North Central Texas
Water Quality Project

AgriLIFE RESEARCH & EXTENSION

Watershed Protection Plan Development for the Cedar Creek Watershed

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The Texas A&M University System

TARRANT REGIONAL WATER DISTRICT

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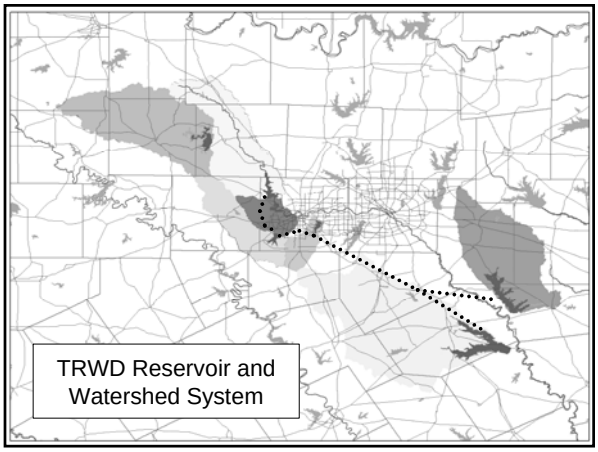
Tarrant Regional Water District

- Serves 1.7 million people
  - –Eleven counties in and around Fort Worth
- Expected to serve a population of 2.6 million people by 2050
- Contracts with 67 cities
- Manages 5 major reservoirs
  - –Cedar Creek, Eagle Mountain, Richland-Chambers, Bridgeport and Benbrook.



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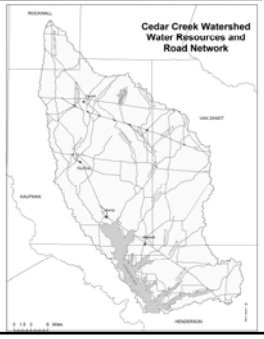
Cedar Creek Reservoir

- Watershed size – 1,007 square-miles
- Surface area - 34,000-acres
- Conservation Storage - 678,000 ac/ft
- Mean Depth – 20 ft
- Maximum Depth – 55 ft
- Shoreline – 320 miles



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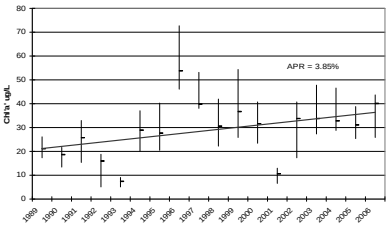
18-Year Trend (Chl'a') in Cedar Creek



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Water Quality - 303 (d) Listing
Draft 2006 Data

- High pH
  - –Category 5c, on 303(d) list
    - Additional data and information will be collected before a TMDL is scheduled
- Use Concerns
  - –Depressed Dissolved Oxygen
    - Aquatic Life Use Concern
  - –Ammonia, Orthophosphorus, Total Phosphorus, Nitrite
    - Nutrient Enrichment Concern
  - –Excessive Algal Growth, Chlorophyll a
    - Algal Growth Concern

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Watershed Modeling: SWAT

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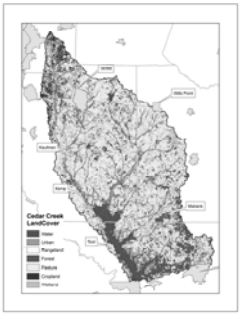
Cedar Creek Watershed

- Landuse



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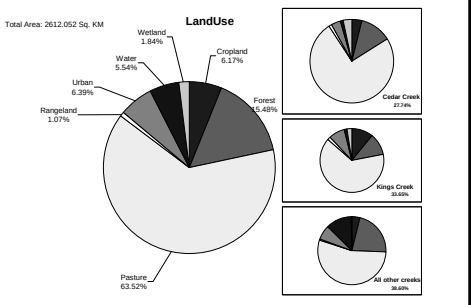

