Lowest Road Elevation: 1410

Flood Protection Strategy

● Decision required at this point

⊙ Trigger point for action, no decision needed

Re Relocate

A Temporary closure of road

Figure 4.19-2

DECISION TREE
FEATURE 19: ND HIGHWAY 1
Devils Lake Infrastructure Protection Study

P:\34\36\020\DECISIONTREES\2002FIGURES\FIGURE4_19.CDR RLG 01-06-03

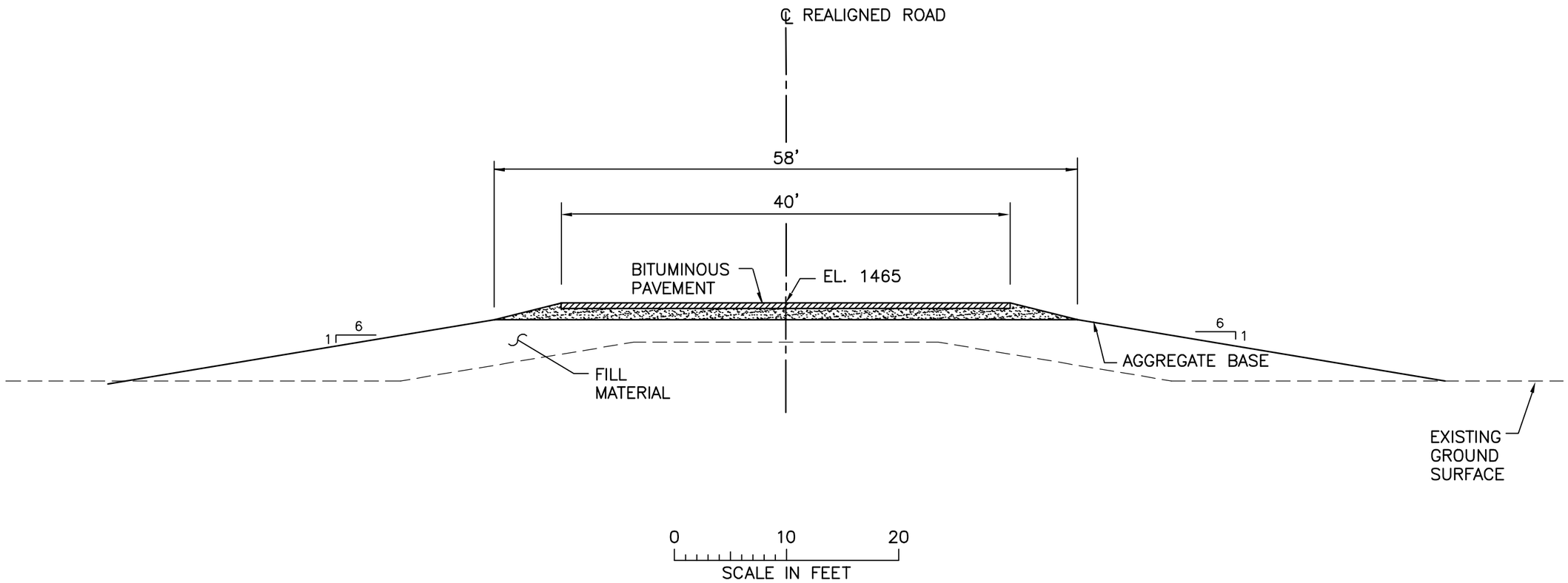


Figure 4.19–3

TYPICAL ROAD CROSS–SECTION

FEATURE 19:
ND HIGHWAY 1

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

NRD M:\CAD\3436020\17295_1.DWG Plot at 10 11/06/2002 14:03:23

Attachment to 4.19:
ND Highway 1 Infrastructure Protection Study Assumptions

A. Existing Road Information

1. Existing road elevations for the feature were obtained through contact with ND DOT representatives, primarily Brad Darr.

2. Existing (relocated) road cross-section for the feature were based on construction drawing typical sections obtained from ND DOT/or their consultants including:

   - ND DOT Road Realignment in Nelson County. Project No. SER-3-001(010)150, dated 9/13/2001.

   - ND DOT Hot Bituminous Pavement in Nelson County. Project No. SER-3-001(008)150, dated 9/13/2001.

B. Road Realignment

No assumptions were necessary related to the road realignment because the strategy has already been implemented.

C. Geotechnical

No geotechnical analysis was completed for this feature.

D. Road Restoration

No restoration damages were calculated since an economic analysis was not completed for this feature.

E. Detours

No detour damages were calculated since an economic analysis was not completed for this feature.

4.22 Summary of Infrastructure Protection Investigation for Feature 22: ND Highway 20 (ND Highway 57 to Tokio)

4.22.0 Flood Protection Strategy

The incremental flood protection strategy that was analyzed for ND Highway 20 (ND Highway 57 to Tokio) was incremental road raises.

4.22.1 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 4.22-1 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 1445 to 1495 near Tokio. Portions of the roadway are acting as dams and other portions are currently being protected by roads that are acting as dams (see analysis of Feature 25). Average daily traffic counts for this feature were 1,070 in 1994 and 663 in 2002.

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. It provides primary access from the north and south between the City of Devils Lake and 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.

4.22.2 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 2001 when the Narrows bridge was constructed to 1465 and the adjacent road was raised to 1455 with a wide base to accommodate future raises to 1465. In 1999, a 3.7-mile segment of the road was raised from 1448.5 to 1452.5. The 1999 raise locations (there were two separate segments) were on the north and east sides of Sections 3 and 4, and in Sections 26 and 35 in Mission Township.

Emergency levees were constructed north and northeast of the east-west portion of ND Highway 20 in 1997. These levees currently protect the 2,000-foot section of the 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 and 1452, its current crest elevation, in 2001. The other two levee sections, located in Section 35 (T153N64W) and Section 31 (T153N63W) were also raised in 1998 and 2001, to 1449 and 1453, respectively.

General Protection Strategy: The Infrastructure Protection Study's analysis for ND Highway 20 (ND Highway 57 to Tokio) considered one incremental flood protection strategy ND Highway 20 (ND Highway 57 to Tokio). That flood protection strategy was the only strategy that was feasible both from an economic and a constructability standpoint. The first action level for that strategy involved raising the road to a minimum road surface elevation of 1457.5. This constitutes a 5-foot raise for the majority of the roadway being raised and a 12.5-foot raise for the 2,000-foot section with current road surface at 1445.

Protection Strategy by Action Level: Figure 4.22-2 shows the decision tree for ND Highway 20 (ND Highway 57 to Tokio). As shown on Figure 4.22-2, the stepwise approach to flood protection for ND Highway 20 (ND Highway 57 to Tokio) consists of the following:

1. At Action Level 1 (AL1), a decision would be made as to whether the road would be raised to 1457.5 or whether the road would be temporarily abandoned

2. If the road were raised at AL1, a decision would be made at Action Level 2 (AL2) whether to raise the road to 1462.5, or to temporarily close the road

3. If the road were raised at AL2, a decision would be made at Action Level 3 (AL3) whether to raise the road to 1465, or to temporarily close the road

The pertinent reference elevations for implementing each increment of flood protection strategy are given below:

Reference Elevations for Feature 22 Road Raises				
Elevation			Name	Significance
AL1	AL2	AL3		
1445	1457.5	1462.5	Low Structure Elevation	Low sill on lowest building or minimum road elevation
Current	1451.5	1456.5	Lake Damage Elevation	Lake elevation at which damage to roadway occurs (a 6-foot wave runup was calculated for this feature)
Current	N/A	N/A	Project Completion Elevation	Lake elevation at which levee construction must be complete
Current	1454.5	1459.5	Construction Initiation Elevation	Lake elevation at which road raise construction must begin. (The current trigger for release of emergency highway funds for road raises is when the lake level reaches within 3 feet of the minimum road surface.)
Current	1452	1458	Planning and Design Initiation Elevation	Lake elevation at which planning and design process must begin

4.22.3 Design Considerations

Sections 4.22.3.0 through 4.22.3.10 describe the analysis of the design of flood protection measures, as well as other considerations (geotechnical, environmental, etc.) necessary to make the cost estimates for the first action level. Section 4.22.3.11 describes the abbreviated cost estimating method for subsequent action levels.

4.22.3.0 General Design

Alignment

Figure 4.22-1 shows the alignment of the existing ND Highway 20 (ND Highway 57 to Tokio). The raised roadway will follow the same alignment.

The length of ND Highway 20 between ND Highway 57 and Tokio is approximately 10.6 miles. Two segments of the highway, both in Mission Township, are currently below the planned 5-foot raise to 1457.5.

Figure 4.22-4 shows the existing road profile and the raised road profile.

Cross-Section

Figure 4.22-3 shows a typical cross-section of the proposed road raise. The raise will maintain the existing road centerline. Fill will be placed on each side of the existing embankment wide enough to provide a base width to accommodate potential future raises to an ultimate road surface at 1465. This section is based on the typical section shown in the plans of the 1999 raise, which was provided by the North Dakota DOT. The road top (pavement) width is assumed to be 40 feet with a 6-foot shoulder on each side for a total road width of 52 feet. The side slopes are 6H:1V on both the sides above elevation 1454.8, and are 3H:1V on both the sides below elevation 1454.8. The minimum raised road elevation is assumed to be 1457.5, a 5-foot raise from the current minimum road surface elevation. It was assumed that unsuitable fill foundation material, averaging 1 foot in depth, would be stripped along the existing embankment toes prior to placement of road fill.

Materials

It was assumed that the roadway fill would be constructed from readily available native silty clay and clay loam. These materials are suitable for road embankment construction. The top 12 inches of the roadway section will be constructed of commercially available aggregate surface course material. Two inches of commercially available hot bituminous pavement will be applied on top of the aggregate, creating the final road surface.

Erosion Protection

On the lake side, riprap was assumed to be placed over geotextile (no additional bedding material) from the existing top edge of riprap all the way to the roadway crest. On the land side, riprap was assumed to be placed over geotextile from 1.5 feet below the crest (vertically) and extend 20 feet down slope (slope distance). No topsoil or seeding was assumed for the raised roadbed.

Riprap sizing and thickness was determined using COE methods described in EM1110-2-1601, with wave height based on a COE Report titled *Devils Lake, North Dakota, Wind-Induced Changes in Water Elevations*, revised September 1998. The riprap design, based on the fetch, depth of water, and the side slope, is summarized in the table below.

Wave	**Wind-Induced Height (ft.)**	**Riprap size (D_{50}, inches)**	**Riprap Thickness (ft.)**
Maximum Predicted	6	30	4
Typical Design	3	15	2

Prevailing winds in the region are from the northwest and southeast, and so have a large effect on waters with large fetches open in those directions. The maximum predicted wave height is large because a limited portion of ND Highway 20 is exposed to a very long fetch of water in the southeast direction. Typical wave height is assumed to be 3 feet for the damage cost estimates. However, the action levels are based on the maximum predicted wave height.

4.22.3.1 Site Geology

In the area of Devils Lake, Late Wisconsin age glacial deposits of varying thickness overly deposits of earlier glaciations and/or Cretaceous age bedrock. Thin lacustrine deposits from the current and prehistoric Lake Minnewaukan are also present in the Devils Lake basin. All the glacial deposits in this area are part of the Coleharbor Formation.

This highway alignment is underlain by (1) boulder clay till in a low-relief stagnation moraine and (2) silt and clay facies representing lake bed deposits. All of these deposits are in the Coleharbor Formation. The till is generally composed of silty clay with sand, pebbles, cobbles, and boulders (CL, CL-ML). This deposit is yellowish brown in the oxidized zone in the uppermost 10 to 25 feet near the ground surface, and olive gray at depth. The glacial deposits range from about 90 to >200 feet in thickness. It is likely that some sand and gravel outwash units are present at depth (the log of a well at 152-63-10DAC indicates the section is mostly sand and gravel at that location). The bedrock is Cretaceous Pierre Shale.

Silt and clay facies (ML, CL CL-ML, CH, OL) are lake bed deposits 0 to +5 feet thick. These were deposited during prehistoric high stands of the lake (prehistoric Lake Minnewaukan). These are present above the till beneath nearly 60 percent of the impacted alignment sections of highway. These include a relatively large amount of fat clays and organic clays and silts along this alignment. Sand beach deposits (SP, SP-SM) are present in some places at the edge of the lake bed deposits (0 to +5 feet thick).

It is assumed 12 soil borings will be sufficient to characterize this alignment. The impacted alignment crosses approximately 17,000 feet of lake bed deposits, which may be poor subgrade due to softness.

4.22.3.2 Hydrology/Interior Drainage issues

It is assumed that culverts will be placed through the raised roadway embankment to allow for water level equalization on both sides of the roadway. Any existing culverts through the raised roadway were assumed to have been previously filled and abandoned

in place. Four new RCP culverts are assumed to be placed at the existing road elevation through the roadway embankment at the following locations:

1. Approximately 1,400 feet from the western end of the northern raise
2. Approximately 2,900 feet north of the BIA Highway 4 intersection
3. Approximately 3,400 feet from the northern end of the southern raise section
4. Approximately 7,400 feet south of the northern end of the southern raise section

4.22.3.3 Real Estate Requirements

Right-of-way requirements for the road raise are assumed to extend 15 feet beyond the land side toes of the raised embankment. The 15-foot buffer will provide sufficient room for temporary construction activities and long-term maintenance access.

4.22.3.4 Environmental/Cultural issues

HTRW

Current land uses, surrounding ND Highway 20 (ND Highway 57 to Tokio), appear to be predominantly agricultural or tree-covered with scattered rural residences and farms. Land use does not appear to have changed significantly since the 1950s.

The regulatory record review for zip code 58370 was obtained from FirstSearch on September 24, 2002. No facilities appear to be located within the impact area.

Three potential HTRW sites identified along the feature alignment are listed below and shown on Figure 4.22-1:

HTRW Site Costs			
Site #	**Action Level Affected**	**HTRW Category**	**HTRW Costs**
22-1-1	1	Excavation or Fill Areas	$500
22-1-2	1	Nonresidential Properties	$1,500
22-1-3	1	Rural Residences & Farmsteads	$500

A more detailed description of site history and a breakdown of costs are in Appendix C. A description of environmental concerns associated with these categories is in Section 4.0.

Cultural

This project has the potential to affect ten known sites and three site leads/isolated finds as shown on Figure 4.22-1. Three of the known sites (32BE0048, 32BE0051, and 32BE0052) are historical archaeological sites that were surface collected but for which eligibility was not determined. Five of the known sites (32BE0063, 32BE0092, 32BE0093, 32BE0416, and 32RY0319) are architectural sites. Site 32BE0063 is a recent farmstead with a historical barn that was recommended as not eligible for listing on the NRHP. Christ the King Catholic Church (32BE0092) and Assembly of God Church (32BE0093) were recorded as part of the "Picture North Dakota Churches!" project sponsored by the State Historical Society of North Dakota, but they were not evaluated for their potential eligibility for listing on the NRHP. Yankton Cabins (32BE0416) is likely associated with an artifact scatter, given that the 1997 database notes "surface collection" there. A recommendation of eligibility has not been made for this site. Devils Lake Carnegie Library (32RY0319) has been nominated to the NRHP. Site 32BE0406 (Ironhawk Site) is the only known prehistoric archaeological site that may be impacted by the ND Highway 20 (ND Highway 57 to Tokio) project. This site was surface collected and recommended as not eligible for listing on the NRHP. The final known site relevant to this project is 32BE0085, a scatter of non-diagnostic lithic artifacts and a bone fragment that was recommended as not eligible for listing on the NRHP.

The site lead that may fall within the ND Highway 20 (ND Highway 57 to Tokio) area of potential impact is 32BEX0004 (Tokio Townsite), a historical archaeological site lead associated with the historical context of "Farming." Two isolated finds, 32BEX0130 and 32BEX0131, may also fall within the project APE. Isolated find 32BEX0130 is comprised of "two old car bodies and a possible homesite" (NDCRS Form, 32BEX0130, on file at the SHSND), while 32BEX0131 is comprised of an old stove and scattered metal fragments. Additional archaeological work was not conducted in the vicinity of these finds. Therefore, recommendations of eligibility were not made for either of these isolated finds.

A summary of the evaluation status of known cultural resources is presented in the following table.

Feature 22 ND Highway 20 (ND Highway 57 to Tokio): Evaluation Status of Known Cultural Resources			
Resource Type	**Resources Listed on or Nominated for the NRHP**	**Resources with Recommendations (Phase I Survey Completed)**	**Resources with Inconclusive or No Recommendations (Require Phase I Survey)**
Architectural	1	1	3
Archaeological	0	2	3
Architectural Site Leads/Isolated Finds	0	0	0
Archaeological Site Leads/Isolated Finds	0	0	3
Total	1	3	9

The estimated cost to conduct Phase 1 Surveys for each of the 9 sites is presented in the following table. The total cost for all surveys is $72,600. As noted in Section 4.0, these costs are believed representative of the cultural resources investigations needed for the next stage of study.

Feature 22 ND Highway 20 (ND Highway 57 to Tokio): Phase 1 Survey Costs		
Site Number	**Investigation Type**	**Estimated Cost**
32BE0092	Phase I Architectural	$6,200
32BE0093	Phase I Architectural	$6,200
32BE0416	Phase I Architectural	$6,200
32BE0048	Phase I Archaeological	$8,000
32BE0051	Phase I Archaeological	$8,000
32BE0052	Phase I Archaeological	$8,000
32BEX0004	Phase I Archaeological	$14,000
32BEX0130	Phase I Archaeological	$8,000
32BEX0131	Phase I Archaeological	$8,000

Environmental

Fill used for the construction of the road raise and relocation could cause environmental impacts due to encroachment upon wetlands and upland plant communities. The natural resources within the right-of-way of ND Highway 20 (ND Highway 57 to Tokio) to be raised include wetlands, oak forest/woodlands, and grasslands. The acres of habitat impacted by land use category are shown on Figure 4.22-1. A total of 5.67 acres of wetland impacts are expected from the proposed infrastructure protection measures. In the 5.67 acres of impacted wetlands 0.44 acres have easements on them. Complete or

partial loss of wetland functions and conversion to upland due to filling is possible in some locations. In areas where some hydrology is maintained and wetland conditions remain, changes in plant community and hydrology could lead to a wetland type change. The loss of wetland area would impact waterfowl, marsh bird and songbird-nesting areas, as well bring about impacts to reptile and amphibian populations due to habitat fragmentation and loss. These environmental impacts are more fully detailed in the general impacts discussion Section 4.0. This loss of wetland would require 10.90 acres of mitigation wetlands as set forth in the project mitigation policy developed through consultation with the Corps and FWS.

In the upland areas a loss of native species due to grading and filling could be expected to occur. Subsequent re-vegetation of fill or borrow locations may allow for the introduction of weedy, non-native species. A loss of native tree species due to grading and filling, as well as the introduction of weedy, non-native under-story species could also be expected in these areas. These environmental impacts are more fully detailed in the general impacts discussion Section 4.0. Environmental impacts to 1.66 acres of oak forest/oak woodland, 2.32 acres of grasslands under easements, 24.05 acres of other grassland habitat acres and 0.05 acres of the grassland habitat impacts within the boundaries of a WPA would result from measures undertaken at this location. There are also 0.33 acres of cover crop under easements that would be impacted from the proposed infrastructure protection measures in this location. The loss of woodland areas would impact songbird nesting and small mammal populations, as well impacting reptile and amphibian populations due to habitat fragmentation. Mitigation activities would require the acquisition of 3.32 acres of oak forest/oak woodland, 49.47 acres of grasslands habitat and 0.33 acres of cover crop of like upland habitat replacement for these impacts.

4.22.3.5 Effects on Existing Infrastructure and Utilities

Utility poles are located along the roadway in the southern raise section, and were assumed to be relocated prior to placing embankment fill along the road segments. Buried electric lines along the roadway of the northern raise area were also assumed to be replaced as part of the raise. Buried telephone was assumed to be replaced as part of both raise sections.

Replacement of local driveway access to adjacent properties was not considered as a separate cost item, but is considered incidental to the other construction items. With the exception of drainage culverts discussed above, no other infrastructure or utilities are expected to be impacted.

4.22.3.6 Interdependencies

The protection of ND Highway 20 (ND Highway 57 to Tokio) is related to the protection of several other features. The following features are functionally dependent on ND Highway 20 (ND Highway 57 to Tokio), and would be affected if it were temporarily closed:

- Feature 2: City of Devils Lake
- Feature 3: Fort Totten
- Feature 5: St. Michael
- Feature 6: Gilbert C. Grafton Military Reservation – Camp Grafton has a separate training area that is located south of the lake

If ND Highway 20 (ND Highway 57 to Tokio) were temporarily closed, the following roads would either experience increased traffic as a detour routes or decreased traffic as travel is routed to other roadways:

- Feature 14: ND Highway 57 – If ND Highway 20 (ND Highway 57 to Tokio) is temporarily closed, ND Highway 57 is impacted because its eastern terminus is at its junction with ND Highway 20
- 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)

Feature 25: Roads Acting as Dams – If lake levels rise and the water levels on each side of any nearby roads acting as dams are allowed to equalize, the raising of ND Highway 20 (ND Highway 57 to Tokio) will be necessary to allow its continued use. However, if appropriate levee protection along the roads currently acting as dams is provided, portions of ND Highway 20 (ND Highway 57 to Tokio) would be protected by those levees. In that case, the ND Highway 20 (ND Highway 57 to Tokio) may not require as much raised length.

Table 4.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

4.22.3.7 O&M

Operation and maintenance requirements for the raised roadway would be similar to the unimpacted roadway with respect to road surface maintenance and shoulder and slope mowing. The increase in O&M on the adjacent routes that are used as detours would be approximately equal to O&M on the temporarily closed road. Additional maintenance requirements for the raised roadway sections would include maintenance of the riprap on both the lake and land sides. Annual maintenance costs for the riprap have been estimated at 0.5 percent of the initial construction cost. The O&M costs were not included in the economic analysis due to limitations of the Feature Analysis Model.

4.22.3.8 Lead Time Required

The raising of ND Highway 20 (ND Highway 57 to Tokio) could be completed in one construction season. A lead time of about twelve months would be necessary for final design, preparation of construction documents and bidding. Total time between initiation of final design and substantial completion of construction would be in the range of 18 to 24 months.

4.22.3.9 Potential Problems and Risks

Potential problems and risks associated with the road raise include:

- Road embankment fill into water will make compaction and quality control difficult
- Foundation conditions will be difficult to assess prior to actual construction
- Utilities will need to be relocated

4.22.3.10 Data Deficiencies

The following data should be collected or verified prior to proceeding with raising ND Highway 20 (ND Highway 57 to Tokio):

- Locations of buried utilities, if any
- Soil borings along toes of existing road embankment
- Precise location and evaluation of nearby cultural resources

4.22.3.11 Abbreviated Cost Estimating for Feature Subsequent Action Levels

As was mentioned previously, for Feature 22, an abbreviated method was necessary for examining the costs of infrastructure protection at action levels above the first. The estimated costs at action levels subsequent to the first are presented in Table 4.22-2b. Estimates of benefits—damages prevented—for subsequent action levels were made in

the same manner as for the first action level. The damage estimates for all action levels are shown in Table 4.22-1.

The same general approach to calculate costs was used for the subsequent action levels. Unit prices were not changed. However, some of the items were simply extrapolated for the higher action levels, rather than being calculated in detail. The relevant design and cost assumptions for the abbreviated method are listed below.

Design Assumptions

- Raise elevations

  Action Level 2: 5-foot raise to 1462.5

  Action Level 3: 2.5-foot raise to 1465

- Cross-section

  Action Level 2: 47-foot top width, 3H: 1V side slopes, centerline-aligned raise

  Action Level 3: 32-foot top width, 3H: 1V side slopes, centerline-aligned raise

- Length

  Action Level 2: Total length of raised roadway 33,500 feet

  Action Level 3: Total length of raised roadway 34,050 feet

- Impacted Area

  Action Level 2: Incremental area impacted by raised roadway- 1.3 acres

  Action Level 3: Incremental area impacted by raised roadway- 0.5 acres

Construction material quantities were calculated in accordance with design assumptions discussed previously, and are listed in Table 4.22-2b. The geological/geotechnical and environmental quantities and costs were estimated in proportion to the Action Level 1 costs as described in Section 3.2.13. Real Estate costs were assumed to be the same for each raise.

4.22.4 Economics of Flood Protection

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 4.22-1.

The top portion of Table 4.22-1 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.

The lower portion of the table shows the breakdown of these summary values. 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, geotextile fabric, aggregate base course, fill, bituminous pavement, and riprap for road restoration work when waters recede.

The unit prices for all the damage computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. 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 4.22.

Costs: The costs of providing flood protection for ND Highway 20 (ND Highway 57 to Tokio) are detailed in the accompanying Table 4.22-2a for the first action level and Table 4.17-2b for the subsequent action levels. 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. The lower portion of the table gives a breakdown of the quantities and costs by line item.

Unit prices for all the cost computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. 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 Feature 22 Assumptions listing, appended to this Section 4.22.

Contingencies: The contingency percentages used for construction materials ranged from 30 to 50 percent (Table 4.22-2). Contingencies for riprap, fill material, and geotechnical items were estimated at the higher end of the range because of the potential variability in the quantities and unit prices.

4.22.5 Economic Results

The flood protection strategy that was analyzed was incremental road raises, which is highlighted on the decision tree (Figure 4.22-2). The results of the Infrastructure Protection Study for ND Highway 20 (ND Highway 57 to Tokio) are listed in Table 4.22-3a for the analysis of all action levels and in Table 4.22-3b for the analysis of the first action level.

Multiple Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for ND Highway 20 (ND Highway 57 to Tokio), the

Infrastructure Protection Study analysis provided relevant economic indices for the incremental road raise strategy. The annual net benefits for this approach were less than zero (-$592,300). The BCR for this approach was less than one (0.50). These results indicate that this strategy is not economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $247,600. The stochastic results are averages over 10,000 traces.

Multiple Action Level Results for Specific Scenarios: The incremental road raise strategy was also analyzed under each of three specific climate futures. For ND Highway 20 (ND Highway 57 to Tokio), the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of raising the road were -$1,210,800, and the BCR was 0.34, indicating that this strategy was not economically justified. No restoration damages are listed under this scenario, indicating that the water level never recedes below the first action level. For this future, the present worth annualized detour damages that would be prevented were computed at $260,200.

- First Moderate Future – Under the first moderate future climate scenario, the annual net benefits of raising the road were -$54,200, and the BCR was 0.95, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $244,100.

- Second Moderate Future – Under the second moderate future climate scenario, the annual net benefits of raising the road were -$902,500, and the BCR was 0.40, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $488,700.

First Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for ND Highway 20 (ND Highway 57 to Tokio), the Infrastructure Protection Study analysis also provided relevant economic indices for the first incremental road raise. The annual net benefits for this approach were less than zero (-$532,300). The BCR for this approach was less than one (0.51). These results indicate that this strategy is not economically justified; the results are similar to the results based on all action levels. The present worth annualized detour damages that would be prevented by this strategy were computed to be $247,600. The stochastic results are averages over 10,000 traces.

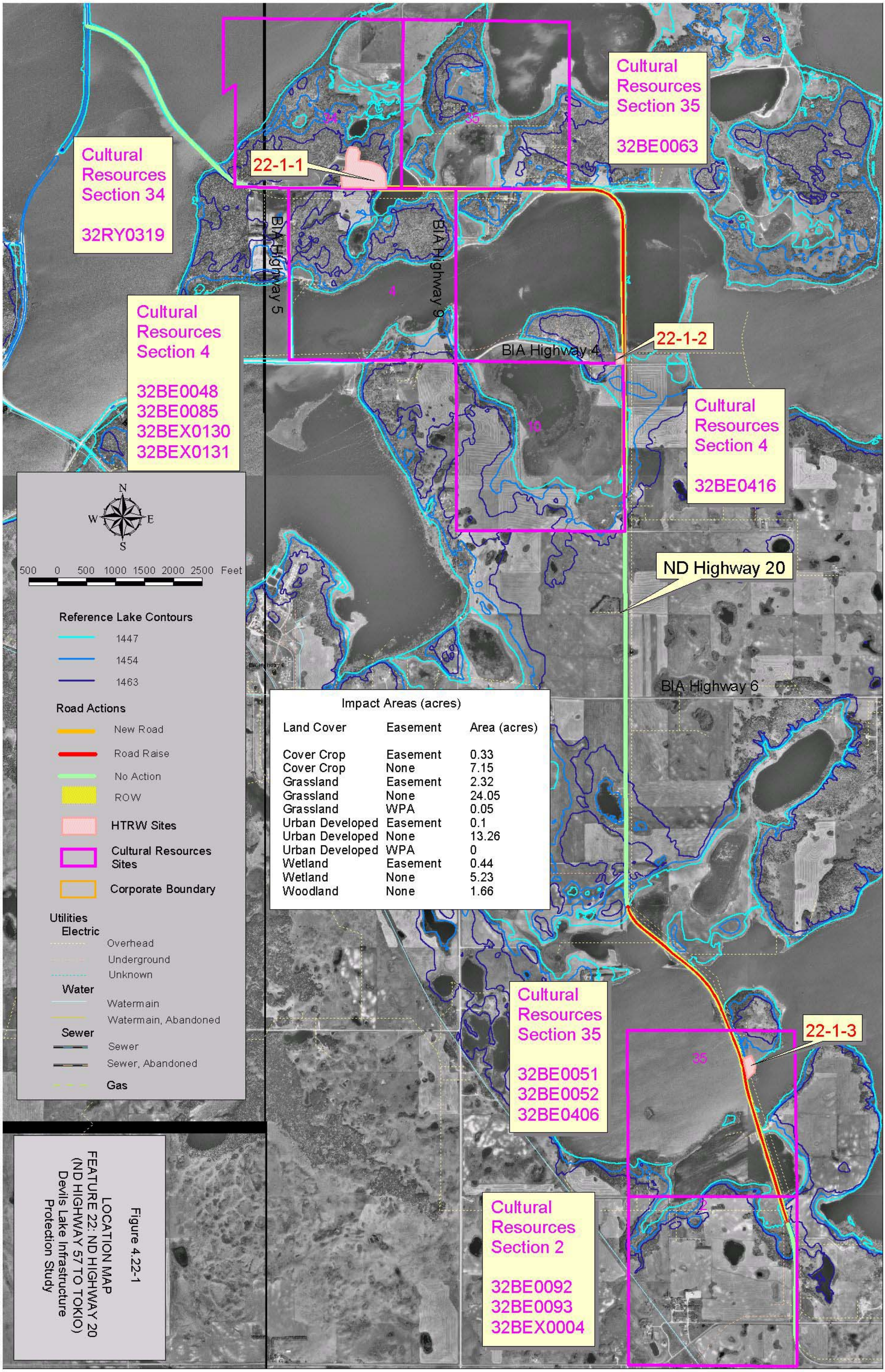
First Action Level Results for Specific Scenarios: The first incremental road raise was also analyzed under each of three specific climate futures. For ND Highway 20 (ND Highway 57 to Tokio), the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the average net benefits of raising the road were -$826,000, and the BCR was 0.24, indicating that this strategy was not economically justified. No restoration damages are listed under this scenario, indicating that the water level never recedes below the first action level. For this future, the present worth annualized detour damages that would be prevented were computed at $260,200.

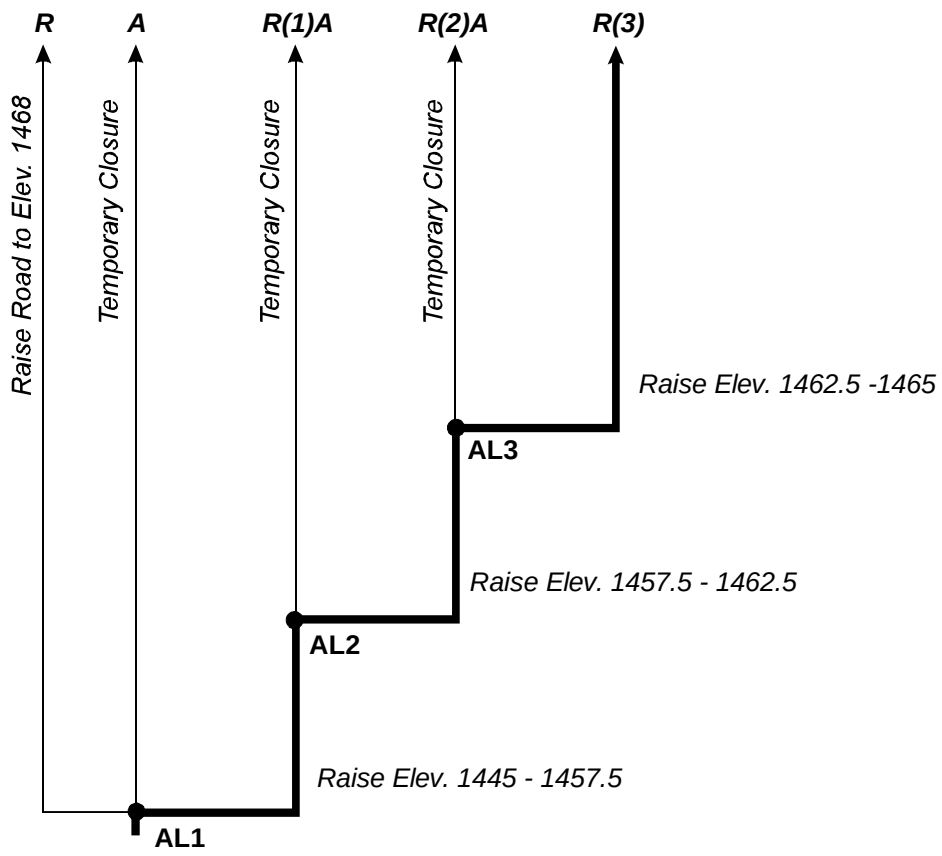
- First Moderate Future – Under the first moderate future climate scenario, the average net benefits of raising the road were -$54,200, and the BCR was 0.95, indicating that this strategy was not economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $244,100.

