to be flooded simultaneously. In that case, it might be more reasonable to apportion detour damages among the several roads, rather than assigning the entire damage amount to each of the roads simultaneously. Nevertheless, the modeling conducted for this study did not permit this sort of apportionment. As a result, a summation of the benefits for flood protection at all the features may exaggerate the benefits – detour damages prevented – for the group of highways in aggregate.

The Economic Analysis did not account for a variety of other flood-related economic impacts, most of which are regional economic damages that would be reflected in the Corps' "Regional Economic Development" calculations. Prime examples are the impacts of flooding on the region's businesses, and on the $50 million per year recreation industry. These operations are affected by disruptions of the transportation corridors and difficulties with boat access. The business impacts are made worse by exaggerated fears (regarding travel difficulties) of would-be visitors and recreational users of the Devils Lake area.

Similarly, it was beyond the scope of the Economic Analysis to account for agricultural losses. According to a report on flooding damages[24] prepared for the City of Devils Lake and the Mayor's Task Force, acres lost to flooding result in a significant loss of potential revenues in an already financially strapped financial sector. The report shows that at elevation 1459, lost revenue due to flooding totals $11 million annually; at elevation 1459 the annual total would be $23 million.

Costs – For the Economic Analysis, a determination of the costs associated with each flood protection strategy was also necessary.

Project costs may be either first costs, or ongoing annual costs. First costs for a project (for example, the one-time expense of a road raise) can be tabulated and summed directly. Annual costs for a strategy (for example, the expenses of pump station operation) must be tabulated for each year of operation.

Depending on the flood protection strategy, the project costs included:

- Construction costs for raising roads, railroads, and levees
- Relocation costs when buildings were to be moved to higher ground
- Operating and maintenance costs for levees that protect communities adjacent to the lake

[24] "Devils Lake Strategic Plan: A Blueprint for Economic Recovery and Revitalization," prepared for the City of Devils Lake and the Mayor's Task Force, CEO Praxis, Inc., October 2000.

Costs for road and railroad maintenance were assumed to be ongoing expenses, included in current budgets. Therefore, in the Economic Analysis' evaluations, these costs were not considered to be project costs.

Economics – In the Economic Analysis, all costs and benefits accruing over the 50-year period of analysis were brought back to present worth, summed, and then reduced to an annual amount.

For the Economic Analysis, all assumptions regarding the cost and benefit calculations for each feature were listed, and presented in the report's Technical Appendix. A presentation of these assumptions can be found attached to the feature summaries presented in Sections 2.1 through 2.25. (For the Infrastructure Protection Study, these original assumptions listings were reviewed and updated as needed – see attachments to Sections 4.1 through 4.25.)

Evaluation of the economic feasibility of flood protection engineering alternatives is a well-established process. At its simplest, the process requires a comparison of the benefits and costs of various projects. The Federal government has formulated standard criteria for calculating the benefits and costs of each project for Federal administrative purposes. These are National Economic Development (NED) procedures. They require comparison of project benefits and project costs[25] at a common point in time. Benefits and costs are considered for the full period of time over which the project would have significant beneficial effects. NED criteria require that benefits and costs must be calculated in terms of an annual cost (comparable to a loan payment) and an annual benefit. If the stream of benefits from the project is not greater than the annual costs of the project, the project is not justified economically by NED criteria. The Economic Analysis was based on NED criteria.

The Economic Analysis used computer models to compute the net benefits and benefit-cost ratio (BCR) of each flood protection strategy. Net benefits equal the total benefits[26] described above, less the total costs for construction and operation of the project(s). The BCR equals the total benefits divided by the total costs. Note that large total benefits do not necessarily result in a large BCR; if the strategy also involves large total costs, these will enlarge the denominator of the ratio and reduce the BCR. A strategy is considered to be economically justified if the net benefit is greater than zero; such strategies will necessarily have a BCR greater than one.

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[25] A "benefit" was defined as the value that is provided by a project or feature protection measure. Cost savings and reduced damages are both tallied as benefits. By contrast, a "cost" is defined as an amount paid to implement a flood protection measure.

[26] More precisely, benefits and costs were determined on the basis of annual totals for each. These annual totals were computed as follows: For each 50-year trace, benefits and costs were totaled and brought back to present worth. The benefits and costs were then annualized to produce the annual total benefit or cost for each trace. In the case of the stochastic analysis, where there were many traces, the totals for all of the 10,000 50-year traces were then averaged.

All benefit and cost values for the Economic Analysis were computed using 2001 dollars. Costs and benefits for the 50-year period of analysis starting on October 1, 2000[27] were brought back to present worth and then annualized using the Fiscal Year 2001 interest rate of 6-3/8 percent. For the stochastic analysis, the 10,000 annualized cost and benefit values – one annualized cost and one annualized benefit for each trace – were averaged.

2.0.1.6 Modeling Process

In general terms, the modeling process for the Economic Analysis proceeded as follows:

1. A computer model simulating the hydrology of the Devils Lake basin provided the set of lake level projections. These 50-year lake level projections were developed by the United States Geological Survey (USGS), and 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. A wet future trace was also created, based on recent wet climate conditions and resulting high inflows to the lake.

2. A second computer program (the Features Analysis Model, or FAM) used the lake level traces to calculate the costs and damages for each of the flood protection strategies for the features around Devils Lake. Listings of the costs of flood protection measures, as well as estimates of expected damages by lake level, were required as input for each feature analyzed by the Features Analysis Model. For each feature, the Features Analysis Model summed costs and damages for both with- and the without-flood protection conditions.

   The Features Analysis Model calculated the benefits of each flood protection strategy by subtracting any damages that would occur with the strategy implemented from the damages that would occur without the strategy in place. The project costs compared to these benefits provided the net benefits and BCR for the flood protection strategy for each feature.

3. The economic modeling results for each feature were then used to evaluate the economic feasibility of the flood protection strategy by comparing the results from different 50-year climate futures. The interested reader can find a detailed description of the outlet alternatives analysis in the Economic Analysis report. (The Infrastructure Protection Study report, however, ignores any possible outlet alternatives and focuses exclusively on the Economic Analysis' investigations into flood protection for the features.)

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[27] The USGS traces were originally developed for use in the Economic Analysis, begun in the spring of 2001. The USGS model requires actual lake level information, which was only available through the October 2000 water year. The Infrastructure Protection Study also uses the traces from the previous (2001) work. Despite the fact that the USGS model was not updated for use in the present study, the model's starting point for the 50-year study period should not adversely affect the analysis of costs and benefits.

2.0.1.7 Climate Assumptions Used for the Modeling

A major challenge for evaluating flood protection strategies 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. Hydrologic models can register the effects of climate, but long-term weather predictions are highly uncertain. Unfortunately however, these predictions are critical. Assumptions regarding future climate patterns make a significant difference in lake level projections, and as a result, in the estimates of costs and benefits of flood protection strategies.

The Economic Analysis dealt with the uncertainty in predicting climate and lake levels by comparing several assumptions regarding future climate patterns. It used a stochastic approach based on a US Geological Survey (USGS) lake level-probability model, but also considered results when assuming a specific Wet Future, two separate Moderate Futures, and a Dry Future.

The USGS model created "traces" of future lake levels. Each trace is a 50-year projected sequence of lake levels. For the analysis of the flood protection strategies, traces of lake levels were subsequently used to estimate the amounts of flood damages and flood protection costs, and to determine in which year(s) these costs and damages would occur.

Stochastic – The stochastic analysis provides a large number (10,000) of lake level predictions varying randomly but fluctuating only within reasonable expectations regarding future weather patterns. Because each lake level trace produced by the USGS model reflects a distinct 50-year projected climate future, each of the 10,000 50-year traces is different.

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 depend on the predictions of lake levels, any cost and benefit calculations can be no more reliable than the lake level predictions. By computing a strategy's costs and benefits for each of the 10,000 traces, and then averaging those costs and benefits over the 10,000 traces, a reasonable expectation of the cost and benefit for the strategy can be determined.

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.[28] After 2015, the simulation model assumes

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

that climatic conditions can be 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.

For the Economic Analysis, the stochastic analysis provided an average economic estimate based on probability. Because the recent lake levels have exceeded the predictions that have been based on historical lake levels, however, a single trace representing a "Wet Future" was also evaluated. It was also necessary to evaluate the economic feasibility of various strategies using single "moderate" or "dry" traces to further define the sensitivity of the analysis to a wide range of potential climate futures.

Wet Future – The Wet Future analysis evaluated one trace of 50-year lake levels 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 it reaches the natural overflow around the year 2014. The lake remains near or above the overflow 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 percent of the stochastic traces, representing those traces that have an average peak lake level of 1461.1.

Moderate Future 1 – The Moderate Future 1 trace was selected from among the stochastic traces. It was among the traces in a category having an average peak lake level of 1450 (approximately 30 percent of the stochastic traces). This moderate future trace was determined to be representative of this category.

Moderate Future 2 – The Moderate Future 2 trace was selected from among the stochastic traces. It was among the traces in a category having an average peak lake level of 1455 (approximately 25 percent of the stochastic traces). This moderate future trace was determined to be representative of this category.

Dry Future – 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 35 percent of the stochastic traces). This dry future trace was obtained from within the stochastic traces, as a trace that was representative of this category. The results of the Dry Future trace are not presented in this report, primarily because the maximum lake level registered in the Dry Future traces has already been reached.

2.0.1.8 Sensitivity Analysis and Feature Protection Strategy Assumptions

As has been mentioned previously, the Economic Analysis tested many basin-wide flood protection approaches, and investigated the sensitivity of its findings to varying climate assumptions. It conducted additional sensitivity analyses by varying the assumptions made regarding feature protection strategies.

The Infrastructure Protection Study focuses on the strategies that provide flood protection for each feature; the flood protection strategy having the largest net benefit is highlighted on the decision trees included with the feature summaries of Sections 2.1 through 2.25. These basin-wide flood protection strategies are the "most likely" set of strategies, as described in the Economic Analysis.

The most likely flood protection strategies for each feature were identified based on flood protection history in the Devils Lake area, and on analysis of which strategies would provide the largest net benefits. It should be noted, however, that the identification of the "most likely" strategy was not bound by the results of the economic analysis of the flood protection strategy; the strategy having the largest net benefits was not necessarily the "most likely."

2.0.2 General Results of Previous Studies

2.0.2.1 Interdependencies

All feature interdependencies identified in the Economic Analysis were between roads or railroads and other roads or railroads, or between roads and railroads and communities or state facilities.
Table 2.0-1 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.

2.0.2.2 Results of Economic Analysis

A summary of the economic results of the previous Economic Analysis is presented in Table 2.0-2. For each feature, the table lists the results for the most likely flood protection strategy. Results are given only for the stochastic analysis; the results obtained for the specific (Wet, Moderate 1, Moderate 2) climate futures can be found in the individual feature summaries of Sections 2.1 through 2.25.

2.1 through 2.25 – Feature-by-Feature Summaries from Economic Analysis

A summary of the findings of the previous investigation for each of the 25 features was prepared as a part of the Infrastructure Protection Study. Detailed and particular information regarding each of the 25 features analyzed in previous studies was extracted, organized, and compiled using a consistent format. The compilations are presented in Sections 2.1 through 2.25, which are bound separately from this report.

Table 2.0-1

Feature Interdependencies
Based on the Study: Economic Analysis of Devils Lake Alternatives

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																					

(shaded cell) 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.

Table 2.0-2

Economic Analysis Stochastic Results Summary
Based on the Economic Analysis of Devils Lake Alternatives

Feature Number		Flood Protection Strategy Having the Largest Net Benefits	Mean Value over 10,000 traces (annualized): Total Costs	Total Remaining Land Damages	Total Benefits to Strategy	Net Benefits	Benefit-Cost Ratio
1	S(2)	2 Incremental Relocations	$334,000	$0	$333,300	-$700	1.00
2	L(3)	3 Levee Raises	$836,100	$0	$5,607,400	$4,771,300	6.71
3	S(3)	3 Incremental Relocations	$11,200	$0	$10,200	-$1,000	0.91
4	L(2)	2 Levee Raises	$112,200	$0	$170,700	$58,500	1.52
5	S(3)	3 Incremental Relocations	$20,200	$0	$19,400	-$900	0.96
6	R(4)	4 Road and Munitions Levee Raises	$268,200	$4,700	$30,500	-$237,600	0.11
7	R(4)*	Relocation of Structure at First, Second, and Fifth Action Levels:4 Road Raises	$128,500	$11,600	$82,400	-$46,200	0.64
8.1	S(11)	11 Incremental Relocations	$940,300	$1,148,200	$1,117,800	$177,500	1.19
8.2	S(1)	Relocation of All Structures below 1468	$3,000	$120,000	$4,300	$1,300	1.43
10	R(3)	3 Incr. Rail Raises	$934,400	$0	$237,600	-$696,700	0.25
11	R(2)	2 Incr. Rail Raises	$294,100	$0	$375,000	$80,800	1.28
12	R(2)	2 Incr. Rail Raises	$223,300	$0	$42,900	-$180,400	0.19
13	R(2)	2 Incr. Road Raises	$585,100	$0	$666,400	$81,400	1.14
14	R(2)	2 Incr. Road Raises	$61,300	$0	$703,000	$641,600	11.47
15	R(2)	2 Incr. Road Raises	$173,500	$0	$523,000	$349,400	3.01
16	R(5)	5 Road Raises	$2,413,200	$0	$2,612,800	$199,600	1.08
17	R(3)	3 Incr. Road Raises	$308,600	$0	$163,600	-$145,000	0.53
18	R(2)	2 Incr. Road Raises	$411,600	$0	$119,600	-$291,900	0.29
19		N/A	N/A	N/A	N/A	N/A	--
20	R(1)	Road Raise to 1468	$77,700	$0	$51,100	-$26,600	0.66
21	R(2)	2 Incr. Road Raises	$106,800	$0	$709,000	$602,100	6.64
22	R(4)	4 Incr. Road Raises	$1,970,300	$0	$696,700	-$1,273,600	0.35
23	R(3)	3 Incr. Road Raises	$158,000	$0	$172,400	$14,400	1.09
24	R(5)	5 Incr. Road Raises	$149,800	$0	$9,394,700	$9,244,900	62.71
		CUMULATIVE TOTAL	**$10,521,400**	**$1,284,500**	**$23,843,800**	**$13,322,200**	**2.27**

Roads Acting as Dams

25	L(2)	2 Levee Raises	$1,149,341	$0	$1,143,200	-$6,141	0.99

NOTES: These results are based on the Stochastic analysis.

3. Infrastructure Protection Study Methodology

3.0 Introduction to Infrastructure Protection Study Methodology

The Infrastructure Protection Study focuses exclusively on protection of the Devils Lake features. Benefits—flood damage reductions—are assessed along with the costs of providing the flood protection for the features. The benefits are then compared with the costs to determine net benefits and BCRs for protecting the features.

This more focused evaluation of feature protection required a more detailed evaluation of the flood protection benefits and costs. The updated damage and cost information was subsequently used as input to the Features Analysis Model to provide economic summary information (net benefits and BCRs) for protecting each of the features. The general methodology for the Infrastructure Protection Study cost and damage evaluations, and for the modeling methods, is described in this Section 3.

3.1 Feature Analysis in the Infrastructure Protection Study

Section 2 of this report included a complete listing of the twenty-five[29] features evaluated in the previous economic analyses, but not all of these were evaluated in detail in the Infrastructure Protection Study. Only those features that had first action levels below 1454 were studied in detail in the Infrastructure Protection Study.

The original intent of the Infrastructure Protection Study was to focus on the economics of the first action level for each of the features. As the work progressed, however, it was recognized that it was important to present economic modeling results not only for the first action level, but also for flood protection up to the maximum lake level. How the analysis of the subsequent action levels was conducted varied, depending on what work had been done initially.

The level of detail for the analysis of the first and subsequent action levels for all the features is indicated below. Table 1.4-1, discussed previously, summarizes the categories of analysis.

3.1.1 Detailed Analysis for First Action Level Only

Seventeen of the original list of 25 features had action levels below 1454, and thus were eligible for the more detailed study of the Infrastructure Protection Study.

[29] The Economic Analysis listed 25 features. In fact, only 24 were analyzed; Feature 9 (Red River Valley and Western Railroad) had been abandoned years ago and was therefore never included. For the sake of consistency, however, the total number of features has been kept at 25 and Feature 9 is included in all listings.

Based on the history of flood protection in the Devils Lake region, 14 of these 17 features were seen to have just one flood protection strategy with a high likelihood of actually being implemented. Therefore, it was not necessary to compare all identified flood protection strategies at all action levels to identify the strategy that had the largest net benefits. Initial analysis, therefore, focused on the first action level only.

Of the list of 14 features, one (Feature 19: ND Highway 1) had already been protected up to the maximum lake level, so a detailed benefit and cost analysis was no longer relevant. For another (Feature 8: Rural Areas), it was decided to conduct a detailed analysis for all action levels.

For the remaining features, the Infrastructure Protection Study proceeded to examine the first action level in detail[30]. The methodology for the detailed analysis is presented in Section 3.2. For these 12 features, if there were additional action levels required to provide flood protection up to the maximum lake level[31], the cost estimating procedure for the subsequent action levels was slightly abridged.

The features for which detailed analysis was conducted only for the first action level were:

Detailed Analysis for First Action Level Only	
Feature Number	**Feature Name**
1	Churchs Ferry
2	City of Devils Lake
6	Gilbert C. Grafton State Military Reservation
7	Grahams Island State Park
10	Canadian Pacific Railroad
11	Burlington Northern Railroad (along US Highway 2)
16	US Highway 281 (South of US Highway 2)
17	US Highway 281 (North of US Highway 2)
22	ND Highway 20 (ND Highway 57 to Tokio)
23	BIA Highway 1
24	BIA Highway 6

[30] After the study commenced, it was determined that the road raise for the first action level for Feature 24: BIA Highway 6 was already underway. As a result, the detailed analysis of the first action level was begun, but later aborted. Strictly speaking, therefore, the first action level was not examined in detail for this feature. Information from the uncompleted analysis was utilized for evaluations of subsequent action levels.

[31] For features 6, 11, and 10, the first action level provided protection up to the maximum lake level, so that no further analysis was required.

Detailed Analysis for First Action Level Only	
Feature Number	**Feature Name**
25	Roads Acting as Dams

3.1.2 Detailed Analysis for Multiple Action Levels

The decision trees for three of the 17 features showed more than one possible flood protection strategy at action levels below 1454. By contrast to other features therefore, for these three features, it was also necessary to analyze the effects of decisions made at action levels above 1454. For each additional action level, analysis was completed at the same level of detail as for the first. Analysis of these three features entailed a comparison of the net benefits of each available strategy so as to determine which had the largest net benefits. Afterward, flood protection using that strategy was analyzed to determine the net benefits of proceeding with flood protection measures at just the first action level.

For Rural Areas, only one flood protection strategy (relocation) was considered. Nevertheless, because GIS-based mapping and the FEMA database were readily available, a detailed analysis of all action levels was conducted.

The features for which detailed analysis was conducted for all action levels, including the first, are listed below:

Detailed Analysis for Multiple Action Levels	
Feature Number	**Feature Name**
3	Fort Totten
4	Minnewaukan
5	St. Michael
8	Rural Areas

3.1.3 Features Not Analyzed in Detail in the Infrastructure Protection Study

To provide a basis for comparison for the economics of flood protection for all the features, the Infrastructure Protection Study included an updated economic analysis for flood protection up to the maximum lake level for the seven features not otherwise addressed. An explanation of the methodology for the cursory analysis is given in Section 3.2.

The features for which updated economic results are provided, but which were not analyzed in detail under the Infrastructure Protection Study for any action level, are listed below:

Features not Analyzed in Detail	
Feature Number	**Feature Name**
12	Burlington Northern Railroad (Churchs Ferry to Cando)
13	US Highway 2
14	ND Highway 57 (between ND Highway 20 and BIA Highway 1)
15	ND Highway 57 (between BIA Highway 1 and US Highway 281)
18	ND Highway 19
20	ND Highway 20 (North of the City of Devils Lake)
21	ND Highway 20 (City of Devils Lake levee to ND Highway 57)

3.2 Approach to the Detailed Analysis of Costs and Damages

For the Infrastructure Protection Study, all of the flood protection measures identified in the previous analyses were re-examined in greater detail. The more detailed analysis was done to provide an updated and more accurate appraisal of both the costs and benefits of providing flood protection for the 17 features identified in Section 3.1. Updating the previous analysis was also necessary to take into account recent flood protection work in the Devils Lake area. Furthermore, with the lake having recently reached elevation 1448, the flood protection measures that would have been undertaken at lower lake elevations are no longer viable.

The re-examination involved a closer look at basic design issues, as well as assessing other aspects (geotechnical, environmental, and real estate) that had not been addressed previously. Evaluations of risk, data deficiencies, planning and construction lead time, and inflationary adjustments were also included in the Infrastructure Protection Study.

For the seventeen[32] features on which the Infrastructure Protection Study focused, the more detailed analysis was used to examine costs and benefits at the first action level. For Features 3, 4, 5, and 8, the more detailed analysis was also used to examine costs and benefits for action levels above the first. Section 3.2 focuses on the methodology for this more detailed analysis.

[32] Because it was determined early in the project that Feature 19: ND Highway 1 had already been protected, the actual number of features analyzed became 16.

For Features 7, 10, 17, 22, 23, 24, and 25, a streamlined method was necessary[33] for examining the costs and benefits of infrastructure protection at action levels above the first. This method is explained in Section 3.2.13. Feature 2 costs and benefits above the first action level were determined using the results from the Economic Analysis. (As was noted previously, for features 1, 6, 11, and 16, there was only one action level to be analyzed for the flood protection strategy being evaluated.)

Finally, to allow comparison of results for the original Economic Analysis' entire list of features, the cost and damage estimates from the Economic Analysis were used to provide economic results for Features 12, 13, 14, 15, 18, 20, and 21[34]. These features were not otherwise addressed in the Infrastructure Protection Study. For these features, the Economic Analysis' cost and damage estimates for feature protection were used directly and without re-examination, as were the assumptions regarding the elevations at which costs and damages would be incurred. The cost and damage analysis was not augmented or considered in greater detail. The only update for the economic analysis involved the assumed interest rate, which was updated from its fiscal year 2001 value (6 3/8%) to its fiscal year 2002 value (6 1/8%). Because the Infrastructure Protection Study did not attempt to increase the level of detail for the analysis of these features, their analysis is not considered in the following portions of Section 3.2.

3.2.1 Lake Levels and Flood Protection Decisions

For the Infrastructure Protection Study, an analysis was made of the decision-making process for flood protection as it relates to rising lake levels. For decisions regarding flood protection, five categories of decision-critical elevations were identified. Which of these elevations are critical for any given feature depends on the flood protection situation at the feature being considered. It was necessary to identify decision-critical elevations for flood protection for each feature at each action level. These elevations were used to determine the lake levels at which costs and damages are incurred in the yearly time steps used in the economics model. They also can serve as "trigger elevations" – elevations at which projects should be initiated.

The decision-critical elevations are described below.

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[33] Late changes to the project scope required examination of the action levels above the first. Road, railroad, and levee raise quantities were computed using the same methods as for the first action level. For other aspects of the cost estimates, however, project deadlines did not allow sufficient time to conduct the full analysis at the level of detail used for the first action level. Extrapolations were therefore utilized for some aspects of the design and cost evaluation to provide rapid, though presumably somewhat less accurate, cost and damage estimates for the higher action levels.

[34] The inclusion of the economic results for these seven features was not originally envisioned for the Infrastructure Protection Study. Those results were included only when it was realized that the original scope of the Infrastructure Protection Study did not provide for a comparison of overall results for the complete list of features. It was recognized that there was a degree of incompatibility between the inflation-adjusted results for these seven features and the results generated for the other features using the more detailed approach of the Infrastructure Protection Study. Nevertheless, it was felt that including at least some form of economic results for these seven features was important in providing some basis for comparison with other feature flood protection analyses.

3.2.1.1 Low Structure Elevation

The low structure elevation is the elevation of a particular low point on a structure (here referring to a building, highway, railway, levee, etc.). This low point is that which would be considered in determining the lake elevation at which water-induced damage would begin. This elevation must be identified in order to make decisions regarding flood protection for the structure.

If a feature contains several structures, the low structure elevation will be that of the lowest of the structures. For a group of homes, for example, the low structure elevation is taken as the ground elevation at the lowest home in the group. For railroads, highways, and levees, it will be the lowest point on the top of the structure (top of levee, roadway surface, top of rail) along the section in consideration.

3.2.1.2 Lake Damage Elevation

At some lake elevations, water damage to the structure will begin to occur. Note that the lake damage elevation can generally be expected to be lower than the low structure elevation. This is because waves and wave runup will cause damage even when the (mean) lake surface elevation is below that of the low structure elevation. In general, the lake damage elevation would be the low structure elevation minus the wave runup height.

For roads, the lake damage elevation was assumed to be three feet below the low structure elevation. This assumption was made after evaluation of wave runup heights and consultation with local highway officials.

