2.17.2 Feature Protection

History of Flood Protection: Flood protection for US Highway 281 (North of US Highway 2) has not been an issue to date. Currently all of this section of road has been above the level of the rising water.

General Protection Strategy: The analysis identified and evaluated several different approaches for protecting US Highway 281 (North of US Highway 2). These included:

- Highway relocation
- Incremental road raises

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives evaluated both of the protection strategies, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.17-2 shows the decision tree for US Highway 281 (North of US Highway 2). As shown on Figure 2.17-2, the stepwise approach to flood protection for US Highway 281 (North of US Highway 2) that was analyzed consisted of the following:

1. At lake elevation 1451, a decision would be made as to whether the road would be raised to 1457, temporarily closed, or relocated to the west.
2. If the road were raised at the first action level, at lake elevation 1456 another decision would be made as to whether the road would be raised to 1462, temporarily closed, or relocated to the west.
3. If the road were raised at the second action level, at lake elevation 1461 another decision would be made as to whether the road would be raised to 1468, temporarily closed, or relocated to the west.

The maximum protection strategy that was analyzed at the first action level was relocating the road to the west. (Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of US Highway 281 (North of US Highway 2) is related to the protection of the following features:

- Feature 1: Churchs Ferry – Churchs Ferry is located at the south end of Feature 17. The protection strategy chosen for either, particularly if the strategy involves relocation, will have an impact on the other feature.

- Feature 20: ND Highway 20 (North of the City of Devils Lake) – If US Highway 281 (North of US Highway 2) is temporarily closed, Feature 20 would experience increased traffic as a detour route.

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.17.3 Feature Economics

Damages: For US Highway 281 (North of US Highway 2), the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for Feature 17 are summarized in the accompanying Table 2.17-1.

The first portion of the table summarizes the detour damages that would occur if the highway were temporarily closed. The second portion of the table is a breakdown of the damages associated with each action level, including annual detour damages and restoration damage costs. Restoration damages represent the costs to restore Feature 17 once the lake levels recede after a period of flooding. Restoration damages include rebuilding the road with excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

Unit costs for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for US Highway 281 (North of US Highway 2) are listed in the Feature 17 Assumptions listing, appended to this Section 2.17.

Costs: The costs of providing flood protection for US Highway 281 (North of US Highway 2) are detailed in the accompanying Table 2.17-2. Unit costs, data sources, and relevant assumptions are listed.

The first portion of the table shows the cost of incremental road raises and relocation costs at each action level (1451, 1456, and 1461). Incremental road raise costs are broken down into six categories: fabric liner, aggregate base, fill, riprap, bituminous, and bridge work. Relocation assumes a per mile cost.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for US Highway 281 (North of US Highway 2) are listed in the Feature 17 Assumptions listing, appended to this Section 2.17.

2.17.4 Results of Economic Analysis

The results of the Economic Analysis for the US Highway 281 (North of US Highway 2) are listed in Table 2.17-3.

Stochastic Analysis Results: The stochastic analysis indicated that both of the protection strategies had net benefits that were less than one. The flood protection strategy with the largest net benefits was for incremental road raises. This strategy is highlighted on the decision tree (Figure 2.17-2). The average annual restoration and detour damages for this strategy were -$145,000 and the BCR was 0.53. These results indicate that this strategy was not economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $142,500. The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For US Highway 281 (North of US Highway 2), the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, both of the protection strategies had net benefits that were less than one. The annual net benefits for the incremental road raise strategy were -$335,100 and the BCR was 0.77. For this future, the present worth annualized detour damages that would be prevented were computed at $1,018,700.
- First Moderate Future – For the first moderate future, lake levels do not reach the first damage levels.
- Second Moderate Future – For the second moderate future, both of the protection strategies had net benefits that were less than one. The annual net benefits for the incremental road raise strategy were -$40,100 and the BCR was 0.90. For this future, the present worth annualized detour damages that would be prevented were computed at $273,800.

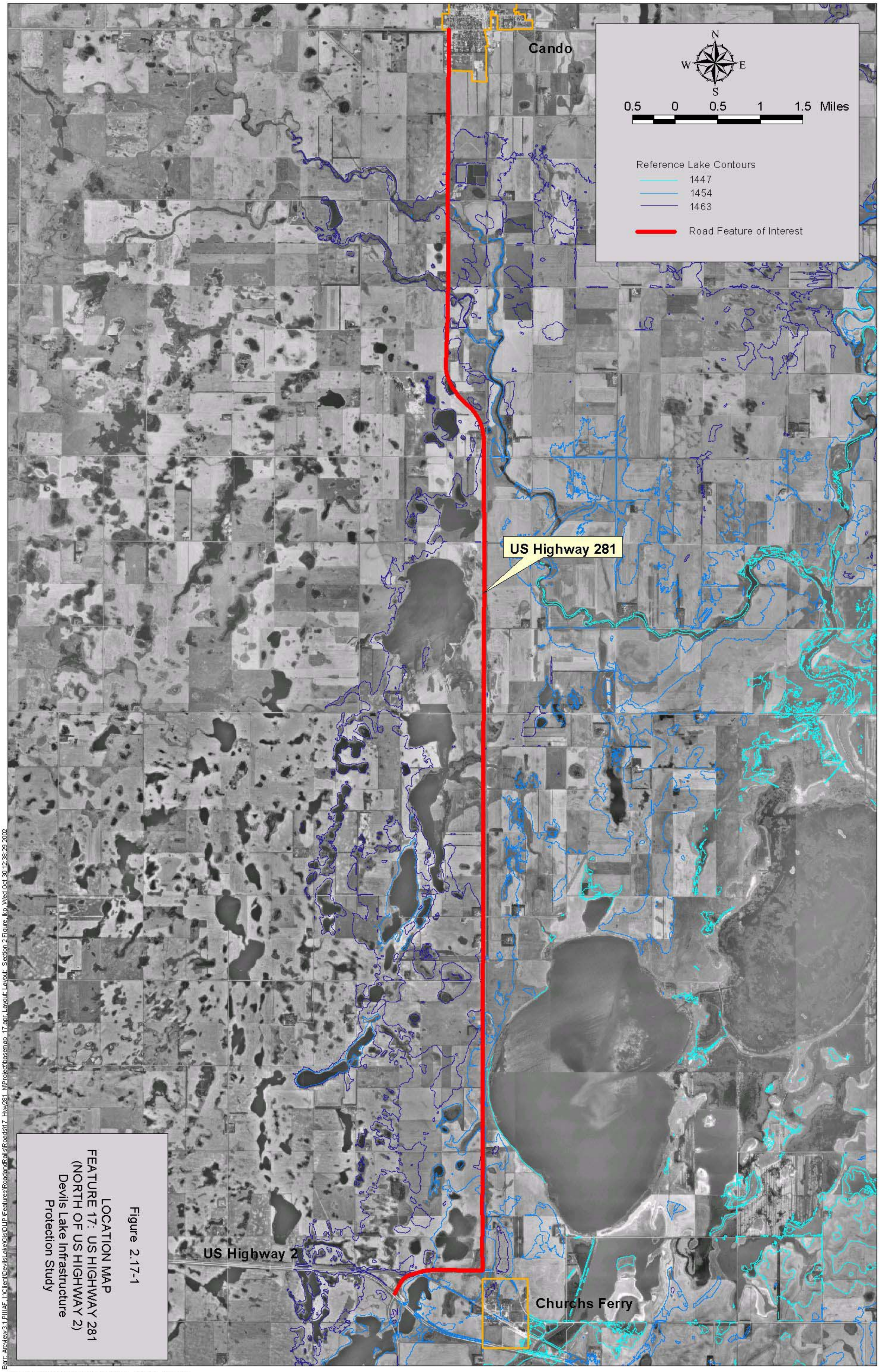
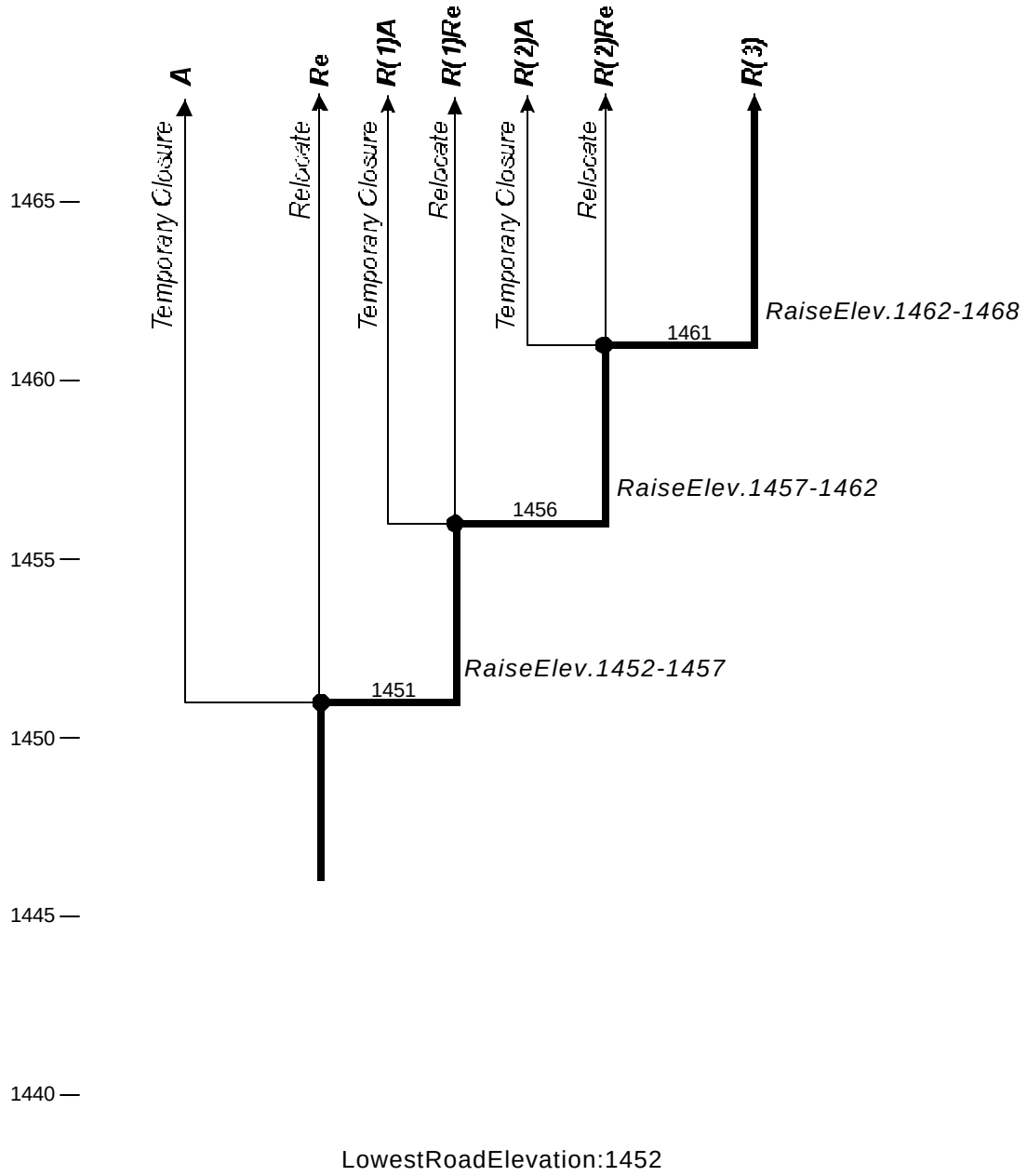


Figure 2.17-1

LOCATION MAP
FEATURE 17: US HIGHWAY 281
(NORTH OF US HIGHWAY 2)
Devils Lake Infrastructure
Protection Study

Barr: Arcview3.1 PIIIAF I:\Client\DevilsLake\Gis\DUP\Features\RoadandRails\Roads\17_Hwy281_NProject\basemap_17.apr Layout: Layout: Section 2 Figure_lkp Wed Oct 30 12:38:29 2002

DATA: 1997 USGS Digital Ortho Quad



FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

A Temporary closureofroad

Re Relocate

Figure2.17-2

DECISION TREE
FEATURE 17:U.S.HIGHWAY281
(Northof U.S.Highway 2)
DevilsLakeInfrastructure ProtectionStudy

P:\4036020\DECISIONTREES\2002FIGURES\FIGURE2_17.CDR RLG 01-02-03

Table 2.17-1

Flood Damages
Feature 17: US Highway 281 (North of US Highway 2)
Devils Lake Infrastructure Protection Study

DAMAGES

Action Levels	Strategy	Annual Detour Damages (THOUSANDS)
AL1 - AL3	A - Temporary Closure at AL1	$1,322
	Re - Relocate at AL1	$1,326

DAMAGE BREAKDOWN

Damage	AL1 - AL3 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	HWY 281				
	HR/YEAR	53,737	HR	$7.00	$376
	MILES/YEAR	2,955,558	MILE	$0.32	$946
	Total				**$1,322**
Annual Relocation Detour Damages	HWY 281				
	HR/YEAR	53,891	HR	$7.00	$377
	MILES/YEAR	2,964,032	MILE	$0.32	$948
	Total				**$1,326**

Restoration Damages

Elevation	Total (THOUSANDS)	Excavation Quantity	Units	Unit Cost	Value (THOUSANDS)	Fabric Liner Quantity	Units	Unit Cost	Value (THOUSANDS)	Aggregate Base Course Quantity	Units	Unit Cost	Value (THOUSANDS)	Fill Quantity	Units	Unit Cost	Value (THOUSANDS)	Bituminous Pavement Quantity	Units	Unit Cost	Value (THOUSANDS)	Bridge Repair Quantity	Units	Unit Cost	Cost (THOUSANDS)
1451	$0																								
1452	$897	25,000	CY	$2.65	$66	44,445	SY	$1.33	$59	5,382	CY	$21.20	$114	37,015	CY	$4.77	$177	10,083	TON	$47.70	$481	0	EA	$530,000	$0
1453	$897	25,000	CY	$2.65	$66	44,445	SY	$1.33	$59	5,382	CY	$21.20	$114	37,015	CY	$4.77	$177	10,083	TON	$47.70	$481	0	EA	$530,000	$0
1454	$897	25,000	CY	$2.65	$66	44,445	SY	$1.33	$59	5,382	CY	$21.20	$114	37,015	CY	$4.77	$177	10,083	TON	$47.70	$481	0	EA	$530,000	$0
1455	$3,774	105,200	CY	$2.65	$279	187,022	SY	$1.33	$248	22,647	CY	$21.20	$480	155,760	CY	$4.77	$743	42,341	TON	$47.70	$2,024	0	EA	$530,000	$0
1456	$3,774	105,200	CY	$2.65	$279	187,022	SY	$1.33	$248	22,647	CY	$21.20	$480	155,760	CY	$4.77	$743	42,341	TON	$47.70	$2,024	0	EA	$530,000	$0
1457	$4,834	105,200	CY	$2.65	$279	187,022	SY	$1.33	$248	22,647	CY	$21.20	$480	155,760	CY	$4.77	$743	42,341	TON	$47.70	$2,024	2	EA	$530,000	$1,060
1458	$4,834	105,200	CY	$2.65	$279	187,022	SY	$1.33	$248	22,647	CY	$21.20	$480	155,760	CY	$4.77	$743	42,341	TON	$47.70	$2,024	2	EA	$530,000	$1,060
1459	$6,634	155,400	CY	$2.65	$412	276,267	SY	$1.33	$366	33,454	CY	$21.20	$709	230,086	CY	$4.77	$1,098	62,678	TON	$47.70	$2,990	2	EA	$530,000	$1,060
1460	$6,634	155,400	CY	$2.65	$412	276,267	SY	$1.33	$366	33,454	CY	$21.20	$709	230,086	CY	$4.77	$1,098	62,678	TON	$47.70	$2,990	2	EA	$530,000	$1,060
1461	$9,665	239,880	CY	$2.65	$636	426,453	SY	$1.33	$565	51,641	CY	$21.20	$1,095	355,168	CY	$4.77	$1,694	96,752	TON	$47.70	$4,615	2	EA	$530,000	$1,060
1462	$9,665	239,880	CY	$2.65	$636	426,453	SY	$1.33	$565	51,641	CY	$21.20	$1,095	355,168	CY	$4.77	$1,694	96,752	TON	$47.70	$4,615	2	EA	$530,000	$1,060
1463	$10,224	255,480	CY	$2.65	$677	454,187	SY	$1.33	$602	54,999	CY	$21.20	$1,166	378,266	CY	$4.77	$1,804	103,044	TON	$47.70	$4,915	2	EA	$530,000	$1,060

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.17-2

Flood Protection Costs
Feature 17: US Highway 281 (North of US Highway 2)
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation (MSL)	A Temporary Closure at AL1	Re Relocate at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(1)Re Raise at AL1; Relocate at AL2	R(2)A Raise at AL1,AL2; Temporary Closure at AL3	R(2)Re Raise at AL1,AL2; Relocate at AL3	R(3) Raise at AL1, AL2, AL3
		(THOUSANDS)						
AL1	1451	$0	$10,067	$12,126	$12,126	$12,126	$12,126	$12,126
AL2	1456	$0	$0	$0	$10,067	$23,537	$23,537	$23,537
AL3	1461	$0	$0	$0	$0	$0	$10,067	$38,376

COST BREAKDOWN

Strategy		Lake Elevation 1451					Lake Elevation 1456					Lake Elevation 1461				
		R(1)A														
		R(1)Re														
		R(2)A					R(2)A									
		R(2)Re					R(2)Re									
		R(3)					R(3)					R(3)				
Incremental Raise		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
	Road Raise	US Highway 281					US Highway 281					US Highway 281				
		Fabric Liner	239,977	SY	$1.33	$319	Fabric Liner	427,931	SY	$1.33	$569	Fabric Liner	561,680	SY	$1.33	$747
		Aggregate Base	22,647	CY	$21.20	$480	Aggregate Base	28,944	CY	$21.20	$614	Aggregate Base	13,072	CY	$21.20	$277
		Fill	380,559	CY	$9.00	$3,425	Fill	1,123,491	CY	$9.00	$10,111	Fill	2,649,751	CY	$9.00	$23,848
		Riprap	160,588	CY	$30.00	$4,818	Riprap	286,364	CY	$30.00	$8,591	Riprap	375,866	CY	$30.00	$11,276
		Bituminous	42,431	TON	$47.70	$2,024	Bituminous	54,321	TON	$47.70	$2,591	Bituminous	24,490	TON	$47.70	$1,168
		Bridge Rebuild	2	EA	$530,000	$1,060	Bridge Rebuild	2	EA	$530,000	$1,060	Bridge Rebuild	2	EA	$530,000	$1,060
		Total				**$12,126**	**Total**				**$23,537**	**Total**				**$38,376**
		Re														
							R(1)Re									
												R(2)Re				
Relocation		Reroute Path: BC 28, BC 25, US 2					Reroute Path: BC 28, BC 25, US 2					Reroute Path: BC 28, BC 25, US 2				
	Reroute	Upgrade BC 28, BC 25					Upgrade BC 28, BC 25					Upgrade BC 28, BC 25				
			14.5	MILE	$694,300	$10,067		14.5	MILE	$694,300	$10,067		14.5	MILE	$694,300	$10,067
		Total				**$10,067**	**Total**				**$10,067**	**Total**				**$10,067**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.17 - 3

Economic Analysis of Strategies for Highway 281 North of US Highway 2

(Feature 17)

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

Strategy		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	$21,000	$142,500	$0	$163,600	$0	$0	--
Re	Relocation of Road at First Action Level	$0	$132,700	$132,700	$0	$0	$265,900	$265,900	-$102,300	-$235,000	-0.77
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$159,800	$0	$159,800	$19,900	$42,700	$0	$62,600	$100,900	-$58,900	0.63
R(2)A	2 Road Raises: Then Temporary Closure During Floods	$266,900	$0	$266,900	$9,400	$4,700	$0	$14,000	$149,500	-$117,300	0.56
R(1)Re	1 Road Raise: Then Relocate	$159,800	$45,800	$205,600	$0	$0	$89,900	$89,900	$73,700	-$132,000	0.36
R(2)Re	2 Road Raises: Then Relocate	$266,900	$11,000	$277,800	$0	$0	$21,200	$21,200	$142,300	-$135,500	0.51
R(3)	3 Incr. Road Raises	$308,600	$0	$308,600	$0	$0	$0	$0	$163,600	-$145,000	0.53

Wet Future Scenario (WF)
(Annual)

Strategy		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	$88,200	$1,018,700	$0	$1,106,800	$0	$0	--
Re	Relocation of Road at First Action Level	$0	$493,600	$493,600	$0	$0	$1,021,700	$1,021,700	$85,100	-$408,500	0.17
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$594,600	$0	$594,600	$108,400	$623,700	$0	$732,100	$374,700	-$219,900	0.63
R(2)A	2 Road Raises: Then Temporary Closure During Floods	$1,442,000	$0	$1,442,000	$0	$0	$0	$0	$1,106,800	-$335,100	0.77
R(1)Re	1 Road Raise: Then Relocate	$594,600	$362,400	$957,000	$0	$0	$733,300	$733,300	$373,500	-$583,500	0.39
R(2)Re	2 Road Raises: Then Relocate	$1,442,000	$0	$1,442,000	$0	$0	$0	$0	$1,106,800	-$335,100	0.77
R(3)	3 Incr. Road Raises	$1,442,000	$0	$1,442,000	$0	$0	$0	$0	$1,106,800	-$335,100	0.77

Moderate Future 1 Scenario (M1)
(Annual)

Strategy		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	--
Re	Relocation of Road at First Action Level	$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)A	2 Road Raises: Then Temporary Closure During Floods	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(1)Re	1 Road Raise: Then Relocate	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(2)Re	2 Road Raises: Then Relocate	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(3)	3 Incr. Road Raises	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Moderate Future 2 Scenario (M2)
(Annual)

Strategy		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	$71,900	$273,800	$0	$345,700	$0	$0	--
Re	Relocation of Road at First Action Level	$0	$320,300	$320,300	$0	$0	$640,700	$640,700	-$295,000	-$615,300	-0.92
R(1)A	1 Road Raise: Then Temporary Closure During Floods	$385,800	$0	$385,800	$0	$0	$0	$0	$345,700	-$40,100	0.90
R(2)A	2 Road Raises: Then Temporary Closure During Floods	$385,800	$0	$385,800	$0	$0	$0	$0	$345,700	-$40,100	0.90
R(1)Re	1 Road Raise: Then Relocate	$385,800	$0	$385,800	$0	$0	$0	$0	$345,700	-$40,100	0.90
R(2)Re	2 Road Raises: Then Relocate	$385,800	$0	$385,800	$0	$0	$0	$0	$345,700	-$40,100	0.90
R(3)	3 Incr. Road Raises	$385,800	$0	$385,800	$0	$0	$0	$0	$345,700	-$40,100	0.90

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% 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) In some cases this results in negative total benefits, and causes a seemingly erroneous negative sign to appear in the BCR.
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.

Attachment to 2.17:
US Highway 281 (North of US Highway 2) Economic Analysis Assumptions

No feature-specific assumptions were made for Feature 17.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been

   water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding, assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. It was assumed that if a road was permanently rerouted, the old route for that road would never be restored. Rerouting a road is an expensive option, so it was assumed that once this investment was made, the old road would not be considered usable. However, detour damages (reflecting the longer distance on the new alignment) will continue to be incurred for every year that the rerouted road is in use. This detour damage is estimated with same model output from the QRS II model described in the assumptions regarding temporary closure during flooding.