- Second Moderate Future – Under the second moderate future climate scenario, the average net benefits of raising the road were -$597,500, and the BCR was 0.45, indicating that this strategy was not economically justified. No restoration damages are listed under this scenario; the lake level exceeds the second action level, and restoration damages would be a function of the subsequent action levels[1]. For this future, the present worth annualized detour damages that would be prevented were computed at $488,700.

[1] For analysis of the first action level, it was assumed that restoration damages would be attributable to the first action level only if the lake level never reached the subsequent action levels. See Section 3.2.2.1 for further discussion of this assumption.



Data: 1997 USGS Digital Ortho Quad



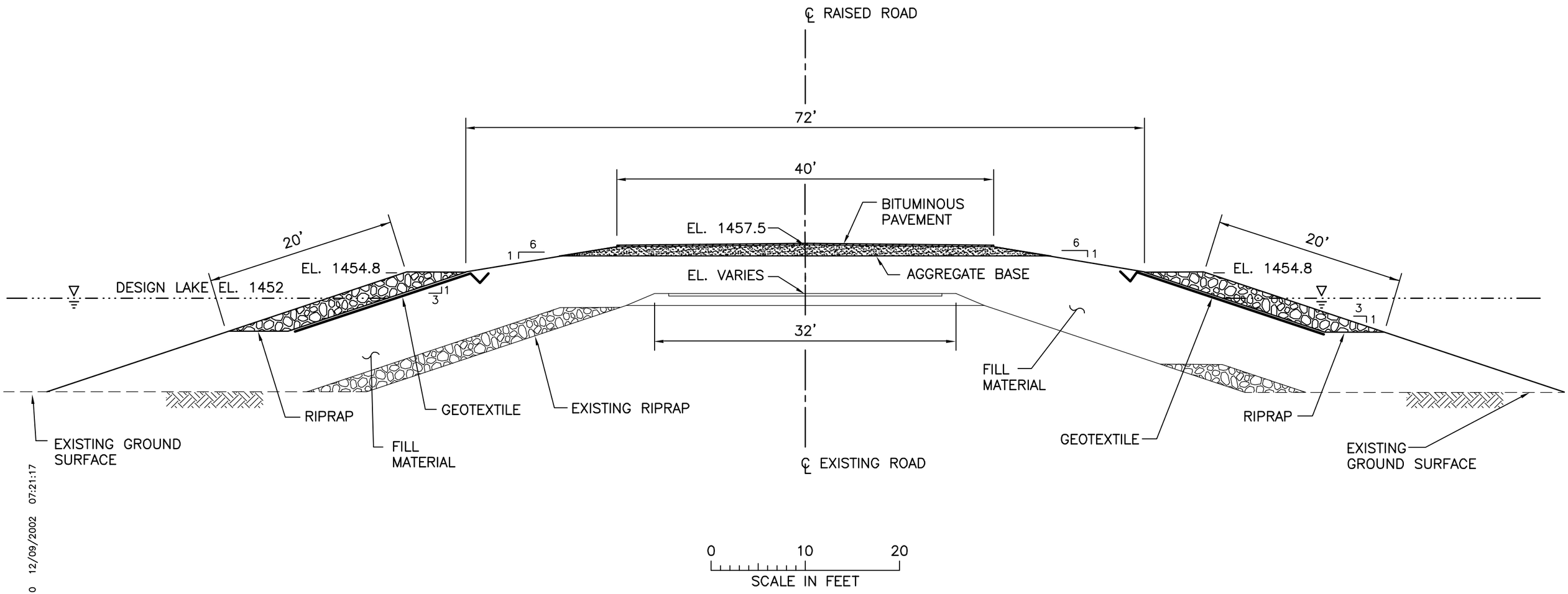
Lowest Road Elevation: 1445

P:\34\36\020\DECISIONTREES\2002FIGURES\FIGURE4_22.CDR RLG 01-06-03

▬	Flood Protection Strategy
●	Decision required at this point
⊙	Trigger point for action, no decision needed
AL1	Decision/Action Level
R(1)	Incremental road raise (number of times)
R	Road raise to 1465
A	Temporary closure of road

Figure 4.22-2

DECISION TREE
FEATURE 22: ND HIGHWAY 20
(ND Highway 57 to Tokio)
Devils Lake Infrastructure Protection Study



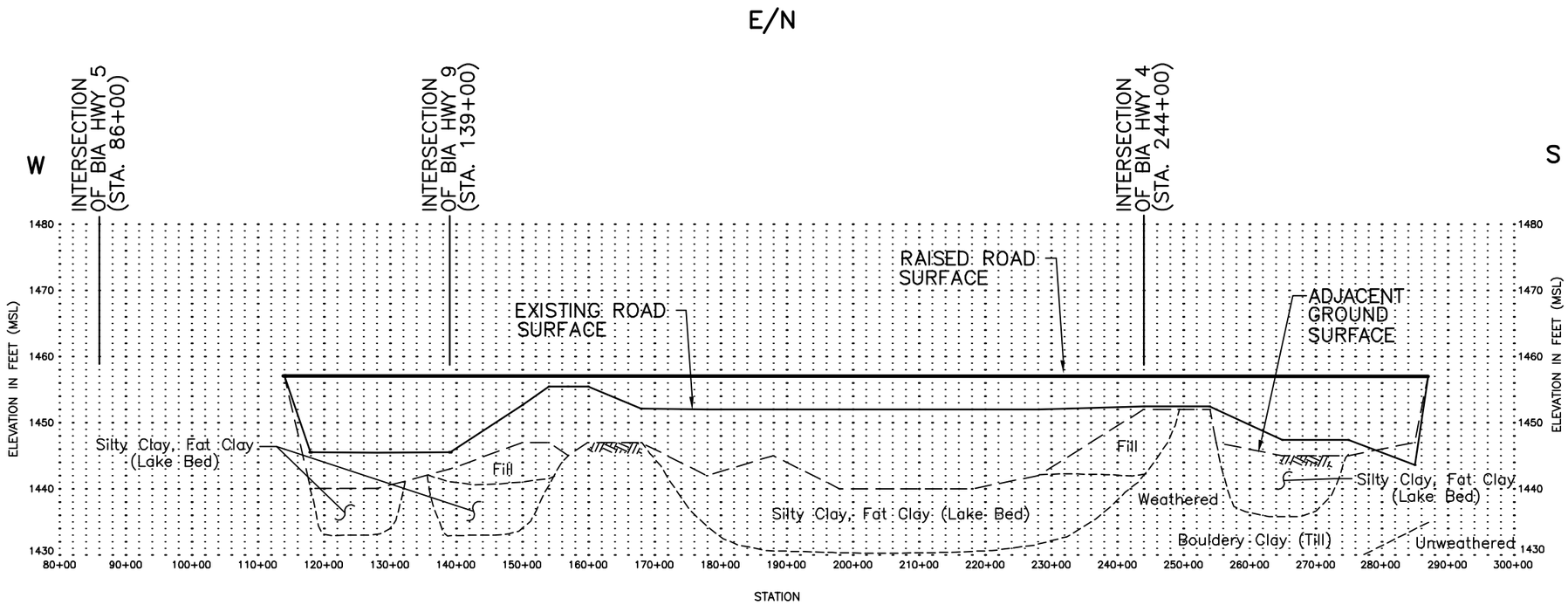
NRD M:\CAD\3436020\17160_2.DWG Plot at 10 12/09/2002 07:21:17

Figure 4.22–3

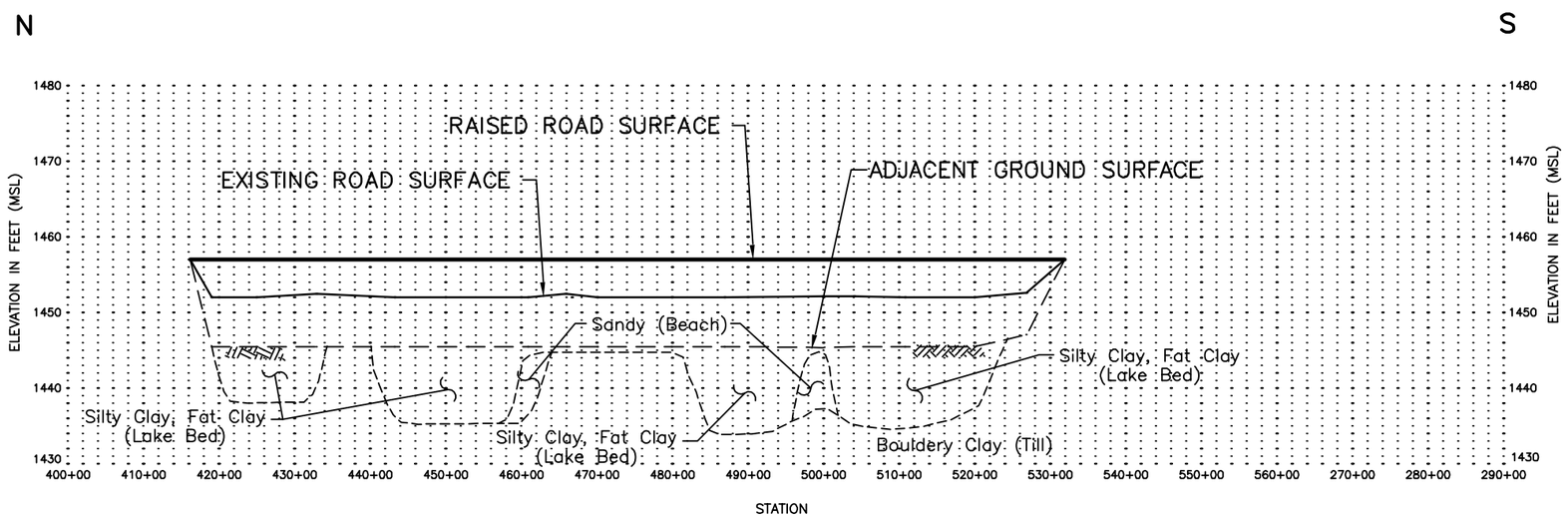
TYPICAL ROAD CROSS–SECTION

FEATURE 22:
ND HIGHWAY 20
(BETWEEN N.D. HIGHWAY 57 AND TOKIO)

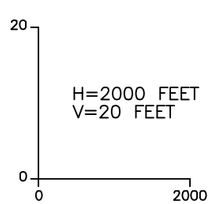
DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY



ND HWY 20 BETWEEN BIA HWY 5 AND 40th ST. NE



ND HWY 20 BETWEEN 38th ST. NE AND TOKIO



1. Adjacent ground elevations obtained from 2000 FEMA LIDAR topography.
2. Existing road surface elevations from the following construction drawings:
3. ND DOT Construction Drawings for Project No. SS–3–020(055)088 dated 5–25–99, and 2000 FEMA LIDAR Topography.
4. Raised road surface elevation based on assumed incremental raise height.
5. Stationing based on the stationing used in the above–referenced drawings.

Figure 4.22–4

ROAD PROFILE

FEATURE 22:
ND HWY 20
(BETWEEN HWY 57 AND TOKIO)

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

NRD M:\CAD\3436020\17228_2.DWG Plot at 100 12/09/2002 07:14:54

Table 4.22-1

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

DAMAGES

	Annual Detour Damages	Restoration Damages	
Lake Elevation (MSL)	**Damage Value (THOUSANDS)**	**Impacted Roadway Length (FEET)**	**Damage Value (THOUSANDS)**
1447	$611	20,000	$4,256
1448	$611	25,000	$4,785
1449	$611	29,880	$5,301
1450	$611	32,840	$5,614
1451	$611	36,230	$5,973
1452	$611	38,440	$6,206
1453	$611	39,680	$6,338
1454	$611	40,460	$6,420
1455	$611	40,790	$6,455
1456	$611	41,120	$6,490
1457	$611	41,440	$6,524
1458	$611	41,770	$6,559
1459	$611	42,100	$6,594
1460	$611	42,420	$6,628
1461	$611	42,750	$6,662
1462	$611	43,070	$6,696
1463	$611	43,400	$6,731
1464	$611	43,730	$6,766
1465	$611	44,060	$6,801

DAMAGE BREAKDOWN

Annual Detour Damages	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Value (THOUSANDS)**
	Hours/Year	23,410	HR	$7.13	$167
	Miles/Year	1,287,320	MILE	$0.35	$444
	Total				**$611**

Restoration Damages	**Item**	**Description**	**Quantity per LF of Road**		**Unit Cost**	**Contingency**	**Value per LF of Road**
	Excavation	Removal of existing bituminous (26' X 0.17'), existing shoulder (3' X 0.5' ea. side), existing aggregate base (41' X 1'), and top 1.5' of existing road embankment fill	4.07	CY/LF	$3.50	30%	$19
	Fill Material	Replace top 1.5' of roadway embankment	2.36	CY/LF	$5.00	30%	$15
	Geotextile Fabric	Place geotextile beneath new aggregate base	4.67	SY/LF	$2.00	30%	$12
	Aggregate Base Course	Replace 1' of subgrade and shoulders (3' X 0.5' ea. side)	1.55	CY/LF	$20.00	30%	$40
	Bituminous	Replace 0.17' of bituminous pavement	0.30	Tons/LF	$50.00	30%	$20
	Total						**$106**
	Item	**Description**	**Quantity per LF of Road**		**Unit Cost**	**Contingency**	**Total Value for Road**
	Riprap	Place riprap from road surface elevation to bottom of embankment replacement for lowest impacted roadway length	1.25	CY/LF	$40.00	30%	$1,942,200
	Geotextile Fabric	For use under riprap restoration	2.54	SY/LF	$2.00	30%	$197,328
	Total						**$2,139,528**

Table 4.22-2a

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R (1)
Action Level	Maximum Raise at AL1
	(THOUSANDS)
AL1	$17,858

COST BREAKDOWN

Strategy	R(1)					
	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Road Raise	**Raise Top of Road to Elevation 1457.7**					
	Performance/Payment Bond	1	JB	$99,409	10%	$109
	Clearing and Grubbing	0.2	AC	$3,000	30%	$1
	Stripping	36,000	CY	$1.50	30%	$70
	Geotextile Fabric	134,500	SY	$2.00	30%	$350
	Aggregate Base Course	55,000	CY	$20	30%	$1,430
	Fill Material	1,018,000	CY	$5.00	45%	$7,381
	Bedding	0	CY	$35	30%	$0
	Riprap	77,000	CY	$40	40%	$4,312
	Bituminous Pavement	9,500	TON	$50	30%	$618
	Culverts	350	LF	$50	30%	$23
	Topsoil	0	CY	$2.50	30%	$0
	Seed	0.0	AC	$1,000	30%	$0
	Geotechnical					
	Slurry Wall	0	SF	$6.00	50%	$0
	Borings	12	EA	$1,000	50%	$18
	Environmental Impacts					
	Mitigation	1	LS			$22
	HTRW	1	LS			$3
	Cultural Resources Investigation	1	LS			$73
	Subtotal					$14,408
	Engineering and Design		15%			$2,161
	Supervision and Administration		8%			$1,153
	Real Estate Acquisition for ROW	1	LS			$136
	Total Road Raise					**$17,858**

ANNUAL OPERATION AND MAINTENANCE COSTS

Action Level	Road Maintenance Costs
	(THOUSANDS)
AL1	$71

Table 4.22-2b

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R (2)	R (3)
Action Level	Maximum Raise at AL2	Maximum Raise at AL3
	(THOUSANDS)	
AL2	$14,852	$0
AL3	$0	$5,277

COST BREAKDOWN

Strategy	R(2) Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)	R(3) Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Road Raise	**Raise Top of Road to Elevation 14xx**						**Raise Top of Road to Elevation 14xx**					
	Performance/Payment Bond	1	JB	$83,112	10%	$91	Performance/Payment Bond	1	JB	$29,032	10%	$32
	Clearing and Grubbing	0.0	AC	$3,000	30%	$0	Clearing and Grubbing	0.0	AC	$3,000	30%	$0
	Stripping	2,100	CY	$1.50	30%	$4	Stripping	0	CY	$1.50	30%	$0
	Geotextile Fabric	205,500	SY	$2.00	30%	$534	Geotextile Fabric	52,000	SY	$2.00	30%	$135
	Aggregate Base Course	56,500	CY	$20	30%	$1,469	Aggregate Base Course	39,500	CY	$20	30%	$1,027
	Fill Material	297,000	CY	$5.00	45%	$2,153	Fill Material	145,000	CY	$5.00	45%	$1,051
	Bedding	0	CY	$35	30%	$0	Bedding	0	CY	$35	30%	$0
	Riprap	122,000	CY	$40	40%	$6,832	Riprap	20,000	CY	$40	40%	$1,120
	Bituminous Pavement	13,500	TON	$50	30%	$878	Bituminous Pavement	12,500	TON	$50	30%	$813
	Culverts	0	LF	$50	30%	$0	Culverts	0	LF	$50	30%	$0
	Topsoil	0	CY	$2.50	30%	$0	Topsoil	0	CY	$2.50	30%	$0
	Seed	0.0	AC	$1,000	30%	$0	Seed	0.0	AC	$1,000	30%	$0
	Geotechnical						**Geotechnical**					
	Slurry Wall	0	SF	$6.00	50%	$0	Slurry Wall	0	SF	$6.00	50%	$0
	Borings	2	EA	$1,000	50%	$3	Borings	1	EA	$1,000	50%	$2
	Environmental Impacts						**Environmental Impacts**					
	Mitigation	0	LS			$0	Mitigation	0	LS			$0
	HTRW	0	LS			$0	HTRW	0	LS			$0
	Cultural Resources Investigation	0	LS			$0	Cultural Resources Investigation	0	LS			$0
	Subtotal					$11,965	Subtotal					$4,179
	Engineering and Design		15%			$1,795	Engineering and Design		15%			$627
	Supervision and Administration		8%			$957	Supervision and Administration		8%			$334
	Real Estate Acquisition for ROW	1	LS			$136	Real Estate Acquisition for ROW	1	LS			$136
	Total Road Raise					**$14,852**	**Total Road Raise**					**$5,277**

ANNUAL OPERATION AND MAINTENANCE COSTS

Action Level	Road Maintenance Costs
	(THOUSANDS)
AL2	$59
AL3	$21

Table 4.22 - 3a

Economics Results: All Action Levels -- to Lake Level 1463
Feature 22: ND Highway 20 (ND Highway 57 to Tokio)
Devils Lake Infrastructure Protection Study

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

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$314,800	$247,600	$0	$562,400	$0	$0	--
R(3)	3 Incr. Road Raises	$1,183,500	$0	$1,183,500	$0	$0	$0	$0	$591,200	-$592,300	0.50

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$260,200	$0	$260,200	$0	$0	--
R(3)	3 Incr. Road Raises	$1,821,800	$0	$1,821,800	$0	$0	$0	$0	$611,000	-$1,210,800	0.34

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

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$787,900	$244,100	$0	$1,032,000	$0	$0	--
R(3)	3 Incr. Road Raises	$1,086,200	$0	$1,086,200	$0	$0	$0	$0	$1,032,000	-$54,200	0.95

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

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$78,800	$488,700	$0	$567,500	$0	$0	--
R(3)	3 Incr. Road Raises	$1,503,400	$0	$1,503,400	$0	$0	$0	$0	$600,900	-$902,500	0.40

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

Table 4.22 - 3b

Economics Results: First Action Level
Feature 22: ND Highway 20 (ND Highway 57 to Tokio)
Devils Lake Infrastructure Protection Study

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

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$302,600	$247,600	$0	$550,200	$0	$0	--
R(1)	1 Incremental Road Raise	$1,082,500	$0	$1,082,500	$0	$0	$0	$0	$550,200	-$532,300	0.51

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$260,200	$0	$260,200	$0	$0	--
R(1)	1 Incremental Road Raise	$1,086,200	$0	$1,086,200	$0	$0	$0	$0	$260,200	-$826,000	0.24

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

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$787,900	$244,100	$0	$1,032,000	$0	$0	--
R(1)	1 Incremental Road Raise	$1,086,200	$0	$1,086,200	$0	$0	$0	$0	$1,032,000	-$54,200	0.95

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

Strategy		COSTS			DAMAGES				Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	Raise A	Relocation B	Total C = A + B	Restoration D	Detour E	Relocation Detour F	Total G = D + E + F	To Strategy (Damages Prevented) H = G(A) - G(S) *	To Strategy I = H - C	(BCR) I = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$488,700	$0	$488,700	$0	$0	--
R(1)	1 Incremental Road Raise	$1,086,200	$0	$1,086,200	$0	$0	$0	$0	$488,700	-$597,500	0.45

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

Attachment to 4.22:
ND Highway 20 (ND Highway 57 to Tokio) Infrastructure Protection Study Assumptions

A. Existing Road Information

1. Existing road elevations for the feature were obtained through contact with ND DOT representatives, primarily Brad Darr.

2. Existing road cross-section for the feature were based on construction drawing typical sections obtained from ND DOT/or their consultants including:

   - ND DOT Plan: Project No. SS-3-020(055)088, 5/25/99

3. Existing road centerline profiles for the features evaluated were obtained from the plans listed above. Plan elevation data was assessed for reasonableness by comparing to the 2000 FEMA LIDAR topography. Where necessary, road plan elevation information was supplemented with the LIDAR information.

B. Road Raise

1. The road raise was assumed to be 1457.5 from existing road surface elevation.

2. Cross-Section – The future road raise cross-section was based on discussions with ND DOT staff and the most recent typical raise sections that have been completed on the highway provided by ND DOT (primarily Leo Boyle) and/or their consultants. It was assumed that the wide base roadway would be implemented on the next raise, and therefore is the basis of the raised road cross-section. The plans referenced included:

   - ND DOT Plan: Project No. SS-3-020(055)088, 5/25/99, Sheet 6 of 18

3. Profile –

   - Adjacent ground elevations obtained from 2001 LIDAR topography prepared for FEMA

   - Existing road surface elevations from the following construction drawings: NDDOT Construction Drawings for Project No. SS-3-020(055)088 dated 5-25-99, and the above LIDAR Data

   - Raised road surface elevation based on assumed 5-foot raise

   - Stationing based on the stationing used in the above-referenced drawings

4. No topsoil or seeding was assumed for the road raise because of the width of the road shoulder and the height of riprap placement.

5. It was assumed that four culverts would be placed in four individual low areas to provide flow equalization. It is assumed that any existing culverts were left in place, and that the four new culverts would be located at an elevation equal to the existing road surface elevation.

C. Geotechnical

1. The scope and cost of geotechnical mitigation are related to: (1) number of borings and soil tests, and (2) soft soils that may require excavation and/or additional construction material,

2. While the county soil surveys have similar descriptions of the subgrade characteristics of glacial till and lake bed deposits (Severe: low strength), experience in the Devils Lake area has indicated that most till deposits are better subgrade than lake. The potential thickness of soft-soil deposits has been estimated based on descriptions of the lake bed deposits in the geologic and soils reports.

3. The potential extents of sand deposits have been estimated based on descriptions in the soils reports. It is likely that in some locations, the surficial sand deposits, typically assumed herein to beach deposits, may be continuous with subsurface sand and gravel deposits (glacial outwash). As such, some of the sand deposits may be of much greater extent vertically and laterally (buried) than has been assumed herein.

4. It is assumed that a soil boring will be completed approximately every 1,000 feet of road length. Additional borings will be completed in areas of critical soils. Each soil boring and associated observation and testing will cost $2,000.

5. Cut off walls are estimated to be $6/square foot based on past work at Devils Lake.

6. In instances where construction may be completed in the wet, it is assumed that soft soil will not be excavated, but instead may be displaced by new fill. In those instances, additional fill contingency is added based on the percentage of the feature alignment that is underlain by potentially soft soil.

7. The subgrade conditions along the alignment of this feature are based upon review of:

   - Carlson, C.G. and T.F. Freers, 1975. Geology of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey, Bulletin 59 – Part 1 (also North Dakota State Water Commission County Groundwater Studies 18 – Part 1)

   - Randich, P.G., 1971. Groundwater Basic Data of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey Bulletin 59 – Part II (also North Dakota State Water Commission County Groundwater Studies 18 – Part II)

   - Randich, P.G., 1977. Groundwater Resources of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey Bulletin 59 – Part III (also North Dakota State Water Commission County Groundwater Studies 18 – Part III)

- USDA Soil Conservation Service, 1977, Soil Survey of Benson County Area, North Dakota

D. Road Restoration

1. For damage calculations it was assumed that if the feature were temporarily closed, it would be restored after the lake level has receded to the minimum road surface elevation less the assumed wave runup (the "Lake Damage Elevation").

2. Restoration damages were calculated assuming that the bituminous surfacing, shoulder and aggregate subgrade would be removed along with an additional 1.5 feet of embankment material. Those materials would then be replaced in kind over a geotextile. It was assumed riprap would be placed on the lake side slope over geotextile from the road surface elevation to the bottom of the embankment replacement. The riprap would be placed along the length of roadway lying below the receded lake damage elevation. The receded lake damage elevation is defined as the receded lake elevation plus the calculated wind-induced wave height.

E. Detours

1. Detour damages were included for every year that the feature 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.

2. Restoration of a road would only occur after the lake has receded to 2 feet 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

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.

4.23 Summary of Infrastructure Protection Investigation for Feature 23: BIA Highway 1

4.23.0 Flood Protection Strategy

The incremental flood protection strategy that was analyzed for BIA Highway 1 was incremental road raises.

4.23.1 General Information

Feature Type: Road

Location: BIA Highway 1 is located in Sections 7, 8, and 17 of Mission Township in Benson County and on the Spirit Lake Nation Reservation. The feature extends 2.72 miles between ND Highway 57 at the northwest to BIA Highway 6 to the southeast. The accompanying Figure 4.23-1 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 1451 to 1488, and crosses Mission Bay (a portion of Devil's Lake) at its northwest end. A portion of the roadway is currently acting as a dam and the feature Roads Acting as Dams would protect another portion of the roadway at higher lake levels 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. The Average Daily Traffic (ADT) counts on this highway were not available.

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.

4.23.2 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. BIA Highway 1 was last raised in 2001 to a minimum road surface elevation of approximately 1451.

General Protection Strategy: The Infrastructure Protection Study's analysis for BIA Highway 1 considered one incremental flood protection strategy for BIA Highway 1. That flood protection strategy was the only strategy that was feasible both from an economic and a constructability standpoint. The first action level for that strategy involved raising the road 5 feet to a minimum road surface elevation of 1456.

Protection Strategy by Action Level: Figure 4.23-2 shows the decision tree for BIA Highway 1. As shown on Figure 4.23-2, the stepwise approach to flood protection for BIA Highway 1 consists of the following:

1. At Action Level 1 (AL1), a decision would be made as to whether the road would be raised to 1456 or whether the road would be temporarily abandoned.
2. If the road were raised at AL1, a decision would be made at Action Level 2 (AL2) whether to raise the road to 1461, or to temporarily close the road.
3. If the road were raised at AL2, a decision would be made at Action Level 3 (AL3) whether to raise the road to 1465, or to temporarily close the road.

The pertinent reference elevations for implementing each increment of flood protection strategy are given below:

Reference Elevations for Feature 23 Road Raises				
Elevation				
AL1	AL2	AL3	Name	Significance
1451	1456	1461	Low Structure Elevation	Low sill on lowest building or minimum road elevation
1448	1452	1457	Lake Damage Elevation	Lake elevation at which damage to roadway occurs (a 4-foot wave runup was calculated for this feature at AL2 and AL3)
N/A	N/A	N/A	Project Completion Elevation	Lake elevation at which levee construction must be complete

Reference Elevations for Feature 23 Road Raises				
Elevation				
AL1	AL2	AL3	Name	Significance
1448	1453	1458	Construction Initiation Elevation	Lake elevation at which road raise construction must begin. (The current trigger for release of emergency highway funds for road raises is when the lake level reaches within 3 feet of the minimum road surface.)
Curre nt	1451	1456	Planning and Design Initiation Elevation	Lake elevation at which planning and design process must begin

4.23.3 Design Considerations

Sections 4.23.3.0 through 4.23.3.10 describe the analysis of the design of flood protection measures, as well as other considerations (geotechnical, environmental, etc.) necessary to make the cost estimates for the first action level. Section 4.23.3.11 describes the abbreviated cost estimating method for subsequent action levels.

4.23.3.0 General Design

Alignment

Figure 4.23-1 shows the alignment of the existing BIA Highway 1. The raised roadway will follow the same alignment. The length of BIA Highway 1 between ND Highway 57 and BIA Highway 6 is approximately 2.7 miles. Approximately 5,600 feet beginning at the intersection with ND Highway 57 and extending southeast is currently below the planned 5-foot raise to 1456. An additional 900 feet of roadway just northwest of the town of St. Michael is currently below 1456 and would be raised. Figure 4.23-4 shows the existing road profile and the raised road profile.

Cross-Section

Figure 4.23-3 shows a typical cross-section of the proposed road raise. The raise will be accomplished by filling on the land side of the existing roadway to minimize fill placement in water or in water with significant wave action. This section is based on the typical section constructed during the 1999 road raise, when portions of BIA Highway 1 were raised to provide a minimum road surface at 1451.0. The road top width was assumed to be 41 feet with a 24-foot asphalt surface and 3-foot aggregate shoulders. The side slopes are 5H:1V on both the lake side and land side of the road. The minimum raised road elevation is assumed to be 1456.0, a 5-foot raise from the current minimum elevation. It was assumed that unsuitable fill foundation material, averaging 1 foot in depth, will be stripped along the land side roadway toe prior to placement of road fill.

Materials

It was assumed that the roadway fill would be constructed from readily available native silty clay and clay loam. These materials are suitable for road embankment construction. The top 6 inches of the roadway section will be constructed of commercially available aggregate surface course material.

Erosion Protection

On the lake side, riprap was assumed to be placed over geotextile (no additional bedding material) from the existing top edge of riprap all the way to the roadway crest. On the land side, riprap was assumed to be placed over geotextile from 1.5 feet below the crest (vertically) and extend 20 feet down slope (slope distance). No topsoil or seeding was assumed for the raised roadbed.

The riprap design, based on the fetch, depth of water, and the side slope, is summarized in the table below. The wind-induced wave height is used to compute the lake elevation at which damage will occur to the roadway due to wave action.

Location	Wind-Induced Wave Height (ft.)	Riprap size (D_{50}, inches)	Riprap Thickness (ft.)
Lake Side	3	12”	2.0
Land Side	1.5	Use same as lake side	

4.23.3.1 Site Geology

In the area of Devils Lake, Late Wisconsin age glacial deposits of varying thickness overly deposits of earlier glaciation or Cretaceous age bedrock. Thin lacustrine deposits from the current and prehistoric lake levels are also present in the Devils Lake basin. All the glacial deposits in this area are part of the Coleharbor Formation.

In the area of BIA Highway 1, the lacustrine deposits include soft lake bottom silt and clay and coarse sand to fine silty sand beach deposits. The lake bottom deposits lie on the easily recognized lake plain. These are mapped as the silt and clay facies of the Coleharbor Formation. This deposit underlies the northwestern section of BIA Highway 1. The beach deposits, where present, are along the slope break around the lake plain. These deposits tend to be of too small in area to be shown on the county geologic map, but are apparent in the county soil maps. The predominant glacial deposit is generally composed of silty clay with sand, pebbles, cobbles, and boulders. This deposit is yellowish brown in the oxidized zone in the uppermost 10 to 25 feet near the ground surface, and olive gray at depth. The southeast portion of BIA Highway 1 is underlain by

till mapped as the North Viking end moraine. The uneven surface, including closed basins, poorly developed drainage, and rounded hills are indications that the till is an ice margin and/or stagnation deposit. Well logs in the area of BIA Highway 1 indicate that the glacial deposits are 100 to 123 feet thick, with boulder clay till in the uppermost 70 to 80 feet, and sand and gravel with some till layers at depth. The bedrock is Cretaceous Pierre Shale.

The northern impacted section of BIA Highway 1 is underlain primarily by two mapped soil units (99C Claire and 101 Lallie) and the unmapped lake bottom, in the sequence, from northwest to southeast, of 101-99C-lake-99C-101. With respect to road construction:

- 101 Lallie loam; ML-CL; lake bed – Severe: wetness, floods, low strength
- 99C Claire loamy coarse sand; SP, SP-SM; beach – Slight

"Slight" means soil properties and site characteristics are generally favorable for this use. "Severe" means special design may be required. Wetness and flooding are a given, since much of the area is already inundated. The concern is the low strength. It is assumed that the unmapped deposits beneath the lake are also of low strength.

The southern impacted section of BIA Highway 1 is underlain by mapped soil units 113C, 31B, 110B and 109. With respect to roads:

- 31B Towner fine sandy loam; SM, SM-SC; beach deposit – Moderate: frost action
- 109 Aquents; CL; lake bed – Severe: low strength
- 110B and 113C Bottineau loams; CL, CL-ML; boulder clay till – Severe: low strength

Six borings need to be completed in the areas of the lake bed and till deposits to determine the strength. About 4,800 feet of the alignment overlies lake deposits which may require excavation.

Any upland soil south of BIA Highway 1 is likely to supply adequate material for impervious core and impervious fill, if required.