In the case of railroads, some wave runup or splashing onto the rails is considered to be acceptable. Railroad routes are not usually abandoned until erosion of the side slopes is observed. However, wave runup heights tend to be higher for railroads because of the steep side slopes used in the construction of the rail beds. Based on the experience of the railroad companies, four feet of freeboard (above the mean water surface elevation) was assumed to be adequate. Therefore, the lake damage elevation given for railroads is four feet lower than the low structure elevation.

Damages to levees and the structures they protect were assumed to occur at one half of the freeboard height. This assumption took into account wave runup analysis, and consideration of the fact that levee design freeboard requirements are intentionally conservative to minimize chances of levee failure by overtopping.

For some buildings, estimation of the runup height was impractical due to the variability in the terrain and the variation in proximity of the buildings to the lake. For these buildings, therefore, the lake damage elevation was considered to be one foot below the low structure elevation.

(Note that the Infrastructure Protection Study differed from the Economic Analysis in the assumptions made regarding the lake damage elevations. For the Economic Analysis, all damages were assumed to occur at the same elevation at which decisions would be made regarding the next phase of flood protection for a given feature. The Infrastructure Protection Study, by contrast, sought to assign damages at the lake elevation at which they would actually occur. Assumptions regarding the determination of lake damage elevations are given in Sections 4.1 through 4.25.)

3.2.1.3 Project Completion Elevation

The flood damage protection project may need to be completed before the lake level actually reaches the lake damage elevation. In most cases, this is to ensure that construction activities are not hampered by or prevented by water at the construction site.

However, in the case of relocations of individual buildings or small groups of buildings, relocation activities will not commence until damage to the buildings has actually occurred[35]. For such relocations, therefore, the project completion elevation does not need to be tied to lake elevations and is therefore not listed in this report. By contrast, a relocation of an entire community will require that the project be completed before water reaches the lake damage elevation.

The project completion elevation will depend on the specifics of the construction considerations for the project in question (levee, road raise, etc.). It would not be greater than the lake damage elevation.

3.2.1.4 Construction Initiation Elevation

To complete the construction of the flood damage protection project before the lake reaches the project completion elevation, construction may have to begin well in advance. The construction initiation elevation will depend on the estimate of the time required for construction, and the assumed rate of rise of the lake.

The construction initiation elevation for levees was determined by comparing the expected project construction duration with probability-based lake elevation curves. (See further description at Section 3.2.10.)

For roads, railroads, and rural features, the construction initiation elevation is assumed to be equal to the lake damage elevation. Rural features, such as homes and farm outbuildings, can be relocated quickly when the lake approaches the damage elevation. Roads and railroad embankments can also be raised reasonably quickly. And the consequences of the lake rising quickly and overtopping the

[35] Typically, FEMA buyout practices require that damage has actually occurred before allowing buyouts. In these cases, assuming that the lake damage elevation is the same as the project completion elevation is reasonable. However, an exception occurs in the cases of Creel Township and the City of Minnewaukan. These communities have both signed a waiver with FEMA, allowing houses to be moved before damage actually occurs. Nevertheless, for modeling purposes, the project completion elevation was considered to be reasonably well approximated by the lake damage elevation even for these communities.

road or railroad, if the rate of rise was faster than the embankment raise, are relatively minor and involve only temporary loss of use of that transitway.

3.2.1.5 Planning and Design Initiation Elevation

In order for the flood damage protection project to be completed by the time that the lake elevation reaches the project completion elevation, planning and design activities must begin at a time when the lake level is below the construction initiation level. The lake level at which planning and design activities must occur will depend on the lead time required for the particular project.

The planning and design initiation elevation was determined using estimated lead times, and in a manner similar to that used for determining the construction initiation elevation.

3.2.2 Damages, Costs, and Economics

3.2.2.1 Feature Damage Estimates

The damages that would be associated with each feature were reviewed to ensure that the damage inventory was comprehensive, and to update the damage estimates to ensure that the values reflected 2002 dollars. Damages for the various features differ by feature type, as described below.

- Community Features – Damage estimates for communities were reviewed and updated to 2002 dollars, as necessary. Abandonment of structures was not considered an option; therefore it was assumed that all structures not protected by a levee would be relocated with FEMA assistance. The average value of a house was obtained from the Federal Emergency Management Agency (FEMA). The average value for the houses had been determined for FEMA by certified flood insurance adjusters and was based on total habitable square footage of the buildings and standardized real estate appraisals[36]. These values did not include the value of land on which the houses were located. Other values for damages – to municipal buildings, infrastructure, etc. – were based on conversations with local officials and utilities. The impacts of flood damage to community infrastructure were taken into account and incorporated into the economic modeling of damages for communities.

  Zero inflation was assumed for the period from 2001 to 2002[37]. Therefore, the damage values for structures were not adjusted upward, and 2002 unit prices were kept the same as the previously determined 2001 unit prices.

- Rail Features – Damages for rail features included the expense of detours during years that the rail would be temporarily closed and restoration damages after the lake level recedes back

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[36] This assumption was based on personal communication with FEMA's Denver CO office, March, 2001
[37] Personal communication with St. Paul District Corps Economist, October 15, 2002.

below the structure damage elevation. Detour damages were expressed in 2002 dollars. Restoration damage quantities were reviewed and revised as necessary to reflect current information. Restoration damages were computed per foot of lake rise, because the length of track requiring restoration depends on the maximum lake level reached.

Railroad centerline profiles were obtained from 2000 FEMA LIDAR topography[38]. Information was also obtained from the report *Preliminary Evaluation of Joint Raise of BNSF Mainline Tracks and US Highway 2 in the Vicinity of Devils Lake North Dakota*, Barr Engineering Company, March 2002.

- Road Features – Damages for road features included detours during years that the road would be temporarily closed and restoration damages after the lake level recedes below the minimum road level. Detour damage estimates from previous reports were updated and expressed in 2002 dollars. However, the general assumptions regarding the detour damages and how they were assigned to the various roads did not change from previous studies. See Sections 2.0.1.4 and 2.0.1.5 for a more complete discussion of the assumptions made for the estimates of detour damages.

  Restoration damage quantities were reviewed and revised as necessary to reflect current information. Restoration damages were computed per foot of lake rise, since the length of restoration is a function of the height of the maximum lake level. Note that the expense of restoration would typically be incurred only when lake levels drop back below the first action level. However, when considering the modeling of the economics of flood protection for just the first action level, one would assume that further flood protection at higher action levels would also take place at some later date. Therefore, it is not reasonable to assign all the benefits of preventing road restoration expense – restoration damages prevented – to the first action level. Accordingly, these benefits were not included in the Infrastructure Protection Study's modeling for the first action level.

- Rural Features – Damages for rural features were reviewed and updated. A GIS database of structures was provided by FEMA and was used to inventory rural structures. This data included building descriptions, elevations, and for most of the structures, estimates of structure values. Rural structures were sorted using GIS tools to allow damage estimates to be made only for structures not within the analytical boundaries of communities included as features in this study (City of Devils Lake, Camp Grafton, St. Michael, Fort Totten, Minnewaukan, Churchs Ferry, and Grahams Island). An inventory of rural structures was thereby created, and the data was further sorted by county, feature, and elevation range.

[38] Obtained from St. Paul District Corps' cost engineer

Spirit Lake Nation reservation boundaries were also used to distinguish between on-reservation and off-reservation houses.

Additional review and evaluation resulted in the development of estimated values for barns, sheds, and silos. The FEMA database did not provide an adequate data set of values for barns, sheds, or silos. Values for barn and shed structures were therefore estimated based on the average size of each structure type, and based on published industry values. Values for silos were estimated by evaluating limited data provided by the North Dakota State Water Commission. While not comprehensive, this data provided a reasonable basis by which the valuation of silos could be estimated.

Total land values for rural properties were also evaluated. These values, however, could not be incorporated in the economic results because it is not generally feasible to protect rural land.

- State Features – Damages for state features were reviewed and updated. At present, for the Gilbert C. Grafton Military Reservation, the only remaining damages were for the relocation of the munitions storage facilities. The estimate of value for these facilities was developed from data provided by the North Dakota National Guard.

  For Grahams Island State Park, damage estimates from the Economic Analysis were updated to reflect only the remaining structures within the park. The updated estimates also took into account rural lands and structures outside of the park boundaries (but still on the island) that would be impacted by flooding if access to Grahams Island were lost. These included all remaining lands and structures on the island, including those above 1463. These lands and structures would be rendered useless, and effectively without value, if accessing them were no longer possible. Damages to the rural lands and structures were estimated based on the same assumptions and methodology used for Rural Features.

- Roads Acting as Dams – The Roads Acting as Dams feature currently protects structures, land, and other features (ND Highway 20, St. Michael, and BIA Highway 6), the loss of which constitutes the potential damages. Damages to structures protected by the roads acting as dams were estimated based on the same basic assumptions as used for rural features. Potential damage to all structures and areas that would be severed from the main land were included as damages prevented by this feature (even if they were above 1463). Loss of use of land that would otherwise be protected by this feature was also included as damages prevented.

  Estimating the potential damage to roads currently protected by the roads acting as dams was complicated and varied, and depended on the particular assumptions for the analysis. These damages were taken to be either the expense of detours from road closures, or the expense of providing road raises if the dams did not exist. The damage estimates are further complicated by the fact that either BIA Highway 6 or ND Highway 20 could serve to prevent the detour damages around the lake.

For the analysis of the first action level, the damages were assumed to include the potential loss of the St. Michael sewage lagoons and the expense of the first raise of ND Highway 20. The assumption that the road raise expense would include ND Highway 20 is based on the fact that BIA Highway 6 is currently being raised, and is now high enough so that detours around the lake can be avoided – at least up to the first action level.

When considering the overall analysis of all features up to maximum lake level, the damages avoided by roads acting as dams include the cost of detours around the lake, and the potential loss of the St. Michael structures.

3.2.2.2 Flood Protection Cost Estimates

Unit prices – Unit prices were investigated using four different sources:

1. Previous in-house experience with road, rail, and levee raise projects
2. Communication with local contractors and construction personnel
3. 2002 RS Means[39] Construction Costs
4. Micro Computer Aided Cost Estimating Software[40] (MCACES) methodology
5. Unit prices provided in the Economic Analysis report. For comparison with unit prices obtained from other sources, unit prices from the Economic Analysis report were increased to account for inflation. For construction cost inflation rates, computations were based on the September 2002 Construction Cost Index from the Engineering News Record. This index shows an annual inflation rate of 2.67%. For updates of expenses not related to construction (land and easement purchase, materials purchase, detour damages, etc.), varying methods were used. These methods are detailed in the assumptions listings provided with the analysis of the individual features.

Unit prices obtained from each of these sources were compared and evaluated to arrive at a final estimate of unit prices. Final unit prices were sometimes higher, and sometimes lower than those provided in the Economic Analysis report. The unit price comparisons are included in the computations files.

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[39] RSMeans 2002 Heavy Construction Data, RSMeans Company Inc., 2001.
[40] MCASES GOLD (Micro-Computer Aided Cost Estimating System) Version 5.31, by Building Systems Design, Licensed to the U.S. Army Corps of Engineers.

Relocations – Based on discussions with Corps personnel[41], unit prices for houses, commercial structures, lots, land, and relocation operations were assumed to be the same as those identified for the Economic Analysis. New unit prices were assigned only for new additions to the structures list.

The cost for actually moving a house 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 assumed cost of $6,000 includes the following: demolition of the existing house, site restoration, and legal, appraisal, and management fees. To estimate the total expense for a FEMA buyout, these costs were added either to the value of the structure, or to the value of an equivalent structure in a nearby community. It was assumed that moving and associated costs would be approximately the same ($6,000) for all the communities as they were in Churchs Ferry. Values for other rural structures and properties were obtained from the FEMA infrastructure database[42].

Quantities – Estimates of quantities were made based on analysis of the existing structures, and upon design plans based on communication with local officials. For roads, railroads, and levees, both design profiles and design cross-sections were developed and used to assist in providing the estimates.

Contingencies – A contingency percentage was estimated for each item to account for the uncertainty in the unit prices and construction materials quantities. Contingency percentages were based on evaluations of the range of unit prices from previous cost estimates, and on uncertainties with respect to site conditions. Contingencies generally ranged from 30 to 50 percent.

E&D, S&A – The costs for engineering and design (E&D) were estimated to be 15 percent of the construction costs. Supervision and administration (S&A) was estimated at 8 percent of the construction costs. Corps personnel[43] provided the values for both of these percentages.

Performance/Payment Bonds – Based on conversations with the Corps cost engineer, the cost for a construction company to provide a performance/payment bond for its work on flood protection measures was estimated at 0.7 percent of the total construction costs. Total construction costs included those for any road raises, railroad raises, culvert installation, levee raises, pump station construction, etc. required to provide flood protection for the feature.

3.2.2.3 Economic Assumptions

The costs and benefits were computed using the Fiscal Year 2002 interest rate of 6-1/8 percent[44] and are presented as an annualized present worth value over a 50-year period. The benefit categories were defined to be consistent with National Economic Development (NED) criteria.

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[41] Corps St. Paul District economist
[42] As provided by FEMA's Denver office, October 2002.
[43] Corps St. Paul District cost engineer

3.2.3 Re-examination of the Design of Flood Protection Measures

Engineering and design aspects of flood protection measures were reassessed for the Infrastructure Protection Study to more fully characterize the costs of providing flood protection. The approach to reassessing the civil design of these measures was as follows:

- Levee design – Both the levee alignment and design were reassessed. Levee alignments were examined in greater detail, using more detailed information regarding local topography (LIDAR data from FEMA) and regarding the damages that would occur if no levee protection was provided. Levee alignment considerations included: minimizing environmental disruption, avoiding cleanup costs, and reducing mitigation expenses. The revised alignments were used to give updated estimates of the lengths of any required levees.

  The updated levee design took into account the following design aspects:

  - Freeboard Requirements: Freeboard was calculated by adding one foot to the wind-induced wave height (rounded up to the nearest whole foot). The wind-induced wave heights were calculated based on a Corps guidance document[45].

  - Side Slope Considerations: The exterior side slopes of all levees will require erosion protection due to wave action. Riprap sizing and thickness was determined using Corps methods[46]. The riprap sizing was evaluated for various side slopes to determine the preferred side slope for each alternative. The interior side slopes would not be protected with riprap.

  Based on alignment and design considerations, cross-sections and profiles were developed for each levee area. Construction quantities were then estimated based on the cross-section, profile, and alignment for each levee element.

- Road raise assumptions – In consultation with the Bureau of Indian Affairs (BIA), the Federal Highway Administration (FHWA), the North Dakota Department of Transportation (ND DOT), and local agencies, the assumptions regarding road raise work were re-examined in the Infrastructure Protection Study. Available plan and profile drawings for the roads were reviewed to provide an assessment of current conditions and raise plans (road raise plans in some cases call for providing a base wide enough to accommodate future raises). Freeboard, side slopes, and riprap needs were re-assessed for the development of updated design cross-sections and profiles. The cross-sections and profiles were then used to develop construction

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[44] Per Corps St. Paul District economist.

[45] Report titled *Devils Lake, North Dakota, Wind Induced Changes in Water Elevations*, revised September 1998.

[46] Riprap sizing was based on EM1110-2-1601: Hydraulic Design of Flood Control Channels (US Army Corps of Engineers, June 30, 1994), with wave height based on a Corps Report titled *Devils Lake, North Dakota, Wind Induced Changes in Water Elevations*, revised September 1998.

quantity estimates. Assumptions regarding bridge and culvert modifications were also re-assessed.

- Railroad upgrades – The Burlington Northern and Santa Fe (BNSF) and Canadian Pacific Railroad (CPR) companies were contacted to get updated information regarding the current status and design requirements for raising tracks and rail beds, and for removal and replacement of switches, controls, bridges, etc. Railroad raise lengths, profiles, and track bed cross-sections were updated. The updated design information was then used to develop construction quantity estimates.

  Railroad construction information was also obtained from the report *Preliminary Evaluation of Joint Raise of BNSF Mainline Tracks and US Highway 2 in the Vicinity of Devils Lake North Dakota*, Barr Engineering Company, March 2002.

3.2.4 Geological and Geotechnical Evaluation

Previous analyses of Devils Lake flood protection measures have not included investigation into site-specific geologic and geotechnical considerations. The Infrastructure Protection Study, by contrast, included evaluation of geologic and geotechnical aspects of flood protection, based on available regional and site-specific information.

The geological/geotechnical investigation involved consulting many published references[47] regarding the geology and soil types[48] of the Devils Lake region. USDA soil survey maps for the area were compared with proposed levee and road alignments to identify foundation issues and borrow sites. Where soil and geological mapping was available in electronic format, GIS overlays on proposed alignments were used. For much of the work, however, photoreproduction and rescaling of existing mapping was used to compare soil type locations with plan sheets showing proposed alignments.

These evaluations helped provide:

- Estimates of the approximate lengths, depths, and costs of any slurry walls that might be required for the levees
- Identification of the need for soil borings, and estimates of the costs of providing the soil borings
- Estimated costs for borrow material for levees and road raises

[47] See Appendix B
[48] In so far as possible, standard United Soil Classification System nomenclature was used for reporting soil types.

The geotechnical analysis for this study focused on three principal issues:

1. Locating Borrow/Disposal Areas

   Borrow sites will be necessary for acquiring materials for the construction of levees and roads. It is likely that disposal sites will also be necessary to dispose of excess unsuitable soils from construction. Unsuitable soils are assumed to include wetland soils and soft lakebed soils. For the purpose of this report, it was assumed that borrow sites can also act as disposal sites. Infrastructure construction activities may also generate other types of materials that will require special disposal, including contaminated soil and building demolition debris. The potential disposal sites for these materials are not addressed in this report.

   The major uses for soil materials used in constructing roads and levees are:

   - Impermeable core (levees)
   - Impermeable fill (levees)
   - Sand drain (levees)
   - Sand drain filter (levees)
   - Topsoil (all)
   - Riprap, multiple sizes (all)
   - Riprap bedding, multiple sizes (all)
   - Road aggregate (all)
   - Pervious fill (pump stations)
   - Common borrow (roads)

   Potential borrow/disposal sites were identified using two methods. The first method was by identifying existing sites. These were identified using:

   - Previous projects at Devils Lake
   - Corps contacts
   - State highway departments contacts
   - County office contacts
   - BIA/reservation contacts

- Contractor contacts
- Telephone directories

The second method used to identify borrow/disposal sites was to review soil types from soil conservation survey reports, and evaluate cover crop land use. Soil data indicates that there is significant coverage of soils likely to suit the borrow needs for feature construction included in this evaluation. Therefore, the "agricultural crop land" land use type was used as an indicator to identify potentially suitable sites that would least likely have impacts on wetland, cultural, and HTRW sites.

Data from both methods were used to develop a GIS database to locate existing and potential borrow sites. The GIS database was then overlaid with the feature locations with 5-mile radius delineations to allow identification of sites in reasonably close proximity to the areas where earthen materials would be needed.

Estimated borrow and disposal requirements were developed from construction quantities used for cost estimating for each feature. Borrow quantities were calculated from the summation of required volumes for levee fill, fill material, and bedding material for each feature. Disposal quantities were calculated from the summation of stripping volumes for each feature.

The required borrow real estate area was calculated assuming an average depth of 10 feet of usable borrow material. This results in 16,133 cubic yards of material assumed to be available per acre. Required borrow area (acres) was derived from dividing borrow quantities (cubic yards) by 16,133 (cubic yards per acre). Similarly, required disposal real estate area was calculated assuming an average of 5 feet of effective fill height. This results in 8,067 cubic yards of disposal fill for each acre. Required disposal area (acres) was derived from dividing disposal quantities (cubic yards) by 8,067 (cubic yards / acre). Further, it was assumed that borrow areas could also be used as fill areas. Once borrow has been harvested from the site, it is reasonable to assume that disposal material could be used for site restoration and final grading. Comparing the required acreage for borrow and disposal, the larger acreage requirement was used in determining the number of borrow sites likely to be needed for each feature.

To determine the number of borrow sites needed for each feature, it was assumed that average borrow sites would likely range between 10 and 20 acres. In some cases, especially for larger features, and where new sites are assumed to be developed, the site sizes were assumed to be larger.

Borrow and disposal site acreage requirements for the first action level for each feature with material needs are shown on Figures 4.0-1a and 4.0-1b, along with suggested specific borrow sites, including expected use of existing sites and new sites.

The costs for acquiring borrow site land and for site investigation were not included as line-item costs in this evaluation, but were considered to be incidental and included as part of the contingencies in the line items for real estate and materials.

2. Evaluating Construction Subgrades and Foundations

   It was assumed that geotechnical investigation will be required for the proposed rights-of-way for raised roads and levees. The investigation will include soil borings and soil testing.

   For roads and levees, it was assumed that there will be at least one soil boring per geologic deposit as shown on the feature profiles, or one boring per 1,000 feet of levee. Soil testing will be incidental to the drilling. It was assumed that the drilling, sampling, testing, and reporting will cost approximately $2,000 per boring, based on experience with similar projects.

3. Evaluating Likely Performance of Levees

   A number of past documents provide assumptions for the construction of levees, including:

   a. *Devils Lake – City of Minnewaukan Assessment.* Prepared by Barr for Corps of Engineers, St. Paul District, April 1998.

   b. *Devils Lake Levee Raise* – Geotechnical & Geology Section, Technical Appendix C, *Design Documentation Report.* Prepared by Corps of Engineers, St. Paul District, August 1998.

   c. *Alternative Alignment Study, Devils Lake Levee at Devils Lake, North Dakota.* Prepared by Barr for Corps of Engineers, St. Paul District, January 2002.

   The typical assumption for design of an impervious core is that the top of the core will coincide with the design water level for the lake.

   The August 1998 *Design Documentation Report* determined that a sand chimney drain is necessary when the levee base is nine feet or more below the design water level assumed for the lake. The January 2002 *Alternative Alignment Study* made the same assumption. Therefore, it was also assumed for the Infrastructure Protection Study that a sand chimney drain would be necessary when the levee base is nine feet or more below the design water level assumed for the lake.

3.2.5 Environmental Issues

For the Infrastructure Protection Study, environmental concerns were evaluated for each flood protection measure considered. The evaluations included hazardous, toxic and radioactive waste (HTRW) assessments, cultural resource assessments, and an assessment of ecological habitat impacts. GIS methods were used extensively in the evaluations.

3.2.5.1 GIS Methodology for Environmental Assessment

Impacts areas for road raises, levee construction, and other flood protection activities were estimated using flood protection design assumptions and routines developed in ArcView GIS.

For levees and roads, the impacted areas were estimated by applying a right and left offset (in feet) from the road and/or levee centerline (based on the top elevation and contours). Polygons representing these impact areas were developed from these offsets. Road centerlines were digitized using the 2000 aerial photos provided by the Corps. For other types of features (e.g., detention ponds), polygons were digitized using shapes and locations developed using standard flood protection design methods. For features with multiple action levels, polygons were developed for each action level. The polygons for each action level were then intersected (overlaid) to create incremental impact areas for each action level.

To identify land and wetlands impacted by the flood protection measures, a land use/wetland GIS layer was developed. This layer consisted of National Wetlands Inventory (NWI) and the USGS National Land Cover Database (NLCD). The land classifications from the NLCD are listed in Appendix C, along with more detailed information regarding source material for this investigation.

The NLCD was converted from a raster to a vector (polygon) format using ArcView Spatial Analyst. The vector NLCD data was then intersected with the NWI data to create the land use/wetland layer. If the NLCD indicates a wetland classification, but it does not fall within a NWI wetland, the layer is populated with the value "Unknown."

The impacted areas were intersected with the land use/wetland layer and a GIS layer representing wetland easements, National Wildlife Refuges and Waterfowl Production Areas.

For the impacted areas, the "Unknown" land use classification was converted to one or more of the other NLCD land uses. The land use for these areas is assigned proportionately based on the other non-wetland land use types in the impacted area for each feature. For example, if the non-wetland classifications are 0.4 acres Cover Crop and 0.6 acres Woodland and 2 acres of Unknown, the two acres would be reclassified to be 0.8 acres Cover Crop and 1.2 acres Woodland.

This GIS analysis thus provided the acreages of wetlands, and the land use types that occur within the impact area. It also indicates when an area (either wetland or upland land use type) falls with a Wetland Easement, National Wildlife Refuge and/or Waterfowl Production Area.

3.2.5.2 HTRW

The objective of the HTRW assessment was to identify any actual or likely HTRW sites that are located within the footprints of the proposed flood protection measures for each feature. An HTRW site is defined as any site that may present a "recognized environmental condition" (REC). A REC is defined in the standards[49] of the American Society for Testing and Materials (ASTM) as "the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property or into the ground, groundwater, or surface water of the property."

HTRW sites for each feature and their associated action levels were identified through inspection of historic aerial photographs, historic topographic maps, and current regulatory reports[50]. In general, the HTRW assessment was completed in conformance with ER 1156-2-132[51]. There were, however, some deviations from the procedures set forth in this guidance document—the site inspection visit was not made, and there were no interviews with persons knowledgeable of the properties/features.

