ANALYSIS

OF

CONSERVATION BUFFER EFFCTIVENESS

FOR

TOLEDO HARBOR PROJECT

PREPARED BY

NATURAL RESOURCES CONSERVTION SERVICE

JULY 15, 1998

STEVE DAVIS

RESOURCE CONSERVATIONIST

ANALYSIS OF CONSERVATION BUFFER EFFECTIVENESS

FOR

TOLEDO HARBOR PROJECT

PURPOSE

This analysis evaluates the effect that widespread installation of conservation buffers in the Maumee Watershed would have on the reduction of dredging in Toledo Harbor. This analysis is prepared as part of the Natural Resource Conservation Service Toledo Harbor Demonstration Project final report submitted to the U. S. Army Corps of Engineers. The objectives of this analysis are to:

- Quantify the effect of conservation buffers on sediment reduction in the harbor.
- Determine the average savings in yards of dredging saved per acre of buffer installed
- Evaluate the cumulative effect that widespread installation of buffers would have on project goals.

BACKGROUND INFORMATION

As part of the Toledo Harbor Project Phase III plan, NRCS initiated a pilot project to demonstrative effectiveness of using land treatment to reduce upland erosion which would result in less sediment delivery into the harbor. The pilot project is the first phase of a multiyear plan to reduce sedimentation and dredging.

The plan contains a goal of reducing sedimentation by 130,000 cubic yards annually through erosion control. The 130,000 cubic yards represents agriculture's contribution to the overall goal of sediment reduction. In addition to the agricultural component, there are several other components in the phase III plan, which also contribute to dredging reduction.

The original plan for achieving 130,000 cubic yards of agricultural related sediment reduction was based on achieving the goal of using conservation tillage to grow 75% of the corn and soybeans in the watershed.

At the time the initial NRCS plan was prepared in 1992 there was no effective program to promote filter strips (conservation buffers), especially ones of widths that would be effective in sediment removal. Since that time the National Conservation Buffer Initiative has been developed as part of the Continuous Signup provisions of the CRP program. Both of these programs now work in tandem to now make the use of filter and buffer strips more attractive to farmers.

Additionally, the Buffer Initiative contains financial and program incentives to promote filter strips that are more effective in sediment removal. Interest in adopting this practice is increasing in the watershed.

CONSERVATION BUFFER EFFECTIVENESS - RESEARCH INFORMATION

Literature Review

There are numerous studies available which document the effectiveness of conservation buffers. According to David L Correll of the Smithsonian Environmental Research Center there are now over 400 research papers available on the subject. In 1991, Dr. W. Findlay, Scientific Authority, National Soil Conservation Program, University of Guelph, Guelph Ontario, published an extensive and comprehensive review and summary of the current literature on buffer strips (Findlay et.al., 1991). This study summarized over 75 papers that evaluated the effectiveness of buffers. In addition, NRCS geologist Jim Wade has made observations on the effectiveness of filter strips in reducing sedimentation in the Maumee River Watershed. This information was used in compiling this analysis.

Benefits of Buffer strips

The literature review shows that conservation buffers are very effective at trapping sediments, nutrients, pesticides and pathogens. Effective buffers trap and hold these contaminants in the edge of field buffers rather than allowing them to be carried away in the runoff. This analysis will concentrate on the effect buffer strips will have on trapping sediment and the reduction of sediment delivery within the Maumee watershed. Buffer strips that are appropriate in the Maumee Watershed include the conservation practices of grass filter strips, grassed waterways, riparian forest buffers, wetland restoration, and field windbreaks. In addition to the trapping benefits of buffers, there is also a fairly significant benefit of reduced erosion on the buffer acreage itself, as a result of the land use conversion from cropland at an elevated erosion rate to permanent vegetation at a lower erosion rate.

Design Principles and Buffer Effectiveness

Buffer strip effectiveness is highly site specific. It depends on buffer width, site, topography, vegetation, buffer size, buffer configuration and climatic factors. In general, required buffer width increases as the drainage area increases, the slope of the land increases the particle size decreases, and volume of runoff increases.