4.23.3.2 Hydrology/Interior Drainage issues

It is assumed that culverts will be placed through the raised roadway embankment to allow for water level equalization on both sides of the roadway. Any existing culverts through the raised roadway were assumed to have been previously filled and abandoned in place. New RCP culverts were assumed to have been placed through the roadway

embankment near the northern raised section and the raised section near St. Michael with inverts at 1448.

4.23.3.3 Real Estate Requirements

Right-of-way requirements for the road raise are assumed to extend 15 feet beyond the land side toe of the raised embankment. The 15-foot buffer will provide sufficient room for temporary construction activities and long-term maintenance access.

4.23.3.4 Environmental/Cultural issues

HTRW

Current land use surrounding BIA Highway 1 is a mostly undeveloped land with some scattered rural residences and farms. Additional rural residences have been constructed over the years and some growth has occurred in the City of St. Michael; however, land use does not appear to have changed significantly since the 1930s.

The regulatory record review for zip code 58370 was obtained from FirstSearch on September 24, 2002. No facilities appear to be located within the impact area.

One potential HTRW site identified along the feature alignment is listed below and shown on Figure 4.23-1:

HTRW Site Costs			
Site #	**Action Level Affected**	**HTRW Category**	**HTRW Costs**
23-1-1	1	Rural Residences & Farmsteads	$500

A more detailed description of site history and a breakdown of costs are in Appendix C. A description of environmental concerns associated with this category is in Section 4.0.

Cultural

This project has the potential to impact two known sites and one site lead as shown on Figure 4.23-1, which are the same sites and site lead that may be affected by the St. Michael project. One of the known sites, St. Michael's Cemetery (32BE0087), is an architectural site and was studied as part of a larger survey of wrought iron crosses as grave markers in North Dakota. Though many cemeteries containing such markers have been recommended as eligible for listing on the NRHP, this cemetery was recommended as not eligible because its two wrought iron crosses "are not representative of any coherent tradition of local artistry" (NDCRS Form, 32BE0087, on file at the SHSND). The second known site, 32BE0410 (Mission Hill), is listed in the 1997 database as a prehistoric archaeological mound group. An artifact scatter is likely associated with the

site since surface collection was conducted there. The eligibility of this site for listing on the NRHP has not been determined.

The site lead that may fall within the St. Michael area of potential effect is 32BEX0022 (St. Michael Mission). The historical context for this site lead was recorded as Irrigation and Conservation.

A summary of the evaluation status of known cultural resources is presented in the following table.

Feature 23 BIA Highway 1: Evaluation Status of Known Cultural Resources			
Resource Type	**Resources Listed on or Nominated for the NRHP**	**Resources with Recommendations (Phase I Survey Completed)**	**Resources with Inconclusive or No Recommendations (Require Phase I Survey)**
Architectural	0	1	0
Archaeological	0	0	1
Architectural Site Leads/Isolated Finds	0	0	0
Archaeological Site Leads/Isolated Finds	0	0	1
Total	0	1	2

The estimated cost to conduct Phase 1 Surveys for each of the 2 sites is presented in the following table. The total cost for all surveys is $22,000. As noted in Section 4.0, these costs are believed representative of the cultural resources investigations needed for the next stage of study.

BIA Highway 1: Phase 1 Survey Costs		
Site Number	**Investigation Type**	**Estimated Cost**
32BE0410	Phase I Archaeological	$8,000
32BEX0022	Phase I Archaeological	$14,000

Environmental

Fill used for the construction of the road could cause environmental impacts due to encroachment upon wetlands and upland plant communities. The natural resources within the right-of-way of BIA Highway 1 include wetlands, oak forest/woodlands, and oak brushlands. The acres of habitat impacted by land use category are shown on Figure 4.23-1. Impacts to the wetland communities represent the most important environmental impact to the natural resources. A total of 1.04 acres of wetland impacts would be

expected from the proposed infrastructure protection measures. Complete or partial loss of wetland functions and conversion to upland due to filling is possible in some locations. In areas where some hydrology is maintained and wetland conditions remain, changes in plant community and hydrology could lead to a wetland type change. The loss of wetland area would impact waterfowl, marsh bird and songbird-nesting areas, as well bring about impacts to reptile and amphibian populations due to habitat fragmentation and loss. These environmental impacts are more fully detailed in the general impacts discussion Section 4.0. This loss of wetland would require 2.08 acres of mitigation wetlands as set forth in the project mitigation policy developed through consultation with the Corps and FWS.

In the upland areas a loss of native species due to grading and filling could be expected in the fill or borrow locations, as well as allowing the introduction of weedy, non-native species. A loss of native tree species due to grading and filling, as well as the introduction of weedy, non-native under-story species could also be expected in these areas. These environmental impacts are more fully detailed in the general impacts discussion Section 4.0. A total of 1.69 acres of oak forest/oak and 6.03 acres grassland habitat impacts would be expected from the proposed infrastructure protection measures in this location. The loss of woodland areas would impact songbird nesting and small mammal populations, as well impacting reptile and amphibian populations due to habitat destruction that will lead to fragmentation. Mitigation activities would require the acquisition of 3.38 acres of like woodland habitat and 12.06 acres of like upland grassland areas for these impacts.

4.23.3.5 Effects on Existing Infrastructure and Utilities

Utility poles located on the land side of the roadway were assumed to be relocated prior to placing embankment fill along both reaches of BIA Highway 1 that will be raised. Replacement of local driveway access to adjacent properties was not considered as a separate cost item, but is considered incidental to the other construction items. With the exception of drainage culverts discussed above, no other infrastructure or utilities are expected to be impacted.

4.23.3.6 Interdependencies

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

- Feature 5: St. Michael – St. Michael is functionally dependent on BIA Highway 1 and would be affected if it were temporarily closed.

- Feature 14: ND Highway 57 – If BIA Highway 1 is temporarily closed, traffic on ND Highway 57 would decrease as travel to St. Michael and other locations is routed on other roadways.
- Feature 22: ND Highway 20 (ND Highway 57 to Tokio) – If BIA Highway 1 were temporarily closed, traffic on ND Highway 20 (ND Highway 57 to Tokio) would increase as a detour route.
- Feature 24: BIA Highway 6 – If BIA Highway 1 is temporarily closed, traffic on BIA Highway 6 would increase as a detour route.
- Feature 25: Roads Acting as Dams – BIA Highway 1 is acting as a dam and providing protection to an area to the southwest (primarily BIA Highway 4 immediately west of BIA Highway 1). If lake levels rise and the water levels on each side of BIA Highway 1 are allowed to equalize, BIA Highway 4 and adjacent areas will be impacted. However, if appropriate levee protection along the portion of BIA Highway 1 currently acting as a dam is provided, BIA Highway 4 and adjacent areas could be protected by those levees.

Table 4.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

4.23.3.7 O&M

Operation and maintenance requirements for the raised roadway would be similar to the unimpacted roadway with respect to road surface maintenance and shoulder and slope mowing. The increase in O&M on the adjacent routes that are used as detours would be approximately equal to O&M on the temporarily closed road. Additional maintenance requirements for the raised roadway sections would include maintenance of the riprap on both the lake and land sides. Annual maintenance costs for the riprap have been estimated at 0.5 percent of the initial construction cost. The O&M costs were not included in the economic analysis due to limitations of the Feature Analysis Model.

4.23.3.8 Lead Time Required

The raising of BIA Highway 1 could be completed in one construction season. A lead time of about twelve months would be necessary for final design, preparation of construction documents and bidding. Total time between initiation of final design and substantial completion of construction would be in the range of 18 to 24 months.

4.23.3.9 Potential Problems and Risks

Potential problems and risks associated with the road raise include:

- Road embankment fill into water will make compaction and quality control difficult
- Foundation conditions will be difficult to assess prior to actual construction
- Utilities may need to be relocated

4.23.3.10 Data Deficiencies

The following data should be collected or verified prior to proceeding with raising BIA Highway 1:

- Locations of buried utilities, if any
- Soil borings along land side toe of existing road embankment
- Precise location and evaluation of nearby cultural resources

4.23.3.11 Abbreviated Cost Estimating for Feature Subsequent Action Levels

As was mentioned previously, for Feature 23, an abbreviated method was necessary for examining the costs of infrastructure protection at action levels above the first. The estimated costs at action levels subsequent to the first are presented in Table 4.23-2b. Estimates of benefits—damages prevented—for subsequent action levels were made in the same manner as for the first action level. The damage estimates for all action levels are shown in Table 4.23-1.

The same general approach to calculate costs was used for the subsequent action levels. Unit prices were not changed. However, some of the cost items were simply extrapolated for the higher action levels, rather than being calculated in detail. The relevant design and cost assumptions for the abbreviated method are listed below.

Design Assumptions

- Raise elevations

  Action Level 2: 5-foot raise to 1461

  Action Level 3: 4-foot raise to 1465

- Cross-section

  Action Level 2: 41foot top width, 5H: 1V side slopes, centerline-offset raise

  Action Level 3: 41-foot top width, 5H: 1V side slopes, centerline-offset raise

- Length

  Action Level 2: Total length of raised roadway- 8,400 feet

  Action Level 3: Total length of raised roadway- 14,400 feet

- Impacted Area

  Action Level 2: Incremental area impacted by raised roadway- 11.4 acres

  Action Level 3: Incremental area impacted by raised roadway- 7.8 acres

Construction material quantities were calculated in accordance with design assumptions discussed previously, and are listed in Table 4.23-2b. The geological/geotechnical and environmental quantities and costs were estimated in proportion to the Action Level 1 costs as described in Section 3.2.13. Real Estate costs were assumed to be the same for each raise.

4.23.4 Economics of Flood Protection

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 4.23-1.

The top portion of Table 4.23-1 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.

The lower portion of the table shows the breakdown of these summary values. 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, geotextile fabric, aggregate base course, fill, bituminous pavement, and riprap for road restoration work when waters recede.

The unit prices for all the damage computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. 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 4.23.

Costs: The costs of providing flood protection for BIA Highway 1 are detailed in the accompanying Table 4.23-2a for the first action level and in Table 4.23-2b for the subsequent action levels. 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. The lower portion of the table gives a breakdown of the quantities and costs by line item.

Unit prices for all the cost computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. 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 4.23.

Contingencies: The contingency percentages used for construction materials ranged from 30 to 50% (Table 4.23-2). Contingencies for riprap, fill material, and geotechnical items were estimated at the higher end of the range because of the potential variability in the quantities and unit prices.

4.23.5 Economic Results

The flood protection strategy that was analyzed was incremental road raises, which is highlighted on the decision tree (Figure 4.23-2). The results of the Infrastructure Protection Study for BIA Highway 1 are listed in Table 4.23-3a for the analysis of all action levels and in Table 4.23-3b for the analysis of the first action level.

Multiple Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for BIA Highway 1, the Infrastructure Protection Study analysis provided relevant economic indices for the three incremental road raises. The annual net benefits for this approach were greater than zero ($188,400). The BCR for this approach was greater than one (2.08). These results indicate that this strategy is economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $310,200. The stochastic results are averages over 10,000 traces.

Multiple Action Level Results for Specific Scenarios: Raising the road was also analyzed under each of three specific climate futures. For BIA Highway 1, the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of raising the road were $469,100, and the BCR was 1.97, indicating that this strategy was economically justified. No restoration damages are listed under this scenario, indicating that the water level never recedes below the first action level. For this future, the present worth annualized detour damages that would be prevented were computed at $950,400.

- First Moderate Future – Under the first moderate future climate scenario, the annual net benefits of raising the road were $25,500, and the BCR was 1.31, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $80,400.

- Second Moderate Future – Under the second moderate future climate scenario, the annual net benefits of raising the road were $392,300, and the BCR was 2.34, indicating that this

strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $663,700.

First Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for BIA Highway 1, the Infrastructure Protection Study analysis also provided relevant economic indices for the first incremental road raise. The annual net benefits for this approach were greater than zero ($161,900). The BCR for this approach was greater than one (2.27). These results show that this strategy is economically justified; the results are similar to the results based on all action levels. The present worth annualized detour damages that would be prevented by this strategy were computed to be $241,800. The stochastic results are averages over 10,000 traces.

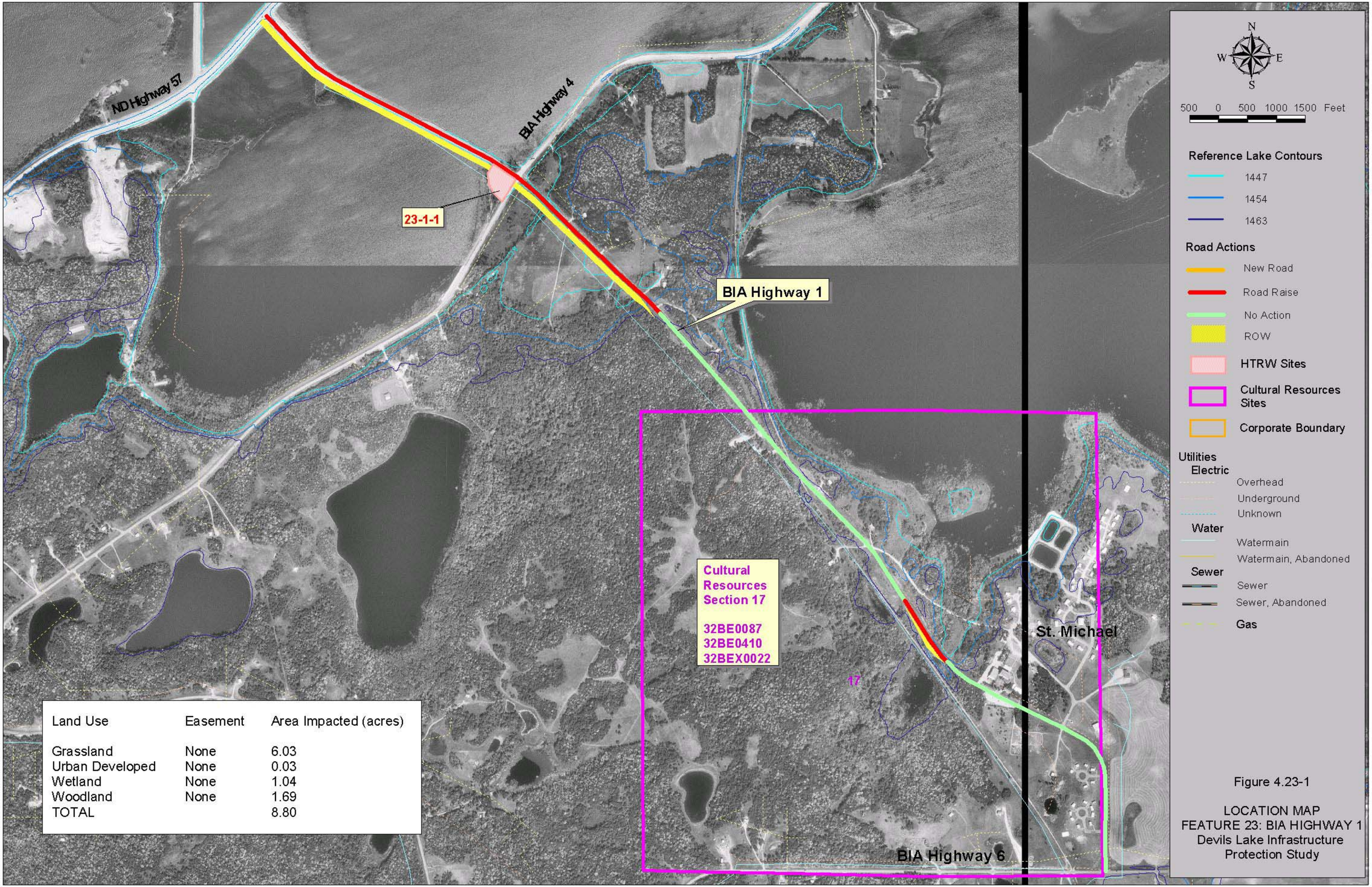
First Action Level Results for Specific Scenarios: Raising the road was also analyzed under each of three specific climate futures. For BIA Highway 1, the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of raising the road were $125,300, and the BCR was 1.73, indicating that this strategy was economically justified. No restoration damages are listed under this scenario, indicating that the water level never recedes below the first action level. For this future, the present worth annualized detour damages that would be prevented were computed at $297,500.

- First Moderate Future – Under the first moderate future climate scenario, the average net benefits of raising the road were $26,500, and the BCR was 1.31, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $80,400.

- Second Moderate Future – Under the second moderate future climate scenario, the average net benefits of raising the road were $334,700, and the BCR was 2.94, indicating that this strategy was economically justified. No restoration damages are listed under this scenario; the lake level exceeds the second action level, and restoration damages would be a function of the subsequent action levels[1]. For this future, the present worth annualized detour damages that would be prevented were computed at $506,900.

[1] For analysis of the first action level, it was assumed that restoration damages would be attributable to the first action level only if the lake level never reached the subsequent action levels. See Section 3.2.2.1 for further discussion of this assumption.



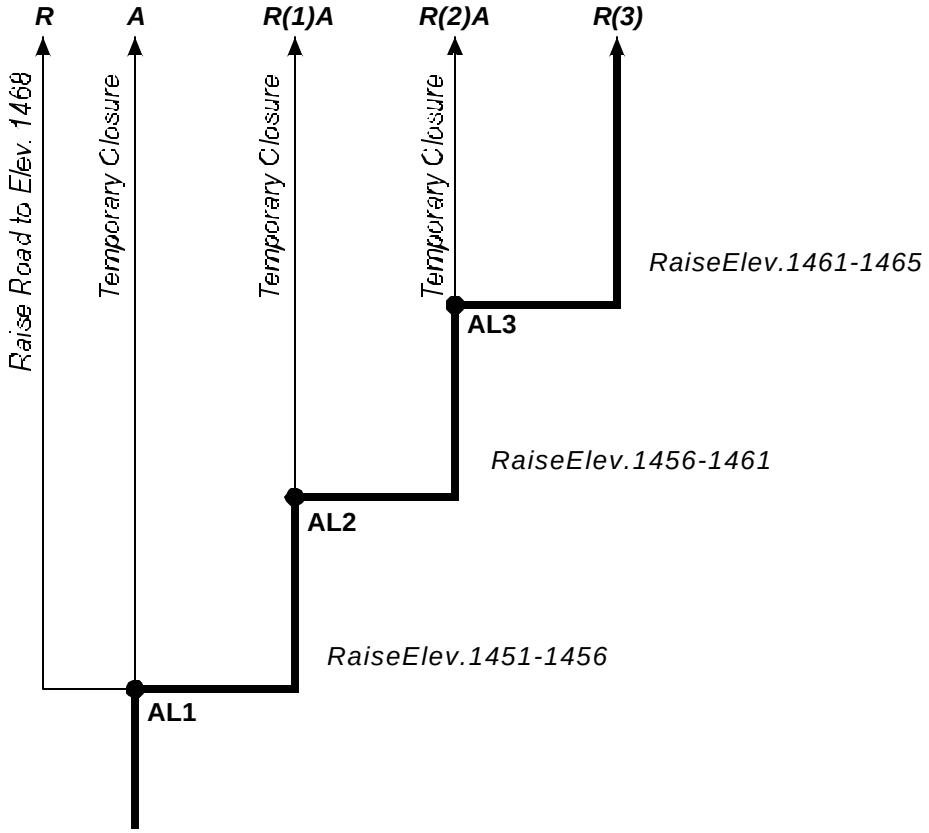
Land Use	Easement	Area Impacted (acres)
Grassland	None	6.03
Urban Developed	None	0.03
Wetland	None	1.04
Woodland	None	1.69
TOTAL		8.80

Figure 4.23-1

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

Barr: Arcview 3.1, OPT2615, I:\Client\DevilsLake\Gis\DLIP\Features\RoadandRails\Roads\23_BIA1\Project\Basemap_23.apr, Layout: Section 4 Figure, lkp, Wed Dec 04 12:38:09 2002

Data: 1997 USGS Digital Ortho Quad



LowestRoadElevation:1451

FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

AL1 Decision/Action Level

R(1) Incrementalroad raise(number oftimes)

R Road raiseto1465

A Temporary closureofroad

Figure4.23-2

DECISION TREE
FEATURE 23:BIAHIGHWAY1
DevilsLakeInfrastructure ProtectionStudy

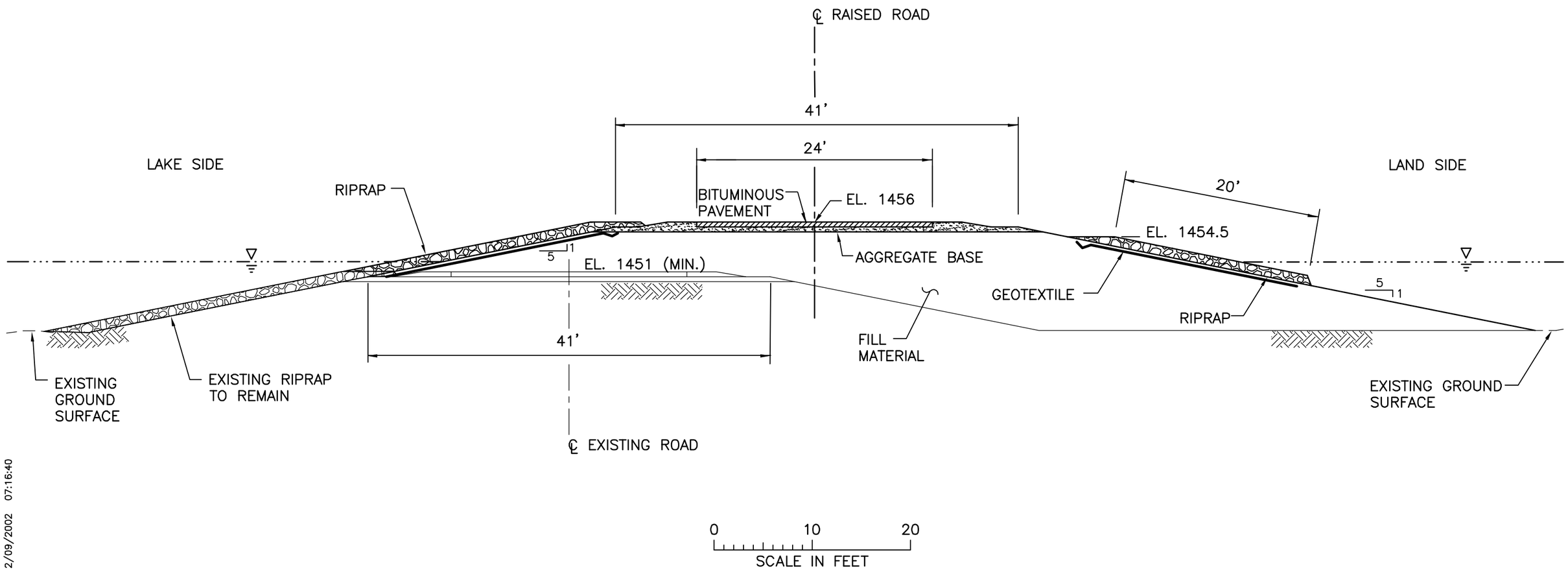


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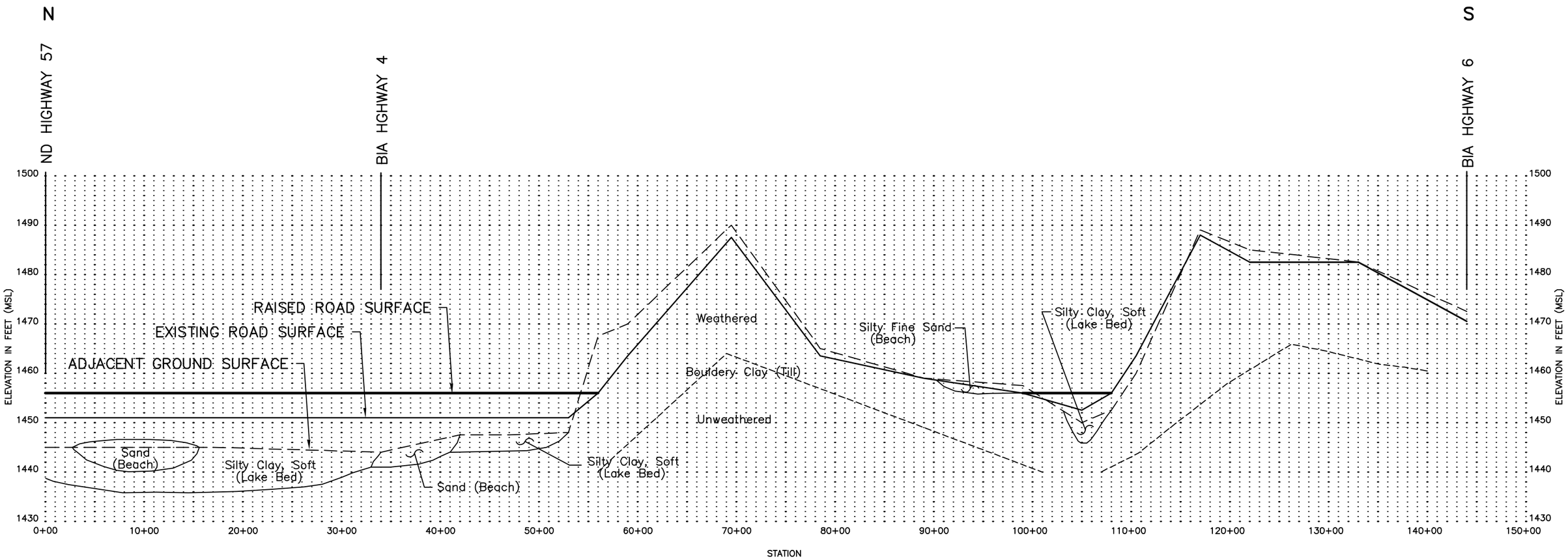
Figure 4.23–3

TYPICAL ROAD CROSS–SECTION

FEATURE 23:
BIA HIGHWAY 1
(BETWEEN N.D. HIGHWAY 57
AND BIA HIGHWAY 6)

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY



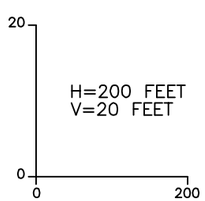


Figure 4.23–4

ROAD PROFILE

FEATURE 23:
BIA HIGHWAY 1

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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Table 4.23-1

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

DAMAGES

	Annual Detour Damages	Restoration Damages	
Lake Elevation (MSL)	**Damage Value (THOUSANDS)**	**Impacted Roadway Length (FEET)**	**Damage Value (THOUSANDS)**
1448	$1,012	5,300	$1,193
1449	$1,012	5,400	$1,205
1450	$1,012	5,550	$1,222
1451	$1,012	5,870	$1,259
1452	$1,012	6,180	$1,295
1453	$1,012	6,500	$1,332
1454	$1,012	6,910	$1,380
1455	$1,012	7,320	$1,427
1456	$1,012	7,730	$1,475
1457	$1,012	8,040	$1,511
1458	$1,012	8,350	$1,547
1459	$1,012	8,660	$1,582
1460	$1,012	8,970	$1,618
1461	$1,012	9,170	$1,642
1462	$1,012	9,280	$1,654
1463	$1,012	9,390	$1,667
1464	$1,012	9,500	$1,654
1465	$1,012	9,600	$1,667

DAMAGE BREAKDOWN

Annual Detour Damages	Description	Quantity	Unit	Unit Cost	Value (THOUSANDS)
	Hours/Year	38,760	HR	$7.13	$276
	Miles/Year	2,131,590	MILE	$0.35	$735
	Total				**$1,012**

Restoration Damages	Item	Description	Quantity per LF of Road		Unit Cost	Contingency	Value per LF of Road
	Excavation	Removal of existing bituminous (24' X 0.5'), existing shoulder (3' X 0.5' ea. side), existing aggregate base (41' X 0.5'), and top 1.5' of existing road embankment fill	4.06	CY/LF	$3.50	30%	$18
	Fill Material	Replace top 1.5' of roadway embankment	2.69	CY/LF	$5.00	30%	$17
	Geotextile Fabric	Place geotextile beneath new aggregate base	5.00	SY/LF	$2.00	30%	$13
	Aggregate Base Course	Replace 0.5' of subgrade and shoulders (3' X 0.5' ea. side)	0.92	CY/LF	$20.00	30%	$24
	Bituminous	Replace 0.5' of bituminous pavement	0.66	Tons/LF	$50.00	30%	$43
	Total						**$116**
	Item	**Description**	**Quantity per LF of Road**		**Unit Cost**	**Contingency**	**Total Value for Road**
	Riprap	Place riprap from road surface elevation to bottom of embankment replacement for lowest impacted roadway length	1.89	CY/LF	$40.00	30%	$530,712
	Geotextile Fabric	For use under riprap restoration	3.5	SY/LF	$2.00	30%	$49,140
	Total						**$579,852**

Table 4.23-2a

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R(1)
Action Level	Raise at AL1
	(THOUSANDS)
AL1	$3,004

COST BREAKDOWN

Strategy	R(1) Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Road Raise	**Raise Top of Road to Elevation 1456.5**					
	Performance/Payment Bond	1	JB	$16,164	10%	$18
	Clearing and Grubbing	0.0	AC	$3,000	30%	$0
	Stripping	10,500	CY	$1.50	40%	$22
	Geotextile Fabric	27,000	SY	$2.00	30%	$70
	Aggregate Base Course	5,500	CY	$20	30%	$143
	Fill Material	118,500	CY	$5.00	50%	$889
	Bedding	0	CY	$35	30%	$0
	Riprap	15,000	CY	$40	40%	$840
	Bituminous Pavement	5,000	TON	$50	30%	$325
	Culverts	170	LF	$50	30%	$11
	Topsoil	0	CY	$2.50	30%	$0
	Seed	0.0	AC	$1,000	30%	$0
	Geotechnical					
	Slurry Wall	0	SF	$6.00	50%	$0
	Borings	6	EA	$1,000	50%	$9
	Environmental Impacts					
	Mitigation	1	LS			$6
	HTRW	1	LS			$1
	Cultural Resources Investigation	1	LS			$22
	Subtotal					$2,355
	Engineering and Design		15%			$353
	Supervision and Administration		8%			$188
	Real Estate Acquisition for ROW	1	LS			$107
	Total Road Raise					**$3,004**

ANNUAL OPERATION AND MAINTENANCE COSTS

Action Level	Road Maintenance Costs
	(THOUSANDS)
AL1	$12

Table 4.23-2b

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R(2)	R(3)
Action Level	Raise at AL2	Raise at AL3
	(THOUSANDS)	
AL2	$4,028	$0
AL3	$0	$4,350

COST BREAKDOWN

	R(2)						R(3)					
Strategy	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Road Raise	**Raise Top of Road to Elevation 14xx**						**Raise Top of Road to Elevation 14xx**					
	Performance/Payment Bond	1	JB	$21,889	10%	$24	Performance/Payment Bond	1	JB	$23,792	10%	$26
	Clearing and Grubbing	0.0	AC	$3,000	30%	$0	Clearing and Grubbing	0.5	AC	$3,000	30%	$2
	Stripping	14,000	CY	$1.50	40%	$29	Stripping	12,500	CY	$1.50	40%	$26
	Geotextile Fabric	32,000	SY	$2.00	30%	$83	Geotextile Fabric	33,500	SY	$2.00	30%	$87
	Aggregate Base Course	7,000	CY	$20	30%	$182	Aggregate Base Course	8,500	CY	$20	30%	$221
	Fill Material	186,500	CY	$5.00	50%	$1,399	Fill Material	204,000	CY	$5.00	50%	$1,530
	Bedding	0	CY	$35	30%	$0	Bedding	0	CY	$35	30%	$0
	Riprap	18,000	CY	$40	40%	$1,008	Riprap	18,500	CY	$40	40%	$1,036
	Bituminous Pavement	6,500	TON	$50	30%	$423	Bituminous Pavement	7,500	TON	$50	30%	$488
	Culverts	0	LF	$50	30%	$0	Culverts	0	LF	$50	30%	$0
	Topsoil	0	CY	$2.50	30%	$0	Topsoil	0	CY	$2.50	30%	$0
	Seed	0.0	AC	$1,000	30%	$0	Seed	0.0	AC	$1,000	30%	$0
	Geotechnical						**Geotechnical**					
	Slurry Wall	0	SF	$6.00	50%	$0	Slurry Wall	0	SF	$6.00	50%	$0
	Borings	2	EA	$1,000	50%	$3	Borings	6	EA	$1,000	50%	$9
	Environmental Impacts						**Environmental Impacts**					
	Mitigation	1	LS			$8	Mitigation	1	LS			$5
	HTRW	1	LS			$1	HTRW	1	LS			$0
	Cultural Resources Investigation	1	LS			$28	Cultural Resources Investigation	1	LS			$20
	Subtotal					$3,188	Subtotal					$3,450
	Engineering and Design		15%			$478	Engineering and Design		15%			$517
	Supervision and Administration		8%			$255	Supervision and Administration		8%			$276
	Real Estate Acquisition for ROW	1	LS			$107	Real Estate Acquisition for ROW	1	LS			$107
	Total Road Raise					**$4,028**	**Total Road Raise**					**$4,350**

ANNUAL OPERATION AND MAINTENANCE COSTS

Action Level	Road Maintenance Costs
	(THOUSANDS)
AL2	$16
AL3	$17

Table 4.23 - 3a

Economics Results: All Action Levels -- to Lake Level 1463
Feature 23: BIA Highway 1
Devils Lake Infrastructure Protection Study

Strategy		Stochastic Analysis (ST-2) Mean Value over 10,000 Traces (Annual)									
		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 Level	$0	$0	$0	$52,600	$310,200	$0	$362,800	$0	$0	--
R(2)	2 Incremental Road Raise	$174,400	$0	$174,400	$0	$0	$0	$0	$362,800	$188,400	2.08

Strategy		Wet Future Scenario (WF-2) (Annual)									
		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 Level	$0	$0	$0	$0	$950,400	$0	$950,400	$0	$0	--
R(2)	2 Incremental Road Raise	$481,300	$0	$481,300	$0	$0	$0	$0	$950,400	$469,100	1.97

Strategy		Moderate Future 1 Scenario (M1-2) (Annual)									
		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 Level	$0	$0	$0	$30,500	$80,400	$0	$110,900	$0	$0	--
R(2)	2 Incremental Road Raise	$84,400	$0	$84,400	$0	$0	$0	$0	$110,900	$26,500	1.31

Strategy		Moderate Future 2 Scenario (M2-2) (Annual)									
		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 Level	$0	$0	$0	$20,800	$663,700	$0	$684,500	$0	$0	--
R(2)	2 Incremental Road Raise	$292,200	$0	$292,200	$0	$0	$0	$0	$684,500	$392,300	2.34

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

Table 4.23 - 3b

Economics Results: First Action Level
Feature 23: BIA Highway 1
Devils Lake Infrastructure Protection Study

Stochastic Analysis (ST-2)
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 Level	$0	$0	$0	$48,000	$241,800	$0	$289,800	$0	$0	
R(1)	1 Incremental Road Raise	$127,900	$0	$127,900	$0	$0	$0	$0	$289,800	$161,900	2.27

Wet Future Scenario (WF-2)
(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 Level	$0	$0	$0	$0	$297,500	$0	$297,500	$0	$0	
R(1)	1 Incremental Road Raise	$172,200	$0	$172,200	$0	$0	$0	$0	$297,500	$125,300	1.73

Moderate Future 1 Scenario (M1-2)
(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 Level	$0	$0	$0	$30,500	$80,400	$0	$110,900	$0	$0	
R(1)	1 Incremental Road Raise	$84,400	$0	$84,400	$0	$0	$0	$0	$110,900	$26,500	1.31

Moderate Future 2 Scenario (M2-2)
(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 Level	$0	$0	$0	$0	$506,900	$0	$506,900	$0	$0	
R(1)	1 Incremental Road Raise	$172,200	$0	$172,200	$0	$0	$0	$0	$506,900	$334,700	2.94

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

Attachment to 4.23:
BIA Highway 1 Infrastructure Protection Study Assumptions

A. Existing Road Information

1. Existing road elevations for the feature were obtained through contact with Spirit Lake Nation representatives, primarily Clarence Greene.