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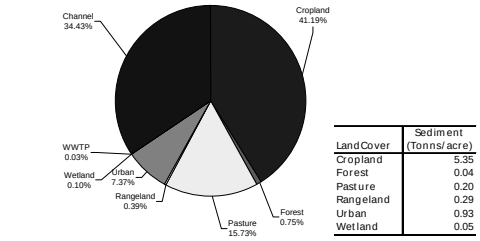

LandCover	Sediment (Tonns/acre)
Cropland	5.35
Forest	0.04
Pasture	0.20
Rangeland	0.29
Urban	0.93
Wetland	0.05

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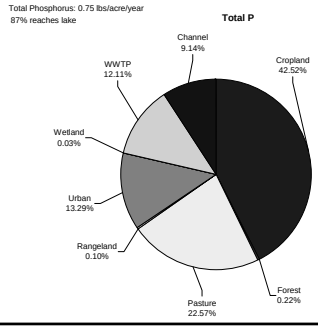
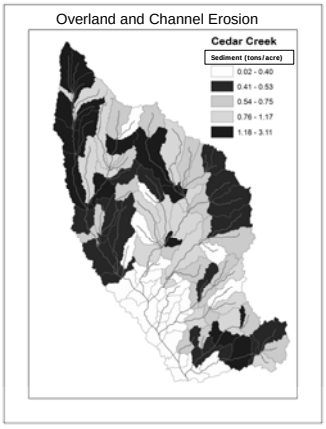
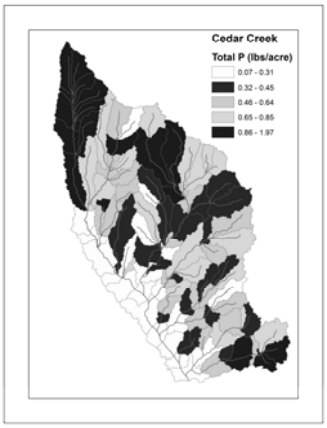


LandCover	Total P (lbs/acre)
Cropland	2.57
Forest	0.01
Pasture	0.13
Rangeland	0.04
Urban	0.78
Wetland	0.01





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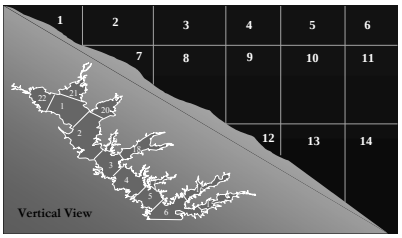
Cedar Creek Reservoir Model Representation using WASP



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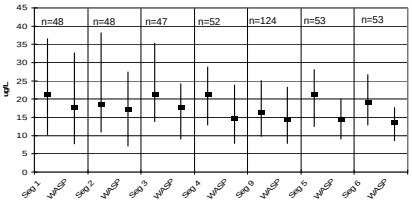
Cedar Creek WASP Modeling Results Chl'a' (1991-2001)



Description: n represents the number of observed data points used for comparison to monthly WASP predicted results.

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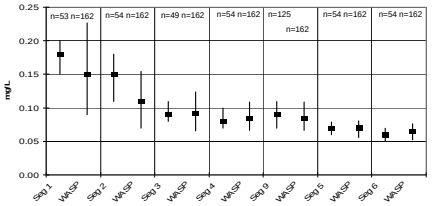
Cedar Creek WASP Modeling Results TP (1991-2001)



Description: n represents the number of observed data points used for comparison to monthly WASP predicted results.

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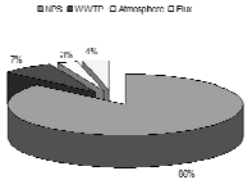
Cedar Creek WASP Model Nutrient Budget – TP (1991-2001)



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Cedar Creek Watershed Point Source Evaluation

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Approach

- Each plant was assessed for the ability to properly treat projected 2050 flows under three sets of discharge limits for nutrients.
  - **Level I**: Existing permit conditions
  - **Level II**: Phosphorus limit of 1 mg/L
    Total nitrogen limit of 10 mg/L
  - **Level III**: Phosphorus limit of 0.5 mg/L
    Total nitrogen limit of 5 mg/L