Nearly all studies have found a positive effect from buffers. Usually the question is not if the buffer is effective, but what is the level of effectiveness. This analysis is based on what is thought to be the typical buffer condition and buffer effectiveness that will be found in the watershed.

BUFFER EFFECTIVENESS IN THE MAUMEE WATERSHED

The effectiveness of conservation buffers in reducing sediment delivery to the Toledo Harbor will be calculated using four factors. These are:

Trapping Efficiency Factor
Landscape Effectiveness Factor
Watershed Delivery Ratio Factor
Ship Channel Trapping Efficiency Factor

Trapping Efficiency Factor

Trapping efficiency is the measure of the ability of the buffer to hold sediment particles in the buffer zone. It is expressed as a percentage of the sediment (tons) retained in the zone relative to the total sediment entering the buffer zone.

$$\text{Trapping Efficiency} = \frac{\text{Tons of Soil Retained in Buffer}}{\text{Total Tons Entering the Buffer}}$$

Trapping efficiency is a function of the width of the buffer, amount of uniform flow through the buffer, soil particle composition, and density of vegetation in the buffer, among other things.

There are numerous examples of various trapping efficiencies in the literature. Neibling and Alberts (1979) found that buffer strips ranging from 2 to 16 feet in width removed over 90% of the total sediment. Magette et al. (1987) found that 15 and 30 foot filter strips removed 72% and 86% of the total sediment load respectively. Young (et al. (1980) found that a 90 foot orchard grass buffer strip removed 66% of the total sediment load. Wilson (1967) found that 10 foot was sufficient to remove the maximum percent of sand, 50 foot for silt and 400 foot for clay.

Jim Wade, NRCS geologist, has observed that each acre of filter strip in the Maumee Basin can trap and retain approximately 50 tons of soil per year and still remain viable, but that average annual trapping is less than this, in the range of 25 tons per acre (personal communication).

For the purposes of this analysis, based on the literature review, **a trapping efficiency of 50% will be assigned to conservation buffers in the Maumee Watershed.** This efficiency assumes a properly designed buffer with a width in the range of 30-45 feet.
Landscape Effectiveness Factor

The proper functioning of a buffer strip for sediment removal requires a shallow uniform flow across the buffer. Buffer effectiveness is reduced where concentrated flow occurs. Because of the topographic nature of the landscape in the Maumee Watershed, the intensively developed drainage systems, and because buffers are installed for a variety of benefits, few buffers will be effective along their entire lengths. For this reason a landscape effectiveness factor has been assigned. The landscape effectiveness factor is a measure of the percent of the total length of buffer that actually provides proper buffering capacity via shallow uniform flow. It is expressed as follows:

$$\text{Landscape Effectiveness Factor} = \frac{\text{Length of buffer that effectively filters}}{\text{Total length of buffer}}$$

For the purpose of this analysis, a **landscape effectiveness factor of 50% will be assigned to the typical buffer in the Maumee Watershed.**

Thus the overall average buffer effectiveness in the Maumee Watershed will be .25 (25%). This is calculated by multiplying the buffer trapping efficiency (.50) times the landscape effectiveness (.50). The .25 figure represents the percent of the total gross erosion which enters a buffer that the conservation buffer can be expected to trap and hold at the edge of the field.

Watershed Delivery Ratio

Not all of the eroded material that leaves field in the watershed makes it to the Toledo Harbor. Some is captured elsewhere in the field, in the drainage ditches, stream channels, flood plains, etc. The percentage of material that enters the Harbor divided by the total tons of soil that erodes in the watershed is termed the delivery ratio. The previously published NRCS Report, Erosion and Sedimentation Dynamics of the Maumee River Basin, and Their Impact on Toledo Harbor, (February 1993) reports a watershed delivery ratio of 12 percent. **This delivery ratio of 12 percent was used for the purposes of this analysis.**

The purpose of this analysis is to compare the proposed end of project conditions with various levels of new conservation buffers applied to the 1992 beginning reference condition without the buffers. For this reason the delivery ratio is held constant throughout the analysis. Most of the conservation buffers used in the analysis will be edge of field buffers and the assumption made is that any material which passes through the buffers and leaves the field will travel through the stream system as it did previously.