2. It was assumed that the rerouted path for any feature would be upgraded to the same level (road width and speed limit) as the existing feature.

3. Road reroutes do not necessarily have to be onto roads that are currently at or above the maximum elevation 1468. If there is a logical reroute path that would require a minor road lift (<10 feet), this reroute path could still be acceptable.

4. The only features that have reroute strategies are Highway 281 north of US Highway 2, and Highway 281 south of US Highway 2. All other strategies either have no logical reroute or have routes that would require more than 10-foot raises.

2.18 Summary of Economic Analysis Investigation for Feature 18: ND Highway 19

2.18.0 Flood Protection Strategy

The flood protection strategy that was analyzed in the Economic Analysis of Devils Lake Alternatives for ND Highway 19 was incremental road raises.

2.18.1 General Information

Feature Type: Road

Location: ND Highway 19 is located in Creel North, Grand Harbor, Pelican, Riggin East and Riggin West Townships, Benson County. The feature extends approximately 16 miles between US Highway 281 at the west to the City of Devils Lake at the east. The accompanying Figure 2.18-1 shows the feature's location and extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: ND Highway 19 is a two-lane bituminous-surfaced state highway. The centerline elevation is, at it's lowest, 1448. The portions of this feature below 1455 are planned to be raised to 1455 in 2001, according to ND DOT sources. Bridges will be raised to road surface elevation 1465 with low chord at 1461.

Significance: ND Highway 19 is important because it is a major east/west arterial route through the Devils Lake region and provides a primary route between the Minnewaukan area and the City of Devils Lake.

Damages: The flooding of ND Highway 19 would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when ND Highway 19 is closed and traffic is detoured
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation

Owner/Sponsor: The North Dakota Department of Transportation is responsible for managing and maintaining ND Highway 19.

Lead Federal Agency: The Federal Highway Administration would take the lead for ND Highway 19 in any flood protection work that may take place.

2.18.2 Feature Protection

History of Flood Protection: In the past, flood protection for ND Highway 19 has consisted of raising the road to keep it from being overtopped. The most recent raise of ND Highway 19 occurred in 1997 when four separate areas of the road were raised to 1448. The raise locations were near Creel Bay, across Six-Mile Bay, near Mavauis Coulee and the US Highway 281 and ND Highway 19 junction.

General Protection Strategy: The analysis identified and evaluated one approach for protecting ND Highway 19: raising the road.

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives considered various protection strategies, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.18-2 shows the decision tree for ND Highway 19. As shown on Figure 2.18-2, the stepwise approach to flood protection for ND Highway 19 that was analyzed consisted of the following:

1. At lake elevation 1454, a decision would be made as to whether the road would be raised to 1460, or temporarily closed.

2. If the road were raised at the first action level, at lake elevation 1459 another decision would be made as to whether the road would be raised to 1468, or temporarily closed.

The maximum protection strategy that was analyzed at the first action level was raising the road to 1468. (Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of ND Highway 19 is related to the protection of several other features:

- Feature 7: Grahams Island State Park – ND Highway 19 is the primary route to Feature 7, so closure or rerouting on ND Highway 19 would impact decisions regarding the protection strategy for Feature 7.

- Feature 13: US Highway 2 – If ND Highway 19 were temporarily closed, traffic on Feature 13 would increase because it is an alternate east-west route to US Highway 281.

- Feature 14: ND Highway 57 (between ND Highway 20 and BIA Highway 1) – If ND Highway 19 were temporarily closed, traffic on ND Highway 57 would increase because it is an alternate east-west route to US Highway 281(and vice versa).

- Feature 15: ND Highway 57 (between BIA Highway 1 and US Hwy 281) – If ND Highway 19 were temporarily closed, traffic on ND Highway 57 would increase because it is an alternate east-west route to US Highway 281 (and vice versa).
- Feature 16: US Highway 281 (South of US Highway 2) – These highways intersect and together provide a major transportation route around the lake, between Minnewaukan and the City of Devils Lake. Therefore, if either highway were temporarily closed, traffic on the other highway would be reduced, as traffic would be detoured on another route around the lake.
- Feature 21: ND Highway 20 (City of Devils Lake Levee to ND Highway 57) – If ND Highway 20 temporarily closes (cutting off access across the lake), traffic would be routed around the lake on ND Highway 19.

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.18.3 Feature Economics

Damages: For ND Highway 19, the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for ND Highway 19 are summarized in the accompanying Table 2.18-1.

The top portion of Table 2.18-1 gives a summary of the annual detour damages that would occur during the years when the highway was flooded. It also shows road restoration damages that can be expected when the lake recedes. Restoration damages include rebuilding the road with excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

The lower portion of the table shows the breakdown of these summary values for each of the three action levels. It gives quantities in terms of miles per year (of extra miles traveled as a result of detours) and hours per year (of additional travel time resulting from detours) for the detour damages. Also shown are quantities and line-item damages for excavation, fabric liner, aggregate base course, and fill for road restoration work when waters recede.

Unit prices for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for ND Highway 19 are listed in the Feature 18 Assumptions listing, appended to this Section 2.18.

Costs: The costs of providing flood protection for ND Highway 19 are detailed in the accompanying Table 2.18-2. Quantities and line-item totals are listed.

The top portion of the table gives the costs of providing flood protection (as represented in the analysis) by action level for all of the flood protection strategies. The lower portion of the table gives a breakdown of the quantities and costs by line item: fabric liner, aggregate base, fill, riprap, and bituminous pavement material.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for ND Highway 19 are listed in the Feature 18 Assumptions listing, appended to this Section 2.18.

2.18.4 Results of Economic Analysis

The results of the Economic Analysis for the ND Highway 19 are listed in Table 2.18-3.

Stochastic Analysis Results: The flood protection strategy that was analyzed for protecting ND Highway 19 was two incremental road raises. This strategy is highlighted on the decision tree (Figure 2.18-2). The average annual net benefits for this strategy were less than zero (-$291,900). The BCR for this strategy was less than one (0.29). These results indicate that this strategy was not economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $70,100. The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For ND Highway 19, the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, the annual net benefits were -$2,421,000, and the BCR was 0.27, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $768,400.
- First Moderate Future – For the first moderate future, lake levels do not reach the first damage levels.
- Second Moderate Future – For the second moderate future, the annual net benefits were -$753,600, and the BCR was 0.35, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $175,400.

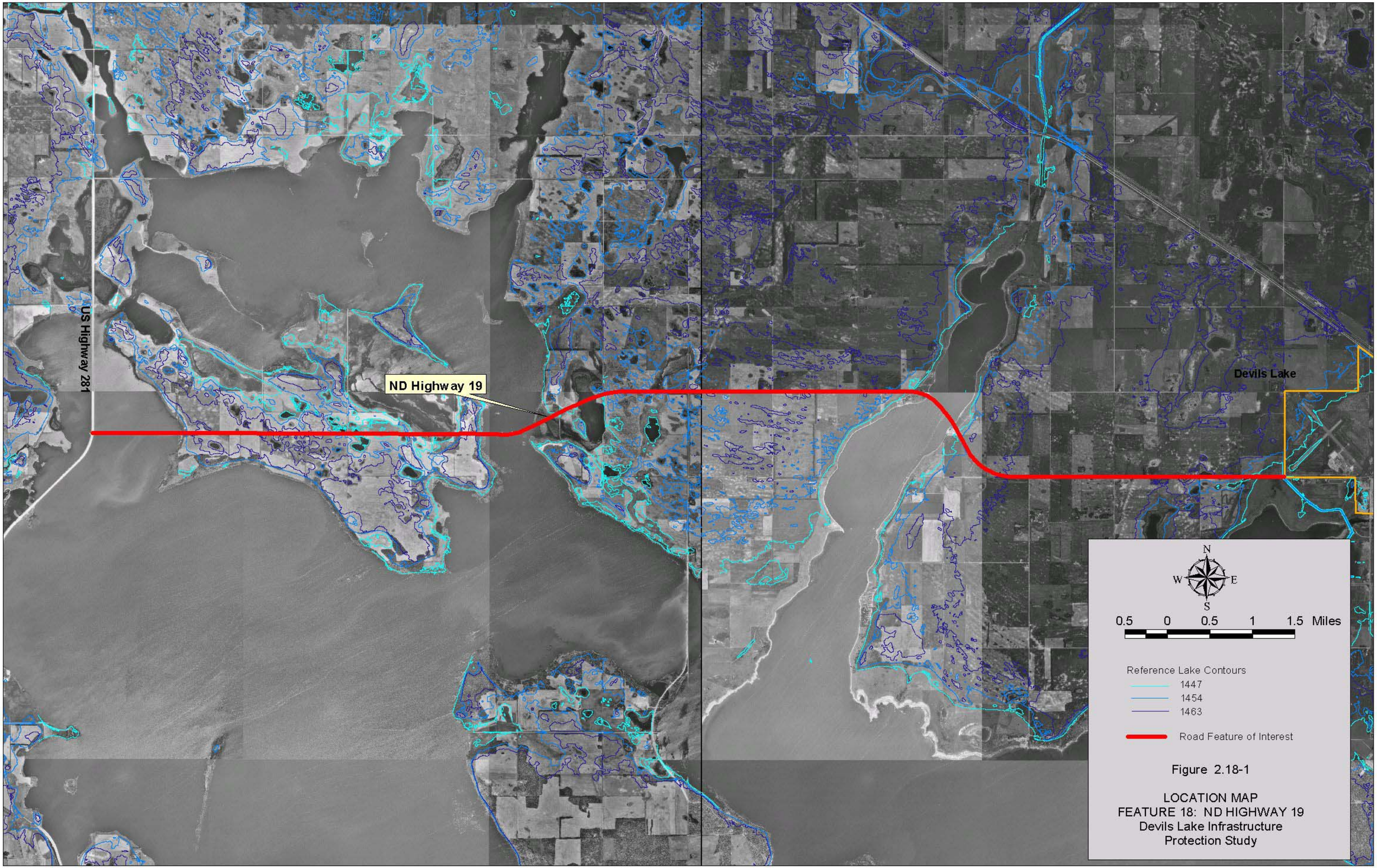
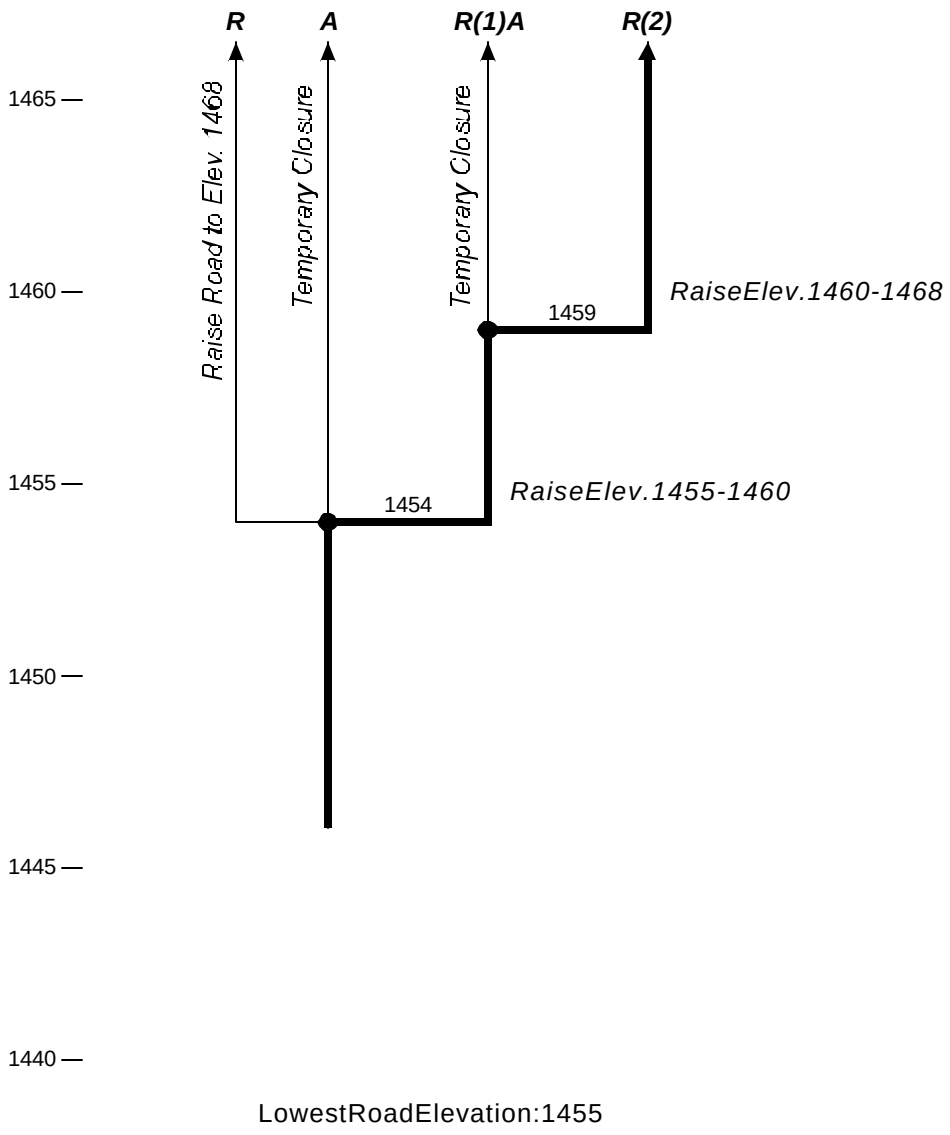


Figure 2.18-1

LOCATION MAP
FEATURE 18: ND HIGHWAY 19
Devils Lake Infrastructure
Protection Study

DATA: 1997 USGS Digital Ortho Quad

Barr: Arcview 3.1, PIII/AF, j:\client\devil\lake\gis\dlip\features\roadandrail\roads\18_hwy19\project\basemap_18.apr, Layout: Section 2 ND Highway 19 , lkp, Tue Oct 29 15:58:33 2002



FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1468

A Temporary closureofroad

Figure2.18-2

DECISION TREE
FEATURE 18:NDHIGHWAY19
DevilsLakeInfrastructure ProtectionStudy

P:\1360\020\DECISIONTREES\2002FIGURES\FIGURE2_18.CDR RLG 01-02-03

Table 2.18-1

Flood Damages
Feature 18: ND Highway 19
Devils Lake Infrastructure Protection Study

DAMAGES

Action Levels	Annual Detour Damages (THOUSANDS)
AL1 - AL2	$1,322

DAMAGE BREAKDOWN

Damage	AL1 - AL2 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	ND HWY 19				
	HR/YEAR	53,737	HR	$7.00	$376
	MILES/YEAR	2,955,558	MILE	$0.32	$946
	Total				**$1,322**

Restoration Damages

Elevation	Total (THOUSANDS)	Excavation Quantity	Excavation Units	Excavation Unit Cost	Excavation Value (THOUSANDS)	Fabric Liner Quantity	Fabric Liner Units	Fabric Liner Unit Cost	Fabric Liner Value (THOUSANDS)	Aggregate Base Course Quantity	Aggregate Base Course Units	Aggregate Base Course Unit Cost	Aggregate Base Course Value (THOUSANDS)	Fill Quantity	Fill Units	Fill Unit Cost	Fill Value (THOUSANDS)	Bituminous Pavement Quantity	Bituminous Pavement Units	Bituminous Pavement Unit Cost	Bituminous Pavement Value (THOUSANDS)	Bridge Repair Quantity	Bridge Repair Units	Bridge Repair Unit Cost	Bridge Repair Cost (THOUSANDS)
1454	$0																								
1455	$9,923	276,640	CY	$2.65	$733	489,956	SY	$1.33	$652	59,554	CY	$21.20	$1,263	409,595	CY	$4.77	$1,954	111,578	TON	$47.70	$5,322	0	EA	$530,000	$0
1456	$9,923	276,640	CY	$2.65	$733	489,956	SY	$1.33	$652	59,554	CY	$21.20	$1,263	409,595	CY	$4.77	$1,954	111,578	TON	$47.70	$5,322	0	EA	$530,000	$0
1457	$9,923	276,640	CY	$2.65	$733	489,956	SY	$1.33	$652	59,554	CY	$21.20	$1,263	409,595	CY	$4.77	$1,954	111,578	TON	$47.70	$5,322	0	EA	$530,000	$0
1458	$9,923	276,640	CY	$2.65	$733	489,956	SY	$1.33	$652	59,554	CY	$21.20	$1,263	409,595	CY	$4.77	$1,954	111,578	TON	$47.70	$5,322	0	EA	$530,000	$0
1459	$9,923	276,640	CY	$2.65	$733	489,956	SY	$1.33	$652	59,554	CY	$21.20	$1,263	409,595	CY	$4.77	$1,954	111,578	TON	$47.70	$5,322	0	EA	$530,000	$0
1460	$11,258	313,840	CY	$2.65	$832	555,841	SY	$1.33	$739	67,563	CY	$21.20	$1,432	464,674	CY	$4.77	$2,216	126,582	TON	$47.70	$6,038	0	EA	$530,000	$0
1461	$12,015	334,960	CY	$2.65	$888	593,246	SY	$1.33	$789	72,109	CY	$21.20	$1,529	495,944	CY	$4.77	$2,366	135,101	TON	$47.70	$6,444	0	EA	$530,000	$0
1462	$14,999	356,080	CY	$2.65	$944	630,651	SY	$1.33	$839	76,656	CY	$21.20	$1,625	527,215	CY	$4.77	$2,515	143,619	TON	$47.70	$6,851	2	EA	$530,000 / $2,226,000	$2,226
1463	$15,272	363,680	CY	$2.65	$964	644,111	SY	$1.33	$857	78,292	CY	$21.20	$1,660	538,468	CY	$4.77	$2,568	146,684	TON	$47.70	$6,997	2	EA	$530,000 / $2,226,000	$2,226

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.18-2

Flood Protection Costs
Feature 18: ND Highway 19
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2) Raise at AL1, AL2
	(MSL)	(THOUSANDS)			
AL1	1454	$101,252	$0	$38,810	$38,810
AL2	1459	$0	$0	$0	$62,442

COST BREAKDOWN

Strategy		R									
		R(1)A									
		R(2)					R(2)				
		Lake Elevation 1454					Lake Elevation 1459				
Incremental Raise		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
	Road Raise	ND Highway 19					ND Highway 19				
		Fabric Liner	808,967	SY	$1.33	$1,076	Fabric Liner	875,645	SY	$1.33	$1,165
		Aggregate Base	67,563	CY	$21.20	$1,432	Aggregate Base	10,729	CY	$21.20	$227
		Fill	1,558,181	CY	$9.00	$14,024	Fill	4,605,879	CY	$9.00	$41,453
		Riprap	541,346	CY	$30.00	$16,240	Riprap	585,966	CY	$30.00	$17,579
		Bituminous	126,582	TON	$47.70	$6,038	Bituminous	20,102	TON	$47.70	$959
		Bridge Rebuild	0	EA	$530,000	$0	Bridge Rebuild	2	EA	$530,000	$1,060
		Total				**$38,810**	**Total**				**$62,443**
							2001 Adjusted Total				**$62,442**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. The costs for the Maximum Raise at AL1 strategy (R) is equal to the sum of the costs for all incremental raises.
4. 2001 Adjusted Total adjusts detailed cost breakdown to match the 2001 totals.

Table 2.18 - 3

Economic Analysis of Strategies for Highway 19 from the City of Devils Lake Levee to Highway 281 (Feature 18)

Stochastic Analysis (ST)
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 Le	$0	$0	$0	$49,600	$70,100	$0	$119,600	$0	$0	--
R	Road Raise to 1468	$694,500	$0	$694,500	$0	$0	$0	$0	$119,600	-$574,900	0.17
R(1)A	1 Road Raise: Then Temporary Closure During Flo	$266,200	$0	$266,200	$22,900	$16,400	$0	$39,300	$80,300	-$185,900	0.30
R(2)	2 Incr. Road Raises	$411,600	$0	$411,600	$0	$0	$0	$0	$119,600	-$291,900	0.29

Wet Future Scenario (WF)
(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 Le	$0	$0	$0	$147,300	#######	$0	$915,700	$0	$0	--
R	Road Raise to 1468	########	$0	$4,124,800	$0	$0	$0	$0	$915,700	-$3,209,100	0.22
R(1)A	1 Road Raise: Then Temporary Closure During Flo	########	$0	$1,581,000	$166,800	#######	$0	$491,600	$424,000	-$1,157,000	0.27
R(2)	2 Incr. Road Raises	########	$0	$3,336,600	$0	$0	$0	$0	$915,700	-$2,421,000	0.27

Moderate Future 1 Scenario (M1)
(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 Le	$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 Flo	$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)
(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 Le	$0	$0	$0	$231,800	#######	$0	$407,100	$0	$0	--
R	Road Raise to 1468	########	$0	$3,028,300	$0	$0	$0	$0	$407,100	-$2,621,100	0.13
R(1)A	1 Road Raise: Then Temporary Closure During Flo	########	$0	$1,160,700	$0	$0	$0	$0	$407,100	-$753,600	0.35
R(2)	2 Incr. Road Raises	########	$0	$1,160,700	$0	$0	$0	$0	$407,100	-$753,600	0.35

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% 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.

Attachment to 2.18:
ND Highway 19 Economic Analysis Assumptions

1. Plans for 2001 include raising Highway 19 to a minimum elevation of 1455 and the bridges at Mauvais Coulee and Six Mile Bay to a minimum elevation of 1461 (low chord). For this analysis, the work was assumed completed and the new elevations were used.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been available until the National Weather Service predicts on February 15th that the road will go under water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding, assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. There is more commitment on the part of the North Dakota Department of Transportation (NDDOT) to the Highway 57 causeway than to the Highway 20 causeway through The Narrows. Therefore, Highway 57 was assumed to be the detour route for the Highway 20 causeway. If the Highway 57 causeway was temporarily closed during flooding, it was assumed that the Highway 20 causeway would also be temporarily closed.

7. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

8. Detour paths were determined assuming that all other featured roads would be open (with three exceptions: the Highway 57 detour assumes that Highway 20 across The Narrows is closed and both the BIA 1 and the BIA 6 detours assume that Highway 20 from Highway 57 to Tokio is closed). No

effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an "interdependency" was noted.

9. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. This feature had no logical reroute due to the close proximity of US Highway 2, where traffic would likely be detoured during periods of temporary closure.

2.19 Summary of Economic Analysis Investigation for Feature 19: ND Highway 1

2.19.0 Flood Protection Strategy

ND Highway 1 was being relocated when the Economic Analysis of Devils Lake Alternatives was conducted. Therefore, no further analysis was done for this feature and it was not included in the Economic Analysis.

2.19.1 General Information

Feature Type: Road

Location: Feature 19 is the portion of ND Highway 1 in Nelson County that begins at the southern ends of Sections 15 and 16 in Wamduska Township, and continues south to the southern end of the border between Sections 34 and 35. It extends approximately 3.4 miles across this stretch. The accompanying Figure 2.19-1 shows the feature's location and approximate extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: ND Highway 1 in Wamduska Township is a two-lane bituminous-surfaced state highway. Prior to the raise, the centerline elevation ranged from 1410 just east of the easternmost part of Stump Lake to 1503 approximately 3 miles south of Stump Lake. The minimum elevation of the road after the relocation was planned to be 1465.