2. Existing road cross-section for the feature were based on construction drawing typical sections obtained from BIA/ND DOT/or their consultants including:

   - ND DOT Plan: Project No. BIA-3-97(006)-Mission Road, 5/30/97

   - BIA Spirit Lake Sioux Nation Plan: Mission Bay Road Project No. 1-10(5), Route 1, 11/22/99

3. Existing road centerline profiles for the features evaluated were obtained from the plans listed above. Plan elevation data was assessed for reasonableness by comparing to the 2000 FEMA LIDAR topography. Where necessary, road plan elevation information was supplemented with the LIDAR information.

B. Road Raise

1. The road raise was assumed to be 5 feet from existing feature minimum road surface elevation. The raise height was applied from the top of the existing bituminous surface course to the top of the new bituminous surface course.

2. Cross-Section – The future road raise cross-section was based on discussions with BIA/Spirit Lake Nation staff and the most recent typical raise sections that have been completed on the highway provided by BIA/ND DOT and/or their consultants. The plans referenced included:

   - BIA Spirit Lake Sioux Nation Plan: Mission Bay Road Project No. 1-10(5), Route 1, 11/22/99. Sheet 3 of 16

3. Profile –

   - Adjacent ground elevations obtained from 2001 LIDAR topography prepared for FEMA

   - Existing road surface elevations from the following construction drawings: BIA Aberdeen Area Fort Totten Indian Reservation Plans for Project No's: 1-A, 1-10(5), 6-10(4), 21-10(2)

   - Raised road surface elevation based on assumed incremental raise height

   - Road stationing was assigned, increasing from north-to-south

4. No topsoil or seeding was assumed for the road raise because of the width of the road shoulder and the height of riprap placement.

5. It was assumed that two new culverts would be placed in two individual areas for flow equalization. It is assumed that any existing culverts were left in place, and that the two new culverts would be located at an elevation equal to the existing road surface elevation.

C. Geotechnical

1. The scope and cost of geotechnical mitigation are related to: (1) number of borings and soil tests, and (2) soft soils that may require excavation and/or additional construction material,

2. While the county soil surveys have similar descriptions of the subgrade characteristics of glacial till and lake bed deposits (Severe: low strength), experience in the Devils Lake area has indicated that most till deposits are better subgrade than lake. The potential thickness of soft-soil deposits has been estimated based on descriptions of the lake bed deposits in the geologic and soils reports.

3. The potential extents of sand deposits have been estimated based on descriptions in the soils reports. It is likely that in some locations, the surficial sand deposits, typically assumed herein to beach deposits, may be continuous with subsurface sand and gravel deposits (glacial outwash). As such, some of the sand deposits may be of much greater extent vertically and laterally (buried) than has been assumed herein.

4. It is assumed that a soil boring will be completed approximately every 1,000 feet of road length. Additional borings will be completed in areas of critical soils. Each soil boring and associated observation and testing will cost $2,000.

5. Cut off walls are estimated to be $6/square foot based on past work at Devils Lake.

6. In instances where construction may be completed in the wet, it is assumed that soft soil will not be excavated, but instead may be displaced by new fill. In those instances, additional fill contingency is added based on the percentage of the feature alignment that is underlain by potentially soft soil.

7. The subgrade conditions along the alignment of this feature are based upon review of:

   - Carlson, C.G. and T.F. Freers, 1975. Geology of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey, Bulletin 59 – Part 1 (also North Dakota State Water Commission County Groundwater Studies 18 – Part 1)

   - Randich, P.G., 1971. Groundwater Basic Data of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey Bulletin 59 – Part II (also North Dakota State Water Commission County Groundwater Studies 18 – Part II)

- Randich, P.G., 1977. Groundwater Resources of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey Bulletin 59 – Part III (also North Dakota State Water Commission County Groundwater Studies 18 – Part III)

- USDA Soil Conservation Service, 1977, Soil Survey of Benson County Area, North Dakota

D. Road Restoration

1. For damage calculations, it was assumed that, if the feature were temporarily closed, it would be restored after the lake level has receded to the minimum road surface elevation less the assumed wave runup (the "Lake Damage Elevation").

2. Restoration damages were calculated assuming that the bituminous surfacing, shoulder and aggregate subgrade would be removed along with an additional 1.5 feet of embankment material. Those materials would then be replaced in kind over a geotextile. It was assumed riprap would be placed on the lake side slope over geotextile from the road surface elevation to the bottom of the embankment replacement. The riprap would be placed along the length of roadway lying below the receded lake damage elevation. The receded lake damage elevation is defined as the receded lake elevation plus the calculated wind-induced wave height.

E. Detours

1. Detour damages were included for every year that the feature 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.

2. Restoration of a road would only occur after the lake has receded to 2 feet 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

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.

4.24 Summary of Infrastructure Protection Investigation for Feature 24: BIA Highway 6

4.24.0 Flood Protection Strategy

The flood protection strategy evaluated for BIA Highway 6 was incremental road raises. The BIA began construction of the first road raise in the fall of 2002, so this Infrastructure Protection Study did not analyze the first action level of flood protection for BIA Highway 6.

4.24.1 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 Benson County. The accompanying Figure 4.24-1 shows the eastern portion of the feature 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 1441.5 just west of ND Highway 20.

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. The Average Daily Traffic (ADT) counts on this highway were not available.

Damages: The flooding of Feature 24 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
- 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.

4.24.2 Feature Protection

History of Flood Protection: BIA Highway 6 is located in the area that is currently being protected by roads that are acting as dams. Therefore, the flood level at BIA Highway 6 is much

lower than the level of Devils Lake and flood protection for BIA Highway 6 has, for the most part, not been an issue. No other flood protection has been implemented for this feature.

General Protection Strategy: The BIA started construction of a raise to the low section of Feature 24 in the Fall 2002. The construction will involve raising 4,700 feet of BIA Highway 6 to a minimum road surface elevation of 1456.9. The roadway embankment will also be widened along that length to accommodate potential future raises up to road surface elevation 1465 without requiring fill placement below water.

Protection Strategy by Action Level: The BIA is constructing the planned road raise to 1456.9 and embankment widening to minimize potential for future work performed in water. The reference elevations the BIA will use, if any, to implement any subsequent raise(s) are not known.

Figure 4.24-2 shows the assumed decision tree for BIA Highway 6. As shown on Figure 4.24-2, the stepwise approach to flood protection for BIA Highway 6 consists of the following:

1. At Action Level 1 (AL1), a decision would be made as to whether the road would be raised to 1456.9 or whether the road would be temporarily abandoned.

2. If the road were raised at AL1, a decision would be made at Action Level 2 (AL2) whether to raise the road to 1461.9, or to temporarily close the road.

3. If the road were raised at AL2, a decision would be made at Action Level 3 (AL3) whether to raise the road to 1465, or to temporarily close the road.

The Infrastructure Protection Study analysis summarized the planned first increment of the flood protection strategy, raising the road to 1456.9. Since the road is protected to at least 1454, the feature was not analyzed in the Infrastructure Protection Study's Feature Analysis Model.

Reference Elevations for Feature 24 Road Raises				
Elevation				
AL1	**AL2**	**AL3**	**Name**	**Significance**
N/A	1456.9	1461.9	Low Structure Elevation	Low sill on lowest building or minimum road elevation
N/A	1453.9	1458.9	Lake Damage Elevation	Lake elevation at which damage to roadway occurs (a 3-foot wave runup was calculated for this feature)
N/A	N/A	N/A	Project Completion Elevation	Lake elevation at which levee construction must be complete

Reference Elevations for Feature 24 Road Raises				
Elevation				
AL1	AL2	AL3	Name	Significance
N/A	1453.9	1458.9	Construction Initiation Elevation	Lake elevation at which road raise construction must begin. (The current trigger for release of emergency highway funds for road raises is when the lake level reaches within 3 feet of the minimum road surface.)
N/A	1452	1457	Planning and Design Initiation Elevation	Lake elevation at which planning and design process must begin

4.24.3 Design Considerations

Sections 4.24.3.0 through 4.24.3.10 describe the analysis of the design of flood protection measures, as well as other considerations (geotechnical, environmental, etc.) necessary to make the cost estimates for the first action level. Section 4.24.3.11 describes the abbreviated cost estimating method for subsequent action levels.

4.24.3.0 General Design

This section summarizes the preliminary design information provided by ND BIA and its consulting engineers, Kadrmas, Lee, and Jackson. This information is preliminary, but is based on construction plans and profiles provided by Kadrmas, Lee and Jackson: Project Number ERFO-BIA#6. The maximum wind-induced wave height along this feature based on fetch, depth of water, and the side slope was calculated to be approximately 2 feet above lake elevation. This wave height is used to compute the lake elevation at which damage will occur to the roadway due to wave action. The incremental raise implemented in the Fall 2002 will be sufficient until the lake level rises to 1453.9, when the road would again become unusable due to wave action.

Alignment

Figure 4.24-1 shows the alignment of the existing BIA Highway 6. The raised roadway will follow the same alignment. The length of BIA Highway 6 between Fort Totten and ND Highway 20 that is being raised is approximately 4,700 feet. Only one segment of the highway is currently below the planned raise to 1456.9. The segment is located to the west of ND Highway 20, beginning approximately 1.36 miles west of its intersection with BIA 6 and ending approximately 2,500 feet west of that intersection.

Figure 4.24-4 shows the existing road profile and the raised road profile.

Cross-Section

Figure 4.24-3 shows a typical cross-section of the proposed road raise. The raise will maintain the existing road centerline. Fill will be placed on each side of the existing embankment wide enough to provide a base width to accommodate potential future raises to an ultimate road surface at 1465. This section is based on ERFO Road Repair Project – BIA #6, July 2001, by Kadrmas, Lee, and Jackson. The road top width was assumed to be 34 feet. The minimum raised road elevation is assumed to be 1456.9 top of pavement. Bituminous surfacing will be 34 feet in width, and will be 4.5 inches in depth. The shoulder side slopes are broken up into three different slopes. The first side slope runs 12 feet horizontally and is at 6H:1V on both the sides. The second side slope is 24H:1V on both sides, and varies in length depending upon the elevation of the road. The final side slope is 5H:1V, and runs to the surrounding ground elevation. This is being done so that if the lake continues to rise, all future raises can be done above water. It was assumed that unsuitable foundation soils, averaging 1 foot in depth, will be stripped along the existing embankment toe prior to placement of road fill.

Materials

It was assumed that the roadway fill would be constructed from readily available native silty clay and clay loam. These materials are suitable for road embankment construction. The top 12 inches of the roadway section will be constructed of commercially available aggregate surface course material.

Erosion Protection

On both sides of the road, riprap was designed to be placed over geotextile (no additional bedding material) from elevation 1449.5 to one foot below the water surface. No topsoil or seeding was assumed for the raised roadbed.

4.24.3.1 Site Geology

No analysis of site geology was completed for BIA Highway 6 because the road raise described is currently being implemented.

4.24.3.2 Hydrology/Interior Drainage issues

It is assumed that culverts will be placed through the raised roadway embankment to allow for water level equalization on both sides of the roadway. Any existing culverts through the raised roadway were assumed to be filled and abandoned in place.

4.24.3.3 Real Estate Requirements

Minimum right-of-way requirements for the road raise are assumed to extend 15 feet beyond the toe on each side of the raised embankment. The 15-foot buffer will provide sufficient room for temporary construction activities and long-term maintenance access.

4.24.3.4 Environmental/Cultural issues

No environmental/cultural analysis was completed for BIA Highway 6 because the road raise described is currently being implemented.

4.24.3.5 Effects on Existing Infrastructure and Utilities

Utilities located along the existing right-of-way limits were not analyzed because the road raise described is currently being implemented. With the exception of drainage culverts discussed above, no other infrastructure or utilities are expected to be impacted.

4.24.3.6 Interdependencies

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

- Feature 3: Fort Totten – Fort Totten is functionally dependent on BIA Highway 6 and would be affected if it were temporarily closed.
- Feature 5: St. Michael – St. Michael is functionally dependent on BIA Highway 6 and would be affected if it were temporarily closed.
- Feature 14: ND Highway 57 – If BIA Highway 6 were temporarily closed, traffic on ND Highway 57 would increase as a detour route.
- Feature 15: ND Highway 57 – If BIA Highway 6 were temporarily closed, traffic on ND Highway 57 would increase as a detour route.
- Feature 22: ND Highway 20 (ND Highway 57 to Tokio) – If BIA Highway 6 were temporarily closed, traffic on ND Highway 20 (ND Highway 57 to Tokio) would increase as a detour route.
- Feature 23: BIA Highway 1 – BIA Highway 1 would likely experience higher traffic if BIA Highway 6 were closed.
- Feature 25: Roads Acting as Dams – If lake levels rise and the water levels on each side of any nearby roads acting as dams are allowed to equalize, the raising of BIA Highway 6 may be necessary to allow its continued use. However, if appropriate levee protection along the roads currently acting as dams is provided, portions of BIA

Highway 6 would be protected by those levees. In that case, the BIA Highway 6 may not require as much raised length.

Table 4.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

4.24.3.7 O&M

Operation and maintenance requirements for the raised roadway would be similar to the unimpacted roadway with respect to road surface maintenance and shoulder and slope mowing. The increase in O&M on the adjacent routes that are used as detours would be approximately equal to O&M on the temporarily closed road. Additional maintenance requirements for the raised roadway sections would include maintenance of the riprap on both the lake and land sides.

4.24.3.8 Lead Time Required

The raising of BIA Highway 6 began in Fall 2002 and is expected to be completed in 2003.

4.24.3.9 Potential Problems and Risks

No analysis of potential problems and risks was completed for BIA Highway 6 because the road raise described has already been initiated.

4.24.3.10 Data Deficiencies

No identification of data deficiencies was completed for BIA Highway 6 because the road raise described has already been initiated.

4.24.3.11 Abbreviated Cost Estimating for Feature Subsequent Action Levels

Feature 24 was raised and widened to accommodate future raises in Fall 2002, so no economic analysis was completed for that current work that would correspond to Action Level 1 (AL1). An abbreviated method was necessary for examining the costs of infrastructure protection at action levels above the construction completed in 2002. The estimated costs at action levels subsequent to the first are presented in Table 4.24-2. Estimates of benefits—damages prevented—for subsequent action levels were also estimated and are presented in Table 4.24-1.

The same general approach to calculate costs was used for the subsequent action levels. Unit prices were not changed from those used on other features. However, some of the cost items were simply extrapolated for the higher action levels, rather than being

calculated in detail. The relevant design and cost assumptions for the abbreviated method are listed below.

Design Assumptions

- Raise elevations

  Action Level 2: 5-foot raise to 1461.9

  Action Level 3: 3.1-foot raise to 1465

- Cross-section

  Action Level 2: 50.5-foot top width, 5H: 1V side slopes, centerline-aligned raise

  Action Level 3: 50.5-foot top width, 5H: 1V side slopes, centerline-aligned raise

- Length

  Action Level 2: Total length of raised roadway - 5,960 feet

  Action Level 3: Total length of raised roadway - 6,700 feet

- Impacted Area

  Action Level 2: Incremental area impacted by raised roadway - 1.2 acres

  Action Level 3: Incremental area impacted by raised roadway - 1.3 acres

Construction material quantities were calculated in accordance with design assumptions discussed previously, and are listed in Table 4.24-2. The geological/geotechnical and environmental quantities and costs were estimated based on similar feature costs. Real Estate costs were assumed to be proportional to the first raise costs.

4.24.4 Economics of Flood Protection

Damages: For BIA Highway 6, the damages resulting from flooding were estimated between the current raise and the maximum lake level (1463). The damage computations for BIA Highway 6 are summarized in the accompanying Table 4.24-1.

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 top portion of Table 4.24-1 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.

The lower portion of the table shows the breakdown of these summary values. 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, geotextile fabric, aggregate base course, fill, bituminous pavement, and riprap for road restoration work when waters recede.

The unit prices for all the damage computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. Assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for BIA Highway 6 are listed in the BIA Highway 6 Assumptions listing, appended to this Section 4.24.

Costs: The cost of providing flood protection for BIA Highway 6 by raising the approximately 4,700 feet of road to minimum elevation 1456.9 has been bid at $1,817,000. The costs of providing flood protection for subsequent action levels are detailed in the accompanying Table 4.24-2. 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. The lower portion of the table gives a breakdown of the quantities and costs by line item.

Unit prices for all the cost computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for BIA Highway 6 are listed in the BIA Highway 6 Assumptions listing, appended to this Section 4.24.

Contingencies: The contingency percentages used for construction materials ranged from 30 to 50% (Table 4.24-2). Contingencies for riprap, fill material, and geotechnical items were estimated at the higher end of the range because of the potential variability in the quantities and unit prices.

4.24.5 Economic Analysis Results

The flood protection strategy that was analyzed was incremental road raises, which is highlighted on the decision tree (Figure 4.24-2). The results of the Infrastructure Protection Study for BIA Highway 6 are listed in Table 4.24-3a for the analysis of all action levels. No economic analysis

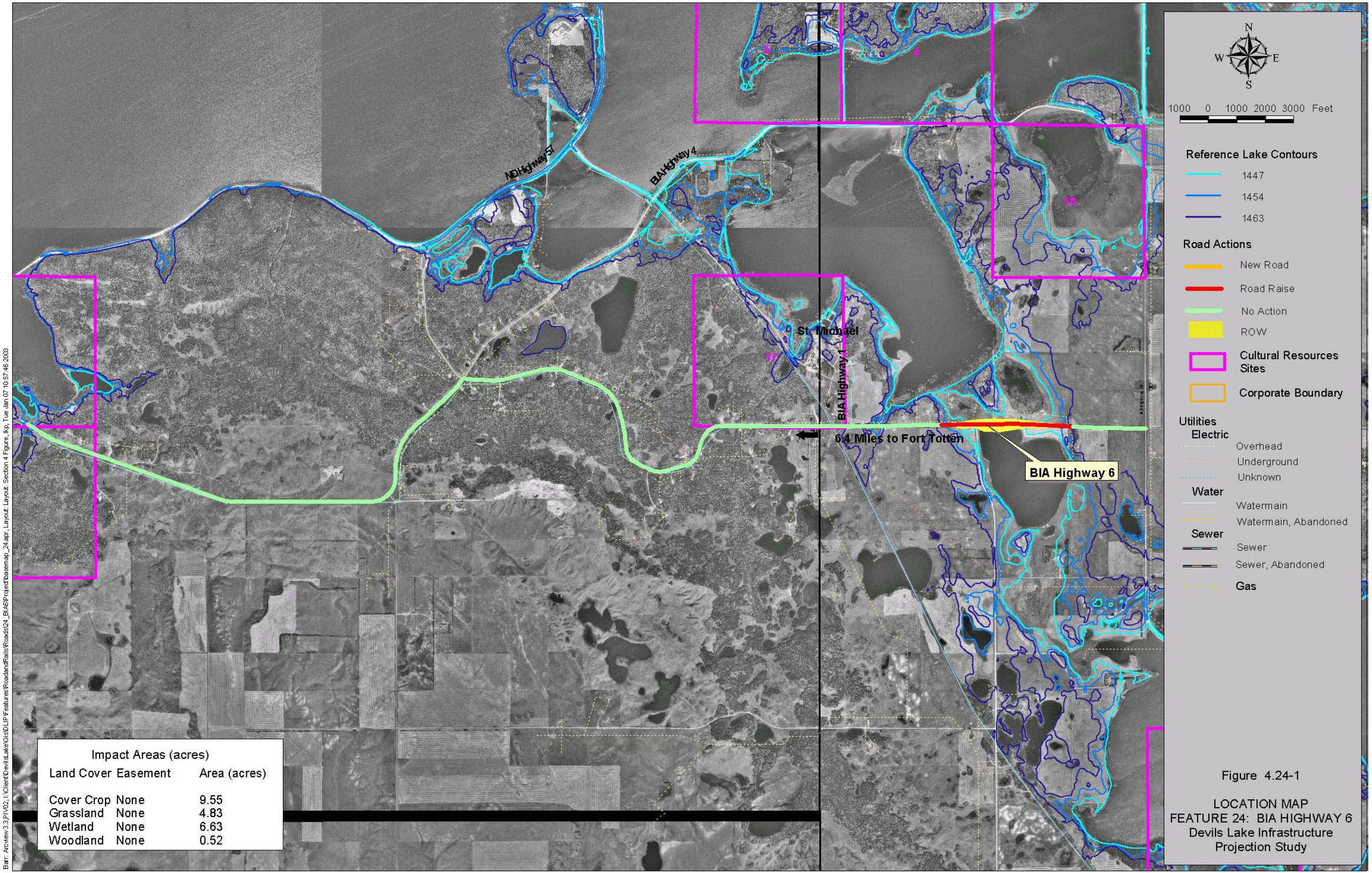
was completed for the first action level for BIA Highway 6, because the road raise described has already been initiated.

Multiple Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for BIA Highway 6, the Infrastructure Protection Study analysis provided relevant economic indices for the incremental road raises. The annual net benefits for this approach were greater than zero ($740,900). The BCR for this approach was greater than one (35.46). These results indicate that this strategy is economically justified. The present worth annualized detour damages that would be prevented by this strategy were computed to be $757,900. 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.

Multiple Action Level Results for Specific Scenarios: Raising the road was also analyzed under each of three specific climate futures. For BIA Highway 1, the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of raising the road were $8,016,700, and the BCR was 52.59, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $8,155,300.
- First Moderate Future – Under the first moderate future climate scenario, the lake levels do not reach the first damage level.
- Second Moderate Future – Under the second moderate future climate scenario, the annual net benefits of raising the road were $1,786,800, and the BCR was 26.78, indicating that this strategy was economically justified. For this future, the present worth annualized detour damages that would be prevented were computed at $1,842,200.



Impact Areas (acres)

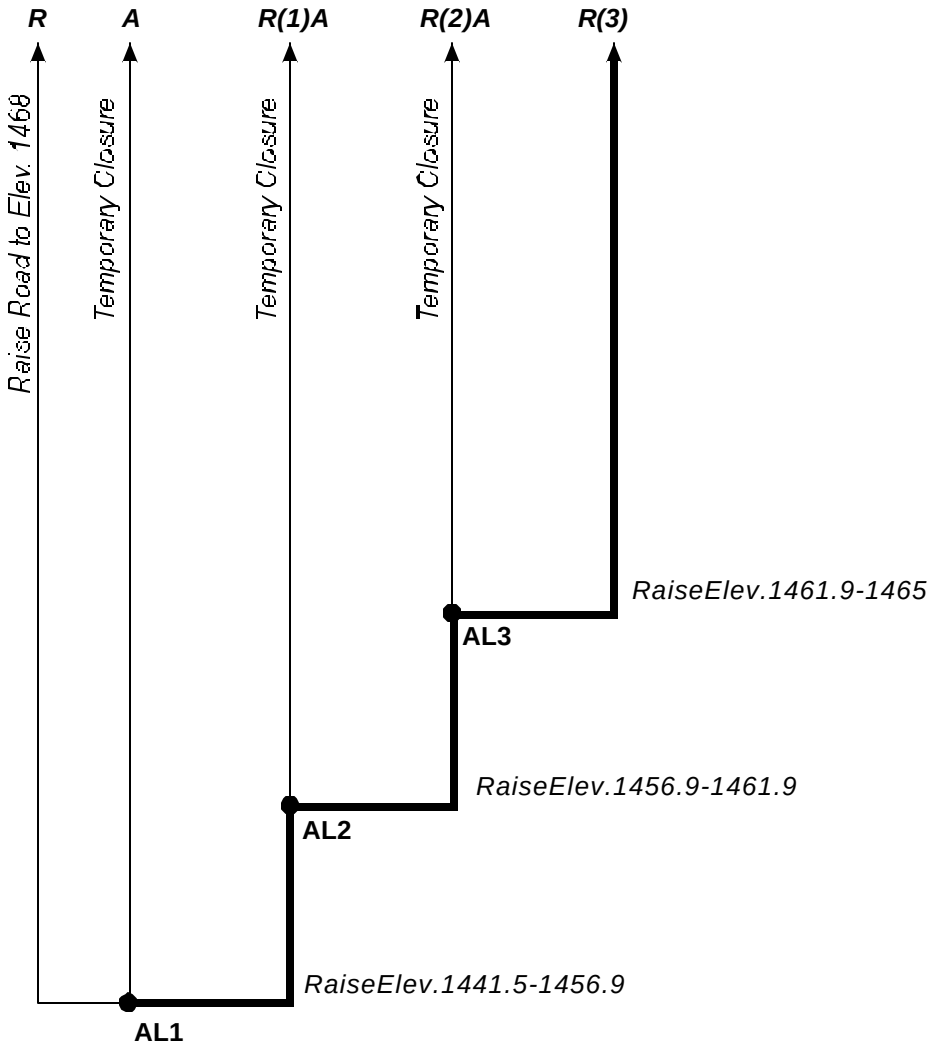
Land Cover	Easement	Area (acres)
Cover Crop	None	9.55
Grassland	None	4.83
Wetland	None	6.63
Woodland	None	0.52

Figure 4.24-1

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

Data: 1997 USGS Digital Ortho Quad

Barr: Arcview 3.3,P1V02, I:\Client\DevilsLake\Gis\DLIP\Features\RoadandRails\Roads\24_BIA6\Project\basemap_24.apr, Layout: Section 4 Figure, lkp, Tue Jan 07 10:57:46 2003



Lowest RoadElevation:1441.5

FloodProtectionStrategy

Decisionrequiredatthispoint

Triggerpointforaction,nodecisionneeded

AL1 Decision/Action Level

R(1) Incrementalroad raise(number oftimes)

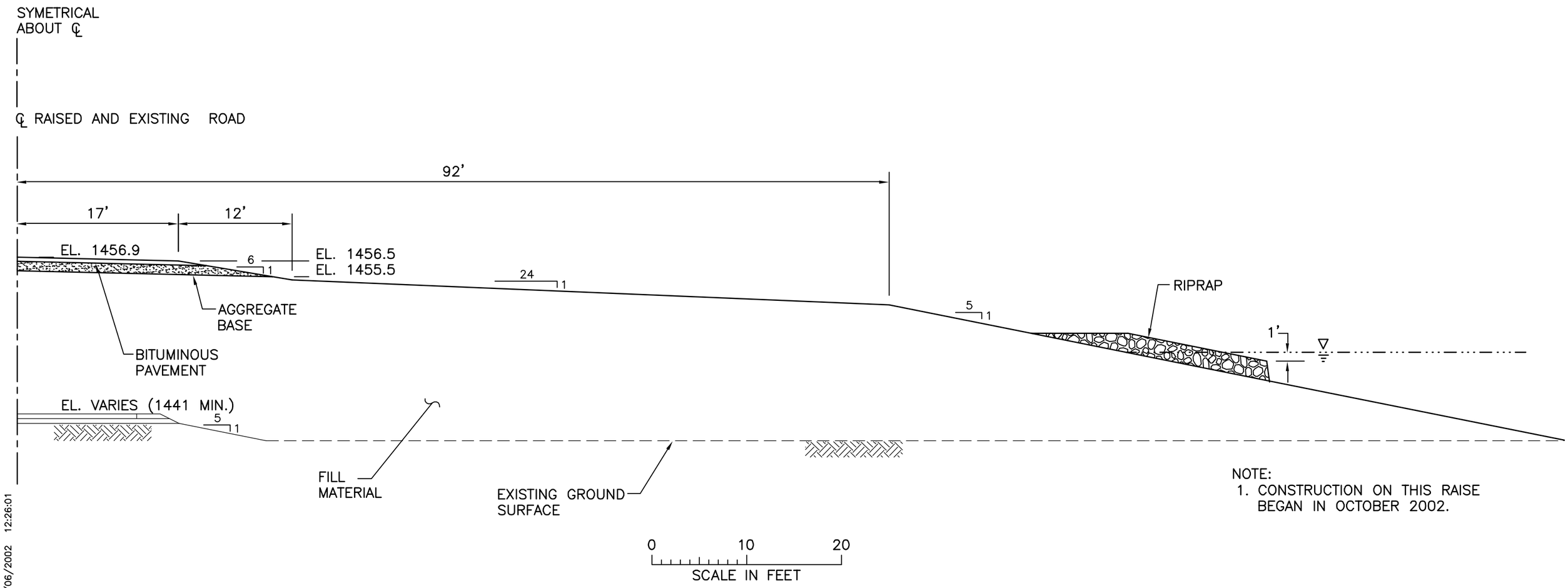
R Road raiseto1465

A Temporary closureofroad

Figure4.24-2

DECISION TREE
FEATURE 24:BIAHIGHWAY6
DevilsLakeInfrastructure ProtectionStudy

P:\4036020\DECISIONTREES\2002FIGURES\FIGURE4_24.CDR RLG 01-06-03



NOTE:
1. CONSTRUCTION ON THIS RAISE BEGAN IN OCTOBER 2002.

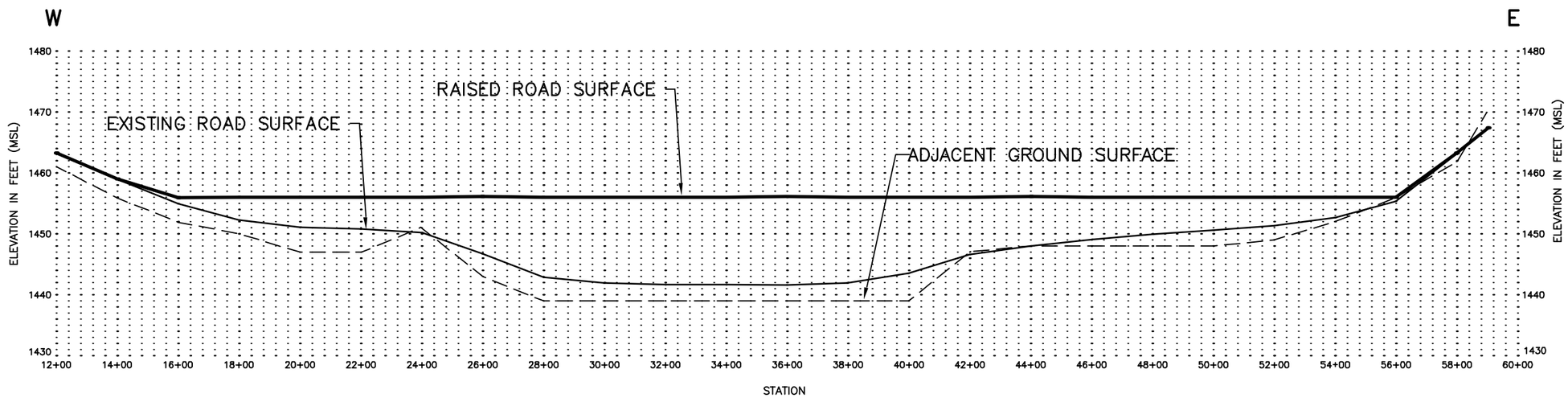
Figure 4.24–3

TYPICAL ROAD CROSS–SECTION

FEATURE 24:
BIA HIGHWAY 6

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

NRD M:\CAD\3436020\17161_2.DWG Plot at 10 11/06/2002 12:26:01



1. Adjacent ground elevations obtained from 2000 FEMA LIDAR topography.
2. Existing road surface elevations from the following construction drawings:
   Kadrmas, Lee & Jackson Plans, Project No. ERFO–BIA #6, 7/27/01.
3. Raised road surface elevation based on above set of plans (raise occurred on 2002).
4. Stationing based on the stationing used in the above–referenced drawings.

