Lake of the Woods County Bostick Creek Flooding and Sediment Source Investigation and Sediment Reduction Study

June 2005

Prepared by:

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1.0 Introduction

HDR Engineering, Inc. (HDR) has completed a study for the portion of Lake of the Woods County included in the Bostick Creek drainage area and presents the following report summarizing the results. The area studied is northwest of Baudette and is primarily in portions of McDougald, Wheeler, and Wabanica Townships (Figures 1 and 2).

Bostick Creek and its tributaries have been a source of localized erosion, sediment deposition, and flooding problems for many years. Specifically, Judicial Ditch 28 (JD 28), which essentially connects Canfield Creek to Bostick Creek and drains through the degraded Graceton Bog, has been prone to high flows and channel instability. In turn, Bostick Creek itself is known to threaten downstream homes and roads with high flows. Finally, Bostick Bay on Lake of the Woods, which functions as the outlet for Bostick Creek, has been slowly filling in with sediment and vegetation making navigation increasingly difficult (Figures 3, 4, and 5).

The Lake of the Woods County Board requested an assessment of flooding and unstable ditches and natural watercourses, the erosion of which may be leading to navigational problems in Bostick Bay. It was with the above general problem statement that HDR developed a scope of work for the study that included the following:

- Problem Definition
- Identification of Study Parameters
- Investigation
- Recommendations