Significance: This portion of ND Highway 1 is important because it is a major north-south traffic route for the area east of Devils Lake and Stump Lake. It is vital to serving local transportation, agricultural needs, and moving products through the area.

Damages: The flooding of Feature 19 would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when ND Highway 1 is closed and traffic is detoured
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation

Owner/Sponsor: The North Dakota Department of Transportation is responsible for managing and maintaining ND Highway 1.

Lead Federal Agency: The Federal Highway Administration would take the lead for ND Highway 1 for any flood protection work that may take place.

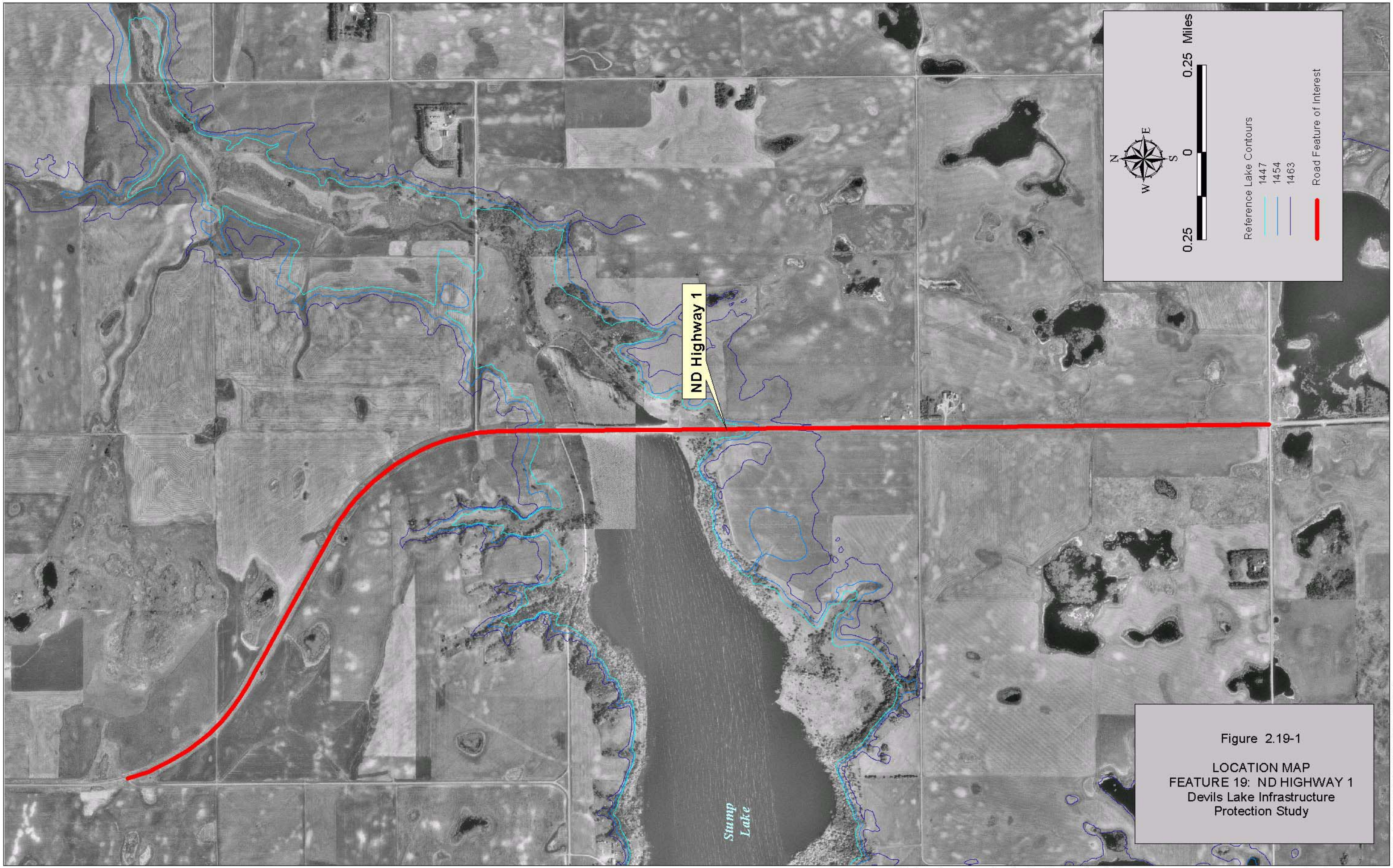
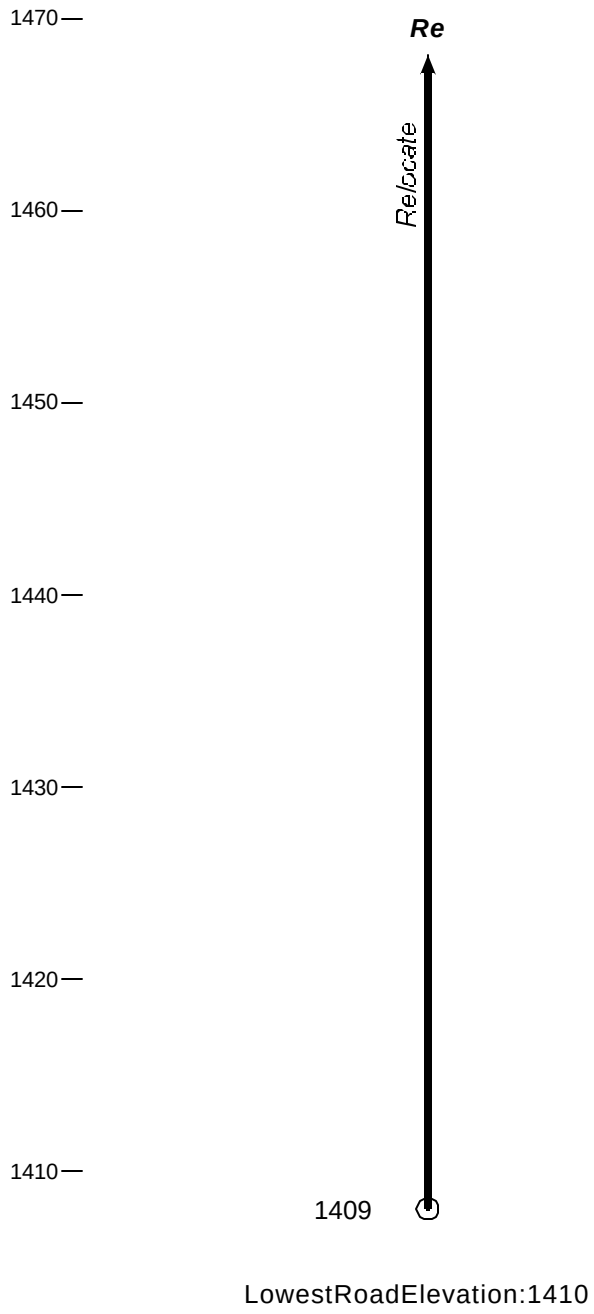


Figure 2.19-1

LOCATION MAP
FEATURE 19: ND HIGHWAY 1
Devils Lake Infrastructure
Protection Study

DATA: 1997 USGS Digital Ortho Quad

Barr: ArcView3.1,PlllAF,1:\Client\DevilsLake\GIS\DLIP\Features\Roads and Rails\Roads\19_Hwy1\Project\basemap_19.apr, Layout: Section 2 Figure Hwy 1, lkp, Wed Oct 30 13:52:49 2002



FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

Re Relocate

A Temporary closureofroad

Figure2.19-2

DECISION TREE
FEATURE 19:NDHIGHWAY1
DevilsLakeInfrastructure ProtectionStudy

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Table 2.19-1

Flood Damages
Feature 19: ND Highway 1
Devils Lake Infrastructure Protection Study

DAMAGES

Action Level	Lake Elevation	Annual Detour Damages
	(MSL)	(THOUSANDS)
AL1	1409	$0

Notes:

1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.19-2

Flood Protection Costs
Feature 19: ND Highway 1
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation	Re Relocation at AL1
	(MSL)	(THOUSANDS)
AL1	1409	$0

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Attachment to 2.19:
ND Highway 1 Economic Analysis Assumptions

1. Plans for 2001 include relocating Highway 1 to the east. For this analysis, the work was assumed completed and no costs or damages were associated with this feature.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been available until the National Weather Service predicts on February 15th that the road will go under water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the
Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding, assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

7. Detour paths were determined assuming that all other featured roads would be open. No effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an "interdependency" was noted.

8. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. It was assumed that if a road was permanently rerouted, the old route for that road would never be restored. Rerouting a road is an expensive option, so it was assumed that once this investment was made, the old road would not be considered usable. However, detour damages (reflecting the longer distance on the new alignment) will continue to be incurred for every year that the rerouted road is in use. This detour damage is estimated with same model output from the QRS II model described in the assumptions regarding temporary closure during flooding.

2. It was assumed that the rerouted path for any feature would be upgraded to the same level (road width and speed limit) as the existing feature.

3. Road reroutes do not necessarily have to be onto roads that are currently at or above the maximum elevation 1468. If there is a logical reroute path that would require a minor road lift (<10 feet), this reroute path could still be acceptable.

4. The only features that have reroute strategies are Highway 281 north of US Highway 2, and Highway 281 south of US Highway 2. All other strategies either have no logical reroute or have routes that would require more than 10-foot raises.

5. Highway 1 is located near Stump Lake, which is currently at about elevation 1409. If Devils Lake overtops into Stump Lake, the lake level would rise to about elevation 1447 and become one lake with Devils Lake. It was found to be considerably less expensive to reroute Highway 1 than to raise it from 1410 to 1452. The rerouting of Highway 1 is planned for 2001. For this analysis, the reroute was assumed complete and therefore no costs or damages were associated with this feature.

2.20 Summary of Economic Analysis Investigation for Feature 20: ND Highway 20 (North of City of Devils Lake)

2.20.0 Flood Protection Strategy

The flood protection strategy that was analyzed in the Economic Analysis of Devils Lake Alternatives for ND Highway 20 (North of City of Devils Lake) was incremental road raises.

2.20.1 General Information

Feature Type: Road

Location: ND Highway 20 (North of City of Devils Lake) is located in Freshwater and Webster Townships, in Ramsey County. The feature extends from 1 mile north of Webster to 3 miles south of Webster. The accompanying Figure 2.20-1 shows the feature's location and extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: ND Highway 20 (North of City of Devils Lake) is a two-lane bituminous-surfaced state highway. The lowest centerline elevation is 1460.

Significance: ND Highway 20 (North of City of Devils Lake) is important because it is a major north/south arterial route through the Devils Lake region.

Damages: The flooding of ND Highway 20 (North of City of Devils Lake) would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when ND Highway 20 (North of City of Devils Lake) is closed and traffic is detoured
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation

Owner/Sponsor: The North Dakota Department of Transportation is responsible for managing and maintaining ND Highway 20 (North of City of Devils Lake).

Lead Federal Agency: The Federal Highway Administration would take the lead for ND Highway 20 (North of City of Devils Lake) in any flood protection work that may take place.

2.20.2 Feature Protection

History of Flood Protection: Flood protection for ND Highway 20 (North of City of Devils Lake) has not yet been an issue because of the high road elevation relative to historic lake levels.

General Protection Strategy: The analysis identified and evaluated one approach for protecting ND Highway 20 (North of City of Devils Lake): road raise.

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives evaluated this protection strategy, with flood protection decisions being made as Devils Lake continued to rise. Figure 2.20-2 shows the decision tree for ND Highway 20 (North of City of Devils Lake). As shown on Figure 2.20-2, the stepwise approach to flood protection for ND Highway 20 (North of City of Devils Lake) that was analyzed consisted of the following:

1. At lake elevation 1459, a decision would be made as to whether the road would be raised to 1468, or temporarily closed.

(Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of ND Highway 20 (North of City of Devils Lake) is related to the protection of several other features:

- Feature 2: City of Devils Lake – ND Highway 20 is the main transportation route to the City of Devils Lake from the north. If ND Highway 20 (North of City of Devils Lake) were temporarily closed, traffic into and out of the City of Devils Lake would be detoured.
- Feature 13: US Highway 2 – ND Highway 20 (North of City of Devils Lake) intersects US Highway 2 in the City of Devils Lake. If either road were temporarily closed, the other road would experience increased traffic as a detour route.
- Feature 17: US Highway 281 (North of US Highway 2) – US Highway 281 and ND Highway 20 are the two main north-south routes north of US Highway 2 in the area. If either road were temporarily closed, the other road would experience increased traffic as a detour route.

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.20.3 Feature Economics

Damages: For ND Highway 20 (North of City of Devils Lake), the damages resulting from flooding were estimated up to the maximum lake level (elevation 1463). The damage computations are summarized in the accompanying Table 2.20-1.

The top portion of Table 2.20-1 gives a summary of the annual detour damages that would occur during the years when the highway was flooded. It also shows road restoration damages that can be expected when the lake recedes. Restoration damages include rebuilding the road with

excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

The lower portion of the table shows the breakdown of these summary values for the action level. It gives quantities in terms of miles per year (of extra miles traveled as a result of detours) and hours per year (of additional travel time resulting from detours) for the detour damages. Also shown are quantities and line-item damages for excavation, fabric liner, aggregate base course, and fill for road restoration work when waters recede.

Unit prices for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for ND Highway 20 (North of City of Devils Lake) are listed in the Feature 20 Assumptions listing, appended to this Section 2.20.

Costs: The costs of providing flood protection for ND Highway 20 (North of City of Devils Lake) are detailed in the accompanying Table 2.20-2. Quantities and line-item totals are listed.

The top portion of the table gives the costs of providing flood protection (as represented in the analysis) by action level for all of the flood protection strategies. The lower portion of the table gives a breakdown of the quantities and costs by line item: fabric liner, aggregate base, fill, riprap, and bituminous pavement material.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for ND Highway 20 (North of City of Devils Lake) are listed in the Feature 20 Assumptions listing, appended to this Section 2.20.

2.20.4 Results of Economic Analysis

The results of the Economic Analysis for the ND Highway 20 (North of City of Devils Lake) are listed in Table 2.20-3.

Stochastic Analysis Results: The flood protection strategy that was analyzed for protecting ND Highway 20 (North of City of Devils Lake) was one road raise. This strategy is highlighted on the decision tree (Figure 2.20-2). The average annual net benefits for this strategy were less than zero (-$26,600). The BCR for this strategy was less than one (0.66). These results indicate that this strategy was not economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $41,900. The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For ND Highway 20 (North of City of Devils Lake),

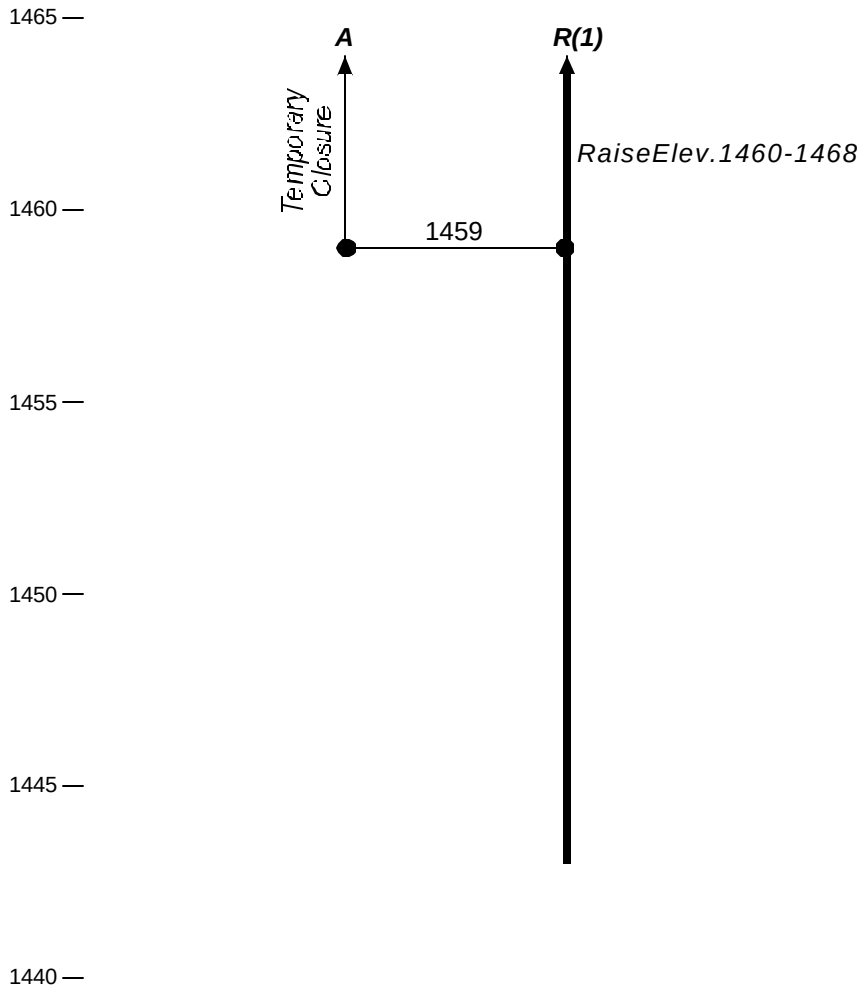
the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, the annual net benefits were -$40,300, and the BCR was 0.96, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $829,100.
- First Moderate Future – For the first moderate future, lake levels do not reach the first damage levels.
- Second Moderate Future – For the second moderate future, lake levels do not reach the first damage levels.

Figure 2.20-1

LOCATION MAP
FEATURE 20: ND HIGHWAY 20
(NORTH OF THE CITY OF
DEVILS LAKE)
Devils Lake Infrastructure
Protection Study

DATA: 1997 USGS Digital Ortho Quad



LowestRoadElevation:1460

FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1468

A Temporary closureofroad

Figure2.20-2

DECISION TREE
FEATURE 20:NDHIGHWAY20
(NorthofCityofDevilsLake)
DevilsLakeInfrastructure ProtectionStudy

P:\1436020\DECISIONTREES\2002FIGURES\FIGURE2_20.CDR RLG 01-02-03

Table 2.20-1

Flood Damages
Feature 20: ND Highway 20 (North of City of Devils Lake)
Devils Lake Infrastructure Protection Study

DAMAGES

Action Level	Annual Detour Damages (THOUSANDS)
AL1	$3,375

DAMAGE BREAKDOWN

Damage	AL1 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	ND HWY 20				
	HR/YEAR	137,190	HR	$7.00	$960
	MILES/YEAR	7,545,456	MILE	$0.32	$2,415
	Total				**$3,375**

Restoration Damages

Elevation	Total (THOUSANDS)	Excavation Quantity	Excavation Units	Excavation Unit Cost	Excavation Value (THOUSANDS)	Fabric Liner Quantity	Fabric Liner Units	Fabric Liner Unit Cost	Fabric Liner Value (THOUSANDS)	Aggregate Base Course Quantity	Aggregate Base Course Units	Aggregate Base Course Unit Cost	Aggregate Base Course Value (THOUSANDS)	Fill Quantity	Fill Units	Fill Unit Cost	Fill Value (THOUSANDS)	Bituminous Pavement Quantity	Bituminous Pavement Units	Bituminous Pavement Unit Cost	Bituminous Pavement Value (THOUSANDS)	Bridge Repair Quantity	Bridge Repair Units	Bridge Repair Unit Cost	Bridge Repair Cost (THOUSANDS)
1459	$0																								
1460	$4,848	105,600	CY	$2.65	$280	187,028	SY	$1.33	$249	22,733	CY	$21.20	$482	156,352	CY	$4.77	$746	42,592	TON	$47.70	$2,032	2	EA	$530,000	$1,060
1461	$4,848	105,600	CY	$2.65	$280	187,028	SY	$1.33	$249	22,733	CY	$21.20	$482	156,352	CY	$4.77	$746	42,592	TON	$47.70	$2,032	2	EA	$530,000	$1,060
1462	$4,848	105,600	CY	$2.65	$280	187,028	SY	$1.33	$249	22,733	CY	$21.20	$482	156,352	CY	$4.77	$746	42,592	TON	$47.70	$2,032	2	EA	$530,000	$1,060
1463	$4,848	105,600	CY	$2.65	$280	187,028	SY	$1.33	$249	22,733	CY	$21.20	$482	156,352	CY	$4.77	$746	42,592	TON	$47.70	$2,032	2	EA	$530,000	$1,060

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.20-2

Flood Protection Costs
Feature 20: ND Highway 20 (North of City of Devils Lake)
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation	A Temporary Closure at AL1	R(1) Raise at AL1
	(MSL)	(THOUSANDS)	
AL1	1459	$0	$33,382

COST BREAKDOWN

Strategy		R(1) Lake Elevation 1454				
Incremental Raise		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
	Road Raise	ND Highway 20				
		Fabric Liner	648,663	SY	$1.33	$863
		Aggregate Base	50,099	CY	$21.20	$1,062
		Fill	1,433,069	CY	$9.00	$12,898
		Riprap	434,074	CY	$30.00	$13,022
		Bituminous	93,864	TON	$47.70	$4,477
		Bridge Rebuild	2	EA	$530,000	$1,060
		Total				**$33,382**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.20 - 3

Economic Analysis of Strategies for Highway 20 North of the City of Devils Lake (Feature 20)

Stochastic Analysis (ST)
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	$41,900	$0	$51,100	$0	$0	--
R(1)	Road Raise to 1468	$77,700	$0	$77,700	$0	$0	$0	$0	$51,100	-$26,600	0.66

Wet Future Scenario (WF)
(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	$69,100	$829,100	$0	$898,200	$0	$0	--
R(1)	Road Raise to 1468	$938,600	$0	$938,600	$0	$0	$0	$0	$898,200	-$40,300	0.96

Moderate Future 1 Scenario (M1)
(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)
(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 6.375% 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.

Attachment to 2.20:
ND Highway 20 (north of the City of Devils Lake) Economic Analysis Assumptions

No feature-specific assumptions were made for Feature 20.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been

   water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding, assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. There was no logical reroute for this feature.

2.21 Summary of Economic Analysis Investigation for Feature 21: ND Highway 20 (City of Devils Lake Levee to ND Highway 57)

2.21.0 Flood Protection Strategy

The flood protection strategy that was analyzed in the Economic Analysis of Devils Lake Alternatives for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) was incremental road raises.

2.21.1 General Information

Feature Type: Road

Location: ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is located in Creel Township in Ramsey County. The feature extends approximately 3 miles between ND Highway 57 at the southeast to the levee on the south side of Devils Lake. The accompanying Figure 2.21-1 shows the feature's location and extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is a two-lane bituminous-surfaced state highway. The centerline elevation is at a minimum of 1455. Portions of this roadway are currently acting as a dam (see analysis of Feature 25).

Significance: ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is important because it is the major north-south arterial route through the Devils Lake region. It provides primary access to and from the City of Devils Lake from the south side of the lake, particularly the Spirit Lake Nation Reservation.