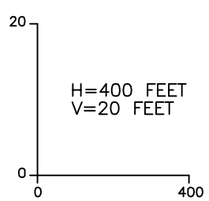


Figure 4.24–4

ROAD PROFILE

FEATURE 24:
BIA HIGHWAY 6

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

NRD M:\CAD\3436020\17226_1.DWG Plot at 1 11/06/2002 12:24:22

Table 4.24-1

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

DAMAGES

	Annual Detour Damages	Restoration Damages	
Lake Elevation (MSL)	**Damage Value (THOUSANDS)**	**Impacted Roadway Length (FEET)**	**Damage Value (THOUSANDS)**
1454	$13,873	200	$561
1455	$13,873	500	$596
1456	$13,873	5,010	$1,118
1457	$13,873	5,310	$1,153
1458	$13,873	5,580	$1,184
1459	$13,873	5,750	$1,204
1460	$13,873	5,980	$1,230
1461	$13,873	6,210	$1,257
1462	$13,873	6,460	$1,286
1463	$13,873	6,700	$1,314
1464	$13,873	6,940	$1,341
1465	$13,873	7,200	$1,372

DAMAGE BREAKDOWN

Annual Detour Damages	Description	Quantity	Unit	Unit Cost	Value (THOUSANDS)
	Hours/Year	531,430	HR	$7.13	$3,789
	Miles/Year	29,228,870	MILE	$0.35	$10,084
	Total				**$13,873**

Restoration Damages	Item	Description	Quantity per LF of Road		Unit Cost	Contingency	Value per LF of Road
	Excavation	Removal of existing bituminous (24' X 0.5'), existing shoulder (3' X 0.5' ea. side), existing aggregate base (41' X 0.5'), and top 1.5' of existing road embankment fill	4.06	CY/LF	$3.50	30%	$18
	Fill Material	Replace top 1.5' of roadway embankment	2.69	CY/LF	$5.00	30%	$17
	Geotextile Fabric	Place geotextile beneath new aggregate base	5.00	SY/LF	$2.00	30%	$13
	Aggregate Base Course	Replace 0.5' of subgrade and shoulders (3' X 0.5' ea. side)	0.92	CY/LF	$20.00	30%	$24
	Bituminous	Replace 0.5' of bituminous pavement	0.66	Tons/LF	$50.00	30%	$43
	Total						**$116**
	Item	**Description**	**Quantity per LF of Road**		**Unit Cost**	**Contingency**	**Total Value for Road**
	Riprap	Place riprap from road surface elevation to bottom of embankment replacement for lowest impacted roadway length	1.89	CY/LF	$40.00	30%	$492,383
	Geotextile Fabric	For use under riprap restoration	3.5	SY/LF	$2.00	30%	$45,591
	Total						**$537,974**

Table 4.24-2

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R(2)	R(3)
Action Level	Raise at AL2	Raise at AL3
	(THOUSANDS)	
AL2	$2,325	$0
AL3	$0	$2,213

COST BREAKDOWN

	R(2)						R(3)					
Strategy	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Road Raise	**Raise Top of Road to Elevation 14xx**						**Raise Top of Road to Elevation 14xx**					
	Performance/Payment Bond	1	JB	$12,965	10%	$14	Performance/Payment Bond	1	JB	$12,252	10%	$13
	Clearing and Grubbing	0.5	AC	$3,000	30%	$2	Clearing and Grubbing	0.6	AC	$3,000	30%	$2
	Stripping	2,000	CY	$1.50	40%	$4	Stripping	2,400	CY	$1.50	40%	$5
	Geotextile Fabric	17,000	SY	$2.00	30%	$44	Geotextile Fabric	12,500	SY	$2.00	30%	$33
	Aggregate Base Course	10,000	CY	$20	30%	$260	Aggregate Base Course	11,000	CY	$20	30%	$286
	Fill Material	81,000	CY	$5.00	50%	$608	Fill Material	79,000	CY	$5.00	50%	$593
	Bedding	0	CY	$35	30%	$0	Bedding	0	CY	$35	30%	$0
	Riprap	10,000	CY	$40	40%	$560	Riprap	7,500	CY	$40	40%	$420
	Bituminous Pavement	5,500	TON	$50	30%	$358	Bituminous Pavement	6,000	TON	$50	30%	$390
	Culverts	0	LF	$50	30%	$0	Culverts	0	LF	$50	30%	$0
	Topsoil	2,500	CY	$2.50	30%	$8	Topsoil	3,600	CY	$2.50	30%	$12
	Seed	4.4	AC	$1,000	30%	$6	Seed	6.7	AC	$1,000	30%	$9
	Geotechnical						**Geotechnical**					
	Slurry Wall	0	SF	$6.00	50%	$0	Slurry Wall	0	SF	$6.00	50%	$0
	Borings	2	EA	$1,000	50%	$3	Borings	1	EA	$1,000	50%	$2
	Environmental Impacts						**Environmental Impacts**					
	Mitigation	1	LS			$1	Mitigation	1	LS			$1
	HTRW	1	LS			$0	HTRW	1	LS			$0
	Cultural Resources Investigation	1	LS			$3	Cultural Resources Investigation	1	LS			$3
	Subtotal					$1,870	Subtotal					$1,768
	Engineering and Design		15%			$281	Engineering and Design		15%			$265
	Supervision and Administration		8%			$150	Supervision and Administration		8%			$141
	Real Estate Acquisition for ROW	1	LS			$25	Real Estate Acquisition for ROW	1	LS			$38
	Total Road Raise					**$2,325**	**Total Road Raise**					**$2,213**

ANNUAL OPERATION AND MAINTENANCE COSTS

Action Level	Road Maintenance Costs
	(THOUSANDS)
AL2	$9
AL3	$9

Table 4.24 - 3a

Economics Results: All Action Levels -- to Lake Level 1463
Feature 24: BIA Highway 6
Devils Lake Infrastructure Protection Study

Stochastic Analysis (ST-2)
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	J = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$4,500	$757,900	$0	$762,400	$0	$0	--
R(2)	2 Incremental Road Raise	$21,500	$0	$21,500	$0	$0	$0	$0	$762,400	$740,900	35.46

Wet Future Scenario (WF-2)
(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	J = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$16,800	$8,155,300	$0	$8,172,100	$0	$0	--
R(2)	2 Incremental Road Raise	$155,400	$0	$155,400	$0	$0	$0	$0	$8,172,100	$8,016,700	52.59

Moderate Future 1 Scenario (M1-2)
(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	J = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$0	$0	$0	$0	$0	$0	--
R(2)	2 Incremental Road Raise	$0	$0	$0	$0	$0	$0	$0	$0	$0	--

Moderate Future 2 Scenario (M2-2)
(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	J = H / C
A	Temporary Closure During Floods at First Action Level	$0	$0	$0	$13,900	$1,842,200	$0	$1,856,100	$0	$0	--
R(2)	2 Incremental Road Raise	$69,300	$0	$69,300	$0	$0	$0	$0	$1,856,100	$1,786,800	26.78

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

Attachment to 4.24:
BIA Highway 6 Infrastructure Protection Study Assumptions

A. Existing Road Information

1. Existing road elevations for the feature were obtained through contact with Spirit Lake Nation representatives, primarily Clarence Greene.

2. Existing road cross-section for the feature were based on construction drawing typical sections obtained from BIA/or their consultants including:

   - BIA Plans: Project No. 6-10(4), 6/1/1988

   - BIA Plans: Project No. 05-51-00761, 1977.

3. Existing road centerline profiles for the features evaluated were obtained from the plans listed above. Plan elevation data was assessed for reasonableness by comparing to the 2000 FEMA LIDAR topography. Where necessary road plan elevation information was supplemented with the LIDAR information.

B. Road Raise

1. The road raise is based on BIA plans. The raise height is applied from the top of the existing bituminous surface course to the top of the new bituminous surface course.

2. Cross-Section – The cross-section and profile for the road raise implemented in Fall 2002 is based on the plans that have been completed by Kadrmas, Lee and Jackson for the BIA. The set of plans are:

   - Kadrmas, Lee and Jackson: Project No. ERFO Road Repair Project – BIA #6, 7/27/01, Sheet 7 of 27

3. Profile –

   - Adjacent ground elevations obtained from 2001 LIDAR topography prepared for FEMA

   - Existing road surface elevations from the following construction drawings: Kadrmas, Lee & Jackson Plans, Project No. ERFO – BIA #6, 7/27/01

   - Raised road surface elevation based on the above set of plans (raise occurred in 2002)

   - Stationing based on the stationing used in the above-referenced drawings

C. Geotechnical

1. No geotechnical analysis was completed for this feature.

D. Road Restoration

1. For damage calculations, it was assumed that, if the feature were temporarily closed, it would be restored after the lake level has receded to the minimum road surface elevation less the assumed wave runup (the "Lake Damage Elevation").

2. Restoration damages were calculated assuming that the bituminous surfacing, shoulder and aggregate subgrade would be removed along with an additional 1.5 feet of embankment material. Those materials would then be replaced in kind over a geotextile. It was assumed riprap would be placed on the lake side slope over geotextile from the road surface elevation to the bottom of the embankment replacement. The riprap would be placed along the length of roadway lying below the receded lake damage elevation. The receded lake damage elevation is defined as the receded lake elevation plus the calculated wind-induced wave height.

E. Detours

1. Detour damages were included for every year that the feature 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.

2. Restoration of a road would only occur after the lake has receded to 2 feet 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

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.

4.25 Summary of Infrastructure Protection Investigation for Feature 25: Roads Acting as Dams

4.25.0 Flood Protection Strategy

The incremental flood protection that was analyzed for Roads Acting as Dams was incremental levee construction.

4.25.1 General Information

Feature Type: Road (Acting as Dams)

Location: Two separate areas are currently being offered protection by a road or series of roads that are acting as dams and emergency levees. These areas include:

1) **Mission Township Area**—approximately 21 square miles of Mission Township within the Spirit Lake Reservation on the southeast side of Devils Lake between Mission Bay and Black Tiger Bay

2) **Acorn Ridge Area**—an area south of the City of Devils Lake west of ND Highway 20 and north of Camp Grafton

The accompanying Figure 4.25-1 shows these locations and approximate extents of these areas, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).

Description: The length of roads currently acting as dams is approximately 7 miles. The roads acting as dams issue originated in 1995 when culverts under those roads were plugged as part of emergency measures to protect existing features. Currently, the difference in water levels on each side of the road is as much as 12 feet. This pressure difference is a potential safety hazard since the roads were not designed to be utilized as dams.

Three emergency levees and portions of ND Highway 20, BIA Highway 4, and BIA Highway 5 that are acting as dams protect the Mission Township area between Mission Bay and Black Tiger Bay. The Acorn Ridge area is protected by a section of ND Highway 20 that is acting as a dam.

Significance: The roads acting as dams, particularly ND Highway 20, are major arterial routes carrying traffic to and through the Mission Township area. By virtue of the roads acting as dams, several square miles of land and several rural structures are protected that would otherwise be inundated.

Damages: The loss of the protection of these areas (to lake elevation 1451) would result in the following damages:

- Potential loss of the sections of ND Highway 20 (Features 21 and 22), BIA Highway 4, and BIA Highway 5 that are currently acting as dams and are below Elevation 1455 (assuming 4 feet of freeboard is required to prevent wave damage to the road surfaces)
- Loss of sections of BIA Highway 6 (Feature 24), BIA Highway 9, BIA Highway 2, and Military Road that lie within the protected area (portions of BIA Highway 1 would also be protected at higher elevations)
- Loss of 34 residential structures in Mission Township Area, 12 residential structures in Highway 57/1 Area, and 15 residential structures in the Acorn Ridge Area (Feature 8.1)
- Loss of rural farmsteads, including: barns, sheds, silos, etc.
- Loss of 1 commercial structure in Mission Township Area
- Loss of the North Sewage Lagoons at St. Michael
- Loss of rural land area

Owner/Sponsor: The North Dakota Department of Transportation (ND DOT) is responsible for maintaining ND Highway 20. The US Department of Interior, Bureau of Indian Affairs is responsible for managing and maintaining BIA Highway 1, BIA Highway 4, BIA Highway 5 BIA Highway 9, and BIA Highway 6.

Lead Federal Agency: Several agencies would be responsible for any flood protection that may take place for Roads Acting as Dams. The Corps would take the lead for any levee flood protection that may take place. The Federal Emergency Management Agency (FEMA) would coordinate relocation of structures. ND DOT 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 BIA would take the lead on raising the BIA roads and individual counties would be responsible for flood protection of county roads.

4.25.2 Feature Protection

History of Flood Protection: In the past, flood protection in the areas protected by Roads Acting as Dams has consisted of (1) incremental raising of the roads when the water level approaches the road surface, and (2) construction of emergency levees. The initial raising of the roads generally included plugging of drainage culverts, which has allowed the roads to act as dams holding back lake water and providing protection to areas on the opposite side of the roads. These actions are summarized in the table below.

Feature 25 Flood Protection History

Road Raises				
Road	**Location**	**Road Surface Elevation**	**Length (miles)**	**Year Constructed**
ND Hwy 20	Acorn Ridge Area	1443	0.28	1997
ND Hwy 20	Acorn Ridge Area	1455	1.27	2001
ND Hwy 20	From ND Highway 57 to Tokio	1447.5	1.91	1997
ND Hwy 20	From ND Highway 57 to Tokio	1451.5	3.71	1999
ND Hwy 20	Narrows Areas	1455 (1465 bridge)	1.2	2001
BIA Hwy 4	From BIA Highway 1 to ND Highway 20	1450.5	1.98	1999
BIA Hwy 5	From BIA Highway 4 to ND Highway 20	1450.5	0.55	1999
BIA Hwy 6	Between BIA Hwy 1 and ND Hwy 20	1456.9	0.9	2002
Emergency Levees				
	Location	**Crest Elevation**	**Approximate Length (feet)**	**Year Constructed**
	Section 35 (west)	1445	500	1997
		1447.6	750	1998
		1452	1000	2001
	Section 35 (central)	1445	400	1997
		1449	500	1998
		1453	600	2001
	Section 31	1445	750	1997
		1449	1000	1998
		1453	1200	2001

General Protection Strategy: The assumed flood protection strategy for each of these areas is as follows:

1) Mission Township Area

This area would be protected by a series of levees designated on Figure 4.25-1 as Levees 25A through 25J. Levee25A would be constructed adjacent to the embankments of BIA Highways 4 and 5 on the land side and utilize those embankments for cofferdams on the lake side. Construction would require temporary cofferdam construction on the land side were water currently inundates the levee foundation area. Levees 25B, C, and G would be constructed adjacent to and on the land side of the emergency levees in those areas. A

cofferdam was assumed to be required on the land side of Levee 25G. Levees 25D, E and F are freeboard levees (base elevation is above the design lake level and height of the levee only provides freeboard protection), so can be constructed without cofferdams. A cofferdam was assumed to be required on both the land side and lake side of Levees 25I and 25J. Equalization culverts would be placed through ND Highway 20 and BIA Highways 4 and 5 to prevent those roadway embankments from acting as levees.

2) Acorn Ridge Area

This area would be protected by a levee, constructed parallel to the portion of ND Highway 20 currently acting as a dam. Levee 25K would be constructed adjacent to the road embankment on the land side and utilize that embankment for a cofferdams on the lake side. Construction would require temporary cofferdam construction on the land side were water currently inundates the levee foundation area.

Protection Strategy by Lake Level: The current analysis evaluated construction of perimeter levees to protect the same areas as the Roads Acting as Dams, without utilizing the roads that are acting as dams. The no protection option for this feature was temporary inundation of the areas by breaching the roads acting as dams and allowing water levels to equalize on each side of the roadways (the no action strategy). Under the no protection strategy, the flood protection strategies for the features affected by the Roads Acting as Dams would be analyzed on a feature-by-feature basis (See the corresponding feature descriptions).

Figure 4.25-2 shows the Decision Tree for incremental protection in the Roads Acting as Dams areas. As shown on Figure 4.25-2, the stepwise approach to flood protection by Roads Acting as Dams consisted of the following:

1. At Action Level 1 (AL1), a decision would be made as to whether the Roads Acting as Dams would be breached and the water levels allowed to equalize, or levees would be constructed with crest elevation 1455 to continue to protect these areas to lake elevation of 1451 (3-foot design wave runup plus additional 1-foot freeboard). If the former strategy is chosen, the areas that are currently protected will become inundated and the structures and features in each area below Elevation 1452 would be damaged. Other flood protection strategies may be implemented for each feature, as discussed in the respective feature descriptions.

2. If the levees were constructed at AL1, at Action Level 2 (AL2), the levees would be raised to crest elevation 1462 to protect the areas to lake elevation 1458 (3-foot design wave runup plus additional 1-foot freeboard).

3. If the levees were raised at AL2, at Action Level 3 (AL3), the levees would be raised to crest elevation 1468 to protect the areas to lake elevation 1463 (4-foot design wave runup plus additional 1-foot freeboard).

The reference elevations for the first action level of the flood protection strategy as used elsewhere in this study, have already been exceeded. Roads are currently acting as dams, where such a condition is not desired. If the Roads Acting as Dams are breached and water levels allowed to equalize (alleviating the concern for dam failure), damages to buildings, roads and land will be incurred immediately.

Reference Elevations for Mission Township Area				
Elevation			**Name**	**Significance**
AL1	**AL2**	**AL3**		
1441.6	1455	1462	Low Structure Elevation	Low sill on lowest building or minimum road elevation
Current	1452	1459	Lake Damage Elevation	Lake elevation at which damage to lowest building occurs
Current	1450	1457	Project Completion Elevation	Lake elevation at which levee construction must be complete
Current	Current	1455	Construction Initiation Elevation	Lake elevation at which levee construction must begin
Current	Current	1454	Planning and Design Initiation Elevation	Lake elevation at which planning and design process must begin

Reference Elevations for Acorn Ridge Area				
Elevation			**Name**	**Significance**
AL1	**AL2**	**AL3**		
1440	1455	1462	Low Structure Elevation	Low sill on lowest building or minimum road elevation
Current	1452	1459	Lake Damage Elevation	Lake elevation at which damage to lowest building occurs
Current	1450	1457	Project Completion Elevation	Lake elevation at which levee construction must be complete
Current	Current	1455	Construction Initiation Elevation	Lake elevation at which levee construction must begin
Current	Current	1454	Planning and Design Initiation Elevation	Lake elevation at which planning and design process must begin

4.25.3 Design Considerations

Sections 4.25.3.0 through 4.25.3.10 describe the analysis of the design of flood protection measures, as well as other considerations (geotechnical, environmental, etc.) necessary to make the cost estimates for the first action level. Section 4.25.3.11 describes the abbreviated cost estimating method for subsequent action levels.

4.25.3.0 General Design

The general plan for flood protection in the Mission Township and Acorn Ridge areas includes the construction of protective levees, as is shown on Figure 4.25-1.

Alignment

The Mission Township area levees would include a parallel levee (25A) adjacent to the portions of BIA Highway 4 and 5 acting as dams. This levee would be constructed on the land side to take advantage of the existing roadway embankments as cofferdams on the lake side. The remaining Mission Township area levees (25B through 25J) would be perimeter levees constructed across low points in the existing area topography. The alignment of the perimeter levees generally follow the alignments shown in the October 1997 *Spirit Lake Nation Reservation Alternative Assessment*.

The Acorn Ridge area levee would be a parallel levee constructed on the land side of the portion of ND Highway 20 acting as a dam to take advantage of the existing roadway embankment as a cofferdam on the lake side.

The table below includes a list of the proposed levee lengths (lake protection elevation 1451):

Levee	AL1
25A	11,200
25B	1,120
25C	1,220
25D	850
25E	1,340
25F	430
25G	2,550
25H	4,620
25I	2,180
25J	1,360
25K	2,600

Cross-section

Figure 4.25-3a shows a typical cross-section of the proposed parallel levees (25A and 25K). Figure 4.25.3b shows a typical cross-section of the proposed parallel levees (25B through 25J). The levee crest elevation was assumed to be 1455 to provide protection to a lake elevation of 1451. The 4-foot freeboard is consistent with previous studies and was found to be adequate for the calculated wind-induced wave run up plus at least 1 foot of additional freeboard at all levee locations.

The top widths for the levees were assumed to be 15 feet (10 feet of compacted fill and 5 feet of riprap tie-in). The side slopes are 3H:1V on the interior (land side) of the levee. The side slopes on the lake side of the perimeter levees are 6H:1V. The parallel levee section has a steeper lake side slope (rather than the typical 6H:1V) because it is assumed the roadway embankment immediately adjacent to the levee will remain in place. The top and interior side of the levees will be covered with 4 inches of topsoil and seeded.

An impervious core was also assumed for all levees, with a top elevation of the core being 1450. A sand drain was assumed for all levees greater than 4 feet high, with a top elevation of the sand drain being 1448. The top of the sand drain layer at elevation 1448 would be 4 feet wide. The sand drain would then slope down at a 1:1 (H:V) slope and be 2 feet thick along the rest of its length (depending on the height of the levee). The actual sand drain elevations should be reviewed during final design and during construction of each levee addition.

Cofferdams were assumed to have a crest elevation of 1450 on the lake side and 1445 on the land side. Crest width was 10 feet and side slopes at 3H:1V.

Profile

Figures 4.25-4a- 4.25-4k shows the profile of the proposed levees. The tops of the levees are at 1455.

Materials

It was assumed that the levees and cofferdams would be constructed from readily available native silty clay and clay loam. These materials are relatively impermeable, and are suitable for levee construction.

Erosion Protection

The exterior side slopes of all levees will require erosion protection due to wave action. The calculated wind-induced wave height (run up) was 4 feet. The riprap thickness was assumed to be 18 inches for each levee section, based on COE methods described in EM1110-2-1601. A 12-inch granular filter was assumed for bedding under the riprap for

each of the levees. The exterior (lake side) slopes are protected with riprap to the top of the levee, with a 5-foot tie-in. The interior side slopes would not be protected with riprap.

The wind-induced wave height is also used to compute the lake elevation at which damage will occur to the levee due to wave action.

Cofferdams were assumed to have riprap on the water side from the crest to a distance down slope 5 feet vertically.

Construction Considerations

The top 12 inches of ground surface would be stripped prior to construction for better adhesion between the ground and the levee. An inspection trench would also be constructed for all levees to permit observation of the top 6 feet of foundation materials.

It is assumed that the levees would be constructed in the dry to allow examination of the foundation when it is under water and better quality control over the placement of levee materials. Construction of levees 25A and 25K will require construction of cofferdams on the side opposite the existing highway embankments, which will be utilized as cofferdams on the lake side. Levees 25B, C and G are assumed to be constructed inland from the emergency levees in those areas, so will not need additional cofferdams. It is assumed levees 25D, E and F will be constructed before the lake level reaches the base elevation of those levees, so no cofferdams will be necessary. A portion of levee 25H and levees 25I and 25 J will require cofferdams on both sides to allow the levees to be constructed in dry conditions.

Cofferdams were assumed to be placed in wet conditions. After construction of the cofferdam, the interior water behind the cofferdams can be pumped out to facilitate examination of the foundation, stripping of the top layer of ground and construction of the inspection trench. Cofferdam and associated dewatering costs are included in the feature cost estimates.

4.25.3.1 Site Geology

In the area of Devils Lake, Late Wisconsin age glacial deposits of varying thickness overly deposits of earlier glaciations and/or Cretaceous age bedrock. Thin lacustrine deposits from the current and prehistoric Lake Minnewaukan are also present in the Devils Lake basin. All the glacial deposits in this area are part of the Coleharbor Formation.

The area proposed for Roads Acting as Dams is covered by two deposits: boulder clay till in a low-relief stagnation moraine of the Coleharbor Formation as the high ground, with silt and clay facies lake bed deposits from past high stands of the lake (prehistoric Lake Minnewaukan) in the low areas which are now beneath the current lake. Beach deposits are present in some areas along the slope break surrounding the lake plain. These deposits tend to be too small in area to be shown on the county geologic map, but are apparent in the county soil maps.

The predominant glacial till is generally composed of silty clay with sand, pebbles, cobbles, and boulders. This deposit is yellowish brown in the oxidized zone in the uppermost 10 to 25 feet near the ground surface, and olive gray at depth. The till is mapped as part of the boulder clay facies of the Coleharbor Formation.

The lake and glacial deposits range from about 70 to 150 feet in thickness. In some places, sand and gravel make up most of the soil section. The bedrock is Cretaceous Pierre Shale.

The proposed Roads Acting as Dams cross the following soil types, which have the indicated comments with respect to levee construction:

- Segment 25A4
  - 113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 31B Towner fine sand; SM. SM-SC; Moderate: frost action (2 to 3 feet thick)
  - 99C Claire loamy coarse sand; SP, SP-SM; beach; Slight (+4 feet thick)
  - 107 Minnewaukan loamy fine sand; SM, SM-SP; beach – Severe: wetness, floods (+5 feet)
  - 101&106 Lallie loam; ML, CL; lake bed; Severe: wetness, floods, low strength
  - 104 Lallie loam, saline; CL, CL-ML, CH; lake bed; Severe: low strength, wetness, floods

- Segment 25A5
  - 110 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 31B Towner fine sand; SM. SM-SC; Moderate: frost action (2 to 3 feet thick)
  - 109 Aquents; CL, CL-ML; lake bed; Severe: low strength, flooding, wetness
  - 104 Lallie loam, saline; CL, CL-ML, CH; lake bed; Severe: low strength, wetness, floods
  - 106 Lallie loam; ML, CL; lake bed; Severe: wetness, floods, low strength

- Segment 25B
  - 110&113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 42 Gardena silt loam; ML; beach; Severe: frost action (+5 feet thick)
  - 59B Maddock-Hecla fine loamy sand; SM, SP-SM, SM-SC; Moderate: frost action (+5 feet)
  - 31B Towner fine sand; SM. SM-SC; Moderate: frost action (2 to 3 feet thick)

- Segment 25C
  - 113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 31B Towner fine sand; SM. SM-SC; beach; Moderate: frost action (2 to 3 feet thick)
  - 99C Claire loamy coarse sand; SP, SP-SM; beach; Slight (+4 feet thick)
  - 109 Aquents; CL, CL-ML; lake bed; Severe: low strength, flooding, wetness

- Segment 25D
  - 110&113 Bottineau loam; CL, CL-ML; till; Severe: low strength

- Segment 25E
  - 110&113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 12B Barnes-Svea loams, CL, CL-ML, till; Moderate: frost action, low strength

- Segment 25F
  - 110&113 Bottineau loam; CL, CL-ML; till; Severe: low strength

- Segment 25G
  - 110&113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 101 Lallie loam; ML, CL; lake bed; Severe: wetness, floods, low strength
  - 99C Claire loamy coarse sand; SP, SP-SM; beach; Slight (+4 feet thick)
  - 14 Svea-Hamerly loams; CL, CL-ML; till; Severe: low strength
  - 45 Beardon silt loam; CL-ML, CL; lake bed – Severe: frost action, low strength

- Segment 25H
  - 110&113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 101 Lallie loam; ML, CL; lake bed – Severe: wetness, floods, low strength
  - 90 Lallie loam; Ml, CL; lake bed; Severe: wetness, floods, low strength
  - 107 Minnewaukan loamy fine sand; SM, SM-SP; beach – Severe: wetness, floods (+5 feet)

- 68B Arvilla sandy loam; SM, SC, SM-SC; beach; Slight (++5 feet, coarse sand & gravel at depth)

- Segment 25I
  - 113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 109 Aquents; CL, CL-ML; lake bed; Severe: low strength, flooding, wetness
  - 90&101&106 Lallie loam; Ml, CL; lake bed; Severe: wetness, floods, low strength
  - 99C Claire loamy coarse sand; SP, SP-SM; beach; Slight (+4 feet thick)

- Segment 25J
  - 113 Bottineau loam; CL, CL-ML; till; Severe: low strength
  - 109 Aquents; CL, CL-ML; lake bed; Severe: low strength, flooding, wetness
  - 90&106 Lallie loam; ML, CL; lake bed; Severe: wetness, floods, low strength
  - 99C Claire loamy coarse sand; SP, SP-SM; beach; Slight (+4 feet thick)
  - 13C Barnes-Buse loams; CL, CL-ML; till; Moderate: frost action, low strength

- Segment 25K
  - 12B&31 Barnes-Svea loams, CL, CL-ML, till; Moderate: frost action, low strength
  - 50B Towner sandy loam; SM, SM-SC; Moderate: frost action (2 feet thick)
  - 70 Lallie clay loam; ML, CL, CL-ML, CH; lake bed; Severe: low strength, flooding, wetness
  - 78C Wamduska loamy sand; SP-SM, GM, GP; beach; Slight (+5 feet thick)
  - 84 Bottineau loam; CL, CL-ML; till; Severe: low strength

"Slight" means soil properties and site characteristics are generally favorable for this use. "Severe" means special design may be required. Wetness and flooding are a given, since much of the area is already inundated.

Following is a summary of the anticipated borings and mitigation:

Segment	Borings	Cut Off Wall	Lake Bed
25A4	Borings – 6	Cut off wall – 3800 *20 feet	Lake bed – 2400 *5 feet
25A5	Borings – 3	Cut off wall – 0 (200 feet of sand can probably be excavated)	Lake bed – 2800 *3 feet
25B	Borings – 3	Cut off wall – 900 * 20	Lake bed – 0
25C	Borings – 3	Cut off wall – 1000 * 10 feet	Lake bed - 200 * 1
25D	Borings – 1	Cut off wall - 0	Lake bed - 0

Segment	Borings	Cut Off Wall	Lake Bed
25E	Borings – 1	Cut off wall – 0	Lake bed – 0
25F	Borings – 1	Cut off wall – 0	Lake bed – 0
25G	Borings – 3	Cut off wall – 200 * 15 feet	Lake bed – 1800 * 3 feet
25H	Borings – 10	Cut off wall – 4000 * 20 feet	Lake bed – 400 * 2 feet
25I	Borings – 3	Cut off wall – 200 * 20 feet	Lake bed – 1800 * 10 feet
25J	Borings – 3	Cut off wall – 200 * 20 feet	Lake bed – 1200 *5 feet
25K	Borings – 6	Cut off wall – 1400 * 20 feet	Lake bed – 1800 * 5 feet

There are extensive beach deposits in the area of 25A-K. This is an indication that there may be exposed or shallowly buried glacial outwash deposits (sand and gravel), which could affect the performance of roads as dams.

4.25.3.2 Hydrology/Interior Drainage Issues

Hydrology

An analysis of the internal drainage system was completed to assist with the sizing of an interior pump station to remove the accumulation of water from the interior area behind the levees. The analysis investigated the amount of water expected from precipitation, seepage through the levees, and groundwater seepage underneath the levees.

The interior drainage tributary watersheds were estimated from USGS quadrangle maps and 1-foot LIDAR contours. The tributary area inside the flood barrier for the Mission Township Area was about 33 square miles (divided into 22 watersheds) and the Acorn Ridge area was about 0.2 square miles. Land use in the tributary areas is mainly cover crop and woodland, with smaller portions of grassland and surface water. The resulting peak flow rate to the pumping station is 222 cfs for Mission Township and 58 cfs for the Acorn Ridge area.

The pump station for Mission Township was designed to maintain the interior water level at an elevation of 1442. The total ponding area was calculated to be 3,338 acres; this includes currently inundated ponding areas.

In order to keep interior roads passable during periods of upper basin ponding, sections of BIA Highway 4, BIA Highway 2, BIA Highway 6 and 38th Street and 42nd Street were assumed to be raised. New culverts were designed at these road crossings.

Pumping Requirements

The interior drainage system was designed to provide a minimum of 1-foot freeboard for structures and 2-foot freeboard for roads during the 100-year event. The capacity of the

pumps designed for Mission Township and the Acorn Ridge area are summarized in the table below.

Roads As Dams

Pumps	Location	Flow (cfs)	Elevation Top of Levee	Minimum Pond Water Level	Total Design Head (ft)	Power (hp)
1	Mission Township	15	1465	1438.5	26.5	66
2	Mission Township	20	1465	1439	26	87
3	Mission Township	20	1465	1439.5	25.5	85
1	Acorn Ridge	5	1465	1436	29	24

4.25.3.3 Real Estate Requirements

Right-of-way requirements for the levees are assumed to extend 15 feet beyond the toes of the embankments. The 15-foot buffer will provide sufficient room for temporary construction activities and long-term maintenance access.

Right-of-way requirements for ponding areas include approximately 5 square miles that will be inundated during the 100 year, 10-day event. This includes naturally occurring ponds and ponding located at outlet control structures at road crossings.

4.25.3.4 Environmental/Cultural issues

HTRW

Current land uses within Feature 25 are generally rural residential, agricultural, and also tree covered in some areas, with the exception of the St. Michael's mixed residential/commercial and potential industrial land uses. Land use does not appear to have changed significantly since overtime.

The regulatory record review for zip code 58370 was obtained from FirstSearch on September 24, 2002. No facilities appear to be located within the footprint of the proposed dams and levees or within the area where the lake may expand.