For most features, one or more aerial photographs per decade from 1950 through the present time were inspected. All available 7.5- and 15-minute historical topographic maps were also inspected; however, some of these maps have not been updated since the 1950s. Historic documentation prior to the 1950s was limited to a few topographic maps from the 1930s. FirstSearch Technology Corporation provided current regulatory data reports for each zip code intersected by the features. These regulatory reports were examined for additional sites that may not have been obvious through visual inspection of the photographs and maps. The utility of the regulatory database data was limited, however, due to the imprecise location of HTRW data associated with rural areas.

After HTRW sites were identified, the sites for each feature were sorted according to their likely land use or site type. GIS-based land use mapping was too general to be used for the HTRW site determinations; it was necessary to confirm (in so far as possible) the specific land use for each site, rather than rely on the broad categories provided by the GIS database. The specific land use for each site was therefore determined by interpretation of site conditions, as observed on aerial photographs

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[49] American Society for Testing and Materials (ASTM) Standards E 1527-00: Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process, 2000.

[50] One exception is that the HTRW information for Feature 2 (City of Devils Lake) was taken directly from a previously report (*HTRW Assessment, Devils Lake, North Dakota, prepared for the Corps, September 2001*).

[51] U.S. Corps Water Resources Policies and Authorities; Hazardous, Toxic and Radioactive Waste (HTRW) Guidance for Civil Works Projects, June 26, 1992.

and maps. A site inspection was not conducted and detailed historical documents were not reviewed. The determinations of land use, therefore, were somewhat uncertain, and the limitations of the study did not allow their verification.

Costs to investigate potential HTRW sites were estimated for each site category. The following assumptions were made for the cost estimates:

- The property owner has already been identified, and access to the property will be arranged prior to any on-site HTRW work.
- The property owner has been made aware that their property will need to be inspected, and the owner will cooperate in the HTRW site inspection.
- Mobilization of personnel to perform HTRW work will be from a local area (within 30 miles). Travel and per diem expenses are therefore not included.

Detailed information regarding cost assumptions for the HTRW analysis is given in Appendix C.

3.2.5.3 Cultural Resources

The primary objective of the cultural resources investigation was to determine whether the areas to be affected by the infrastructure protection projects contained any known cultural resources, site leads, or isolated finds.

Potentially affected archeological and historical sites were identified through a literature and records search, using site files and previous survey reports at the State Historical Society of North Dakota in Bismarck, ND and the ND State Historic Preservation Office (SHPO). Background research also included checking the National Register of Historic Places as well as the State Register of Historic Sites. This work was completed under contract with The 106 Group Ltd. of St. Paul. The 106 Group had conducted a similar records search for the entire Devils Lake Basin in 1997 for the Corps.

Work for the Infrastructure Protection Study used the results of that previous records search, and updated them to include sites recorded since 1997. The update included only those areas that might be impacted by the flood protection measures that are the subject of this report. The updated results thus included identification of all known archaeological sites, site leads and isolated finds, and historic structures and buildings over 50 years of age identified to date. The location of proposed projects was compared with any sites identified in the area.

Because the cultural resources area of potential effect for each project may change slightly as more analysis is completed, the literature search and records review encompassed the entirety of each legal section containing portions of the proposed project areas (i.e., the search was not restricted to the quarter-quarter-quarter sections in which the proposed projects are located). Therefore, where cultural sites were found to be within the general vicinity of the project area, those sites were identified and it was noted that there is a potential for cultural resource impacts at those sites. In addition, other sites may be present that have not yet been identified.

Sites and site leads/isolated finds were identified through the use of the State Historical Society of North Dakota (SHSND) site card catalog, which is organized by legal location. Site leads are potential sites that have not been verified, and these were assigned numbers containing an "X" after the county code. For example a site lead in Benson County would be 32BEX0134. Isolated finds are also assigned numbers containing an "X." In general, this assignment was made because isolated finds may indicate the presence of a larger site and, in that sense, also constitute a site lead. It should be noted, however, that in some cases, additional testing was conducted in the area of an isolated find and led to the determination that a site was not present. These cases were noted in the project summaries for each feature.

3.2.5.4 Ecological Habitat Concerns

Using GIS techniques described in 3.2.5.1, areas impacted by proposed levee and road alignments were identified and the land use type and acreage were shown on the feature location maps. Impacted areas that were identified as wetlands, grasslands or woodlands, and any impacts on National Wildlife Refuges or Waterfowl Production Areas were noted. These areas were assumed to require mitigation or replacement with nearby like land. Cost for the mitigation or replacement was estimated using a per-acre value provided by the Corps. Mitigation policy was determined in consultation with the Corps and the US Fish and Wildlife Service (USFWS). The following describes the mitigation policy assumed for this study:

1. For wetlands and upland areas that are under a Federal easement, there must be a replacement in kind, equal in value to at least the real estate cost of the original easement. The intent of this policy is that habitat of like quality will be replaced and managed to achieve the same ecological benefits derived from the original easement. Replacement of management costs is not necessary because existing management funds are still available. Because this level of investigation will not permit determining the cost of the original easement, the cost of replacement is derived by an easement on nearby like lands on an acre-for-acre basis.

2. For all other wetlands affected, the policy is to acquire lands that can be restored and managed as wetlands to offset the loss of the habitat. To achieve this, there is both a real estate cost for acquisition and a habitat management cost. At this level of investigation, the most commonly accepted method of estimating the overall cost is to assume that for every one acre of lost wetland, it will be necessary to acquire two acres of nearby lands that can be restored to wetlands. Lands to be acquired are usually croplands containing formerly drained

wetlands. This cost-estimating practice reasonably covers both the real estate and management costs.

3. For woodlands and grasslands affected, the policy is to acquire nearby like habitat and manage that habitat to offset losses. At this level of investigation, the most commonly accepted method of estimating the overall cost is to assume that for every one acre lost, it will be necessary to acquire two acres of nearby lands of similar habitat type. This cost-estimating practice reasonably covers both real estate and management costs.

4. For Waterfowl Production Areas and National Wildlife Refuges affected, the policy is that the loss cannot be mitigated. However, the Refuge Administration Act requires compatibility for changes in the purpose and intent of the refuge. In consultation with the USFWS, compatibility requirements usually take the form of creating new habitat areas, additional management of existing areas, or modifications of operations to achieve better habitat management. At this level of investigation, the most expedient method of estimating the overall cost is to assume that for every one acre lost, it will be necessary to acquire one acre of nearby lands of similar habitat type. The replacement of management costs is not necessary since existing management funds can be transferred to cover costs on the newly acquired land.

For each flood protection measure for each feature, the Infrastructure Protection Study identified the habitat type and acreage impacted, as well as the effects on the wildlife and aquatic species that likely inhabit those areas. In consultation with the USFWS, potential adverse effects on any threatened or endangered plant and animal communities or on other species or habitats of concern were also identified.

Resources used in the habitat evaluations – for general ecoregion locations and descriptions, for plant community descriptions for upland areas, and for wetland community descriptions and descriptions of wetland impacts – are listed in Appendix C to this report.

3.2.6 Hydrology and Hydraulics

3.2.6.1 General

An analysis of hydrology and hydraulics of the interior drainage system was completed to assist with the sizing of interior pump station(s) to remove accumulations of water from the interior areas behind levees. The analysis considered the amount of water expected from precipitation and the possibility of seepage through or beneath the levees. The interior drainage tributary watersheds were estimated from USGS quadrangle maps.

3.2.6.2 Hydrology

A hydrologic analysis was completed for the 100-year 10-day precipitation event, which produces about six inches of runoff. Using the HEC-1 model, runoff from this event was evaluated for the tributary area. The analysis used the storage volume in the existing low areas to pond water. A copy of the HEC-1 data file is included with the computations summaries for this report.

The runoff and unit hydrograph parameters used for the hydrologic model were developed by the Corps for other hydrologic analyses in the area. The analysis assumed a runoff curve number of 70 for the 100-year event. Snyder's method was used to determine the unit hydrograph for each area. The watershed storage coefficient C_t was developed from Fort Totten gage data and had a value of 4.38. The second Snyder's coefficient C_p was developed from data from Edmore Coulee near Webster and had a value of 0.35.

The results of the HEC-1 analysis were used to size the interior drainage channels and pump stations for the levees.

3.2.6.3 Channel and Pond Design

Construction of a levee may require installation of drainage channel systems to route runoff from low areas to the pumping station. These interior drainage channels were included in the construction costs for flood protection projects. The drainage channels could be constructed along street easements or on the inside right-of-way of the levee.

Ponding areas to accommodate the interior drainage were also evaluated. Pond areas and volumes were estimated by inspection of maps showing local ground contours. It was assumed that any buildings adjacent to (but not within) the ponding areas would remain in place. To protect the buildings, local excavation or filling could be conducted as necessary.

The assumed side slopes for drainage channels was 3H:1V. Channel bottom widths varied between 4 to 5 feet with an assumed Manning's "n" of 0.045. Drainage channels and storm sewers were sized with capacity for the 100-year event, as described above.

3.2.6.4 Culvert Design

Analysis of culverts to carry drainage flows at all road and railroad crossings was included in the analysis of the interior drainage system. The culvert designs assumed inlet control, due to the relatively short culvert lengths and the lack of invert elevation data. Concrete pipe was assumed in all cases, and a Manning's "n" of 0.012 was used to arrive at an approximate full-flow design using the computed peak discharges. Standard concrete pipe nomographs were used to estimate discharges.

For existing culverts, plan sheets were used to determine culvert diameters. For the interior drainage for Roads Acting as Dams, the culvert sizing was done to accommodate the anticipated flows.

3.2.6.5 Pump Station Design

Installation of a pump station would be required to remove interior drainage water. The pump station discharge capacity was sized to be capable of removing water accumulated as a result of precipitation within 10 days. The required capacity of the pumps would vary, depending on how much area is available for the holding ponds, and depending on the peak inflows.

In previous studies of the Devils Lake levees, analysis of the potential for seepage – both through and beneath the levees – showed that seepage amounts were likely to be negligible. As a result, seepage was not accounted for in the pump station design.

3.2.7 Real Estate Evaluations

The real estate evaluations were conducted by the Corps, but relied on the alignment and area estimates provided by Barr. Barr provided the Corps with digital-format mapping of showing approximate locations of levees, roads, railroads, borrow sites, ponding areas, and a possible site for relocating Minnewaukan. Structures which would require relocation at the various action levels were identified.

Corps personnel then compared the footprints with current land use mapping to determine the types of land—commercial, residential, wetland, crop, pasture, etc.—that would be affected. Plat maps were examined to determine the number of landowners that would be affected.

In this way it could be determined whether the required land would most likely be obtained through purchase of fee title or permanent easements. Based on current urban and agricultural land prices in the area[52], fee title and easement purchase prices for each feature could be determined. Acquisition costs, based on local experience and on the number of landowners involved, were also provided by the Corps.

3.2.8 Operations and Maintenance

Operations and maintenance (O&M) needs would be associated with several of the flood protection measures and installations. Raised roads and railroads would need periodic inspections and maintenance. Levees would also require periodic inspection and repair. The pump stations associated with the levees would require power, in addition to periodic mechanical maintenance.

Estimates of O&M costs for the roads, railroads, levees, and pump stations were estimated as follows:

- A per-mile, per year cost of road and railroad inspection and maintenance was established at 0.5 percent of the cost of raising the road or railroad. This percentage was based on discussions with local road and railroad staff, and on estimates made for similar projects. Due

[52] Land prices were obtained through analysis of comparable land sales in the region; analysis conducted by a certified general appraiser.

to limitations of the computer model, however, O&M costs for roads and railroads were excluded from the economic analysis.

- A per-mile, per-year cost of levee inspection and maintenance was established at 1 percent of the construction cost. This percentage was based on experience with similar projects.
- For the pump stations, unit prices for electricity were established; typical municipal pumping station electricity rates are $0.029 per kW-hour, with a demand charge of $6.50 per kW[53] in the Devils Lake area. A customer charge of $15 per year was also included. Based on the pumping needs established in the hydraulic analysis, the pumping horsepower and electrical requirements were estimated. Using an evaluation of the ratio of precipitation to evaporation for the area, 24 hours per year of pumping was assumed. The demand charge was assumed to be incurred in each of the 9 months of the pumping season.

3.2.9 Estimates of Lead Time

The planning, design, and construction of a flood protection project can require many months or years. To be able to complete such projects in time to prevent damage to roads, railroads, or communities, it is necessary to determine the time that will be required for the planning and design, and for the construction of the proposed flood protection project. Once these lead time estimates are made, they can be used in conjunction with a projected rate of lake rise to select target elevations for initiating planning and design, and construction—especially for levee projects, for which the timing of implementation is critical (see Section 3.2.1).

Lead time estimates made for the Infrastructure Protection Study were based on experience with similar projects and discussions with Devils Lake contacts regarding specific features. Required times for the road and railroad raises and levee construction were assumed to be as follows:

- Time required for planning and design – a lead time of about twelve months would typically be necessary for final design, preparation of construction documents and bidding
- Time required for construction – construction could typically be completed in one or two construction seasons
- The total time between initiation of final design and substantial completion of construction would typically be in the range of 18 to 24 months

Lead times will vary for those features for which flood protection planning and implementation will require a greater effort (such as a Minnewaukan relocation, Devils Lake levee raise, etc). Lead time for each feature is discussed in Section 4.1 through 4.25.

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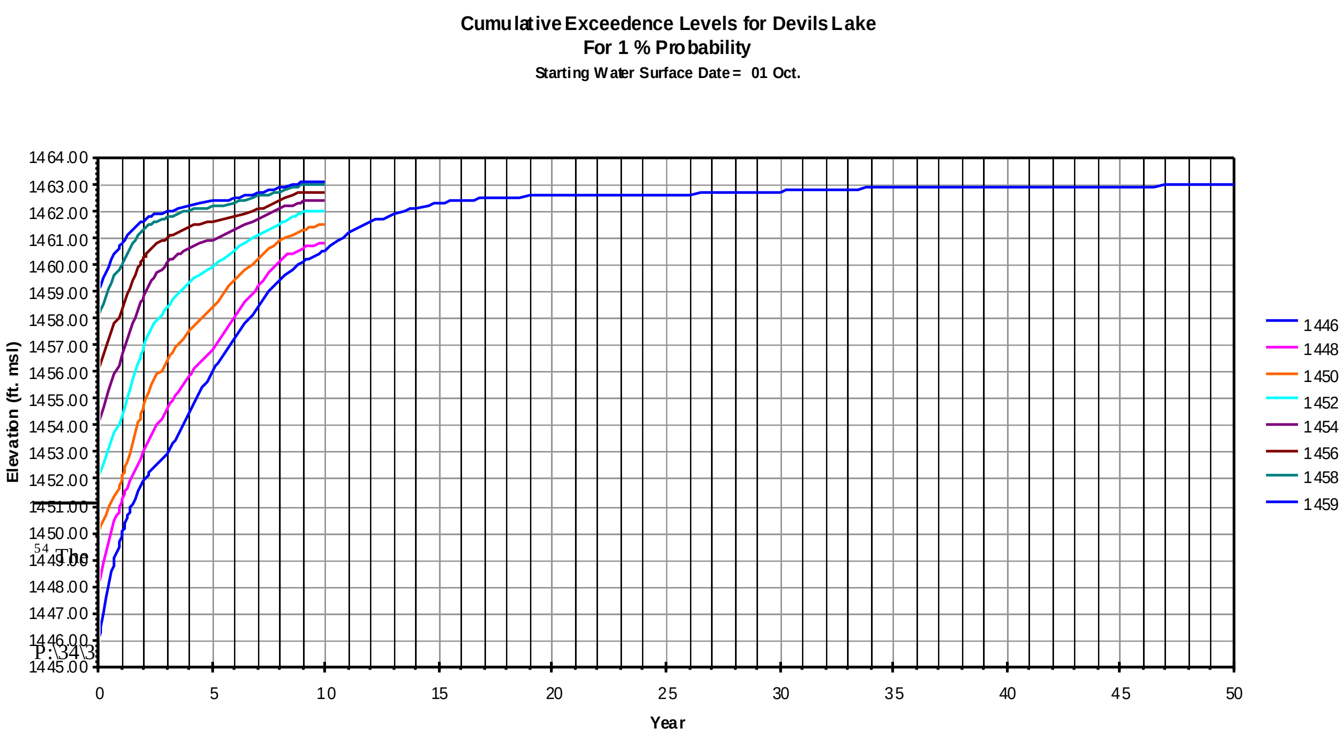
[53] NSP Electric Rate Book, Municipal Pumping Service, June-September; 1999.

3.2.10 Probability-based Lake Rise Curves

For levee raises, lead time estimates were used along with the probability-based projections of the rate of rise of Devils Lake to estimate lake levels at which construction would need to begin (shown in the tables of reference lake levels presented in the feature summaries - Sections 4.1 – 4.5, and 4.25).

Overtopping and failure of a levee could result in very large amounts of property damages and possibly create hazards to personal safety for those behind the levee. Based on this concern, it has been determined that the goal for a Federal flood protection project should be to provide protection so that there is less than a 1 percent chance that the lake level will exceed the design elevation of the levee (top of levee minus the freeboard for wave run up). In order to do this, the flood control project construction must begin at or below lake levels at which there is a 1 percent chance of a lake rise reaching the design level of the levees in a length of time equal to the expected construction period. To compute this, curves were prepared of the 1 percent lake rise over periods of time beginning at different starting lake elevations. Knowing the design level of the levee and the expected length of the construction period, the lake level at which construction should be initiated can be calculated.

The figure below shows the relationship for the one-percent exceedance event for various starting water surface elevations vs. time in years[54]. The figure is based on the USGS stochastic model, with a starting water surface elevation of 1446.0 on October 1, 2000. The base curve was used as a guide for the determination of the other curves that represent higher starting water surface elevations, in two-foot increments. By using these curves, one can determine the water surface elevation by which construction must begin before a given design water surface elevation is reached. For example, for a levee with a design water surface elevation of 1457, construction must be initiated at 1452 so that the levee would, in 99 percent of cases, be able to provide the design level of protection at the end of



[54] The

a two-year construction period.

3.2.11 Risks

The potential risks that are inherent in the design and construction of the feature protection strategies were identified based on available data, analysis of design plans, experience with similar projects, and on discussions with local officials. The potential risks include only those that affect the feasibility and construction of the project; risks associated with the ongoing operations of a flood protection measure (e.g., pump stations for levees) were not considered. The risks associated with specific flood protection measures are detailed in the discussions of the individual features (see Sections 4.1 through 4.25).

3.2.12 Data Deficiencies

The investigations of each feature included a review of available information. However, the design of flood protection measures may depend at least to some extent on data that is not currently available. Such data deficiencies would need to be addressed as part of the final design of the flood protection measures. If any data deficiencies could be identified, they were noted and are listed for each feature in the feature summaries of Sections 4.1 through 4.25.

3.2.13 Abbreviated Cost Estimating for Select Features

As was mentioned previously, for Features 7, 10, 17, 22, 23, 24[55], and 25, an abbreviated method was necessary for examining the costs of infrastructure protection at action levels above the first. For determining materials quantities, the methods used were the same as those for evaluating the first action level, as described previously. Unit prices also remained the same. However, for estimating the costs for addressing geological/geotechnical, real estate, and environmental issues, an abbreviated method was used. Rather than conducting a detailed analysis of these issues for action levels above the first, the costs for addressing them were pro-rated in proportion to the length and width of the raised road (or railroad). The abbreviated method is explained in more detail below:

Design Assumptions

- Raise elevations – the subsequent action levels would typically involve a 5-foot increase; the height of the final raise for the highest action level would be whatever was necessary to provide flood protection up to the maximum lake level (1463)
- Cross-section – the levee, road, or railroad cross-section varies by raise and by the segment in question, but would be in accordance with current raise plans as discussed with local agencies

[55] Because the analysis for the first action level for feature 24 had been aborted (see footnote, Section 3.1.1), the analysis of subsequent action levels proceeded in a slightly different fashion from that of the other features in the group. See Section 4.25 for greater detail.

- Length – the lengths of the raised levee, road, or railroad segments would be increased as necessary
- Alignment – the alignment for the raised levee, road, or railroad remained as identified previously in the Infrastructure Protection Report

Construction Material Quantities – Material quantities were estimated in accordance with above-listed design assumptions.

Unit Prices – There were no changes from the pricing assumptions listed in Section 3.2.2.2.

Geological/Geotechnical Costs – With each levee, road, or railroad raise, these costs were increased proportionally based on a per-foot cost calculated using the costs and lengths estimated for the first action level. Note that foundations and soils issues were not reviewed for action levels above the first.

Environmental Costs – The HTRW, cultural, and mitigation costs for flood protection at action levels above the first were based on the incremental addition to footprint area; costs were increased proportionally based on a calculated cost per square foot. No additional environmental investigations were conducted for action levels above the first.

Real Estate Costs – The (relatively minor) real estate costs were simply increased by a fixed amount (similar to the cost for the first increment) for each additional level of flood protection. No additional real estate investigations were conducted for action levels above the first.

Contingencies, O&M, P&D, S&A – As was done for the first action level, these costs were taken to be a fixed percentage of the relevant cost or damage item

3.3 Interdependencies

As was the case for the Economic Analysis, the Infrastructure Protection Study made note of several features for which the decisions regarding flood protection would be to some extent dependent upon the flood protection decisions made for other features. Most of these "interdependencies" were the same as those identified in the previous analyses. However, the additional investigations conducted for the Infrastructure Protection Study indicated that for some features, additional interdependencies must be taken into account when making flood protection decisions. Additional interdependencies were added to the register of interdependencies previously compiled in the Economic Analysis, and are presented in Section 4.

3.4 Infrastructure Protection Study Economic Modeling

3.4.1 General Approach

In general, the economics modeling conducted for the Infrastructure Protection Study proceeded according to the methods explained in Section 2. The focus of this analysis was on the incremental protection strategies. Therefore, this analysis did not consider maximum protection strategies or hybrid strategies that did not provide protection to the maximum lake level.

One important exception was in the way that costs and damages were registered in the modeling process. In the previous studies, costs were registered at the same water level – and at the same point in the 50-year period – as that at which damages would have been recorded had there been no flood protection project in place.

For the Infrastructure Protection Study, the economics modeling refined the method by which costs and damages were registered. In the absence of a flood protection project, flood damages were registered when the 50-year trace water level reached the identified *lake damage* elevation. When evaluating the case when a flood protection project would be constructed, the cost of that construction was registered when Devils Lake water reached the *construction initiation* level.

Although planning and design costs would typically be incurred earlier, modeling limitations required these costs to be lumped with the construction costs. The planning and design costs represent a small percentage of the overall project costs, so that lumping the two costs together was not likely to impair the accuracy of the overall economic results.

This change meant that costs were generally registered earlier than damages. It can be seen that the updated methodology more accurately represents what is likely to take place in the course of providing flood protection for Devils Lake features. However, it should also be noted that the earlier registration of costs is likely to reduce the estimate of net benefits for a given flood protection project.

3.4.2 Initial Modeling of Multiple Action Levels

The multi-action level approach was initially used for four features, as noted in Section 3.1. This approach considered all of the identified flood protection strategies up to the maximum lake level. These strategies were evaluated for all 10,000 stochastic traces and for the Wet Future, Moderate 1 Future, and Moderate 2 Future climate scenarios.

To analyze the various strategies for each feature, algorithms were developed to compile economic results of proceeding along each of the branches of the decision trees. Under the assumptions of the Infrastructure Protection Study, the algorithms defined the steps necessary to compute costs and damages for the 50-year traces. Using the traces, computer analysis of the costs and benefits of each of the strategies allowed identification of that incremental flood protection strategy having the largest net benefits at the first action level. That strategy was then further analyzed to determine costs and benefits for flood protection at only the first action level.

3.4.3 Modeling the First Action Level

For the 17 features for which analysis of the first action level was relevant, the economic model was used to analyze the first action level for the strategy that showed the largest net benefit. The strategy that showed the largest net benefit was identified using a multi-action level approach, conducted either previously in the Economic Analysis, or as described in Section 3.4.2.

Evaluation of the first level was completed for all 10,000 stochastic traces and for the Wet, Moderate 1, and Moderate 2 Future Scenarios. The costs and damages for the 50-year traces were analyzed for this first action level. Further analysis, however, identified the costs and benefits for proceeding with the same strategy to provide flood protection up to the maximum lake level.

3.4.4 Modeling Additional Action Levels

For those features for which all action levels up to the maximum lake level had not already been analyzed (See Section 3.1.1) under the Infrastructure Protection Study, modeling of the additional action levels was required. The methodology for providing damage and cost estimates for the additional action levels has already been described. Modeling the additional action levels was done using the FAM, but the FAM in this case was configured to consider only the incremental flood protection strategy that had been previously identified as providing the largest net benefits.

4. Infrastructure Protection Study Results

4.0 General Results

The majority of the information collected for the investigations of the 17 selected Devils Lake features is particular to the individual features. However, some of the findings of this Infrastructure Protection Study are general, applying to many or all of the features. The general findings are reported in this Section 4.0.

4.0.1 Interdependencies

Previous studies identified many cases where decisions regarding flood protection at one feature were dependent to some degree on the decisions regarding flood protection at a different feature. Work done under the Infrastructure Protection Study uncovered interdependencies not previously noted. All of the interdependencies are noted in the feature summaries (Sections 4.1-4.25). For convenience, however, a summary listing of all feature interdependencies identified in the Infrastructure Protection Study is provided – see Table 4.0-1.