Damages: The flooding of ND Highway 20 (City of Devils Lake Levee to ND Highway 57) would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is closed and traffic is detoured
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation

Owner/Sponsor: The North Dakota Department of Transportation is responsible for managing and maintaining ND Highway 20 (City of Devils Lake Levee to ND Highway 57).

Lead Federal Agency: The Federal Highway Administration would take the lead for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) in any flood protection work that may take place.

2.21.2 Feature Protection

History of Flood Protection: In the past, flood protection for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) has consisted of raising the road to keep it from being overtopped.

General Protection Strategy: The analysis identified and evaluated one approach for protecting ND Highway 20 (City of Devils Lake Levee to ND Highway 57): incremental road raises.

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives evaluated this protection strategy, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.21-2 shows the decision tree for ND Highway 20 (City of Devils Lake Levee to ND Highway 57). As shown on Figure 2.21-2, the stepwise approach to flood protection for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) that was analyzed consisted of the following:

1. At lake elevation 1454, a decision would be made as to whether the road would be raised to 1460, or temporarily closed.

2. If the road were raised at the first action level, at lake elevation 1459 another decision would be made as to whether the road would be raised to 1468, or temporarily closed.

The maximum protection strategy that was analyzed at the first action level was raising the road to 1468. (Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is related to the protection of several other features:

- Feature 2: City of Devils Lake – ND Highway 20 is the main transportation route to the City of Devils Lake from the south. If ND Highway 20 (City of Devils Lake Levee to ND Highway 57) were temporarily closed, traffic into and out of the City of Devils Lake would be detoured.

- Feature 3: Fort Totten – ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is one segment of the primary route between the City of Devils Lake and Fort Totten. Therefore, If ND Highway 20 (City of Devils Lake Levee to ND Highway 57) were temporarily closed, traffic between Fort Totten and the City of Devils Lake would be detoured.

- Feature 5: St. Michael – ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is one segment of the primary route between the City of Devils Lake and St. Michael.

Therefore, if ND Highway 20 (City of Devils Lake Levee to ND Highway 57) were temporarily closed, traffic between St. Michael and the City of Devils Lake would be detoured.

- Feature 6: Gilbert C. Grafton Military Reservation – The protection of Camp Grafton is directly related to the protection of ND Highway 20 because the primary access to Camp Grafton is from ND Highway 20. Temporary closure of ND Highway 20 would impact access to the Camp.
- Feature 13: US Highway 2 – ND Highway 20 (City of Devils Lake Levee to ND Highway 57) intersects US Highway 2 in the City of Devils Lake. If US Highway 2 is closed, ND Highway 20 (City of Devils Lake Levee to ND Highway 57) would experience changes in traffic as a detour routes are implemented (and vice versa).
- Feature 15: ND Highway 57 (between BIA Highway 1 and US Highway 281) – If ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is temporarily closed, ND Highway 57 (BIA Highway 1 to US Highway 281) would experience changes in traffic as a detour routes are implemented.
- Feature 16: US Highway 281 (South of US Highway 2) – If ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is closed, US Highway 281 (South of US Highway 2) would experience increased traffic as a detour route.
- Feature 18: ND Highway 19 – If ND Highway 20 (City of Devils Lake Levee to ND Highway 57) is closed, ND Highway 19 would experience increased traffic as a detour route.
- Feature 24: BIA Highway 6 – Temporary closure of ND Highway 20 (City of Devils Lake Levee to ND Highway 57) will increase the amount of traffic on BIA Highway 6 as a detour route.

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.21.3 Feature Economics

Damages: For ND Highway 20 (City of Devils Lake Levee to ND Highway 57), the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) are summarized in the accompanying Table 2.21-1.

The detour damages for ND Highway 20 (City of Devils Lake Levee to ND Highway 57), assume that all other features are open, and traffic is routed around the lake if ND Highway 20 (City of

Devils Lake Levee to ND Highway 57) is temporarily closed. This was one of the four features in the Economics Analysis that was credited with the large detour damages around the lake (See discussion in Section 2.0.1.5). The computation of basin-wide damages required certain assumptions regarding interdependent roads in order to ensure that the basin-wide Economic Analysis was accurately representing overall traffic patterns.

The top portion of Table 2.21-1 gives a summary of the annual detour damages that would occur during the years when the highway was flooded. It also shows road restoration damages that can be expected when the lake recedes. Restoration damages include rebuilding the road with excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

The lower portion of the table shows the breakdown of these summary values for each of the three action levels. It gives quantities in terms of miles per year (of extra miles traveled as a result of detours) and hours per year (of additional travel time resulting from detours) for the detour damages. Also shown are quantities and line-item damages for excavation, fabric liner, aggregate base course, and fill for road restoration work when waters recede.

Unit prices for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) are listed in the Feature 21 Assumptions listing, appended to this Section 2.21.

Costs: The costs of providing flood protection for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) are detailed in the accompanying Table 2.21-2. Quantities and line-item totals are listed.

The top portion of the table gives the costs of providing flood protection (as represented in the analysis) by action level for all of the flood protection strategies. The lower portion of the table gives a breakdown of the quantities and costs by line item: fabric liner, aggregate base, fill, riprap, and bituminous pavement material.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for ND Highway 20 (City of Devils Lake Levee to ND Highway 57) are listed in the Feature 21 Assumptions listing, appended to this Section 2.21.

2.21.4 Results of Economic Analysis

The results of the Economic Analysis for the ND Highway 20 (City of Devils Lake Levee to ND Highway 57) are listed in Table 2.21-3.

Stochastic Analysis Results: The flood protection strategy that was analyzed for protecting ND Highway 20 (City of Devils Lake Levee to ND Highway 57) was two incremental road raises. This strategy is highlighted on the decision tree (Figure 2.21-2). The average annual net benefits for this strategy were greater than zero ($602,100). The BCR for this strategy was greater than one (6.64). These results indicate that this strategy was economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $694,900. The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For ND Highway 20 (City of Devils Lake Levee to ND Highway 57), the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, the annual net benefits were $6,820,000, and the BCR was 9.16, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $7,616,700.
- First Moderate Future – For the first moderate future, lake levels do not reach first damage levels.
- Second Moderate Future – For the second moderate future, the annual net benefits were $1,484,200, and the BCR was 5.59, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $1,738,400.

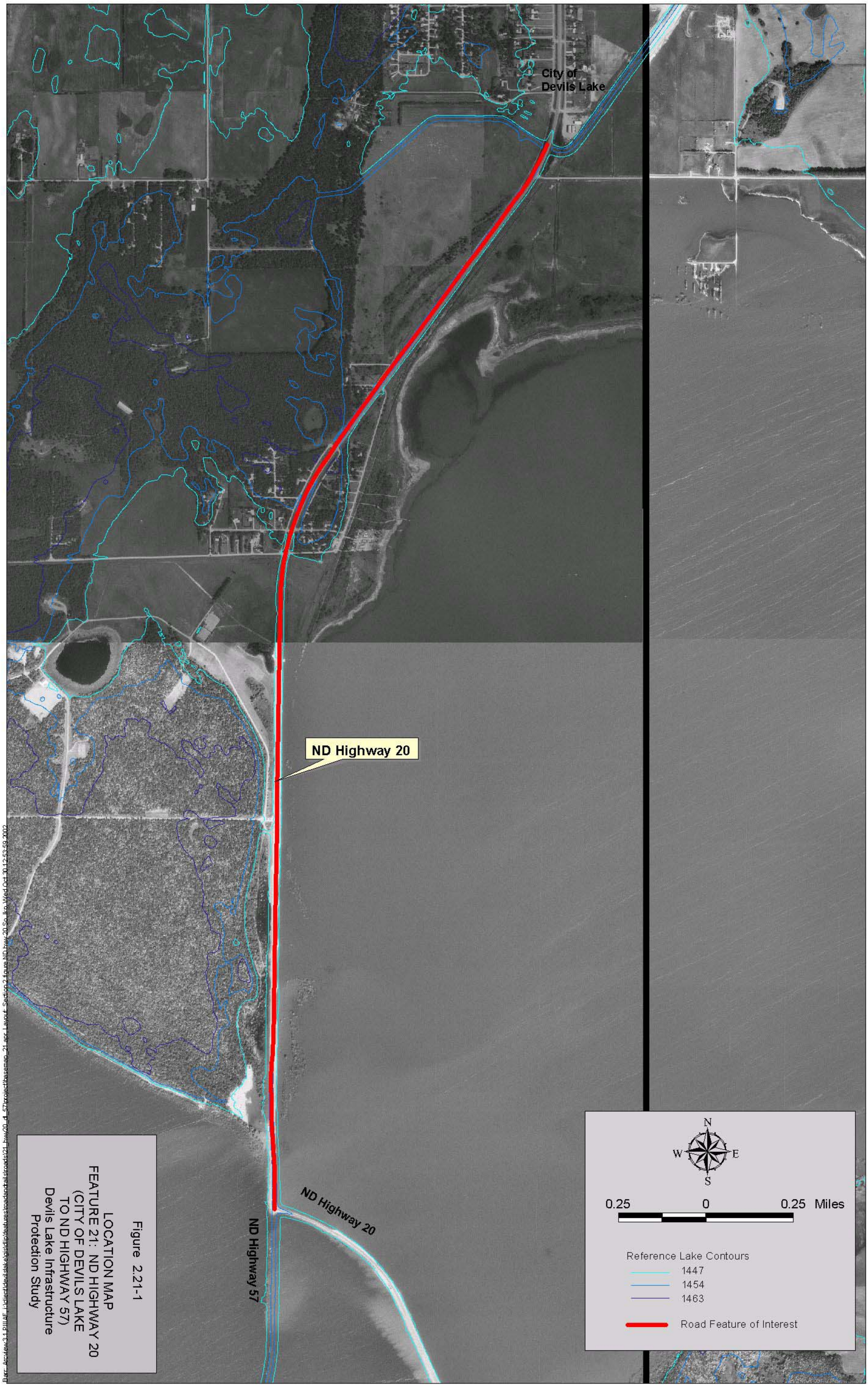
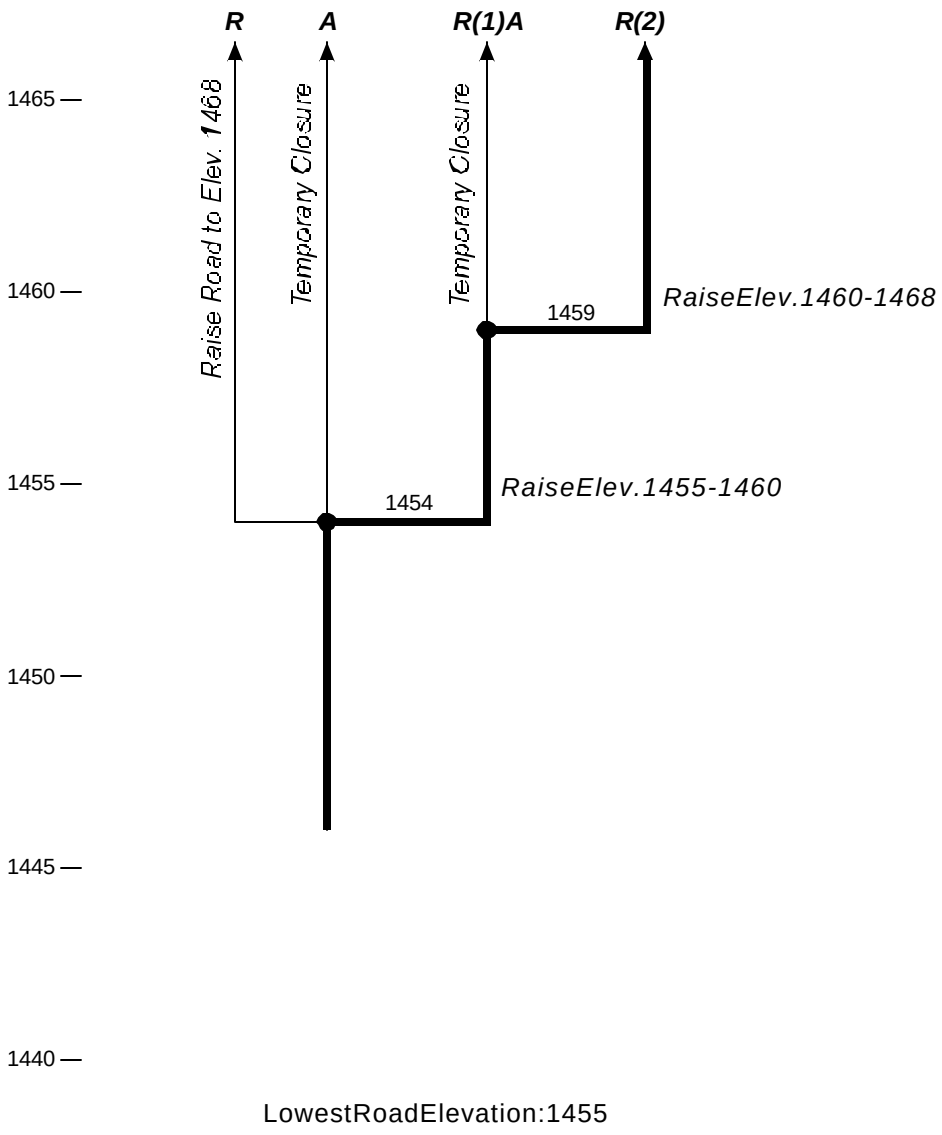


Figure 2.21-1

LOCATION MAP
FEATURE 21: ND HIGHWAY 20
(CITY OF DEVILS LAKE
TO ND HIGHWAY 57)
Devils Lake Infrastructure
Protection Study

DATA: 1997 USGS Digital Ortho Quad



FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1468

A Temporary closureofroad

Figure2.21-2

DECISION TREE
FEATURE 21:NDHIGHWAY20
(CityofDevilsLake Levee toNDHighway57)
DevilsLakeInfrastructure ProtectionStudy

P:\4036020\DECISIONTREES\2002FIGURES\FIGURE2_21.CDR RLG 01-02-03

Table 2.21-1

Flood Damages
Feature 21: ND Highway 20 (City of Devils Lake Levee to ND Highway 57)
Devils Lake Infrastructure Protection Study

DAMAGES

Action Levels	Annual Detour Damages (THOUSANDS)
AL1 - AL2	$13,104

DAMAGE BREAKDOWN

Damage	AL1 - AL2 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	ND HWY 20				
	HR/YEAR	532,687	HR	$7.00	$3,729
	MILES/YEAR	29,297,805	MILE	$0.32	$9,375
	Total				**$13,104**

Restoration Damages

Elevation	Total (THOUSANDS)	Excavation Quantity	Excavation Units	Excavation Unit Cost	Excavation Value (THOUSANDS)	Fabric Liner Quantity	Fabric Liner Units	Fabric Liner Unit Cost	Fabric Liner Value (THOUSANDS)	Aggregate Base Course Quantity	Aggregate Base Course Units	Aggregate Base Course Unit Cost	Aggregate Base Course Value (THOUSANDS)	Fill Quantity	Fill Units	Fill Unit Cost	Fill Value (THOUSANDS)	Bituminous Pavement Quantity	Bituminous Pavement Units	Bituminous Pavement Unit Cost	Bituminous Pavement Value (THOUSANDS)	Bridge Repair Quantity	Bridge Repair Units	Bridge Repair Unit Cost	Bridge Repair Cost (THOUSANDS)
1454	$0																								
1455	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1456	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1457	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1458	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1459	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1460	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1461	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1462	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0
1463	$2,949	82,200	CY	$2.65	$218	145,584	SY	$1.33	$194	17,696	CY	$21.20	$375	121,706	CY	$4.77	$581	33,154	TON	$47.70	$1,581	0	EA	$530,000	$0

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.21-2

Flood Protection Costs
Feature 21: ND Highway 20 (City of Devils Lake Levee to ND Highway 57)
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2) Raise at AL1, AL2
	(MSL)	(THOUSANDS)			
AL1	1454	$24,859	$0	$10,803	$10,803
AL2	1459	$0	$0	$0	$14,056

COST BREAKDOWN

		R									
		R(1)A									
		R(2)					R(2)				
		Lake Elevation 1454					Lake Elevation 1459				
Strategy		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Incremental Raise											
	Road Raise	ND Highway 20					ND Highway 20				
		Fabric Liner	222,881	SY	$1.33	$296	Fabric Liner	185,583	SY	$1.33	$247
		Aggregate Base	17,696	CY	$21.20	$375	Aggregate Base	0	CY	$21.20	$0
		Fill	452,861	CY	$9.00	$4,076	Fill	1,120,356	CY	$9.00	$10,083
		Riprap	149,148	CY	$30.00	$4,474	Riprap	124,189	CY	$30.00	$3,726
		Bituminous	33,154	TON	$47.70	$1,581	Bituminous	0	TON	$47.70	$0
		Bridge Rebuild	0	EA	$530,000	$0	Bridge Rebuild	0	EA	$530,000	$0
		Total				**$10,803**	**Total**				**$14,056**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. The costs for the Maximum Raise at AL1 strategy (R) is equal to the sum of the costs for all incremental raises.

Table 2.21 - 3

Economic Analysis of Strategies for Highway 20 from the City of Devils Lake Levee to Highway 57 (Feature 21)

Stochastic Analysis (ST)
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 Le	$0	$0	$0	$14,100	$694,900	$0	$709,000	$0	$0	--
R	Road Raise to 1468	$170,500	$0	$170,500	$0	$0	$0	$0	$709,000	$538,500	4.16
R(1)A	1 Road Raise: Then Temporary Closure During Flo	$74,100	$0	$74,100	$5,700	$162,800	$0	$168,500	$540,500	$466,300	7.29
R(2)	2 Incr. Road Raises	$106,800	$0	$106,800	$0	$0	$0	$0	$709,000	$602,100	6.64

Wet Future Scenario (WF)
(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 Le	$0	$0	$0	$38,500	########	$0	$7,655,300	$0	$0	--
R	Road Raise to 1468	########	$0	$1,012,700	$0	$0	$0	$0	$7,655,300	$6,642,600	7.56
R(1)A	1 Road Raise: Then Temporary Closure During Flo	$440,100	$0	$440,100	$42,000	########	$0	$3,261,300	$4,394,000	$3,953,900	9.98
R(2)	2 Incr. Road Raises	$835,300	$0	$835,300	$0	$0	$0	$0	$7,655,300	$6,820,000	9.16

Moderate Future 1 Scenario (M1)
(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 Le	$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 Flo	$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)
(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 Le	$0	$0	$0	$68,900	########	$0	$1,807,200	$0	$0	--
R	Road Raise to 1468	$743,500	$0	$743,500	$0	$0	$0	$0	$1,807,200	$1,063,700	2.43
R(1)A	1 Road Raise: Then Temporary Closure During Flo	$323,100	$0	$323,100	$0	$0	$0	$0	$1,807,200	$1,484,200	5.59
R(2)	2 Incr. Road Raises	$323,100	$0	$323,100	$0	$0	$0	$0	$1,807,200	$1,484,200	5.59

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% 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.

Attachment to 2.21:
ND Highway 20 (City of Devils Lake Levee to ND Highway 57) Economic Analysis Assumptions

No feature-specific assumptions were made for Feature 21.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been

   water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding, assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. There is more commitment on the part of the North Dakota Department of Transportation (NDDOT) to the Highway 57 causeway than to the Highway 20 causeway through The Narrows. Therefore, Highway 57 was assumed to be the detour route for the Highway 20 causeway. If the Highway 57 causeway was temporarily closed during flooding, it was assumed that the Highway 20 causeway would also be temporarily closed.

7. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

8. Detour paths were determined assuming that all other featured roads would be open (with three exceptions: the Highway 57 detour assumes that Highway 20 across The Narrows is closed and both the BIA 1 and the BIA 6 detours assume that Highway 20 from Highway 57 to Tokio is closed). No

effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an "interdependency" was noted.

9. The analysis of Features 23 (BIA 1 between Highway 57 and BIA 6) and Feature 24 (BIA 6 between Highway 20 and Fort Totten) assumed that Feature 22 (Highway 20 between Highway 57 and Tokio) is temporarily closed during high lake levels. BIA 1 and BIA 6 are part of the north-south detour for Highway 20 and the preliminary analysis indicated that Feature 22 would likely be temporarily closed during high lake levels.

10. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. There were no logical reroutes for this feature.

2.22 Summary of Economic Analysis Investigation for Feature 22: ND Highway 20 (ND Highway 57 to Tokio)

2.22.0 Flood Protection Strategy

The flood protection strategy that was analyzed in the Economic Analysis of Devils Lake Alternatives for ND Highway 20 (ND Highway 57 to Tokio) was incremental road raises.

2.22.1 General Information

Feature Type: Road

Location: ND Highway 20 (ND Highway 57 to Tokio) is located primarily in Mission Township, Benson County, on the Spirit Lake Nation Reservation. The northern portion of the feature is located in Creel South Township, Ramsey County. The feature extends 10.6 miles between ND Highway 57 at the northwest to the town of Tokio to the south. The accompanying Figure 2.22-1 shows the feature's location and extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: ND Highway 20 (ND Highway 57 to Tokio) is a two-lane bituminous-surfaced state highway. The centerline elevation varies from 1447.5 to 1495 near Tokio. Portions of this roadway are acting as dams (see analysis of Feature 25).

Significance: ND Highway 20 (ND Highway 57 to Tokio) is important because it is the major north/south arterial route through the Devils Lake region and it provides primary access across Devils Lake from the north to Mission Township and the eastern portion of the Spirit Lake Nation Reservation.

Damages: The flooding of ND Highway 20 (ND Highway 57 to Tokio) would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when ND Highway 20 (ND Highway 57 to Tokio) is closed and traffic is detoured
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation

Owner/Sponsor: The North Dakota Department of Transportation is responsible for managing and maintaining ND Highway 20 (ND Highway 57 to Tokio).

Lead Federal Agency: The Federal Highway Administration would take the lead for ND Highway 20 (ND Highway 57 to Tokio) in any flood protection work that may take place.

2.22.2 Feature Protection

History of Flood Protection: In the past, flood protection for ND Highway 20 (ND Highway 57 to Tokio) has consisted of raising the road to keep it from being overtopped. The most recent raise of ND Highway 20 occurred in 1999 when the road elevation was raised from 1448.5 to 1452.5 for 3.7 miles. The two raise locations were on the north and east side of Sections 3 and 4 and in Sections 26 and 35 in Mission Township.

In 1997, the Corps of Engineers constructed three emergency levees north and northeast of the east-west portion of ND Highway 20. These levees protect the 2,000-foot section of ND Highway 20 immediately west of the road's intersection with BIA Highway 9 that has a surface elevation at about 1445. The western-most of the three levees, constructed along a township road in Section 35 (T153N64W), was raised to 1447.6 in 1998. The other two levee sections, located in Section 35 (T153N64W) and Section 31 (T153N63W), were also raised in 1998 to 1449.

General Protection Strategy: The analysis identified and evaluated one approach for protecting ND Highway 20 (ND Highway 57 to Tokio): incremental road raises.

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives evaluated this protection strategy, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.22-2 shows the decision tree for ND Highway 20 (ND Highway 57 to Tokio). As shown on Figure 2.22-2, the stepwise approach to flood protection for ND Highway 20 (ND Highway 57 to Tokio) that was analyzed consisted of the following:

1. At lake elevation 1446.5, a decision would be made as to whether the road would be raised to 1452.5, or temporarily closed.