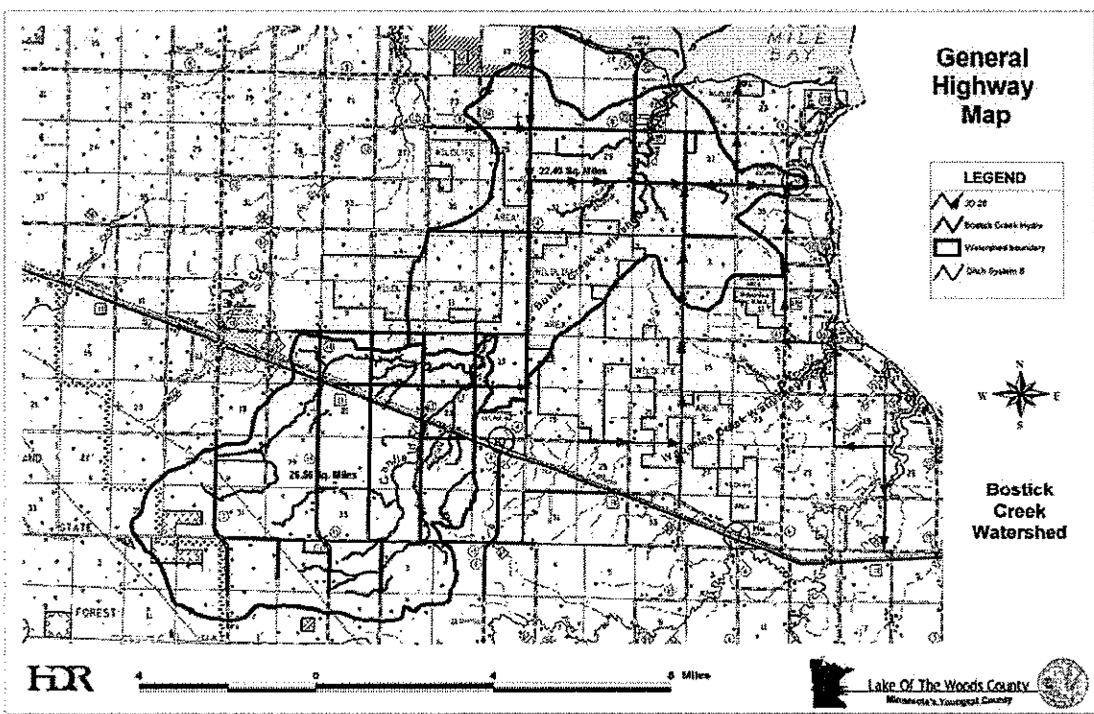

Figure 1

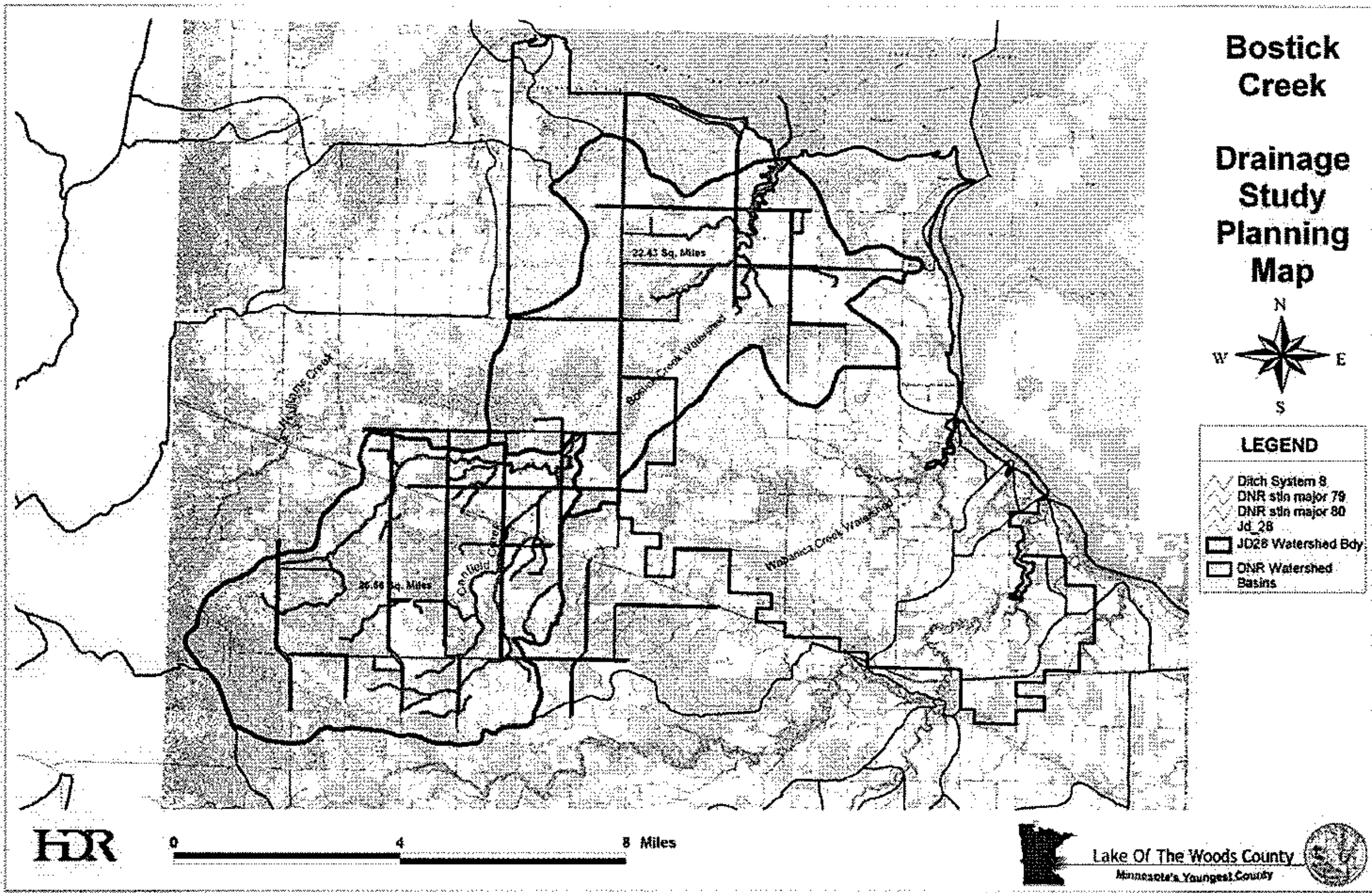

Figure 2

Figure 3 – Bostick Bay Looking North near County Road 8

Figure 4 – Judicial Ditch 28

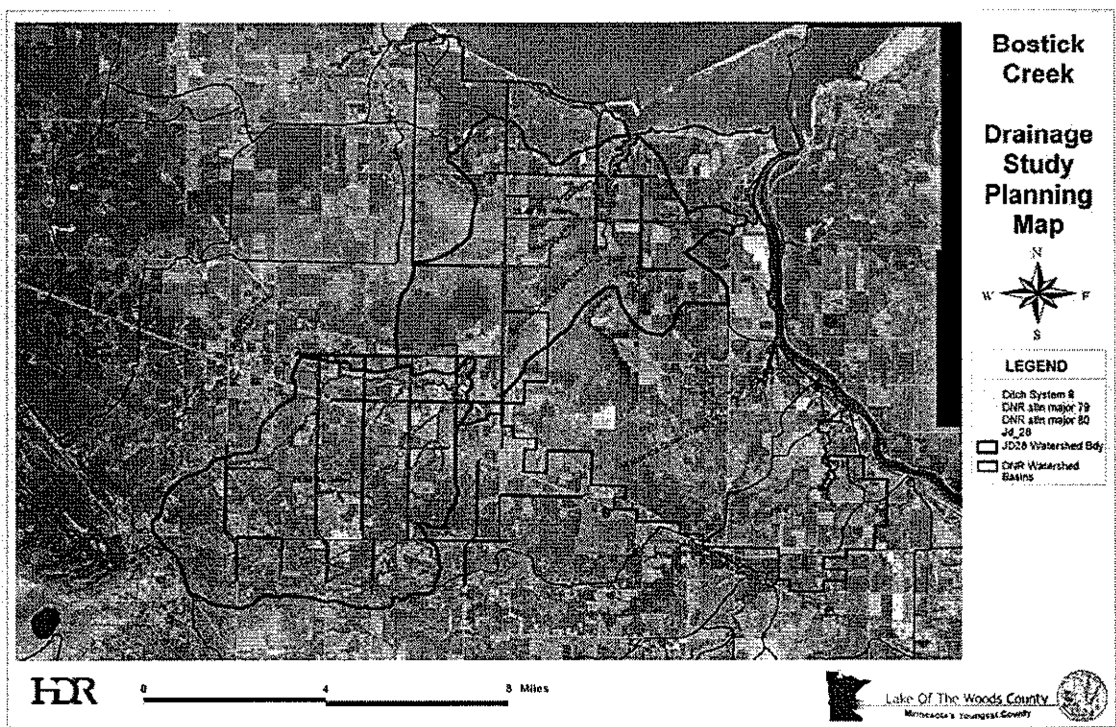

Figure 5

2.0 Purpose and Approach

The ultimate purpose of this study is to develop findings and recommendations for reducing flood damages, erosion, and downstream sediment deposition. The existing physical hydraulic drainage conditions were essentially re-created during the analysis, in order to understand the probable cause of recent erosion problems and flooding, and also what structural improvements in the infrastructure could help alleviate the situation. HDR developed recommendations for further study and also for improvements that should be implemented as priorities and funding will allow.

3.0 Background

HDR and County Highway Department staff visited the watershed area in November of 2004 and May 2005 to review the basin and visually document drainage patterns, erosion areas, and the general watershed conditions. The basin was inspected from the upstream areas to the discharge points. The study area consists of approximately 49 square miles that drain northeasterly to Lake of the Woods. The watershed is steeply sloped in the upper reaches and more gradually sloped in the lower half (from JD 28 to Bostick Creek to Lake of the Woods). Land use consists of a mixture of woodlands, wetlands, hay land, and minimal agricultural land in the lower end of the watershed. Residential homes are spread throughout the basin. Low areas, wetlands, and road embankments (with outletting cross-culverts) detain water in the study area (Figures 6 and 7).

