Final Report

For the

WQMP Implementation Assistance

In the

Arroyo Colorado Watershed Management Project

FY 99, Clean Water Act, Section 319(h) Nonpoint Source Grant
Contract No. 99-104

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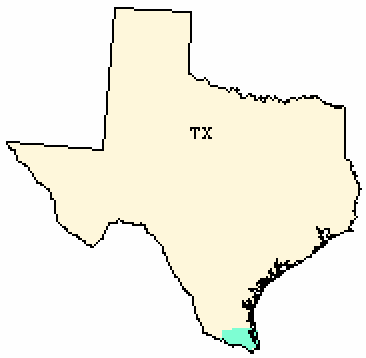
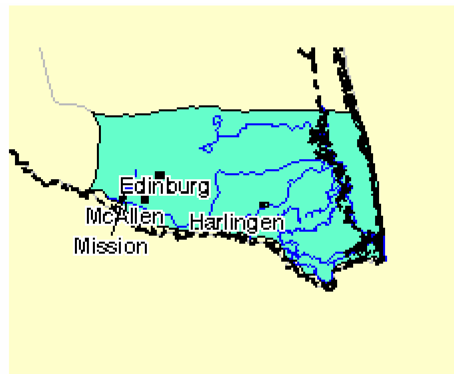
Acknowledgements

The implementation of this project required a great deal of cooperation and participation from several state and federal agencies. We would especially like to express our gratitude to the Natural Resources Conservation Service for providing technical and database assistance. A special thanks goes to the Texas State Soil and Water Conservation board for their promotional support and management of the project.

INTRODUCTION

The Arroyo Colorado River stretches approximately 143 kilometers (89 miles) from Hidalgo County, across Cameron County, and empties into the Laguna Madre, just north of the Cameron Willacy County line (TIAER, 1998). The Lower Laguna is home to hundreds of coastal species of waterfowl such as pelicans, flamingos and ducks. Twelve rivers and streams are located in this watershed (South Laguna Madre, 1999)





Rainfall across the watershed averages 22 to 26 inches annually, categorizing it as a semi-arid region (TDWR, 1984). Municipal wastewater treatment plant effluent and irrigation return flows supersede rainfall runoff as the major contributors to the river's flow (TIAER, 1998). Average annual lake evaporation in the Arroyo Colorado watershed is approximately 32 inches greater than average annual precipitation (USDA, 1977).

The fertile soils of the Arroyo Colorado watershed serve to make the area one of the most productive agricultural regions of Texas (TIAER, 1998). One third of Cameron County's 300,190 hectares are used as cropland (Texas Agricultural Statistics, 1996). Surface water serves as the source of irrigation water for the agricultural enterprises of the area (TIAER, 1998). Agricultural and urban runoff contribute to numerous water quality problems in the area. The *1990 Update to the Nonpoint Source Water Pollution Assessment Report for the State of Texas* (TWC & TSSWCB, 1991) listed the status of Segment 2201 and 2202 a "Known Concern" due to elevated phosphorous, nitrogen, nutrients, fecal coliform, mercury, dissolved oxygen, and chlordane in fish tissue. The potential sources identified for the segment were irrigated crop production, septic tanks, and urban sewers (TIAER, 1998). A 1987 intensive priority monitoring of the Arroyo Colorado concluded that nonpoint sources, primarily agriculture, contribute the majority of the toxic pollutants to the Arroyo Colorado (TWC, 1989b).

Nonpoint source pollution generated from urban and agricultural runoff has the potential for contaminating groundwater and surface water resources in the Arroyo Colorado River Basin. The large volume of water per acre that is used to irrigate crops in this semi-arid region results in a potential for pollution by runoff carrying agricultural chemicals from the field.

Total number of watershed acres: 39241.2

River and stream miles:

- 2064.2 total river miles
- 1891.1 perennial river miles

This modeling project will establish long-term effects of implemented best management practices (BMPs) designed to reduce NPS pollutants in the watershed. Techniques of managing water, land resources, fertility programs, and cropping sequences have been introduced to landowners. BMPs were selected based on local needs and their potential to reduce nutrient loading of the watershed from agricultural activities.

Beneficiaries of this project will include rural and metropolitan areas that depend on Arroyo Colorado water resources for domestic uses. The coordinated modeling phase of the project will inform land users and area residents of BMPs that will improve and protect the quality of water resources.

