

Description of the land and water phases of the SWAT model

Land or terrestrial phase: At this stage, the model calculates the amount of water, sediments and nutrient concentrations that are discharged to the main stream from each sub-basin. The necessary inputs are: daily precipitation data for at least the last 5 years, land use/cover, soil types, digital elevation model and a hydrological network for flat terrain.

The hydrological cycle is simulated by SWAT based on the equation of the water balance:

$$SW_t = SW_o + (R_{day} + Q_{surf} - E_a - W_{seep} - Q_{gw}), \quad (1)$$

Where SW_t is the final content of water in the soil (mm H₂O), SW_o is the initial content of water and soil at day i (mm H₂O), t is the time (days), R_{day} is the amount of precipitation in a Day i (mm H₂O), Q_{surf} is the amount of surface runoff in a day i (mm H₂O), E_a is the amount of evapotranspiration in a day i (mm H₂O), W_{seep} is the amount of water entering the vadose zone in a Soil profile in one day i (mm H₂O), and Q_{gw} is the amount of return flow in one day i (mm H₂O).

The subdivision of the basin allows the model to reflect differences in evapotranspiration for various crops and soils. Runoff is estimated separately for each HRU and set in route to obtain total runoff from the basin. This increases accuracy and gives a better physical description of the water balance. The volume of surface runoff is calculated using a modification of the Curve Number SCS (USDA Soil Conservation Service) or the Green & Ampt infiltration method. In the curve number, the curves vary non-linearly with the soil moisture content. The Green & Ampt method requires daily precipitation data and calculates infiltration as a potential matrix function and effective hydraulic conductivity. Thus, water that fails to infiltrate becomes surface runoff. Erosion and sediments are estimated for each HRU with the modified universal soil loss equation or modified universal soil loss equation (MUSLE). MUSLE uses the amount of runoff to simulate erosion and sediment. This results in a number of benefits: accurate prediction of the model is increased and estimation of sediments from a single storm can be calculated. The hydrological model provides estimates of runoff volume and maximum runoff rates, which are used to calculate the erosive energy variable of the runoff with the sub-basin area. The crop management factor is recalculated each day the runoff occurs.

Water phase: This phase includes the movement of water, sediments, etc. through the network of channels until it leaves the basin at the outlet. Displacement in the main channel can be divided into water and sediment components:

Water: With water flowing downstream, a portion may be lost due to evaporation and transmission through the channel bed. Another potential loss is due to the removal of water from the channel for agricultural or human use. The flow can be supplemented by rain falling directly on the channel and from point sources. The flow is directed through the channel using a variable method of storage coefficients.

Sediments: The transport of sediments in the channel is controlled by the simultaneous operation of two processes: deposition and degradation. SWAT uses simplified equations and the maximum amount of sediment that can be transported from a segment is a function of the maximum velocity of runoff.

Table S1. Hydrometric stations used in each watershed – weblinks to access the data online