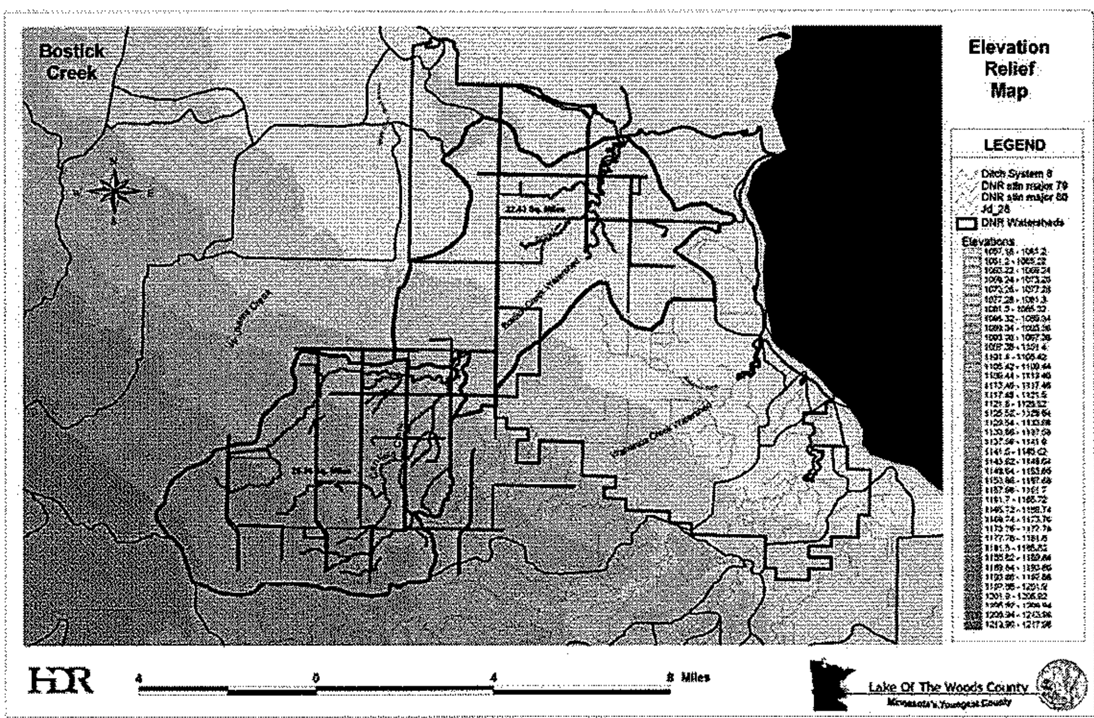

Figure 6

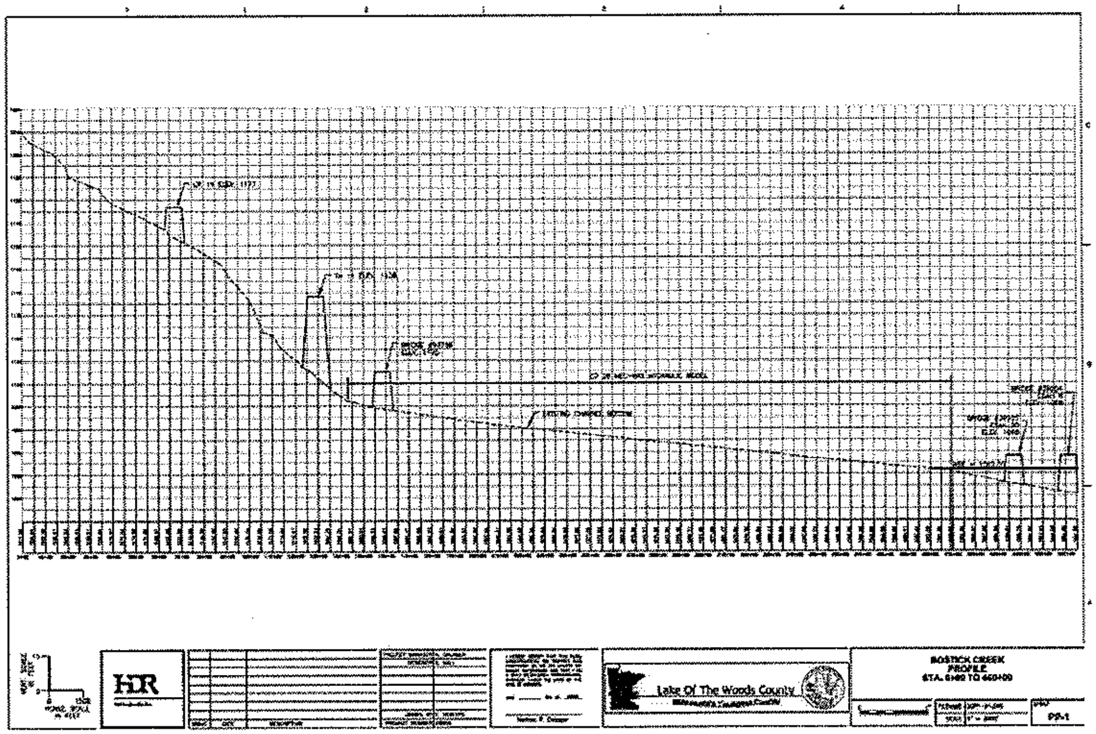

Figure 7

4.0 Hydrologic/Hydraulic Data and Modeling

HDR created a hydraulic model (HEC-RAS) for the study area. The study included hydraulic modeling of stream reaches within JD 28 using HEC-RAS. The hydrology for the study area was conducted using National Flood Frequency regional regression equations developed by the USGS (Figures 8 and 9, Table 1).

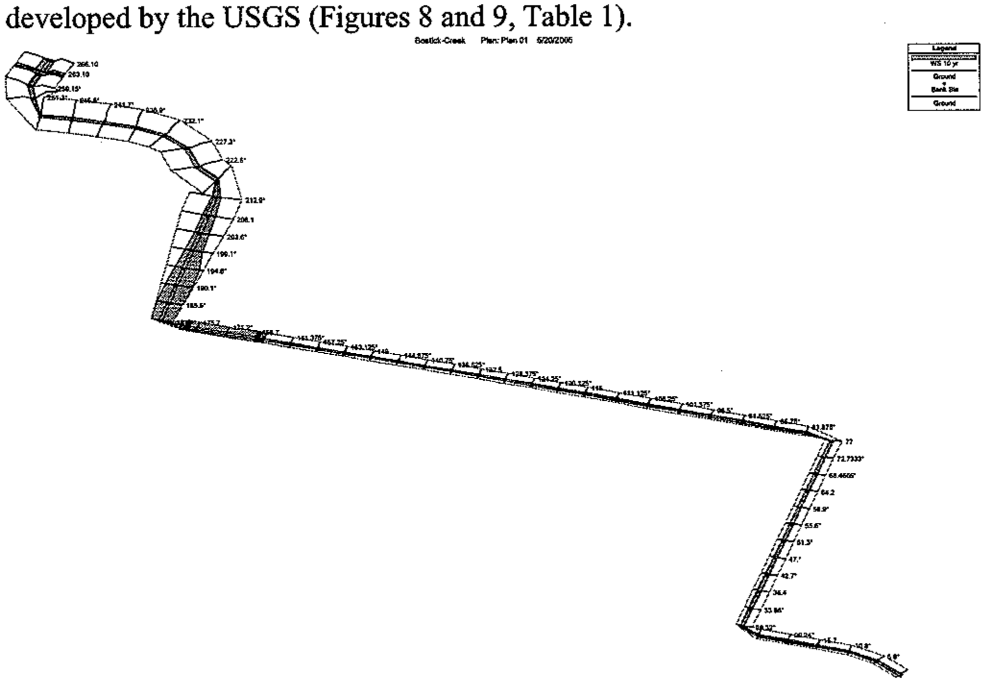

Figure 8 – JD 28 HEC-RAS Reach

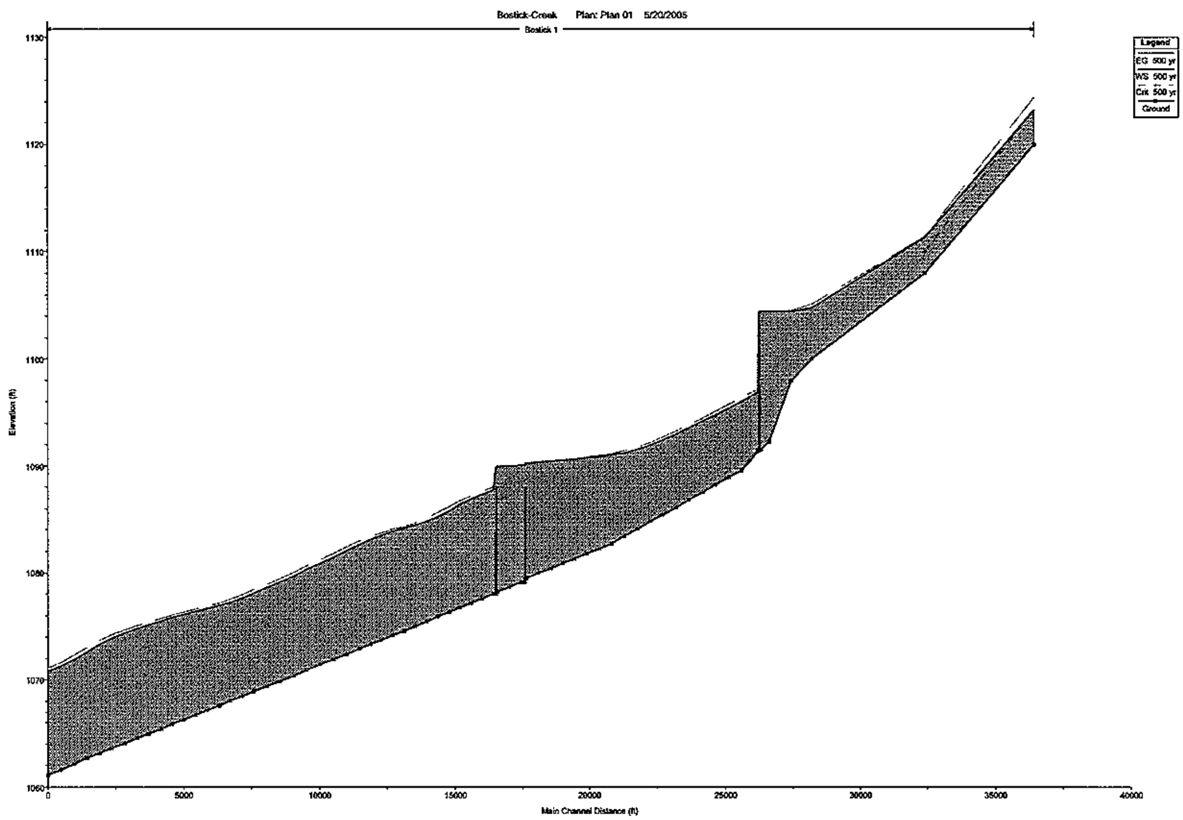

Figure 9 – JD 28 HEC-RAS Profile

<u>Peak Flows</u>

The regression equations yielded the peak flows identified in Table 1.