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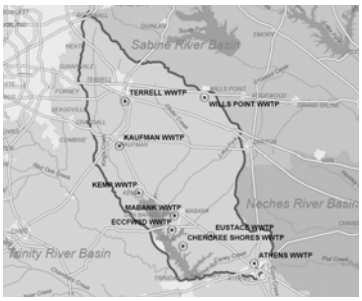
Wastewater Treatment Plants Evaluated



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Nutrient Loads* Associated with Each Level Upgrade (2050 Loads vs. Current)

City or Facility	Total Nitrogen Load (lbs/day)			
	Current Permitted Flow	2050 Flows		
		Level I	Level II	Level III
Athens	116	129	95	48
Cherokee Shores	47	57	15	8
East Cedar Creek	122	312	133	67
Eustace	25	25	11	5
Kaufman	135	186	138	69
Kemp	24	14	9	5
Mabank	39	51	43	22
Terrell	740	947	480	240
Wills Point	80	51	43	21
Total Loads	1,328	1,772	967	485
Increase or (Decrease) from Current Load		444	(361)	(843)

*Current and Level I loads based on average effluent concentration determined by nutrient testing done by the cities

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Nutrient Loads* Associated with Each Level Upgrade (2050 Loads vs. Current)

City or Facility	Total Phosphorous Load (lbs/day)			
	Current Permitted Flow	2050 Flows		
		Level I	Level II	Level III
Athens	24	27	10	5
Cherokee Shores	5	6	2	0.8
East Cedar Creek	11	29	13	7
Eustace	5	5	1	0.5
Kaufman	29	39	14	7
Kemp	5	3	0.9	0.5
Mabank	13	17	4	2
Terrell	151	194	48	24
Wills Point	18	11	4	2
Total Loads	261	331	97	49
Increase or (Decrease) from Current Load		70	(164)	(212)

*Current and Level I loads based on average effluent concentration determined by nutrient testing done by the cities

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Setting Water Quality Goals

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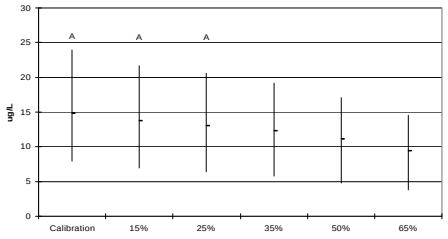
Chl'a' Segment 4: Reduction in SWAT *NPS File Loading – Median and Percentiles (91-01)



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Selection and Prioritization of Best Management Practices

Targeting Sub-basins

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Cropland

- 6% of the Watershed
  - 40% of Total Sediment Yield
  - 23% of Total Nitrogen Yield
  - 42% of Total Phosphorus Yield
- Cropland Erosion rate is 5.35 mt/ac/yr
  - Equivalent to .8 to 1.1 mm of topsoil per year

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Cropland BMP's

- Filter Strips
- Contour Farming
- Terracing
- Grassed Waterways
- Crop Residue Management
- Cropland Conversion to Pasture
- Fertilizer/ Nutrient Management

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Sub-basins With More Than 10% Cropland Area

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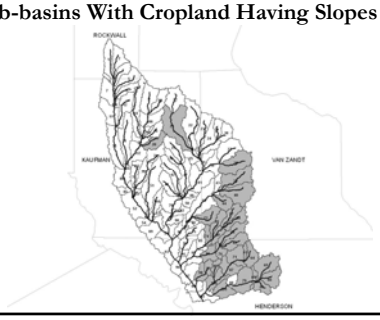
Sub-basins With Cropland Having Slopes >2%



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Pasture and Rangeland

- 62% of the Watershed
  - 16% of Total Sediment Yield
  - 44% of Total Nitrogen Yield
  - 23% of Total Phosphorus Yield

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Pasture and Rangeland BMP's

- Prescribed Grazing
- Fencing
- Water Facility
- Fertilizer/ Nutrient Management
- Pasture Planting
- Range Planting
- Grassed Waterway
- Riparian Buffer strips