Unit	USGS Code	Station Name	Elev.	Years of record	Weblink – Entire Time Series	Weblink – Time Series used in this study
Wat01	09289500	Lake Fork River, UT	2493	1933-2017	https://waterdata.usgs.gov/ut/nwis/dv/?site_no=09289500&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/ut/nwis/dv?cb_00060=on&format=rdb&site_no=09289500&referred_module=sw&period=&begin_date=1990-01-01&end_date=2011-12-31
Wat02	10249300	South Twin River, NV	1950	1965-2017	https://waterdata.usgs.gov/nv/nwis/dv/?site_no=10249300&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/nv/nwis/dv?cb_00010=on&cb_00060=on&format=rdb&site_no=10249300&referred_module=sw&period=&begin_date=1990-01-01&end_date=2011-12-31
Wat03	12359800	South Flathead River, MT	1089	1965-2017	https://waterdata.usgs.gov/mt/nwis/dv/?site_no=12359800&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/mt/nwis/dv?cb_00060=on&format=rdb&site_no=12359800&referred_module=sw&period=&begin_date=1990-01-01&end_date=2011-12-31
Wat04	13310700	Salmon River Station, ID	1143	1966-2017	https://waterdata.usgs.gov/nwis/dv/?site_no=13310700&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=rdb&site_no=13310700&referred_module=sw&period=&begin_date=1990-01-01&end_date=2011-12-31
Wat05	13336500	Selway River Lowell, ID	469	1911-2017	https://waterdata.usgs.gov/id/nwis/dv/?site_no=13336500&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/id/nwis/dv?cb_00060=on&format=rdb&site_no=13336500&referred_module=sw&period=&begin_date=1990-01-01&end_date=2011-12-31
Wat06	13340600	Clearwater River, ID	505	1967-2017	https://waterdata.usgs.gov/nwis/dv/?site_no=13340600&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=rdb&site_no=13340600&referred_module=sw&period=&begin_date=1990-01-01&end_date=2011-12-31
Wat07	9277800	Rock Creek above South Fork, Utah	2428	1965-1994	https://waterdata.usgs.gov/nwis/dv/?site_no=09277800&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=rdb&site_no=09277800&referred_module=sw&period=&begin_date=1990-01-01&end_date=1995-12-31
Wat10	10153800	North Fork Provo River, UT	2280	1963-1996	https://waterdata.usgs.gov/nwis/dv/?site_no=10153800&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=rdb&site_no=10153800&referred_module=sw&period=&begin_date=1990-01-01&end_date=1997-12-31
Wat13	13335690	Selway River, ID	667	1995-2006	https://waterdata.usgs.gov/nwis/dv?referred_module=sw&huc2_cd=17060301&index_pmcode_00065=3&index_pmcode_00060=4&index_pmcode_00062=5&index_pmcode_72020=6&sort_key=site_no&group_key=county_cd&sitefile_output_format=html_table	https://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=rdb&site_no=13335690&referred_module=sw&period=&begin_date=1990-01-01&end_date=2007-12-31
Wat14	13335700	Moose Creek Ranger St. ID	667	1995-2005	https://waterdata.usgs.gov/nwis/dv/?site_no=13335700&agency_cd=USGS&referred_module=sw	https://waterdata.usgs.gov/nwis/dv?cb_00010=on&cb_00060=on&format=rdb&site_no=13335700&referred_module=sw&period=&begin_date=1995-01-01&end_date=2007-12-31

Table S2. Climatic information used for each watershed – weblinks to access the data online

Unit	HUC-12 Name, Code, State	HUC-08Name and Code08	Coverage (%)		Weblink
			Temp.	Precip.	
Wat01	North Fork Provo River, UT - 160202030103	Provo River	100	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:16020203/detail
Wat02	South Twin River, NV – 160600040701	Norther Big Smoky Valley - 16060004	99	97	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:16060004/detail
Wat03	Multiple: HUC-12 units, MT	South Fork Flathead - 17010209	100	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:17010209/detail
Wat04	Multiple: HUC-12 units, ID	South Fork Salmon - 17060208	99	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:17060208/detail
Wat05	Multiple: HUC-12 units, ID	Lower Selway - 17060302	99	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:17060302/detail
Wat06	Multiple: HUC-12 units, ID	Upper North Fork Clearwater - 17060307	99	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:17060307/detail
Wat07	Multiple: HUC-12 units, UT	Duchesne - 14060003	100	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:14060003/detail
Wat10	Multiple: HUC-12 units, UT	Duchesne - 14060003	100	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:14060003/detail
Wat13	Multiple: HUC-12 units, ID	Upper Selway - 17060301	98	98	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:17060301/detail
Wat14	Multiple: HUC-12 units, ID	Lower Selway - 17060302	99	100	https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/locations/HUC:17060302/detail

Table S3. SWAT parameters and initial range of values used during calibration.