Table 1
Peak Flows

Subwatershed	Drainage Area (Square Miles)	2 Year (cfs)	10 Year (cfs)	50 Year (cfs)	100 Year (cfs)
Canfield Creek	26.5	132	356	616	743
Bostick Creek	49	219	588	1020	1230

5.0 Hydraulic Methodology

The hydraulics for the watershed consist mostly of culverts functioning much like "reservoir" outlet structures. Each road embankment and culvert functions much like a dam during significant runoff events, slowing down flows and impounding water on the upstream side of the roadway embankments, to some degree reducing downstream flood damages. The HEC-RAS model was developed to simulate flow patterns and channel velocities in JD 28 in order to assess channel performance seen in recent years. Based upon modeled channel velocities, certain conclusions can be made regarding erodibility by correlating field observation with modeled areas having high channel velocities during flood events. Typically, velocities of 2-3 ft/s can erode bare soils and velocities of 5 ft/s can erode established vegetation. For flood events greater than a 5-year frequency event (2.75" in 24 hours), JD 28 commonly has velocities exceeding 3 ft/s. These channel velocities passing over bare soils will continue to erode the ditch until vegetation is established or the banks are stabilized through other means.

6.0 Results

Analysis of the flooding and sedimentation problem resulted in the identification of four general causes that may be contributing to the problem.

1. Long Term Watershed Sediment Yield (Natural)
2. Long Term Watershed Changes (Land Use)
3. Short-Term Catastrophe (Natural Disaster)
4. Structural Changes (Culverts/Ditches)

Each cause is discussed in detail below.

<u>Long Term Watershed Sediment Yield (Natural)</u>

Erosion and movement of soil particles through a watershed and stream system is a natural process. In a balanced environment, the erosion and deposition is essentially self-sustaining. Before the Bostick Creek area was settled, the overall basin sediment yield was likely very low (Soil Texture - Figure 10).

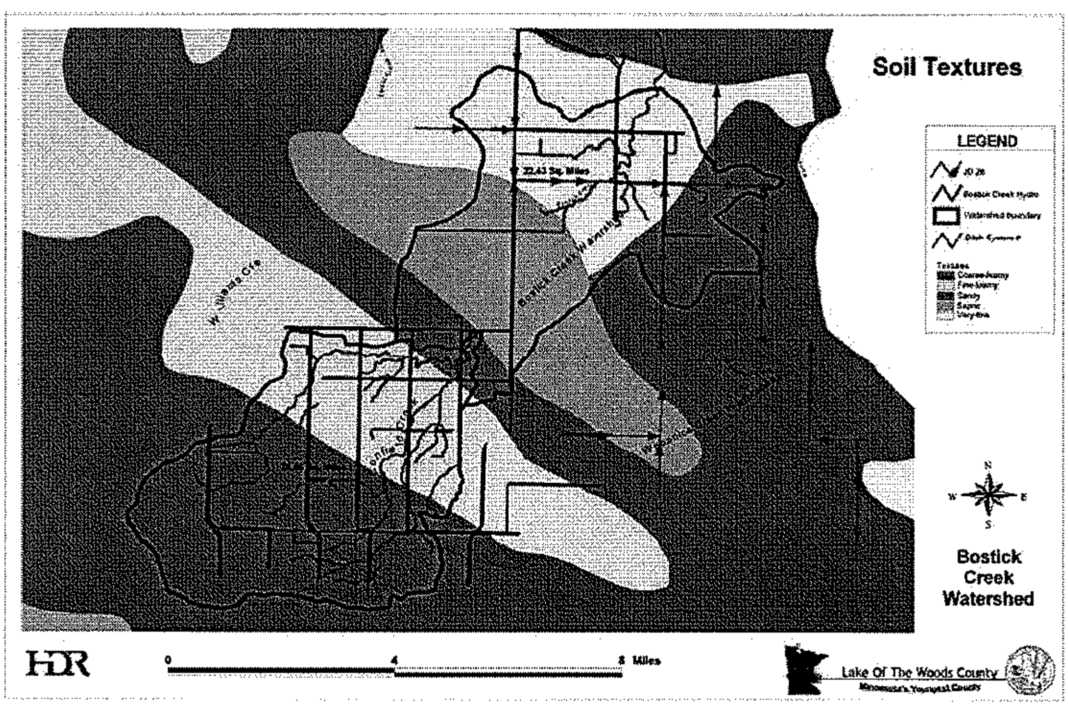

Figure 10

Long Term Watershed Changes (Land Use and/or Climate)

The settlement of Lake of the Woods County brought many changes to the landscape. Construction of roads, clearing of land for agriculture and pasture, logging, and residential homes likely changed the balance of the watershed sediment yield. To what degree is another question. Typically, if the changes in land use occurred in a short time frame and erosion of the landscape was not addressed in terms of best management practices, there would likely be a large imbalance in the system, with lots of erosion, movement of soil particles in the streams, and eventual deposition in Lake of the Woods (Figure 11).

Figure 11 – Examples of Soil Erosion – clockwise sheet, gully, bank, rill

In 2005, the Bostick Creek watershed appears to be reasonably "in balance" with respect to overall watershed sediment yield. A tour of the watershed revealed no obvious large-scale erosion problems. Generally, the land, road ditches (except JD 28), and stream banks are well vegetated and stable. Total suspended solids (TSS) readings provided by the Soil and Water Conservation District also indicate acceptable readings in Bostick Creek with the exception of extreme runoff events. The universal soil loss equation indicates that the average annual sediment for the watershed is 0.13 tons/acre/year, where an acceptable level approaches a vastly larger 3.0 tons/acre/year. Clearly, based upon current land use and soils, the Bostick Creek watershed sediment yield is low, acceptable, and not a significant source of sediment causing problems downstream (Figures12, 13, 14, and 15).