The Texas State Soil and Water Conservation Board (TSSWCB) in cooperation with the Texas Agricultural Experiment Station (TAES), and local Soil and Water Conservation Districts (SWCD) will implement this project in accordance with interagency contracts. The purpose of this project is to conduct a water quality-modeling program to document the reduction of NPS impact to the Arroyo Colorado watershed resulting from implementation of appropriate nutrient, tillage, and irrigation BMPs.

TAES-BRC is under contract with TSSWCB and will develop and conduct modeling efforts to document the effects of BMP implementation within selected demonstration areas.

The Texas Natural Resources Conservation Commission has listed the Arroyo Colorado river watershed as a watershed of concern regarding excessive nutrient losses potentially contributed by various pollutant sources, such as urban runoff, agricultural runoff, irrigation return flow, and municipal and industrial wastewater and effluent. Due to the limited data sources, this analysis focuses on the issue of nutrient losses largely contributed by commercial fertilizer applications in crop production and better management techniques. To do so, all GIS-identified urban land areas were simulated as unfertilized bermudagrass to isolate the effects of agricultural fertilization. For purposes of this study, the whole watershed is considered to end at the Gulf coast in eastern Cameron county, with its beginning at the west end of Hidalgo county. The study area is 828.7 square miles. It contains two moderately sized sub-watersheds delineated by the mainstreams of Floodway River and Arroyo River.

The area is comprised of 87% cropland, 9% urban and 4% rangeland. Of the total cropland, 40% is irrigated and 60% is dryland. Sorghum is the most dominant crop, accounting for 58% of the cropland, cotton, 26%; and corn, 16%. Minor acreage of vegetables and citrus orchards were excluded from the simulated area. Soil types in the immediate watershed vary from loamy sand to clay loam in texture. Common range grasses include several bluestems, lovegrass tridens, fourflowered trichloris, red grama, curly-mesquite, and Arizona cottontop.

Yearly rainfall is approximately 22.7 inches. Monthly rainfall during the year has two seasonal peaks, May and October.

TASK 1: PROGRAM COORDINATION WITH PROJECT PARTICIPANTS

OBJECTIVE: *To foster coordinated technical assistance activities in the Arroyo Colorado watershed between the TSSWCB, local SWCDs, NRCS, and BRC*

Progress reports were submitted to the TSSWCB on the following dates:

June 18, 2000
October 24, 2000
January 15, 2000
April 17, 2001
July 13, 2001
November 8, 2001

Progress was essentially completed after this last progress report. Additional information from TSSWCB on recent 2000/2001 implementation necessitated further mapping and model simulation during the last quarter (February-April, 2002).

TASK 2: DEVELOPMENT AND IMPLEMENTATION WQMPs

OBJECTIVE: *To provide technical assistance to landowners in developing and implementing WQMPs within the Arroyo watershed within each SWCD.*

Task 2.1 TAES-BRC will model the Arroyo Colorado watershed to identify areas within the watershed to target for WQMP implementation.

The process to target areas is through the use of the Geographic Information System (GIS) geographic Resources Analysis Support System (GRASS) spatial data bases and hydrologic models. The hydrologic model used for this task is the Soil and Water Assessment Tool (SWAT). SWAT is an improved version of the Simulator for Water Resources of Rural Basins (Neitsch et al., 1999) (http://www.brc.tamus.edu/swat) and operates on a daily time step. Major model output components include surface runoff percolation, groundwater contribution to stream flow, and sediment, pesticide and nutrient loadings.

Available spatial data bases include the U.S. Geological Survey 1:250,000 digital elevation model, land use, and the NRCS STATSGO soils data base. None of the databases were altered for this analysis. Thirty (1969-1999) years of weather data from three sites in the watershed were used to get a range of rainfall conditions. The model was run over 30 years to represent the common range of precipitation and runoff events. To ensure that representative output values were obtained, the procedures followed a quality assurance project plan (QAPP). The plan is given in Appendix A.

Output of NO_3, soluble P in the runoff, organic N and P, and sediment concentration are mapped on Figures 1A-5A. The maps were created early in the project and indicate that there are significant loadings from specific subbasins, but are generally uniform throughout the watershed. This information was used by TSSWCB and NRCS to try and implement BMPs throughout the watershed.