2. If the road were raised at the first action level, at lake elevation 1451.5 another decision would be made as to whether the road would be raised to 1457.5, or temporarily closed.

3. If the road were raised at the second action level, at lake elevation 1456.5 another decision would be made as to whether the road would be raised to 1462.5, or temporarily closed.

4. If the road were raised at the third action level, at lake elevation 1461.5 another decision would be made as to whether the road would be raised to 1468, or temporarily closed.

The maximum protection strategy that was analyzed at the first action level was raising the road to 1468. (Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of ND Highway 20 (ND Highway 57 to Tokio) is related to the protection of several other features:

- Feature 2: City of Devils Lake – ND Highway 20 is the main transportation route to the City of Devils Lake from the south. If ND Highway 20 (ND Highway 57 to Tokio) were temporarily closed, traffic into and out of the City of Devils Lake would be detoured.
- Feature 3: Fort Totten – ND Highway 20 (ND Highway 57 to Tokio) is one segment of a route between the City of Devils Lake and Fort Totten. Therefore, If ND Highway 20 (City of Devils Lake Levee to ND Highway 57) were temporarily closed, traffic between Fort Totten and the City of Devils Lake would be detoured.
- Feature 5: St. Michael – ND Highway 20 (ND Highway 57 to Tokio) is one segment of a route between the City of Devils Lake and St. Michael. Therefore, if ND Highway 20 (ND Highway 57 to Tokio) were temporarily closed, traffic between St. Michael and the City of Devils Lake would be detoured.
- Feature 15: ND Highway 57 (between BIA Highway 1 and US Highway 281) – If ND Highway 20 (ND Highway 57 to Tokio) is temporarily closed, traffic on ND Highway 57 would increase as a detour route.
- Feature 23: BIA Highway 1 – If ND Highway 20 (ND Highway 57 to Tokio) is temporarily closed, BIA Highway 1 becomes critical for carrying north-south traffic in the Devils Lake area.
- Feature 24: BIA Highway 6 – BIA Highway 6 shares a major intersection with ND Highway 20 (ND Highway 57 to Tokio), so traffic on BIA 6 will be impacted by decisions regarding ND Highway 20 (ND Highway 57 to Tokio).

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.22.3 Feature Economics

Damages: For ND Highway 20 (ND Highway 57 to Tokio), the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for ND Highway 20 (ND Highway 57 to Tokio) are summarized in the accompanying Table 2.22-1.

The top portion of Table 2.22-1 gives a summary of the annual detour damages that would occur during the years when the highway was flooded. It also shows road restoration damages that can be expected when the lake recedes. Restoration damages include rebuilding the road with

excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

The lower portion of the table shows the breakdown of these summary values for each of the three action levels. It gives quantities in terms of miles per year (of extra miles traveled as a result of detours) and hours per year (of additional travel time resulting from detours) for the detour damages. Also shown are quantities and line-item damages for excavation, fabric liner, aggregate base course, and fill for road restoration work when waters recede.

Unit prices for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for ND Highway 20 (ND Highway 57 to Tokio) are listed in the Feature 22 Assumptions listing, appended to this Section 2.22.

Costs: The costs of providing flood protection for ND Highway 20 (ND Highway 57 to Tokio) are detailed in the accompanying Table 2.22-2 for ND Highway 20 (ND Highway 57 to Tokio). Quantities and line-item totals are listed.

The top portion of the table gives the costs of providing flood protection (as represented in the analysis) by action level for all of the flood protection strategies. The lower portion of the table gives a breakdown of the quantities and costs by line item: fabric liner, aggregate base, fill, riprap, and bituminous pavement material.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for ND Highway 20 (ND Highway 57 to Tokio) are listed in the ND Highway 20 (ND Highway 57 to Tokio) Assumptions listing, appended to this Section 2.22.

2.22.4 Results of Economic Analysis

The results of the Economic Analysis for the ND Highway 20 (ND Highway 57 to Tokio) are listed in Table 2.22-3.

Stochastic Analysis Results: The flood protection strategy that was analyzed for protecting ND Highway 20 (ND Highway 57 to Tokio) was four incremental road raises. This strategy is highlighted on the decision tree (Figure 2.22-2). The average annual net benefits for this strategy were less than zero (-$1,273,600). The BCR for this strategy was less than one (0.35). These results indicate that this strategy was not economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $289,000. The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For ND Highway 20 (ND Highway 57 to Tokio), the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, the annual net benefits were -$3,053,800, and the BCR was 0.16, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $576,000.

- First Moderate Future – For the first moderate future, the annual net benefits were -$561,300, and the BCR was 0.64, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $294,500.

- Second Moderate Future – For the second moderate future, the annual net benefits were -$1,661,100, and the BCR was 0.26, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $496,500.

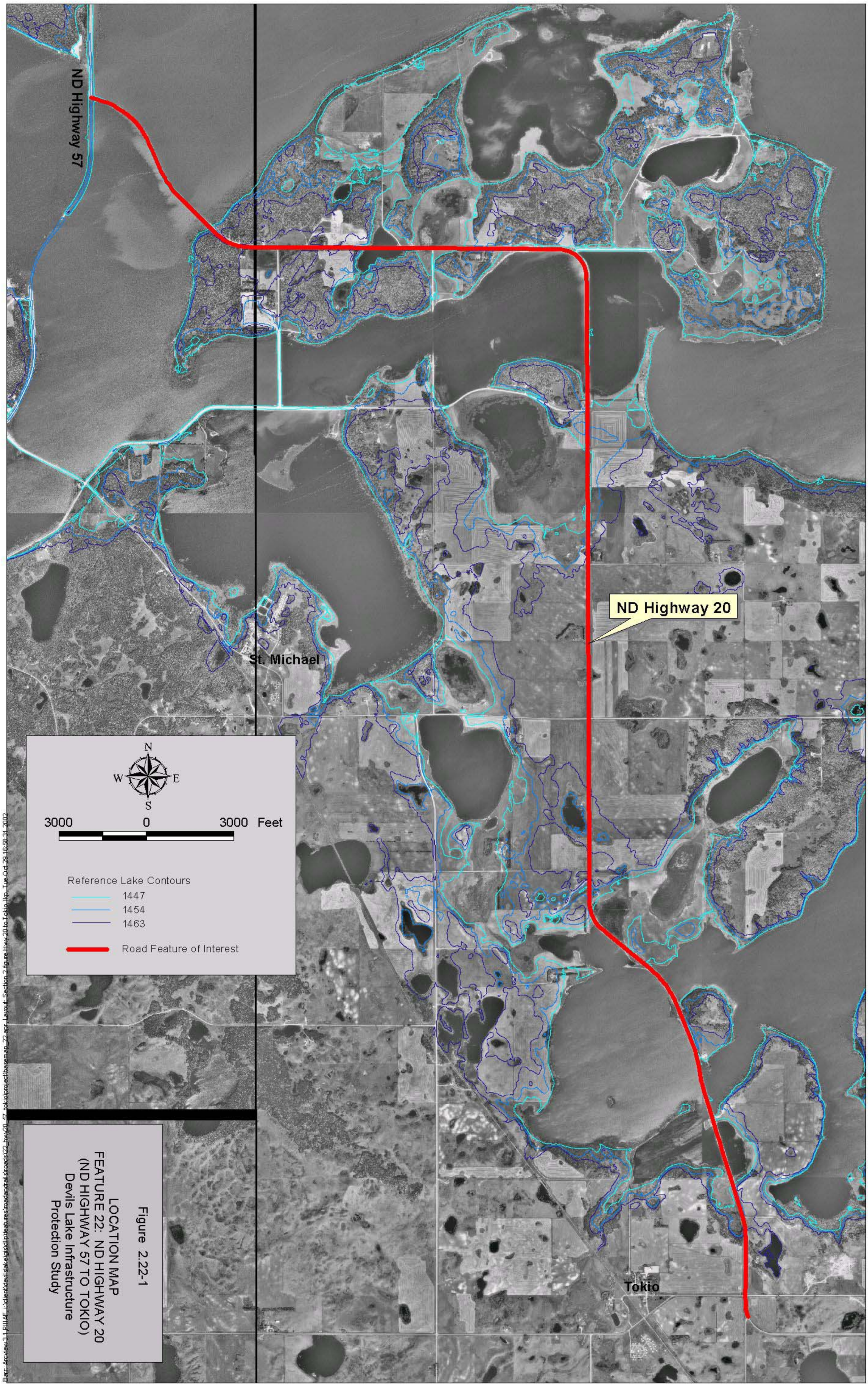
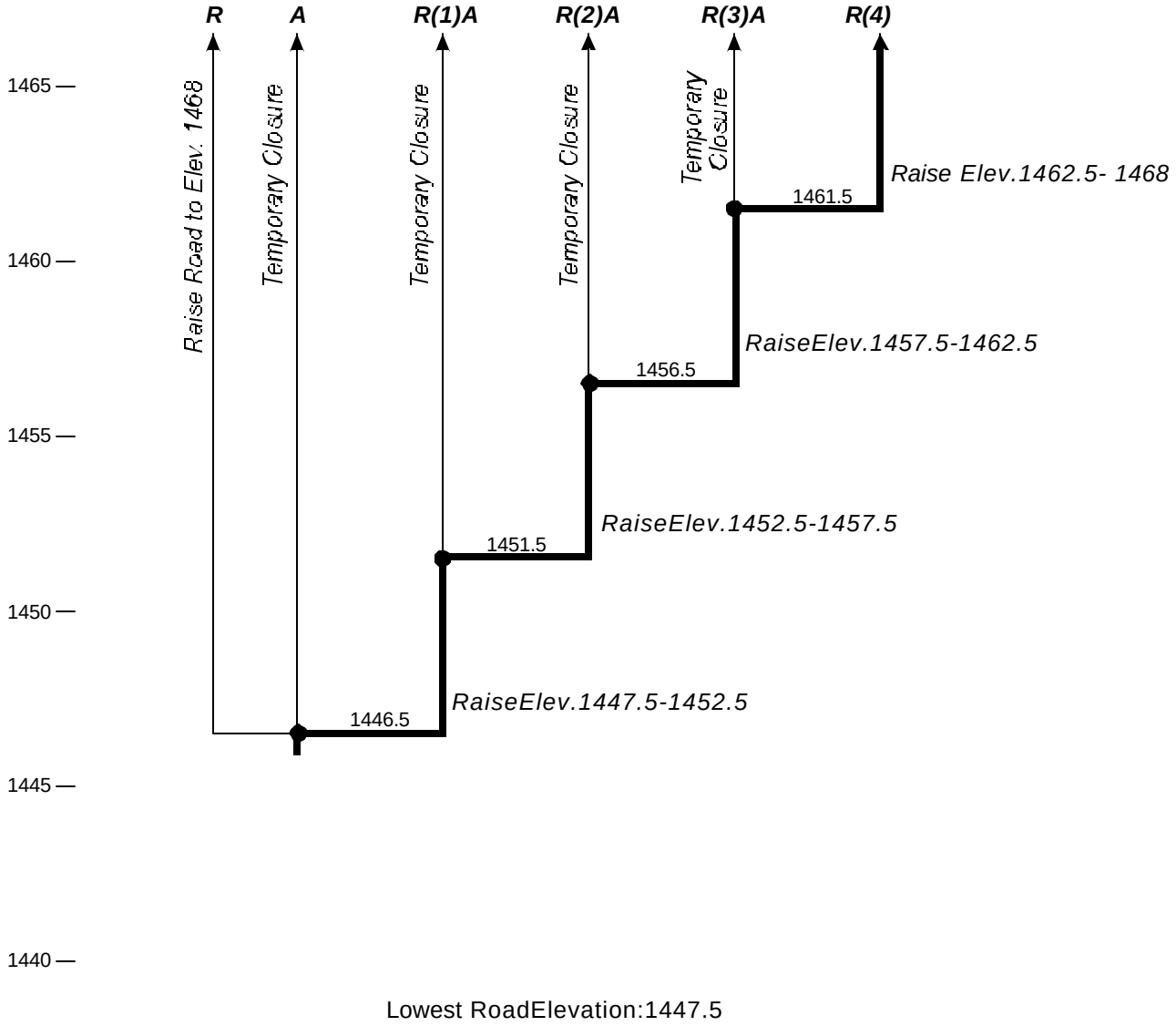


Figure 2.22-1

LOCATION MAP
FEATURE 22: ND HIGHWAY 20
(ND HIGHWAY 57 TO TOKIO)
Devils Lake Infrastructure
Protection Study

DATA: 1997 USGS Digital Ortho Quad



FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1468

A Temporary closureofroad

Figure2.22-2

DECISION TREE
FEATURE 22:NDHIGHWAY20
(NDHighway57toTokio)
DevilsLakeInfrastructure ProtectionStudy

P:\1036020\DECISIONTREES\2002FIGURES\FIGURE2_22.CDR RLG 01-02-03

Table 2.22-1

Flood Damages
Feature 22: ND Highway 20 (ND Highway 57 and Tokio)
Devils Lake Infrastructure Protection Study

DAMAGES

Action Levels	Annual Detour Damages (THOUSANDS)
AL1 - AL4	$576

DAMAGE BREAKDOWN

Damage	AL1 - AL4 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	HWY 20				
	HR/YEAR	23,406	HR	$7.00	$164
	MILES/YEAR	1,287,324	MILE	$0.32	$412
	Total				**$576**

Restoration Damages

Elevation	Total (THOUSANDS)	Excavation Quantity	Excavation Units	Excavation Unit Cost	Excavation Value (THOUSANDS)	Fabric Liner Quantity	Fabric Liner Units	Fabric Liner Unit Cost	Fabric Liner Value (THOUSANDS)	Aggregate Base Course Quantity	Aggregate Base Course Units	Aggregate Base Course Unit Cost	Aggregate Base Course Value (THOUSANDS)	Fill Quantity	Fill Units	Fill Unit Cost	Fill Value (THOUSANDS)	Bituminous Pavement Quantity	Bituminous Pavement Units	Bituminous Pavement Unit Cost	Bituminous Pavement Value (THOUSANDS)	Bridge Repair Quantity	Bridge Repair Units	Bridge Repair Unit Cost	Bridge Repair Cost (THOUSANDS)
1446	$0																								
1447	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1448	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1449	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1450	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1451	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1452	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1453	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1454	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1455	$6,836	190,560	CY	$2.65	$505	337,500	SY	$1.33	$449	41,023	CY	$21.20	$870	282,145	CY	$4.77	$1,346	76,859	TON	$47.70	$3,666	0	EA	$530,000	$0
1456	$8,084	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	0	EA	$530,000	$0
1457	$8,084	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	0	EA	$530,000	$0
1458	$8,084	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	0	EA	$530,000	$0
1459	$8,084	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	0	EA	$530,000	$0
1460	$8,084	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	0	EA	$530,000	$0
1461	$8,084	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	0	EA	$530,000	$0
1462	$8,614	225,360	CY	$2.65	$597	399,134	SY	$1.33	$531	48,515	CY	$21.20	$1,029	333,670	CY	$4.77	$1,592	90,895	TON	$47.70	$4,336	1	EA	$530,000	$530

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.22-2

Flood Protection Costs
Feature 22: ND Highway 20 (ND Highway 57 to Tokio)
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2)A Raise at AL1, AL2; Temporary Closure at AL3	R(3)A Raise at AL1, AL2, AL3; Temporary Closure at AL4	R(4) Raise at AL1, AL2, AL3, AL4
		(THOUSANDS)					
AL1	1446	$110,322	$0	$25,045	$25,045	$5,119	$5,119
AL2	1451	$0	$0	$0	$22,269	$4,607	$4,607
AL3	1456	$0	$0	$0	$0	$26,814	$26,814
AL4	1461	$0	$0	$0	$0	$0	$36,194

COST BREAKDOWN

Strategy		R																			
		R(1)A																			
		R(2)A					R(2)A														
		R(3)A					R(3)A					R(3)A									
		R(4)A					R(4)A					R(4)A					R(4)A				
		Lake Elevation 1446					Lake Elevation 1451					Lake Elevation 1456					Lake Elevation 1461				
Incremental Raise		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
	Road Raise	ND Highway 20					ND Highway 20					ND Highway 20					ND Highway 20				
		Fabric Liner	516,693	SY	$1.33	$687	Fabric Liner	338,699	SY	$1.33	$450	Fabric Liner	317,998	SY	$1.33	$423	Fabric Liner	380,381	SY	$1.33	$506
		Aggregate Ba	41,023	CY	$21.20	$870	Aggregate Base	7,492	CY	$21.20	$159	Aggregate Base	0	CY	$21.20	$0	Aggregate Base	3,531	CY	$21.20	$75
		Fill	1,049,844	CY	$9.00	$9,449	Fill	1,576,747	CY	$9.00	$14,191	Fill	2,164,067	CY	$9.00	$19,477	Fill	3,014,584	CY	$9.00	$27,131
		Riprap	345,762	TON	$30.00	$10,373	Riprap	226,652	TON	$30.00	$6,800	Riprap	212,799	TON	$30.00	$6,384	Riprap	254,544	TON	$30.00	$7,636
		Bituminous	76,859	TON	$47.70	$3,666	Bituminous	14,036	TON	$47.70	$670	Bituminous	0	TON	$47.70	$0	Bituminous	6,615	TON	$47.70	$316
		Bridge Repair	0	EA	$530,000	$0	Bridge Repair	0	EA	$530,000	$0	Bridge Repair	1	EA	$530,000	$530	Bridge Repair	1	EA	$530,000	$530
		Subtotal				$25,045	Subtotal				$22,269	Subtotal				$26,814	Subtotal				$36,194
		Total				**$25,045**	**Total**				**$22,269**	**Total**				**$26,814**	**Total**				**$36,194**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. The costs for the Maximum Raise at AL1 strategy (R) is equal to the sum of the costs for all incremental raises.

Table 2.22 - 3

Economic Analysis of Strategies for Highway 20 between Highway 57 and Tokio (Feature 22)

Stochastic Analysis (ST)
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 Lev	$0	$0	$0	$407,700	#######	$0	$696,700	$0	$0	--
R	Road Raise to 1468	########	$0	$6,926,700	$0	$0	$0	$0	$696,700	-$6,230,000	0.10
R(1)A	1 Road Raise: Then Temporary Closure During Floo	########	$0	$1,572,500	$61,800	$55,000	$0	$116,700	$580,000	-$992,500	0.37
R(2)A	2 Road Raises: Then Temporary Closure During Floo	########	$0	$1,832,200	$24,200	$16,200	$0	$40,400	$656,300	-$1,176,000	0.36
R(3)A	3 Road Raises: Then Temporary Closure During Floo	########	$0	$1,941,400	$5,300	$1,300	$0	$6,700	$690,100	-$1,251,400	0.36
R(4)	4 Incr. Road Raises	########	$0	$1,970,300	$0	$0	$0	$0	$696,700	-$1,273,600	0.35

Wet Future Scenario (WF)
(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 Lev	$0	$0	$0	$0	#######	$0	$576,000	$0	$0	--
R	Road Raise to 1468	########	$0	$6,926,700	$0	$0	$0	$0	$576,000	-$6,350,700	0.08
R(1)A	1 Road Raise: Then Temporary Closure During Floo	########	$0	$1,572,500	$99,300	#######	$0	$533,400	$42,600	-$1,529,900	0.03
R(2)A	2 Road Raises: Then Temporary Closure During Floo	########	$0	$2,664,500	$125,600	#######	$0	$385,400	$190,500	-$2,473,900	0.07
R(3)A	3 Road Raises: Then Temporary Closure During Floo	########	$0	$3,629,800	$0	$0	$0	$0	$576,000	-$3,053,800	0.16
R(4)	4 Incr. Road Raises	########	$0	$3,629,800	$0	$0	$0	$0	$576,000	-$3,053,800	0.16

Moderate Future 1 Scenario (M1)
(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 Lev	$0	$0	$0	$716,600	#######	$0	$1,011,200	$0	$0	--
R	Road Raise to 1468	########	$0	$6,926,700	$0	$0	$0	$0	$1,011,200	-$5,915,500	0.15
R(1)A	1 Road Raise: Then Temporary Closure During Floo	########	$0	$1,572,500	$0	$0	$0	$0	$1,011,200	-$561,300	0.64
R(2)A	2 Road Raises: Then Temporary Closure During Floo	########	$0	$1,572,500	$0	$0	$0	$0	$1,011,200	-$561,300	0.64
R(3)A	3 Road Raises: Then Temporary Closure During Floo	########	$0	$1,572,500	$0	$0	$0	$0	$1,011,200	-$561,300	0.64
R(4)	4 Incr. Road Raises	########	$0	$1,572,500	$0	$0	$0	$0	$1,011,200	-$561,300	0.64

Moderate Future 2 Scenario (M2)
(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 Lev	$0	$0	$0	$80,900	#######	$0	$577,500	$0	$0	--
R	Road Raise to 1468	########	$0	$6,926,700	$0	$0	$0	$0	$577,500	-$6,349,300	0.08
R(1)A	1 Road Raise: Then Temporary Closure During Floo	########	$0	$1,572,500	$150,100	$89,000	$0	$239,200	$338,300	-$1,234,200	0.22
R(2)A	2 Road Raises: Then Temporary Closure During Floo	########	$0	$2,238,500	$0	$0	$0	$0	$577,500	-$1,661,100	0.26
R(3)A	3 Road Raises: Then Temporary Closure During Floo	########	$0	$2,238,500	$0	$0	$0	$0	$577,500	-$1,661,100	0.26
R(4)	4 Incr. Road Raises	########	$0	$2,238,500	$0	$0	$0	$0	$577,500	-$1,661,100	0.26

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% 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.

Attachment to 2.22:
ND Highway 20 (ND Highway 57 to Tokio) Economic Analysis Assumptions

1. Plans for 2001 include raising portions of Highway 20 from a minimum elevation of 1447.5 to 1455 and the bridge across Devils Lake from 1443.5 to 1461 (low chord). For this analysis, the work was assumed completed and the new elevations were used.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been available until the National Weather Service predicts on February 15th that the road will go under water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the
Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding,

assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. There is more commitment on the part of the North Dakota Department of Transportation (NDDOT) to the Highway 57 causeway than to the Highway 20 causeway through The Narrows. Therefore, Highway 57 was assumed to be the detour route for the Highway 20 causeway. If the Highway 57 causeway was temporarily closed during flooding, it was assumed that the Highway 20 causeway would also be temporarily closed.

7. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

8. Detour paths were determined assuming that all other featured roads would be open (with three exceptions: the Highway 57 detour assumes that Highway 20 across The Narrows is closed and both

the BIA 1 and the BIA 6 detours assume that Highway 20 from Highway 57 to Tokio is closed). No effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an "interdependency" was noted.

9. The analysis of Features 23 (BIA 1 between Highway 57 and BIA 6) and Feature 24 (BIA 6 between Highway 20 and Fort Totten) assumed that Feature 22 (Highway 20 between Highway 57 and Tokio) is temporarily closed during high lake levels. BIA 1 and BIA 6 are part of the north-south detour for Highway 20 and the preliminary analysis indicated that Feature 22 would likely be temporarily closed during high lake levels.

10. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. No logical reroute was identified for this feature.

2.23 Summary of Economic Analysis Investigation for Feature 23: BIA Highway 1

2.23.0 Flood Protection Strategy

The flood protection strategy that was analyzed in the Economic Analysis of Devils Lake Alternatives for BIA Highway 1 was incremental road raises.