Parameter name	Range	Parameter name	Range
v__ALPHA_BF.gw	0	1 v__ESCO.bsn	0 1
v__GW_DELAY.gw	0	100 v__CH_N2.rte	0 0.3
v__GWQMN.gw	0	2 v__CANMX.hru	0 100
v__SMTMP.bsn	0	5 v__CH_K2.rte	0 150
v__SFTMP.bsn	0	5 v__GW_REVAP.gw	0.02 0.2
v__SMFMX.bsn	0	10 r__SOL_Z().sol	-0.5 0.5
v__SMFMN.bsn	0	10 v__REVAPMN.gw	0 500
v__TIMP.bsn	0.01	1 r__EPCO.bsn	-0.5 0.5
v__SURLAG.bsn	0	4 r__TLAPS.sub	-0.5 0.5
v__RCHRG_DP.gw	0	1 r__SLSUBBSN.hru	-0.5 0.5
r__SOL_AWC().sol	-0.5	0.5 r__BLAI{8}.plant.dat	-0.5 0.5
r__SOL_K().sol	-0.5	0.5 v__BIOMIX.mgt	0 1
r__CN2.mgt	-0.1	0.1 v__SOL_ALB().sol	0 1

Table S4. Breakdown of disturbance by causal agents across all pilot watersheds

Unit	Area (ha)	Disturbance Year	Area Disturbed	Fires (ha)	Harvest (ha)	Insects (ha)	Fires %	Harvest %	Insects %
1	19851.48	2002	1.17		1.17		0	0.058441558	0
1	19851.48	2004	11.79			11.79	0	0	0.059391038
1	19851.48	2005	1.62		1.62		0	0.008160601	0
1	19851.48	2006	116.46			116.46	0	0	0.586656511
1	19851.48	2008	22.95			22.95	0	0	0.115608509
1	19851.48	2009	253.89			253.89	0	0	1.278947464
1	19851.48	2010	333			333	0	0	1.677456794
1	19851.48	2011	5665.23			5665.23	0	0	28.53807374
2	5021.55	2002	4.59	4.59			0.09140604	0	0
3	299949.39	1991	82.62	64.71	17.91		0.021573639	0.005971007	0
3	299949.39	1992	44.01		29.61	14.4	0	0.009871665	0.00480081
3	299949.39	1993	9		9		0	0.003000506	0
3	299949.39	1995	3066.21	3026.34	24.75	15.12	1.00895021	0.008251392	0.00504085
3	299949.39	1996	18.54	11.79	3.96	2.79	0.003930663	0.001320223	0.000930157
3	299949.39	1997	1.08		1.08		0	0.000360061	0
3	299949.39	1998	42.84		42.84		0	0.014282409	0
3	299949.39	1999	258.93	70.83	21.51	166.59	0.023613984	0.00717121	0.055539369
3	299949.39	2000	3550.95	3292.2	128.61	130.14	1.097585163	0.042877233	0.043387319
3	299949.39	2001	1623.51	1596.78	11.25	15.48	0.532349807	0.003750633	0.005160871
3	299949.39	2002	1706.4	1633.14		73.26	0.544471852	0	0.02442412
3	299949.39	2003	7761.96	7744.05		17.91	2.581785547	0	0.005971007
3	299949.39	2004	8215.92	8077.77	138.15		2.693044317	0.04605777	0
3	299949.39	2005	1187.37	1144.62	42.75		0.381604377	0.014252404	0
3	299949.39	2006	99.45	72.81	26.64		0.024274095	0.008881498	0

