Barton Springs Turf

This scenario is intended to represent turf areas (golf courses, parks, sod farms, and recreational fields) in the Barton Springs Segment (BSS) of the Edwards Aquifer. Because golf courses are expected to be the most likely turf areas where pesticides may be applied, much of this scenario has been parameterized to be reflective of golf course turf. NASS data for 1997 and 2002 (USDA 1997, 2002) contained no record of sod harvest in either Hays or Travis counties. Since there are several golf courses located within the BSS (COA 2003), this scenario was parameterized to represent turf on golf courses and may be generally representative of other potential turf areas.

Crop parameters are based primarily on bermudagrass (*Cynodon* spp.) since it is a primary turf grass for golf courses and athletic fields. Within the vicinity of the BSS, bermudagrass is a common turf grass for golf courses, specifically common and improved bermudagrass (personal communication with Nick Smithamn). Bermudagrass is also used for lawns, parks, playgrounds, and cemeteries. In the U.S., the distribution of bermudagrass extends from across the Southern states, including: Texas, California, New Mexico, Arizona, Oklahoma, Arkansas, Mississippi, Alabama, Florida, Georgia, South Carolina, North Carolina, Virginia. There are several different varieties of bermudagrass that are used for golf course turf and sports fields, including: U-3, Tiflawn, Tifgreen, Tifway, Santa Ana, Ormond, Tifdwarf, and Pee Dee (Duble 2004). Bermudagrass grows on a wide variety of soils, from heavy clays to deep sands; tolerating acidic, alkaline and saline conditions. Bermudagrass does best on well-drained sites. Bermuda grass can survive low fertility conditions but requires high nitrogen concentrations for production of good quality turf (Duble 2004).

Soils were selected based primarily on the extent within golf courses in BSS, with secondary emphasis placed on the extent within other turf areas (parks and cemeteries). Based on a geospatial analysis of soils (USDA 2006) and land use data (COA 2003), Brackett soils were chosen to represent turf in the BSS (Table 5). It should be noted that the land use classifications were not solely turf and may have included some forested areas within golf courses and parks. Therefore, after soil extents were computed, soils were cross-checked with aerial photography to ensure that the soil chosen was representative of turf areas where pesticides would realistically be applied (non-forested areas). The soil series were also cross-checked with NRCS crop suitability ratings (USDA 2006) to ensure the series supported improved bermudagrass.

The Brackett series was chosen to represent turf areas in the BSS (Table 5) because it is a benchmark soil, is highly representative of golf course areas in the BSS, and it represents the 90th percentile of vulnerability in drainage, erodibility, and slope. Brackett soils are in Hydrologic Group C soils and are found in both the contributing and recharge zones of the Edwards Aquifer. Bracket soils are the most common soil found in golf course areas (USDA 2006; COA 2003) and the second most common within the entire turf land cover class (golf courses, cemeteries, parks, and greenways). Since this scenario is intended to represent golf course type areas, Tarrant soils (also widespread) were considered inappropriate for pesticide modeling since Tarrant soils occur in predominantly forested areas of parks and golf courses where pesticides would not likely be applied (based on analysis of soils and aerial photos). Brackett soils have a USLE K factor of 0.37 which includes the 90th percentile of these soils in erodibility (Table 5). The Brackett series is loamy, carbonatic, thermic, shallow Typic Haplustepts. The soil consists of very shallow to shallow soils over bedrock. They are well drained and moderately permeable soils that formed in residuum over chalky limestone bedrock (USDA 2001). Slopes range from 1 to 60 percent; however the most typical slope range for the Brackett series on turf areas is 1-12 percent (USDA 2006; COA 2003).

Two zones are modeled for the purposes of PRZM scenarios: the cropped zone and the soil zone. The cropped zone includes the region above the soil surface. The soil zone includes the region below the land surface. Turf, unlike most agricultural crops, can have a third important zone: the thatch zone. The thatch zone is located between the cropped zone (grass) and the soil. Thatch is made up of dead, undecomposed grass, leaf, and root material. Thatch may be important in turf modeling because it possesses hydrologic and pesticide fate properties which may differ significantly from the other two zones described above. The thatch zone may strongly influence movement of both water and pesticide from the surface into the soil. Correctly representing the properties of the thatch zone is therefore important to simulation of pesticide runoff and leaching from turf areas. In order to appropriately model this thatch layer, the soil zone is modified by adding a 2 cm deep layer of "thatch" on top of the soil profile, with set properties (Table 4). A 2 cm layer of thatch is typical for golf course fairways, but is probably thicker than average for golf course greens (Mike Kenna, USGA, personal communication). Modern greens built according to current USGA specifications are designed to rapidly infiltrate water, and are built upon sand/peat mixtures, with tile underdrainage. However, a large fraction of the greens in this country are of the old-style "push-up" variety, composed essentially of existing soil from the site, and lacking underdrainage. For preliminary modeling purposes, turf will be considered to be essentially generic, with no distinction made between fairways, greens, tees, or residential lawns. For chemicals applied to golf courses, the fraction of the total area composed of greens, tees, and fairways may however be used to modify the results of a modeling run, somewhat in the fashion of a percent cropped area (PCA) adjustment. The approximate average percent areas (confirmed by Mike Kenna, USGA, personal communication) are as follows: fairways, 23%; greens, 2%; tees, 2%. Thus if a pesticide is only used on greens and tees, for example, the modeling results would be multiplied by a factor of 0.04. It is possible that current PCA development efforts may produce PCAs for golf courses, turf farms, and/or residential lawns that may also be used to refine the results of modeling runs.