4.0.2 Damages and Costs

An updated and expanded compilation of damage and cost estimates resulted from the re-evaluation of damages for Devils Lake features, and of the costs for the flood protection measures that might protect the features. Specifics of the damage and cost estimates are provided in the feature summaries of Sections 4.1 through 4.25.

Many of the estimates needed to compute damage amounts—in particular those concerned with damage to communities—are specific to the individual features. However, some of the unit prices related to damage estimates (for example, those that would be associated with repairs to a flood-damaged road or railroad) are common to many features. Furthermore, many of the unit prices for the construction cost estimates apply to many features.

The unit prices that were used for more than one feature are listed in Table 4.0-2. These unit prices are categorized by the type of construction project (road, railroad, or levee raise) for which they would be used. All values in Table 4.0-2 are given in 2002 dollars.

These damages all increase as the lake level rises. The Infrastructure Protection Study indicated that "continuously occurring" damages (detour, trucking, and lost recreational use damages when roads are closed and access is denied) for each year of closure would total over $79 million at the maximum lake level. The one-time-only damages to land and infrastructure would total $403 million at the maximum lake level. The once-per-event restoration damages to roads and rail lines would total just over $145 million at the maximum lake level.

Construction material requirements for the first action level for the incremental flood protection strategy having the largest net benefits for all 17 features are shown in Table 4.0-3.

4.0.3 Geology/Geotechnical

Maps showing the locations, estimated acreage requirements, and likely status (new or existing) of the borrow/disposal sites identified through the Infrastructure Protection Study are presented as Figures 4.0-1a and 4.0-1b. Note that the quantities listed on the figures are those calculated for the first action level only. The results of the geology/geotechnical investigation related to specific features are given in the individual feature summaries (Sections 4.1 through 4.25).

4.0.4 Environmental

The environmental investigation considered environmental impacts of flood protection for each of the features. However, during the course of the investigation, it was discovered that Features 19 and 24 (both roads) have already been raised or are in the process of being raised. These features were not investigated, therefore, because it was not considered important to investigate the environmental impacts of a flood protection effort that had already been implemented.

For cases in which flood protection was likely to involve only the relocation of buildings (Features 1, 6 and 8), the environmental impacts were assumed to be minimal. Therefore, only a general environmental investigation was conducted for those features—detailed HTRW, cultural, and habitat evaluations were not deemed necessary.

The general results of the environmental investigations for the features are given in the following sections.

4.0.4.1 HTRW

Through examination of historical aerial photographs and maps, and examination of regulatory databases, the HTRW investigation conducted for the Infrastructure Protection Study identified many sites at which environmental contamination is likely. These sites were grouped into the following categories:

- Rural residences and farmsteads
- Non-residential properties
- Former communities
- Sites having cylindrical structures
- Excavation or fill areas
- Sites having artificial ponds

- Pipeline crossings
- Former recreation facilities
- Railroad-related land uses
- Possible dump sites

Each of these HTRW site categories has it's own particular risk of environmental contamination. These risks are listed and explained in detail in Appendix C. The Infrastructure Protection Study assigned the cost of assessing those risks to the flood protection project that would impinge on the sites. The cost tables (See Sections 4.1 through 4.25) for flood protection at each feature, therefore, include costs for HTRW investigations.

For reference, all identified HTRW sites were given a unique identification number. The identification number is based on the feature number, the feature protection strategy involved, and the number of HTRW sites pertaining to the feature. For example, five HTRW sites were identified for Feature 17, US Highway 281 (North of US Highway 2). Feature 17 has only one action level that was analyzed; therefore, their site identification numbers would be 17-1-1 through 17-1-5. General historical information for each HTRW site is summarized in the table provided as part of Appendix C. Also, HTRW sites are noted on the Site Location figures in Sections 4.1 through 4.25.

The work anticipated for the HTRW investigations fell into one of three categories:

- Site inspection – this would include visual inspection for evaluation of site status, and signs of soil staining or contaminant release.
- Asbestos survey – at sites where a building is within the impact area and asbestos-containing materials are likely to be present, a building inspection to determine the presence or absence of asbestos-containing materials would be required.
- Field investigation – a field investigation would follow up on the site inspection, and allow characterization of site contaminants. Depending upon the site and which contaminants were suspected, the field investigation could include: preparation of a work plan, shallow hand auger borings, shallow push-probe soil borings, field screening of soils, chemical analysis of select soil or groundwater samples, and the development of a brief summary report.

Based on the examination of the historical aerial photographs and maps, contacts with local officials and environmental consultants, and experience with similar projects, unit prices for the HTRW investigations were approximated as follows:

Task	Estimated Cost
Site Inspection	$500 to $1,000
Asbestos Survey	$1,000 to $3,000
Field Investigation	$4,000 to $14,000

Greater detail related to the HTRW costs assigned to each flood protection strategy for each feature is provided in the HTRW Site History Summary, included in Appendix C.

4.0.4.2 Cultural

The general location of any known cultural resources, site leads or isolated finds are listed and shown on the figures for each feature in Section 4. A summary of the evaluation status of known cultural resources is presented in each of the feature discussions.

Any architectural properties over 50 years old and any archaeological sites or site leads/isolated finds for which an evaluation was inconclusive will need to have their potential eligibility to the National Register of Historic Places (NRHP) evaluated through a Phase I survey prior to any potential impacts. Impacts to architectural properties can be physical, visual or auditory. The cost to conduct these Phase I Surveys was listed in each of the feature summaries and was included in the flood protection costs for the feature. Such costs do not include possible future cultural resources Phase II site evaluation and Phase III mitigation costs.

A Phase I survey included pedestrian survey and (for archaeology) shovel testing of the project area to identify and record all cultural resources located therein in order to evaluate the potential eligibility of sites to the NRH. If a site or other property has obviously poor integrity, is a non-diagnostic isolated find, etc. and is, therefore, clearly not eligible, a Phase II formal evaluation for actual eligibility is not recommended. If a site or property appears during the Phase I survey to have good integrity and the potential to meet NRHP criteria, it is considered potentially eligible and should be recommended for a formal Phase II evaluation of actual eligibility. In the case of archaeology, Phase II evaluation includes the excavation of one-by-one meter test units to confirm integrity and determine whether the site meets NRHP criteria, while for architectural history, it involves intensive research and examination of a property to accomplish the same.

In addition to the known cultural resources sites, other sites that have not yet been identified may be present in the project feature areas. Therefore, a Phase I survey will need to be conducted to determine the locations of any cultural resources in the project feature areas and to evaluate their *potential* eligibility to the NRHP.

A Phase I survey would also be required at borrow sites for earthen construction materials. Even though these borrow sites are likely to be located on lands currently used for farming, the survey would be necessary to determine whether cultural sites exist beneath the plow zone.

Because the cultural resources area of effect has not yet been finalized for each feature, the cost to conduct Phase I surveys to determine the presence of any unknown resources cannot be determined at this time. However, the Phase I survey costs included for the known sites and site leads encompasses a rather large area, some of which will likely not be included in the area of effect that is ultimately determined for each feature. Therefore, the survey costs determined for each feature were assumed to be reasonable in representing the costs for the next the stage of investigation.

Further detail regarding the research on potential cultural concerns for the Devils Lake flood protection measures can be found in the report by the 106 Group, provided to the Corps as a separate document.

4.0.4.3 Habitat

The habitat investigation results specific to each feature are discussed in the individual feature summaries (Sections 4.1 through 4.25). A detailed description of the overall findings—including habitat descriptions and species listings—can be found in Appendix C. A summary of the general results of the habitat investigations is provided in the succeeding paragraphs.

Ecoregions – The Devils lake basin is located within the Northern Glaciated Plains ecoregion. The Northern Glaciated Plains ecoregion is characterized by a landscape composed of deposited glacial till resulting in flat to gently rolling topography. Climatic conditions of the area originally supported a grassland community composed of short grass prairie, dominated by wheat grass, little and big bluestem and needle grass. The landscape has high concentrations of prairie pothole wetlands—both temporary and seasonal wetlands. Most of these depressions have been categorized as isolated wetlands, although recent work has shown them to be hydrologically connected wetlands. High soil fertility has led to the replacement of much of the native grassland community by agricultural crops.

The Northern Glaciated Plains ecoregion within the areas of concern has three distinct level IV ecoregions based upon glacial drainage and depositional features. These three ecoregions are glacial lake basins, end moraine complexes, and drift plains. The glacial lake basins are flatter than the surrounding drift plains, have fewer wetlands, and are now extensively cultivated. The end moraine complexes are found at the south end of the lake basin and have wooded areas due to elevation mediated precipitation increases.

Wetland Impacts – Impacts to wetland communities due to the infrastructure protection measures can include filling and hydrology alterations due to levee and road construction activities, and flooding due to ponding behind the roads that are acting as dams. Fill used in the construction of the levees could cause environmental impacts due to encroachment upon wetlands and surrounding upland plant communities. Impacts to the wetland communities represent an important environmental impact to these natural resources. Complete or partial loss of wetland functions and conversion to upland due to filling is possible in some locations. In areas where some hydrology is maintained and wetland conditions remain, changes in plant community and hydrology could lead to a wetland type change. The loss of wetland area will impact waterfowl, marsh bird and songbird-nesting areas, as well bring about impacts to reptile and amphibian populations due to habitat loss and fragmentation. Many bird species, such as American bittern and eared grebes are area-sensitive species. Reduction in wetland size will impact these species more so through the loss of habitat than fragmentation.

Upland Impacts – In the upland areas, a loss of native species due to grading and filling could be expected to occur. Subsequent revegetation of fill or borrow locations may allow for the introduction of weedy, non-native species. A loss of native tree species due to grading and filling, as well as the introduction of weedy, non-native under-story species could also be expected in these areas. The loss of woodland areas will impact songbird nesting and small mammal populations, as well impact reptile and amphibian populations due to habitat fragmentation. Impacts to upland plant communities, including woodland, grasslands and cover crop easement areas, have the potential to impact nesting bird populations.

Additional upland impacts are expected from levees and the roads that are acting as dams. These impacts relate to inundation and a subsequent conversion of upland areas to aquatic habitat—either open water or wetland. Complete or partial loss of habitat functions due to conversion to deep-water habitat is possible in some locations. In areas where wetland conditions remain (i.e., water depths less than 2 meters), changes in plant community and hydrology will lead to wetland creation. Inundation will also lead to the displacement of terrestrial species and those aquatic species that need shallow water areas.

Potential Impacts upon Species of Concern – Potential impacts to the Federally listed species of concern have been assessed as part of this study. Federally listed species of concern include Bald Eagle (*Haliaeetus leucocephalis* – threatened), Whooping Crane (*Grus americana* – endangered), Piping Plover (*Charadrius melodus* – threatened) and the Gray Wolf (*Canis lupus* – endangered). Within the area of this analysis, the Whooping crane (*Grus americana)* is the only North Dakota listed threatened or endangered species that has been identified.

Potential effects on the Bald Eagle (*Haliaeetus leucocephalis*), a threatened species, include loss of nesting sites due to tree removal or disturbances to existing nesting locations due to construction-related activities. The presence of bald eagle nests in the Devils Lake basin has been documented, and there have been unconfirmed reports of other eagles nesting in the surrounding areas. Normally, however, bald eagles require open water areas larger than 1,000 hectares per nesting site and thus small, localized wetland losses may not impact the population (Johnsgard, 1990).

The Whooping Crane (*Grus americana*) North American population is comprised of approximately 300 individuals in the wild and in captivity. This species is a seasonal migrant in North Dakota, summering in Canada and wintering in Texas. Areas of western North Dakota have been determined to be critical habitat for this species by the USFWS. Localized losses of wetland habitat due to Devils Lake infrastructure protections measures would be expected to lead to only minimal impacts on the North America population (Berthold, 1993).

The northern Great Plains population of the Piping Plover (*Charadrius melodus*) is a resident breeding species and is considered critically imperiled within the area of analysis. Studies have suggested that beach width may affect habitat use by breeding piping plovers on inland lakes (Federal Register, 2001; Natureserve, 2001; DOI, 1978). Loss of lakeshore areas due to filling and conversion to upland due to infrastructure protection measures could impact this species.

The study area is outside the current range of the Gray Wolf (*Canis lupus)* – an endangered species. The Gray Wolf was extirpated from North Dakota, although occurrences in the Dakotas have increased in recent years. Given the current population status in North Dakota, impacts on this species due to infrastructure protection measures would be expected to be very limited.

4.0.5 Economic Modeling Results

The economic modeling results for the flood protection strategies for each of the features are provided in the tables attached to the individual feature summaries (Sections 4.1 through 4.25). Separate tables show the results of the analysis for the first action level, and for all action levels. Summary listings of economic modeling results are provided and discussed in Section 5. A more detailed look at the results of the economic updates made for features 12, 13, 14, 15, 18, 20, and 21 is provided in Appendix D.

4.1 through 4.25 Feature-by-Feature Results of Infrastructure Protection Study

Appendix A provides a feature-by-feature summary of the findings of the investigation for each of the 17 features selected for special attention in the Infrastructure Protection Study.

Figure 4.0-1a
BORROW AREA SITE IDENTIFICATION
WEST FEATURES
Devils Lake Infrastructure Protection Study

Barr: Arcview 3.1, PIIIAF, i:\client\devilslake\gis\dp\projects\soils.apr, Layout: BorrowSite West, lkp, Thu Nov 07 10:28:21 2002

Figure 4.0-1b
BORROW AREA SITE IDENTIFICATION
EAST FEATURES
Devils Lake Infrastructure Protection Study

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Table 4.0-1
Feature Interdependencies
Based on the Devils Lake Infrastructure Protection Study

Features 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	9	10	11	12	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	Red River Valley and Western Railroad	Canadian Pacific Railroad	Burlington Northern Railroad (Along US Highway 2)	Burlington Northern Railroad (Churchs Ferry to Cando)	US Hwy 2	ND Highway 57 (between ND Highway 20 and BIA Highway 1)	ND Highway 57 (between BIA Highway 1 and US Highway 281)	US Highway 281 (South of US Highway 2)	US Highway 281 (North of US Highway 2)	NH Highway 19	ND Highway 1	ND Highway 20 (North of City of Devils Lake)	ND Highway 20 (City of Devils Lake Levee to ND Highway 57)	ND Highway 20 (ND Highway 57 to Tokio)	BIA Highway 1	BIA Highway 6
10. Canadian Pacific Railroad		o												+			+		+						
11. Burlington Northern Railroad (Along US Highway 2)	o	o												+											
12. Burlington Northern Railroad (Churchs Ferry to Cando)	o																	+							
13. US Highway 2	o	o	o	o	o	o	o	o	o						+	+	+		+	+		+			+
14. ND Highway 57 (between ND Highway 20 and BIA Highway 1)		o	o		o											+	+		+			+	+	+	+
15. ND Highway 57 (between BIA Highway 1 and ND Highway 281)		o	o		o										+		+		+			+	+	+	+
16. US Highway 281 (South of Highway 2)	o	o	o	o	o	o	o	o	o					+	+	+			+			+	+		+
17. US Highway 281 (North of Highway 2)	o													+							+				
18. ND Highway 19		o		o			o	o						+	+	+	+					+			
19. ND Highway 1									o																
20. ND Highway 20 (North of City of Devils Lake)		o												+				+							
21. ND Highway 20 (City of Devils Lake Levee to ND Highway 57)		o	o		o	o		o						+	+	+	+		+				+	+	+
22. ND Highway 20 (ND Highway 57 to Tokio)		o	o		o	o									+									+	+
23. BIA Highway 1					o										+								+		+
24. BIA Highway 6			o		o										+	+							+	+	

NOTES:

(shaded cell) A feature's dependency on itself was not considered a legitimate dependecy

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

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

Table 4.0-2

Unit Price Assumptions
Devils Lake Infrastructure Protection Study

Road and Railroad Raise Unit Prices

Clearing and Grubbing	$3,000 /AC
Stripping (6")	$1.50 /CY
Excavation	$3.50 /CY
Geotextile Fabric	$2.00 /SY
Fill Material	$5.00 /CY
Aggregate Base Course	$20 /CY
Bituminous Pavement[2]	$50 /TON
Bedding	$35 /CY
Riprap	$40 /CY
Culverts[3]	$50 /LF
Topsoil	$2.50 /CY
Seed	$1,000 /AC
Rail Material[4]	$170 /LF
Borings	$1,000 /EA
Slurry Wall	$6.00 /SF

Levee Raise Unit Prices

Clearing and Grubbing	$3,000 /AC
Stripping (6")	$1.50 /CY
Inspection Trench	$4.00 /LF
Levee Fill	$5.00 /CY
Bedding	$35 /CY
Riprap	$40 /CY
Sand Drain	$22 /CY
Topsoil (4")	$2.50 /CY
Seed	$1,000 /AC
Culverts[3]	$50.00 /LF
Borings	$1,000 /EA
Slurry Wall	$6.00 /SF

Notes:
1. All costs include material and labor.
2. This cost includes all materials associated with using bituminous pavement (I.e. prime coat, etc.).
3. Culverts assumed to be 24" CMP.
4. This cost includes removal of old track, installation of new track, ballast, subballast, and ties.

Table 4.0-3

Construction Material and Mitigation Requirements for First Action Level
Devils Lake Infrastructure Protection Study

Feature Number	Feature Name	Flood Protection Strategy	Total Mitigation Required[1] (Acres)	Construction Quantities: Fill Material (CY)	Construction Quantities: Bedding (CY)	Construction Quantities: Riprap (CY)	Number of Structures Relocated[2]
1	Churchs Ferry	Relocation of All Structures	--	--	--	--	16
2	City of Devils Lake[3]	One Incremental Levee Raise	1.2	19,018	2,826	3,327	--
3	Fort Totten	One Incremental Relocation	--	--	--	--	5
4	City of Minnewaukan	One Incremental Levee Raise	50.0	95,900	16,100	22,700	6
5	St. Michael	One Incremental Relocation	--	--	--	--	1
6	Gilbert C. Grafton Military Reservation	Relocation of Munitions Facility	--	--	--	--	6
7	Grahams Island State Park	One Incremental Road Raise and Relocation of Structures	84.7	329,000	0	14,000	1
8.1	Devils Lake Rural Areas	Five Incremental Relocations (total up to 1454)	--	--	--	--	257
8.2	Stump Lake Rural Areas	Eight Incremental Relocations (total up to 1454)	--	--	--	--	35
10	Canadian Pacific Railroad	One Incremental Rail Raise	83.2	305,700	0	129,000	--
11	Burlington Northern Railroad (along US Highway 2)	One Incremental Rail Raise	250.7	518,700	0	182,200	--
16	US Highway 281 (South of US Highway 2)	One Incremental Road Raise	235.4	2,643,300	0	25,000	--
17	US Highway 281 (North of US Highway 2)	One Incremental Road Raise	178.2	670,000	0	300	--
19	ND Highway 1	- NA -	--	--	--	--	--
22	ND Highway 20 (between ND Highway 57 and Tokio)	One Incremental Road Raise	65.1	1,018,000	0	77,000	--
23	BIA Highway 1	One Incremental Road Raise	17.5	118,500	0	15,000	--
24	BIA Highway 6	- NA -	--	--	--	--	--
CUMULATIVE TOTAL			**966.0**	**5,718,118**	**18,926**	**468,527**	**327**

Summary Including Roads Acting as Dams (Expanded Infrastructure Protection)

5	St. Michael	Protected by Roads Acting as Dams	--	--	--	--	--
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	--	--	--
25.1	Roads Acting as Dams (Acorn Ridge Area)	One Incremental Levee Raise	0	85,000	5,700	8,500	1
25.2	Roads Acting as Dams (Mission Township Area)	One Incremental Levee Raise	6,789	677,000	60,000	90,000	15
CUMULATIVE TOTAL WITH ROADS ACTING AS DAMS			**7,689.9**	**5,462,118**	**84,626**	**490,027**	**342**

Notes

1 Required mitigation for wildlife habitat impacted by flood protection measures.

2 Structures include all residences, barns, sheds, and commercial/industrial buildings.

3 Wildlife habitat mitigation estimate for the City of Devils Lake levee was obtained from the Alternatives Alignment Study, 2001.

5. Flood Protection Summary Tables

5.0 Explanation of Flood Protection Summary Tables

The Infrastructure Protection Study provided the information necessary to construct two Flood Protection Summary Tables (5.0-1a and 5.0-1b) for the flood protection that may be considered for Devils Lake features. The Flood Protection Summary Tables are explained below.

5.1 Flood Protection Summary Tables Description

The Flood Protection Summary Tables are presented at the end of Section 5. The tables list, by feature number and name, the incremental strategy having the largest net benefits and that strategy's net costs, net benefits, and BCR.

For both the stochastic analysis and the Wet Future, Table 5.0-1a addresses all 25 features and presents economic modeling results for flood protection up to the maximum lake level. In contrast to Table 5.0-1a, Table 5.0-1b focuses on results for the first action level for the 17 features that were the principal concern of the Infrastructure Protection Study. (For comparison, Table 5.0-1b also shows the economic results for completing flood protection for all action levels.) Also shown on Table 5.0-1b are the low structure (LS) elevation, the elevation at which damage from lake waters would be expected to occur (LD); and (for the first action level only) the elevations at which project planning should be initiated (PI), construction should be initiated (CI), and construction should be complete (PC).

Both tables also provide present worth values for costs and damages for each feature and flood protection strategy; in Table 5.0-1b these values are given for the first action level only.

The Flood Protection Summary Tables identify for the user the incremental flood protection strategy that would be recommended solely on the basis of the economic modeling results. First costs are shown, so funding requirements can be anticipated. The listing of decision-critical elevations for the first action level provides an indication of the timeline under which project work should proceed.

5.2 Development of the Tables

The Flood Protection Summary Tables draw on the results of the analysis of critical feature protection at Devils Lake. They are based on the results of all the investigations conducted for the Infrastructure Protection Study, as detailed in Sections 3 and 4 of this report. The Flood Protection Summary Tables rely heavily on the results of the investigation into construction methods, lead times, and the probabilistic evaluation of possible rates of lake rise. They also are based on the distillation of the feature protection investigations that is produced by the Features Analysis (economics) Model employed for this study.

5.2.1 Decision-critical Lake Elevations

Lake elevations were identified for critical points in the flood protection planning and construction process for each feature, as described in Sections 3 and 4 of this report. For a selected flood protection strategy, these elevations can be used for guidance in determining when it is critical to take action with respect to protecting a given feature. The Flood Protection Summary Table 5.0-1b lists the decision-critical elevations identified for the first action level for each of the features, as identified in the reference-level tables included in Sections 4.1 through 4.25. Only the elevations for the incremental flood protection strategy having the largest net benefits are shown in the Flood Protection Summary Tables.

5.2.2 Economic Results

For each of the features and for each of the flood protection strategies considered, the Infrastructure Protection Study made an estimate of the flood damage amounts and flood protection costs. These estimates were used as input to the Features Analysis Model, which used them to evaluate the net benefits and BCRs for each flood protection strategy. For each feature, comparison of the strategies' net benefits then allows identification of the incremental flood protection strategy with the largest net benefits under the stochastic analysis. (The stochastic analysis results are used because they are considered to represent the likely net benefits under a wide range of possible climate futures.) The Flood Protection Summary Tables assume that the incremental flood protection strategy adopted for each feature will be the strategy having the largest net benefits.

5.3 Intended Use for Tables

The Flood Protection Summary Tables may be of use for the evaluation, planning, and implementation of flood protection efforts for a variety of local, state, and Federal agencies. These agencies include:

- Engineering, planning, and governing groups within the communities of the Devils Lake area
- Spirit Lake Nation
- North Dakota Parks Department
- North Dakota Army National Guard
- State and Federal governments
- Bureau of Indian Affairs

- North Dakota Department of Transportation
- Burlington Northern and Santa Fe, and Canadian Pacific Railroads
- US Fish and Wildlife Service
- US Army Corps of Engineers
- Federal Emergency Management Agency

Agencies may wish to refer to the table to:

- Help consider whether flood protection for the individual features may be preferable to a more global (outlet) approach to dealing with the Devils Lake flooding problem
- Help in the consideration of whether or not to proceed with flood protection for the features, based on the listed net benefits and BCR
- Consider whether other approaches to flood protection may be preferred, for reasons not represented in the economic analysis
- Use the economics results to decide whether or not they have sufficient resources to pursue the identified flood protection efforts
- Budget for the flood protection work, and determine the magnitude of additional or outside funding that may be required
- Estimate the urgency of the need to begin and complete the flood protection effort
- Compare the net benefits of flood protection at the various features, to assist in determining priorities for flood protection projects

The supporting information provided in Sections 4.1 through 4.25 will help the agencies to identify and evaluate additional considerations (e.g., environmental concerns, mitigation needs, geotechnical issues, availability of construction materials) that may affect flood protection decisions.