Unit	Area (ha)	Disturbance Year	Area Disturbed	Fires (ha)	Harvest (ha)	Insects (ha)	Fires %	Harvest %	Insects %
3	299949.39	2007	5569.83	5335.74		234.09	1.778880097	0	0.078043166
3	299949.39	2008	966.24	966.24			0.322134344	0	0
3	299949.39	2009	143.1		33.84	109.26	0	0.011281903	0.036426145
3	299949.39	2010	1084.05	1082.7	1.35		0.360960894	0.000450076	0
3	299949.39	2011	2031.12	1757.34		273.78	0.585878838	0	0.091275398
4	85283.28	1992	463.41	449.55	9.81	4.05	0.527125598	0.011502841	0.004748879
4	85283.28	1993	7.92		7.92		0	0.009286697	0
4	85283.28	1994	587.79	587.79			0.689220677	0	0
4	85283.28	1995	1277.28	1264.86	12.42		1.48312776	0.01456323	0
4	85283.28	1996	543.6	487.53	56.07		0.571659533	0.065745595	0
4	85283.28	1997	190.44	174.78	15.66		0.204940523	0.018362333	0
4	85283.28	1998	28.62	5.31	23.31		0.006226308	0.027332438	0
4	85283.28	1999	2.61			2.61	0	0	0.003060389
4	85283.28	2000	403.29	402.12	1.17		0.471510946	0.001371898	0
4	85283.28	2001	7.2	5.13	2.07		0.006015247	0.002427205	0
4	85283.28	2002	135	91.08	43.92		0.106797018	0.051498957	0
4	85283.28	2003	1310.22	1310.22			1.536315207	0	0
4	85283.28	2004	377.1	315.54	40.5	21.06	0.36999046	0.047488793	0.024694172
4	85283.28	2005	89.37	50.58	8.55	30.24	0.059308225	0.010025412	0.035458299
4	85283.28	2006	448.11	20.16		427.95	0.023638866	0	0.501798242
4	85283.28	2007	12979.17	12941.19		37.98	15.17435774	0	0.044533934
4	85283.28	2008	10763.1	10730.07	33.03		12.58168072	0.038729749	0
4	85283.28	2009	70.47	41.67	6.93	21.87	0.048860691	0.00812586	0.025643948
4	85283.28	2010	72.27	8.64		63.63	0.010130942	0	0.07461017
4	85283.28	2011	247.23			247.23	0	0	0.289892696
5	171407.43	1991	658.71	536.76	121.95		0.313148619	0.071146274	0

Unit	Area (ha)	Disturbance Year	Area Disturbed	Fires (ha)	Harvest (ha)	Insects (ha)	Fires %	Harvest %	Insects %
5	171407.43	1992	430.02	414.81	15.21		0.242002345	0.008873594	0
5	171407.43	1993	96.84		96.84		0	0.056496967	0
5	171407.43	1994	35.1		35.1		0	0.020477525	0
5	171407.43	1995	90.72		90.72		0	0.052926527	0
5	171407.43	1996	158.94	108.09	43.56	7.29	0.063060277	0.025413134	0.004253025
5	171407.43	1999	125.91	91.44	34.47		0.053346579	0.02010998	0
5	171407.43	2000	54.18	35.55	18.63		0.020740058	0.01086884	0
5	171407.43	2001	4.68			4.68	0	0	0.002730337
5	171407.43	2002	274.41	256.59	17.82		0.149695961	0.010396282	0
5	171407.43	2003	119.34	117.45		1.89	0.06852095	0	0.001102636
5	171407.43	2004	4267.8	4147.38	6.3	114.12	2.419603398	0.003675453	0.066578211
5	171407.43	2005	308.52	304.2	4.32		0.177471887	0.002520311	0
5	171407.43	2006	108.09	108.09			0.063060277	0	0
5	171407.43	2007	3882.06	3876.57	5.49		2.261611413	0.003202895	0
5	171407.43	2008	649.44	649.44			0.378886726	0	0
5	171407.43	2009	744.21	719.91		24.3	0.419999296	0	0.014176748
5	171407.43	2010	214.29	210.15		4.14	0.12260262	0	0.002415298
5	171407.43	2011	15.75	14.67	1.08		0.008558555	0.000630078	0
6	335489.76	1991	425.07		425.07		0	0.126701334	0
6	335489.76	1992	168.39	7.74	160.65		0.002307075	0.047885217	0
6	335489.76	1993	276.03	20.34	255.69		0.006062778	0.076213951	0
6	335489.76	1994	119.79		119.79		0	0.035706008	0
6	335489.76	1995	605.16	388.26	216.9		0.115729315	0.06465175	0
6	335489.76	1996	60.21	11.34	48.87		0.003380133	0.014566764	0
6	335489.76	1997	58.32		58.32		0	0.017383541	0
6	335489.76	1998	133.92		133.92		0	0.039917761	0