Tasks 2.2-2.6 Completed by TSSWCB, NRCS, SWCDs

Task 2.7 Map the locations of WQMP implementation areas

BMP implementation areas are separated into 2 groups: 1999-2000 and 2001-2002. Locations of the areas (by latitude and longitude) were input into the available data bases and maps were created on how the areas overlaid with subbasins. (Additional subbasins from the initial targeting task 2.1 were developed to isolate additional potential impact differences). The maps are shown in Appendix B (with tables describing the types of implemented practices for 1999-2000 and locations and the 2001-2002 locations).

TASK 4: MAPPING AND MODELING OF WQMPS IMPLEMENTED IN THE ARROYO COLORADO WATERSHED

OBJECTIVE: *To map the location and types of BMPs implemented and to model the reductions in NPS pollution from WQMP implementation.*

Task 4.1. Based on the information compiled on the location and types of BMPs for each WQMP implemented within the Arroyo Colorado watershed, BRC will map those locations of each WQMP implemented in the Arroyo watershed.

From 1999-2000 and in 2001-2002, the TSSWCB obtained information on individual farmers/ranchers that implemented BMP's within the watershed. All of the participating farmers implemented nutrient, irrigation, and residue management BMPs. An interim map that displays the location of each farmer/rancher that implemented BMPs in 1999-2000 within the watershed was developed based on latitude and longitude locations provided by the TSSWCB (Figures 1 and 2 in Appendix B). A follow-up map was developed based on the location of the farms/ranches that implemented BMPs in 2001-2002 (Figure 3 in Appendix B). Approximately 90% of the sub-basins include farms/ranches that have implemented BMPs during either period.

Task 4.2. BRC will use the SWAT model or comparable model to show reductions in NPS pollution derived from WQMP implementation in the Arroyo watershed.

MODEL SIMULATIONS OF THE ARROYO COLORADO
OBEJCTIVES OF THE ANALYSIS

Objectives of this analysis include:

1. With computer simulation, estimate the annual Arroyo Colorado River watershed nutrient losses based on present crop production for a 30-year period,
2. Analyze the 30-year impact on nutrient losses using conservation tillage versus conventional tillage practices, and
3. Analyze the 30-year impact on nutrient losses using improved nutrient management.

Using a computer simulation model, SWAT (Soil and Water Assessment Tool), developed by Neitsch et al. (1999) (http://www.brc.tamus.edu/swat) will attain these objectives,

TILLAGE (RESIDUE MANAGEMENT) PRACTICES

Simulations compare two tillage alternatives: conventional and conservation tillage. Conventional tillage reflects current land use and management practices in the watershed whereas conservation tillage practices enhance residue levels on the soil surface. They are expected to produce different environmental impacts. A full description of each follows:

A. Conventional tillage –conventionally tilled crop rotations corn/cotton, cotton/corn, sorghum/cotton, cotton/sorghum, and continuous sorghum. Except for the continuous sorghum produced only on dryland, all other crop rotations were both irrigated and dryland. For irrigated crop production, 10.8 inches/ac irrigation was applied to sorghum, 12.8 inches/ac to corn, and 11.8 inches/ac to cotton (Texas Water Development Board, 2000). Commercial fertilizer nitrogen (N) as well as phosphorus (P were utilized for crop production. Irrigated sorghum received 103 lbs N/ac and 13 lbs P/zc; 152 lbs N/ac and 50 lbs P/ac were applied to irrigated corn; 89 lbs N/ac and 40 lbs P/ac to irrigated cotton. In contrast, 58 lbs N/ac was applied to dryland sorghum with no P; 143 lbs N/ac and 36 lb P/ac to dryland corn; and 63 lbs N/ac and 36 lbs P/ac to dryland cotton. Additionally, 2.7-lbs/ac atrazine was used on sorghum and corn for weed control.
B. Conservation Tillage—Same as conventional tillage except all tandem disk, offset disk, and moldboard plow operations were replaced with a field cultivator. Lower runoff curve numbers that reduce runoff were used to reflect the change in tillage operations.

ANALYTICAL METHODS AND PROCEDURES

The analytical methods and procedures involved the following approach:

1. Based on current agricultural practices in the two sub-watersheds, Floodway River and Arroyo River, and previously developed hydrologic parameters as well as precipitation data from three weather stations in the watershed (Bednarz, personal communication, 2001). The three weather stations included Harlingen, McAllen, and Weslaco, which were respectively located in the west, central, and northeast areas in the watershed.
2. Five crop rotations outlined above and unfertilized pasture and bermudagrass (urban) were simulated for a 30-year period to assess differences in nutrient losses resulting from converntional and conservation tillage practices.