Table 5.0-1a

Flood Protection Summary Table
Economic Results: All Action Levels -- to Lake Level 1463
Devils Lake Infrastructure Protection Study

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Present Worth[1]: Total First Costs	Present Worth[1]: Total Damages Prevented	Present Worth[1]: Annual Damages Prevented[2]	Stochastic Analysis: Average Annual Net Benefits[3]	Stochastic Analysis: Benefit- Cost Ratio	Wet Future Scenario: Average Annual Net Benefits[3]	Wet Future Scenario: Benefit- Cost Ratio	Lake Level of First Damages
1	Churchs Ferry	Relocation of All Structures	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (22,400)	0.76	1451
2	City of Devils Lake	Incremental Levee Raises	$ 78,174,000	$ 305,380,000	--	$ 365,200	1.30	$ 6,972,700	2.84	1454.5
3	Fort Totten	Incremental Relocations	$ 5,367,000	$ 4,086,000	--	$ (20,500)	0.76	$ (65,600)	0.76	1448
4	City of Minnewaukan	Incremental Levee Raises	$ 17,605,000	$ 25,042,000	--	$ (25,300)	0.88	$ 149,700	1.17	1451
5	St. Michael	Incremental Relocations	$ 1,720,000	$ 1,224,000	--	$ (11,700)	0.71	$ (21,200)	0.71	Current[4]
6	Gilbert C. Grafton Military Reservation	Relocation of Munitions Facility	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,100)	0.64	Current
7	Grahams Island State Park	Incremental Road Raises and Structure Relocations	$ 23,764,000	$ 2,718,000	$ 516,000	$ (66,400)	0.86	$ (414,400)	0.59	Current
8.1	Devils Lake Rural Areas	Incremental Relocations	$ 79,764,000	$ 58,670,000	--	$ (273,700)	0.72	$ (831,300)	0.73	Current
8.2	Stump Lake Rural Areas	Incremental Relocations	$ 5,457,000	$ 3,547,000	--	$ (28,700)	0.65	$ (87,700)	0.65	1413
9	Red River Valley and Western Railroad	N/A	--	--	--	--	--	--	--	N/A
10	Canadian Pacific Railroad	Incremental Rail Raises	$ 67,260,000	--	$ 533,000	$ (895,900)	0.48	$ (2,646,700)	0.17	Current
11	Burlington Northern Railroad (along US	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ 1,060,300	1.48	1452
12	Burlington Northern Railroad (Churchs Ferry to	Incremental Rail Raises	$ 69,394,000	--	$ 509,000	$ (179,100)	0.19	$ (1,595,500)	0.20	1451
13	US Highway 2	Incremental Road Raises	$ 152,738,000	--	$ 11,863,000	$ 88,200	1.15	$ 2,298,800	1.47	1452
14	ND Highway 57 (between ND Highway 20 and BIA Highway 1)	Incremental Road Raises	$ 14,274,000	--	$ 13,104,000	$ 646,100	11.57	$ 7,251,000	16.25	1452
15	ND Highway 57 (between BIA Highway 1 and US Highway 281)	Incremental Road Raises	$ 42,667,000	--	$ 9,488,000	$ 353,400	3.05	$ 4,250,500	4.05	1452
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 2,733,000	1.98	Current
17	US Highway 281 (North of US Highway 2)	Incremental Road Raises	$ 38,459,000	--	$ 1,403,000	$ (35,200)	0.85	$ (198,300)	0.86	1451
18	ND Highway 19	Incremental Road Raises	$ 101,252,000	--	$ 1,322,000	$ (289,000)	0.29	$ (2,379,100)	0.28	1452
19	ND Highway 1	- NA -	--	--	--	--	--	--	--	1462
20	ND Highway 20 (North of City of Devils Lake)	Incremental Road Raises	$ 33,382,000	--	$ 3,375,000	$ (26,200)	0.66	$ (29,100)	0.97	1457
21	ND Highway 20 (City of Devils Lake Levee to ND Highway 57)	Incremental Road Raises	$ 24,859,000	--	$ 13,104,000	$ 606,900	6.71	$ 6,915,500	9.35	1452
22	ND Highway 20 (ND Highway 57 to Tokio)	Incremental Road Raises	$ 37,987,000	--	$ 611,000	$ (592,300)	0.50	$ (1,210,800)	0.34	Current
23	BIA Highway 1	Incremental Road Raises	$ 11,382,000	--	$ 1,012,000	$ 188,400	2.08	$ 469,100	1.97	1448
24	BIA Highway 6[5]	Incremental Road Raises	$ 4,538,000	--	$ 13,873,000	$ 740,900	35.46	$ 8,016,700	52.59	1453.9
		CUMULATIVE TOTAL	**$ 908,117,000**	**$ 403,116,000**	**$ 78,907,000**	**$ 759,000**	**1.07**	**$ 30,582,100**	**1.86**	

Summary Including Roads Acting as Dams

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Total First Costs	Total Damages Prevented	Annual Damages Prevented[2]	Stochastic: Average Annual Net Benefits[3]	Stochastic: Benefit- Cost Ratio	Wet Future: Average Annual Net Benefits[3]	Wet Future: Benefit- Cost Ratio	Lake Level of First Damages
5	St. Michael	Protected by Roads Acting as Dams	--	$ 1,224,000	--	$ -	--	$ -	--	Current[4]
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	$ 611,000	$ -	--	$ -	--	Current
24	BIA Highway 6[5]	Protected by Roads Acting as Dams	--	--	$ 13,873,000	$ -	--	$ -	--	1453.9
25.1	Roads Acting as Dams (Acorn Ridge Area)	Incremental Levee Raises	$ 15,209,000	$ 3,098,000	$ -	$ (468,500)	0.12	$ (193,400)	0.21	Current[4]
25.2	Roads Acting as Dams (Mission Township Area)[6]	Incremental Levee Raises	$ 87,509,000	$ 7,220,000	$ -	$ (1,410,200)	0.61	$ (166,100)	0.93	Current[4]
CUMULATIVE TOTAL WITH ROADS ACTING AS DAMS			**$ 966,590,000**	**$ 413,434,000**	**$ 78,907,000**	**$ (1,256,600)**	**0.91**	**$ 23,437,900**	**1.65**	

Notes

1. Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2. Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented in this table.
3. The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.
4. Currently protected by temporary dikes and roads that are acting as dams.
5. Currently protected by tempoary dikes and roads that are acting as dams, and is being raised to a minimum elevation of 1456.9.

Table 5.0-1b

Flood Protection Summary Table
Economic Results: First Action Level
Devils Lake Infrastructure Protection Study

			Present Worth[1]			Stochastic Analysis				Wet Future Scenario Analysis				Decision-Critical Lake Elevations[4]											
						First Action Level		All Action Levels		First Action Level		All Action Levels													
Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Total First Costs for First Action Level	Damages Prevented	Annual Damages Prevented[2]	Average Annual Net Benefits[3]	Benefit-Cost Ratio	Average Annual Net Benefits[3]	Benefit-Cost Ratio	Average Annual Net Benefits[3]	Benefit-Cost Ratio	Average Annual Net Benefits[3]	Benefit-Cost Ratio	Current	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	Notes
1	Churchs Ferry	Relocation of All Structures Below 1468	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (6,100)	0.76	$ (22,400)	0.76	$ (22,400)	0.76					PC, LD, CI	LS						
2	City of Devils Lake	One Incremental Levee Raise	$ 6,327,000	$ 223,729,000	--	$ 1,294,000	5.74	$ 365,200	1.30	$ 10,392,400	29.46	$ 6,972,700	2.84	PI	CI				PC		LD			LS	
3	Fort Totten	One Incremental Relocation	$ 4,753,000	$ 3,638,000	--	$ (19,900)	0.77	$ (20,500)	0.76	$ (60,200)	0.77	$ (65,600)	0.76		LD, CI	LS									
4	City of Minnewaukan	One Incremental Levee Raise	$ 11,298,000	$ 10,493,000	--	$ (23,600)	0.85	$ (25,300)	0.88	$ (62,000)	0.89	$ 149,700	1.17		PI			CI, LD	LS	PC					Temporary Protection of Low Homes
5	St. Michael	One Incremental Relocation	$ 582,000	$ 409,000	--	$ (10,500)	0.70	$ (11,700)	0.71	$ (10,500)	0.70	$ (21,200)	0.71	PI, CI, PC, LD				LS							
6	Gilbert C. Grafton Military Reservation	Relocation of All Structures	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,000)	0.64	$ (33,100)	0.64	$ (33,100)	0.64	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS=1444
7	Grahams Island State Park	One Incremental Road Raise	$ 5,668,000	$ 531,000	$ 516,000	$ (67,500)	0.80	$ (66,400)	0.86	$ 173,000	1.50	$ (414,400)	0.59	PI, CI, PC, LD				LS							
8.1	Devils Lake Rural Areas	Five Incremental Relocations	$ 23,511,000	$ 17,055,000	--	$ (218,500)	0.72	$ (273,700)	0.72	$ (359,500)	0.72	$ (831,300)	0.73												Broad Range of Elevations
8.2	Stump Lake Rural Areas	Eight Incremental Relocations	$ 2,982,000	$ 1,960,000	--	$ (22,900)	0.66	$ (28,700)	0.65	$ (53,100)	0.66	$ (87,700)	0.65												Broad Range of Elevations
10	Canadian Pacific Railroad	One Incremental Rail Raise	$ 23,234,000	--	$ 533,000	$ (654,500)	0.54	$ (895,900)	0.48	$ (1,193,600)	0.16	$ (2,646,700)	0.17	PI, CI, PC, LD			LS								
11	Burlington Northern Railroad (along US Highway 2)	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ (62,600)	0.87	$ 1,060,300	1.48	$ 1,060,300	1.48				PI		CI, LD				LS		
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 315,600	1.11	$ 2,733,000	1.98	$ 2,733,000	1.98	PI, CI, LD			LS								
17	US Highway 281 (North of US Highway 2)	One Incremental Road Raise	$ 9,953,000	--	$ 1,403,000	$ (15,300)	0.88	$ (35,200)	0.85	$ (207,000)	0.57	$ (198,300)	0.86		PI			CI, LD			LS				
19	ND Highway 1	- NA -	--	--	--	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -												LS=1465, Has been relocated
22	ND Highway 20 (ND Highway 57 to Tokio)	One Incremental Road Raise	$ 17,858,000	--	$ 611,000	$ (532,300)	0.51	$ (592,300)	0.50	$ (826,000)	0.24	$ (1,210,800)	0.34	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS=1445
23	BIA Highway 1	One Incremental Road Raise	$ 3,004,000	--	$ 1,012,000	$ 161,900	2.27	$ 188,400	2.08	$ 125,300	1.73	$ 469,100	1.97	PI	CI, LD			LS							
24	BIA Highway 6	- NA -	--	--	--	- NA -	- NA -	$ 740,900	35.46	- NA -	- NA -	$ 8,016,700	52.59												Being raised to LS=1457

Roads Acting as Dams

5	St. Michael	Protected by Roads Acting as Dams	--	--	--	--	- NA -	--	- NA -	--	- NA -	--	- NA -	PI, CI, PC, LD				LS							
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	--	--	- NA -	--	- NA -	--	- NA -	--	- NA -	PI, CI, PC, LD, LS											LS = 1445
25.1	Roads Acting as Dams (Acorn Ridge Area)	One Incremental Levee Raise	$ 3,404,000	$ 853,000	--	$ (172,300)	0.23	$ (468,500)	0.12	$ (160,800)	0.24	$ (193,400)	0.21	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS =
25.2	Roads Acting as Dams (Mission Township Area)	One Incremental Levee Raise	$ 35,674,000	$ 20,763,000	--	$ (1,047,500)	0.55	$ (1,410,200)	0.61	$ (945,700)	0.57	$ (166,100)	0.93	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS =

LS = Low Structure, LD = Lake Damage, PC = Project Completion, CI = Construction Initiation, PI = Project Initiation. For further description of decision-critical lake elevations, see Section 3.2.1.

Notes
1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2 Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented in this table.
3 The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.
4 Decision-critical elevations are rounded to the nearest foot.

6. Summary and Discussion

6.0 Important Aspects of the Infrastructure Protection Study

The Infrastructure Protection Study built on the work of previous studies of flood protection at Devils Lake, and extended that work to provide analysis and results that were not available previously. The Infrastructure Protection Study:

- Addressed issues and documented data regarding flood protection for the Devils Lake features taken individually. In general, previous studies had addressed the features in aggregate, and information regarding flood protection for individual features had not been provided. Concise, standardized summaries of previous analysis of flood protection for individual features are now available (provided in Sections 2.1 through 2.25). Updated and more comprehensive summaries for 17 selected features are now also available (provided in Sections 4.1 through 4.25).

- Focused on the first action level for 17 selected features susceptible to flooding below 1454. This more detailed analysis for the first action level for these features allows a more informed flood protection decision-making process for the urgent questions that may arise in the near future.

- For the 17 selected features, provided flood protection analysis at a much greater level of detail. Issues not previously addressed – such as HTRW investigations, cultural considerations, environmental damage and mitigation, real estate issues, and geologic and geotechnical aspects of the flood protection work – were studied in some detail. The more detailed and refined analysis should provide decision-makers with better information when considering flood protection measures.

- Identified decision-critical elevations for flood protection at each of the17 selected features for the first action level. These elevations, not previously identified, may be of use in directing flood protection planning and construction efforts.

- By one of three methods, provided economic analysis results for flood protection for each of the 25 features up to the maximum lake level. It should be noted that the disparate methods of providing these results make comparisons tentative. Nevertheless, the availability of such results means that there is some indication of whether complete flood protection for each feature is economically justified. For the 17 selected features, these results allow a comparison of the economic benefits of providing flood protection at the first action level only with the benefits of continuing with that flood protection strategy up to the maximum lake level.

- For the first action level for the 17 selected features, quantified and listed construction material requirements, as well as provided estimates for acreage needed for environmental mitigation, and numbers of structures to be relocated. Providing estimates for these needs is likely to increase awareness of accessory considerations and allow better planning when making flood protection decisions.

6.1 Notes on Why Results Differed from Previous Studies

Because the Infrastructure Protection Study expanded upon and refined the work done under the Economic Analysis (which itself built on previous studies), results from the two studies differed. It is useful to call attention to some of these differences, and to make note of the reasons that the results varied.

- Some of the features (such as BIA Highway 6) have already been raised, eliminating some of the benefits shown in previous economic analyses of feature protection. Given that some flood protection work has taken place in the interim, it is not surprising that the benefits for this work are no longer available, and the BCRs are reduced.
- For the Economic Analysis, flood protection costs and flood damages for a particular feature and action level were assumed to be incurred at the same elevation. Under the analytic methodology of the Infrastructure Protection Study, however, planning and construction costs could be incurred earlier than the damages. Planning and construction costs were incurred at the Planning Initiation elevation identified for each feature protection strategy. A similar process would be expected to occur in actual practice, and would allow sufficient construction time to minimize the possibility of catastrophic damages. Although registering costs earlier provides a better approximation of actual conditions, it increases the present worth costs (by registering them earlier) and in some traces registers costs when the damages are not registered at all – because the damage elevation is never reached.
- Similarly, the Infrastructure Protection Study also differed from the Economic Analysis in the assumptions made regarding damages. For the Economic Analysis, all damages were assumed to occur at the same elevation at which decisions would be made regarding the next phase of flood protection for a given feature. The Infrastructure Protection Study, by contrast, sought to assign damages at the lake elevation at which they would actually occur. Although this provides a better approximation of actual conditions, it decreases the present worth damages (by registering them later) and registers traces in some cases when the damages may not be registered. By comparison to the Economic Analysis, the benefits (damages prevented) registered under the Infrastructure Protection Study were thereby reduced.

Such differences can be seen in the results tables (2.0-2, and 5.0-1) for the two studies. Under the Infrastructure Protection Study, flood protection costs are generally higher, and flood damages are lower. This can be seen by comparing net benefits for the stochastic analysis, which dropped from $13 million (Economic Analysis) to $0.8 million (Infrastructure Protection Study). Similarly, the overall BCR dropped from 2.27 in the Economic Analysis to 1.07 in the Infrastructure Protection Study (stochastic analysis results).

In some cases, the costs for feature protection changed markedly from those identified in the Economic Analysis. Some costs increased and others were reduced. The changes resulted primarily from the more detailed data used in evaluating relocations, more detailed analysis of road plans, and accounting for recent raises. For similar reasons, estimates of damage (if flood protection were not provided) also changed dramatically for some features. Overall, the aggregate feature protection costs of the Economic Analysis decreased slightly when computed for the Infrastructure Protection Study (dropping from $1,150 million to $912 million). The aggregate structure and infrastructure damage estimates were also reduced, from $519 million to $403 million. Aggregate annual detour damage estimates were the same ($79 million), but the per-event aggregate restoration damages rose slightly (from $131 million to $145 million).

The results of the Economic Analysis indicated that the protection of infrastructure up to the maximum lake level, for all features in aggregate, was economically justified (BCR = 2.27). The Infrastructure Protection Study also indicated economic justification for feature protection in aggregate (BCR = 1.07), but the benefits were more nearly equal to the damages prevented. This reduction can be at least partially explained by noting that especially in the case of the Economic Analysis, large benefits are derived from flood protection at just two features: the City of Devils Lake and BIA Highway 6. Flood protection for the City of Devils Lake showed large benefits because of the density of structures and infrastructure there. The large benefits (damages prevented) shown for flood protection at BIA Highway 6 are a consequence of the assumption that if BIA Highway 6 were closed due to flooding, ND Highway 20 would also be under water. As discussed previously, this assumption results in large damages for BIA Highway 6, because it means that long detours would be required.

Under the Infrastructure Protection Study, the estimates of the benefits of flood protection at these two features were reduced significantly. The City of Devils Lake benefits were reduced mainly as a consequence of registering costs and damages at different elevations. As explained above, this can make a large difference in the economic results. In the case of BIA Highway 6, the main reason for the reduction in benefits was the fact that the road had already been raised. This eliminated a significant portion of the detour damages that are prevented when this highway is kept from flooding.

Overall, the Economic Analysis showed that 11 of the 25 features had net benefits that were greater than zero (under the stochastic analysis). By contrast, the Infrastructure Protection Study showed that only eight of the feature protection strategies have net benefits that are greater than zero. The three features for which flood protection is no longer shown to be economically justified are:

1. Feature 4: City of Minnewaukan – The Economic Analysis assumed that flood protection would involve the construction of a road/levee to protect portions of the city. It was assumed that some of the construction expense would be borne by the ND DOT. Under the Infrastructure Protection Study, however, this assumption was determined to be invalid. As a result, the Infrastructure Protection Study assumed a different and higher-priced levee configuration, without any funding support from other agencies. Costs therefore increased significantly, and the BCR fell.

2. Feature 8: Rural Areas – In the Economic Analysis, land damages for rural areas were included in the overall analysis. This inclusion could not be made under the terms of the Infrastructure Protection Study, which evaluated all features individually. As a result, prevention of land damages could not be registered, and the economic results showed a decline in the BCR.

3. Feature 11: Burlington Northern Railroad – The Economic Analysis' assumptions regarding flood protection for this feature were significantly different from those of the Infrastructure Protection Study. The Economic Analysis assumed that there would be two incremental rail raises for the Burlington Northern Railroad. However, more recent conversations with railroad personnel made it clear that the only flood protection strategy that would be implemented would be raising the road all at once to the maximum level. Economic modeling shows that this strategy compares unfavorably with the two-step raise contemplated previously.

6.2 Infrastructure Protection Study Economic Results Highlights

Even without reference and comparison to the previously conducted Economic Analysis, several results of the economic analysis conducted for the Infrastructure Protection Study deserve mention:

- The four features showing the largest net benefits are all roads – ND Highway 57 (two features, two different segments), ND Highway 20 (City of Devils Lake to ND Highway 57), and BIA Highway 6. The large net benefits for these features result primarily from the detour damages that are prevented when the road is raised. (These roads also showed similarly large net benefits under the Economic Analysis.) As was mentioned previously, because of interdependencies among these roads, summing the benefits of flood protection for these features may result in artificial inflation of the aggregate BCR.

- First costs for feature protection show wide variation – from approximately $2 million to $152 million. In general, the higher costs are registered in cases where road, railroad, or levee raises involve wide cross-sections and long segments.

- The economic analysis of the Wet Future climate scenario generally showed larger net benefits and BCRs than those for the stochastic analysis. Under the Wet Future scenario, lake levels rise quickly and stay high. Consequently, the benefits of flood protection are large, and are registered early in the 50-year modeling period. Relatively large net benefits and BCRs are generally the result. This also points to the fact that the modeling results are quite sensitive to climate assumptions.

- The Infrastructure Protection Study showed that although the net benefits are negative for constructing a levee for the City of Minnewaukan, this strategy provides the largest net benefits of any flood protection strategy for that feature. Construction of a levee would be less expensive than relocation of the entire community. A sensitivity analysis conducted for this feature indicated that the annual net benefits would be positive ($29,500) if relocation was assumed as the base (without-project) condition for this feature. Under the terms of that analysis, the levee raise is economically justified.

- Because some of the interior roads have now been raised, the Infrastructure Protection Study indicated that the benefits for the Roads Acting as Dams feature were less than those shown in previous analyses. Having the interior roads already raised decreases the dollar value of damages prevented by construction of the perimeter levees. The use of Roads Acting as Dams was not shown to be economically justified previously (BCR of 0.99 in the Economic Analysis), and is shown to have an even smaller BCR of 0.61 under the Infrastructure Protection Study (stochastic results).

- Of the 17 selected features, the three that are economically justified for the first action level are the three that are economically justified for all action levels (stochastic analysis) – Feature 2: City of Devils Lake, Feature 16: US Highway 281 (South of US Highway 2), and Feature 23: BIA Highway 1. Under the Wet Future analysis for the first action level, two additional features are economically justified for the first action level – Feature 7: Grahams Island State Park and Feature 11: Burlington Northern Railroad.

- The results of the stochastic analysis for flood protection up to the maximum lake level are slightly different than the results under the wet future analysis. Eight features are shown to be economically justified under the stochastic analysis, while ten are shown to be economically justified under Wet Future conditions. The two additional features showing economic justification under Wet Future conditions are Feature 4: City of Minnewaukan, and Feature 11: Burlington Northern Railroad.

6.3 Additional Findings

Several additional findings with respect to the findings of the Infrastructure Protection Study – findings not specific to the economic results – are worth noting for the Infrastructure Protection Study. Several of these findings have implications for planning and scheduling flood protection activities. These observations include:

- Eight of the 25 features have a lake damage elevation at or below 1448 – the level at which the lake peaked in 2001.
- Nine features appear to require initiation of planning, design, and construction activities at a lake level of 1448 or below. Another five features can be expected to require construction initiation at elevation 1451 or 1452, with planning and design elevations between 1448 and 1450.
- It appears that if Devils Lake continues to rise, a significant number of structures will need to be moved in the near future. Analysis of flood protection at the first action level showed that 330 structures would be affected.
- Large amounts of fill material (nearly 6 million cubic yards) and riprap (0.5 million cubic yards) are likely to be needed for flood protection projects likely to be initiated soon. There appears to be many different options for borrow (and fill) sites close to the features. However, negotiations with landowners for use of the potential borrow sites of such sites can be protracted. As such, it may be advisable for the responsible parties to begin such negotiations without delay.
- Real estate evaluations indicated that real estate costs will not be a large percentage of total costs for flood protection in the area. Nevertheless, the negotiation of easements may be protracted and complicated, so that it may be advisable for the responsible parties to begin such negotiations without delay.
- Environmental mitigation is expected to require approximately 1,000 acres for flood protection at the first action level for the 17 selected features. A substantial amount of time and effort may be required to locate appropriate lands and negotiate easements.
- While there is a potential to encounter numerous HTRW sites when implementing Action Level 1 flood damage reduction measures for the various features, none of the sites identified during the initial identification phase were particularly worrisome. Furthermore, it should be possible to modify alignments to either avoid or minimize the need for costly HTRW cleanup measures. Therefore, HTRW costs are not expected to significantly affect the economic feasibility of any feature.

- The evaluation of the cultural resources in the area suggests that problems regarding cultural sites should not be expected to be of large concern. It should be possible to readily find solutions to any cultural site issues that may arise.

6.4 Interpreting the Study's Results

The results of the Infrastructure Protection Study, while well grounded, should not be used without discretion. Users of the information presented herein should keep in mind that key assumptions and modeling methods played a central role in determining the results of the study. The remainder of this section highlights some of those key assumptions and methods, and indicates how they may bear on the interpretation and use of the study's results.

A central feature of the economic analysis on which the Flood Protection Summary Tables are based is the use of a stochastic approach to deal with the uncertainties in predicting the fluctuations of the water level in Devils Lake. The modeling used to produce the set of 10,000 traces used for the stochastic analysis relied on a set of climate assumptions. Modeling results are also given for a specific set of climate assumptions (the Wet Future). But it should be emphasized that other assumptions regarding the future climate – the future may be assumed to be wetter or drier – would produce different economic results. Such variations in results have been shown both in this study and in previous analyses. Other results, resulting from different climate assumptions, might suggest a different course of action with respect to flood protection for the Devils Lake features.