Trapping Efficiency

Not all of the sediment that the stream system transports to the harbor is deposited in the shipping channel. The previously cited Erosion and Sedimentation Dynamics Report assigned a ship channel trapping efficiency of 32 percent which represents the percent of total sediment that is deposited in the channel. **This value of .32 (32%) is used for this analysis.**

CALCULATION OF THE CUMULATIVE BUFFER EFFECT

The cumulative effectiveness of one acre of conservation buffer is the product of the four buffer efficiency factors. It is calculated as follows:

Sediment = **Reduction** (Tons)	Soil Loss in Buffer Watershed (Tons)	x	Buffer Trap Efficiency Factor	x	Landscape Effectiveness Factor	x	Watershed Delivery Ratio	x	Ship Channel Trapping Factor
Sediment = **Reduction**	Soil Loss	x	.50	x	.50	x	.12	x	.32
Sediment = Reduction	**Soil Loss Above Buffer**	**x**	**.0096**						

WATERSHED ANALYSIS – EFFECT OF BUFFERS

Buffer effectiveness is related to the soil loss of the contributing watershed flowing across each buffer. The procedure used for this analysis was to compare the soil loss for the end of project conditions, with and conservation buffers in place, to the soil loss for the reference year of 1992 without the buffers. The 1993 Erosion and Sedimentation Dynamics Report contained data for agricultural land use, crop acres, USLE erosion rates for each crop and total tons of erosion for each crop. This data was used for the analysis to maintain consistency in terms of effect buffers on the original project goals.

A spreadsheet model was developed which calculated the cubic yard reduction of sedimentation in the harbor when conservation buffers were applied to the 1992 watershed cropping and erosion data. Buffers were applied to 5,15,25, 35, and 50 percent of the agricultural crop fields (minus the hay and 1992 Conservation Reserve Acres). The sediment reduction was calculated by determining how many tons of soil would be retained in the edge of field buffers using the buffer efficiency factors. The result was then multiplied by the delivery ratio and ship channel trapping efficiency to determine how many of those saved tons would have been deposited in the harbor. These tons were converted to yards using a previously established conversion factor of 1.85 yards of dredging per ton of sediment (Erosion and Sedimentation Report – 1993).

The buffer levels were expressed as a percentage of the agricultural fields in the watershed which were protected by a buffer system. Thus at a buffer level of 5%, five percent of the crop fields (or 5% of the total acres) were protected with buffers. One acre of buffer would be installed for each 15 acres of crop field protected. Thus the total acres of buffers needed could be calculated by multiplying the crop acres in the watershed times the percent of watershed protected with new buffers and dividing by 15.

As buffer acres were applied at various levels, the spreadsheet model credited the increased CRP acres in the watershed and deducted the acres equally from the total corn and soybean acreage. It also calculated the savings due to the change in erosion rates and determined the number of acres of buffers necessary to treat the watershed at each of the various percentage levels, as well as the percentage of watershed acreage that would be occupied by buffers.

The spreadsheet model also simulated the changes in watershed erosion as different levels of conservation tillage were applied to the corn and soybean acreage. It calculated the sediment reduction effects for both the buffer effect and the conservation tillage effect, based on the changes in the erosion rates.

Assumptions in Analysis

The following assumptions were applied in developing the model:

- It was assumed farmers would use the Continuous CRP program to apply most of the buffers.

- It was assumed that farmers would tend to install smaller buffers along drainage ditches and larger buffers along larger streams, rivers and watershed. The minimum width of buffers would be 20 feet and maximum width 100 feet. Consultations with field personnel indicated the average buffer width would be 30-45 feet.

- The average area that could be protected by each acre of buffer was chosen to be 15 acres based on field and soil map observations. It was assumed that in most cases beyond this 15:1 field acres to buffer acres ratio, the buffer would not be effective. Fifteen acres was also used as the average area protected by each buffer to determine how many acres would be occupied by the buffers.