Twenty-seven potential HTRW sites identified within the feature are listed below and shown on Figure 4.25-1:

HTRW Site Costs			
Site #	Action Level Affected	HTRW Category	HTRW Costs
25-1-1	1	Rural Residences & Farmsteads	$1,500
25-1-2	1	Rural Residences & Farmsteads	$1,500

HTRW Site Costs			
Site #	**Action Level Affected**	**HTRW Category**	**HTRW Costs**
25-1-3	1	Rural Residences & Farmsteads	$500
25-1-4	1	Nonresidential Properties	* $14,000
25-1-8	1	Rural Residences & Farmsteads	$500
25-1-9	1	Railroad Related Land Uses	$5,500
25-1-10	1	Potential Dumps	$9,000
25-1-11	1	Rural Residences & Farmsteads	$1,500
25-1-12	1	Rural Residences & Farmsteads	$1,500
25-1-13	1	Rural Residences & Farmsteads	$1,500
25-1-14	1	Rural Residences & Farmsteads	$1,500
25-1-15	1	Rural Residences & Farmsteads	$1,500
25-1-16	1	Rural Residences & Farmsteads	$1,500
25-1-17	1	Rural Residences & Farmsteads	$1,500
25-1-18	1	Nonresidential Properties	$3,000
25-1-19	1	Rural Residences & Farmsteads	$500
25-1-20	1	Excavation or Fill Areas	$5,500
25-1-21	1	Rural Residences & Farmsteads	$3,000
25-1-22	1	Potential Dumps	$5,500
25-1-23	1	Rural Residences & Farmsteads	$1,500
25-1-24	1	Rural Residences & Farmsteads	$1,500
25-1-25	1	Rural Residences & Farmsteads	$1,500
25-1-26	1	Rural Residences & Farmsteads	$1,500
25-1-27	1	Rural Residences & Farmsteads	$500

*Cost increased due to size and type of site.

A more detailed description of site history and a breakdown of costs are in Appendix C. A description of environmental concerns associated with these categories is in Section 4.0.

Cultural

This project has the potential to affect eight known sites and three site leads/isolated finds as shown on Figure 4.25-1, including seven known sites (32BE0048, 32BE0051, 32BE0052, 32BE0063, 32BE0085, 32BE0406, 32RY0319) and two isolated finds (32BEX0130 and 32BEX0131) discussed for the ND Highway 20 (ND Highway 57 to Tokio) project. Three of the known sites (32BE0048, 32BE0051, and 32BE0052) are historical archaeological sites that were surface collected but for which eligibility was not

determined. Two of the known sites (32BE0063 and 32RY0319) are architectural sites. Site 32BE0063 is a recent farmstead with a historical barn that was recommended as not eligible for listing on the NRHP. Devils Lake Carnegie Library (32RY0319) has been nominated to the NRHP. Site 32BE0406 (Ironhawk Site) is the only known prehistoric archaeological site that may be impacted by the Roads Acting as Dams feature. This site was surface collected and recommended as not eligible for listing on the NRHP. Site 32BE0085 is a scatter of non-diagnostic lithic artifacts and a bone fragment that was recommended as not eligible for listing on the NRHP.

Two isolated finds, 32BEX0130 and 32BEX0131, may also fall within the project area of potential impact. Isolated find 32BEX0130 is comprised of "two old car bodies and a possible homesite" (NDCRS Form, 32BEX0130, on file at the SHSND), while 32BEX0131 is comprised of an old stove and scattered metal fragments. Additional archaeological work was not conducted in the vicinity of these finds. Therefore, recommendations of eligibility were not made for either of these isolated finds.

The additional known site that may be affected by the Roads Acting as Dams project is 32BE0086 (Dokken Pit Site), an undated scatter of lithics and bone that has not been subject to subsurface testing and, therefore, for which a recommendation of eligibility has not been made.

The site lead that may fall within the Roads Acting as Dams area of potential impact is a historical archaeological site lead, 32BEX0021 (Narrows Post Office).

A summary of the evaluation status of known cultural resources is presented in the following table.

Feature 25 Roads Acting as Dams: Evaluation Status of Known Cultural Resources			
Resource Type	**Resources Listed on or Nominated for the NRHP**	**Resources with Recommendations (Phase I Survey Completed)**	**Resources with Inconclusive or No Recommendations (Require Phase I Survey)**
Architectural	1	1	0
Archaeological	0	2	4
Architectural Site Leads/Isolated Finds	0	0	0
Archaeological Site Leads/Isolated Finds	0	0	3
Total	1	3	7

The estimated cost to conduct Phase 1 Surveys for each of the seven sites is presented in the following table. The total cost for all surveys is $62,000. As noted in Section 4.0, these costs are believed representative of the cultural resources investigations needed for the next stage of study.

Feature 25 Roads Acting as Dams: Phase 1 Survey Costs		
Site Number	**Investigation Type**	**Estimated Cost**
32BE0048	Phase I Archaeological	$8,000
32BE0051	Phase I Archaeological	$8,000
32BE0052	Phase I Archaeological	$8,000
32BE0086	Phase I Archaeological	$8,000
32BEX0021	Phase I Archaeological	$14,000
32BEX0130	Phase I Archaeological	$8,000
32BEX0131	Phase I Archaeological	$8,000

Environmental

The natural resources within the areas impacted by protection measures due to Roads Acting as Dams include wetlands, oak forest/woodlands and grasslands. The acres of habitat impacted by land use category are shown on Figure 4.25-1. Fill used for the construction of the road raise could cause environmental impacts due to encroachment upon wetlands and upland plant communities. Additionally, the ponding areas behind these roads acting as dams would cause additional impacts. These impacts would include the flooding of upland areas and the deepening of existing wetland areas. The environmental impacts are more fully detailed in the general impacts discussion Section 4.0.

A total of 61.50 acres of wetland impacts are expected from the proposed levee construction, with 0.52 acres of those wetlands having easements on them. Complete or partial loss of wetland functions and conversion to upland due to filling is possible in some locations. In areas where some hydrology is maintained and wetland conditions remain, changes in plant community and hydrology could lead to a wetland type change. The loss of wetland area would impact waterfowl, marsh bird and songbird-nesting areas, as well bring about impacts to reptile and amphibian populations due to habitat loss and fragmentation. These impacts on wetland would require 122.48 acres of mitigation wetlands as set forth in the project mitigation policy developed through consultation with the Corps and FWS.

A total of 1,839.24 acres of wetland impacts are expected from the roads acting as dams due to inundation and a subsequent wetland-type change. Wetland easements are present

on 201.86 acres of those wetlands and 342.26 acres of those wetland acres impacted are within a Waterfowl Production Area (WPA). Complete or partial loss of wetland functions due to conversion to deep-water habitat is possible in some locations. In areas where some hydrology is maintained and wetland conditions remain, changes in plant community and hydrology would lead to a wetland type change. The loss of wetland area would impact waterfowl, marsh bird and songbird-nesting areas, as well bring about impacts to reptile and amphibian populations due to habitat fragmentation. This loss of wetland would require 3,678.48 acres of mitigation wetlands as set forth in the project mitigation policy developed through consultation with the Corps and FWS.

In the upland areas a loss of native species due to grading and filling could be expected to occur as a result of levee construction. Subsequent re-vegetation of fill or borrow locations may allow for the introduction of weedy, non-native species. A loss of native tree species due to grading and filling, as well as the introduction of weedy, non-native under-story species could also be expected in these areas. These environmental impacts are more fully detailed in the general impacts discussion Section 4.0. Environmental impacts due to levee construction would adversely affect 33.08 acres of oak forest/oak woodland (0.38 acres are under easement), 0.37 acres of grasslands under easements, 58.17 acres of other grassland habitat acres, and 6.30 acres of the cropland under. The loss of woodland and grassland areas would impact songbird nesting and small mammal populations, as well impacting reptile and amphibian populations due to habitat fragmentation. Mitigation activities would require the acquisition of 65.78 acres of woodland, 116.71 acres of grasslands habitat and 6.30 acres of cover crop of like upland habitat replacement for these impacts.

Upland impacts are expected from the roads acting as dams due to inundation and a subsequent conversion of upland areas to aquatic habitat – either open water or wetland. Complete or partial loss of habitat functions due to conversion to deep-water habitat is possible in some locations. In areas where wetland conditions remain (i.e., water depths less than 2 meters), changes in plant community and hydrology would lead to wetland creation. Environmental impacts due to inundation would affect 438.57 acres of oak forest/oak woodland (0.22 acres are under easement), 30.00 acres of grasslands under easements, 944.98 acres of other grassland habitat acres, and 2.38 acres of the cropland under easement. A total of 29.76 of these upland acres are within the boundaries of a WPA. The loss of woodland and grassland areas would impact songbird nesting and small mammal populations, as well impacting reptile and amphibian populations due to further habitat fragmentation. Mitigation activities would require the acquisition of 876.91 acres of woodland, 1919.96 acres of grasslands habitat and 2.38 acres of cover crop of like upland habitat replacement for these impacts.

4.25.3.5 Effects on Existing Infrastructure and Utilities

Mission Township Area

- After the Mission Township area levees are constructed the Roads Acting as Dams in this area would be allowed to equalize on each side of the roadway embankments. This will be accomplished by the installation of new culverts through the roadway embankments. These sections of roads that are outside of the protected area could be relocated inside the protection area, to reduce future raise costs.

- Pumping of the interior area may draw water levels down to allow the restoration and reopening of the portion of BIA Highway 9 currently under water. The cost of restoration is included in the feature cost estimates.

- As the lake level rises, it is assumed that BIA Highways 4 and 5 in the vicinity of levee 25A will no longer be raised and that eventually those roads may be abandoned should water levels inundate the roads or wave action make the roads impassable.

Acorn Ridge Area

- After construction of the ND Highway 20 levee, the water would be allowed to equalize on both sides of the roadway. New culverts would need to be installed to allow equalization. The section ND Highway 20 that is outside of the protected area could be relocated inside the protection area, to reduce future raise costs.

4.25.3.6 Interdependencies

Flood protection for the areas protected by Roads Acting as Dams is related to the highway features that are acting as dams, the highways that serve the areas and the other features in the areas protected.

The road features that are acting as dams include portions of:

- Feature 21: ND Highway 20 (Devils Lake levee to ND Highway 57)

- Feature 22: ND Highway 20 (ND Highway 57 to Tokio)

These features are all major arterial routes in the region and provide access to the Roads Acting as Dams areas. The need to raise, protect or abandon portions of these features is dependent on the actions taken regarding protection with new levees.

The road features and other features within the areas protected by Roads Acting as Dams include portions of:

- Feature 22: ND Highway 20 (ND Highway 57 to Tokio)

- Feature 23: BIA Highway 1
- Feature 24: BIA Highway 6
- Feature 8.1: Rural – Structures in the Mission Township Area, the Highway 57/1 Area and the Acorn Ridge area
- Feature 5: St. Michael – North Sewage Lagoon and residences

The need to raise, protect or abandon portions of these features is dependent on the actions taken regarding protection with new levees.

Table 4.0-1, mentioned earlier in this report, provides a summary of the interdependencies among the features.

4.25.3.7 O&M

The annual costs for operation and maintenance of the pumps and levees were estimated using data from the City of Devils Lake levees and pumping stations obtained from the Corps.

The annual maintenance costs for the levees were assumed to be 1 percent of the initial construction cost. The annual operation and maintenance cost for the pump station was assumed to be 1.5 percent of the pump station construction costs plus $13,000 for electricity at the Mission Township area pump station and $2,000 for electricity at the Acorn Ridge area pump station.

4.25.3.8 Lead Time Required

The construction of the protective levees could be completed in one construction season. A lead time of about twelve months would be necessary for final design, preparation of construction documents and bidding. Total time between initiation of final design and substantial completion of construction would be in the range of 18 to 24 months.

4.25.3.9 Potential Problems and Risks

Potential problems and risks associated with the levees and house relocations include:

- Dewatering behind cofferdams could become a significant effort
- Foundation conditions will be difficult to assess prior to actual construction
- Levee fill placement for levee construction may be difficult to control because of seepage

- Cofferdam construction may be difficult, particularly in areas of high wave action
- Abandoning of utilities and wells may be necessary as part of the house relocations

4.25.3.10 Data Deficiencies

The following items would need to be acquired or verified prior to implementing the project.

- Verify location, number, and elevation of homes that would need relocating
- Perform soil borings prior to constructing levees
- Verification of above-ground and buried utilities

4.25.3.11 Abbreviated Cost Estimating for Feature Subsequent Action Levels

As was mentioned previously, for Feature 25, an abbreviated method was necessary for examining the costs of infrastructure protection at action levels above the first. The estimated costs at action levels subsequent to the first are presented in Table 4.25-2b. Estimates of benefits—damages prevented—for subsequent action levels were made in the same manner as for the first action level. The damage estimates for all action levels are shown in Table 4.25-1.

The same general approach to calculate costs was used for the subsequent action levels. Unit prices were not changed. However, some of the cost and damage items were simply extrapolated for the higher action levels, rather than being calculated in detail. The relevant design and cost assumptions for the abbreviated method are listed below.

Design Assumptions

- Levee crest elevations

  Action Level 2: 7-foot raise to 1462

  Action Level 3: 6-foot raise to 1468

- Cross-section

  Action Level 2: 15-foot crest width, 6H: 1V lake side side slopes, 3H: 1V land side side slopes, centerline-offset (to land side) raise

  Action Level 3: 15-foot crest width, 6H: 1V lake side side slopes, 3H: 1V land side side slopes, centerline-offset (to land side) raise

- Length

  Action Level 2: Total length of raised levee – 45,200 feet

  Action Level 3: Total length of raised levee – 49,600 feet

- Impacted Area

  Action Level 2: Incremental area impacted by raised levee – 63 acres

  Action Level 3: Incremental area impacted by raised levee – 60 acres

Construction material quantities were calculated in accordance with design assumptions discussed previously, and are listed in Table 4.25-2b. The geological/geotechnical and environmental quantities and costs were estimated in proportion to the Action Level 1 costs as described in Section 3.2.13. Real Estate costs were assumed to be proportional to the first raise costs.

4.25.4 Economics of Flood Protection

Damages: For the 2002 analysis, the flood damage estimates for Roads Acting as Dams were reassessed in order to update and more accurately characterize the nature of the damages. The updated damage computations for Roads Acting as Dams are summarized in the accompanying Table 4.25-1.

The primary damages include:

- Relocation of residences
- Detour, restoration and raising costs associated with roads in the protected areas
- Relocation of the North Sewage Lagoon in St. Michael
- Land area inundated

Although the restoration damages to interior roads are listed in Table 4.25-1, the limitations of the economics model do not allow consideration of these damages in the economic results.

Unit prices for all the damage computations were listed in Section 4.0, and are detailed in Table 4.0-2. An updated (as of 2002) list of assumptions regarding the damage computations, data sources, and other aspects of the economic analysis for roads acting as dams are listed in the roads acting as dams assumptions listing, appended to this Section 4.25.

Costs: The updated costs of providing flood protection for roads acting as dams are detailed in the accompanying Table 4.25-2a for the first action level and in Table 4.25-2b for subsequent

action levels. Unit prices, data sources, and relevant assumptions are listed. All costs are given in 2002 dollars.

The primary costs include:

- Earthwork items associated with levees and cofferdam construction
- Equipment items for the pump station for interior drainage
- Real estate costs associated with levees and ponding areas
- Raising costs associated with interior roads adjacent to the ponding areas

Unit prices for all the cost computations were discussed previously in Section 4.0, and are detailed in Table 4.0-2. Assumptions regarding the cost computations, data sources, and other aspects of the economic analysis for roads acting as dams are listed in the Roads Acting as Dams assumptions listing, appended to this Section 4.25.

4.25.4 Economic Results

The flood protection strategy that was analyzed for this feature was incremental levee raises.

Acorn Ridge Area

The results of the Infrastructure Protection Study for Roads Acting as Dams in the Acorn Ridge Area are listed in Table 4.25.1-3a for the analysis of all action levels and in Table 4.25.1-3b for the analysis of the first action level.

Multiple Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for Roads Acting as Dams-Acorn Ridge Area, the Infrastructure Protection Study analysis provided relevant economic indices for constructing the levees. This strategy is highlighted on the decision tree (Figure 4.25-2). The annual net benefits for this approach were less than zero (-$468,500). The BCR for this approach was less than one (0.12). These results show that this strategy is not economically justified. The stochastic results are averages over 10,000 traces.

Multiple Action Level Results for Specific Scenarios: Constructing the perimeter levees was also analyzed under each of three specific climate futures. For Roads Acting as Dams-Acorn Ridge Area, the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of constructing the levees were -$193,400, and the BCR was 0.21, indicating that this strategy was not economically justified.

- First Moderate Future – Under the first moderate future climate scenario, the annual net benefits of constructing the levees were -$356,100, and the BCR was 0.13, indicating that this strategy was not economically justified.

- Second Moderate Future – Under the second moderate future climate scenario, the average net benefits of constructing the levees were -$510,000, and the BCR was 0.15, indicating that this strategy was not economically justified.

First Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for Roads Acting as Dams-Acorn Ridge Area, the Infrastructure Protection Study analysis also provided relevant economic indices for constructing the first levee raise. The annual net benefits for this approach were less than zero (-$172,300). The BCR for this approach was less than one (0.23). These results show that this strategy is not economically justified. The stochastic results are averages over 10,000 traces.

First Action Level Results for Specific Scenarios: Constructing the perimeter levees was also analyzed under each of three specific climate futures. For Roads Acting as Dams-Acorn Ridge Area, the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of constructing the levees were -$160,800, and the BCR was 0.24, indicating that this strategy was not economically justified.

- First Moderate Future – Under the first moderate future climate scenario, the annual net benefits of constructing the levees were -$175,800, and the BCR was 0.23, indicating that this strategy was not economically justified.

- Second Moderate Future – Under the second moderate future climate scenario, the average net benefits of constructing the levees were -$166,300, and the BCR was 0.24, indicating that this strategy was not economically justified.

Mission Township Area

The results of the Infrastructure Protection Study for Roads Acting as Dams in the Mission Township Area are listed in Table 4.25.2-3a for the analysis of all action levels and in Table 4.25.2-3b for the analysis of the first action level.

Multiple Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for Roads Acting as Dams-Mission Township Area, the Infrastructure Protection Study analysis provided relevant economic indices for constructing the levees. This strategy is highlighted on the decision tree (Figure 4.25-2). The annual net benefits for this approach were less than zero (-$1,410,200). The BCR for this approach was less than one

(0.61). These results show that this strategy is not economically justified. The stochastic results are averages over 10,000 traces.

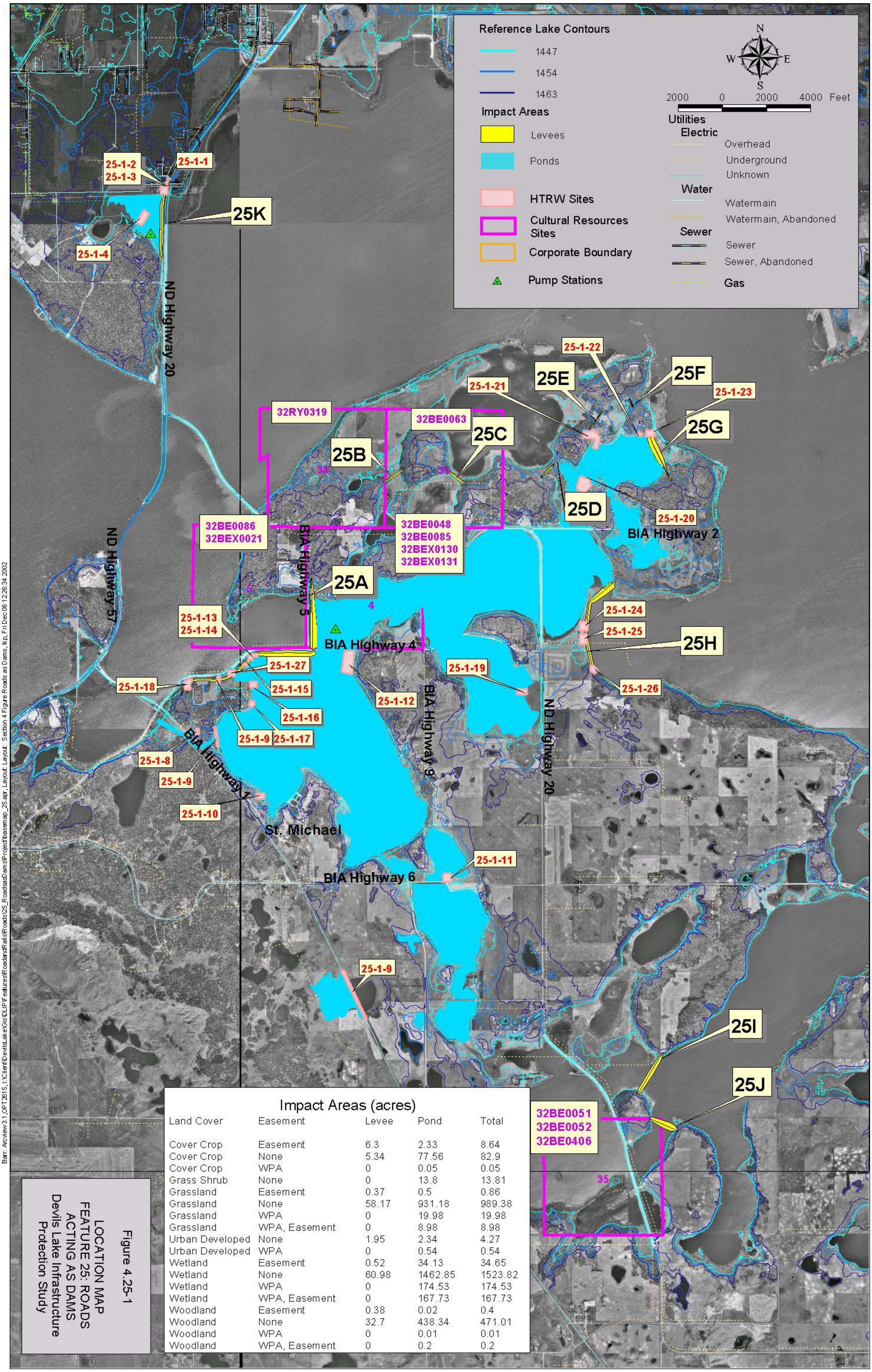
Multiple Action Level Results for Specific Scenarios: Constructing the perimeter levees was also analyzed under each of three specific climate futures. For Roads Acting as Dams-Mission Township Area, the economic indices for each of the three climate futures are as follows:

- Wet Future – Under the wet future climate scenario, the annual net benefits of constructing the levees were -$166,100, and the BCR was 0.93, indicating that this strategy was not economically justified.
- First Moderate Future – Under the first moderate future climate scenario, the annual net benefits of constructing the levees were -$1,791,700, and the BCR was 0.42, indicating that this strategy was not economically justified.
- Second Moderate Future – Under the second moderate future climate scenario, the annual net benefits of constructing the levees were -$1,966,200, and the BCR was 0.48, indicating that this strategy was not economically justified.

First Action Level Stochastic Analysis Results: Using the stochastic analysis along with the updated damage and cost estimates for Roads Acting as Dams-Mission Township Area, the Infrastructure Protection Study analysis provided relevant economic indices for constructing the levees. This strategy is highlighted on the decision tree (Figure 4.25-2). The annual net benefits for this approach were less than zero (-$1,047,500). The BCR for this approach was less than one (0.55). These results show that this strategy is not economically justified. The stochastic results are averages over 10,000 traces.

First Action Level Results for Specific Scenarios: Constructing the perimeter levees was also analyzed under each of three specific climate futures. For Roads Acting as Dams-Mission Township Area, the economic indices for each of the three climate futures are as follows:

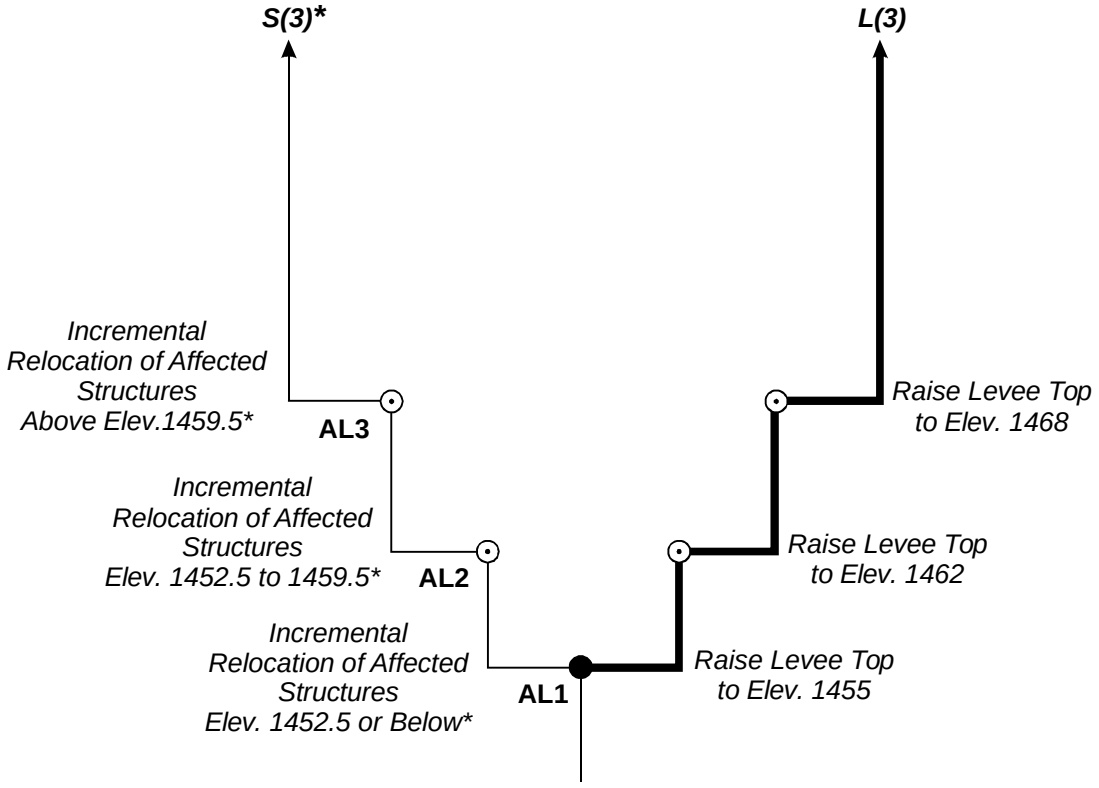
- Wet Future – Under the wet future climate scenario, the annual net benefits of constructing the levees were -$945,700, and the BCR was 0.57, indicating that this strategy was not economically justified.
- First Moderate Future – Under the first moderate future climate scenario, the annual net benefits of constructing the levees were -$1,076,900, and the BCR was 0.54, indicating that this strategy was not economically justified.
- Second Moderate Future – Under the second moderate future climate scenario, the annual net benefits of constructing the levees were -$933,800, and the BCR was 0.56, indicating that this strategy was not economically justified.



Impact Areas (acres)

Land Cover	Easement	Levee	Pond	Total
Cover Crop	Easement	6.3	2.33	8.64
Cover Crop	None	5.34	77.56	82.9
Cover Crop	WPA	0	0.05	0.05
Grass Shrub	None	0	13.8	13.81
Grassland	Easement	0.37	0.5	0.86
Grassland	None	58.17	931.18	989.38
Grassland	WPA	0	19.98	19.98
Grassland	WPA, Easement	0	8.98	8.98
Urban Developed	None	1.95	2.34	4.27
Urban Developed	WPA	0	0.54	0.54
Wetland	Easement	0.52	34.13	34.65
Wetland	None	60.98	1462.85	1523.82
Wetland	WPA	0	174.53	174.53
Wetland	WPA, Easement	0	167.73	167.73
Woodland	Easement	0.38	0.02	0.4
Woodland	None	32.7	438.34	471.01
Woodland	WPA	0	0.01	0.01
Woodland	WPA, Easement	0	0.2	0.2

Figure 4.25-1
LOCATION MAP
FEATURE 25: ROADS
ACTING AS DAMS
Devils Lake Infrastructure
Protection Study



━━━	Flood Protection Strategy
●	Decision required at this point
⊙	Trigger point for action, no decision needed
AL1	Decision/Action Level
L(1)	Incremental levee raise (number of times)
S(1)	Structure relocation (number of times)
*	In addition to structure relocations, ND Highway 20, BIA Highway 6 and St. Michael would require flood protection. These analyses were included as other features.

Figure 4.25-2

DECISION TREE
FEATURE 25: ROADS ACTING AS DAMS
Devils Lake Infrastructure Protection Study

P:\34\36\016\DECISIONTREES\FIGURE4_25.CDR RLG 01-06-03

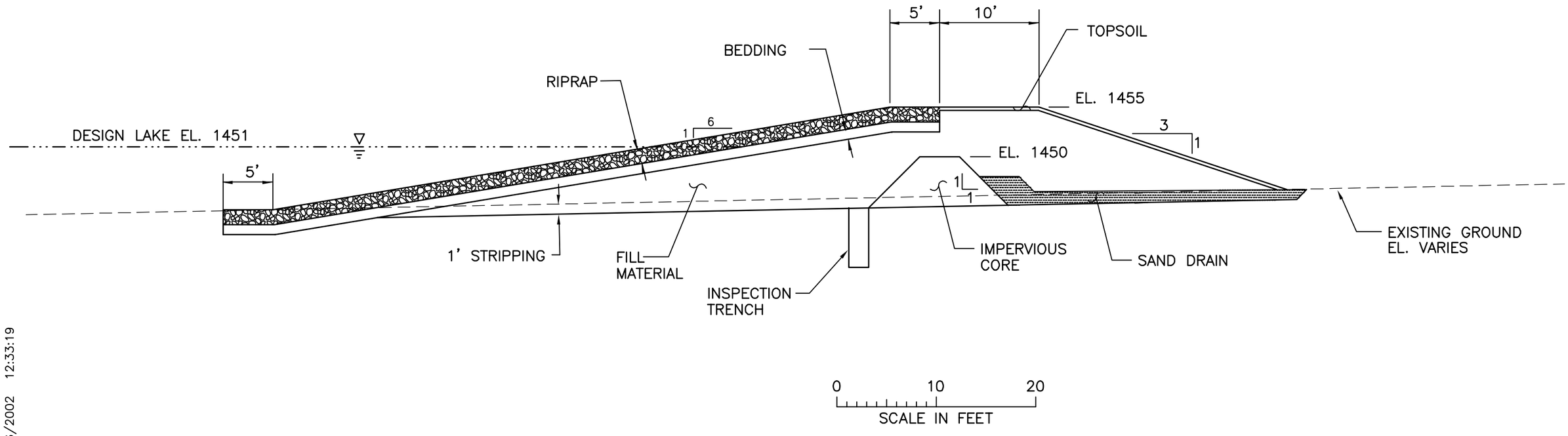


Figure 4.25–3a

TYPICAL LEVEE CROSS–SECTION

FEATURE 25:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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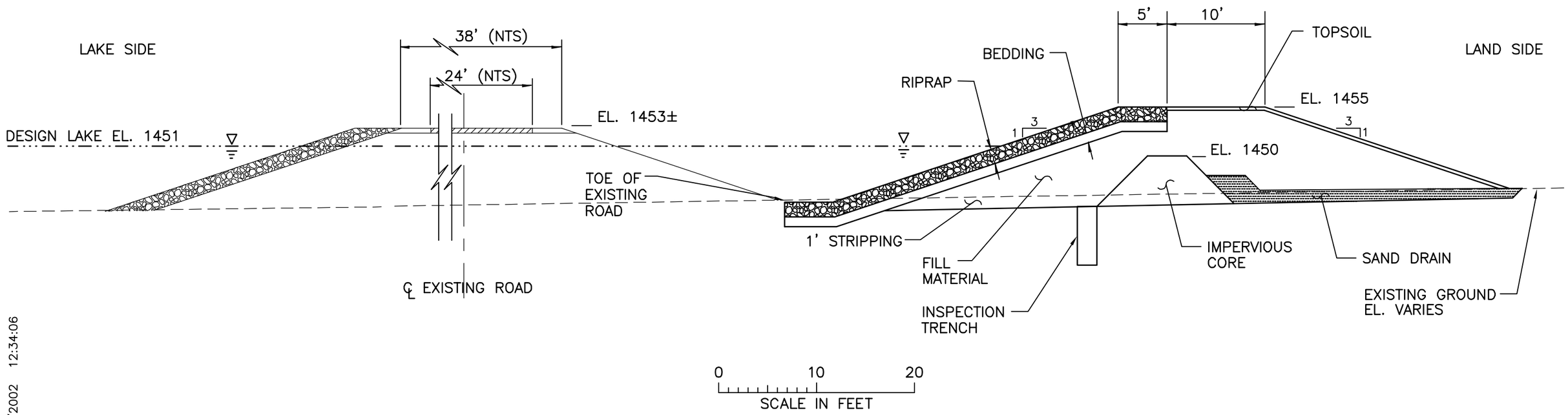