Initially, using a GIS interface with digital elevation measurements and locating separate sub-watershed boundaries identified sub-areas by appropriate changes in elevation. Land use/land cover data was utilized to identify the sub-basins having predominantly cropland, range or urban land. Secondly, dominant soil types for all sub-areas were determined by a computerized SWAT interface program utilizing STATSGO soils. Dominant soils for each sub-basin were verified with published county soil surveys (USDA-NRCS, 1977 and 1981). Due to the fact that most dominant soil types in the sub-basins accounted for more than 50% of the soil compositions, the dominant soil was selected. Thirdly, sub-basin sizes, land slopes, stream slopes and slope lengths were all internally determined by an ArcView interface program using digital elevation mapping (DEM) and various threshold magnitudes. However, if the interface sometime determined few or several very small or excessively large sub-basin areas, adjustments were made by manually adding/removing outlets on the streams until each sub-basin was a reasonable size.

Climate conditions, except rainfall and temperature, were based on generated weather data in validation runs where two time periods of actual weather data were utilized. The 1991-98 period was chosen for crop yield validation and the other (1982-94) was utilized for validation of P losses. The reason for using these two time periods was that measured data used for validation was collected in the corresponding years. For the 30-year simulations only generated, weather data were utilized.

Crop acreage were aggregated for the total watershed and compared with 1991-98 average crop acreage for the two counties (Texas Agricultural Statistics Service, 1991-1998).

VALIDATION OF THE SWAT MODEL BASED ON HISTORICAL COUNTY CROP YIELDS

Simulated yields of corn, sorghum, and cotton were compared with 1991-1998 average yields of Cameron, and Hidalgo Counties (Texas Agricultural Statistics Service, 1991-1998). For grain yield validation purposes, the same period (1991-98) of actual rainfall and temperature data was utilized for simulating average crop yields. The average crop yields were simulated: 79 bu/ac for corn, 4,299 lbs/ac for irrigated sorghum, 2,108 lbs/ac for dryland sorghum, 556 lbs/ac for irrigated cotton, and 444 lbs/ac for dryland cotton. The actual measured crop yields were 83 bu/ac for corn, 4174 lbs/ac for irrigated sorghum, 2,586 lbs/ac for dryland sorghum, 541 lbs/ac for irrigated cotton, and 422 lbs/ac for dryland cotton. The small yield differences between simulated and actual records validate the SWAT model.

VALIDATION OF THE SWAT MODEL FOR TOTAL P CONCENTRATION IN RUNOFF AND SEDIMENT

Earlier, nutrient concentration measurements were based on three stations: the non-tidal reach, the tidal reach, and the North Floodway which is a tributary to the Arroyo. From 1982 to 1994, the average measured concentration of total P was 0.8 ppm (Fipps, 1997). SWAT simulated 0.72 ppm of total P, which was accurate enough for validation. The simulated P loss may be lower due to the fact that urban land was treated as unfertilized bermudagrass. Obviously, this assumption benefited water quality by minimizing urban influences of lawn fertilization. Another reason is that the measured total P concentrations were conducted at three spots in the the watershed, whereas the simulated results were based on concentrations at the Floodway and Arroyo River outlets to the Gulf of Mexico.

The model was validated by by crop yields as well as total P concentrations, it was directly used to carry out 30 years of a long-term simulation using actual weather conditions. The results follow.

IMPACTS OF NUTRIENT LOSSES UNDER ALTERNATIVE MANAGEMENT PRACTICES

Discussion of the simulation results focuses on the 30-year average N and P concentrations in runoff and sediment in the Arroyo Colorado River watershed.

Conventional Tillage

Surface runoff for the total area of the Arroyo Colorado River watershed averaged 5.78 inches per year, ranging across sub-basins from a minimum of 0.5 inches to a maximum of 11 inches. The lowest runoff occurred on rangeland with a Willacy soil and the highest occurred on an irrigated cotton field with a Hidalgo soil. Sediment losses averaged 1.51 tons/ac annually or approximately 801 thousand tons/year from the waershed (Table 1). The yearly average sediment loss ranged across sub-basins from a minimum of 0.01 tons/ac which occurred on dryland cotton with a Raymondville soil to a maximum of 6 tons/ac which occurred on irrigated cotton with a Harlingen soil.

