Chesapeake Bay Program

Agricultural BMP Effectiveness Estimates

n represents the number of studies
TN – total nitrogen
TP – total phosphorous
TSS – total suspended solids

As a general rule during the BMP effectiveness estimate development process, for all TP effectiveness estimates where specific data is not available on phosphorous the TP load reductions are calculated to be 75% of the sediment reductions to account for soluble phosphorous losses. In the Chesapeake Bay watershed dissolved reactive phosphorous is assumed to be 25% and sediment bound phosphorous is 75% of the total phosphorous load (Sharpley et al 1993). Thus 75% of the TSS load reduction is an estimate of the sediment bound phosphorous reductions. Dissolved reactive phosphorous will not be reduced with a sediment reduction.

Conservation Plans:
These effectiveness estimates were reviewed and refined in 2003 with more recent data. As we are not aware of any new studies since 2003, UMD-MAWQ did not recommend a change.

BMP	TN	TP	TSS
Current effectiveness estimate			
Conventional tillage	8%	15%	25%
Conservation tillage	3%	5%	8%
Hayland	3%	5%	8%
Pastureland	5%	10%	14%
Initial UMD/MAWP recommendation and New CBP Effectiveness Estimate			
Conventional tillage	**8%**	**15%**	**25%**
Conservation tillage	**3%**	**5%**	**8%**
Hayland	**3%**	**5%**	**8%**
Pastureland	**5%**	**10%**	**14%**

Conservation Tillage:
Data on the effectiveness of conservation tillage was not found. There is data, however, on the increase in nitrate leaching from conservation tillage. Based on these studies nitrogen effectiveness estimates for surface flow and subsurface flow are derived.

BMP	TN	TP	TSS
Current effectiveness estimate	18%	30%	30%
Initial UMD/MAWP and Developer rec'd Effectiveness	Surface flow 18%*; Subsurface flow 0%*	30%	30%

Estimate			
	8%	30%	30%
New CBP Effectiveness Estimate	**8%**	**22%**	**30%**
Avg	0	30	30
Min	-10	20	20
Max	10	40	40
n (UMD/MAWQP project review)	15	16	16
n (current effectiveness estimate)	0 (best professional judgment)	0 (best professional judgment)	0 (best professional judgment)

*The estimated TN effectiveness estimates are based on the ability of the watershed model to separate surface and subsurface flow. If it cannot separate the two flow paths then 8% reduction effectiveness estimate for total nitrogen is assigned to the practice

Forest and Grass Buffer:
UMD/MAWQP/FWG recommended assigning effectiveness estimates based on geomorphic region, because groundwater flow through buffer systems will have a strong influence on effectiveness and hydrogeomorphic regions help identify different groundwater flow patterns. TN values are capped at 65% and TP is capped at 45%. The general rule for TP and TSS apply to both grass and forest buffers. For grass buffers, TN reduction effectiveness estimates are relatively 70% of forest buffer nitrogen effectiveness estimates.

Forest Buffer:

BMP	TN	TP	TSS
n (UMD/MAWQP project review)	8 (plus FWG literature review)	9 (plus FWG literature review)	9 (plus FWG literature review)
n (current effectiveness estimate)	6	6	6

Grass Buffer:

BMP	TN	TP	TSS
n (UMD/MAWQP project review)	4	5	5
n (current effectiveness estimate)	2	2	2

Riparian Buffers

New Riparian Forest Buffers - Nutrient and Sediment Reduction Effectiveness Estimates			
	TN	TP	TSS
Inner Coastal Plain	65	42	56

Previous Riparian Forest Buffers – Nutrient and Sediment Reduction Effectiveness Estimates			
	TN	TP	TSS
Coastal Plain Lowlands	25	75	75

Outer Coastal Plain Well Drained	31	45	60
Outer Coastal Plain Poorly Drained	56	39	52
Tidal Influenced	19	45	60
Piedmont Scnist/Gneiss	46	36	48
Piedmont Sandstone	56	42	56
Valley and Ridge - marble/limestone	34	30	40
Valley and Ridge - Sandstone/Shale	46	39	52
Appalachian Plateau	54	42	56