Related to the matter of climate assumptions is the fact that for the economic analysis of flood protection, timing is critical. Prevention of damages in the distant future is less valuable than preventing damages immediately. Conversely, flood protection costs incurred in the distant future decrease net benefits much less than flood protection costs incurred immediately. This means that the exact pattern of lake rise and fall displayed in any trace will have a large bearing on when and if costs and benefits are registered. The economic results, therefore, will also be dependent on the particulars of each trace. The stochastic approach to the analysis sought to mitigate this concern by averaging results over 10,000 traces. But the sensitivity of the results to the particulars of each trace should be kept in mind when examining economic results for a specific trace (for example, the Wet Future, Moderate 1, and Moderate 2 traces that were analyzed for the Infrastructure Protection Study).

Climate assumptions will also bear on the anticipated rate of lake level rise. In the Infrastructure Protection Study, that rate (used in conjunction with the lead time estimates to determine the decision-critical lake elevations) was based on a probabilistic determination using the best current information. If climate patterns in the future deviate from those assumed for the analysis, the determinations of lake level rise rates would also change. Such changes would result in different elevations at which flood protection activities should commence and be completed. These changes would in turn result in different net benefits and BCRs for the projects.

Other examples of modeling conditions and assumptions that bear on economic results include:

- The large benefits (damages prevented) shown for flood protection at BIA Highway 6 are a consequence of the assumption that if BIA Highway 6 were closed due to flooding, ND Highway 20 would also be under water. As discussed previously, this assumption results in large damages for BIA Highway 6, because it means that long detours would be required. If the ND DOT establishes a commitment to keeping ND Highway 20 open as lake waters rise, the assumption regarding detour damages at BIA Highway 6 would have to be revisited. Having an alternate route available would mean that the detour damages prevented by road raises at BIA Highway 6 would be diminished. The net benefits for protecting BIA Highway 6 would be significantly reduced, and the aggregate BCR for flood protection at Devils Lake would also decrease.
- The benefits of preventing road restoration expense were not included in the Infrastructure Protection Study's modeling for the first action level (see Section 3.2.2.1). The exclusion of these benefits, while necessary, somewhat unfairly depresses the BCRs for flood protection at the first action level for the road and railroad features.
- The methodology employed for the environmental (HTRW, cultural, and habitat) analyses is likely to have overestimated environmental costs and mitigation needs. This fact deserves mention, though environmental costs do not play a large role in determining the BCRs for flood protection at the features.
- This study did not capture all the costs and benefits involved with flood protection in the Devils Lake area. It was beyond the scope of the study, for example, to account for agricultural losses or for the losses that would be suffered if entire communities had to be relocated. Such issues, while difficult to account for when determining BCRs for flood protection at the Devils Lake features, should be taken into consideration when regional planning is conducted.

In general, the economic results presented in this report should be used with caution. For this study, some components of the flood protection strategies – for example, the Devils Lake levees – were analyzed relatively thoroughly. However, it should also be noted that due to limitations on time and resources, it was in general impossible to conduct exhaustive investigations regarding the flood protection measures at the many features. The investigations did not include, for example, detailed design analysis or field investigations. In addition, because of time constraints it was not possible to coordinate fully with local officials regarding ongoing and planned flood protection efforts.

Further study would be necessary before actually proceeding with flood protection projects. Similarly, the damage and cost estimates provided can be considered to be adequate for planning purposes. However, more detailed project or mitigation costs must be determined if and when the projects proceed. Ultimately, flood protection decisions must be based on an in-depth assessment by local, state, and Federal officials to ensure that whichever plan is selected is technically, economically, environmentally, and socially sound.

Infrastructure Protection Study Glossary

action level – refers to a range of lake levels at which choices regarding flood protection strategies would be made. Note that an action level is not associated with a precise lake elevation. This is because for any action level, the elevation at which the initiation of flood protection activities would occur depends on which strategy is chosen.

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, or "cost-effective."

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, however for this Infrastructure Protection Study negative benefits 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 sometimes used to refer to damages induced by a project, but for the Infrastructure Protection Study, costs are strictly limited to the expenses of project implementation.

cost-effective – having positive net benefits; having a BCR greater than one.

damage – loss of value to infrastructure or features due to flooding.

decision tree – a graphical representation that indicates action levels for each feature and the flood protection strategies available 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 (and the BCR is greater than one).

features – physical entities or groups of entities that would be susceptible to damage from the rising lake waters.

future – refers to an event that will happen in a time period later than the present.

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.

interdependency – condition in which decisions regarding flood protection for one feature depend on the decisions that have been made for another feature. For example, a decision to relocate an entire community will make it unnecessary to protect the roads serving that community.

interior – Refers to the land area protected by a levee, or to portions of the levee away from the lake side of the levee's centerline. "Exterior," by contrast, refers to land areas or portions of the levee on the lake side of the levee's centerline.

maximum lake level - There are many uncertainties with respect to the maximum lake level that Devils Lake could or will achieve. It is uncertain, for example, what the condition and invert of the natural outlet will be as the lake approaches its maximum level. How erosion of the natural outlet may affect flow rates is also open to debate. However, several studies have taken 1463 as the expected maximum water level for Devils Lake under prolonged wet climate conditions. Accordingly, 1463 has been used in the present study as the "maximum" lake level.

multi-action level strategy – several flood protection strategies are compared involving decisions that are made at more than one action level. Contrast *single-action level strategy*, in which (because of the particulars of the situation at the feature) one protection strategy has been selected, therefore only the first action level is analyzed.

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 by the rising lake waters—by protecting or relocating the features adjacent to the lake.

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.

reference elevations – the elevations associated with decisions regarding a particular flood protection measure for a given feature. The five reference elevations used for the Infrastructure Protection Study are: low structure elevation, lake damage elevation, project completion elevation, construction initiation elevation, and planning and design initiation elevation. The meaning of these terms varies slightly, depending on the type of flood protection measure being considered.

risk – the possibility of encountering significant difficulties and expense in the implementation of flood control measures. Risk increases when data with which to evaluate potential problems is lacking.

scenario – a conditional forecast based on certain climatic and hydrologic assumptions. The assumptions inherent in the forecast determine the lake level traces. The scenarios used for this study include a Wet Future, and two Moderate Futures.

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 protection measure (or sequence of flood protection measures) specific to a particular feature around the lake (for example, raise ND Highway 2 above the current flood level, or relocate homes in Churchs Ferry).

structures - Residential, agricultural, commercial, and municipal buildings. The term includes accessory structures such as barns, sheds, garages, silos, etc. It generally excludes roads and levees, which are dealt with separately.

trace – a 50-year sequence of projected lake levels

Appendix B
List of References

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Appendix C

General Information Regarding HTRW Findings and Requirements for Further HTRW Investigations for Features

The following discusses each HTRW category and its associated environmental concerns. Specific costs for each site were addressed on a site-by-site basis within the summaries (Sections 4.1 through 4.25) for the appropriate features.

Rural Residences & Farmsteads

The following items are likely to be encountered at a rural residence or farmstead: septic systems with tanks and drain fields, transformers that may contain polychlorinated biphenyls (PCBs), private water supply wells, propane above ground storage tanks (ASTs), ASTs or underground storage tanks (USTs) for storage of fuel oil for heating or storage of gasoline/diesel for farm equipment, and potentially asbestos containing materials.

Farmsteads or rural residences have the potential for releases associated with their properties. Farmsteads typically have miscellaneous farm machinery used in cultivation or general operation of the farm. Operation and maintenance of farm machinery can involve use of petroleum products and other hazardous chemicals. The potential for a release of chemicals from fuel oil tanks and the potential for a release of PCB containing oils from transformers exist for both rural residences and farmsteads. The potential for a release of metals, nitrates, and possibly volatile organic compounds from septic systems exists at both farmsteads and rural residences. Farmsteads and rural residences may also contain farm dumps or debris piles with miscellaneous machinery, equipment parts, and some abandoned automobiles. Additionally, the potential for fertilizer and pesticide/herbicide storage are likely on most farms. If bulk silo grain storage is present, the potential for fumigants exists. If the farmstead or rural residence was built prior to 1985, the potential for asbestos containing material exists.

Typically, releases of hazardous substances or petroleum at farmsteads and rural residences are minimal. The potential for a more extensive release exists from underground fuel tanks. A site inspection should be conducted at each HTRW site categorized as a rural residence or farmstead to determine the location of fuel tanks, septic systems, wells, transformers, and any other potential environmental concerns that may affect the impact area of the feature. Additionally, should a building be within the feature's impact area, an asbestos survey should be completed. The estimated cost for each site inspection is $500 and the cost for a non-destructive asbestos survey of a rural residence is $1000. Costs may vary according to the size and number of buildings.

Should a site inspection discover indications of more extensive contamination than expected, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the site inspection.

Nonresidential Properties
Sites with buildings atypical of a rural residence or farmstead were categorized as nonresidential properties. There are two types of nonresidential properties: properties with a high potential for a release of hazardous substances or petroleum products, and properties with a low potential for a release. Properties suspected to be present in the infrastructure project study area with a low potential for a release would be offices, apartments or group housing facilities, warehouses, schools, churches, restaurants, and stores. Properties suspected to be present in the infrastructure project study with a high potential for a release would be gas stations, grain elevators, maintenance shops, agricultural processing facilities, lift stations and comfort buildings, or potentially industrial or manufacturing facilities.

Any of these facilities would likely have some or all of the same items as a rural residence or farmstead. These items would include septic systems with tanks and drain fields, transformers that may contain polychlorinated biphenyls (PCBs), private water supply wells, propane above ground storage tanks (ASTs), and ASTs or underground storage tanks (USTs) for storage of fuel oil for heating. The potential for a release of chemicals from AST or UST fuel oil tanks and the potential for a release of PCB containing oils from transformers exist. The potential for a release of metals, nitrates, and possibly volatile organic compounds from septic systems exists. A site inspection should be conducted at each nonresidential property site to determine the location of fuel tanks, septic systems, wells, transformers, and any other potential environmental concerns that may affect the impact area of the feature. Additionally, should a building associated with the site be within a feature impact area, an asbestos survey should be completed. Properties with a low potential for a release are expected to have conditions similar to a rural residence or farmstead. The estimated costs for a site inspection at these properties are similar to the cost for rural residences and farmsteads. In some cases, the cost is increased to account for multiple buildings or property size.

Properties with a high potential for a release would have all of the same environmental concerns as the properties with a low potential for a release and also some additional concerns. Gas stations, grain elevators, and maintenance shops would be expected to contain larger ASTs or USTs for storage of fuel or oil for automobiles, equipment, or machinery. Agricultural processing facilities and industrial or manufacturing facilities would also likely possess tanks containing petroleum products or other process chemicals. The lift station and comfort building at Grahams Island State Park may have releases similar to septic tanks (i.e. metals, nitrates, and possible volatile organic compounds).

Additional work for properties with a high potential of a release would be a Phase II field investigation to assess conditions at the properties. A field investigation would include:

- Development of a work plan
- Installation of several shallow soil borings in areas of concern via push-probe techniques (a.k.a Geoprobe) or hand auger.
- Field screening of soil and collection of soil and groundwater samples
- Analysis of select samples for a combination of volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), gasoline range organics (GRO), or diesel range organics (DRO)
- Compilation of a brief summary report of results and findings

The estimated lump sum costs for addressing HTRW concerns at the high potential nonresidential sites are based on the following table:

Task	Estimated Cost
Site Inspection	$500
Asbestos Survey	$1000
Field Investigation	$8500

Should a site inspection or field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial site inspection or field investigation.

Former Communities
Former communities typically would have had rural residences or farmsteads, as well as potentially nonresidential properties such as offices, schools, churches, restaurants, stores, gas stations, grain elevators, maintenance shops, agricultural processing facilities, and potentially industrial or manufacturing facilities. Former communities would have all of the same environmental concerns as both the Nonresidential Properties category and the Rural Residences & Farmsteads category, as discussed above.

A site inspection should be conducted at each former community to determine the location of any remaining fuel tanks, septic systems, wells, transformers, and any other potential environmental concerns that may affect the impact area of the feature.

Additional work to address former communities would include a field investigation to determine if any contamination exists within the feature's impact area from historic land-uses. The field investigation would include:

- Development of a work plan
- Installation of several shallow soil borings along the feature alignment via push-probe techniques (a.k.a. Geoprobe)
- Field screening of soil and collection of soil and groundwater samples
- Analysis of select samples for a combination of volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), gasoline range organics (GRO), or diesel range organics (DRO)
- Compilation of a brief summary report of results and findings.

The estimated costs for the former communities are $500 for the site inspection and $8,500 for a field investigation.

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial field investigation.

Cylindrical Structures
Groups of cylindrical structures were observed on aerial photographs. Cylindrical structures in groups may represent bulk petroleum storage ASTs, silos for grain storage, or radio signal dishes and associated towers. Bulk petroleum storage areas have the potential for releases of petroleum products associated with their properties. Historic bulk grain storage may have involved the use of grain fumigants such as ethylene dibromide; and therefore, the potential exists for encountering contaminated soil in these areas. Properties associated with radio dishes and towers are not suspected to present a significant environmental concern or threat of a release of hazardous substances unless there is a UST on site.

A field investigation is proposed to address areas of cylindrical structures. This field investigation would include:

- Site inspection for evidence of historic and current cylindrical structures and any staining on the ground surface
- Shallow hand augers or borings in the vicinity of the structures
- Field screening of soil and collection of select soil analytical samples or groundwater samples, depending on the type of contaminant suspected.
- Analysis of samples for a combination of VOCs, GRO, or DRO
- Compilation of a brief summary report of results and findings

The estimated lump sum costs for addressing HTRW concerns at the cylindrical structures sites are based on the following table:

Task	Estimated Cost
Site Inspection	$500
Field Investigation (if UST present)	$8500

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial field investigation.

Excavation or Fill Areas
Sites grouped into this category would include observation of scraping, excavation, disturbed land, and potential filling. Excavations or scraping do not pose a significant environmental concern. Observation of filling or disturbed land indicating the potential presence of fill may present an environmental concern. Fill may contain contaminated soils from unknown locations and should be inspected. Additionally, evidence of filling may potentially indicate dumping of other materials underneath the fill cover.

A site inspection should be completed at each site to assess site conditions and to look for evidence of releases and staining. If the site has a moderate to high potential for contamination, a field investigation should be conducted. A field investigation would include:

- Several shallow hand auger borings in areas of concern
- Field screening of soil and collection of soil analytical samples
- Analysis of select samples for a combination of VOCs, GRO, or DRO
- Compilation of a brief summary report of results and findings

The estimated lump sum costs for addressing the HTRW concerns at the excavation and fill areas are based on the following table:

Task	Estimated Cost
Site Inspection	$500
Field Investigation	$4000-$5000

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial field investigation.

Substations

Electrical substations generally have transformers and electrical equipment. Transformers may have contained or may currently contain polychlorinated biphenyls (PCBs), and electrical equipment may have mercury switches. The potential for releases from these items exists. A field investigation should be conducted to determine the condition of the site and assess the potential for contamination. A field investigation would include:

- Site inspection for evidence of releases and staining
- Field screening of soil and collection of select soil analytical samples from the ground surface or from shallow hand auger borings.
- Analysis of select samples for mercury or PCBs in areas suspected of a release or areas that are stained
- Compilation of a brief summary report of results and findings

The estimated lump sum cost for a field investigation of a substation is $5000. A site inspection would not be necessary if a site diagram can be provided by the utility.

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial field investigation.

Artificial Ponds

Historic presence of artificial ponds suggests that they may have once been used for water treatment or sewage disposal. Sludge generated by these processes present an environmental concern. Sediments from these ponds may be encountered during construction of features. A site inspection should be performed to assess conditions of the site. It is likely that a field investigation will be necessary. A field investigation would include:

- Installation of several shallow soil borings along the south side of the pond via push-probe techniques (a.k.a. Geoprobe)
- Field screening of soil and collection of soil and groundwater samples
- Analysis of select samples for a combination of metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), gasoline range organics (GRO), or diesel range organics (DRO.)

- Compilation of a brief summary report of results and findings.

The estimated lump sum costs for addressing HTRW concerns at an artificial pond are based on the following table:

Task	Estimated Cost
Site Inspection	$500
Field Investigation	$8,500

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial field investigation.

Pipeline Crossings

A pipeline significant enough to be marked on a topographic map likely contains a petroleum product or hazardous substance. Pipelines have the potential for releases at valves and joints. A field investigation should be completed where a pipeline intersects a feature. A field investigation would include:

- Installation of several shallow soil borings via push-probe techniques (a.k.a. Geoprobe) on both sides of the pipeline where it intersects the feature
- Field screening of soil and collection of soil samples and potentially a groundwater samples
- Analysis of select samples for a combination of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), gasoline range organics (GRO), or diesel range organics (DRO)
- Compilation of a brief summary report of results and findings.

The estimated lump sum costs for HTRW concerns of a pipeline crossing is estimated to be $8500.

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the initial field investigation.

Former Recreation Facilities

Historic recreation facilities have the potential for the presence of a number of contaminants. For example, one historic recreation facility was observed consisting of a track and a few associated buildings. Due to the age of the former buildings and track, the following features may still be present:

- Septic system with a tank or a drain field
- Transformers that may have contained polychlorinated biphenyls (PCBs)
- Water supply well
- Propane above ground storage tanks (ASTs)
- ASTs or underground storage tanks (USTs) used for storage of fuel oil for heating

Any of these items may not have been properly abandoned. The potential for a release of chemicals from former AST or UST fuel oil tanks and the potential for a release of PCB containing oils from former transformers exist. A site inspection should be conducted to assess current conditions and look for staining and abandoned wells. The estimated cost for a site inspection is $500.

The need for field investigation is not suspected. Should the site inspection discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the site inspection.

Railroad Related Land-Uses

It is typical to elevate a railroad bed above the ground surface, which may indicate the use of fill materials from unknown locations and conditions. Rail ties, which are chemically treated to prevent deterioration, and miscellaneous debris along the embankments may need to collected and disposed of. Railroads within towns and cities may have had spills associated with rail car loading and unloading of materials. Sites within this category should have a site inspection performed to look for evidence of debris, staining, and other contamination. Railroad related sites that have a moderate or high potential for contamination should have a field investigation conducted. A field investigation would include:

- Several shallow hand auger borings in areas of concern
- Field screening of soil and collection of soil analytical samples where contamination is observed
- Analysis of select samples for a combination of VOCs or SVOCs
- Compilation of a brief summary report of results and findings

The estimated lump sum costs for HTRW concerns at railroad related land-use sites are based on the following table:

Task	Estimated Cost
Site Inspection	$500
Field Investigation	$5,000

Should the field investigation discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the site inspection or initial field investigation.

Likely Former Dumps

Some areas observed in aerial photographs suggested activities typically indicative of dumping. Dumps may include household goods as well as items that may present a release of petroleum products or hazardous substances. A site inspection should be performed at each potential dumpsite to determine if the presence of a dump exists. The estimated cost for a site inspection at a potential dump is $500. Should the site inspection discover contamination, additional costs may be incurred in follow-up investigative or remedial work. These actions and costs cannot be anticipated and would be assessed after the site inspection.

Appendix C

ENVIRONMENTAL: Habitat and Species – Detailed Findings
Devils Lake Infrastructure Protection Study

The Devils lake basin is located within the Northern Glaciated Plains ecoregion. The Northern Glaciated Plains ecoregion is characterized by a landscape composed of deposited glacial till resulting in flat to gently rolling topography. Climatic conditions of the area originally supported an extensive grassland community composed of short grass prairie, dominated by wheat grass, little and big bluestem and needle grass. The landscape has high concentrations of prairie pothole wetlands – both temporary and seasonal wetlands. Most of these depressions have been categorized as isolated wetlands, although recent work has shown them to be hydrologically connected wetlands. High soil fertility has lead to the replacement of much of the native grassland community by agricultural crops.

The Northern Glaciated Plains ecoregion within the areas of concern has three distinct level IV ecoregions based upon glacial drainage and depositional features. These three ecoregions are glacial lake basins, end moraine complexes, and drift plains. The glacial lake basins are flatter than the surrounding drift plains, have fewer wetlands, and are now extensively cultivated. The end moraine complexes are found at the south end of the lake basin and have wooded areas due to elevation mediated precipitation increases.

Federal listed species of concern include Bald Eagle (*Haliaeetus leucocephalis* - threatened), Whooping Crane (*Grus americana* - endangered), Piping Plover (*Charadrius melodus* - threatened) and the Gray Wolf (*Canis lupus* - endangered). Within the area of this analysis the Whooping crane (*Grus americana)* is the only North Dakota listed threatened or endangered species that have been identified (Grondahl and Martin, not dated).

Wetland Habitats

The prairie pothole region extends from southern Canada southward to Iowa and South Dakota. Glacial activity created literally millions of depressions in the landscape that became isolated wetlands. Although these basins may be physically isolated, the basins are hydrologically connected, serving as groundwater discharge and recharge areas. The hydrology and varying water depth of these depressional basins leads to a zonation of vegetation. These zones of vegetation typically form concentric circles, with the plant community composition being strongly influenced by elevation, in relationship to water level in the basin. Basin classification is based upon the hydrology of the deepest portion of the basin (Cowardin, Carter, Golet and LaRoe, 1979). Degradation and drainage of wetland habitat is a major threat to waterfowl and other marsh bird populations. It has been estimated that 60% the wetland areas of North Dakota have been drained since settlement.

Wetlands can be classified as either;

1) Palustrine – nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses and lichens and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts of less than 0.5%. It also includes wetlands lacking such vegetation but with all of the following four characteristics: (1) an area of less than 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of the basin less than 2 meters at low water; and (4) salinity due to ocean-derived salts of less than 0.5% (Cowardin, *et al*, 1979).

2) Lacustrine – wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topgraphic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses and lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2.2 m (6.6 feet) at low water (Cowardin, *et al*,1979).

Wetland Type	**Description**
Type 1 Seasonally Flooded Basin, Floodplain Forest	Soil is covered with water or is waterlogged during variable seasonal periods but usually is well-drained during much of the growing season.
Type 2 Wet Meadow, Fresh Wet Meadow, Wet to Wet-Mesic Prairie, Sedge Meadow, and Calcareous Fen	Soil is usually without standing water during most of the growing season but is waterlogged within at least a few inches of the surface. Meadows may fill shallow basins, sloughs, or farmland sags, or these meadows may border shallow marshes on the landward side.
Type 3 Shallow Marsh	Soil is usually waterlogged early during the growing season and may often be covered with as much as 6 inches or more of water. These marshes may nearly fill shallow lake basins or sloughs, or may border deep marshes on the landward side.
Type 4 Deep marsh.	Soil is usually covered with 6 inches to 3 feet or more of water during the growing season. These deep marshes may completely fill shallow lake basins, potholes, limestone sinks and sloughs, or they may border open water in such depressions.

Type 5 Shallow Open Water	Shallow ponds and reservoirs are included in this type. Water is usually less than 10 feet deep and is fringed by a border of emergent vegetation similar to open areas of Type 4. Vegetation mainly at water depths less than 6 feet.
Type 6 Shrub Swamp; Shrub Carr, Alder Thicket	The soil is usually waterlogged during the growing season and is often covered with as much as 6 inches of water. Shrub swamps occur mostly along sluggish streams and occasionally on flood plains.
Littoral Zone Type 5	All wetland habitats in the Lacustrine System. Extends from the shoreward boundary of the system to a depth of 2 m (6.6 feet) below low water or to the maximum extent of non-persistent emergents, if these grow at depths greater than 2 m.
Limnetic Zone Open Water	All deepwater habitats within the Lacustrine system

Plants species commonly found in the vegetational zones of the prairie pothole region include (from: Tiner, Bergquist, DeAlessio and Starr. 2002)

- permanently flooded zone
  - widgeon-grass (*Ruppia maritima*)
  - pondweeds (*Potamogeton* spp.)
  - duckweeds (*Lemna* spp. and *Spirodela polyrhiza*)
- semipermanently flooded zone
  - cattails (*Typha* spp.)
  - bulrushes (*Scirpus* spp.)
- seasonally flooded zone
  - spikerush (*Eleocharis palustris*)
  - giant bur-reed (*Sparganium eurycarpum*)
  - water plantain (*Alisma plantago-aquatica*)
  - slough sedge (*Carex atherodes*)
  - hydrophytic grasses (e.g., *Phalaris arundinacea*, *Glyceria grandis*, *Scolochloa estucacea*, and *Beckmannia syzigachne*)
  - water smartweed (*Polygonum coccineum*)
- temporarily flooded zone
  - salt grass (*Distichlis spicata*)
  - squirrel-tail (*Hordeum jubatum*)
  - prairie cordgrass (*Spartina pectinata*)
  - baltic rush (*Juncus balticus*)
  - sedges (e.g., *Carex sartwellii*, *C.lanuginosa*, and *C. praegracilis*)

The prairie pothole wetlands are important breeding and nesting grounds for a wide variety of North American waterfowl. The prairie pothole region produces on average 50% of North America's waterfowl, even though it is only about 10% of the breeding area. These pothole wetlands are primary breeding habitats for:

- mallard (*Anas platyrhynchos*)
- northern pintail (*A. acuta)*
- American wigeon (*A. americana*)
- gadwall (*A. strepera*)
- northern shoveler (*A. clypeata*)
- green-winged teal (*A. crecca*)
- blue-winged teal (*A. discors*)
- canvasback (*Aythya valisineria*)
- redhead (*A. americana*),
- ring-necked duck (*A. collaris*) (Tiner, *et al*, 2002)

These wetland habitats and surrounding areas are also important migratory feeding sites and breeding locations for many non-game birds:

- horned grebe (*Podiceps auritus*)
- eared grebe (*P.nigricollis*)
- pied-billed grebe (*Podilymbus podiceps*)
- black-crowned night heron (*Nycticorax nycticorax*)
- American bittern (*Botaurus lentiginosus*)
- northern harrier (*Circus cyaneus*)
- Virginia rail (*Rallus limicola*)
- sora rail (*Porzana carolina*)
- American coot (*Fulica americana*)
- killdeer (*Charadrius vociferus*)
- willet (*Catoptrophorus semipalmatus*)
- marbled godwit (*Limosa fedoa*)
- American avocet (*Recurvirostra americana*)
- Wilson's phalarope (*Phalaropus tricolor*)
- black tern (*Chlidonias niger)*
- marsh wren (*Cistothorus palustris*)
- yellow-headed blackbird (*Xanthocephalus xanthocephalus*)
- red-winged blackbird (*Agelaius phoenicus*)
- savannah sparrow (*Passerculus sandwichensis*) (Kantrud and Stewart 1984).