The meteorological station selected for this scenario is located in Austin, Texas. This station is the closest available weather station that includes the necessary data to run PRZM.

Table 1. PRZM 3.12 Climate and Time Parameters for Barton Springs, TX.

Parameter	Value	Source/Comments
Starting Date	Jan. 1, 1961	Meteorological File from Austin, TX (W13958)
Ending Date	Dec. 31, 1990	Meteorological File from Austin, TX (W13958)
Pan Evaporation Factor (PFAC)	0.69	PRZM Manual Figure 5.1 (EPA 1998).
Snowmelt Factor (SFAC)	0.36	PRZM Manual, Table 5.1 (EPA 1998).
Minimum Depth of Evaporation (ANETD)	25	Mid point of range (20-30), PRZM Manual, Figure 5.2 (EPA 1998).

Table 2. PRZM 3.12 Erosion and Landscape Parameters for Barton Springs Turf.		
Parameter	**Value**	**Source/Comments**
Method to Calculate Erosion (ERFLAG)	4 (MUSS)	Default value.
USLE K Factor (USLEK)	0.37 tons EI^{-1}*	NRCS Soil Data Mart Database for Brackett-Rock outcrop-complex, 1-12% slopes, Travis County, TX. (http://soildatamart.nrcs.usda.gov/).
USLE LS Factor (USLELS)	1.34	Calculated according to Haan and Barfield (1978) equation: $LS = ((\lambda/72.6)^m)((430x^2 + 30x + 0.43)/6.613)$, where λ = slope length, x = SLP/100 and m = constant. In this case, λ = 400 m (default value) and m = 0.5 (EPA 2004).
USLE P Factor (USLEP)	0.5	Set to 0.5 for 3-8% slopes(EPA 2004). Verified sediment loss with local studies on turf areas.
Field Area (AFIELD)	10 ha	Default value for area of standard farm pond.
NRCS Hyetograph (IREG)	4	PRZM Manual, Figure 5.12 (EPA, 1998).
Slope (SLP)	6 %	Brackett-Rock Outcrop-Complex slope range 1-12% (USDA 2006).
Hydraulic Length (HL)	356 m	Default value for Pond (EPA, 2004)
Irrigation Flag (IRFLAG)	1	Nick Smithamn, Superintendent of Austin Municipal Golf Courses, Date: 3-16-06, Phone: 512-447-2616 1 = year round
Irrigation Type (IRTYP)	3 (sprinkler)	Karen Stewart, Senior Water Conservation Specialist, City of Austin Water Utility, Date: 3/23/06, Phone: 512-974-2978. Irrigation Guidance for developing PRZM Scenario, Table 3; (June 15, 2005).
Leaching Factor (FLEACH)	0.1	Irrigation Guidance for developing PRZM Scenario, Table 3; (June 15, 2005).
Fraction of Water Capacity when Irrigation is Applied (PCDEPL)	0.95	Golf courses typically irrrigate ¼ to ½ inch every night, no matter what, in the summer. They may water less in the winter, every other night, and not when a freeze is expected. (Karen Stewart, Senior Water Conservation Specialist, City of Austin Water Utility, Date: 3/23/06, Phone: 512-974-2978.) Irrigation Guidance for developing PRZM Scenario, Table 3; (June 15, 2005).
Maximum Rate at which Irrigation is Applied (RATEAP)	0.053 cm hr^{-1}	½ inch irrigation (see above for PCDEPL) Irrigation Guidance for developing PRZM Scenario, Table 1; (June 15, 2005).
* EI = 100 ft-tons * in/ acre*hr		