New Riparian Grass Buffers - Nutrient Reduction Effectiveness Estimates

	TN	TP	TSS
Inner Coastal Plain	46	42	56
Outer Coastal Plain Well Drained	21	45	60
Outer Coastal Plain Poorly Drained	39	39	52
Tidal Influenced	13	45	60
Piedmont Scnist/Gneiss	32	36	48
Piedmont Sandstone	39	42	56
Valley and Ridge - marble/limestone	24	30	40
Valley and Ridge - Sandstone/Shale	32	39	52
Appalachian Plateau	38	42	56

Coastal Plain Dissected Uplands	40	75	75
Coastal Plain Uplands	83	69	69
Piedmont Crystalline	60	60	60
Blue Ridge	45	50	50
Mesozoic Lowlands	70	70	70
Piedmont Carbonate	45	50	50
Valley and Ridge Carbonate	45	50	50

Previous Riparian Grass Buffers – Nutrient Reduction Effectiveness Estimates

	TN	TP	TSS
Coastal Plain Lowlands	17	75	75
Coastal Plain Dissected Uplands	27	75	75
Coastal Plain Uplands	57	69	69
Piedmont Crystalline	41	60	60
Blue Ridge	31	50	50
Mesozoic Lowlands	48	70	70
Piedmont Carbonate	31	50	50
Valley and Ridge Carbonate	31	50	50

New CBP Cover Crop Effectiveness Estimates
Total Nitrogen Estimates

Coastal Plain/Piedmont Crystalline/Karst Settings

Watershed scale = plot scale * .85 (subsurface edge of field) *.75 (landscape scale)

Seeding method:	Drilled	Other	Aerial/soy	Aerial/corn	Drilled	Other	Aerial/soy	Aerial/corn	Drilled	Other	Aerial/soy	Aerial/corn
Species:	Rye	Rye	Rye	Rye	Wheat	Wheat	Wheat	Wheat	Barley	Barley	Barley	Barley
Early planting	45	38	31	18	31	27	22	13 (7)***	38	32	27 (22)***	15 (7)***
Normal planting	41	35	ne	ne	29	24	ne	ne	29	24	Ne	ne
Late planting	19	16	ne	ne	13	11	ne	ne	na	na	Ne	ne
Commodity SGE	*	na	ne	ne	*	na	ne	ne	*	na	Ne	ne

Mesozoic Lowlands/Valley and Ridge Siliciclastic**

Watershed scale = plot scale * .65 (subsurface edge of field) *.75 (landscape scale)

Seeding method:	Drilled	Other	Aerial/soy	Aerial/corn	Drilled	Other	Aerial/soy	Aerial/corn	Drilled	Other	Aerial/soy	Aerial/corn
Species:	Rye	Rye	Rye	Rye	Wheat	Wheat	Wheat	Wheat	Barley	Barley	Barley	Barley
Early planting	34	29	24	14	24	20	17	10 (6)***	29	25	20 (17)***	12 (6)***
Normal planting	31	27	ne	ne	22	18	ne	ne	22	19	ne	ne
Late planting	15	12	ne	ne	10	9	ne	ne	na	na	ne	ne
Commodity SGE	*	na	ne	ne	*	na	ne	ne	*	na	ne	ne

na – not applicable

ne – Not eligible for credit. Aerial seeded grains require a significant rain event to germinate, and early aerial seeding is desirable because it increases the chance of experiencing significant rainfall prior to the end of the growing season.

* These effectiveness estimates will be finalized following further discussions between the cover crop scientists and modelers.

** Particulate nitrogen was not considered in developing the recommendation for the two settings.

*** Actual effectiveness to be used pending on cover crop panel review. See discussion below.

The cover crop scientists and MAWP recommend analyzing particulate N in the future.

For the Mesozoic lowlands/valley and ridge siliciclastic settings the effects of cover crops on surface runoff N were not addressed.

Studying any impact that cover crops may have on surface runoff N losses is a topic for future research and discussion.