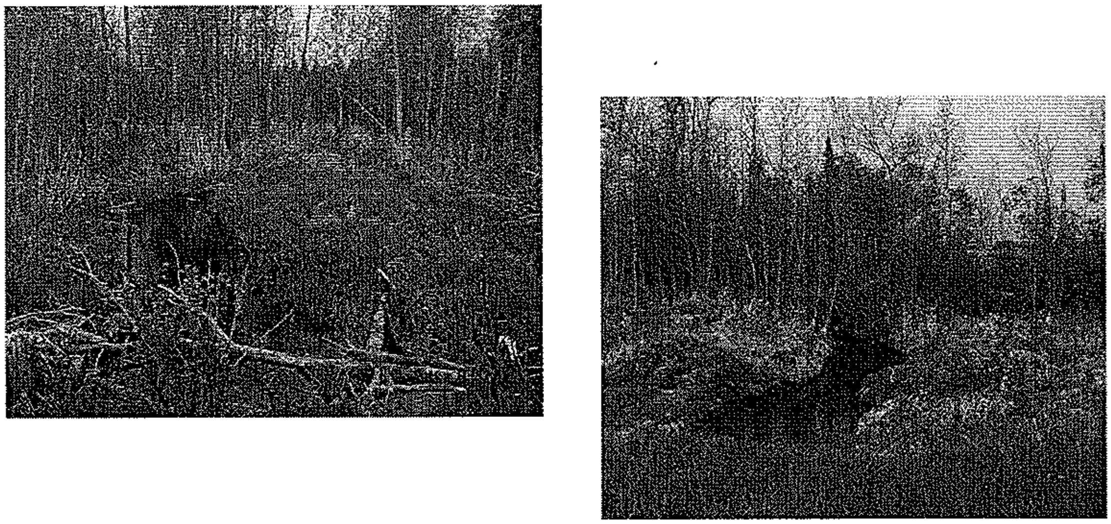

Figure 12 – Bostick Creek Watershed is Stable

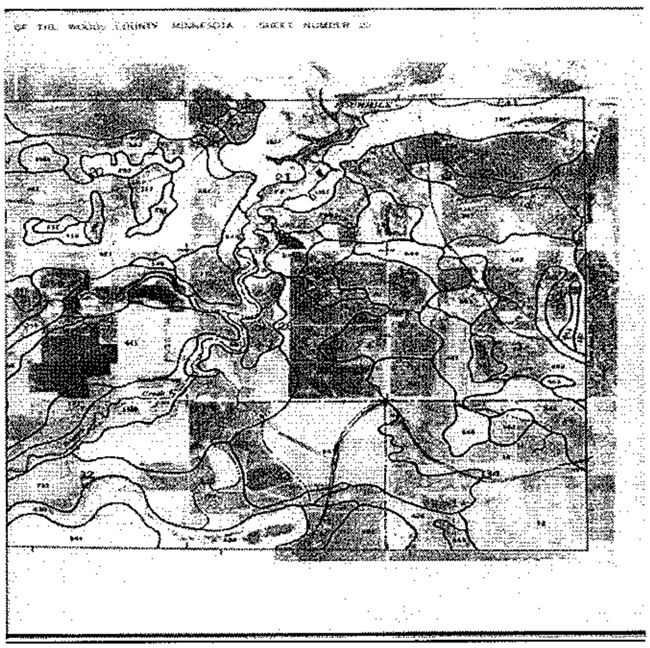

Figure 13 – LOW Soils Map Used to Determine Sediment Yield

ACRES TOTAL FOR WS	SOIL Type	K FAC	SOIL TYPE % OF WATERSHED	K-FACTOR COMPOSITE PORTION
960	46B	0.15	1.56%	0.00235
2910	52	0.28	4.64%	0.01300
460	77B	0.32	0.73%	0.00235
2290	116	0.17	3.64%	0.00616
2950	117	0.17	4.71%	0.00800
320	122B	0.43	0.51%	0.00220
1260	145	0.17	2.01%	0.00342
140	147	0.37	0.22%	0.00083
170	167B	0.28	0.27%	0.00076
1195	172	0.28	1.91%	0.00534
1710	187	0.2	2.73%	0.00546
180	191	0.17	0.29%	0.00043
650	195B	0.17	1.04%	0.00176
170	202	0.17	0.27%	0.00046
260	205	0.17	0.41%	0.00071
30	242B	0.17	0.05%	0.00008
20	242D	0.17	0.03%	0.00005
180	280	0.24	0.29%	0.00069
0	379	0.28	0.00%	0.00000
260	387	0.28	0.41%	0.00116
2360	404	0.28	3.77%	0.01054
220	425	0.2	0.35%	0.00070
60	432	0.2	0.10%	0.00019
130	456B	0.15	0.21%	0.00031
3140	461	0.17	5.01%	0.00852
7550	462	0.13	12.05%	0.01507
180	514	0.32	0.29%	0.00092
0	532	0.28	0.00%	0.00000
380	540	0	0.61%	0.00000
6790	541	0	10.83%	0.00000
2910	543	0.15	4.64%	0.00696
4700	544	0.2	7.50%	0.01500
0	546	0	0.00%	0.00000
0	549	0	0.00%	0.00000
0	560	0	0.00%	0.00000
2860	563	0.37	4.56%	0.01688
2660	565	0.17	4.24%	0.00721
360	568	0.28	0.57%	0.00161
0	569	0.28	0.00%	0.00000
40	570	0.15	0.06%	0.00010
1180	581	0.28	1.88%	0.00527
160	582	0.24	0.26%	0.00061
110	616	0.37	0.18%	0.00065
390	626	0.43	0.62%	0.00268
160	627	0.15	0.26%	0.00038
1420	630	0.28	2.27%	0.00634
2410	641	0.28	3.85%	0.01077
630	644	0.32	1.01%	0.00322
0	656	0.15	0.00%	0.00000
0	702	0.32	0.00%	0.00000
1400	755	0.28	2.23%	0.00625
0	792	0.2	0.00%	0.00000
40	794	0.17	0.06%	0.00011
0	828D	0.17	0.00%	0.00000
0	852E	0.32	0.00%	0.00000
210	1030	0.24	0.34%	0.00080
0	1033	0.15	0.00%	0.00000
0	1059	0.32	0.00%	0.00000
0	1066	0.32	0.00%	0.00000
1550	1067	0.32	2.47%	0.00791
530	1807	0.2	0.85%	0.00169
270	1808	0.15	0.43%	0.00065
0	1823	0.32	0.00%	0.00000
0	1924	0.24	0.00%	0.00000
0	1925	0.1	0.00%	0.00000
1750	1984	0.17	2.79%	0.00475
62676				0.19436213

Figure 14 – Composite K-Factor (representing erodibility) for Bostick Creek Watershed

Weighted soil loss erod. portion, t/ac/yr	*Weighted detachment, t/ac/yr*	*Weighted cons. plan. soil loss, t/ac/yr*	*Weighted delivery, t/ac/yr*
0.13	0.13	0.11	0.036

Figure 15 – Universal Soil Loss Equation – Results for Bostick Creek Watershed

Short-Term Catastrophe (Natural Disaster)

Between June 9-11, 2002, Lake of the Woods County experienced between 10 – 18 inches of rainfall. According to anecdotal accounts, County Road 4 (which parallels JD 28) was overtopped. JD 28 was severely undermined and eroded a significant amount. Nearer Bostick Bay, large areas of streambank and other channel material near the County Road 8 bridge was relocated out into Bostick Bay, essentially filling in traditional navigational channels. TSS levels were understandably high during this extreme runoff event. Natural disasters such as this event are rare and tend to skew long-term trends. However, this event substantially affected JD 28 and Bostick Bay such that this investigation was initiated to address navigational issues on Bostick Bay and future actions required to maintain an acceptable sediment balance in the watershed (Figures 16, 17, and 18).