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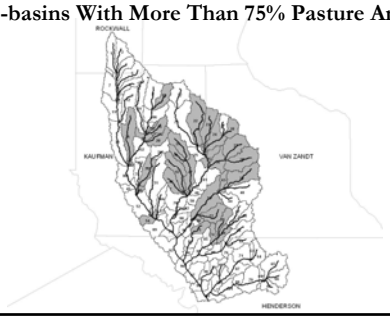
Sub-basins With More Than 75% Pasture Area



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Channels

- 751 km of channels in the watershed
  - 35% of Total Sediment Yield
  - 5.5% of Total Nitrogen Yield
  - 9% of Total Phosphorus Yield

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Channel BMPs

- Riparian Buffers
- Channel Stabilization
- Shoreline Protection
- On and Off Channel Water and Sedimentation Control Basins

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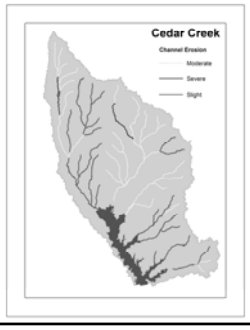
Channel Erosion



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Watershed

- Total Area 2612.052 Sq. km
  - Pasture 63.52%
  - Rangeland 1.07%
  - Urban 6.39%
  - Water 5.54%
  - Wetlands 1.84%
  - Cropland 6.17%
  - Forest 15.48%

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Watershed BMP's

- Sediment Basins
- Channel Stabilization
- Streambank Protection
- Wetlands
- Grade Stabilization

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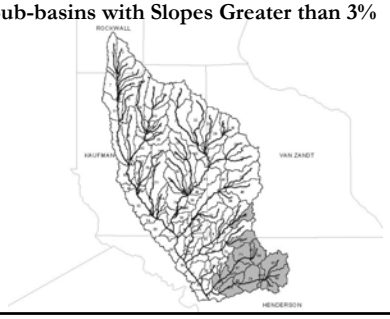
Sub-basins with Slopes Greater than 3%



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Distribution of Urban Land Cover

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Reservoir BMP's

- Hypolimnetic Aeration
- Hypolimnetic Release
- Dredging
- Water Colum Mixing
- Alum Treatment

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Economic Analysis

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BMP	Type	Description	Adoption Rates		
			Current	Maximum	Marginal
#001	Cropland	Cropland to Grass	0.0%	20.0%	20.0%
#001A	Cropland	Contour Farming	30.0%	75.0%	15.0%
#003	Cropland	Fertilizer/ Nutrient Mgmt	0.0%	75.0%	75.0%
#004	Cropland	Filter Strip	0.0%	75.0%	50.0%
#006	Cropland	Grassed Waterways	10.0%	50.0%	10.0%
#007	Cropland	Terracing	50.0%	75.0%	15.0%
#101	Pasture & Rangeland	Prescribed Grazing	10.0%	50.0%	25.0%
#105	Pasture & Rangeland	Pasture Planting	5.0%	50.0%	40.0%
#107	Pasture & Rangeland	Critical Pasture Planting	70.0%	90.0%	20.0%
#s 201 - 209	Urban	Phase II Urban BMPs	0.0%	100.0%	65.0%
#210	Urban	Voluntary Urban Nutrient Mgmt	10.0%	25.0%	15.0%
#211	Urban	Required Urban Nutrient Mgmt in 2,000 ft Reservoir Buffer Strip	10.0%	80.0%	70.0%

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BMP	Type	Description	Adoption Rates		
			Current	Maximum	Marginal
#301A	Channel	Riparian Buffer Strips — except critical areas	0.0%	50.0%	20.0%
#302	Channel	Riparian Buffer Strips — critical areas	0.0%	10.0%	10.0%
#401A1	Watershed	Wetland - Lower Kings Creek (SB 54)	0.0%	100.0%	100.0%
#401B1	Watershed	Wetland - End Cedar Creek (SB 70)	0.0%	100.0%	100.0%
#402	Watershed	Grade Stabilization	0.0%	100.0%	100.0%
#501	Reservoir 'In-Lake'	Hypolimnetic Aeration	0.0%	100.0%	100.0%
#502B	Reservoir 'In-Lake'	P Inactivation with Alum – 1/3 of Reservoir	0.0%	100.0%	100.0%
#505	Reservoir 'In-Lake'	Hypolimnetic Water Release from Reservoir	0.0%	100.0%	100.0%
#701	WWTP	WWTP - - from Level I to Level II	0.0%	100.0%	100.0%
#702	WWTP	WWTP - - from Level I to Level III	0.0%	100.0%	100.0%