2.23.1 General Information

Feature Type: Road

Location: BIA Highway 1 is located in Sections 7, 8, and 17 of Mission Township, Benson County and on the Spirit Lake Nation Reservation. The feature extends 2.72 miles between ND Highway 57 at the northwest to Highway BIA 6 to the southeast. The accompanying Figure 2.23-1 shows the feature's location and extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: BIA Highway 1 is a two-lane bituminous-surfaced federal highway. The centerline elevation varies from 1450.5 to 1487.5, and crosses Mission Bay (a portion of Devils Lake) at its northwest end. A portion of the roadway is currently acting as a dam (see analysis of Feature 25).

Significance: BIA Highway 1 is important because it is the major northbound and southbound route to and from the town of St. Michael and surrounding areas.

Damages: The flooding of BIA Highway 1 would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when BIA Highway 1 is closed and traffic is detoured
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation

Owner/Sponsor: The US Department of Interior, Bureau of Indian Affairs, is responsible for managing and maintaining BIA Highway 1.

Lead Federal Agency: The Bureau of Indian Affairs would take the lead for BIA Highway 1 in any flood protection work that may take place.

2.23.2 Feature Protection

History of Flood Protection: In the past, flood protection for BIA Highway 1 has consisted of raising the road to keep it from being overtopped.

General Protection Strategy: The analysis identified and evaluated one approach for protecting BIA Highway 1: incremental road raises.

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives evaluated this protection strategies, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.23-2 shows the decision tree for BIA Highway 1. As shown on Figure 2.23-2, the stepwise approach to flood protection for BIA Highway 1 that was analyzed consisted of the following:

1. At lake elevation 1449.5, a decision would be made as to whether the road would be raised to 1455.5, or temporarily closed.

2. If the road were raised at the first action level, at lake elevation 1454.5 another decision would be made as to whether the road would be raised to 1460.5, or temporarily closed.

3. If the road were raised at the second action level, at lake elevation 1459.5 another decision would be made as to whether the road would be raised to 1468, or temporarily closed.

The maximum protection strategy that was analyzed at the first action level was raising the road to 1468. (Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of BIA Highway 1 is related to the protection of several other features:

- Feature 5: St. Michael – BIA Highway 1 is the major road for traffic entering or leaving St. Michael. Therefore, decisions regarding flood protection in St. Michael are dependent on flood protection for BIA Highway 1.

- Feature 22: ND Highway 20 (ND Highway 57 to Tokio) – If ND Highway 20 (ND Highway 57 to Tokio) is temporarily closed, BIA Highway 1 becomes critical for carrying north-south traffic in the Devils Lake area.

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.23.3 Feature Economics

Damages: For BIA Highway 1, the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for BIA Highway 1 are summarized in the accompanying Table 2.23-1.

The top portion of Table 2.23-1 gives a summary of the annual detour damages that would occur during the years when the highway was flooded. It also shows road restoration damages that can be expected when the lake recedes. Restoration damages include rebuilding the road with excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

The lower portion of the table shows the breakdown of these summary values for each of the three action levels. It gives quantities in terms of miles per year (of extra miles traveled as a result of detours) and hours per year (of additional travel time resulting from detours) for the detour damages. Also shown are quantities and line-item damages for excavation, fabric liner, aggregate base course, and fill for road restoration work when waters recede.

Unit prices for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for BIA Highway 1 are listed in the BIA Highway 1 Assumptions listing, appended to this Section 2.23.

Costs: The costs of providing flood protection for BIA Highway 1 are detailed in the accompanying Table 2.23-2 for BIA Highway 1. Quantities and line-item totals are listed.

The top portion of the table gives the costs of providing flood protection (as represented in the analysis) by action level for all of the five flood protection strategies. The lower portion of the table gives a breakdown of the quantities and costs by line item: fabric liner, aggregate base, fill, riprap, and bituminous pavement material.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for BIA Highway 1 are listed in the BIA Highway 1 Assumptions listing, appended to this Section 2.23.

2.23.4 Results of Economic Analysis

The results of the Economic Analysis for the BIA Highway 1 are listed in Table 2.23-3.

Stochastic Analysis Results: The flood protection strategy that was analyzed for protecting BIA Highway 1 was three incremental road raises. This strategy is highlighted on the decision tree (Figure 2.23-2). The average annual net benefits for this strategy were greater than zero ($14,400). The BCR for this strategy was greater than one (1.09). These results indicate that this strategy was economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $158,600. The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For BIA Highway 1, the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, the annual net benefits were $136,900, and the BCR was 1.20, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $838,700.

- First Moderate Future – For the first moderate future, the annual net benefits were -$72,200, and the BCR was 0.50, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $52,100.

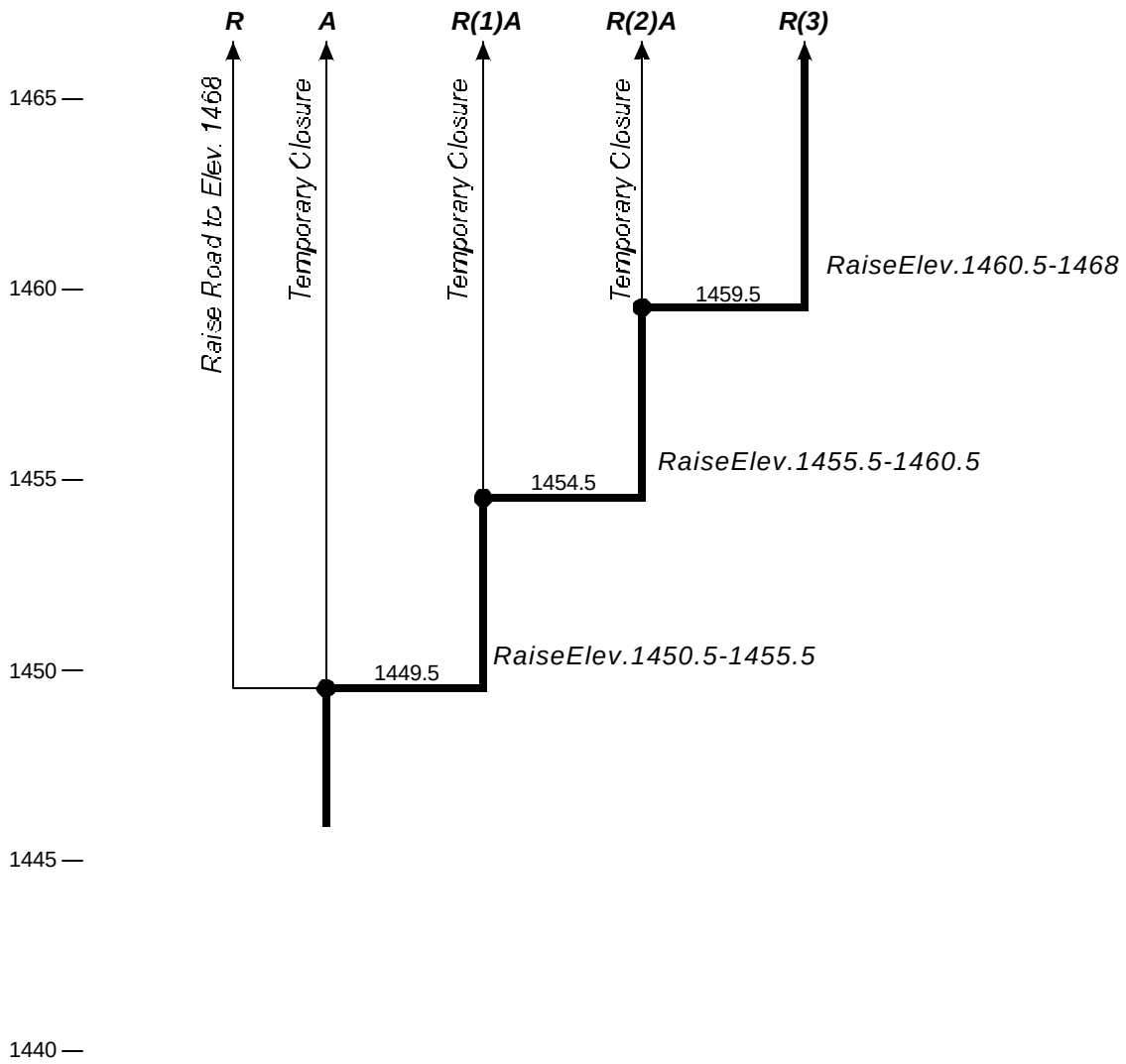
- Second Moderate Future – For the second moderate future, the annual net benefits were $92,800, and the BCR was 1.25, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $443,900.

Figure 2.23-1

LOCATION MAP
FEATURE 23: BIA HIGHWAY 1
Devils Lake Infrastructure
Protection Study

Barr: Arcview 3.1, PIII/AF, j:\client\devilslake\gis\dlip\features\roadandrail\roads\23_bia1\project\basemap_23.apr, Layout: Layout: Section 2 Figure, lkp, Tue Oct 29 17:16:13 2002

Data: 1997 USGS Digital Ortho Quad



Lowest RoadElevation:1450.5

FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1468

A Temporary closureofroad

Figure2.23-2

DECISION TREE
FEATURE 23:BIAHIGHWAY1
DevilsLakeInfrastructure ProtectionStudy

Table 2.23-1

Flood Damages
Feature 23: BIA Highway 1
Devils Lake Infrastructure Protection Study

DAMAGES

Action Levels	Annual Detour Damages	Restoration Damages
	(THOUSANDS)	
AL1 - AL3	$955	$742

DAMAGE BREAKDOWN

Damage	AL1 - AL3 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	BIA Highway 1				
	HR/YEAR	38,756	HR	$7.00	$271
	MILES/YEAR	2,131,593	MILE	$0.32	$682
	Total				$953
	2001 Adjusted Total				**$955**
Restoration Damages	BIA Highway 1				
	Excavation	44,645	CY	$2.65	$118
	Fabric Liner	79,423	SY	$1.33	$106
	Aggregate Base Course	9,567	CY	$21.20	$203
	Fill	35,078	CY	$9.00	$316
	Total				**$742**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. 2001 Adjusted Total adjusts detailed damage breakdown to match the 2001 totals.

Table 2.23-2

Flood Protection Costs
Feature 23: BIA Highway 1
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2)A Raise at AL1, AL2; Temporary Closure at AL3	R(3) Raise at AL1, AL2, AL3
	(MSL)	(THOUSANDS)				
AL1	1449	$18,430	$0	$5,119	$5,119	$5,119
AL2	1454	$0	$0	$0	$4,607	$4,607
AL3	1459	$0	$0	$0	$0	$8,704

COST BREAKDOWN

Strategy		R														
		R(1)A														
		R(2)A					R(2)A									
		R(3)A					R(3)A					R(3)A				
		Lake Elevation 1449					Lake Elevation 1454					Lake Elevation 1459				
Incremental Raise		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
	Road Raise	BIA Highway 1					BIA Highway 1					BIA Highway 1				
		Fabric Liner	124,633	SY	$1.33	$166	Fabric Liner	65,493	SY	$1.33	$87	Fabric Liner	98,241	SY	$1.33	$131
		Aggregate Bas	9,567	CY	$21.20	$203	Aggregate Base	0	CY	$21.20	$0	Aggregate Base	0	CY	$21.20	$0
		Fill	249,796	CY	$9.00	$2,248	Fill	356,093	CY	$9.00	$3,205	Fill	733,444	CY	$9.00	$6,601
		Riprap	83,402	TON	$30.00	$2,502	Riprap	43,827	TON	$30.00	$1,315	Riprap	65,741	TON	$30.00	$1,972
		Bituminous	0	TON	$47.70	$0	Bituminous	0	TON	$47.70	$0	Bituminous	0	TON	$47.70	$0
		Subtotal				$5,119	Subtotal				$4,607	Subtotal				$8,704
		Total				**$5,119**	**Total**				**$4,607**	**Total**				**$8,704**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. The costs for the Maximum Raise at AL1 strategy (R) is equal to the sum of the costs for all incremental raises.

Table 2.23 - 3

Economic Analysis of Strategies for BIA 1 between Highway 57 and BIA 6

(Feature 23)

Stochastic Analysis (ST)
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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$13,800	#######	$0	$172,400	$0	$0	--
R	Road Raise to 1468	$404,400	$0	$404,400	$0	$0	$0	$0	$172,400	-$232,000	0.43
R(1)A	1 Road Raise: Then Temporary Closure During F	$112,300	$0	$112,300	$3,100	$44,700	$0	$47,900	$124,500	$12,200	1.11
R(2)A	2 Road Raises: Then Temporary Closure During	$140,500	$0	$140,500	$1,300	$9,300	$0	$10,600	$161,800	$21,300	1.15
R(3)	3 Incr. Road Raises	$158,000	$0	$158,000	$0	$0	$0	$0	$172,400	$14,400	1.09

Wet Future Scenario (WF)
(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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$0	#######	$0	$838,700	$0	$0	--
R	Road Raise to 1468	########	$0	$1,022,500	$0	$0	$0	$0	$838,700	-$183,900	0.82
R(1)A	1 Road Raise: Then Temporary Closure During F	$284,100	$0	$284,100	$10,300	#######	$0	$552,900	$285,700	$1,700	1.01
R(2)A	2 Road Raises: Then Temporary Closure During	$471,700	$0	$471,700	$10,600	#######	$0	$218,300	$620,300	$148,600	1.32
R(3)	3 Incr. Road Raises	$701,800	$0	$701,800	$0	$0	$0	$0	$838,700	$136,900	1.20

Moderate Future 1 Scenario (M1)
(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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$19,600	$52,100	$0	$71,700	$0	$0	--
R	Road Raise to 1468	$518,100	$0	$518,100	$0	$0	$0	$0	$71,700	-$446,400	0.14
R(1)A	1 Road Raise: Then Temporary Closure During F	$143,900	$0	$143,900	$0	$0	$0	$0	$71,700	-$72,200	0.50
R(2)A	2 Road Raises: Then Temporary Closure During	$143,900	$0	$143,900	$0	$0	$0	$0	$71,700	-$72,200	0.50
R(3)	3 Incr. Road Raises	$143,900	$0	$143,900	$0	$0	$0	$0	$71,700	-$72,200	0.50

Moderate Future 2 Scenario (M2)
(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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$14,400	#######	$0	$458,200	$0	$0	--
R	Road Raise to 1468	$849,500	$0	$849,500	$0	$0	$0	$0	$458,200	-$391,200	0.54
R(1)A	1 Road Raise: Then Temporary Closure During F	$236,000	$0	$236,000	$19,600	$52,100	$0	$71,700	$386,600	$150,600	1.64
R(2)A	2 Road Raises: Then Temporary Closure During	$365,500	$0	$365,500	$0	$0	$0	$0	$458,200	$92,800	1.25
R(3)	3 Incr. Road Raises	$365,500	$0	$365,500	$0	$0	$0	$0	$458,200	$92,800	1.25

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% 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.

Attachment to 2.23:
BIA Highway 1 Economic Analysis Assumptions

No feature-specific assumptions were made for Feature 23.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been available until the National Weather Service predicts on February 15th that the road will go under water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

4. Bureau of Indian Affairs (BIA) roads were assumed to be raised in 5-foot increments (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998).

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding,

assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. There is more commitment on the part of the North Dakota Department of Transportation (NDDOT) to the Highway 57 causeway than to the Highway 20 causeway through The Narrows. Therefore, Highway 57 was assumed to be the detour route for the Highway 20 causeway. If the Highway 57 causeway was temporarily closed during flooding, it was assumed that the Highway 20 causeway would also be temporarily closed.

7. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

8. Detour paths were determined assuming that all other featured roads would be open (with three exceptions: the Highway 57 detour assumes that Highway 20 across The Narrows is closed and both

the BIA 1 and the BIA 6 detours assume that Highway 20 from Highway 57 to Tokio is closed). No effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an "interdependency" was noted.

9. The analysis of Features 23 (BIA 1 between Highway 57 and BIA 6) and Feature 24 (BIA 6 between Highway 20 and Fort Totten) assumed that Feature 22 (Highway 20 between Highway 57 and Tokio) is temporarily closed during high lake levels. BIA 1 and BIA 6 are part of the north-south detour for Highway 20 and the preliminary analysis indicated that Feature 22 would likely be temporarily closed during high lake levels.

10. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. No logical reroute was identified for Feature 23.

2.24 Summary of Economic Analysis Investigation for Feature 24: BIA Highway 6

2.24.0 Flood Protection Strategy

The flood protection strategy that was analyzed in the Economic Analysis of Devils Lake Alternatives for BIA Highway 6 was incremental road raises.

2.24.1 General Information

Feature Type: Road

Location: Feature 24 is the 9-mile portion of BIA Highway 6 between Fort Totten at the west and ND Highway 20 at the east, and is located in Mission Township, Benson County. The accompanying Figure 2.24-1 shows the feature's location and approximate extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: BIA Highway 6 is a two-lane bituminous-surfaced federal highway. The centerline elevation varies from 1625.0 just east of Fort Totten to 1444 just west of ND Highway 20. BIA Highway 6 is currently being protected by roads that are acting as dams (see analysis of Feature 25).

Significance: BIA Highway 6 is important because it is a major traffic route in the area, including the main route between Fort Totten and St. Michael.

Damages: The flooding of BIA Highway 6 would result in the following damages:

- Detour damages resulting from the added travel time and miles traveled when BIA Highway 6 is closed and traffic is detoured. The detour damages for BIA Highway 6 assume that ND Highway 57 and ND Highway 20 are closed, and traffic is routed around the lake (for further description, see Section 2.24.3).
- Restoration damages resulting from repairs that would be necessary to bring the highway back to a useable condition after a period of inundation.

Owner/Sponsor: The US Department of Interior, Bureau of Indian Affairs, is responsible for managing and maintaining BIA Highway 6.

Lead Federal Agency: The Bureau of Indian Affairs would take the lead for BIA Highway 6 in any flood protection work that may take place.

2.24.2 Feature Protection

History of Flood Protection: No direct flood protection measures have been implemented for BIA Highway 6.

General Protection Strategy: The analysis identified and evaluated one approach for protecting BIA Highway 6: incremental road raises.

Protection Strategy by Lake Level: The Economic Analysis of Devils Lake Alternatives evaluated this protection strategy, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.24-2 shows the decision tree for BIA Highway 6. As shown on Figure 2.24-2, the stepwise approach to flood protection for BIA Highway 6 that was analyzed consisted of the following:

1. When the interior water elevation behind the roads acting as dams rises to 1443 (or are no longer protecting this feature), a decision would be made as to whether the road would be raised to 1449, or temporarily closed.

2. If the road were raised at the first action level, at lake elevation 1448 another decision would be made as to whether the road would be raised to 1454, or temporarily closed.

3. If the road were raised at the second action level, at lake elevation 1453 another decision would be made as to whether the road would be raised to 1459, or temporarily closed.

4. If the road were raised at the third action level, at lake elevation 1458 another decision would be made as to whether the road would be raised to 1464, or temporarily closed.

5. If the road were raised at the fourth action level, at lake elevation 1463 another decision would be made as to whether the road would be raised to 1468, or temporarily closed.

The maximum protection strategy that was analyzed at the first action level was raising the road to 1468. (Note that for the analysis, the decision regarding whether or not to raise the road is made at a time when the lake is one foot below the minimum highway elevation that resulted from the most recent raise.)

Interdependencies: The protection of BIA Highway 6 is related to the protection of several other features:

- Feature 3: Fort Totten – BIA Highway 6 is a major road for traffic entering or leaving Fort Totten. Therefore, decisions regarding flood protection in Fort Totten are dependent on flood protection for BIA Highway 6.

- Feature 5: St. Michael – The BIA Highway 6 connection with BIA Highway 1 provides a major route for traffic entering or leaving St. Michael. Therefore, decisions regarding flood protection in St. Michael are dependent on flood protection for BIA Highway 6.
- Feature 13: US Highway 2 – If US Highway 2 is temporarily closed, traffic on BIA Highway 6 may increase as a detour route.
- Feature 14: ND Highway 57 (between ND Highway 20 and BIA Highway 1) – If ND Highway 57 is temporarily closed, traffic on BIA Highway 6 would increase as a detour route.
- Feature 15: ND Highway 57 (between BIA Highway 1 and US Highway 281) – If ND Highway 57 is temporarily closed, traffic on BIA Highway 6 would increase as a detour route.
- Feature 16: US Highway 281 (South of US Highway 2) – If US Highway 281 is temporarily closed, traffic on BIA Highway 6 would increase as a detour route.
- Feature 21: ND Highway 20 (City of Devils Lake Levee to ND Highway 27) – If ND Highway 20 is temporarily closed, BIA Highway 6 becomes critical for carrying north-south traffic in the Devils Lake area.
- Feature 22: ND Highway 20 (ND Highway 57 to Tokio) – If ND Highway 20 is temporarily closed, BIA Highway 6 becomes critical for carrying north-south traffic in the Devils Lake area.

Table 2.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

2.24.3 Feature Economics

Damages: For BIA Highway 6, the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for BIA Highway 6 are summarized in the accompanying Table 2.24-1.

The top portion of Table 2.24-1 gives a summary of the annual detour damages that would occur during the years when the highway was flooded. It also shows road restoration damages that can be expected when the lake recedes. Restoration damages include rebuilding the road with excavation, fill, surface material, and bridge repairs. Restoration damages are a per-event damage.

The detour damages for BIA Highway 6 assume that Feature 22, ND Highway 20 (ND Highway 57 to Tokio), is closed, and traffic is routed around the lake if BIA Highway 6 is temporarily

closed. This was one of the four features in the Economics Analysis that was credited with the large detour damages around the lake (See discussion in Section 2.0.1.5). The computation of basin-wide damages required certain assumptions regarding interdependent roads in order to ensure that the basin-wide Economic Analysis was accurately representing overall traffic patterns. BIA Highway 6 was assigned the large detour damages because the roadway was less expensive to raise than ND Highway 20, and temporary closure of both segments would cause large detours.

The lower portion of the table shows the breakdown of these summary values for each of the three action levels. It gives quantities in terms of miles per year (of extra miles traveled as a result of detours) and hours per year (of additional travel time resulting from detours) for the detour damages. Also shown are quantities and line-item damages for excavation, fabric liner, aggregate base course, and fill for road restoration work when waters recede.

Unit prices for all the damage computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for BIA Highway 6 are listed in the Feature 24 Assumptions listing, appended to this Section 2.24.

Costs: The costs of providing flood protection for BIA Highway 6 are detailed in the accompanying Table 2.24-2 for BIA Highway 6. Quantities and line-item totals are listed.

The top portion of the table gives the costs of providing flood protection (as represented in the analysis) by action level for all of the five flood protection strategies. The lower portion of the table gives a breakdown of the quantities and costs by line item: fabric liner, aggregate base, fill, riprap, and bituminous pavement material.

Unit costs for all the cost computations were discussed previously in Section 2.0, and are detailed in Table 2.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for BIA Highway 6 are listed in the Feature Assumptions listing, appended to this Section 2.24.

2.24.4 Results of Economic Analysis

The results of the Economic Analysis for the BIA Highway 6 are listed in Table 2.24-3.