- Buffer trapping efficiency was assumed to be 50% and efficiency was further reduced by a landscape efficiency factor of 50%. **This resulted in cumulative buffer efficiency of 25% for the typical buffer in the Maumee watershed.** The net result is that it is believed to be a very conservative analysis based on the literature review.

- The buffer acres were projected to come from half corn and half soybeans since those are the predominant crops in the watershed. They were deducted equally from conservation and conventional tillage.

- The model did not account for any differences in sediment delivery based on the location of buffers within the watershed.

- Buffers applied in the analysis represented “new buffers” beyond what existed in 1992, that either will be installed, or were installed during the NRCS pilot project.

RESULTS

The analysis shows that widespread adoption of conservation buffers could be highly effective in reducing sedimentation into the Toledo Harbor. Buffers can contribute a significant portion of the NRCS goal of 130,000 cubic yards. Applying buffers to 35% of the agricultural acres (at a 60 and 70 % conservation tillage level) would account for 29,000 yards of sediment reduction due to the buffers and would represent approximately 22% of the NRCS goal of 130,000 cubic yards.

The buffer contribution will allow the agricultural goal of 130,000 cubic yards sediment reduction to be achieved at a more moderate level of conservation tillage adoption. Whereas the original phase III plan called for achieving this with a 75% level of conservation tillage in the watershed, this goal can now be achieved with a lesser amount of conservation tillage. This is highly significant. As the percentage of conservation tillage increases in the watershed, it becomes slightly more difficult to convert the remaining acres!

Soil trapped in the buffers is inversely related to the level of conservation tillage applied to the watershed. As conservation tillage increases, conservation buffers provide less sediment reduction because there is less erosion to filter out as opposed to low levels of conservation tillage. However, even at 75 percent conservation tillage levels, buffers provide a significant sediment reduction contribution. The cumulative effect of many buffers is highly significant. Additionally, as conservation tillage increases, buffers become more effective. They do not fill up as quickly and maintain their trapping efficiency longer. Also, the conservation tillage moderates the run-off from the field which further helps buffer efficiency.

Table 1 lists the sediment reduction as various combinations of conservation tillage and conservation buffers are applied to the watershed. Any value below and to the right of the dashed line represents a combination of buffers and conservation tillage that would meet or exceed the agricultural goal in the phase III plan.

The table would indicate that a level of 25 – 30% of the cropland in conservation buffers, combined with 55 – 65% of the corn and soybean acres in conservation tillage, will achieve the agricultural goal as called for in the phase II plan. This amount appears highly achievable in the time frame of the original NRCS Soil Conservation Program, **if the resources are provided for accelerated technical assistance (staff) and financial assistance as called for in that plan.**

OTHER OBSERVATIONS AND LIMITATIONS OF THIS ANALYSIS

Observations

- The success of this plan is predicated on continuation of the Conservation Reserve Program continuous signup provisions. At this time there is no reason to believe that this program will not be in existence for the time frame of the proposed NRCS project.

- The estimates chosen for the effectiveness of buffers are conservative based on the literature reviewed. Overall savings may be greater than those projected.

- The effectiveness of the buffers is very elastic with respect to the value chosen for the trapping efficiencies. Table 2 contains examples of the contributions of buffers to sediment reduction at various levels of buffer trapping efficiencies.

- Significant savings come from the reduced erosion on the land taken out of production to seed or vegetate the buffer.

- As conservation tillage acres increase in the watershed, there is less gross erosion for each acre of buffer to trap. However, the savings from buffers are still significant, even at the 75% conservation tillage adoption level. Average savings in dredging reduction is .497 yards per acre of buffer at the 1997 conservation tillage level of 43% corn and 60% soybeans, and declines gradually to .383 yards per acre at the 75% conservation tillage adoption level.

- If 35% of the agricultural cropland were buffered by applying new conservation buffers, the acreage needed would by 68,000 acres and occupy approximately 1.6% of the watershed's cropland base.