Table 3. PRZM 3.12 Crop Parameters for Barton Springs - Turf.		
Parameter	**Value**	**Source/Comments**
Initial Crop (INICRP)	1	Default value
Initial Surface Condition (ISCOND)	2	2 = cover crop. Cover crops are typically planted on golf courses to keep them green when bermudagrass goes dormant (Karen Stewart, Senior Water Conservation Specialist, City of Austin Water Utility, Date: 3/23/06, Phone: 512-974-2978).
Number of Different Crops (NDC)	1	Set to number of crops in simulation. Default value.
Number of Cropping Periods (NCPDS)	30	Set to weather data in meteorological file: Austin, TX (W13958).
Maximum rainfall interception storage of crop (CINTCP)	0.1	Taken from PAturf and FLturf scenarios.
Maximum Active Root Depth (AMXDR)	15 cm	Nick Smithamn, Superintendent of Austin Municipal Golf Courses, Date: 3-16-06, Phone: 512-447-2616
Maximum Canopy Coverage (COVMAX)	100	Taken from PAturf and FLturf scenarios.
Soil Surface Condition After Harvest (ICNAH)	2	2 = cover crop. Cover crops are typically planted on golf courses to keep them green when bermudagrass goes dormant (Karen Stewart, Senior Water Conservation Specialist, City of Austin Water Utility, Date: 3/23/06, Phone: 512-974-2978).
Date of Crop Emergence (EMD, EMM, IYREM)	01/01/61	Winter grass is planted on the greens so that they stay “green” year round. The tees, fairways and roughs go dormant from November to March (Nick Smithamn, Superintendent of Austin Municipal Golf Courses, Date: 3-16-06, Phone: 512-447-2616). The average first and last frost dates of the winter season are November 10 and March 10, respectively (Karen Stewart, Senior Water Conservation Specialist, City of Austin Water Utility, Date: 3/23/06, Phone: 512-974-2978). Dates set to model year round grass coverage.
Date of Crop Maturity (MAD, MAM, IYRMAT)	01/02/61	
Date of Crop Harvest (HAD, HAM, IYRHAR)	31/12/61	
Maximum Dry Weight (WFMAX)	0.0	Not used in scenario.
Maximum Canopy Height (HTMAX)	2.5 cm	Nick Smithamn, Superintendent of Austin Municipal Golf Courses, Date: 3-16-06, Phone: 512-447-2616
SCS Curve Number (CN)	74, 74, 74	Table 2-2a, USDA 1986. Curve numbers are selected based on “good condition” open space areas for hydrologic soil group C. Same number year round, since no cropping season. This is consistent with other turf scenarios (FL turf and PA turf).
Manning's N Value (MNGN)	0.110	San Antonio Hay/Grass (I93HGHGC). Represents cover code 2 for first year hay/grass, moderately dense cover.

Table 3. PRZM 3.12 Crop Parameters for Barton Springs - Turf.		
Parameter	**Value**	**Source/Comments**
USLE C Factor (USLEC)	0.000 – 0.004	San Antonio Hay/Grass (I93HGHGC)

Table 4. PRZM 3.12 "Brackett-Rock Outcrop-Complex" Soil Parameters for Barton Springs, TX - Turf.		
Parameter	**Value**	**Source/Comments**
Total Soil Depth (CORED)	48 cm	Brackett-Rock outcrop-complex, 1-12% slopes, Travis County, TX. NRCS Soil Data Mart Database (http://soildatamart.nrcs.usda.gov/). According to an extension agent (Robert Martinez, phone: 512-454-2571 x3), golf courses between Bee Cave and Austin TX reside primarily upon Brackett soils. Top horizon split in two and thatch layer added as HORIZN 1. Soil parameters of HORIZN 1 according to EPA guidance on development of turf scenario. Additional data were listed for a 5th HORIZN. However, these were not included in this soil profile since the 5th HORIZN is composed of bedrock.
Number of Horizons (NHORIZ)	4	
Horizon Thickness (THKNS)	2 cm (HORIZN =1) 10 cm (HORIZN =2) 5 cm (HORIZN =3) 31 cm (HORIZN =4)	
Bulk Density (BD)	0.37 g/cm3 (HORIZN = 1) 1.4 g/cm3 (HORIZN =2) 1.4 g/cm3 (HORIZN =3) 1.43 g/cm3 (HORIZN =4)	
Initial Water Content (THETO)	0.47 cm3/cm3 (HORIZN =1) 0.28 cm3/cm3 (HORIZN =2) 0.28 cm3/cm3 (HORIZN =3) 0.252 cm3/cm3 (HORIZN =4)	
Compartment Thickness (DPN)	0.1 cm (HORIZN = 1) 5 cm (HORIZN = 2) 5 cm (HORIZN = 3) 1 cm (HORIZN = 4)	
Field Capacity (THEFC)	0.47 cm3/cm3 (HORIZN =1) 0.28 cm3/cm3 (HORIZN =2) 0.28 cm3/cm3 (HORIZN =3) 0.252 cm3/cm3 (HORIZN =4)	PRZM Scenario Guidance (2004).
Wilting Point (THEWP)	0.27 cm3/cm3 (HORIZN =1) 0.164 cm3/cm3 (HORIZN =2) 0.164 cm3/cm3 (HORIZN =3) 0.145 cm3/cm3 (HORIZN =4)	
Organic Carbon Content (OC)	7.5 % (HORIZN = 1) 1.16 % (HORIZN =2) 1.16 % (HORIZN =3) 0.73 % (HORIZN =4)	Adjusted using the relationship % OC = % Organic Matter/1.724 (Doucette 2000).