Stochastic Analysis Results: The flood protection strategy that was analyzed for protecting BIA Highway 6 was five incremental road raises. This strategy is highlighted on the decision tree (Figure 2.24-2). The average annual net benefits for this strategy were greater than zero ($9,244,900). The BCR for this strategy was greater than one (62.71). These results indicate that this strategy was economically justified. The present worth annualized detour damages that

would be prevented by this strategy were computed to be $9,392,500. The stochastic results are averages over 10,000 traces.

The large net benefits for this feature are primarily the result of the large detour damages when the road is temporarily closed. If it were assumed that ND Highway 20 would be available as the detour route, the net benefits for this feature would be significantly lower, potentially changing the economic feasibility of the flood protection strategy.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for three specific climate futures. For BIA Highway 6, the identified strategy and the economic indices for each of the three climate futures are as follows:

- Wet Future – For the wet future, the annual net benefits were $12,532,900, and the BCR was 24.20, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $13,073,000.
- First Moderate Future – For the first moderate future, the annual net benefits were $10,714,900, and the BCR was 178.99, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $10,774,700.
- Second Moderate Future – For the second moderate future, the annual net benefits were $11,655,900, and the BCR was 45.30, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $11,914,200.

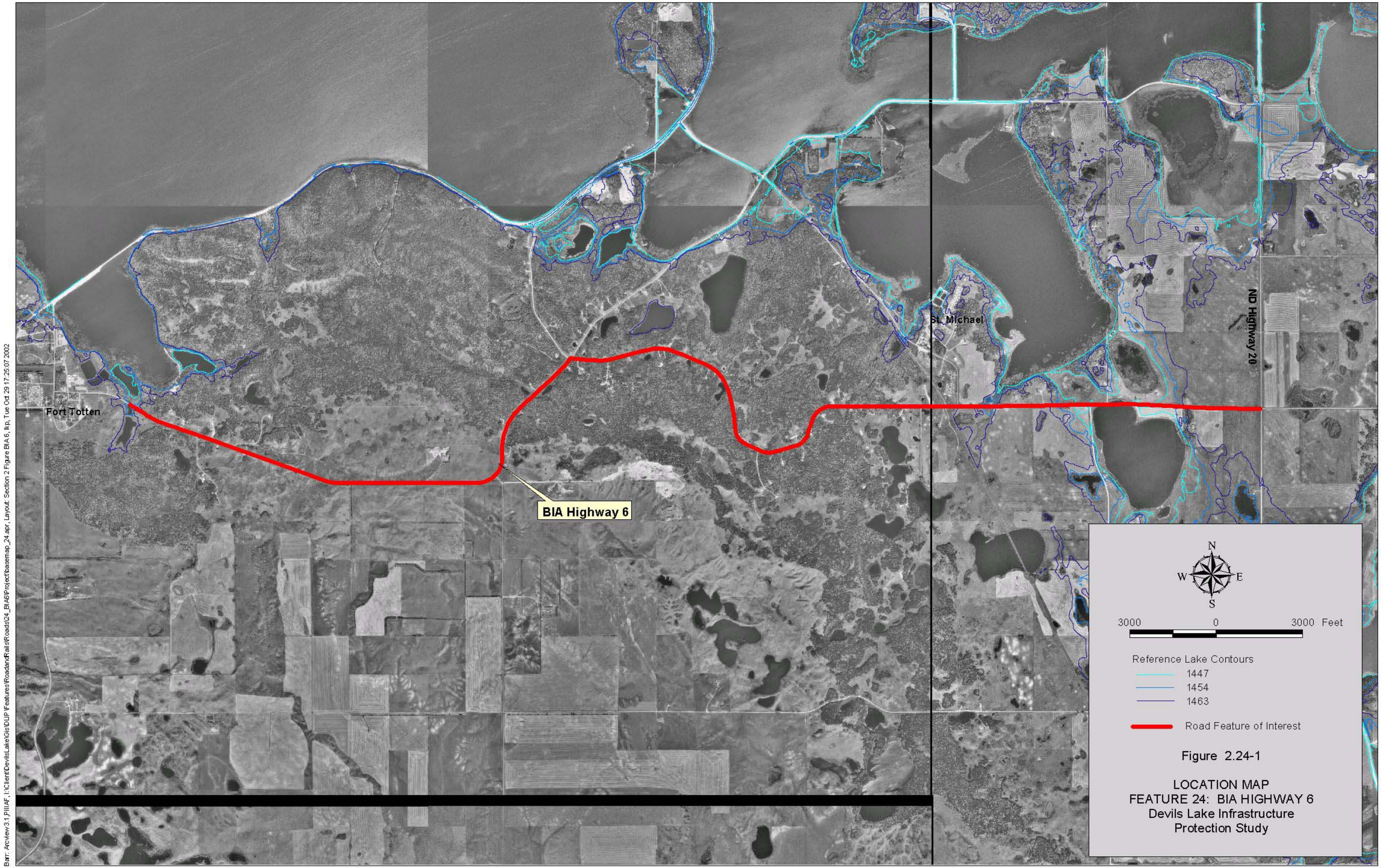
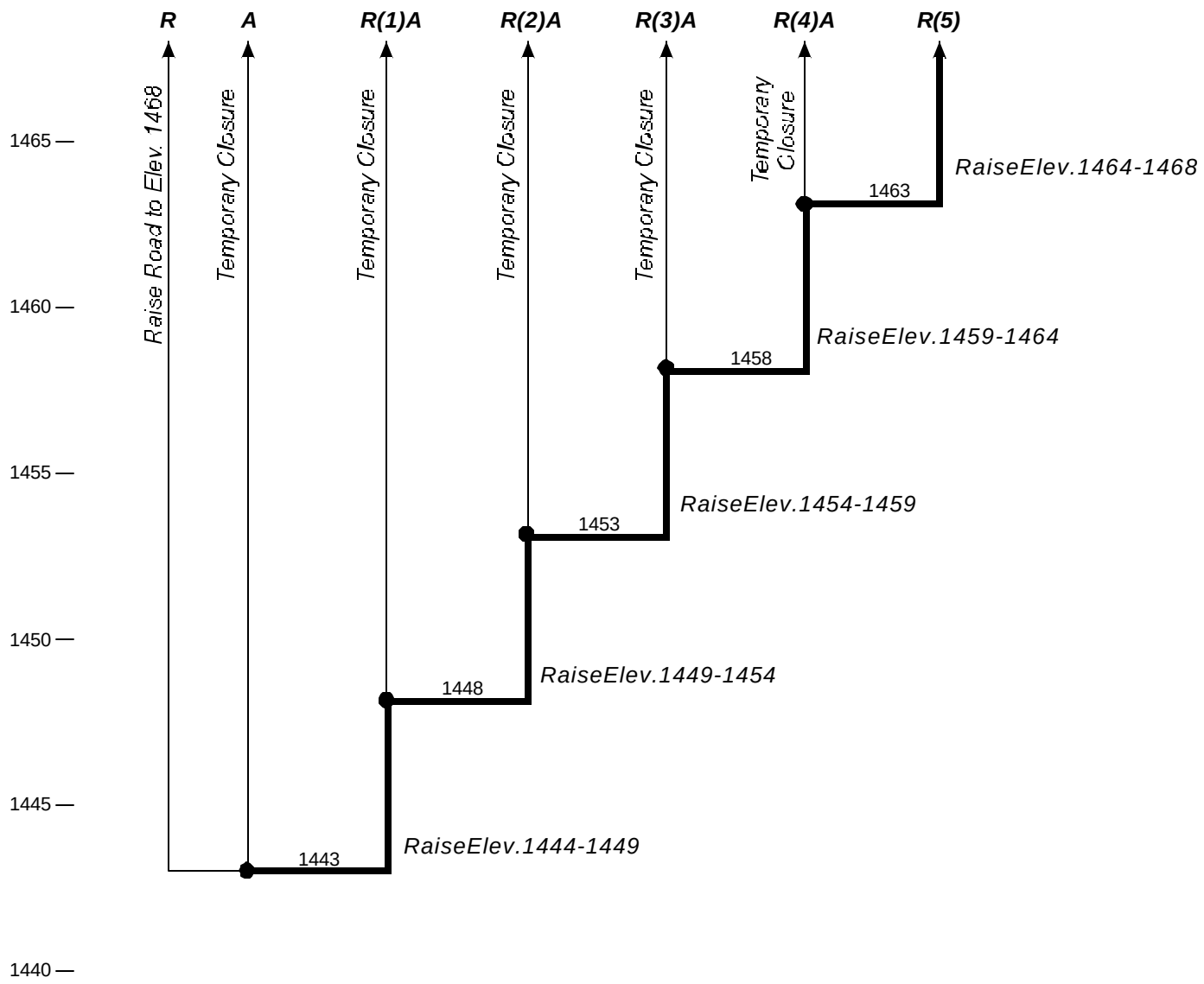


Figure 2.24-1

LOCATION MAP
FEATURE 24: BIA HIGHWAY 6
Devils Lake Infrastructure
Protection Study

DATA: 1997 USGS Digital Ortho Quad

Barr: ArcView 3.1, PIII AF, I:\Client\DevilsLake\Gis\DLIP\Features\Roadway\Rail\Roads\24_BIA6\Project\basemap_24.apr, Layout: Section 2 Figure BIA 6, lkp, Tue Oct 29 17:25:07 2002



FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1468

A Temporary closureofroad

Figure2.24-2

DECISION TREE
FEATURE 24:BIAHIGHWAY6
DevilsLakeInfrastructure ProtectionStudy

P:\1036020\DECISIONTREES\2002FIGURES\FIGURE2_24.CDR RLG 01-02-03

Table 2.24-1

Flood Damages
Feature 24: BIA Highway 6
Devils Lake Infrastructure Protection Study

DAMAGES

Action Levels	Annual Detour Damages (THOUSANDS)
AL1 - AL5	$13,073

DAMAGE BREAKDOWN

Damage	AL1 - AL5 Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Annual Detour Damages	BIA Highway 6				
	HR/YEAR	531,434	HR	$7.00	$3,720
	MILES/YEAR	29,228,873	MILE	$0.32	$9,353
	Total				**$13,073**

Restoration Damages

Elevation	Total (THOUSANDS)	Excavation Quantity	Excavation Units	Excavation Unit Cost	Excavation Value (THOUSANDS)	Fabric Liner Quantity	Fabric Liner Units	Fabric Liner Unit Cost	Fabric Liner Value (THOUSANDS)	Aggregate Base Course Quantity	Aggregate Base Course Units	Aggregate Base Course Unit Cost	Aggregate Base Course Value (THOUSANDS)	Fill Quantity	Fill Units	Fill Unit Cost	Fill Value (THOUSANDS)	Bituminous Pavement Quantity	Bituminous Pavement Units	Bituminous Pavement Unit Cost	Bituminous Pavement Value (THOUSANDS)	Bridge Repair Quantity	Bridge Repair Units	Bridge Repair Unit Cost	Bridge Repair Cost (THOUSANDS)
1443	$0																								
1444	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1445	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1446	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1447	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1448	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1449	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1450	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1451	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1452	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1453	$31	1,867	CY	$2.65	$5	3,321	SY	$1.33	$4	400	CY	$21.20	$8	2,767	CY	$4.77	$13	0	TON	$47.70	$0	0	EA	$530,000	$0
1454	$546	32,822	CY	$2.65	$87	58,391	SY	$1.33	$78	7,033	CY	$21.20	$149	48,658	CY	$4.77	$232	0	TON	$47.70	$0	0	EA	$530,000	$0
1455	$546	32,822	CY	$2.65	$87	58,391	SY	$1.33	$78	7,033	CY	$21.20	$149	48,658	CY	$4.77	$232	0	TON	$47.70	$0	0	EA	$530,000	$0
1456	$546	32,822	CY	$2.65	$87	58,391	SY	$1.33	$78	7,033	CY	$21.20	$149	48,658	CY	$4.77	$232	0	TON	$47.70	$0	0	EA	$530,000	$0
1457	$667	40,133	CY	$2.65	$106	71,397	SY	$1.33	$95	8,600	CY	$21.20	$182	59,497	CY	$4.77	$284	0	TON	$47.70	$0	0	EA	$530,000	$0
1458	$1,087	65,333	CY	$2.65	$173	116,228	SY	$1.33	$155	14,000	CY	$21.20	$297	96,855	CY	$4.77	$462	0	TON	$47.70	$0	0	EA	$530,000	$0
1459	$1,087	65,333	CY	$2.65	$173	116,228	SY	$1.33	$155	14,000	CY	$21.20	$297	96,855	CY	$4.77	$462	0	TON	$47.70	$0	0	EA	$530,000	$0
1460	$1,087	65,333	CY	$2.65	$173	116,228	SY	$1.33	$155	14,000	CY	$21.20	$297	96,855	CY	$4.77	$462	0	TON	$47.70	$0	0	EA	$530,000	$0
1461	$1,087	65,333	CY	$2.65	$173	116,228	SY	$1.33	$155	14,000	CY	$21.20	$297	96,855	CY	$4.77	$462	0	TON	$47.70	$0	0	EA	$530,000	$0
1462	$1,087	65,333	CY	$2.65	$173	116,228	SY	$1.33	$155	14,000	CY	$21.20	$297	96,855	CY	$4.77	$462	0	TON	$47.70	$0	0	EA	$530,000	$0
1463	$1,087	65,333	CY	$2.65	$173	116,228	SY	$1.33	$155	14,000	CY	$21.20	$297	96,855	CY	$4.77	$462	0	TON	$47.70	$0	0	EA	$530,000	$0

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.

Table 2.24-2

Flood Protection Costs
Feature 24: BIA Highway 6
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation (MSL)	R Maximum Raise at AL1	A Temporary Closure at AL1	R(1)A Raise at AL1; Temporary Closure at AL2	R(2)A Raise at AL1, AL2; Temporary Closure at AL3	R(3)A Raise at AL1, AL2, AL3; Temporary Closure at AL4	R(4)A Raise at AL1, AL2, AL3, AL4; Temporary Closure at AL5	R(5) Raise at AL1, AL2, AL3, AL4, AL5
		(THOUSANDS)						
AL1	1443	$19,773	$0	$214	$214	$214	$214	$214
AL2	1448	$0	$0	$0	$1,664	$1,664	$1,664	$1,664
AL3	1453	$0	$0	$0	$0	$5,065	$5,065	$5,065
AL4	1458	$0	$0	$0	$0	$0	$6,568	$6,568
AL5	1463	$0	$0	$0	$0	$0	$0	$6,262

COST BREAKDOWN

		R																								
		R(1)A																								
		R(2)A					R(2)A																			
		R(3)A					R(3)A					R(3)A														
		R(4)A					R(4)A					R(4)A					R(4)A									
		R(5)					R(5)					R(5)					R(5)					R(5)				
		Lake Elevation 1443					Lake Elevation 1448					Lake Elevation 1453					Lake Elevation 1458					Lake Elevation 1463				
Strategy		Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Incremental Raise																										
	Road Raise	BIA Highway 6					BIA Highway 6					BIA Highway 6					BIA Highway 6					BIA Highway 6				
		Fabric Liner	5,211	SY	$1.33	$7	Fabric Liner	52,827	SY	$1.33	$70	Fabric Liner	112,438	SY	$1.33	$150	Fabric Liner	95,845	SY	$1.33	$127	Fabric Liner	76,675	SY	$1.33	$102
		Aggregate Base	400	CY	$21.20	$8	Aggregate Base	6,633	CY	$21.20	$141	Aggregate Base	6,967	CY	$21.20	$148	Aggregate Base	0	CY	$21.20	$0	Aggregate Base	0	CY	$21.20	$0
		Fill	10,444	CY	$9.00	$94	Fill	43,633	CY	$9.00	$393	Fill	278,933	CY	$9.00	$2,510	Fill	501,778	CY	$9.00	$4,516	Fill	513,422	CY	$9.00	$4,621
		Riprap	3,487	TON	$30.00	$105	Riprap	35,351	TON	$30.00	$1,061	Riprap	75,243	TON	$30.00	$2,257	Riprap	64,137	TON	$30.00	$1,924	Riprap	51,310	TON	$30.00	$1,539
		Bituminous	0	TON	$47.70	$0	Bituminous	0	TON	$47.70	$0	Bituminous	0	TON	$47.70	$0	Bituminous	0	TON	$47.70	$0	Bituminous	0	TON	$47.70	$0
		Subtotal				$214	Subtotal				$1,664	Subtotal				$5,065	Subtotal				$6,568	Subtotal				$6,262
		Total				**$214**	**Total**				**$1,664**	**Total**				**$5,065**	**Total**				**$6,568**	**Total**				**$6,262**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. The costs for the Maximum Raise at AL1 strategy (R) is equal to the sum of the costs for all incremental raises.

Table 2.24 - 3

Economic Analysis of Strategies for BIA 6 between Highway 1 and Fort Totten

(Feature 24)

Stochastic Analysis (ST)
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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$2,200	$9,392,500	$0	$9,394,700	$0	$0	--
R	Road Raise to 1468	########	$0	$1,241,500	$0	$0	$0	$0	$9,394,700	$8,153,300	7.57
R(1)A	1 Road Raise: Then Temporary Closure During F	$13,400	$0	$13,400	$3,300	$4,038,200	$0	$4,041,500	$5,353,300	$5,339,800	399.50
R(2)A	2 Road Raises: Then Temporary Closure During	$86,300	$0	$86,300	$3,500	$878,000	$0	$881,500	$8,513,200	$8,427,000	98.65
R(3)A	3 Road Raises: Then Temporary Closure During	$128,900	$0	$128,900	$2,500	$235,500	$0	$238,000	$9,156,800	$9,027,900	71.04
R(4)A	4 Road Raises: Then Temporary Closure During	$148,300	$0	$148,300	$0	$6,900	$0	$6,900	$9,387,900	$9,239,600	63.30
R(5)	5 Incr. Road Raises	$149,800	$0	$149,800	$0	$0	$0	$0	$9,394,700	$9,244,900	62.71

Wet Future Scenario (WF)
(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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$0	#########	$0	$13,073,000	$0	$0	--
R	Road Raise to 1468	########	$0	$1,241,500	$0	$0	$0	$0	$13,073,000	$11,831,500	10.53
R(1)A	1 Road Raise: Then Temporary Closure During F	$13,400	$0	$13,400	$0	#########	$0	$12,252,200	$820,800	$807,300	61.25
R(2)A	2 Road Raises: Then Temporary Closure During	$111,700	$0	$111,700	$13,400	$8,348,300	$0	$8,361,700	$4,711,300	$4,599,700	42.18
R(3)A	3 Road Raises: Then Temporary Closure During	$331,100	$0	$331,100	$14,600	$4,193,600	$0	$4,208,200	$8,864,800	$8,533,700	26.77
R(4)A	4 Road Raises: Then Temporary Closure During	$540,100	$0	$540,100	$0	$0	$0	$0	$13,073,000	$12,532,900	24.20
R(5)	5 Incr. Road Raises	$540,100	$0	$540,100	$0	$0	$0	$0	$13,073,000	$12,532,900	24.20

Moderate Future 1 Scenario (M1)
(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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$500	#########	$0	$10,775,100	$0	$0	--
R	Road Raise to 1468	########	$0	$1,241,500	$0	$0	$0	$0	$10,775,100	$9,533,700	8.68
R(1)A	1 Road Raise: Then Temporary Closure During F	$13,400	$0	$13,400	$800	$1,037,900	$0	$1,038,700	$9,736,400	$9,723,000	726.60
R(2)A	2 Road Raises: Then Temporary Closure During	$60,200	$0	$60,200	$0	$0	$0	$0	$10,775,100	$10,714,900	178.99
R(3)A	3 Road Raises: Then Temporary Closure During	$60,200	$0	$60,200	$0	$0	$0	$0	$10,775,100	$10,714,900	178.99
R(4)A	4 Road Raises: Then Temporary Closure During	$60,200	$0	$60,200	$0	$0	$0	$0	$10,775,100	$10,714,900	178.99
R(5)	5 Incr. Road Raises	$60,200	$0	$60,200	$0	$0	$0	$0	$10,775,100	$10,714,900	178.99

Moderate Future 2 Scenario (M2)
(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) J = H / C
A	Temporary Closure During Floods at First Action	$0	$0	$0	$4,700	#########	$0	$11,919,000	$0	$0	--
R	Road Raise to 1468	########	$0	$1,241,500	$0	$0	$0	$0	$11,919,000	$10,677,500	9.60
R(1)A	1 Road Raise: Then Temporary Closure During F	$13,400	$0	$13,400	$9,500	$8,630,900	$0	$8,640,400	$3,278,600	$3,265,100	244.67
R(2)A	2 Road Raises: Then Temporary Closure During	$111,700	$0	$111,700	$12,000	$2,021,300	$0	$2,033,300	$9,885,700	$9,774,000	88.50
R(3)A	3 Road Raises: Then Temporary Closure During	$263,100	$0	$263,100	$0	$0	$0	$0	$11,919,000	$11,655,900	45.30
R(4)A	4 Road Raises: Then Temporary Closure During	$263,100	$0	$263,100	$0	$0	$0	$0	$11,919,000	$11,655,900	45.30
R(5)	5 Incr. Road Raises	$263,100	$0	$263,100	$0	$0	$0	$0	$11,919,000	$11,655,900	45.30

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% 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.

Attachment to 2.24:
BIA Highway 6 Economic Analysis Assumptions

No feature-specific assumptions were made for Feature 24.

A. General Assumptions

1. Decisions were assumed to occur when the lake level is within (or predicted by the National Weather Service to be within) 1 foot of the lowest road elevation. This assumption is consistent with current practices in the area as dictated by funding agencies. In the past, funding for road raises has not been available until the National Weather Service predicts on February 15th that the road will go under water during that year.

2. If the road includes a bridge having a low chord elevation below the lowest road elevation, it was assumed that no decision would occur until the lake level was within 1 foot of the lowest road elevation. This assumption follows current practices in the area.

B. Road Raises

1. Road raise costs were calculated in the manner presented in a previous study (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998). Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001. Additionally the cost of riprap and fill were increased from $20 to $30 and $4.50 to $9.00, respectively. Based on conversations with the NDDOT, railroad companies, and the Corps of Engineers the new costs for riprap and fill are more representative of the costs in the area.

2. The last road raise was assumed to be to elevation 1468. At this elevation, roads would be 5 feet above the assumed maximum lake level (elevation 1463).

3. The final incremental road raise (to elevation 1468) was assumed to be no more than 8 feet and no less than 4 feet.

4. Bureau of Indian Affairs (BIA) roads were assumed to be raised in 5-foot increments (*Devils Lake Flood Control: Economics Database Update: Transportation Report,* Barr Engineering Company, January 1998).

C. Temporary Road Closure During Floods

1. It was assumed that if a road was temporarily closed, it would be restored after the lake level has receded 1 foot below the top of road. All of the road features in this study are highly traveled. It is very likely that people would want to use these roads again if the lake level receded after flooding,

assuming that communities, businesses, farmsteads, and residents continue to generate the same level of traffic as at present.

2. Restoration damages were calculated in the manner presented in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. Unit costs for construction materials were updated for inflation by multiplying them by the ENR Construction Cost Index of 1.06. This accounts for 6% inflation during the period from 1998 to February 2001.