Change to aerial seeding coefficient:

UMD/MAWP assumed a transposing error occurred during recording of the seeding coefficients for the different variations of aerial seeding choices for either barley or wheat, and consequently changed the variations of aerial seeding choices for either wheat or barley. This change was made because all discussion by the cover crop panel indicated spinner spreading followed by disking produced a better stand than aerial seeding. The original coefficient, however, did not reflect this. Also, as written, the original coefficients implied wheat and barley performed better under aerial seeding than rye, contrary to science and experience that indicate rye's greater ease in germination and stand establishment compared to wheat or barley's. The specific changes, and supporting science and discussion points, follow.

UMD/MAWP changed early aerial corn/wheat to .4 (originally .7) because the panel agreed, and science supports the notion, that rye is one of the easiest crops to grow. It has a wide range of adaptability due to its great winter hardiness and tolerance of different soil types (Johnny's Selected Seeds, 1983; Miller, 1984; Brinton, 1989; Bushuk, 1976) and marginal soils; outyielding other cereals on droughty, sandy, and infertile soils (Stoskopf, 1985). It can be grown in soils too poor to produce other grains or clover (McLeod, 1982), or too acidic for wheat (Evans and Scoles, 1976). Rye also has an extensive root system that enables it to be the most drought-tolerant cereal crops (Evans and Scoles, 1976). To be consistent with science wheat should not be assigned a higher coefficient, thus UMD/MAWP reduced wheat to equal aerial corn/rye's value.

Originally aerial seeding for corn/barley and soy/barley was higher (.85) than 'other' seeding methods (includes any non-drilled seeding method where the seed is incorporated into the soil, e.g. broadcast and disked) and was equal to the coefficient assigned to plantings done by a seed drill. This contradicts the narrative the cover crop panel provided for aerial seeding; stating aerial seeding would result in reduced effectiveness due to better stand establishment by 'other' and drilled seeding methods resulting from aerial seedings reduced germination, attributable to poor seed-soil contact. To reflect reduced effectiveness due to aerial seeding aerial soy/barley and corn/barley was reduced from .85 to .7 and .4, respectively.

Old Cover Crop Effectiveness Estimates

	Total Nitrogen Reduction Effectiveness Estimate	Total Phosphorous Reduction Effectiveness Estimate	Total Suspended Sediment Reduction Effectiveness Estimate
Cereal Cover Crops on Conventional-Till:			
Early-Planting	45	15	20
Late-Planting	30	7	10
Cereal Cover Crops on Conservation-Till:			
Early-Planting	45	0	0
Late-Planting	30	0	0
Commodity Cereal			

Cover Crops/Small Grain Enhancement on Conventional-Till:			
Early-Planting	25	0	0
Late-Planting	17	0	0
Commodity Cereal Cover Crops/Small Grain Enhancement on Conservation-Till:			
Early-Planting	25	0	0
Late-Planting	17	0	0

Wetland Restoration and Wetland Creation:

The BMP expert for wetlands recommends using drainage area to predict effectiveness. Removal of total N and P by restored wetlands can be predicted from the relationship between the percentage of N or P removed and the percentage of the watershed occupied by wetland receiving discharge from the entire watershed. We assume that removal proceeds exponentially with detention time, as expected with first order kinetics. We also assume that detention time (wetland volume divided by water flow rate) is proportional to the percentage of watershed occupied by wetland. This follows if water discharge is proportional to watershed area and if different wetlands have similar average depths. Finally, we assume that there is no removal if there is no wetland area (i.e., the curve must go through the origin). Based on these assumptions:

$$\text{Removal} = 1 - e^{-k\,(\text{area})}$$

Where "removal" is the proportion (not percentage) of the input removed by the wetland, "area" is the proportion watershed area occupied by wetland, and "k" is a fitted parameter. We used non-linear regression (SAS 2004) to fit this equation to data from studies reported in the literature.

Using our guidelines for effectiveness estimate development, and the report below, UMD/MAWQP and the CBP support the effectiveness estimation approach recommended by the expert. When wetland area or drainage area is not reported we recommend the following:

TN and TP removal effectiveness estimates for wetlands broken down by geomorphic region.