Table 5. Soils co-located with turf areas in the Barton Spring Segment based on USDA 2006 soils data and COA 2003 land use data.										
Soil	**Total Acreage**	**% Area**	**Drainage Class**	**KF**	**Slope**	**pH**	**OM (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**
Tarrant	2,056.44	28.7%	D	0.32	0 - 50	8	5	22	28	50
Brackett	1,556.57	21.7%	C	0.37	1 - 60	8	2	34	37	28
Speck	1,393.72	19.4%	D	0.32	1 - 5	7	2	34	37	30
Volente	615.26	8.6%	C	0.32	1 - 8	8	3	7	32	39
Alluvial land	488.06	6.8%	A	0.15	0 - 1	8	1	90	0	5
Crawford	178.58	2.5%	D	0.32	0 - 2	7	2	22	28	50
San Saba	156.55	2.2%	D	0.32	0 - 2	8	3	18	29	53
Purves	90.19	1.3%	D	0.32	1 - 5	8	3	6	47	48
Doss	86.66	1.2%	D	0.32	1 - 5	8	2	7	49	44
Heiden	75.48	1.1%	D	0.32	1 - 8	8	3	22	28	50
Denton	63.10	0.9%	D	0.32	1 - 5	8	3	6	48	46
Bergstrom	55.76	0.8%	B	0.32	0 - 2	8	2	7	62	31
Comfort	54.35	0.8%	D	0.32	1 - 8	8	6	28	29	43
Ferris	49.02	0.7%	D	0.32	8 - 20	8	1	18	29	53
Hardeman	48.20	0.7%	B	0.24	3 - 12	8	1	66	20	14
Altoga	32.09	0.4%	C	0.32	2 - 8	8	1	7	48	45
Eddy	26.77	0.4%	C	0.32	1 - 6	8	1	38	36	26
Austin	26.67	0.4%	C	0.32	1 - 6	8	3	7	48	45
Sunev	24.05	0.3%	B	0.32	1 - 3	8	2	34	37	30
Bolar	20.17	0.3%	C	0.32	1 - 3	8	2	34	37	30
Houston Black	15.65	0.2%	D	0.32	0 - 8	8	3	17	28	55
Lewisville	14.63	0.2%	B	0.32	0 - 2	8	2	8	51	41
Krum	13.15	0.2%	D	0.32	1 - 3	8	2	26	29	45
Patrick	12.24	0.2%	B	0.32	1 - 10	8	2	28	29	43
Travis	5.36	0.1%	C	0.24	1 - 8	7	1	66	19	15
Oakalla	4.46	0.1%	B	0.32	0 - 1	8	4	18	48	34
Real	3.45	0.0%	D	0.28	1 - 8	8	6	36	34	31
Gaddy	1.54	0.0%	A	0.17	0 - 1	8	0	84	7	10
Rumple	1.11	0.0%	C	0.32	1 - 8	7	2	34	37	30
Castephen	<1	0.0%	C	0.32	3 - 5	8	2	19	48	34
Gruene	<1	0.0%	D	0.28	1 - 5	8	2	28	29	43
Tarpley	<1	0.0%	D	0.32	1 - 3	7	3	30	30	40

Sensitive Parameter Uncertainties

Slope

Depending upon the specific golf course and upon the portion of that golf course, slopes can range significantly. In order to obtain a slope value that would be representative of a BSS golf course, the midpoint was used for the slope range (1 to 12%) of the of Brackett soil with the greatest extent on golf course areas. The slope value of 6% is representative of a slope that would be found for a soil type that overlaps with golf courses in BSS. Also, this selection is not disputed by existing turf scenarios. The SLP values of FL turf and PA turf are 2 and 12, respectively. The slope of 6% for BSSTurf falls within this range.

Since the overall slope of this soil type ranges from 1 to 60 percent, the SLP value could be higher. If the overall slope range (1 to 60%) were considered for the conceptual model of this scenario, the default value of 12% (corresponding to hay crops and orchards) could be used. This would result in a higher USLE LS factor, and thus, a higher runoff potential.

USLE C Factor and Manning's N Value

The RUSLE Project did not include data that were specific to an area within the BSS. Therefore, USLE C Factor and Manning's N values were selected from data representing the closest available climate station, which was San Antonio. For USLEC and Manning's N values, the file for San Antonio hay/grass. Sediment yield were compared to observed data for golf courses in the area and are reasonable. Sediment yield are high end relative to observed data.

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