Ring-necked pheasants (*Phasianus colchicus*) also depend on prairie pothole wetlands for winter cover. Prairie pothole wetlands and adjacent upland areas provide habitat for many macroinvertebrates, small mammals, amphibians and reptiles. Species typically found in wetlands or in adjacent upland areas in North Dakota include:

- Northern prairie skink (*Eumeces septentrionalis)*
- common snapping turtle (*Chelydra serpentina)*
- Western painted turtle *(Chrysemys picta belli)*
- common garter snake *(Thamnophis sirtalis)*
- plains garter snake *(Thamnophis radix)*
- redbelly snake *(Storeria occipitomaculata)*
- smooth green snake *(Opheodrys vernalis)*
- American toad *(Bufo americanus)*
- Canadian toad *(Bufo hemiophrys)*

- Great Plains toad *(Bufo cognatus)*
- gray tree frog *(Hyla versicolor)*
- Northern leopard frog *(Rana pipiens)*
- Western chorus frog *(Pseudacris triseriata)*
- wood frog *(Rana sylvatica)*
- tiger salamander *(Ambystoma tigrinum)*
- masked shrew (*orex cinereus)*
- short-tailed shrew (*Blarina brevicauda)*
- fox squirrel (*Sciurus niger*)
- gray squirrel (*Sciurus carolinensis)*
- Richardson's ground squirrel (*Spermophilus richardsonii*)
- thirteen-lined ground squirrel (*Spermophilus tridecemlineatus)*
- Eastern cottontail (*Sylvilagus floridanus)*
- white-tailed jackrabbit (*Lepus townsendii)*
- Northern pocket gopher (*Thomomys talpoides)*
- deer mouse (*Peromyscus maniculatus*)
- meadow vole (*Microtus pennsylvanicus*)
- house mouse (*Mus musculus*)
- Norway rat (*Rattus norvegious*)
- little brown bat (*Myotis lucifugus*)
- beaver (*Castor Canadensis)*
- muskrat (*Ondatra zibethicus)*
- mink (*Mustela vison)*

Potential Wetland Effects

Impacts to wetland communities due to the infrastructure protection measures can include filling and hydrology alterations due to levee and road construction activities, and flooding due to ponding behind roads acting as dams. Fill used in the construction of the levees could cause environmental impacts due to encroachment upon wetlands and surrounding upland plant communities. Impacts to the wetland communities represent an important environmental impact to these natural resources. Complete or partial loss of wetland functions and conversion to upland due to filling is possible in some locations. In areas where some hydrology is maintained and wetland conditions remain, changes in plant community and hydrology could lead to a wetland type change. The loss of wetland area will impact waterfowl, marsh bird and songbird-nesting areas, as well bring about impacts to reptile and amphibian populations due to habitat loss and fragmentation. Many bird species, such as American bittern and eared grebes are area-sensitive species. Reduction in wetland size will impact these species more so through the loss of habitat than fragmentation. Potential impacts to these wetlands will vary depending upon the original wetland type. Summarized in the following table are some of the impacts due to filling.

Inundation will move a wetland plant community to a type characteristic of deeper water, until the water depth exceeds 2 meters throughout the wetland and then the system takes on the characteristics of an open-water limnetic system. Complete or partial loss of habitat functions due to conversion to deep-water habitat is possible in some locations. In areas where wetland conditions remain (i.e., water depths less than 2 meters), changes in plant community and hydrology will lead to wetland creation. Inundation will also lead to the displacement of terrestrial species and those aquatic species that need shallow water areas.

Wetland Type	**Vegetation/ Hydrology/Other Impacts**
Type 1 Seasonally Flooded Basin, Floodplain Forest	Complete loss of wetland functions and conversion to upland due to filling;
Type 2 Wet Meadow, Fresh Wet Meadow, Wet to Wet-Mesic Prairie, Sedge Meadow, and Calcareous Fen	Complete loss of wetland functions and conversion to upland due to filling; Changes in plant community and hydrology may lead to a type 1 wetland condition;
Type 3 Shallow Marsh	Complete or partial loss of wetland functions and conversion to upland due to filling; Changes in plant community and hydrology may lead to a type 2 wetland condition if some hydrology is maintained;
Type 4 Deep marsh.	Complete or partial loss of wetland functions and conversion to upland due to filling; Changes in plant community and hydrology that lead to a type 3 wetland condition if some hydrology is maintained;
Type 5 Shallow Open Water	Complete or partial loss of wetland functions and conversion to upland due to filling; Changes in plant community and hydrology that lead to a type 4 wetland condition if some hydrology is maintained;
Type 6 Shrub Swamp; Shrub Carr, Alder Thicket	Complete or partial loss of wetland functions and conversion to upland due to filling; Complete or partial loss of woody vegetation and conversion to upland due to filling;
Littoral Zone Type 5	Complete or partial loss of wetland functions and conversion to upland due to complete filling; Complete or partial loss of vegetation and conversion to type 3 or 4 wetland due to partial filling;
Limnetic Zone Open Water	Complete or partial loss of submerged plant community functions due to complete inundation;

Upland habitats

This area originally supported an extensive grassland community composed of short grass prairie, dominated by wheat grass, little and big bluestem and needle grass. Many of the woodland areas could be classified as savanna or bur oak woodlands having less that 30% tree cover. These areas typically have a shrub layer dominated by bur oak saplings with some serviceberry. Ground cover is quite high, being reflective of the open nature of this forest type. Songbird species richness can be good in bur oak forest areas. Breeding birds are divided between ground-foraging seedeaters, canopy or sub-canopy flycatchers, foliage gleaners and ground-layer insect eaters in these woodland areas (Fannes and Andrew, 1983).

The invasion of grasslands by woody vegetation can negatively impact area-sensitive grasslands birds by fragmenting the habitat and precluding some species from the area. Trees also can lead to increased predation by providing perching locations for raptors and cowbirds and providing corridors for the movement of mammalian predators. Competition with non-grassland species may also reduce grassland-dependant species.

Habitat Type	Description
Grasslands - Prairie or Savanna	Mixed Grass prairie is a mixture of the tallgrass and shortgrass prairies. The dominant grasses include grama *(Bouteloua gracilis),* little bluestem *(Schizachrium scoparium),* needle-and-thread grass *(Stipa comata),* wheatgrass *(Agropyron smithii), Carex filifolia*, junegrass *(Koelaria cristata)*, and *Poa secunda*. Kuchler classified the dominant vegetation as wheatgrass-bluestem-needlegrass. The plant community composition is determined largely by drought and grazing pressure, with fire having a minimal role.
Forested – Woodland or Savanna	This transitional zone supports a vegetation of quaking aspen (*Populus tremuloides*), bur oak (*Quercus macrocarpa*) groves, mixed tall shrubs, and intermittent fescue grasslands. Generally, quaking aspen and shrubs occur on moist sites, whereas the bur oaks occur on drier sites.

Faanes and Stewart (1982), Gomes (1997), and Grondahl and Gomes (1997) identify the following bird species as being present within the Devils Lake study area.

- Western kingbird (*Tyrannus verticalis*
- Eastern kingbird (*Tyrannus tyrannus*):
- purple martin (*Progne subis*)
- tree swallow (*Tachycineta bicolor*)
- bank swallow (*Riparia riparia*)
- horned larks (*Eremophila alpestris)*
- black-capped chickadee (*Parus atricapillus)*
- white-breasted nuthatch (*Sitta carolinensis)*
- house wren (*Troglodytes aedon)*
- American robin (*Turdus migratorius)*
- Eastern bluebird (*Sialia sialis)*

- loggerhead shrike (*Lanius ludovicianus)*
- brown thrasher (*Toxostoma rufum)*
- cedar waxwing (*Bombycilla cedrorum)*
- blue jay (Cyanocitta cristata)
- warbling vireo (Vireo gilvus)
- American goldfinch (*Carduelis tristis)*
- yellow warbler (*Dendroica petechia)*
- chipping sparrow (*Spizella passerina)*
- Western meadowlark (*Sturnella neglecta)*
- Northern oriole (*Icterus galbula)*
- common grackle (*Quiscalus quiscula)*
- red-winged blackbird (*Agelaius phoeniceus)*
- red-tailed hawk (*Buteo jamaicensis)*
- Swainson's hawk (*Buteo swainsoni)*
- rough-legged hawk (*Buteo lagopus)*
- Northern harrier (*Circus cyaneus)*
- broad-winged hawk (*Buteo platypterus)*
- sharp-shinned hawk (*Accipiter striatus)*
- Cooper's hawk (*Accipiter cooperii)*
- osprey (*Pandion haliaetus)*
- turkey vulture (*Cathartes aura)*
- merlin (*Falco columbarius)*
- American kestrel (*Falco sparverius)*
- peregrine falcon (*Falco peregrinus)*
- Western burrowing Owl (*Athene cunicularia)*
- great-horned owl (*Bubo virginianus)*
- snowy owl (*Nyctea scandiaca)*
- Eastern screech owl (*Otus asio)*
- long-eared owl (*Asio otus)* considered rare and of special concern in ND
- short-eared owl (*Asio flammeus)*

Potential Upland Effects

In the upland areas a loss of native species due to grading and filling could be expected to occur. Impacts to upland plant communities, including woodland, grasslands and cover crop easement areas, have the potential to impact nesting bird populations. Subsequent re-vegetation of fill or borrow locations may allow for the introduction of weedy, non-native species. A loss of native tree species due to grading and filling, as well as the introduction of weedy, non-native under-story species could also be expected in these areas. The loss of woodland areas will impact songbird nesting and small mammal populations, as well impacting reptile and amphibian populations due to habitat fragmentation. Upland impacts are expected from the roads acting as dams due to inundation and a subsequent conversion of upland areas to aquatic habitat – either open water or wetland.

The conversion of native prairie to cropland has lead to large changes in prairie wildlife. Few other habitat groups have experienced the widespread declines seen in prairie birds over the last

30 years (Johnson, 2000). Most birds do not do well in cropland settings due to nesting disruption from agricultural activities and lack of habitat structure. The remaining patches of remnant prairie are so highly fragmented in many cases that bird populations are exposed to edge effects that lead to further population reductions. Increases in woody vegetation have lead to the displacement of native grassland bird populations by the generalist species such as gray catbird, song sparrow, brown thrasher, American robin, and common grackle. The presence of non-native trees also may reduce the quality of habitat for native grassland dependant species.

Habitat Type	Vegetation/Other Impacts
Grasslands - Prairie or Savanna	Loss of native species due to grading and filling; Subsequent revegetation of fill or borrow locations may allow for the introduction of weedy, non-native species. Restoration efforts will typically have lower diversity over intact native plant communities.
Forested – Woodland or Savanna	Loss of native tree species due to grading and filling; Subsequent revegetation may allow for the introduction of weedy, non-native understory species. Restoration efforts will typically have fewer trees and lower overall plant diversity.

Potential Impacts upon Species of Concern

Within the area of this analysis potential impacts to the Federally listed species of concern have been assessed as part of this study. Federal listed species of concern include Bald Eagle (*Haliaeetus leucocephalis* - threatened), Whooping Crane (*Grus americana* - endangered), Piping Plover (*Charadrius melodus* - threatened) and the Gray Wolf (*Canis lupus* - endangered). Within the area of this analysis the Whooping crane (*Grus americana)* is the only North Dakota listed threatened or endangered species that have been identified .

Potential impacts to the Bald Eagle (*Haliaeetus leucocephalis*), a threatened species, include loss of nesting sites due to tree removal or disturbances to existing nesting locations due to construction related activities. Due the territoriality of bald eagles, any such loss of nesting sites or a sufficiently large loss of perching trees within a half kilometer of nesting sites could lead to displacement. Outside the nesting season, bald eagle densities are more variable and dependant upon adequate supplies of fish, so that a loss open water habitats could impact the population. However, normally bald eagles require open water areas larger than 1,000 hectares per nesting site and thus small, localized wetland losses may not impact the population (Johnsgard, 1990).

The Whooping Crane (*Grus americana*) North American population is comprised of ~ 300 individuals in the wild and in captivity. This species is a seasonal migrant in North Dakota, summering in Canada and wintering in Texas. Areas of western North Dakota have been determined to be critical habitat for this species by the US Fish and Wildlife Service. Whooping cranes do not readily tolerate disturbances to themselves or their habitat. Whooping cranes are dependant upon wetlands, primarily wooded and brushy swamps, for food. This species migrates in family groups and during migration the cranes are most often found within short flight distances (15 miles or less) of wetlands that offer open sand or gravel bars for nightly roosting. Insects, crayfish, frogs, small fish, and other small animal, as well as cereal crops in adjacent croplands and some aquatic vegetation are reported to be major food items taken during migration. The greatest long-term concern for this species is protection of breeding areas, migratory staging areas and wintering grounds. Localized losses of wetland habitat due to infrastructure protections measures would lead to minimal impacts on the North America population (Berthold, 1993).

The northern Great Plains population of the Piping Plover (*Charadrius melodus*) is a resident breeding species and is considered critically imperiled within the area of analysis. The species is primarily an inhabitant of sandy beaches and lakeshores. Piping plovers primarily breed in four habitats - alkali lakes and wetlands, lakes, reservoirs, and rivers. Threats to the piping plover include destruction and degradation habitat, shoreline erosion, human disturbance, and predation. The primary concerns would be for protection of nesting, rearing and feeding areas and any negative impacts to these areas. Critical breeding population habitat includes sparsely vegetated and windswept, sandy to gravelly islands, beaches, and peninsulas, and their interface with water. Habitats that provide the essential combination of prey, forage, nesting, brooding and chick-rearing areas are important to piping plover populations. Studies have suggested that beach width may affect habitat use by breeding piping plovers on inland lakes (Federal Register, 200; Natureserve, 2001; DOI, 1978). Loss of lakeshore areas due to filling and conversion to upland due to infrastructure protection measures could impact this species.

The study area is outside the current range of the Gray Wolf (*Canis lupus)* - an endangered species. The Gray Wolf was extirpated from North Dakota, although occurrences in the Dakotas have increased in recent years. These occurrences are likely related to range expansion and population increases in Minnesota (Natureserve, 2001). The Gray wolf is primarily a woodland and tundra species. Given the current population status in North Dakota, impacts due to infrastructure protection measures would be expected to have very limited impacts on this species.

Appendix C
HTRW Site History Summary
Devils Lake Infrastructure Project

Feature Number	Site #	Action Level Affected	HTRW Category	Observed in Aerial Photos in Year:	Observed in Topographic Maps in Year:	Comments	Site Inspection Cost	Asbestos Survey Cost	Field Investigation Cost	Total HTRW Cost
3	03-1-1	1	Rural Residences & Farmsteads	1967-1994	1994	Driveway apparent in aerial photos from 1967-1997, presence of house difficult to determine. Structure seen in 1994 topographic map only.	$ 500	$ 1,000		$ 1,500
3	03-1-2	1	Rural Residences & Farmsteads	1952-1997	1951, 1975, 1994	Structure visible in aerial photos and topographic maps.	$ 500	$ 1,000		$ 1,500
3	03-1-3	1	Rural Residences & Farmsteads	1959, 1967	None	Appears to be a driveway only by 1975 aerial photo.	$ 500			$ 500
3	03-2-4	2	Rural Residences & Farmsteads	1959, 1967	None	Appears to be a driveway only by 1975 aerial photo.	$ 500			$ 500
3	03-3-5	3	Rural Residences & Farmsteads	None	1951, 1975, 1994	Not visible in aerial photos, possibly too many trees.	$ 500			$ 500
3	03-1-6	1	Excavation or Fill Areas	1952, 1959	None	Earth movement, scraping, or filling.	$ 500		$ 4,000	$ 4,500
4	04-R-1	Relocate	Rural Residences & Farmsteads	1952-1997	1958	Farmstead located in area to where Minnewaukan will move.	$ 500	$ 1,000		$ 1,500
4	04-1-2	1	Excavation or Fill Areas	1952, 1983, 1990	None	Periodic scraping or filling in different areas of the site.	$ 500		$ 4,000	$ 4,500
4	04-1-3	1	Rural Residences & Farmsteads	1997	None	House observed in 1997 aerial photo, 1990 photo shows disturbed land but no house.	$ 500	$ 1,000		$ 1,500
4	04-1-4	1	Rural Residences & Farmsteads	1952-1997	1958	House observed adjacent to impact area.	$ 500			$ 500
4	04-1-5	1	Excavation or Fill Areas	1990, 1997	None	Potentially disturbed land appears in in 1997 and 1990 aerial photos, not observed in earlier photos.	$ 500		$ 4,000	$ 4,500
4	04-1-6	1	Nonresidential Properties	1975-1997	1958	Nonresidential building(s) are visible in the 1975-1997 aerial photos. The 1958 topographic map indicated that a house used to be present in the southwest corner of the lot. Aerial photos from 1967, 1959, and 1952 suggest the presence of the house, although it is not obvious.	$ 500	$ 1,000	$ 8,500	$ 10,000
4	04-1-7	1	Rural Residences & Farmsteads	1978-1997	1994	House observed 1978 through 1997, potentially present in 1975, no evidence prior to 1975.	$ 500	$ 1,000		$ 1,500
4	04-1-8	1	Nonresidential Properties	1952-1997	1951, 1994	Large structure and multiple smaller structures/piles. Area has become more busy (more piles/structures) over the years. One large and one small building (to the northwest) are shown in 1994 topographic map, and only the small building is shown on the 1951.	$ 500	$ 1,000	$ 8,500	$ 10,000
4	04-1-9	1	Excavation or Fill Areas	1952-1994	None	Disturbed land.	$ 500		$ 4,000	$ 4,500
4	04-2-10	2	Rural Residences & Farmsteads	1952-1978	None	Residence or building, no longer present.	$ 500			$ 500
4	04-1-11	1	Former Recreation Facility	1952-1978	1951	Buildings seen near the track in 1951, 1952, 1959, and 1967. No buildings present by 1975 although outline of track is visible and slowly fades over the years.	$ 500			$ 500
4	04-1-12	1	Potential Dumps	1952, 1959	None	Road leads out to an area of disturbed land in 1952. Only road is present in 1959. No other evidence of use in aerial photos.	$ 500			$ 500
4	04-1-13	1	Railroad Related Land-Uses	1952-1997	1951, 1958, 1994	Railroad marked in topographic maps and alignment apparent in aerial photos since the 1950's.	$ 500		$ 5,000	$ 5,500
5	05-3-1	3	Nonresidential Properties	1997	None	One building only observed on 1997 aerial photo, previously in an empty field (partially wooded). Appears to be a park building, and would be too new for asbestos concerns.	$ 500			$ 500
5	05-1-2	1	Rural Residences & Farmsteads	None	1950, 1975	Structure only visible in the topographic maps, no aerial evidence observed.	$ 500			$ 500
7	07-1-1	1	Nonresidential Properties	1997	None	No structures seen in topographic maps, only 1997 aerial coverage. Appears to be temporary construction buildings. Not seen on 1990 air photo.	$ 500			$ 500

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Feature Number	Site #	Action Level Affected	HTRW Category	Observed in Aerial Photos in Year:	Observed in Topographic Maps in Year:	Comments	Site Inspection Cost	Asbestos Survey Cost	Field Investigation Cost	Total HTRW Cost
7	07-1-2	1	Cylindrical Structures	1952-1997	None	No structures seen in topographic maps.	$ 500		$ 8,500	$ 9,000
7	07-1-3	1	Rural Residences & Farmsteads	1997, 1990, 1984	None	Farmstead observed in aerial photos. Current road went through the farmstead and may have intersected the location of a former building. By 1975 area is covered in field and trees.	$ 500			$ 500
10	10-1-1	1	Pipeline Crossings	None	1994	Does not cross the portion of the alignment of concern; however, it is close enough to note. Site inspection to verify pipeline location with respect to impact area.	$ 500			$ 500
11	1-11-1	1	Pipeline Crossings	None	1994, 1975	Only visible in topographic maps. Note: Not all quadrangles west of Grand Harbor have recent data.			$ 8,500	$ 8,500
11	11-1-2	1	Pipeline Crossings	None	1994	Only visible in topographic maps. Note: Not all quadrangles west of Grand Harbor have recent data.			$ 8,500	$ 8,500
11	11-1-3	1	Nonresidential Properties	1952-1997	1957, 1994	Former facility with miscellaneous cylindrical structures and buildings of varying size, shapes, and numbers on either side of the railroad 1952-1997. Filling/earth movement observed throughout the site over the years.	$ 500		$ 8,500	$ 9,000
11	11-1-4	1	Nonresidential Properties	1978-1997	1994	Facility with a few buildings and large cylindrical structures. Only small structures and earth movement in the 1978 aerial photo. Field only in the 1975 aerial photo. Dark spot observed at the west end in the 1952 aerial photo.	$ 500		$ 8,500	$ 9,000
11	11-1-5	1	Artificial Pond	1952-1997	1957, 1994	Pond observed, potentially the former sewage disposal pond, although it is not labeled. Present prior to current sewage disposal ponds located nearby.	$ 500		$ 8,500	$ 9,000
11	11-1-6	1	Railroad Related Land-Uses	1952-1984	None	Possible railroad related site. Only potential presence of a building was in the 1984 aerial photo. Driveway to a group of trees and some disturbed land observed from 1952-1978. A square lot next to the driveway is seen in the 1967 aerial photo.	$ 500			$ 500
11	11-1-7	1	Nonresidential Properties	1952-1978	1932?, 1951	Driveway leading to one or more buildings present through 1978, by 1984 no buildings are present in aerial photos.	$ 500		$ 8,500	$ 9,000
11	11-1-8	1	Nonresidential Properties	1952-1984	1932?, 1951	Building(s) present from 1952-1984 on the west half of the site, topographic map indicates 3 buildings. Dark spot on the east half of the site in 1967.	$ 500		$ 8,500	$ 9,000
11	11-1-9	1	Nonresidential Properties	1952-1997	1932?, 1951	One obvious large building. Potentially a grain elevator.	$ 500		$ 8,500	$ 9,000
11	11-1-10	1	Nonresidential Properties	1952-1967	1932?, 1951	Potentially present in 1952-1967 aerial photos (difficult to distinguish). One building shown on 1951 topographic map.	$ 500			$ 500
11	11-1-11	1	Rural Residences & Farmsteads	1952-1997	1931, 1951, 1975, 1994	Potentially a rural residence/farmstead. Visible on all aerial photos.	$ 500	$ 1,000		$ 1,500
11	11-1-12	1	Railroad Related Land-Uses	None	1994	Building shown on 1994 topographic map; not observed on any other maps or in aerial photos. Will be investigated as part of site 11-1-2.	$ 500			$ 500
11	11-1-13	1	Railroad Related Land-Uses	1952-1997	None	No structures observed and no major issues, only some earth movement /filling in 1978. Land looks lumpy. Potential for dumping and spills along railroad within a city.	$ 500		$ 5,000	$ 5,500
11	11-1-14	1	Former Communities	1952-1997	1931, 1950, 1951, 1975, 1994	City of Grand Harbor is much larger in the 1931 topographic map, structures (about four) are present near the railroad. By 1950, no houses are shown in the vicinity of the railroad.	$ 500		$ 8,500	$ 9,000