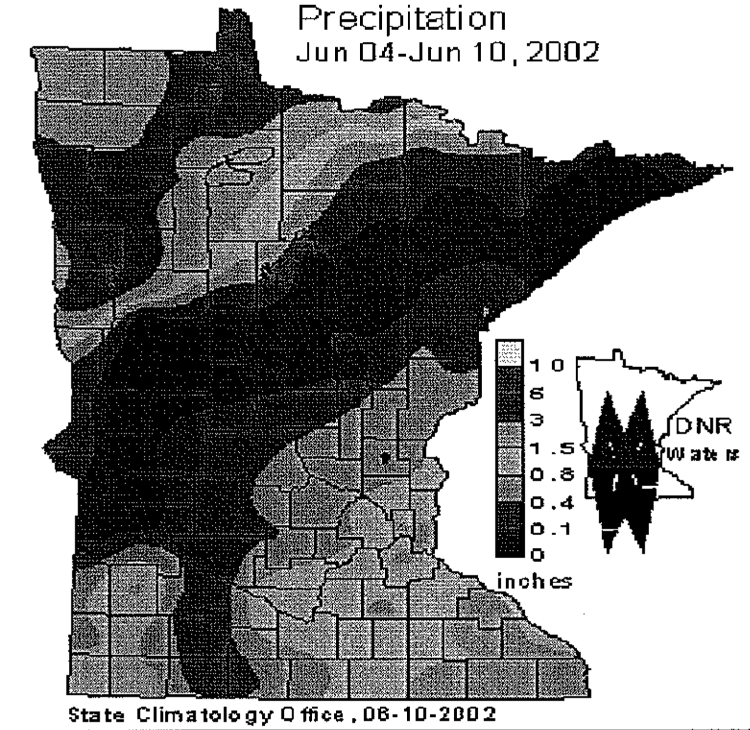

Figure 16 – June 2002 Flood Event

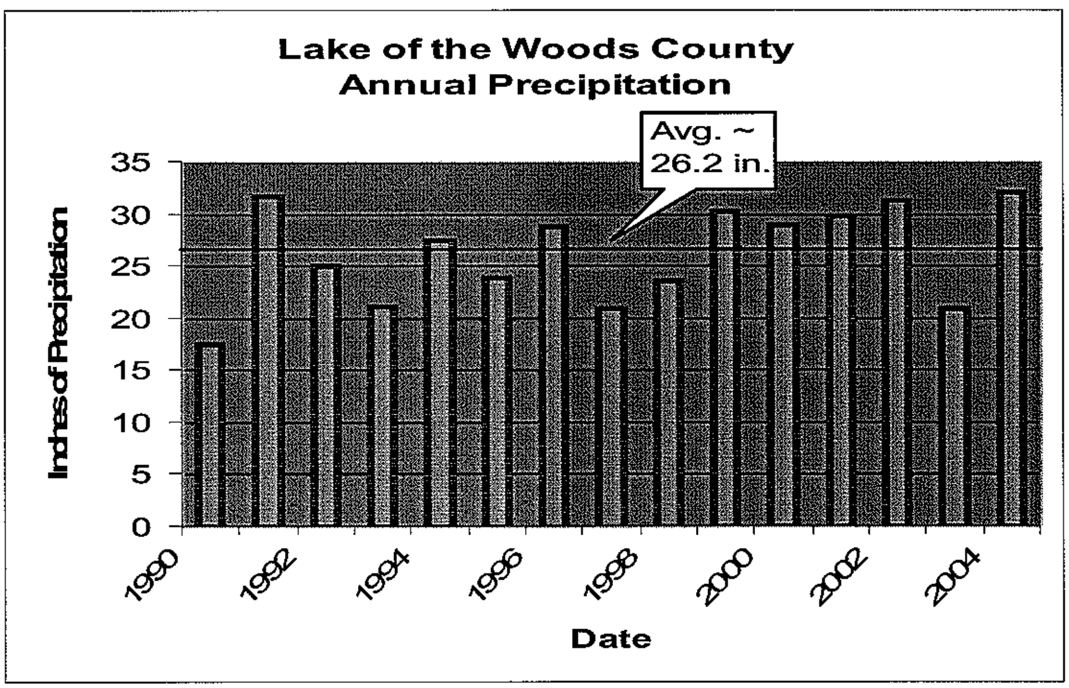

Figure 17 – Recent Precipitation, Note Upward Trend. 5/6 Years Above Average Since 1999

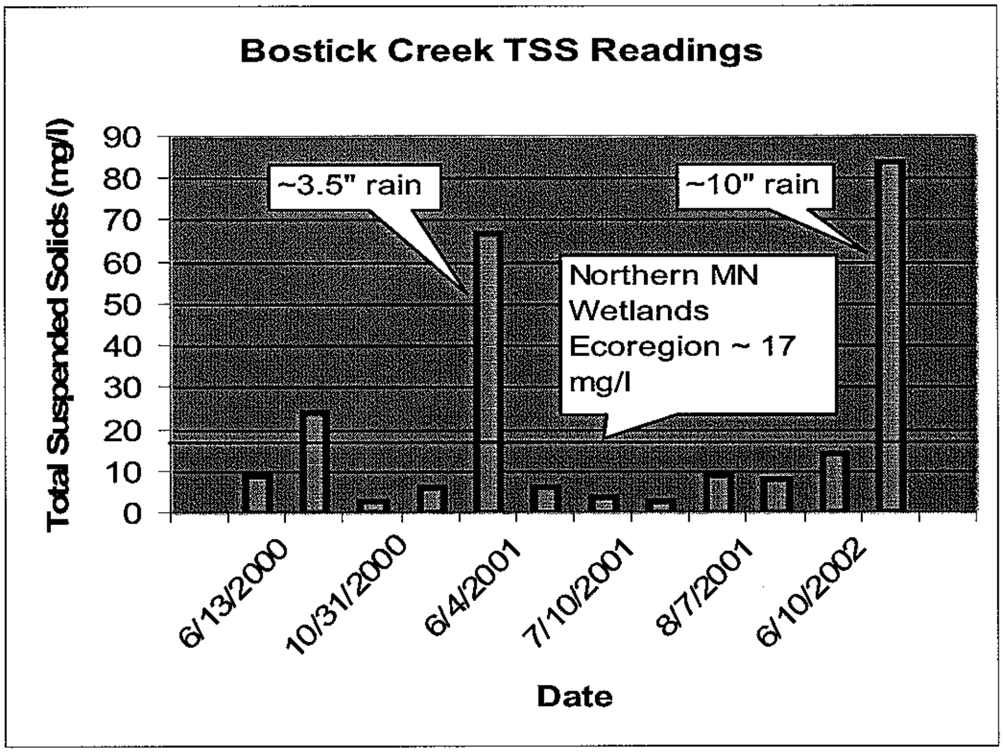

Figure 18 – LOW SWCD Total Suspended Solids Measurements

<u>Structural Changes (Culverts/Ditches/Dams)</u>

JD 28:

Development of infrastructure within the watershed can have both short-term and long-term affects. In this case, the Bostick Creek area was developed in the early to mid 1900's. Typically, once the construction areas were stabilized (short-term erosion/deposition), the affects of culverts and ditches begin to change the geomorphology of the area until a hydrologic and hydraulic balance (long-term erosion/deposition) was/is attained. It is noted that the use of the term "balance" is subjective and is intended to describe overall system soil stability as opposed to other environmental factors or values. Typically, ditches and culverts contribute to higher flow peaks and lower base flows compared to a more moderate pre-settlement stream system. These flashier peak flows contribute to ditch and streambank erosion and the resulting downstream sediment deposition. JD 28 and areas of Bostick Creek downstream of JD 28 are still actively eroding and have not achieved a balance. It can take many decades for an altered system to achieve such a balance. The June 2002 event essentially forced JD 28 and portions of Bostick Creek out of any state of balance it had achieved over the years such that they are currently unstable and a contributing source to the overall problem of sedimentation in Bostick Bay.

Bostick Bay:

Lake of the Woods is managed as a reservoir due to operation of a dam near Kenora in Canada. Current water levels are about 4 feet higher on average than pre-dam lake levels. It has been suggested that this water level regime has in effect caused former floodplain uplands that are adjacent to the submerged Bostick Creek channel to loosen and slough into the historic channel causing sedimentation in navigation channels. Since the dam has been in existence for over 100 years, this phenomenon is likely permanent and not currently in a great state of change.

7.0 Summary / Recommendations

Problem: Ditch and Streambank erosion

Status: Overall, the Bostick Creek watershed is in good condition. The annual sediment yield of 0.13 tons/acre/year is considerably less than the published acceptable sediment yield. The Bostick and Canfield Creek natural stream banks are well vegetated and generally stable. The streams in the upper reaches do not appear to be significantly aggrading or degrading.

JD 28 is generally unstable. Re-sloping work conducted in 2003 after the June 2002 event appears to have been reasonably successful. However, there are isolated areas of ditch bank sloughing, the worst of which is in Sections 29, 30, and 31 of Wheeler Township. Velocities in the ditch approach 4 ft/s during flood events causing erosion and sloughing of the highly erodible soils that the ditch passes through.

Recommendation: Conduct an inventory of problem areas on the lower 2-3 miles of the ditch and affected areas of Bostick Creek just downstream. Using SWCD cost share monies and other grant sources, implement stabilization projects to include bio-engineering, re-sloping, riprap, fiber blanket, and other methods.

Cost: $50,000 - $100,000

Other Alternatives:

- Restore Graceton Bog (Abandon JD 28): The Graceton Bog loosely defines an expansive historical bog/wetland area that lies between higher uplands and ridges to the south and Lake of the Woods to the north. The area is oriented in a Northwest-Southeast fashion and is depicted in Figure 19. Presettlement streams discharged into this expansive bog area essentially vanishing into the swamp. Stream beds reappeared near the Lake. The Graceton Bog undoubtedly functioned as an effective floodwater and sediment attenuation system. As the area settled and developed, roads and ditches were constructed in many areas greatly diminishing the Bog's filtering capabilities.

  The Bog's aerial extent covers as many as 30 square miles and its lateral extent covers as much as 8 miles along a line of similar elevation. The Bog also drains into 3 different Creek systems, Zippel, Bostick, and Wabanica. The system essentially lies on the side of a slope.