Figure 4.25–3b

TYPICAL LEVEE CROSS–SECTION

FEATURE 25:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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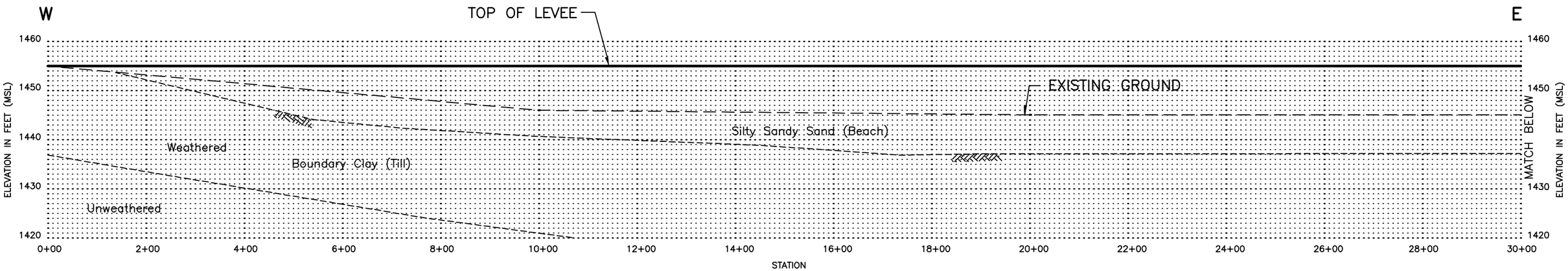
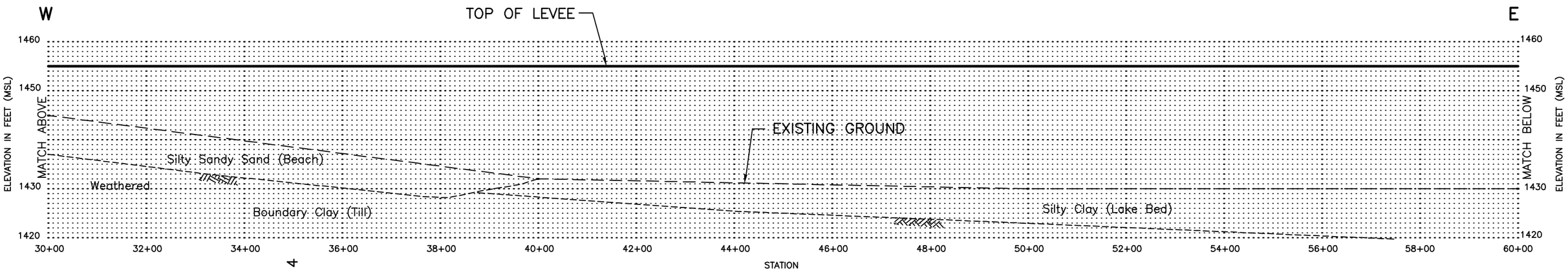
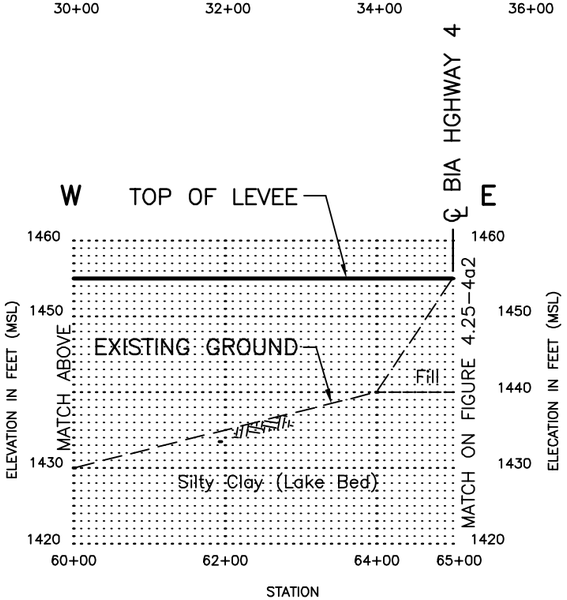




SEGMENT 25A



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

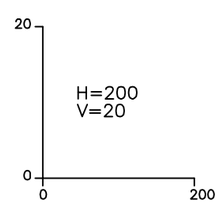


Figure 4.25–4a1

LEVEE PROFILE

FEATURE 25A:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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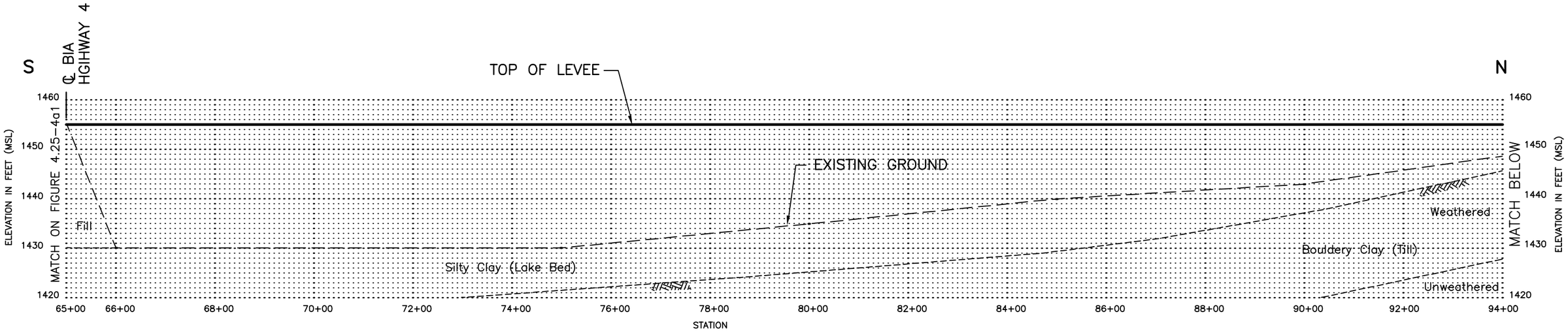
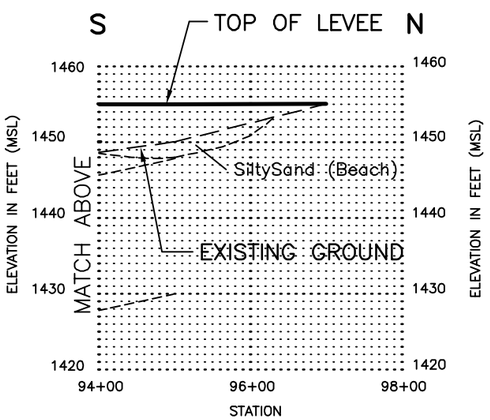


SEGMENT 25A

1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.



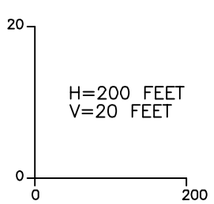


Figure 4.25–4a2

PROFILE

FEATURE 25A:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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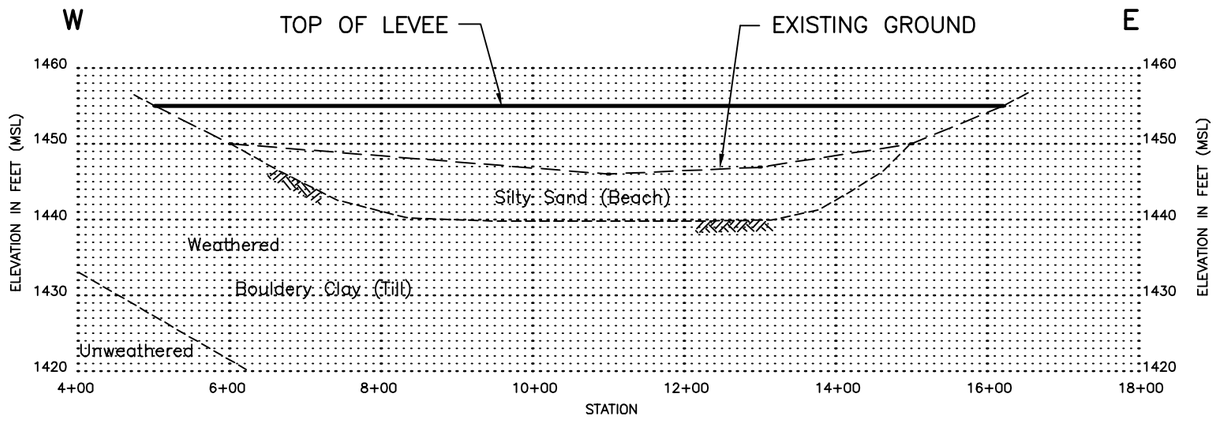
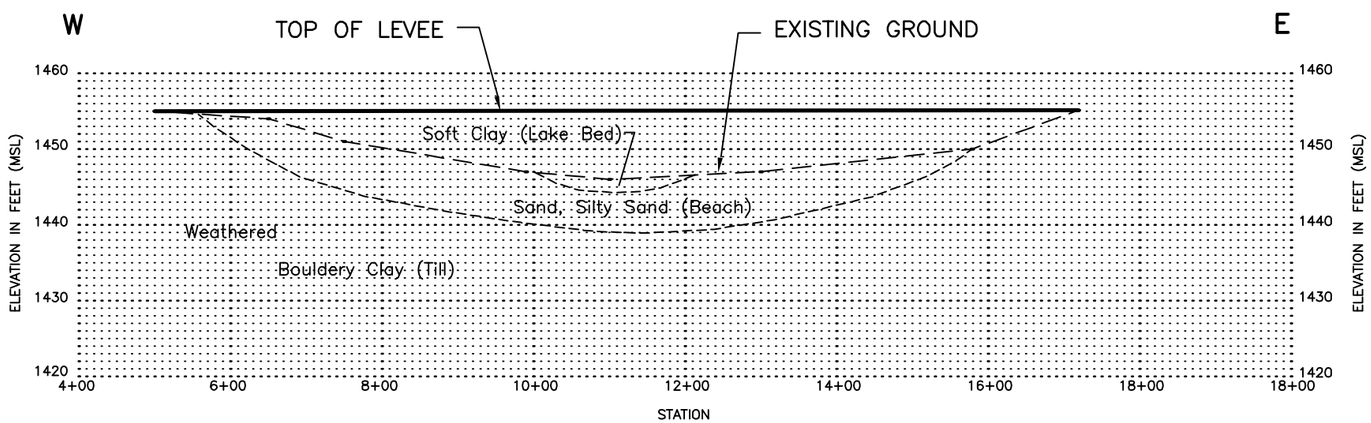
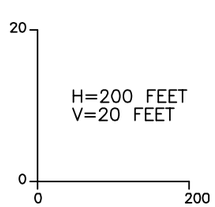


SEGMENT 25B



SEGMENT 25C



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

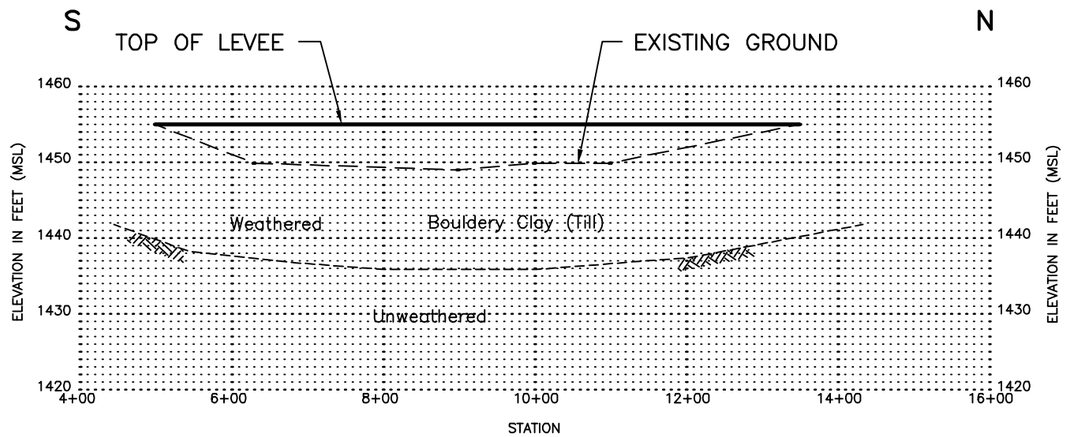
Figure 4.25–4b,c

LEVEE PROFILES

FEATURE 25B and 25C:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

NRD M:\cad\3436020\17170_1.DWG Plot at 200 11/01/2002 14:47:16



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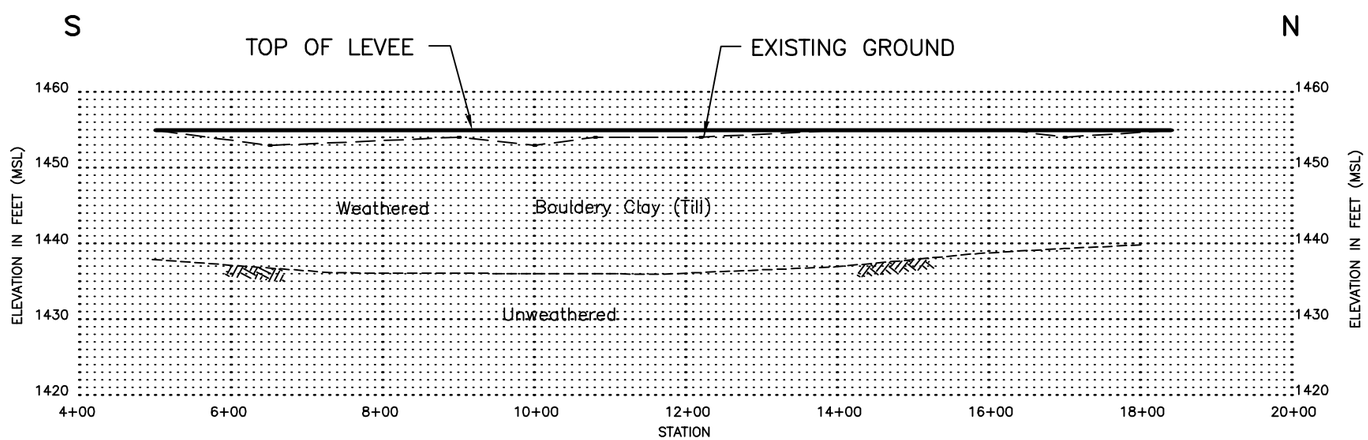

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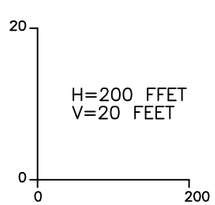

1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

Figure 4.25–4d,e

LEVEE PROFILES

FEATURE 25D and 25E:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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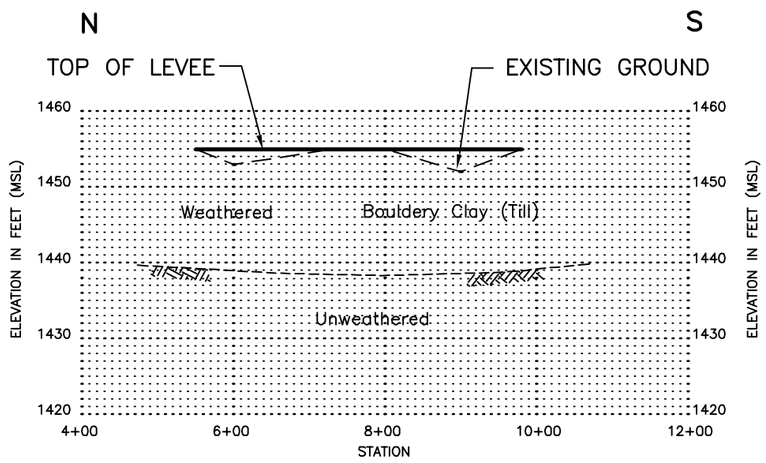

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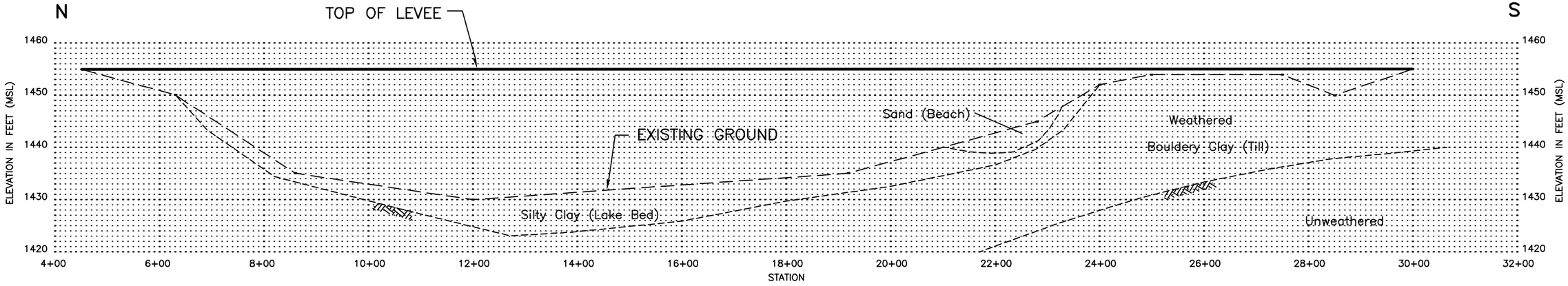
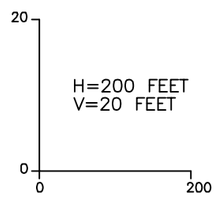


SEGMENT 25G



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

Figure 4.25–4f,g

LEVEE PROFILES

FEATURE 25F and 25G:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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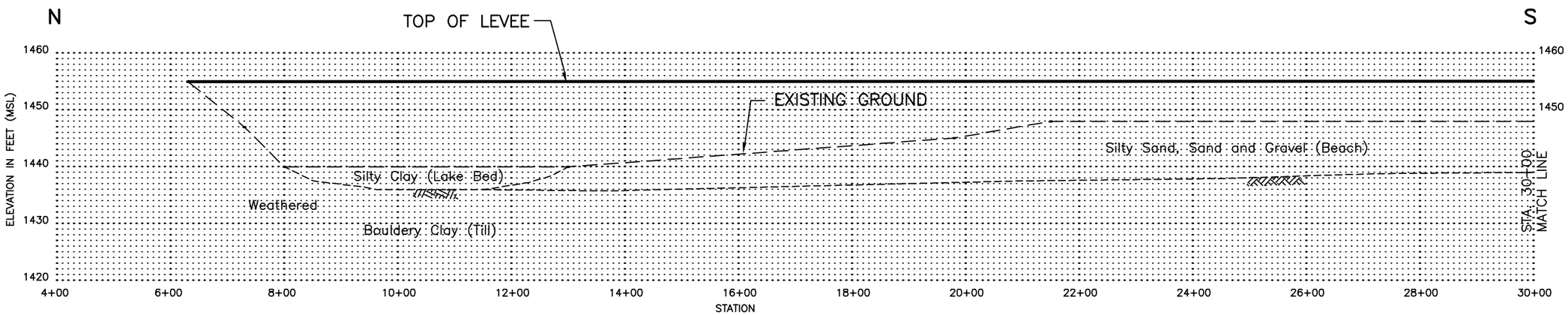
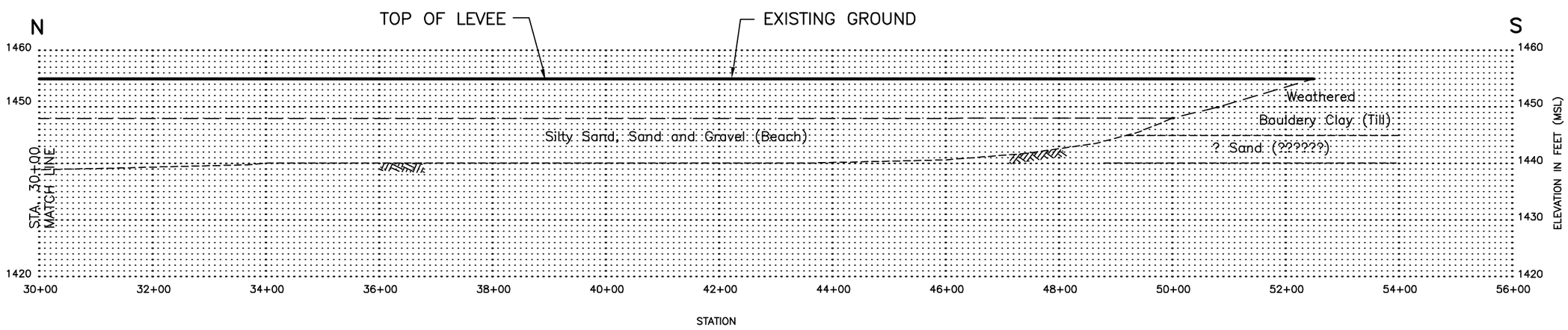
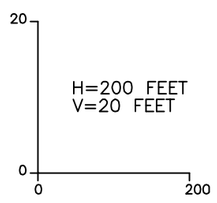




SEGMENT 25H



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

Figure 4.25–4h

LEVEE PROFILE

FEATURE 25H:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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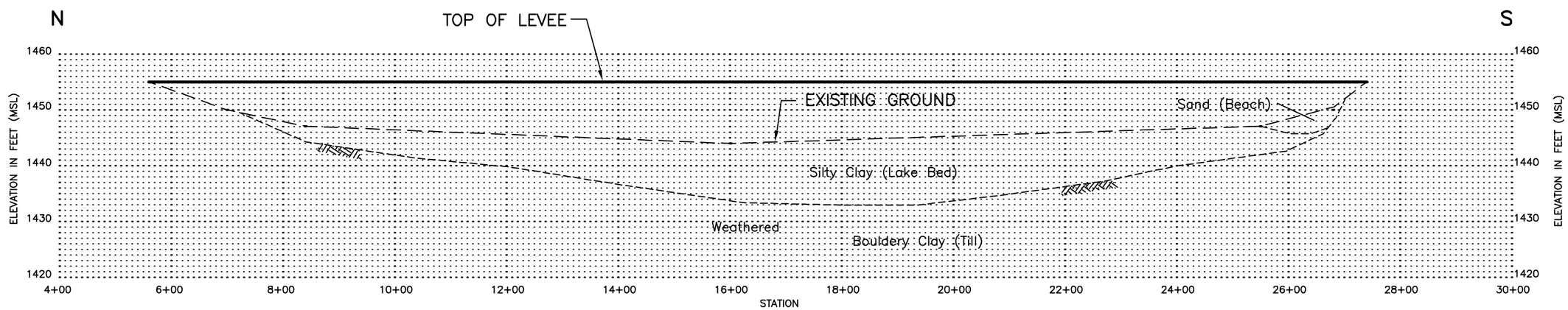
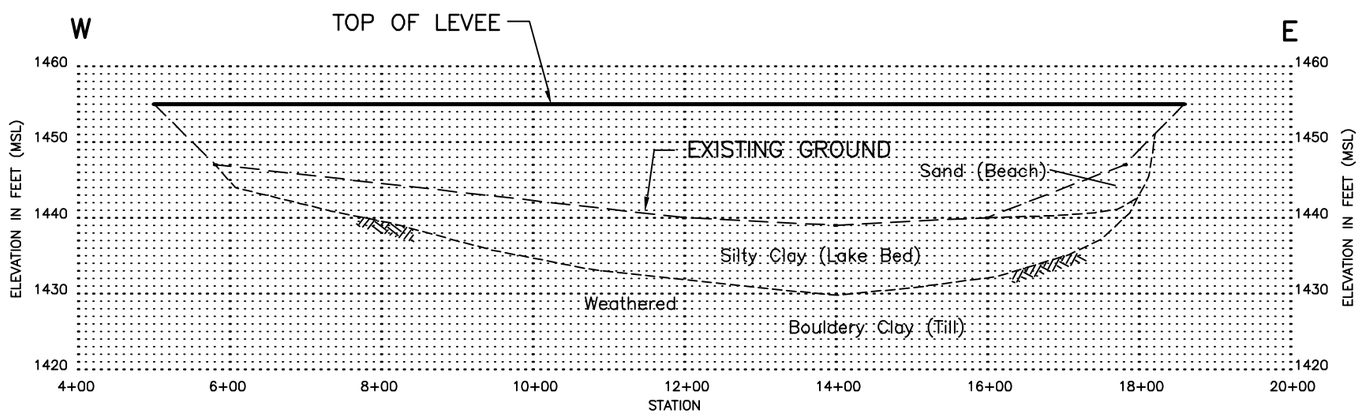
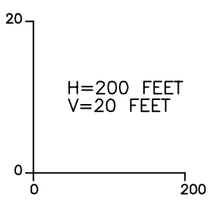


SEGMENT 25I



SEGMENT 25J



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

Figure 4.25–4i,j

LEVEE PROFILES

FEATURE 25I and 25J:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

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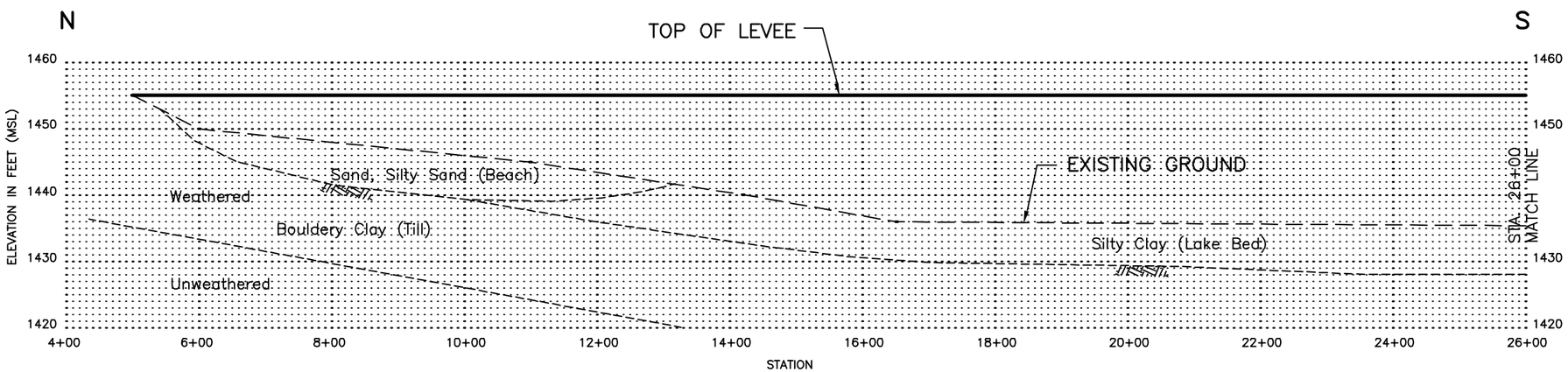
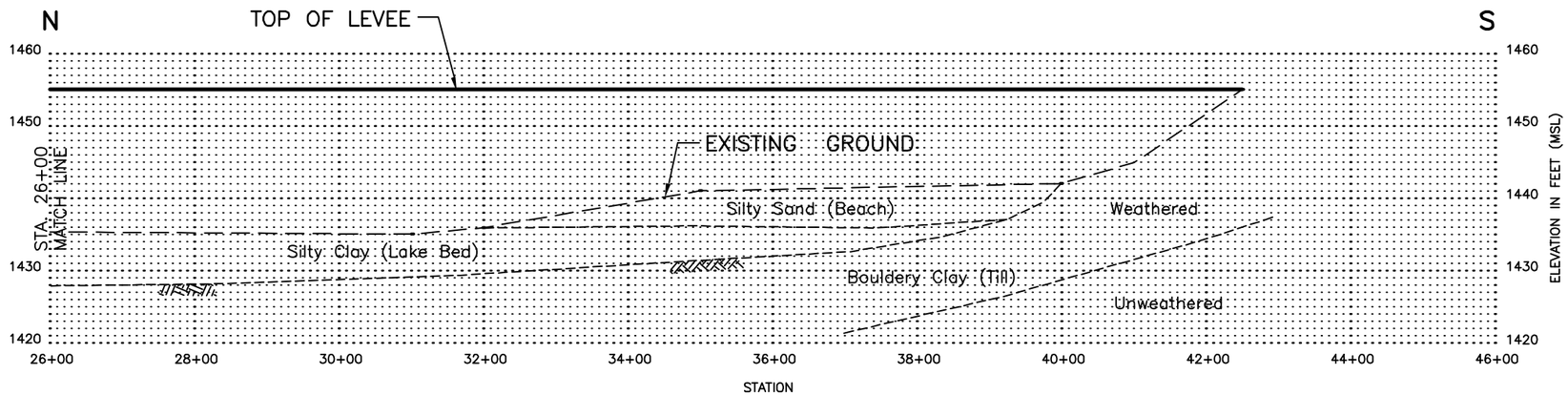
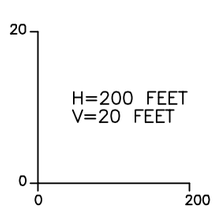




SEGMENT 25K



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

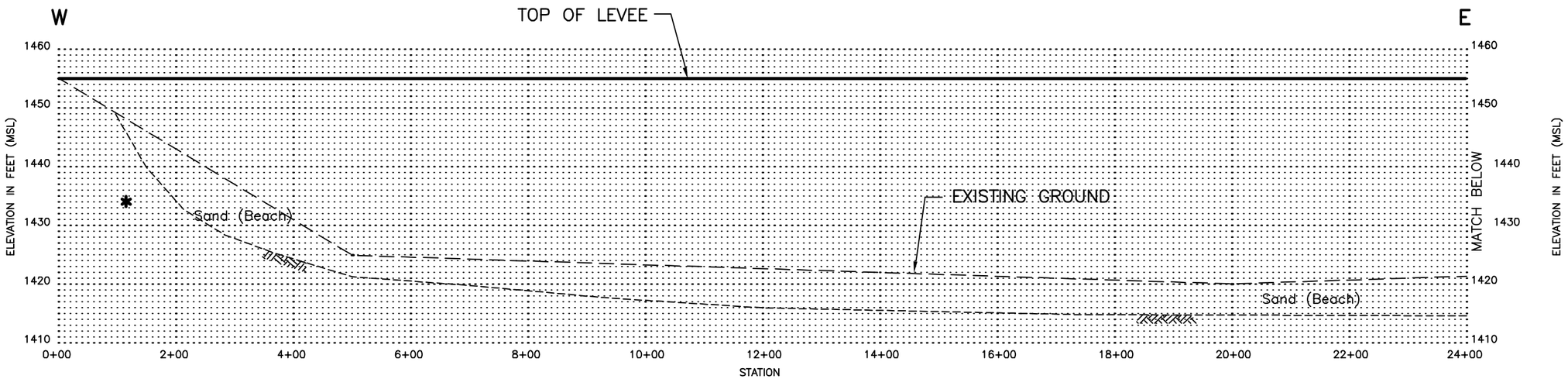
Figure 4.25–4k

LEVEE PROFILE

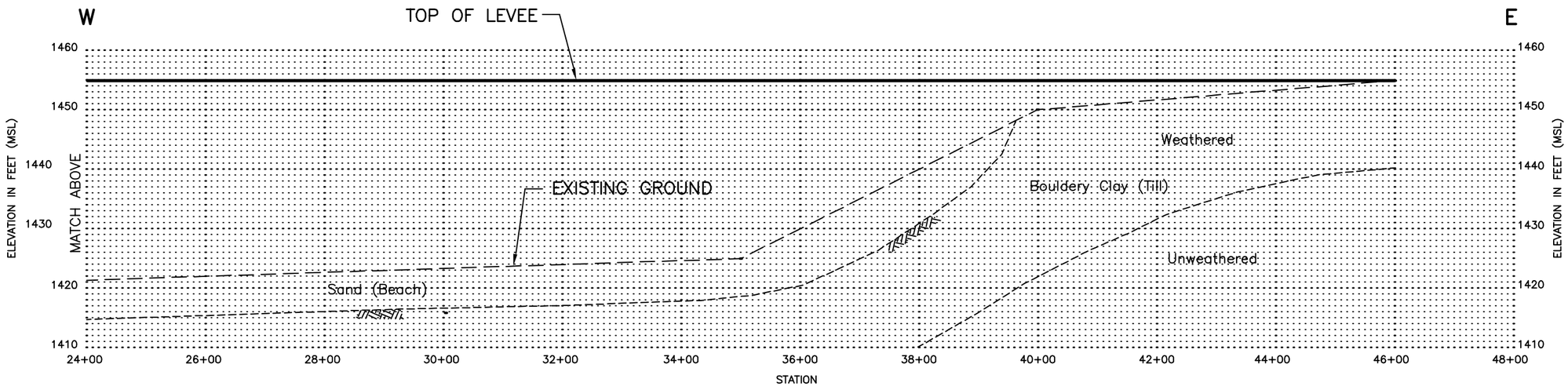
FEATURE 25K:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

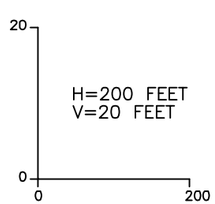
NRD M:\cad\3436020\17175_1.DWG Plot at 200 11/01/2002 14:56:00



✱ EXTENT OF SAND SUGGESTS HIGH LIKELY HEAD OF THE PRESENCE OF A BURIED SAND OUTWASH UNIT.



25L



1. Ground elevations obtained from 2000 FEMA LIDAR topography.
2. Levee crest elevation based on assumed first incremental construction height.
3. Levee segment designation and stationing assigned as part of this analysis with segment designation and stationing generally increasing clockwise.