Appendix C
HTRW Site History Summary
Devils Lake Infrastructure Project

Feature Number	Site #	Action Level Affected	HTRW Category	Observed in Aerial Photos in Year:	Observed in Topographic Maps in Year:	Comments	Site Inspection Cost	Asbestos Survey Cost	Field Investigation Cost	Total HTRW Cost
16	16-1-1	1	Rural Residences & Farmsteads	1952-1997	1971	Farmstead observed with structures potentially in the impact area.	$ 500	$ 1,000		$ 1,500
16	16-1-2	1	Rural Residences & Farmsteads	1952, 1959	None	Rectangular structure observed in impact area in 1952 and 1959.	$ 500			$ 500
16	16-1-3	1	Rural Residences & Farmsteads	1952-1984	1971	Farmstead is present 1952 through 1984. In 1967, one structure may potentially be in the impact area. 1978 photo is too dark to see if structure is still present. Farmstead is gone by 1984, but cylindrical structures (outside of the impact area) that were part of the farm remain through 1997. No other evidence of structures in impact area. Two buildings shown nearby on the 1971 topographic map.	$ 500			$ 500
16	16-1-4	1	Rural Residences & Farmsteads	1952-1997	1957	Area of multiple rural residences or farmsteads. Structures potentially in the impact area 1967-1997.	$ 500	$ 1,000		$ 1,500
16	16-1-5	1	Rural Residences & Farmsteads	1952-1997	1957	Farmstead present since 1952. One to two buildings in the impact area from 1952-1984.	$ 500			$ 500
16	16-1-6	1	Railroad Related Land-Uses	1952-1997	1957	Railroad observed crossing the feature alignment 1957 topographic map lists it as the Minneapolis and St. Paul Sault Ste Marie.	$ 500		$ 5,000	$ 5,500
16	16-1-7	1	Railroad Related Land-Uses	1952-1997	1951, 1957, 1994	Railroad crosses the feature in three different places. 1957 topographic map lists it as the Northern Pacific, no label in 1994.	$ 500		$ 5,000	$ 5,500
16	16-1-8	1	Substation	1967-1997	None	Currently occupied by an electrical substation, potentially since 1967 or earlier.			$ 5,000	$ 5,000
17	16-1-9	1	Rural Residences & Farmsteads	1952	None	One structure observed in impact area in 1952, no evidence by 1959.	$ 500			$ 500
18	16-1-10	1	Cylindrical Structures	1997	None	Currently occupied by cylindrical structures, no evidence prior to 1997. Shown as a swampy area on the topographic map.	$ 500		$ 8,500	$ 9,000
19	16-1-11	1	Rural Residences & Farmsteads	1952-1997	1994	Farmstead or rural residence. Buildings are obviously apparent from 1952 through at least 1978. Some structures may still be present--building or foundation outlines still observed on 1997 aerial photograph. Some structures may be in the impact area.	$ 500	$ 1,000		$ 1,500
20	16-1-12	1	Rural Residences & Farmsteads	1952-1967	1951	Currently a clearing, difficult to determine if buildings are present, no obvious buildings in impact area. One building nearby observed in 1951 topographic map, but not in the 1994. Multiple structures at site and some in the impact area in 1952, only two left by 1959, only one potentially in 1967, and no obvious buildings by 1978.	$ 500			$ 500
17	17-1-1	1	Former Communities	1952-1997	1957, 1994	1952-1978 quite a few buildings west of the centerline and also in the impact area, 1952-1967 building between Hwy 281 and the railroad. Labeled as the village of Maza in some topographic maps.	$ 500		$ 8,500	$ 9,000
17	17-1-2	1	Rural Residences & Farmsteads	1952-1997	1957, 1994	Possible building in impact area in 1990, possible shed in impact area observed in 1967.	$ 500			$ 500
17	17-1-3	1	Rural Residences & Farmsteads	1952-1997	1957, 1994	Farmstead, disturbed land in 1967, possible building in impact area in 1952.	$ 500			$ 500
17	17-1-4	1	Rural Residences & Farmsteads	1952-1967	1957	Farmstead structures observed from 1952 through the 1967 photo, afterwards only trees. Some disturbed land and a building are seen in the impact area.	$ 500			$ 500
17	17-1-5	1	Railroad Related Land-Uses	1952-1997	1957, 1994	A railroad. Crosses the alignment in all photos and maps. Railroad labeled as the Great Northern.	$ 500		$ 5,000	$ 5,500
22	22-1-1	1	Excavation or Fill Areas	1997	None	Earth movement, scraping, or filling visible in 1997 aerial photo.	$ 500			$ 500
22	22-1-2	1	Nonresidential Properties	1952-1997	1931-1994	Structure adjacent to or beneath the impact area footprint and is visible on aerial photos. School #1 1931-1975, 1994 has no label.	$ 500	$ 1,000		$ 1,500

Appendix C
HTRW Site History Summary
Devils Lake Infrastructure Project

Feature Number	Site #	Action Level Affected	HTRW Category	Observed in Aerial Photos in Year:	Observed in Topographic Maps in Year:	Comments	Site Inspection Cost	Asbestos Survey Cost	Field Investigation Cost	Total HTRW Cost
22	22-1-3	1	Rural Residences & Farmsteads	1952-1997	1950, 1951, 1975	Structures evident in a few topographic maps and aerial photos, difficult to see evidence of structures in some aerial photos. Currently, historical structures appear to be gone and unidentified structures/features are present.	$ 500			$ 500
23	23-1-1	1	Rural Residences & Farmsteads	1952-1997	1994	Evidence of activity seen in each aerial photo (driveways or structures), structures are not always present/visible.	$ 500			$ 500
25	25-1-1	1	Rural Residences & Farmsteads	1978-1997	1994	Residence present 1978-1997. Topographic map indicates structure in 1994.	$ 500	$ 1,000		$ 1,500
25	25-1-2	1	Rural Residences & Farmsteads	1959-1997	1975, 1994	Residence present 1959-1997, aerial photo from 1952 is too dark to determine presence. Structure seen on topographic map in 1994 and 1975, not 1951.	$ 500	$ 1,000		$ 1,500
25	25-1-3	1	Rural Residences & Farmsteads	1959-1975	1950, 1951, 1975	Potential residence. Appears vacant in photos except for a driveway from 1959-1975 and lots of tree. Topographic map indicates structures in 1950, 1951, and 1975.	$ 500			$ 500
25	25-1-4	1	Nonresidential Properties	1952-1997	1931, 1994	Military building and open area (shooting range), high potential for a release. Only the 1994 topographic map shows a building. In 1931, the area is listed as a rifle range.			$ 14,000	$ 14,000
25	25-1-5	1	Rural Residences & Farmsteads	1959-1997	1951, 1975, 1994		$ 500	$ 1,000		$ 1,500
25	25-1-6	1	Nonresidential Properties	1959-1997	1951, 1975, 1994	Potential resort or other nonresidential buildings. Large barns apparent in photos and maps, multiple structures on topographic map. High potential for a release. 1952 photo is dark. Only small structures on the 1951 topographic map.	$ 500	$ 3,000	$ 8,500	$ 12,000
25	25-1-7	1	Rural Residences & Farmsteads	1959, 1967, 1990, 1997	1994	Residence. Structure in 1994 topographic map. Evidence of earlier structures in aerial photos. Currently no structure present.	$ 500			$ 500
25	25-1-8	1	Rural Residences & Farmsteads	1975-1997	1975, 1994	Residence, one small building present in impact areas (asbestos is not anticipated due to size and suspected use). Structure seen on 1975 and 1994 topographic maps.	$ 500			$ 500
25	25-1-9		Railroad Related Land-Uses	1952-1997	1931-1994	Railroad alignment intersects the impact area in three places.	$ 500		$ 5,000	$ 5,500
25	25-1-10	1	Potential Dumps	1981-1997	None	1967 Potential dump, may still be present. Clearing and a road to it seen over the years, potentially may have been some structures at one point.	$ 500		$ 8,500	$ 9,000
25	25-1-11	1	Rural Residences & Farmsteads	1978-1997	1994	Rural residence with a structure potentially in the impact area. Vacant in 1975. One building on the 1994 topographic map.	$ 500	$ 1,000		$ 1,500
25	25-1-12	1	Rural Residences & Farmsteads	1967-1997	1975, 1994	Farmstead within the impact area of the pond. Multiple structures present. First observed in 1967.	$ 500	$ 1,000		$ 1,500
25	25-1-13	1	Rural Residences & Farmsteads	1959-1997	1951, 1975, 1994	Appears to be a rural residence under lots of tree cover. In aerial photos, presence of driveways observed on and off through the years. Structures are not obvious in photos. 1952 aerial photograph is too dark to determine presence. Structure first visible on the 1951 topographic map.	$ 500	$ 1,000		$ 1,500

Appendix C
HTRW Site History Summary
Devils Lake Infrastructure Project

Feature Number	Site #	Action Level Affected	HTRW Category	Observed in Aerial Photos in Year:	Observed in Topographic Maps in Year:	Comments	Site Inspection Cost	Asbestos Survey Cost	Field Investigation Cost	Total HTRW Cost
25	25-1-14	1	Rural Residences & Farmsteads	1959-1997	1931-1994	Appears to be a rural residence under lots of tree cover. In aerial photos, presence of driveways observed on and off through the years. Structure are not obvious in photos. 1952 aerial photograph is too dark to determine presence. Structure apparent on topographic map beginning in 1931.	$ 500	$ 1,000		$ 1,500
25	25-1-15	1	Rural Residences & Farmsteads	1978-1997	1994	Appears to be a rural residence under lots of tree cover. In aerial photos, presence of driveways observed on and off through the years. Structure are not obvious in photos. Evidence of activity first observed in 1978. Two structures on the 1994 topographic map.	$ 500	$ 1,000		$ 1,500
25	25-1-16	1	Rural Residences & Farmsteads	1990, 1997	1994	Rural residence observed in 1990 and 1997 aerial photos. Two structures on the 1994 topographic map. Structures may be affected by the impact area.	$ 500	$ 1,000		$ 1,500
25	25-1-17	1	Rural Residences & Farmsteads	1952-1997	1931-1994	Farmstead observed with structures in the impact area.	$ 500	$ 1,000		$ 1,500
25	25-1-18	1	Nonresidential Properties	1952-1997	1975, 1994	Appears to be a nonresidential property with a low potential for a release. Looks like a farmstead; however, it is not located near any agricultural fields. Multiple driveways and potentially multiple structures.	$ 1,000	$ 2,000		$ 3,000
25	25-1-19	1	Rural Residences & Farmsteads	1952-1967	1931, 1950, 1951	Abandoned rural residence or farmstead. Small structures visible in 1952 and 1959 aerial photos, land look disturbed in 1967. Vacant by 1975. Multiple structures on 1951 topographic map.	$ 500			$ 500
25	25-1-20	1	Excavation or Fill Areas	1981-1997	None	Surface has been scraped in 1997, clearing or potential dump in 1981 and 1990.	$ 500		$ 5,000	$ 5,500
25	25-1-21	1	Rural Residences & Farmsteads	1952-1997	1931-1994	Large farmstead with several buildings under the dam/levee. Former buildings intersected the pond to the south.	$ 1,000	$ 2,000		$ 3,000
25	25-1-22	1	Potential Dumps	1975	None	Road out to wooded area where land looks like it has been cleared/scrapped.	$ 500		$ 5,000	$ 5,500
25	25-1-23	1	Rural Residences & Farmsteads	1978, 1981	1994	Small rural residence, lots of tree cover.	$ 500	$ 1,000		$ 1,500
25	25-1-24	1	Rural Residences & Farmsteads	1990, 1997	1951	Potential rural residence with structures inside the impact area. Disturbed land in 1990 (potential dump?) and only trees in 1981. One structure in the vicinity on the 1951 topographic map.	$ 500	$ 1,000		$ 1,500
25	25-1-25	1	Rural Residences & Farmsteads	1952-1997	1950-1994	Rural residence with structures inside the impact area 1997-1981. Vacant in 1978. Structures visible in 1975-1959 again, and potentially in 1952.	$ 500	$ 1,000		$ 1,500
25	25-1-26	1	Rural Residences & Farmsteads	1952-1997	1931-1975	Rural residence with structures inside the impact area in 1997. Vacant in 1990-1978. Structures evident again 1975-1959 and potentially 1952.	$ 500	$ 1,000		$ 1,500
25	25-1-27	1	Rural Residences & Farmsteads	1959, 1967	1950, 1951, 1975	Abandoned rural residence shown in early topographic maps. Observed in 1959 and 1967 aerial photos. Tree cover is too dense to see evidence of structure or driveway in any other aerial photos.	$ 500			$ 500

Accompanying Note for Appendix D

Appendix D provides the results of the economic analysis done for the Infrastructure Protection Study for features 12-15, 18, 20, and 21. Because these features were not among those likely to be affected by rising water in the near future, they were not originally scheduled to be part of the study. However, during the course of work on the study, it became apparent that it would be beneficial to provide economic results for these features to allow comparisons across all the features.

In providing results for features 12-15, 18, 20, and 21, no additional investigations were conducted as part of the Infrastructure Protection Study. No analysis of individual action levels was provided. The updating of these features was limited to rerunning the Features Analysis Model using the same cost and benefits inputs as for the previous Economic Analysis, but using the 2002 interest rate (6 1/8%) rather than the 2001 value (6 3/8 %) used previously for these features.

Table D-12

Economics Results
Feature 12: Burlington Northern Railroad (Churchs Ferry to Cando)
Devils Lake Infrastructure Protection Study

Stochastic Analysis (ST-9) — Mean Value over 10,000 Traces (Annual)

Strategy		COSTS		DAMAGES			Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Total B = A	Restoration C	Detour D	Total E = C + D	To Strategy (Damages Prevented) F = E(A) - E(S) *	To Strategy G = F - B	(BCR) I = F / B
A	Temporary Closure During Floods at First Action Level	$0	$0	$16,200	$27,100	$43,300	$0	$0	--
R	Rail Raise to 1468	$435,500	$435,500	$0	$0	$0	$43,300	-$392,200	0.10
R(1)A	1 Rail Raise: Then Temporary Closure During Floods	$112,200	$112,200	$15,900	$6,300	$22,300	$21,000	-$91,200	0.19
R(2)	2 Incr. Rail Raises	$222,400	$222,400	$0	$0	$0	$43,300	-$179,100	0.19

Wet Future Scenario (WF-9) (Annual)

Strategy		COSTS		DAMAGES			Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Total B = A	Restoration C	Detour D	Total E = C + D	To Strategy (Damages Prevented) F = E(A) - E(S) *	To Strategy G = F - B	(BCR) I = F / B
A	Temporary Closure During Floods at First Action Level	$0	$0	$97,500	$299,100	$396,600	$0	$0	--
R	Rail Raise to 1468	$2,563,000	$2,563,000	$0	$0	$0	$396,600	-$2,166,400	0.15
R(1)A	1 Rail Raise: Then Temporary Closure During Floods	$660,100	$660,100	$121,400	$126,300	$247,600	$148,900	-$511,200	0.23
R(2)	2 Incr. Rail Raises	$1,992,100	$1,992,100	$0	$0	$0	$396,600	-$1,595,500	0.20

Moderate Future 1 Scenario (M1-4) (Annual)

Strategy		COSTS		DAMAGES			Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Total B = A	Restoration C	Detour D	Total E = C + D	To Strategy (Damages Prevented) F = E(A) - E(S) *	To Strategy G = F - B	(BCR) I = F / B
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	--
R	Rail Raise to 1468	$0	$0	$0	$0	$0	$0	$0	--
R(1)A	1 Rail Raise: Then Temporary Closure During Floods	$0	$0	$0	$0	$0	$0	$0	--
R(2)	2 Incr. Rail Raises	$0	$0	$0	$0	$0	$0	$0	--

Moderate Future 2 Scenario (M2-4) (Annual)

Strategy		COSTS		DAMAGES			Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Total B = A	Restoration C	Detour D	Total E = C + D	To Strategy (Damages Prevented) F = E(A) - E(S) *	To Strategy G = F - B	(BCR) I = F / B
A	Temporary Closure During Floods at First Action Level	$0	$0	$28,600	$67,600	$96,200	$0	$0	--
R	Rail Raise to 1468	$1,904,000	$1,904,000	$0	$0	$0	$96,200	-$1,807,800	0.05
R(1)A	1 Rail Raise: Then Temporary Closure During Floods	$490,400	$490,400	$0	$0	$0	$96,200	-$394,200	0.20
R(2)	2 Incr. Rail Raises	$490,400	$490,400	$0	$0	$0	$96,200	-$394,200	0.20

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for "temporary closure strategy" minus the total damages for the strategy implemented (E(S)).

Table D-13

Economics Results
Feature 13: US Highway 2
Devils Lake Infrastructure Protection Study

Strategy		Stochastic Analysis (ST-9) Mean Value over 10,000 Traces (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$38,100	$632,800	$0	$670,800	$0	$0	--
R	Road Raise to 1468	$1,041,400	$0	$1,041,400	$0	$0	$0	$0	$670,800	-$370,500	0.64
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$345,300	$0	$345,300	$35,200	$148,200	$0	$183,400	$487,400	$142,100	1.41
R(2)	2 Incr. Road Raises	$582,600	$0	$582,600	$0	$0	$0	$0	$670,800	$88,200	1.15

Strategy		Wet Future Scenario (WF-9) (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$224,500	$6,973,700	$0	$7,198,200	$0	$0	--
R	Road Raise to 1468	$6,128,100	$0	$6,128,100	$0	$0	$0	$0	$7,198,200	$1,070,000	1.17
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$2,032,100	$0	$2,032,100	$258,900	$2,944,200	$0	$3,203,000	$3,995,100	$1,963,000	1.97
R(2)	2 Incr. Road Raises	$4,899,300	$0	$4,899,300	$0	$0	$0	$0	$7,198,200	$2,298,800	1.47

Strategy		Moderate Future 1 Scenario (M1-4) (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R	Road Raise to 1468	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(2)	2 Incr. Road Raises	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Strategy		Moderate Future 2 Scenario (M2-4) (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$39,400	$1,575,200	$0	$1,614,800	$0	$0	--
R	Road Raise to 1468	$4,552,400	$0	$4,552,400	$0	$0	$0	$0	$1,614,800	-$2,937,700	0.35
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$1,509,600	$0	$1,509,600	$0	$0	$0	$0	$1,614,800	$105,200	1.07
R(2)	2 Incr. Road Raises	$1,509,600	$0	$1,509,600	$0	$0	$0	$0	$1,614,800	$105,200	1.07

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for "temporary closure strategy" minus the total damages for the strategy implemented (G(S)).
The "No Protection" strategy for roads has been defined as temporary closure during floods at the first action level with restoration when the lake recedes.
The top action level (1463) is never reached in the 10,000 traces, rendering some of the costs and damages equal between different strategies.

Table D-14

Economics Results
Feature 14: ND Highway 57 (between ND Highway 20 and BIA Highway 1)
Devils Lake Infrastructure Protection Study

Stochastic Analysis (ST-9) — Mean Value over 10,000 Traces (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$8,200	$698,900	$0	$707,100	$0	$0	--
R	Road Raise to 1468	$97,300	$0	$97,300	$0	$0	$0	$0	$707,100	$609,800	7.27
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$42,300	$0	$42,300	$3,300	$163,600	$0	$166,900	$540,200	$497,900	12.77
R(2)	2 Incr. Road Raises	$61,100	$0	$61,100	$0	$0	$0	$0	$707,100	$646,100	11.57

Wet Future Scenario (WF-9) (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$23,200	$7,703,200	$0	$7,726,500	$0	$0	--
R	Road Raise to 1468	$572,700	$0	$572,700	$0	$0	$0	$0	$7,726,500	$7,153,800	13.49
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$248,900	$0	$248,900	$24,700	$3,252,200	$0	$3,276,900	$4,449,600	$4,200,700	17.88
R(2)	2 Incr. Road Raises	$475,600	$0	$475,600	$0	$0	$0	$0	$7,726,500	$7,251,000	16.25

Moderate Future 1 Scenario (M1-4) (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R	Road Raise to 1468	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(2)	2 Incr. Road Raises	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Moderate Future 2 Scenario (M2-4) (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$39,800	$1,740,100	$0	$1,779,800	$0	$0	--
R	Road Raise to 1468	$425,400	$0	$425,400	$0	$0	$0	$0	$1,779,800	$1,354,400	4.18
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$184,900	$0	$184,900	$0	$0	$0	$0	$1,779,800	$1,594,900	9.63
R(2)	2 Incr. Road Raises	$184,900	$0	$184,900	$0	$0	$0	$0	$1,779,800	$1,594,900	9.63

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for "temporary closure strategy" minus the total damages for the strategy implemented (G(S)).
The "No Protection" strategy for roads has been defined as temporary closure during floods at the first action level with restoration when the lake recedes.

Table D-15

Economics Results
Feature 15: ND Highway 57 (between BIA Highway 1 and US Highway 281)
Devils Lake Infrastructure Protection Study

Strategy		Stochastic Analysis (ST-9) Mean Value over 10,000 Traces (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$20,100	$506,000	$0	$526,200	$0	$0	--
R	Road Raise to 1468	$290,900	$0	$290,900	$0	$0	$0	$0	$526,200	$235,200	1.81
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$111,700	$0	$111,700	$9,700	$118,500	$0	$128,200	$398,000	$286,300	3.56
R(2)	2 Incr. Road Raises	$172,700	$0	$172,700	$0	$0	$0	$0	$526,200	$353,400	3.05

Strategy		Wet Future Scenario (WF-9) (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$68,400	$5,577,500	$0	$5,646,000	$0	$0	--
R	Road Raise to 1468	$1,711,900	$0	$1,711,900	$0	$0	$0	$0	$5,646,000	$3,934,100	3.30
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$657,200	$0	$657,200	$74,700	$2,354,700	$0	$2,429,400	$3,216,500	$2,559,400	4.89
R(2)	2 Incr. Road Raises	$1,395,500	$0	$1,395,500	$0	$0	$0	$0	$5,646,000	$4,250,500	4.05

Strategy		Moderate Future 1 Scenario (M1-4) Mean Value over 10,000 Traces (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R	Road Raise to 1468	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(2)	2 Incr. Road Raises	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Strategy		Moderate Future 2 Scenario (M2-4) (Annual)									
		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
		Raise	Relocation	Total	Restoration	Detour	Relocation Detour	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
Designation	Description	A	B	C = A + B	D	E	F	G = D + E + F	H = G(A) - G(S) *	I = H - C	I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$85,600	$1,259,900	$0	$1,345,500	$0	$0	--
R	Road Raise to 1468	$1,271,700	$0	$1,271,700	$0	$0	$0	$0	$1,345,500	$73,800	1.06
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$488,200	$0	$488,200	$0	$0	$0	$0	$1,345,500	$857,300	2.76
R(2)	2 Incr. Road Raises	$488,200	$0	$488,200	$0	$0	$0	$0	$1,345,500	$857,300	2.76

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for "temporary closure strategy" minus the total damages for the strategy implemented (G(S)).
The "No Protection" strategy for roads has been defined as temporary closure during floods at the first action level with restoration when the lake recedes.

Table D-18

Economics Results
Feature 18: ND Highway 19
Devils Lake Infrastructure Protection Study

Stochastic Analysis (ST-9)
Mean Value over 10,000 Traces (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$50,200	$70,500	$0	$120,700	$0	$0	--
R	Road Raise to 1468	$690,300	$0	$690,300	$0	$0	$0	$0	$120,700	-$569,700	0.17
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$264,600	$0	$264,600	$23,200	$16,500	$0	$39,600	$81,000	-$183,600	0.31
R(2)	2 Incr. Road Raises	$409,700	$0	$409,700	$0	$0	$0	$0	$120,700	-$289,000	0.29

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$154,500	$777,200	$0	$931,600	$0	$0	--
R	Road Raise to 1468	$4,062,400	$0	$4,062,400	$0	$0	$0	$0	$931,600	-$3,130,800	0.23
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$1,557,100	$0	$1,557,100	$171,100	$328,100	$0	$499,100	$432,500	-$1,124,600	0.28
R(2)	2 Incr. Road Raises	$3,310,800	$0	$3,310,800	$0	$0	$0	$0	$931,600	-$2,379,100	0.28

Moderate Future 1 Scenario (M1-4)
(Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R	Road Raise to 1468	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(2)	2 Incr. Road Raises	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Moderate Future 2 Scenario (M2-4)
(Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$233,200	$175,500	$0	$408,700	$0	$0	--
R	Road Raise to 1468	$3,017,900	$0	$3,017,900	$0	$0	$0	$0	$408,700	-$2,609,100	0.14
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$1,156,700	$0	$1,156,700	$0	$0	$0	$0	$408,700	-$748,100	0.35
R(2)	2 Incr. Road Raises	$1,156,700	$0	$1,156,700	$0	$0	$0	$0	$408,700	-$748,100	0.35

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for "temporary closure strategy" minus the total damages for the strategy implemented (G(S)).
The "No Protection" strategy for roads has been defined as temporary closure during floods at the first action level with restoration when the lake recedes.

Table D-20

Economics Results
Feature 20: ND Highway 20 (North of City of Devils Lake)
Devils Lake Infrastructure Protection Study

Stochastic Analysis (ST-9) — Mean Value over 10,000 Traces (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$9,200	$42,200	$0	$51,400	$0	$0	--
R(1)	Road Raise to 1468	$77,600	$0	$77,600	$0	$0	$0	$0	$51,400	-$26,200	0.66

Wet Future Scenario (WF-9) — (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$70,800	$837,600	$0	$908,400	$0	$0	--
R(1)	Road Raise to 1468	$937,500	$0	$937,500	$0	$0	$0	$0	$908,400	-$29,100	0.97

Moderate Future 1 Scenario (M1-4) — (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)	Road Raise to 1468	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Moderate Future 2 Scenario (M2-4) — (Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)	Road Raise to 1468	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for "temporary closure strategy" minus the total damages for the strategy implemented (G(S)).
The "No Protection" strategy for roads has been defined as temporary closure during floods at the first action level with restoration when the lake recedes.