Because of the sheer magnitude of the in-place roads, ditches, and private infrastructure both around and within the Graceton Bog, implementation of a restoration project would be technically complex, politically and socially complicated, and prohibitively expensive. The context in which this assessment is made is with respect to the stated problems downstream – erosion, flooding, and sedimentation. Restoration of the Bog would likely address the stated problems, but the practicality of restoring the Bog for the sole purpose of addressing these stated problems is questionable.

To explain the technical feasibility in a little more detail, the following scenario of raising County Road 4 and decreasing the size of the culvert (or gating it) is addressed as follows. Because of the elevations and slope of the bog laterally, the Bog area essentially "sheet flows" down the side of a broad slope. Actual watershed boundary definition between the Creeks depends more upon water levels than topography. The water will flow where the water is lower and/or where the ditch and road infrastructure directs it. If water is held back at CR 4, it will move west into the Zippel Creek watershed without extensive diking in wetland areas. Because of its topographic setting, the Graceton Bog is difficult to contain in a sense, and would really need to be restored as whole system, with abandonment of several roads and ditches required.

Legal ditch abandonment, placement of fill in wetlands, and alteration of wetland hydrology is known to be technically difficult in today's regulatory environment. With the difficulties stated, it is noted that the environmental benefits of such an undertaking would be substantial, possibly worthy of the attention of a privately funded environmental organization. Further study of this alternative may be warranted.

- <u>Convert JD 28 to a meandering stream inside of setback levees:</u> Stream geomorphology research has shown that, in general, straight ditches do not represent a stable channel form. A straight ditch will inevitably tend to erode or fill in. A ditch or stream naturally seeks a balance between aggradation and degradation. Depending upon annual flow volume, peak flow, stream gradient, and soils, a particular stream must have sinuosity, pools, and riffles that develop over time. Once this balance is achieved, a stream becomes stable until hydrologic conditions change. Several projects have been implemented in Northern Minnesota whereby a straight ditch has been re-constructed in a sinuous fashion in an attempt to improve its stability. By this method, the drainage function of the waterway is not compromised. However, downstream peak flows are moderated to some degree. The cost for construction of this approach and the additional land required for right-of-way is considerable. Further study of this alternative may be warranted.

- <u>Upstream Water Retention:</u> Storage of floodwater behind road grades through the use of gate structures on culverts is an option for reducing peak flows in the system and allowing some sediment to settle out. However, location of these sites, because of reasons stated regarding the Graceton Bog restoration, would need to occur upstream of the Bog in the Ridge area or uplands to the south. Figure 19 outlines this area.

Previous experience has shown that identification of specific sites at the conceptual stage of analysis causes undue public concern and has been purposely avoided.

Actual flow reductions downstream would be subject to site specific conditions, the event considered, and is beyond the scope of this study. Landowner acceptability and wetland permitting concerns would factor heavily in site selection. Current costs for impoundment construction are roughly $1,000/acre-ft of storage, all costs included. Typical costs include land acquisition, levees, structures, administration and engineering, and environmental permitting. In order to develop a site or sites with a meaningful storage volume, it is estimated that between $500,000 - $1,000,000 worth of storage would need to be constructed at a minimum. Further study of this alternative may be warranted.

Problem: Flooding

Status: Flooding of homes downstream of JD 28 did not occur during the extreme June 2002 event, but was imminent. However, roads, outbuildings, farmlands, and pasture lands were significantly flooded. There is also the perception that flooding has been becoming increasingly common when compared to unsubstantiated historical accounts along Bostick Creek. This perception likely has merit upon review of short-term hydrological records shown in Figure 17. Over a period of 15 years of precipitation, the last 5 of 6 years have been over the 15-year average of 26.2 inches. Over a period of record of 75 years, the average precipitation has been 22 inches per year. There has been a steady rise in recorded annual precipitation over that time, exemplified by the more recent 15-year average and recent years of precipitation in the 30 inch plus range.

Recommendation: Because of the small number of homes actually affected, it is most cost-effective to protect flood-prone properties in the Bostick Creek watershed by individual structural means, such as a constructed levee surrounding the home or property (ring dike). Relocation of other affected buildings and land uses would also reduce flood damage along flood prone lands adjacent to Bostick Creek.

Cost: $35,000

Other Alternatives:

- Restore Graceton Bog
- Convert JD 28 to a Meandering Stream
- Upstream Water Retention

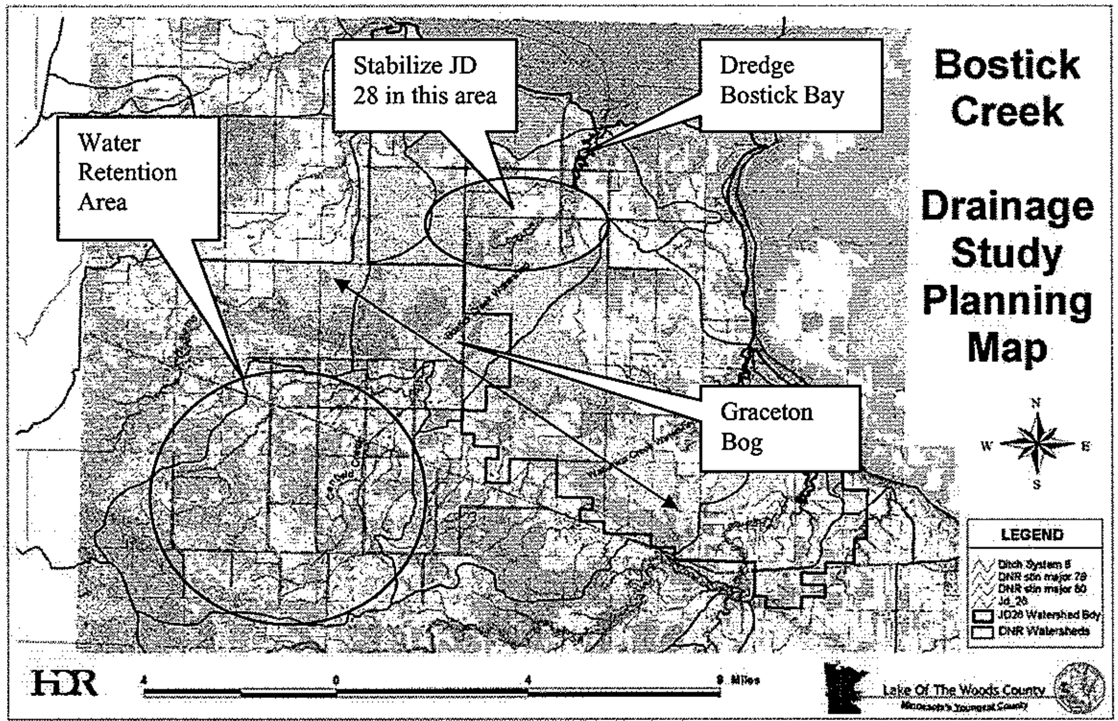

Figure 19 – Graceton Bog and Water Retention Sites

Problem: Sediment Deposition in Bostick Bay

Status: Currently, reasonable navigation is possible given adequate water levels in Lake of the Woods. Past and future sediment deposition remain a concern as water levels fluctuate, navigation may become limited. Over time, approximately 2 feet of sediment has settled into the Bostick Bay navigational channel. A significant source of this sediment appears to be JD 28 and selected stream banks of Bostick Creek downstream of JD 28.

Recommendation: Perform a comprehensive sediment survey of the known problem areas to define the scope and extent of the sediment as it relates to preferred locations of navigational channels. Apply to DNR Waters for a dredging permit for the preferred navigational channel. Identify a site ideally less than 1 mile away for dredge spoil disposal. Implement a navigational dredging project by means of a floating hydraulic dredge or winter excavation using backhoes and dump trucks.