Limitations

- No provisions are made in the analysis to account for differences in delivery rates do to watershed position or distances from the harbor. For simplicity this analysis assumes that sediment is contributed uniformly over the watershed.

- This analysis looks only at crop acres as they existed in the 1992 reference year. Recent changes in USDA commodity programs and crop market prices are probably having the effect of increasing corn and soybean acres in the watershed and decreasing small grain acres. This is resulting in more gross erosion, which is increasing sediment delivery to the harbor and increasing the need for conservation buffers and conservation tillage. A more detailed model with updated land use data is needed to track these changes as they occur.

SUMMARY

Conservation buffers can provide a significant portion of the sediment reduction needed to meet the agricultural goals of the Toledo Harbor Study Phase III Report. Each acre of conservation buffer installed would provide from .383 cubic yards to .497 cubic yards of sediment reduction, depending on the level of conservation tillage in the watershed. Based on 1992 crop patterns, the combination of additional conservation buffers on 25% of the cropland acres, 55% conservation tillage corn, and 66% conservation tillage soybeans would provide an estimated sediment reduction of 131,163 cubic yards. This would meet the agricultural goal of 130,000 cubic yards in the Phase III report.

At the end of the pilot project (1997 crop year) 53 percent of the agricultural sediment reduction goal had been reached. This included installation of conservation buffers at the 5% level, conservation tillage corn at the 43 percent level, and conservation tillage soybeans at the 60 percent level.

Buffer effectiveness is very elastic due to the low erosion rates in the watershed. The impact of buffers is dependent on the number of acres applied as well as the value of the trapping efficiency used for each buffer.

As a result of the USDA commodity programs, cropping patterns may be changing to more acres of the most erosive crops. Hence one of the future project efforts should be to update this model to account for year to year changes in crop patterns.

REFERENCES

Correll, David L., Buffer Zones and Water Quality Protection: General Principles. Smithsonian Environmental Research Center. Edgewater, Maryland.

Findlay, Dr. W, Helen Lammers-Helps, and Douglas M. Robinson, July 1991. Literature Review Pertaining to Buffer Strips. National Soil Conservation Program, University of Guelph, Guelph, Ontario, Canada.

Magette, W., R.B. Brinsfield, R. Pallmer, J.D. Wood, T.a. Dillaha and R.b Reneau. 1987. Vegetative Filter Strips for Agricultural Runoff Treatment. U. S. EPA CBP/TRS 2/87

Neibling, W. H. and E.E. Alberts. 1979. Composition and Yield of Soil Particles Transported Through Sod strips. ASAE Paper No. 79-2065. Soil Particle Size

Natural Resources Conservation Service, February, 1993. Erosion and Sedimentation Dynamics of the Maumee River Basin and Their Impact on Toledo Harbor. Columbus, Ohio.

Wade, Jim, 1998. Geologist, Natural resource Conservation Service, Delaware, Ohio. Personal Communication.

Wilson, L.G. 1967. Sediment Removal From Flood Water by Grass Filtration, Transactions of the ASAE 10(1):35-37.

Young, R. A., T. Huntrods, W. Anderson. 1980 Effectiveness of Vegetated Buffer Strips in Controlling Pollution from Feedlot Runoff. J. Environ. Quality. (9) 3:483-487.

TOLEDO HARBOR PROJECT

POTENTIAL SEDIMENT REDUCTION FROM BUFFERS
(In Cubic Yards)

Conservation Tillage Level	**Conservation Buffer Level**				
	5%	**15%**	**25%**	**35%**	**45%**
1997 Pilot Project Corn @ 43% Soybeans @ 60% (with 5% new buffers)	***68,776***				
corn @ 50% soybeans @ 60% (56% avg.)	80,686	95,443	110,020	124,418	145,678
corn @ 55% soybeans @ 65% (61% avg.)	100,662	114,913	128,985	142,877	156,599
corn @ 60% soybeans @ 70% (66% avg.)	120,638	134,483	147,949	161,336	174,542
corn @ 75% soybeans @ 75%	157,682	170,437	183,067	195,516	207,787

Table 1.