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BMP	Type	Description	Efficacy Rates		
			P	N	Sed
#001	Cropland	Cropland to Grass	-7.00%	-3.70%	-5.60%
#001A	Cropland	Contour Farming	-1.29%	-0.21%	-1.29%
#003	Cropland	Fertilizer/ Nutrient Mgmt	-1.50%	0.00%	0.00%
#004	Cropland	Filter Strip	-15.00%	-8.50%	-11.00%
#006	Cropland	Grassed Waterways	-0.18%	-0.31%	-0.57%
#007	Cropland	Terracing	-2.10%	-0.45%	-2.10%
#101	Pasture & Rangeland	Prescribed Grazing	-1.56%	-4.33%	-2.22%
#105	Pasture & Rangeland	Pasture Planting	-2.36%	-6.57%	-3.37%
#107	Pasture & Rangeland	Critical Pasture Planting	-1.87%	-4.19%	-2.95%
#s 201 - 209	Urban	Phase II Urban BMPs	-10.0%	-10.99%	-5.00%
#210	Urban	Voluntary Urban Nutrient Mgmt	-1.56%	-0.98%	-0.28%
#211	Urban	Required Urban Nutrient Mgmt in 2,000 ft Reservoir Buffer Strip	-1.11%	-2.20%	0.00%

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BMP	Type	Description	Efficacy Rates		
			P	N	Sed
#301A	Channel	Riparian Buffer Strips — except critical areas	-0.80%	-0.70%	-3.64%
#302	Channel	Riparian Buffer Strips — critical areas	-0.13%	-0.08%	-0.51%
#401A1	Watershed	Wetland - Lower Kings Creek (SB 54)	-1.61%	-1.90%	-2.98%
#401B1	Watershed	Wetland - End Cedar Creek (SB 70)	-0.63%	-1.04%	-1.58%
#402	Watershed	Grade Stabilization	-2.30%	-1.60%	-2.40%
#501	Reservoir 'In-Lake'	Hypolimnetic Aeration	-1.60%	0.00%	0.00%
#502B	Reservoir 'In-Lake'	P Inactivation with Alum – 1/3 of Reservoir	-3.15%	0.00%	0.00%
#505	Reservoir 'In-Lake'	Hypolimnetic Water Release from Reservoir	-0.65%	0.00%	0.00%
#701	WWTP	WWTP - - from Level I to Level II	-4.60%	-1.60%	0.00%
#702	WWTP	WWTP - - from Level I to Level III	-5.30%	-2.70%	0.00%

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Financial Economics

BMP	Description	Initial Costs	AE of Initial & Cap. Repl. Costs	AE of Operating Costs	AE of All Costs
#001	Cropland to Grass	$ 1,407,766	$ 75,927	$ 779,506	$ 855,433
#001A	Contour Farming	$ 30,000	$ 6,910	$ 94,867	$ 101,777
#003	Nut. Mgmt	$ 15,000	$ 1,435	$ 1,995,917	$ 1,997,352
#004	Filter Strip	$ 135,532	$ 31,172	$ 132,218	$ 163,390
#006	Grassed Waterways	$ 69,414	$ 8,946	$ 62,591	$ 71,537
#007	Terracing	$ 408,772	$ 52,682	$ 99,314	$ 151,995
#101	Prescribed Grazing	$ 3,089,907	$ 166,652	$ 40,068	$ 206,720
#105	Past. Planting	$ 1,900,943	$ 244,989	$ 457,040	$ 702,029
#107	Crit. Pasture Planting	$ 270,701	$ 62,353	$ 27,128	$ 89,481
#s 201 - 209	Phase II Urban BMPs	$ -	$ -	$ 2,295,967	$ 2,295,967
#210	Vol. Urb. Nut. Mgmt	$ -	$ -	$ 285,720	$ 285,720
#211	Req. Urban Nut. Mgmt in Res. Buffer	$ 350,000	$ 18,877	$ 129,780	$ 148,657