3. Detour damages were included for every year that a road is temporarily closed, as well as for the first year that the lake has receded. It was assumed that during the first year after the lake has receded, the road would be under restoration. During this first year, there would be both a detour damage and restoration damage. After this first year, there would be no further detour or restoration damages unless the lake rises to within 1 foot of the road again.

4. Restoration of a road would only occur after the lake has receded to 1 foot below the lowest elevation in that road. This was based on the assumption that restoration would only occur when there is no water on any part of the road and there would be only minor potential for wave action damage on the road.

5. Detour damages were calculated using a cost of $7 per hour of additional travel time, 1.5 people per vehicle, and $0.32 per mile for additional travel distance (Corps of Engineers, March, 2001). Additional time and miles traveled were taken from the results of the QRS II model used in *Devils Lake Flood Control: Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998. The QRS II model determines the overall effect of a closed road on an entire network of traffic, incorporating the fact that traffic consists of trips having different origins and destinations.

6. There is more commitment on the part of the North Dakota Department of Transportation (NDDOT) to the Highway 57 causeway than to the Highway 20 causeway through The Narrows. Therefore, Highway 57 was assumed to be the detour route for the Highway 20 causeway. If the Highway 57 causeway was temporarily closed during flooding, it was assumed that the Highway 20 causeway would also be temporarily closed.

7. The detour route for Highway 57 is around the lake to the west via Highway 281 and Highway 19. Woods-Rutten Road was considered as a detour route for Highway 57, but it was not retained as a viable alternative, because it would have to be significantly raised and improved to carry the traffic of Highway 57.

8. Detour paths were determined assuming that all other featured roads would be open (with three exceptions: the Highway 57 detour assumes that Highway 20 across The Narrows is closed and both

the BIA 1 and the BIA 6 detours assume that Highway 20 from Highway 57 to Tokio is closed). No effort was made to link detour routes with lake level. However, if a featured road was presented as a detour route, an "interdependency" was noted.

9. The analysis of Features 23 (BIA 1 between Highway 57 and BIA 6) and Feature 24 (BIA 6 between Highway 20 and Fort Totten) assumed that Feature 22 (Highway 20 between Highway 57 and Tokio) is temporarily closed during high lake levels. BIA 1 and BIA 6 are part of the north-south detour for Highway 20 and the preliminary analysis indicated that Feature 22 would likely be temporarily closed during high lake levels.

10. Two features can have mutually interdependent detour routes if they are the most reasonable detours. In these cases, it was assumed that either the analyzed feature or the other feature would be raised or rerouted. In these cases, the interdependency was noted.

D. Road Reroutes

1. No logical reroute was located for this feature.

2.25 Summary of Economic Analysis Investigation for Feature 25: Roads Acting as Dams

2.25.0 Flood Protection Strategy

The flood protection strategy that was analyzed for the Roads Acting as Dams area was incremental levee raises.

2.25.1 General Information

This feature was not originally included in the Economic Analysis of Devils Lake Alternatives as a feature. However it was analyzed as the Expanded Infrastructure Measures alternative ST-2b and WF-2b, which are summarized in this section. No assumptions attachment is included in this write-up. Assumptions for the Economic Analysis can be found in the *Roadways Serving as Water Barriers Report*, Devils Lake Surface Transportation Task Force, May 2000.

Feature Type: Combination

Location: The Roads Acting as Dams feature includes two separate sections: (1) along ND Highway 20, located near the Acorn Ridge area in Creel Township, Ramsey County; and (2) the Mission Township peninsula on the south side of the lake near St. Michael (located in Mission Township, Benson County). The accompanying Figure 2.25-1 shows the feature's location and approximate extents, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: There are several locations around Devils Lake in which roads are currently holding back water, providing barriers to the rising and expanding waters of Devils Lake. The problem originated when culverts were plugged in 1995 to protect existing features. The difference in water levels on each side of the road is now as much as 12 feet. The extent of the roads currently holding back water is approximately 10.8 miles. Since these roads are acting as dams, but were not designed or constructed to function as dams, there is a potential safety hazard to road users and to the people living behind and using the areas being protected by these barriers. Portions of ND Highway 57, ND Highway 20, BIA Highway 1, BIA Highway 4, and BIA Highway 5 are currently holding back water and providing barriers for the rising and expanding Devils Lake. There are also three sections of temporary levees that have been constructed by the Corps to protect the area in Mission Township.

This alternative examined the economic feasibility of taking additional measures to provide a safe level of flood protection behind these barriers. The alternative assumed that several perimeter dams would be constructed between high ground (to minimize the number of roads that need to be raised) and that dams would be constructed adjacent to and inside the protection of any

remaining exterior roads (including: Highway 20 near the Acorn Ridge development, BIA 4, and BIA 5). These dams would then become the flood protection for the interior areas, allowing the roads to be relocated or temporarily closed.

Significance: The areas behind these roads have been protected because of their value to the local community. The roads that are being used as dams and the interior roads are significant for transportation reasons (the major roads were evaluated separately as other features). The Roads Acting as Dams are currently protecting the following features from flooding: Feature 5, St. Michael, Feature 8.1; Rural Areas, Feature 22; ND Highway 20 (ND Highway 57 to Tokio); Feature 24, BIA Highway 6.

Damages: The loss of these "dams" from either failure or flooding up to the maximum lake level would result in the following damages:

- Loss of the portions of ND Highway 57 (Feature 14), ND Highway 20 (Features 21 and 22), BIA Highway 1 (Feature 23), BIA Highway 4, and BIA Highway 5 that are currently acting as dams
- Loss of portions of ND Highway 22 (Feature 22), BIA Highway 1 (Feature 23), BIA Highway 6 (Feature 24), BIA Highway 9, BIA Highway 2, and Military Road due to flooding
- Loss of commercial and residential structures in St. Michael (Feature 5)
- Loss of the St. Michael sewer lagoon system
- Loss of approximately 71 rural residential structures (Feature 8.1)
- Loss of land area that is currently protected

Owner/Sponsor: The North Dakota Department of Transportation (ND DOT) is responsible for maintaining ND Highways 57 and 20. The Bureau of Indian Affairs is responsible for managing and maintaining BIA Highway 1, BIA Highway 4, BIA Highway 5, and BIA Highway 9. The Spirit Lake Nation is responsible for managing and maintaining St. Michael.

Lead Federal Agency: Several agencies could be responsible for portions of flood protection that may take place for the Roads Acting as Dams feature. The Corps would take the lead for any levee flood protection that may take place. Federal Emergency Management Agency (FEMA) would coordinate relocation of structures. The Federal Highway Administration would take the lead in installing pipe(s) to equalize water on both sides of the roadway, and to raise the elevation of state roads. The Bureau of Indian Affairs would take the lead on raising the BIA roads and individual counties would be responsible for flood protection of county roads.

2.25.2 Feature Protection

History of Flood Protection: In the past, flood protection for the Roads Acting as Dams has consisted of raising the roads in 5-foot increments when the water level reaches one foot below the road elevation.

In addition, emergency levees were constructed north and northeast of the east-west portion of ND Highway 20. The western-most of the three levees, constructed along a township road in Section 35 (T153N64W), was raised to 1447.6 in 1998. The other two levee sections, located in Section 35 (T153N64W) and Section 31 (T153N63W), were also raised in 1998 to 1449. These levees protect land to the south and the 2,000-foot section of ND Highway 20 immediately west of the road's intersection with BIA Highway 9 that has a surface elevation at about 1445.

General Protection Strategy: Several approaches were taken in the analysis that was completed by the Corps and the Devils Lake Surface Transportation Task Force, including:

- Construction of several perimeter dams between areas of high ground, with the remaining exterior roads being converted to dams
- Construction of several perimeter dams between areas of high ground, with construction of parallel dams along exterior roads

The Economic Analysis evaluated the second approach for protecting the Roads Acting as Dams: construction of perimeter dams.

Protection Strategy by Lake Level: The Economic Analysis considered one protection strategy, with flood protection decisions being made at various lake levels as Devils Lake continued to rise. Figure 2.25-2 shows the decision tree for Roads Acting as Dams. As shown on Figure 2.25-2, the stepwise approach to flood protection for Roads Acting as Dams that was analyzed consisted of the following:

1. At lake elevation 1447, a decision would be made whether to construct the perimeter levees with a top at 1455 or allow the water levels to equalize and conduct the flood protection strategies for each feature as analyzed.
2. At lake elevation 1450, if the perimeter levees were constructed at the first action level, the perimeter dams would be raised to a top of 1465.

Interdependencies: The protection of Roads Acting as Dams is related to the protection of:

- Feature 5: St. Michael – St. Michael is currently protected by Roads Acting as Dams, and decisions regarding these features must be considered jointly.

- Feature 8.1: Rural Areas – There are portions of rural areas that are being protected by Roads Acting as Dams, and future flood protection decisions should consider the Rural Areas.
- Feature 14: ND Highway 57 (between ND Highway 20 and BIA Highway 1) – A portion of ND Highway 57 is acting as a dam, and decisions regarding this road will affect other features in the interior areas that are being protected.
- Features 21 and 22: ND Highway 20 – Two sections of ND Highway 20 are acting as dams, and decisions regarding these road segments will affect other features in the interior areas that are being protected. Other sections of ND Highway 20 are being protected by Roads Acting as Dams. Therefore, decisions regarding these features must be considered at the same time.
- Feature 23: BIA Highway 1 – A segment of BIA Highway 1 is acting as a dam, and decisions regarding this road will affect other features in the interior areas that are being protected. As the lake rises, other portions of BIA Highway 1 would be protected by Roads Acting as Dams. Therefore, decisions regarding these features must be considered at the same time.
- Feature 24: BIA Highway 6 – BIA Highway 6 is currently protected by Roads Acting as Dams, and decisions regarding these features must be considered jointly.
- Additional roadways including Military Road and BIA Highways 2, 4, and 5 – These roadways were not considered as individual features, however they would be impacted by future flood protection decisions for the Roads Acting as Dams.

2.25.3 Feature Economics

Damages: For Roads Acting as Dams, the damages resulting from flooding were estimated up to the maximum lake level (1463). The damage computations for Roads Acting as Dams are the prevention of protection measures at the affected features, and are summarized in the accompanying Table 2.25-1 as the annual benefits from each respective feature. These damages prevented included feature costs as follows:

- Feature 5 (St. Michael) – Relocation costs were eliminated.
- Feature 24 (BIA Highway 6) – Road raise costs were eliminated.
- Feature 22 (Highway 20 (ND Highway 57 and Tokio) – Road raise costs were eliminated for the segment between BIA Highway 5 and Tokio. The revised Feature 22 costs would reflect only those costs for raising the segment between Highway 57 and BIA Highway 5 (at the perimeter dam). The revised raises for Feature 22 were computed to be $4,574,000 at elevation 1454 and $6,481,000 at 1459.

- Feature 8.1 (Devils Lake Rural Areas) – Damages to structures were eliminated. Homes that would be within the protected area include 54 homes on the reservation and 21 homes in the Acorn Ridge area (near Camp Grafton). There were also an additional 84 homes where access would be protected by this feature. The total reduction in damages to homes that are protected was computed to be $7,800,000. The total reduction in relocation costs was computed at $7,956,000. Land that is protected by this alternative (valued at $178,600) was also removed from the potential damages.

Costs: The construction costs for implementation of the Expanded Infrastructure Measures alternative were obtained from the *Roadways Serving as Water Barriers Report*, Devils Lake Surface Transportation Task Force, May 2000. These costs are summarized in Table 2.25-2.

The project costs include:

- Costs to raise levees on the landward side of US Highway 20 near Acorn Ridge, BIA Highway 4, and BIA Highway 5. These costs occur incrementally as necessary due to the rising lake levels.

- Costs for levee (perimeter dam) construction to connect high ground. These costs also occur incrementally as necessary due to the rising lake levels.

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

2.25.4 Results of Economic Analysis

The results of the Economic Analysis for the Roads Acting as Dams are listed in Table 2.25-3.

Stochastic Analysis Results: The stochastic analysis indicated that the annual net benefits for Expanded Infrastructure Measures (Roads Acting as Dams) were less than zero (-$6,141) and were therefore not economically justified. This protection strategy is highlighted on the decision tree (Figure 2.25-2). The BCR for this strategy was less than one (0.99). The stochastic results are averages over 10,000 traces.

Results for Specific Scenarios: In the economic analysis, flood protection strategies were also analyzed for the Wet Future climate future. For the wet future, the protection strategy had an annual net benefits that were less than zero (-$2,803,900) and a BCR of 0.31. Therefore, this protection strategy was not economically justified under the wet future.

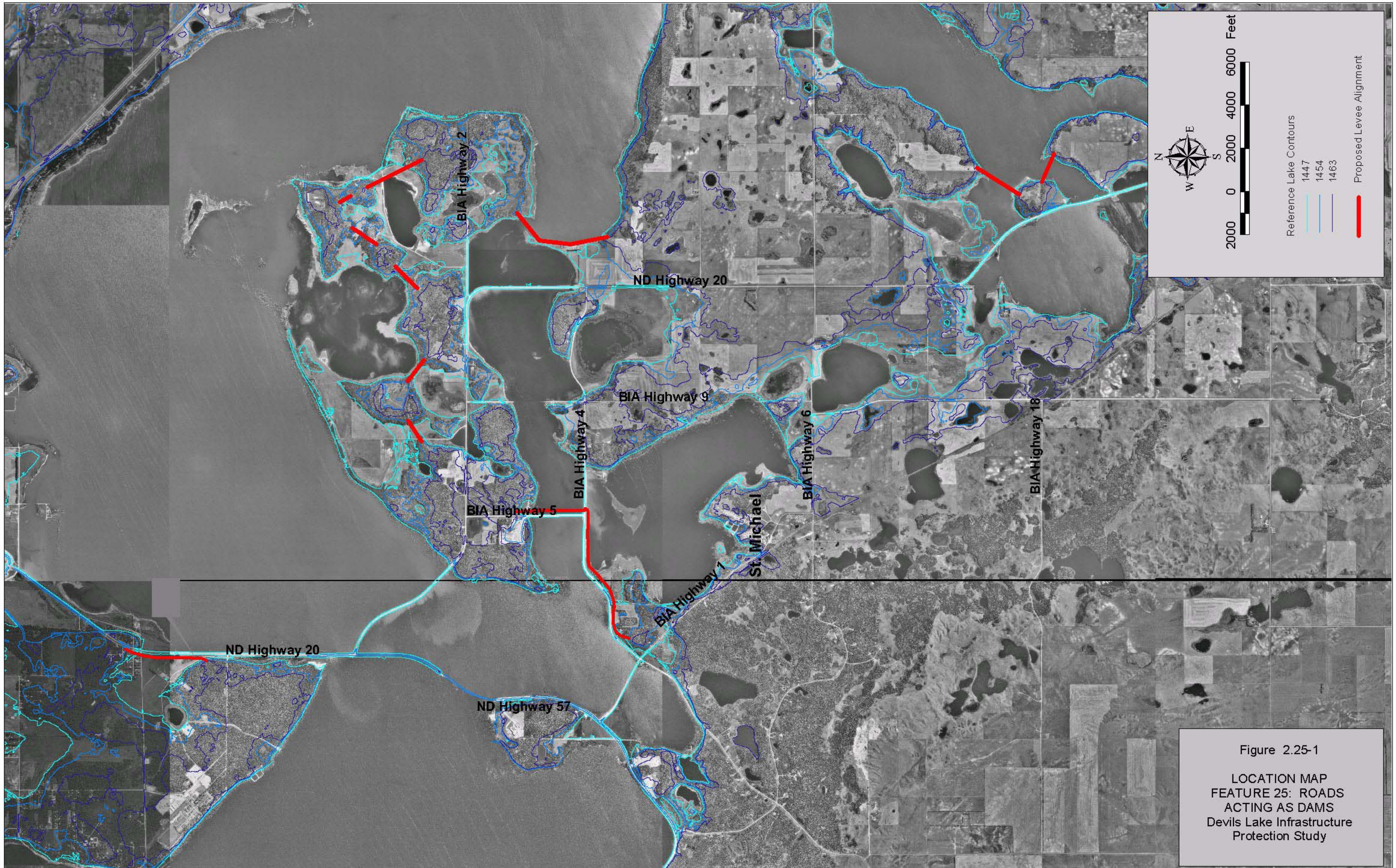


Figure 2.25-1

LOCATION MAP
FEATURE 25: ROADS
ACTING AS DAMS
Devils Lake Infrastructure
Protection Study

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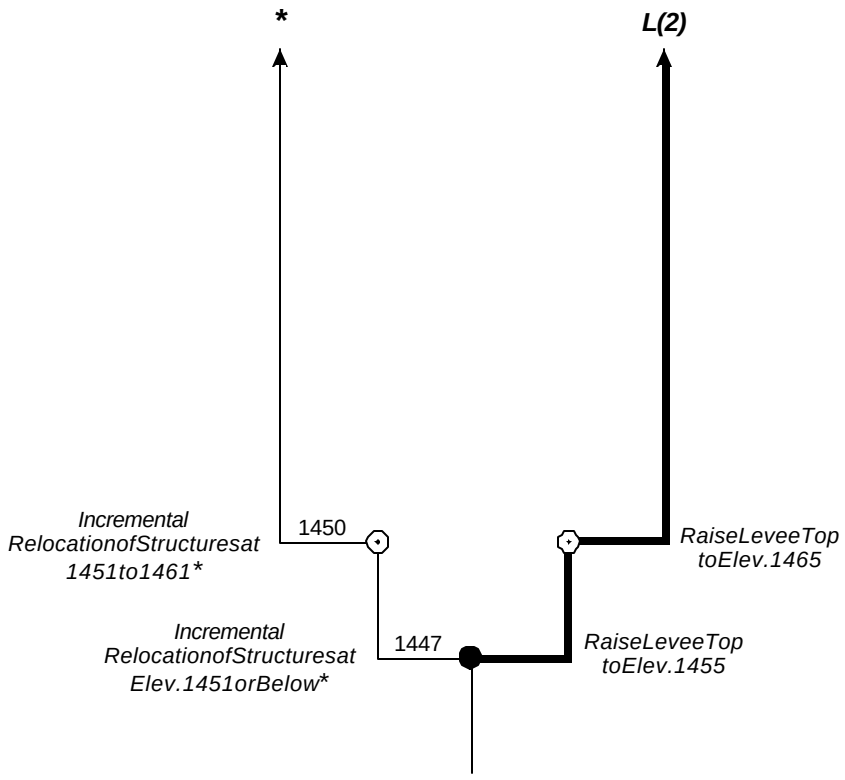

FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

L(1) Incrementalleveeraise(numberoftimes)

S(1) Structurerelocation(numberoftimes)

***** Inadditiontostructurerelocations,NDHighway20, BIAHighway6andSt.Michaelwouldrequireflood protection.Theseanalyses wereincludedasother features.

Figure2.25-2

DECISION TREE
FEATURE25:ROADSACTINGASDAMS
DevilsLakeInfrastructure ProtectionStudy

P:\4\96016\DECISIONTREES\FIGURE2_25.CDR RLG 01-02-03

Table 2.25-1

Flood Damages
Feature 25: Roads Acting as Dams
Devils Lake Infrastructure Protection Study

DAMAGES

		Stochastic Analysis		
	Impacted Feature	**Annual Costs Avoided** (averaged over 10,000 traces) (Thousands)	**Annual Damages Reduced** (averaged over 10,000 traces) (Thousands)	**TOTAL** (averaged over 10,000 traces) (Thousands)
5	St. Michael	$20	$0	$20
8.1	Devils Lake Rural Areas	$311	$5	$316
22	ND Highway 20 (ND Highway 57 to Tokio	-$47	$697	$650
23	BIA Highway 1	$18	-$11	$7
24	BIA Highway 6	$150	$0	$150
			TOTAL	**$1,143**

		Wet Future Scenario Analysis		
	Impacted Feature	**Annual Costs Avoided** (averaged over 10,000 traces)	**Annual Damages Reduced** (averaged over 10,000 traces)	**TOTAL** (averaged over 10,000 traces)
5	St. Michael	$76	$0	$76
8.1	Devils Lake Rural Areas	$415	$9	$423
22	ND Highway 20 (ND Highway 57 to Tokio	-$369	$576	$208
23	BIA Highway 1	$230	-$218	$12
24	BIA Highway 6	$540	$0	$540
			TOTAL	**$1,259**

Table 2.25-2

Flood Protection Costs
Feature 25: Roads Acting as Dams
Devils Lake Infrastructure Protection Study

STRATEGY COSTS BY ACTION LEVEL

Action Level	Lake Elevation	L(2) Incremental Install Perimeter Dams, Incremental Raise Hwy 20 (Acorn Ridge) at AL 1, raise perimeter dams and parallel dam at AL 2
	(MSL)	(THOUSANDS)
AL1	1447	$31,771
AL2	1450	$63,602

COST BREAKDOWN - Perimeter Dams

Strategy		L(2)			
		Lake Elevation 1447		Lake Elevation 1450	
		Dam Segment	Estimated Cost	Dam Segment	Estimated Cost
Perimeter Dam			(THOUSANDS)		(THOUSANDS)
	Dam Construction	A & L	$13,303	A & L	$22,822
		B	$194	B	$2,386
		C	$479	C	$3,027
		D	$254	D	$1,961
		E	$227	E	$392
		F	$116	F	$167
		G	$6,270	G	$10,717
		H	$2,580	H	$4,315
		I	$2,539	I	$5,546
		J	$1,357	J	$3,543
		K	$4,452	K	$8,726
		TOTAL	**$31,771**	**TOTAL**	**$63,602**

Notes:
1. AL = Decision/Action Level specified on decision tree.
2. Elevations for decision/action levels are shown at 1-foot increments, rounded down to the nearest foot.
3. Costs from Alternatives Analysis, Alternative 3, completed by Paul Madison, COE St. Paul District, March 2000.

Table 2.25 - 3

Economic Analysis of Strategies for Roads Acting as Dams (Feature 25)

Strategy		Stochastic Analysis (ST) Mean Value over 10,000 Traces (Annual)								
		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Levee Raise A	O&M B	Relocation C	Total D = A + B + C	Damages E	Total F = E	To Strategy (Damages Prevented) G = F(No Protection) - F(S) *	To Strategy H = G - D	(BCR) I = G / D
No Protection	No Protection or Relocation	$0	$0	$0	$0	$1,143,200	$1,143,200	$0	$0	--
L(2)	2 Levee Raises	$1,013,290	$136,052	$0	$1,149,341	$0	$0	$1,143,200	-$6,100	0.99

Strategy		Wet Future Scenario (WF) (Annual)								
		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Levee Raise A	O&M B	Relocation C	Total D = A + B + C	Damages E	Total F = E	To Strategy (Damages Prevented) G = F(No Protection) - F(S) *	To Strategy H = G - D	(BCR) I = G / D
No Protection	No Protection or Relocation	$0	$0	$0	$0	$1,259,100	$1,259,100	$0	$0	--
L(2)	2 Levee Raises	$3,660,051	$402,963	$0	$4,063,014	$0	$0	$1,259,100	-$2,803,900	0.31

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.375% and rounded to the nearest $100.
The Moderate Future Scenarios were not analyzed for this feature in the Economic Analysis of Devils Lake Alternatives study.
* Total benefits are calculated as the totall damages incurred for the "No Protection stragegy" minus the totall damages for the strategy implemented (F(S)).