ELASTICITY OF BUFFER EFFECTIVENESS

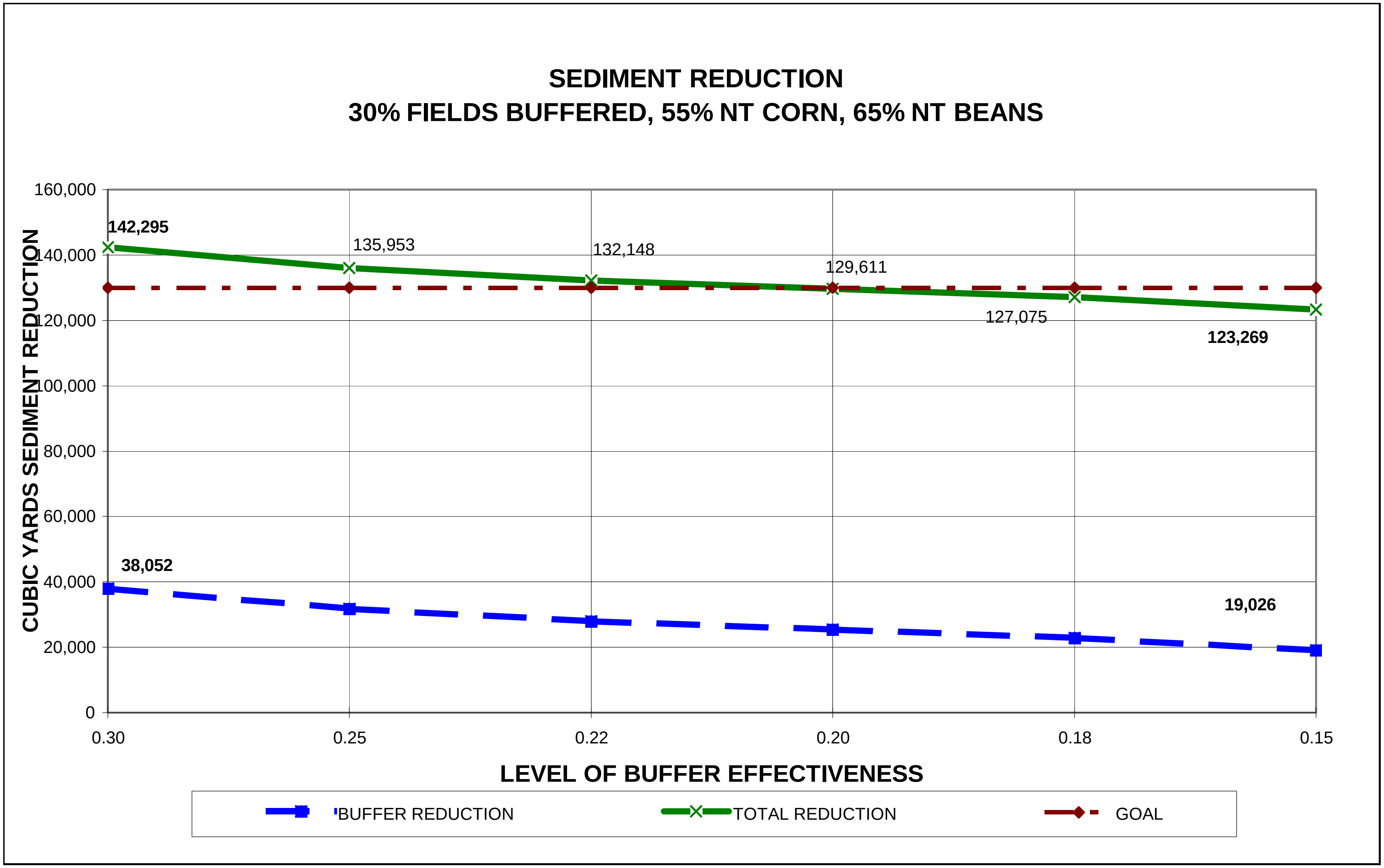

TABLE 2