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Financial Economics

BMP	Description	Initial Costs	AE of Initial & Cap. Repl. Costs	AE of Operating Costs	AE of All Costs
#301A	Rip. Buffer Strips — non crit. areas	$ 2,160,000	$ 171,860	$ -	$ 171,860
#302	Rip. Buffer Strips — crit. areas	$ 3,500,000	$ 188,770	$ -	$ 188,770
#401A1	Wetland - Lower Kings Creek	$12,408,654	$ 669,252	$ 202,796	$ 872,048
#401B1	Wetland - End Cedar Creek	$ 9,572,193	$ 473,012	$ 217,304	$ 690,316
#402	Grade Stabilization	$ 330,000	$ 42,530	$ -	$ 42,530
#501	Hypolimnetic Aeration	$ 1,200,000	$ 95,478	$ 301,478	$ 396,956
#502B	P Inactivation with Alum	$ 6,700,000	$ 863,480	$ -	$ 863,480
#505	Hypolimnetic Water Release	$ -	$ -	$ 1,836,774	$ 1,836,774
#701	WWTP - - Level I to Level II	$ 6,865,942	$ 370,310	$ 72,299	$ 442,609
#702	WWTP - - Level I to Level III	$11,957,148	$ 644,900	$656,739	$ 1,301,640

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BMP	Description	AE Costs per Engl. Ton of P Reduction	AE Costs per Engl. Ton of N Reduction	AE Costs per Engl. Ton of Sed Reduction	Ranked Order for Least Cost		
					P	N	Sed
#001	Cropland to Grass	$ 58,760	$ 14,777	$ 31	7	9	9
#001A	Contour Farming	$ 38,063	$ 30,357	$ 16	5	15	6
#003	Nut. Mgmt	$ 640,267	$ ∞	$ ∞	20	19	16
#004	Filter Strip	$ 5,238	$ 1,229	$ 3	1	1	1
#006	Grassed Waterways	$ 193,486	$ 14,697	$ 25	17	8	8
#007	Terracing	$ 34,802	$ 21,588	$ 15	4	13	5
#101	Prescribed Grazing	$ 63,899	$ 3,049	$ 19	8	4	7
#105	Past. Planting	$ 143,162	$ 6,831	$ 42	16	6	10
#107	Crit. Pasture Planting	$ 22,967	$ 1,366	$ 6	3	2	3
#s 201 - 209	Phase II Urban BMPs	$ 110,418	$ 13,357	$ 93	12	7	14
#210	Vol. Urb. Nut. Mgmt	$ 87,973	$ 18,666	$ 203	10	12	15
#211	Req. Urban Nut. Mgmt in Res. Buffer	$ 64,267	$ 4,317	$ ∞	9	5	16

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BMP	Description	AE Costs per Engl. Ton of P Reduction	AE Costs per Engl. Ton of N Reduction	AE Costs per Engl. Ton of Sed Reduction	Ranked Order for Least Cost P	N	Sed
#301A	Rip. Buffer Strips — non crit. areas	$ 103,296	$ 15,692	$ 10	11	10	4
#302	Rip. Buffer Strips — crit. areas	$ 698,212	$ 150,815	$ 75	21	18	12
#401A1	Wetland - Lower Kings Creek	$ 260,443	$ 29,335	$ 59	18	14	11
#401B1	Wetland - End Cedar Creek	$ 526,872	$ 42,424	$ 88	19	17	13
#402	Grade Stabilization	$ 8,891	$ 1,699	$ 4	2	3	2
#501	Hypolimnetic Aeration	$ 119,294	$ ∞	$ ∞	14	19	16
#502B	P Inactivation with Alum	$ 131,807	$ ∞	$ ∞	15	19	16
#505	Hypolimnetic Water Release	$ 1,358,750	$ ∞	$ ∞	22	19	16
#701	WWTP - - Level I to Level II	$ 46,266	$ 17,681	$ ∞	6	11	16
#702	WWTP - - Level I to Level III	$ 118,090	$ 30,813	$ ∞	13	16	16