Figure 4.25–4l

PROFILES

FEATURE 25L:
ROADS ACTING AS DAMS

DEVILS LAKE
INFRASTRUCTURE PROTECTION STUDY

NRD M:\cad\3436020\17240_1.DWG Plot at 200 11/01/2002 15:00:21

Table 4.25-1

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

DAMAGES

Action Level	Structure Elevation Range (MSL)	Mission Township Area: Structures and Infrastructure (THOUSANDS)	Mission Township Area: Land (THOUSANDS)	Acorn Ridge Area: Structures and Infrastructure (THOUSANDS)	Acorn Ridge Area: Land (THOUSANDS)
AL1	Below 1452	$1,876	$620	$793	$60
AL2	1452.5 - 1459.5	$1,703	$906	$1,071	$102
AL3	Above 1459.5	$1,528	$588	$954	$118

Lake Elevation (MSL)	Restoration Damages*: Impacted Roadway Length (FEET)	Restoration Damages*: Damage Value (THOUSANDS)
1449	41,250	$9,205
1450	42,300	$9,327
1451	43,330	$9,446
1452	44,480	$9,579
1453	44,470	$9,578
1454	45,240	$9,667
1455	45,940	$9,748
1456	46,490	$9,812
1457	47,680	$9,950
1458	48,940	$10,096
1459	49,910	$10,208
1460	50,990	$10,333
1461	51,790	$10,426
1462	52,560	$10,515
1463	53,400	$10,612
1464	54,200	$10,705
1465	55,000	$10,797

*Restoration Damages for interior roads: BIA Highways 2, 4, 5, 6, and 9 and one impacted township road

DAMAGE BREAKDOWN

Mission Township Area

Structure Elevation Below 1452.5					Structure Elevation 1452.5 - 1459.5					Structure Elevation Above 1459.5				
Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Structures and Infrastructure					**Structures and Infrastructure**					**Structures and Infrastructure**				
Barn	3	EA	$72,000	$216	Barn	4	EA	$72,000	$288	Barn	1	EA	$72,000	$72
Commercial	1	EA	$63,000	$63	Commercial	0	EA	$63,000	$0	Commercial	0	EA	$63,000	$0
Residence	16	EA	$62,000	$992	Residence	19	EA	$62,000	$1,178	Residence	20	EA	$62,000	$1,240
Shed	14	EA	$43,200	$605	Shed	5	EA	$43,200	$216	Shed	5	EA	$43,200	$216
Silo	0	EA	$20,500	$0	Silo	1	EA	$20,500	$21	Silo	0	EA	$20,500	$0
Total Relocation				**$1,876**	**Total Relocation**				**$1,703**	**Total Relocation**				**$1,528**
Land					**Land**					**Land**				
Land	1,550	AC	$400	$620	Land	2,264	AC	$400	$906	Land	1,470	AC	$400	$588
Total Land				**$620**	**Total Land**				**$906**	**Total Land**				**$588**

Acorn Ridge Area

Structure Elevation Below 1452.5					Structure Elevation 1452.5 - 1459.5					Structure Elevation Above 1459.5				
Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Value (THOUSANDS)
Structures and Infrastructure					**Structures and Infrastructure**					**Structures and Infrastructure**				
Barn	0	EA	$72,000	$0	Barn	0	EA	$72,000	$0	Barn	0	EA	$72,000	$0
Commercial	0	EA	$63,000	$0	Commercial	0	EA	$63,000	$0	Commercial	0	EA	$63,000	$0
Residence	10	EA	$62,000	$620	Residence	11	EA	$62,000	$682	Residence	14	EA	$62,000	$868
Shed	4	EA	$43,200	$173	Shed	9	EA	$43,200	$389	Shed	2	EA	$43,200	$86
Silo	0	EA	$20,500	$0	Silo	0	EA	$20,500	$0	Silo	0	EA	$20,500	$0
Total Relocation				**$793**	**Total Relocation**				**$1,071**	**Total Relocation**				**$954**
Land					**Land**					**Land**				
Land	150	AC	$400	$60	Land	256	AC	$400	$102	Land	295	AC	$400	$118
Total Land				**$60**	**Total Land**				**$102**	**Total Land**				**$118**

Restoration Damages

Item	Description	Quantity per LF of Road		Unit Cost	Contingency	Value per LF of Road
Excavation	Removal of existing bituminous (24' X 0.5'), existing shoulder (3' X 0.5' ea. side), existing aggregate base (41' X 0.5'), and top 1.5' of existing road	4.06	CY/LF	$3.50	30%	$18
Fill Material	Replace top 1.5' of roadway	2.69	CY/LF	$5.00	30%	$17
Geotextile Fabric	Place geotextile beneath new aggregate base	5.00	SY/LF	$2.00	30%	$13
Aggregate Base Course	Replace 0.5' of subgrade and shoulders (3' X 0.5' ea. side)	0.92	CY/LF	$20.00	30%	$24
Bituminous	Replace 0.5' of bituminous pavement	0.66	Tons/LF	$50.00	30%	$43
		Total				**$116**
Item	**Description**	**Quantity per LF of Road**		**Unit Cost**	**Contingency**	**Total Value for Road**
Riprap	Place riprap from road surface elevation to bottom of embankment replacement for lowest impacted	1.89	CY/LF	$40.00	30%	$4,054,050
Geotextile Fabric	For use under riprap restoration	3.5	SY/LF	$2.00	30%	$375,375
		Total				**$4,429,425**

	Impacted Feature	Stochastic Analysis: 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	$35	$0	$35
22	ND Highway 20 (ND Highway 57 to Tok	$0	$498	$498
24	BIA Highway 6	$0	$498	$498
			TOTAL	**$1,031**

	Impacted Feature	Wet Future Scenario Analysis: Annual Costs Avoided	Annual Damages Reduced	TOTAL
5	St. Michael	$35	$0	$35
22	ND Highway 20 (ND Highway 57 to Tok	$0	$147	$147
24	BIA Highway 6	$0	$147	$147
			TOTAL	**$330**

	Impacted Feature	Moderate Future 1: Annual Costs Avoided	Annual Damages Reduced	TOTAL
5	St. Michael	$35	$0	$35
22	ND Highway 20 (ND Highway 57 to Tok	$0	$1,016	$1,016
24	BIA Highway 6	$0	$1,016	$1,016
			TOTAL	**$2,068**

	Impacted Feature	Moderate Future 2: Annual Costs Avoided	Annual Damages Reduced	TOTAL
5	St. Michael	$35	$0	$35
22	ND Highway 20 (ND Highway 57 to Tok	$0	$427	$427
24	BIA Highway 6	$0	$427	$427
			TOTAL	**$890**

Table 4.25-2a

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R (1)	
Action Level	Mission Township Area	Acorn Ridge Area
	(THOUSANDS)	
AL1	$35,674	$3,404

COST BREAKDOWN

Strategy	R(1) Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Levee Construction Mission Township Area	**Levee Construction to Elevation 1455**					
	Performance/Payment Bond	1	JB	$155,670	10%	$171
	Residence Relocation	6	EA	$68,000	30%	$530
	Barn Relocation	2	EA	$72,000	100%	$288
	Shed Relocation	7	EA	$43,200	50%	$454
	Clearing and Grubbing	31.2	AC	$3,000	30%	$122
	Stripping (1')	97,000	CY	$1.50	30%	$189
	Inspection Trench	27,000	LF	$4.00	30%	$140
	Levee Fill	677,000	CY	$5.00	30%	$4,401
	Bedding	60,000	CY	$35	30%	$2,730
	Riprap	90,000	CY	$40	40%	$5,040
	Sand Drain	86,000	CY	$22	30%	$2,460
	Topsoil (4")	15,000	CY	$2.50	30%	$49
	Seed	28.5	AC	$1,000	30%	$37
	Culverts	510	LF	$50	30%	$33
	Cofferdams - Geotextile Fabric	48,000	SY	$2.00	30%	$125
	Cofferdams - Fill	301,000	CY	$5.00	30%	$1,957
	Cofferdams - Excavation	301,000	CY	$3.50	30%	$1,370
	Cofferdams - Riprap	20,000	CY	$40	40%	$1,120
	Interior Drainage					
	Culverts	1,700	LF	$50	50%	$128
	Channel	0	LF	$12	50%	$0
	Pump Station	1	EA	$1,800,000	30%	$2,340
	Geotechnical					
	Slurry Wall	195,000	SF	$6.00	50%	$1,755
	Borings	37	EA	$1,000	50%	$56
	Excavation of Unsuitable Material	28,900	CY	$8.50	50%	$368
	Environmental Impacts					
	Mitigation	1	LS			$2,651
	HTRW	1	LS			$81
	Cultural Resources Investigation	1	LS			$62
	Mission Township Area Levee Subtotal					$28,655
	Engineering and Design		15%			$4,298
	Supervision and Administration		8%			$2,292
	Real Estate Acquisition for ROW	1	LS			$428
	Total Mission Township Area Levee Cost					**$35,674**
Levee Construction Acorn Ridge Area	**Levee Construction to Elevation 1455**					
	Performance/Payment Bond	1	JB	$16,252	10%	$18
	Shed Relocation	1	EA	$43,200	50%	$65
	Clearing and Grubbing	0.9	AC	$3,000	30%	$4
	Stripping (1')	10,000	CY	$1.50	30%	$20
	Inspection Trench	2,600	LF	$4.00	30%	$14
	Levee Fill	85,000	CY	$5.00	30%	$553
	Bedding	5,700	CY	$35	30%	$259
	Riprap	8,500	CY	$40	40%	$476
	Sand Drain	11,000	CY	$22	30%	$315
	Topsoil (4")	1,900	CY	$2.50	30%	$6
	Seed	3.5	AC	$1,000	30%	$5
	Culverts	100	LF	$50	30%	$7
	Cofferdams - Geotextile Fabric	4,000	SY	$2.00	30%	$10
	Cofferdams - Fill	22,000	CY	$5.00	30%	$143
	Cofferdams - Excavation	22,000	CY	$3.50	30%	$100
	Cofferdams - Riprap	2,000	CY	$40	40%	$112
	Interior Drainage					
	Culverts	0	LF	$50	50%	$0
	Channel	0	LF	$12	50%	$0
	Pump Station	1	EA	$200,000	50%	$300
	Geotechnical					
	Slurry Wall	28,000	SF	$6.00	50%	$252
	Borings	6	EA	$1,000	50%	$9
	Excavation of Unsuitable Material	5,000	CY	$8.50	50%	$64
	Acorn Ridge Area Subtotal					$2,729
	Engineering and Design		15%			$409
	Supervision and Administration		8%			$218
	Real Estate Acquisition for ROW	1	LS			$48
	Total Acorn Ridge Area Levee Cost					**$3,404**

ANNUAL OPERATION AND MAINTENANCE COSTS

Levee Area	Levee Maintenance	Pump O&M	Total Operation and Maintenance Cost
	(THOUSANDS)		
AL1-Mission Twnshp	$152	$40	$192
AL1-Acorn Ridge	$17	$5	$22

Table 4.25-2b

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

STRATEGY COSTS BY ACTION LEVEL

Strategy:	R (2)		R (3)	
Action Level	Mission Township Area	Acorn Ridge Area	Mission Township Area	Acorn Ridge Area
	(THOUSANDS)			
AL2	$25,206	$6,072	$0	$0
AL3	$0	$0	$26,629	$5,733

COST BREAKDOWN

	R(2)						R(3)					
Strategy	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)	Description	Quantity	Units	Unit Cost	Contingency	Value (THOUSANDS)
Levee Construction	**Levee Construction to Elevation 1462**						**Levee Construction to Elevation 1468**					
Mission	Performance/Payment Bond	1	JB	$118,577	10%	$130	Performance/Payment Bond	1	JB	$131,119	10%	$144
Township	Clearing and Grubbing	50.5	AC	$3,000	30%	$197	Clearing and Grubbing	48.3	AC	$3,000	30%	$188
Area	Stripping (1')	81,500	CY	$1.50	30%	$159	Stripping (1')	78,000	CY	$1.50	30%	$152
	Inspection Trench	9,550	LF	$4.00	30%	$50	Inspection Trench	3,190	LF	$4.00	30%	$17
	Levee Fill	872,000	CY	$5.00	30%	$5,668	Levee Fill	1,196,000	CY	$5.00	30%	$7,774
	Bedding	43,000	CY	$35	30%	$1,957	Bedding	41,000	CY	$35	30%	$1,866
	Riprap	77,000	CY	$40	40%	$4,312	Riprap	75,000	CY	$40	40%	$4,200
	Sand Drain	156,000	CY	$22	30%	$4,462	Sand Drain	152,000	CY	$22	30%	$4,347
	Topsoil (4")	24,000	CY	$2.50	30%	$78	Topsoil (4")	33,000	CY	$2.50	30%	$107
	Seed	44.6	AC	$1,000	30%	$58	Seed	61.7	AC	$1,000	30%	$80
	Culverts	0	LF	$50	30%	$0	Culverts	0	LF	$50	30%	$0
	Cofferdams - Geotextile Fabric	0	SY	$2.00	30%	$0	Cofferdams - Geotextile Fabric	0	SY	$2.00	30%	$0
	Cofferdams - Fill	0	CY	$5.00	30%	$0	Cofferdams - Fill	0	CY	$5.00	30%	$0
	Cofferdams - Excavation	0	CY	$3.50	30%	$0	Cofferdams - Excavation	0	CY	$3.50	30%	$0
	Cofferdams - Riprap	0	CY	$40	40%	$0	Cofferdams - Riprap	0	CY	$40	40%	$0
	Interior Drainage						**Interior Drainage**					
	Culverts	0	LF	$50	50%	$0	Culverts	0	LF	$50	50%	$0
	Channel	0	LF	$12	50%	$0	Channel	0	LF	$12	50%	$0
	Pump Station	0	EA	$1,800,000	30%	$0	Pump Station	0	EA	$1,800,000	30%	$0
	Geotechnical						**Geotechnical**					
	Slurry Wall	70,000	SF	$6.00	50%	$630	Slurry Wall	23,200	SF	$6.00	50%	$209
	Borings	13	EA	$1,000	50%	$20	Borings	4	EA	$1,000	50%	$7
	Excavation of Unsuitable Material	10,400	CY	$8.50	50%	$133	Excavation of Unsuitable Material	3,400	CY	$8.50	50%	$43
	Environmental Impacts						**Environmental Impacts**					
	Mitigation	1	LS			$2,227	Mitigation	1	LS			$2,121
	HTRW	1	LS			$68	HTRW	1	LS			$65
	Cultural Resources Investigation	1	LS			$52	Cultural Resources Investigation	1	LS			$50
	Mission Township Area Levee Subtotal					$20,200	Mission Township Area Levee Subtotal					$21,371
	Engineering and Design		15%			$3,030	Engineering and Design		15%			$3,206
	Supervision and Administration		8%			$1,616	Supervision and Administration		8%			$1,710
	Real Estate Acquisition for ROW	1	LS			$360	Real Estate Acquisition for ROW	1	LS			$343
	Total Mission Township Area Levee Cost					**$25,206**	**Total Mission Township Area Levee Cost**					**$26,629**
Levee Construction	**Levee Construction to Elevation 1462**						**Levee Construction to Elevation 1468**					
Acorn	Performance/Payment Bond	1	JB	$28,402	10%	$31	Performance/Payment Bond	1	JB	$30,805	10%	$34
Ridge Area	Clearing and Grubbing	12.5	AC	$3,000	30%	$49	Clearing and Grubbing	12.1	AC	$3,000	30%	$47
	Stripping (1')	20,000	CY	$1.50	30%	$39	Stripping (1')	19,500	CY	$1.50	30%	$38
	Inspection Trench	6,180	LF	$4.00	30%	$32	Inspection Trench	1,230	LF	$4.00	30%	$6
	Levee Fill	176,000	CY	$5.00	30%	$1,144	Levee Fill	262,000	CY	$5.00	30%	$1,703
	Bedding	11,000	CY	$35	30%	$501	Bedding	10,000	CY	$35	30%	$455
	Riprap	20,000	CY	$40	40%	$1,120	Riprap	18,500	CY	$40	40%	$1,036
	Sand Drain	40,000	CY	$22	30%	$1,144	Sand Drain	37,500	CY	$22	30%	$1,073
	Topsoil (4")	5,000	CY	$2.50	30%	$16	Topsoil (4")	7,500	CY	$2.50	30%	$24
	Seed	9.8	AC	$1,000	30%	$13	Seed	14	AC	$1,000	30%	$18
	Culverts	0	LF	$50	30%	$0	Culverts	0	LF	$50	30%	$0
	Cofferdams - Geotextile Fabric	0	SY	$2.00	30%	$0	Cofferdams - Geotextile Fabric	0	SY	$2.00	30%	$0
	Cofferdams - Fill	0	CY	$5.00	30%	$0	Cofferdams - Fill	0	CY	$5.00	30%	$0
	Cofferdams - Excavation	0	CY	$3.50	30%	$0	Cofferdams - Excavation	0	CY	$3.50	30%	$0
	Cofferdams - Riprap	0	CY	$40	40%	$0	Cofferdams - Riprap	0	CY	$40	40%	$0
	Interior Drainage						**Interior Drainage**					
	Culverts	0	LF	$50	50%	$0	Culverts	0	LF	$50	50%	$0
	Channel	0	LF	$12	50%	$0	Channel	0	LF	$12	50%	$0
	Pump Station	0	EA	$200,000	50%	$0	Pump Station	0	EA	$200,000	50%	$0
	Geotechnical						**Geotechnical**					
	Slurry Wall	66,600	SF	$6.00	50%	$599	Slurry Wall	13,200	SF	$6.00	50%	$119
	Borings	14	EA	$1,000	50%	$21	Borings	3	EA	$1,000	50%	$4
	Excavation of Unsuitable Material	11,900	CY	$8.50	50%	$152	Excavation of Unsuitable Material	2,400	CY	$8.50	50%	$31
	Acorn Ridge Area Subtotal					$4,861	Acorn Ridge Area Subtotal					$4,588
	Engineering and Design		15%			$729	Engineering and Design		15%			$688
	Supervision and Administration		8%			$389	Supervision and Administration		8%			$367
	Real Estate Acquisition for ROW	1	LS			$92	Real Estate Acquisition for ROW	1	LS			$89
	Total Acorn Ridge Area Levee Cost					**$6,072**	**Total Acorn Ridge Area Levee Cost**					**$5,733**

ANNUAL OPERATION AND MAINTENANCE COSTS

Levee Area	Levee Maintenance	Pump O&M	Total Operation and Maintenance Cost
	(THOUSANDS)		
AL2-Mission Twnshp	$169	$40	$209
AL2-Acorn Ridge	$41	$5	$46
AL3-Mission Twnshp	$187	$40	$227
AL3-Acorn Ridge	$44	$5	$49

Table 4.25.1 - 3a

Economics Results: All Action Levels -- to Lake Level 1463
Feature 25.1: Roads Acting as Dams (Acorn Ridge Area)
Devils Lake Infrastructure Protection Study

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

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	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	$0	$0	$0	$0	$64,700	$64,700	$0	$0	--
L(3)	3 Levee Raise	$496,700	$36,500	$0	$533,200	$0	$0	$64,700	-$468,500	0.12

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
		Levee Raise	O&M	Relocation	Total	Damages	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
No Protection	No Protection	$0	$0	$0	$0	$51,900	$51,900	$0	$0	--
L(3)	3 Levee Raise	$207,100	$38,200	$0	$245,200	$0	$0	$51,900	-$193,400	0.21

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

Strategy		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	$0	$0	$0	$0	$51,900	$51,900	$0	$0	--
L(3)	3 Levee Raise	$377,600	$30,300	$0	$408,000	$0	$0	$51,900	-$356,100	0.13

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

Strategy		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	$0	$0	$0	$0	$86,800	$86,800	$0	$0	--
L(3)	3 Levee Raise	$555,100	$41,800	$0	$596,900	$0	$0	$86,800	-$510,000	0.15

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
*Total benefits are calculated as the total damages incurred for the "No Protection" strategy minus the total damages for the strategy implemented (F(S)).

Table 4.25.1 - 3b

Economics Results: First Action Level
Feature 25.1: Roads Acting as Dams (Acorn Ridge Area)
Devils Lake Infrastructure Protection Study

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

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	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	$0	$0	$0	$0	$51,700	$51,700	$0	$0	--
L(1)	1 Levee Raise	$206,300	$17,600	$0	$224,000	$0	$0	$51,700	-$172,300	0.23

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
		Levee Raise	O&M	Relocation	Total	Damages	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
No Protection	No Protection	$0	$0	$0	$0	$51,900	$51,900	$0	$0	--
L(1)	1 Levee Raise	$207,100	$5,600	$0	$212,700	$0	$0	$51,900	-$160,800	0.24

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

Strategy		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	$0	$0	$0	$0	$51,900	$51,900	$0	$0	--
L(1)	1 Levee Raise	$207,100	$20,700	$0	$227,700	$0	$0	$51,900	-$175,800	0.23

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

Strategy		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	$0	$0	$0	$0	$51,900	$51,900	$0	$0	--
L(1)	1 Levee Raise	$207,100	$11,200	$0	$218,200	$0	$0	$51,900	-$166,300	0.24

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for the "No Protection" strategy minus the total damages for the strategy implemented (F(S)).

Table 4.25.2 - 3a

Economics Results: All Action Levels -- to Lake Level 1463
Feature 25.2: Roads Acting as Dams (Mission Township Area)
Devils Lake Infrastructure Protection Study

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

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	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	$0	$0	$0	$0	$2,165,300	$2,165,300	$0	$0	--
L(3)	3 Levee Raise	$3,383,300	$192,200	$0	$3,575,500	$0	$0	$2,165,300	-$1,410,200	0.61

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
		Levee Raise	O&M	Relocation	Total	Damages	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
No Protection	No Protection	$0	$0	$0	$0	$2,202,700	$2,202,700	$0	$0	--
L(3)	3 Levee Raise	$2,170,000	$198,800	$0	$2,368,800	$0	$0	$2,202,700	-$166,100	0.93

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

Strategy		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	$0	$0	$0	$0	$1,273,400	$1,273,400	$0	$0	--
L(3)	3 Levee Raise	$2,877,900	$187,200	$0	$3,065,100	$0	$0	$1,273,400	-$1,791,700	0.42

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

Strategy		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	$0	$0	$0	$0	$1,843,900	$1,843,900	$0	$0	--
L(3)	3 Levee Raise	$3,614,800	$195,300	$0	$3,810,100	$0	$0	$1,843,900	-$1,966,200	0.48

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
*Total benefits are calculated as the total damages incurred for the "No Protection" strategy minus the total damages for the strategy implemented (F(S)).

Table 4.25.2 - 3b

Economics Results: First Action Level
Feature 25.2: Roads Acting as Dams (Mission Township Area)
Devils Lake Infrastructure Protection Study

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

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
Designation	Description	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	$0	$0	$0	$0	$1,269,100	$1,269,100	$0	$0	--
L(1)	1 Levee Raise	$2,162,500	$154,100	$0	$2,316,600	$0	$0	$1,269,100	-$1,047,500	0.55

Wet Future Scenario (WF-9)
(Annual)

Strategy		COSTS				DAMAGES		Total Benefits	Net Benefits	Benefit- Cost Ratio
		Levee Raise	O&M	Relocation	Total	Damages	Total	To Strategy (Damages Prevented)	To Strategy	(BCR)
No Protection	No Protection	$0	$0	$0	$0	$1,273,400	$1,273,400	$0	$0	--
L(1)	1 Levee Raise	$2,170,000	$49,100	$0	$2,219,100	$0	$0	$1,273,400	-$945,700	0.57

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

Strategy		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	$0	$0	$0	$0	$1,273,400	$1,273,400	$0	$0	--
L(1)	1 Levee Raise	$2,170,000	$180,300	$0	$2,350,300	$0	$0	$1,273,400	-$1,076,900	0.54

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

Strategy		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	$0	$0	$0	$0	$1,273,400	$1,273,400	$0	$0	--
L(1)	1 Levee Raise	$2,170,000	$97,200	$0	$2,267,200	$0	$0	$1,273,400	-$993,800	0.56

All dollar values are present worth values annualized over a 50-year period at an interest rate of 6.125% and rounded to the nearest $100.
* Total benefits are calculated as the total damages incurred for the "No Protection" strategy minus the total damages for the strategy implemented (F(S)).

Attachment to 4.25:
Roads Acting as Dams Infrastructure Protection Study Assumptions

A. General Assumptions

1. Levee alignments based on alignments presented in the following studies:

   - Devils Lake Spirit Nation Reservation Alternatives Assessment, prepared for the U.S. Army Corps of Engineers, St. Paul District by Barr Engineering Company, October 1997
   - Alternatives Analysis, Alternative 3, completed by U.S. Army Corps of Engineers, St. Paul District, March 2000

2. Decisions and calculations were dependent on the selected strategy for each feature involved with Roads Acting as Dams.

3. Structure elevation and land elevation data was obtained from the 2000 FEMA LIDAR topography.

4. All roads currently acting as dams are equalized for safety reasons.

B. Levees

1. Levee cross-section was based on levees sections previously built in Devils Lake.

2. Levees constructed parallel to existing highway embankments were assumed to have steeper lake side slopes because of their being constructed immediately adjacent to substantial roadway embankments.

3. For levee protection, it was assumed that 4 feet of freeboard would be required for all of the. The assumed freeboard was based on calculated wave heights for this area plus one foot.

4. Sand drains were assumed to be included for all levees with a height of 9 feet or greater

5. It was assumed that the impervious fill materials for levees would come from nearby clay borrow areas.

6. Although it was recognized that special handling, placement and compaction methods would be required for construction of impervious core, it was assumed that the unit price for impervious core would be similar to levee fill. Impervious core was included in the levee fill quantity.

7. The annual maintenance cost for the levees was assumed to be 1% of the construction costs.

C. Residential and Commercial Properties

1. For relocation strategies, structures are relocated when the lake level reached one foot below the ground elevation at each structure.

2. A GIS database of structures was provided by FEMA and was used to inventory rural structures. This data included building descriptions, elevations, and for most of the structures, estimates of structure values. Rural structures were sorted using GIS tools to drop those structures that fall within the analytical boundaries of communities included in the affected area, mainly St. Michael and Fort Grafton. From this inventory of rural structures, the data was further sorted by building type and elevation range. Spirit Lake Nation reservation boundaries were also used to discern on-reservation v. off-reservation houses.

3. Average values for houses were obtained from FEMA values provided in 2001. The average value of rural houses located in the Acorn Ridge area was $88,000. The average value for rural houses located on the Spirit Lake Nation Reservation (the Mission Township and Highway 57/1 areas) was $62,000. These figures were obtained from the Federal Emergency Management Agency (FEMA). The average values for off-reservation and on-reservation houses were based upon 1,219 and 88 houses, respectively. The value for each house was determined for FEMA by certified flood insurance adjusters and was based on total habitable square footage of the buildings and standardized real estate appraisals. These values did not include the value of land on which the houses were located. FEMA has been using these average values for planning purposes only (FEMA, March, 2001). Contingency for houses was assumed to be 30 percent, to reflect the large database of costs, and therefore the relative certainty in quantity and unit price.

4. Relocation cost for a house was estimated to be $68,000. This cost was obtained from the North Dakota-North Central Planning Council and represents the average cost to relocate a residence during the buyout program conducted in Churchs Ferry (2000). The $68,000 includes the following costs: demolition of the existing house, purchase of an equivalent house in a nearby community, purchase of a lot, and legal, appraisal, and management fees. It was assumed relocation costs would be approximately the same in Fort Totten as they were in Churchs Ferry.

5. The FEMA database did not provide an adequate data set of values for barns, sheds, or silos. The FEMA database did include estimated values for three barn structures, ranging from $100,000 to $200,000. Limited market research resulted in estimated costs for pre-fabricated metal structures at between $10 and $30 per square foot. At $30 per square foot, a 30-foot by 80-foot pole barn would result in $72,000 value. This was used as the assumed value for a barn. Sheds were assumed to be 24 feet by 60 feet, resulting in an assumed value of $43,200. Values for silos were developed by using data provided by the North Dakota State Water Commission (Michael Hove, 10/11/2002 phone call and follow-up data). While not comprehensive, this data provided a reasonable data set for silos included in the FEMA inventory, matched a subset of these with field observation, and placed values to each of these structures based on field dimensions and estimated structure cost per bushel storage. This analysis resulted in an average value of $20,453, and was used as the estimated average value for

silos. Based on the uncertainty in the database counts for these structures, and the unit prices assumed, the contingency for these structures was assumed to be 100 percent.

D. Land

1. Land value in rural areas was assumed to be $400/acre. This value was provided by the Corps of Engineers (personal communication, April, 2001) and is an estimate of the average value of all land surrounding Devils Lake.

2. Land damaged is land that is inundated or not accessible without levee construction minus the land needed for ponding areas after levee construction.

3. Land area was interpolated from 1451-1454 and 1456 to 1463.

E. Existing Road and Levee Information

1. Existing road information for the existing roads were obtained through contact with:

   - Spirit Lake Nation representatives, primarily Clarence Greene
   - ND DOT representatives, primarily Brad Darr
   - COE representatives, primarily Lowell Hansen

2. Existing road cross-section for the feature were based on construction drawing typical sections obtained from BIA/ND DOT/or their consultants including:

   - ND DOT Plan: Project No. SS-3-020(055)088, 5/25/99, Sheet 6 of 18
   - BIA Spirit Lake Sioux Nation Plan: Mission Bay Road Project No. 1-10(5), Route 1, 11/22/99. Sheet 3 of 16
   - Kadrmas, Lee and Jackson: Project No. ERFO Road Repair Project – BIA #6, 7/27/01, Sheet 7 of 27

3. Existing road centerline profiles for the features evaluated were obtained from the plans listed above. Plan elevation data was assessed for reasonableness by comparing to the 2000 FEMA LIDAR topography. Where necessary road plan elevation information was supplemented with the LIDAR information.

F. Roads

1. BIA Highway 4 and BIA Highway 5 are abandoned when the lake level or wave height makes them impassible.

2. BIA Highway 4, BIA Highway 2, BIA Highway 6, and 38th Street and 42nd Street are raised so ponding occurs and the roads are protected.

F. Road Restoration

1. For damage calculations it was assumed that if the feature were temporarily closed, it would be restored after the lake level has receded to the minimum road surface elevation less the assumed wave runup (the "Lake Damage Elevation").

2. Restoration damages were calculated assuming that the bituminous surfacing, shoulder and aggregate subgrade would be removed along with an additional 1.5 feet of embankment material. Those materials would then be replaced in kind over a geotextile. It was assumed riprap would be placed on the lake side slope over geotextile from the road surface elevation to the bottom of the embankment replacement. The riprap would be placed along the length of roadway lying below the receded lake damage elevation. The receded lake damage elevation is defined as the receded lake elevation plus the calculated wind-induced wave height.

G. Geotechnical Information

1. The scope and cost of geotechnical mitigation are related to three issues: (1) number of borings and soil tests, (2) soft soils that may require excavation and/or additional construction material, and (3) sand deposits which may require excavation or other mitigation such as cut-off walls if such occurs in the alignments of levees.

2. While the county soil surveys have similar descriptions of the subgrade characteristics of glacial till and lake bed deposits (Severe: low strength), experience in the Devils Lake area has indicated that most till deposits are better subgrade than lake. The potential thickness of soft-soil deposits has been estimated based on descriptions of the lake bed deposits in the geologic and soils reports.

3. The potential extents of sand deposits have been estimated based on descriptions in the soils reports. It is likely that in some locations, the surficial sand deposits, typically assumed herein to beach deposits, may be continuous with subsurface sand and gravel deposits (glacial outwash). As such, some of the sand deposits may be of much greater extent vertically and laterally (buried) than has been assumed herein. The feature most at-risk to extensive buried sand deposits is feature #25 Roads-As-Dams, followed by feature #4 City of Minnewaukan.

4. It is assumed that a soil boring will be completed approximately every 1,000 feet. Additional borings will be completed in areas of critical soils. Each soil boring and associated observation and testing will cost $2,000.

5. Cut off walls are estimated to be $6/square foot based on past work at Devils Lake.

6. In instances where construction may be completed in the wet, it is assumed that soft soil will not be excavated, but instead may be displaced by new fill. In those instances, additional fill contingency is added based on the percentage of the feature alignment that is underlain by potentially soft soil – for 50 percent of the alignment, the contingency is increased by 10 percent, and thereafter the amount is pro-rated.

7. The subgrade conditions along the alignment of this feature's levees are based upon review of:

   - Carlson, C.G. and T.F. Freers, 1975. Geology of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey, Bulletin 59 – Part 1 (also North Dakota State Water Commission County Groundwater Studies 18 – Part 1)
   - Randich, P.G., 1971. Groundwater Basic Data of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey Bulletin 59 – Part II (also North Dakota State Water Commission County Groundwater Studies 18 – Part II)
   - Randich, P.G., 1977. Groundwater Resources of Benson and Pierce Counties, North Dakota. North Dakota Geological Survey Bulletin 59 – Part III (also North Dakota State Water Commission County Groundwater Studies 18 – Part III)
   - USDA Soil Conservation Service, 1977, Soil Survey of Benson County Area, North Dakota
   - Hobbs, Howard C. and J.P. Bluemle, 1987. Geology of Ramsey County, North Dakota. North Dakota Geological Survey Bulletin 71 – Part I (also North Dakota State Water Commission County Groundwater Studies 26 – Part I)
   - Hutchinson, R.D., 1977. Groundwater Basic Data for Ramsey County, North Dakota. North Dakota Geological Survey Bulletin 71 – Part II (also North Dakota State Water Commission County Groundwater Studies 26 – Part II)
   - Hutchinson, R.D. and Robert L. Klausing, 1980. Groundwater Resources of Ramsey County, North Dakota. North Dakota Geological Survey Bulletin 71 – Part III (also North Dakota State Water Commission County Groundwater Studies 26 – Part III)
   - USDA Soil Conservation Service, 1986, Soil Survey of Ramsey County, North Dakota. Hardcopy and electronically from http://nasis.nrcs.usda.gov/

H. Geotechnical - Borrow Sites

1. Use of tilled agricultural land avoids impacts to natural resources but a Phase I cultural resources survey will still be required to determine if any cultural resources are present in the area.

2. Based on the soil county surveys, there is abundant source material (clay till) available for impervious core and impervious fill.

3. It is assumed that the investigation and testing of a new or expanded borrow site can be done for $5,000.