Yearly total N losses average 7.2 lbs/ac, ranging from 0.1 lbs/ac to 20.6 labs/ac across sub-basins. Again, the former occurred on rangeland with the Willacy soil, the same area as the minimum runoff occurred, and the latter happened on irrigated cotton with a Raymondville soil. Total P losses averaged 0.93 lb/ac yearly in which 0.80 lbs was from sediment loss and 0.13 lbs ws from runoff. Converting these losses into concentrations, nitrate-N at 4.9 ppm was about half of EPA's regulated standard of 10 ppm for drinking water quality. The total P concentration was 0.71 ppm, about 11% lower than the in-stream measurements conducted during 1982-94 (Table 1).

<u>Table 1. Arroyo Colorado River Simulated Average Total N and P Losses, and Yields From Alternative Residue Practices</u>

Category	Conv. Tillage	Cons. Tillage	Difference	% Change
Surface runoff (in)	*5.78*	*5.79*	*0.01*	*0.21*
Sediment (ton/ac)	*1.51*	*1.41*	*-0.10*	*-6.51*
N losses:				
N losses in sediment (lbs/ac)	6.32	5.93	-0.39	-6.22
NO_3 losses in runoff (lbs/ac)	0.86	0.95	0.08	9.62
NO_3 leached (lbs/ac)	0.01	0.02	0.00	13.33
Total NO_3-N losses (lbs/ac)	7.20	6.89	-0.31	-4.28
NO_3 –N concentration in the water (ppm)	4.90	4.70	-0.20	-4.08
P losses:				
P losses in runoff (lbs/ac)	0.13	0.13	0.01	4.26
P losses in sediment (lbs/ac)	0.80	0.76	-0.04	-4.68
Total P losses (lbs/ac)	0.93	0.90	-0.03	-3.46
P concentration in the water (ppm)	0.71	0.68	-0.03	-4.23
Crop Yields:				
All corn	91.6	91.6	0.00	0.00
Irrigated Sorghum (bu/ac)	4735	4735	0.00	0.00
Dryland Sorghum (lbs/ac)	2295	2295	0.00	0.00
Irrigated Cotton (lbs/ac)	491	491	0.00	0.00
Dryland Cotton (lbs/ac)	459	459	0.00	0.00

Conservation Tillage

As the intensity of soil disturbance was diminished and residue levels were enhanced with conservation tillage, total N and P losses were decreased relative to conventional tillage. Reductions were largely due to lower sediment losses, which were responsible for the majority of N and P losses. Total yearly sediment losses averaged 1.41 tons/ac, over 6% below conventional tillage. The average annual sediment losses ranged from 0.01 tons/ac to 5 tons/ac occurring in the same sub-areas as conventional tillage, i.e., the minimum occurred on dryland cotton with a Raymondville soil, and the maximum occurred on irrigated cotton with a Harlingen soil. In contrast, annual surface runoff was approximately the same as conventional tillage, averaging 5.79 inches/ac and ranging across sub-basins from a minimum of 0.49 inches/ac to a maximum of 11.4 inches/ac which also occurred in the same sub-areas as conventional tillage.

Total N losses averaged 6.89 lbs/ac, more than 4% below conventional tillage. Across sub-basins, N losses ranged from 0.06 lbs/ac to 20 lbs/ac. Total annual P losses averaged 0.90 lbs/ac, again over 3% lower than conventional tillage (Table 1). In terms of the concentrations, total nitrate-N losses averaged 4.7 ppm, 4% lower than conventional tillage, and the total P losses averaged 0.68 ppm, also about 4% lower than conventional tillage (Table 1).

SWAT RUNS ON THE IMPACT OF BMP IMPLEMENTATION

The SWAT model was run to evaluate the impact of BMP implementation within the watershed. Implemented BMP acreage was input with different levels on fertilization (60, 90, and 120 kg/ha application of N fertilizer). The fertilizer selected was one with a 12-20-15 ratio. These were expected to produce a range of environmental impacts. Three types of scenarios were analyzed: (1) BMP implementation on all agricultural land within the specified BMP implemented sub-basins, and (2) BMP implementation on only the implemented acreages and (3) no fertilizer applications. The input databases were developed as described for tillage management.