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Economic Optimization

- **Four scenarios for consideration**
  - (A) Base, focused on reducing P by 35%
  - (B) Base, with value accorded also reducing sediment
  - (C) Perceived "Most Likely" adoption path
  - (D) No Ag BMPs
- **Model results of importance**
  - Objective function value (AE)
  - Initial costs
  - BMPs in the solution
  - Other details available

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Water Quality Project

Baseline: Reducing P by 35%

North Central Texas
Water Quality Project

Labels	Units	A	B	C	D
Description	n/a	Base	Sed Reduction Valued	Most Unlikely BMPs elim.	No Ag BMPs
Total AE Cost	$	$ 2.029 M			
AE Initial & Cap. Repl. $s	$	$ 0.763 M			
AE Operating $	$	$ 1.266 M			
Initial $s	$	$ 11.784 M			
Reductions in P	%	35			
Reductions in P	English tons	72.79			
Marginal Cost of Another Unit of P Reduction	$/English tons	$ 63,899			
Average Cost per Unit of P Reduction	$/English tons	$ 27,874			
Reductions in N	%	25.1			
Reductions in N	English tons	392.15			
Marginal Cost of Another Unit of N Reduction	$/English tons	nc			
Average Cost per Unit of N Reduction	$/English tons	$ 5,174			
Reductions in Sed	%	25.5			
Reductions in Sed	English tons	126,469.0			
Marginal Cost of Another Unit of Sed Reduction	$/English tons	nc			
Average Cost per Unit of Sed Reduction	$/English tons	$ 16			

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Labels		A		B		C		D	
Description		Base		Sed Reduction Valued		Most Unlikely BMPs elim. (only 28.84% P)		No Ag BMPs	
001	401A	001							
001A	302								
003	401A								
004	401B	004							
006	402		402						
007	501	007							
101	502B	101							
105	505								
107	701	107	701						
201\209	702								
210									
211		211							

In solution at maximum level In solution at partial level Blocked from being included in the solution

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Optimal Solution

BMP	Description	Marg. Units Affected	Units	Activity Level in Optimal Solution (%)	NPV of Construct. Costs Only	AE of Initial Construct. and Capital Replace. Costs	AE of Operating and Mainten. Costs	AE of All Costs	Marginal P Reduction (Engl tons)	Cum. P Red. (Engl tons)	Marg. AE Cost per Engl. Ton of P Red.
004	Filter Strip	947.5	acs	100	$135,332	$31,172	$132,218	$163,390	-31.2	-31.20	$ 5,238
402	Grade Stabilization	33	struct.	100	$330,000	$42,530	$ -	$42,530	-4.78	-35.98	$ 8,891
107	Critical Pasture\and Area Planting	511.4	acs	100	$270,701	$62,353	$27,128	$89,481	-3.9	-39.88	$ 22,967
007	Terracing	77.4	acs	100	$408,772	$52,682	$99,314	$51,995	-4.37	-44.25	$ 34,802
001A	Contour Farming	1,625.80	acs	0a	0a	0a	0a	0a	0a		$ 38,063
701	All Nine (9) WWTP - - from Level I to Level II	1	WWTP group	100	$6,865,942	$370,310	$72,299	$442,609	-9.57	-53.82	$ 46,266
001	Cropland to Grass	7,959.80	acs	100	$1,407,766	$75,927	$779,506	$855,433	-14.56	-68.38	$ 58,760
101	Prescribed Grazing	102.5	acs	65.22	$2,015,237	$108,690	$26,132	$134,822	-2.11	-70.49	$ 63,899
211	Required Urban Nutrient Management in 2,000 ft Buffer Strip around the Reservoir	1	total specified urban area	100	$350,000	$18,877	$129,780	$148,657	-2.31	-72.80	$ 64,267
				Totals	$11,783,750	$762,541	$1,266,377	$2,028,917	-72.80		Avg= $ 27,874