Cost: $100,000 minimum

Other Alternatives (to reduce future sediment deposition):

- Restore Graceton Bog
- Convert JD 28 to a Meandering Stream
- Upstream Water Retention

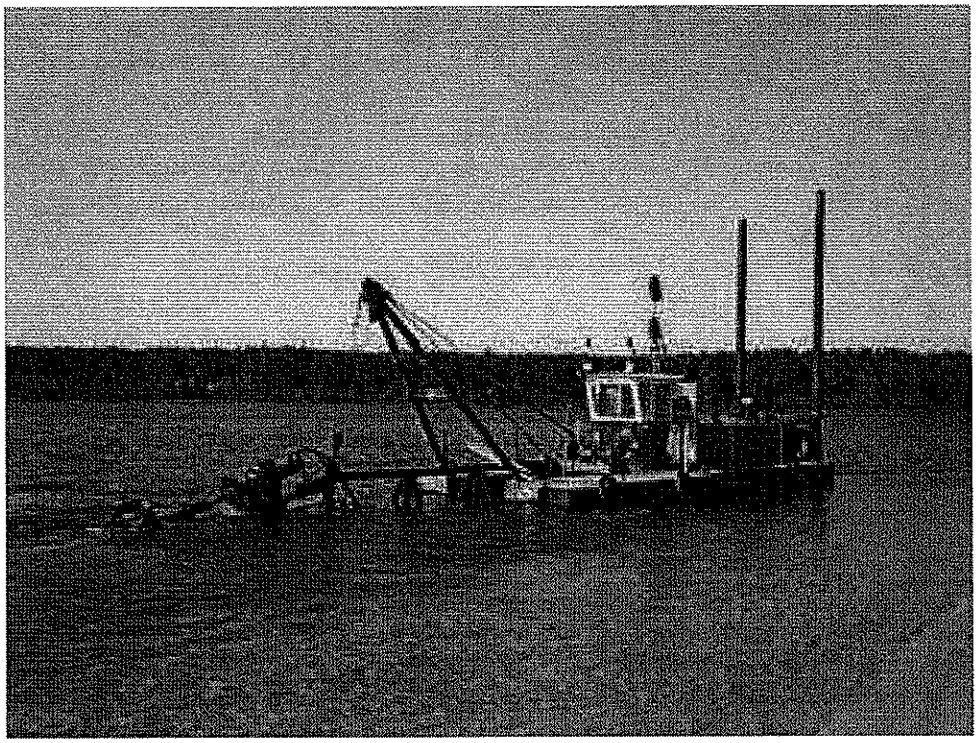

Figure 20 – Floating Hydraulic Suction Dredge

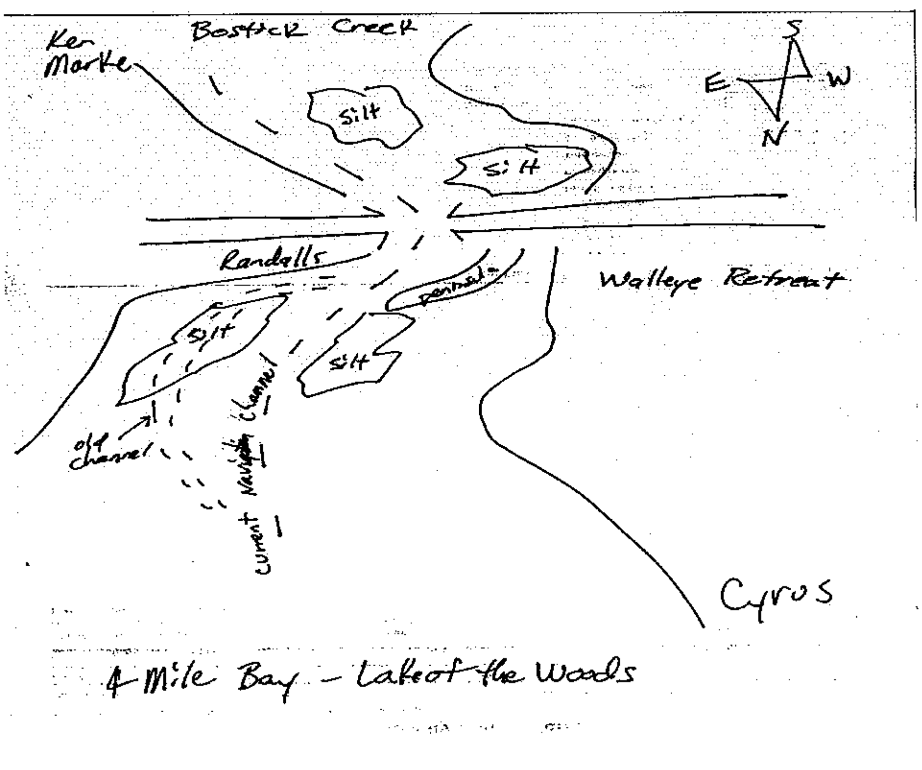

Figure 21 – Sketch of Current Location of Bostick Bay Navigational Channel

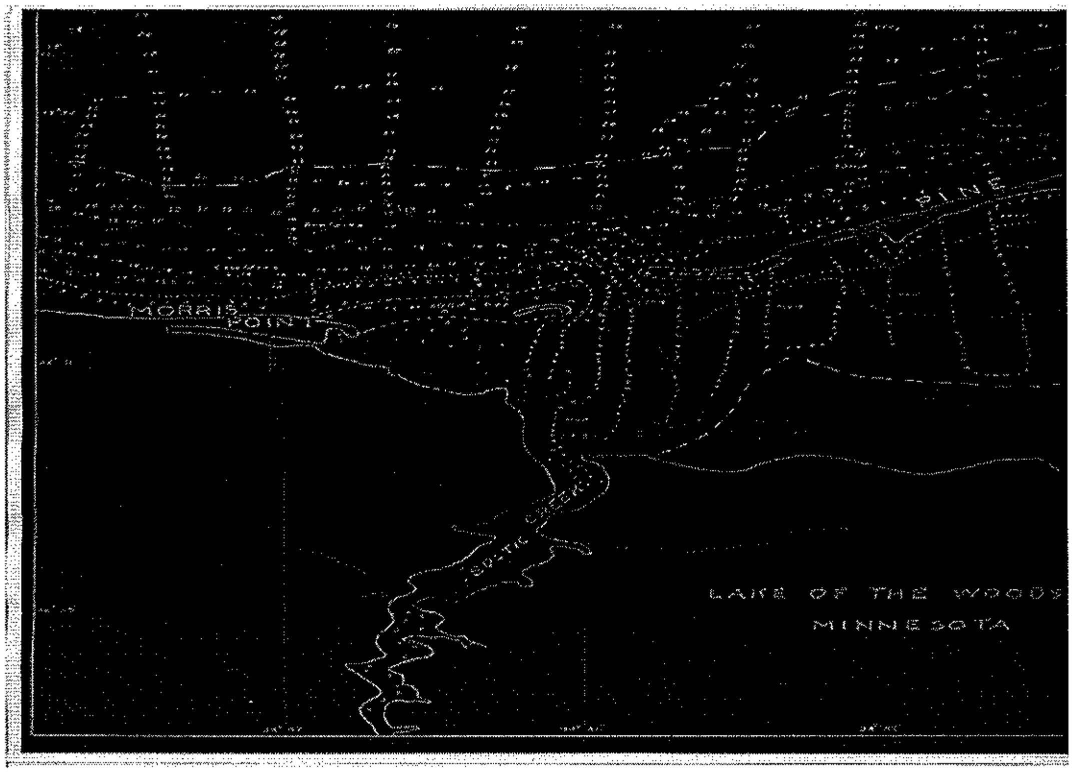

Figure 22 – Historical Water Depth Data Reveals Approximately 2 Feet of Sediment in the Navigational Channel of Bostick Bay