Results (Figure 1 in Appendix C) indicate that through fertilizer management on all agricultural land in the watershed, there can be as much as a 50% decrease in soluble P in runoff (decrease from 12 kg/ha for 120 kg/ha application to 6 kg/ha for a 60 kg/ha application). For the scenario of BMP implementation on the 1999-2002-application area, there is an approximate 36% decrease in soluble P in runoff comparing the same application rates (120 kg/ha vs. 60 kg/ha application rate). There was a corresponding 27% reduction in N loading in runoff. Phosphorus decreased from 0.301 kg/ha to 0.194 kg/ha and nitrogen decreased from 0.989 to 0.354 kg/ha. This reduction was greater than anticipated as stated in the QAPP. Additional figures showing the monthly average loading over the 30-year period are also in Appendix C. There were several months that the loading (kg) can get very high in conjunction with high precipitation.

These loadings are reasonable to what has been measured in the watershed. Calculated average annual concentrations from these loadings are 0.5 ppm for phosphorus and 4 ppm for N. TIAER (1998) found those concentrations of 0.2 and 0.3 ppm for soluble N and P, respectively, in plot studies. Fipps (1997) measured soluble N concentrations averaging approximately 3-4 ppm and soluble P concentrations of 0.8 ppm at several sites in the watershed. Consequently, the simulated nutrient concentrations are within 20-30% of measured data. This is within the range as specified within the QAPP. Other measured data from the watershed and same time period have not been found.

SUMMARY AND CONCLUSIONS

This study evaluated the expected change in yearly average nutrient losses resulting from runoff and sedimentation for a 30-year period if cropland management practices using conventional and conservation tillage were compared in the Arroyo Colorado River watershed. SWAT simulation results indicate both tillage practices are not expected to degrade the ambient water quality on average below EPA drinking water quality for nitrate-N levels. Both conventional and conservation tillage and nutrient management resulted in less than 5 ppm of nitrate-N concentrations. Total P concentrations were even less, below 0.8 ppm.

Low nutrient losses were probably attributed to the fact that this watershed area has a very flat topography, which minimizes runoff and sediment losses. Conservation tillage resulted in small reductions of N and P losses compared with conventional tillage, mostly less than 5%. Since the watershed has little slope, changing tillage practices affect runoff and sedimentation in only a small way. Also, the model would not be sensitive enough for irrigation management improvements.

Additionally, the low N and P losses may be due to the fact that simulations were based on the simplified land use/cover conditions, i.e., all urban land was treated as unfertilized bermudagrass. Such a simplification underestimates nutrient losses two ways: (1) Applying no fertilizer to urban and rangeland sub-basins contributes no additional nutrients to the watershed beyond those mineralized naturally, and (2) Urban areas simulated as bermudagrass and rangeland sub-basins provide natural buffers for upstream cropland sub-basins, thereby safeguarding against nutrient losses from sediment and runoff water (Harman and Wang, 2000). In the event that such simplifications were removed, using the actual urban land will probably simulate higher magnitudes of N and P losses.

LIMITATIONS

This study is limited by the scarcity of validation data for sedimentation and in-stream flow measurements of runoff. The model was first validated using historical crop yields which, in turn, validates the accuracy of simulated nutrient applications and soil water balances. Secondly, historical in-stream measurements at specific locations were utilized to validate total P concentrations at the watershed outlets. The concentrations were based on three stations on the low end of the Arroyo Colorado River. Due to the large size of the watershed, which has diversified crop rotations and soil types, simply using three sites of P concentrations for validation may be inadequate.

However, in the event that simulated nutrient losses are in error, comparisons between the residue and nutrient alternatives analyzed in the study would be affected only by magnitude—not their relative relationship. Consequently, policy makers, public water supply managers, soil and water conservationists, water consumers, ranchers, farmers, and others having a vested interest in extending the useful life of Arroyo Colorado River watershed by minimizing nutrient losses can utilize these comparisons with a high degree of confidence that the relative impacts will be accurate.

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APPENDIX A

MODELING QUALITY ASSURANCE PROJECT PLAN (QAPP)

APPENDIX B

MAPS SHOWING LOCATIONS OF BMP IMPLEMENTATION

APPENDIX C

MODEL SIMULATIONS 30-YEAR AVERAGE EFFECTS OF IMPLEMENTED NUTRIENT MANAGEMENT