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Conclusions

- 35% P reduction is achievable
- Base annual costs are approx. $2 million
- Up front, time 0 costs are approx. $12 million
- A portfolio of BMPs is optimal
- Inclusion of ag-related BMPs is cost-effective
- Optimal economic solution is based on a myriad of factors

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Optimal Scenario: Adoption Rates

- Filter Strips: 50%
- Graded Stabilization Structures: 100%
- Critical Pastureland Planting: 20%
- Terrace: 15%
- WWTP Level II: 100%
- Conversion Cropland to Grass: 20%
- Prescribed Grazing: 25%

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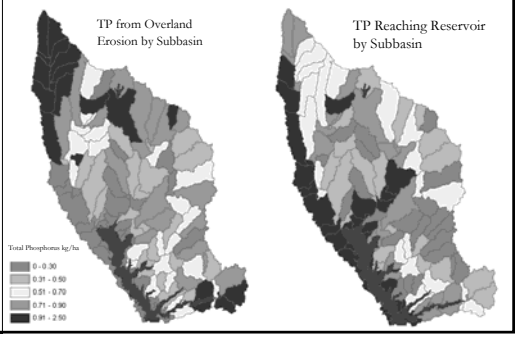

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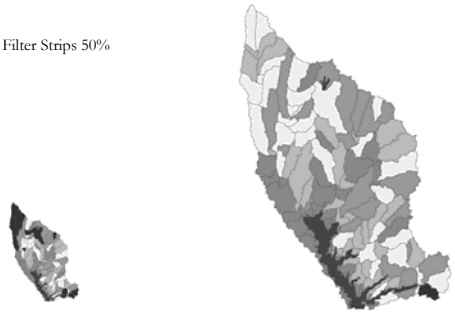
- Filter Strips 50%



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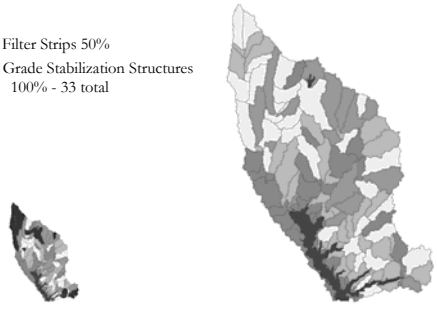
- Filter Strips 50%
- Grade Stabilization Structures 100% - 33 total



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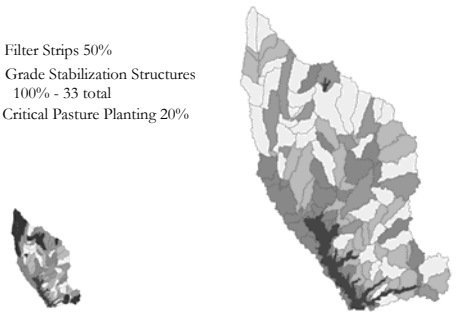

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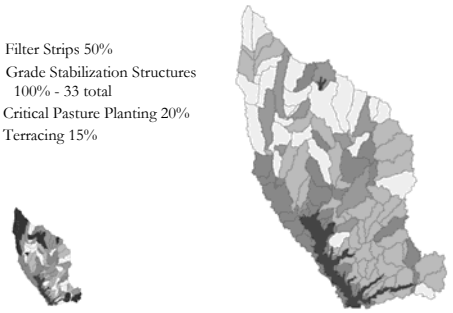

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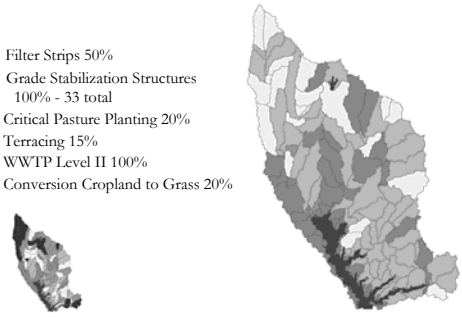

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Watershed Protection Plan Development for the Cedar Creek Watershed

http://nctx-water.tamu.edu
972-952-9635