Geomorphic Province	Area of wetland as % of watershed area	TN Removal Effectiveness Estimate	TP Removal Effectiveness Estimate
Appalachian	1%	7%	12%
Piedmont and Valley	2%	14%	26%
Coastal Plain	4%	25%	50%

The assigned percents for each geomorphic area are based on scientific understanding of the natural hydrology and geology found in each region and is used to determine the drainage area. The area of wetland as a percent of watershed area is then compared to the graph provided from the equation to determine TN removal and TP removal.

CBP assigned a total suspended solid pollutant removal effectiveness estimate of 15%. The expert recommends the average calculated from seven annual removal rates of 20%

(from two studies). Per our guidelines the average effectiveness was adjusted because the research projects used to calculate the average do not always represent operational conditions (see Criteria document). UMD would like to continue discussions with the Wetlands Workgroup to see if they can develop an effectiveness estimate for TSS.

BMP	TN	TP	TSS
n (project review)	16	16	2
n for current effectiveness estimate	0 wetland effectiveness estimates assumed to be the same as riparian buffers	0 wetland effectiveness estimates assumed to be the same as riparian buffers	0 wetland effectiveness estimates assumed to be the same as riparian buffers

Off-Stream Watering BMPs:

BMP and Study	Percentage Reduction												
	NO_3	NO_2	NO_3+ NO_2	NH_4	Dissolved TKN	TKN	Total N	Sediment Bound N	Dissolved P	Total P	Sediment Bound P	TSS	Flow
Off-stream watering with fencing													
Galeone et al. (2006)													
Watershed T-1	18	28		36	20	26			-19	14		37	
Watershed T-2	-15	-15		-10	-30	-43			-94	-51		44	
n (project review)	1	1		1	1				1	1		1	
n (current effectiveness estimate)							0 (best profession al judgment)			0 (best profession al judgment)		0 (best professional judgment)	
Effectiveness estimate Recommendation													
Current Effectiveness Estimate							60			60		75	
Expert							14			7		19	
Initial UMD/MAWP Recommendation and New CBP Effectiveness Estimate							**25**			**30**		**40**	
Off-stream watering without fencing													
Line et al. (2000)			41			-27				-13		38	27
Sheffield et al. (1987)	-37			72			8		-99	65		89	
n (project review)	1		1	1		1	1		1	2		2	
n (current effectiveness estimate)							0			0		0	
Effectiveness estimate													

Recommendation													
Current Effectiveness Estimate							30			30		38	
Expert							4			7		19	
Initial UMD/MAWP Recommendation and New CBP Effectiveness Estimates							**15**			**22**		**30**	

In this case, the literature did not support the current reduction effectiveness estimates, so some adjustment was warranted. However, the developer used a conservative view of the literature values and then reduced them by 50% based on his experience to account for variability and uncertainty. While the literature made it evident that some reductions were needed, we felt the developer had reduced the effectiveness estimates further than warranted so we proposed values close to the conservative literature base that the developer cited.

Breakdown of effectiveness estimates for BMPs classified as 'other':

Forest harvesting:

BMP	TN	TP	TSS
Current	50	50	50
Developer rec'd	60	75	75
Initial UMD/MAWP Recommendation and New CBP Effectiveness Estimates	**50**	**60**	**60**
Median	60	85	77
Avg	50	71	67
Min	12	44	2
Max	80	86	96
n (UMD/MAWQP project review)	2	2	3
n (current effectiveness estimate)	0 (best professional judgment)	0 (best professional judgment)	0 (best professional judgment)

The developers proposed effectiveness estimates substantially higher than current ones based primarily in two coastal plain studies. We felt that these two studies were likely to be optimistic when applied across the watershed particularly when given the variability in terrain and expertise of the harvester in BMPs application. We kept effectiveness estimates close to where they are currently but reduced N slightly to account for losses through subsurface flow that do not appear to have been acknowledged in the current effectiveness estimate. For other BMPs research level effectiveness estimates were reduced by 25% to account for variability and loss in precision/control when going from research scale to widespread application. The FWG felt this was too severe of a reduction because of the regulatory program governing forest harvesting practices. To accommodate limitations in the data, wide spread implementation, and the current regulatory program, forest harvesting BMPs were only discounted by 20%, relatively.