Unit	Area (ha)	Disturbance Year	Area Disturbed	Fires (ha)	Harvest (ha)	Insects (ha)	Fires %	Harvest %	Insects %
6	335489.76	1999	155.61		129.06	26.55	0	0.038469132	0.007913803
6	335489.76	2000	219.87	130.68	11.16	78.03	0.038952009	0.00332648	0.023258534
6	335489.76	2001	261.72	120.24	51.12	90.36	0.03584014	0.015237425	0.026933758
6	335489.76	2002	81.09		43.56	37.53	0	0.012984003	0.011186631
6	335489.76	2003	371.16	294.21	39.78	37.17	0.087695672	0.011857292	0.011079325
6	335489.76	2004	437.85	231.48	27.54	178.83	0.068997635	0.008208894	0.05330416
6	335489.76	2005	402.03	318.42	33.3	50.31	0.094911988	0.009925787	0.014995987
6	335489.76	2006	177.75	140.22	37.53		0.041795612	0.011186631	0
6	335489.76	2007	1890.54	1686.78		203.76	0.502781367	0	0.060735088
6	335489.76	2008	325.53	266.76	18.36	40.41	0.079513604	0.005472596	0.012045077
6	335489.76	2009	391.14	377.1	2.52	11.52	0.112402835	0.000751141	0.003433786
6	335489.76	2010	7.11		1.26	5.85	0	0.00037557	0.001743719
6	335489.76	2011	639.09	633.6		5.49	0.188858223	0	0.001636414
7	17728.02	2002	4.59		4.59		0	0.025891216	0
7	17728.02	2004	88.92			88.92	0	0	0.501578857
7	17728.02	2005	55.44			55.44	0	0	0.312725279
7	17728.02	2006	156.15			156.15	0	0	0.880809024
7	17728.02	2007	4.41			4.41	0	0	0.024875874
7	17728.02	2008	6.93			6.93	0	0	0.03909066
7	17728.02	2009	74.61			74.61	0	0	0.420859182
7	17728.02	2010	509.67			509.67	0	0	2.874940349
7	17728.02	2011	3214.53			3214.53	0	0	18.1324818
10	6280.2	2001	109.26			109.26	0	0	1.739753511
10	6280.2	2009	104.22			104.22	0	0	1.65950129
10	6280.2	2010	122.67			122.67	0	0	1.953281743
10	6280.2	2011	576.27			576.27	0	0	9.175981657

Unit	Area (ha)	Disturbance Year	Area Disturbed	Fires (ha)	Harvest (ha)	Insects (ha)	Fires %	Harvest %	Insects %
13	254950.2	1991	6.66	3.6		3.06	0.00141204	0	0.001200234
13	254950.2	1992	136.62	136.62			0.053586936	0	0
13	254950.2	1993	8.64			8.64	0	0	0.003388897
13	254950.2	1994	91.8	89.28		2.52	0.035018604	0	0.000988428
13	254950.2	1995	316.17	288.9		27.27	0.113316248	0	0.010696207
13	254950.2	1996	12326.94	12308.13	17.1	1.71	4.827660461	0.006707192	0.000670719
13	254950.2	1997	157.14	157.14			0.061635566	0	0
13	254950.2	1998	19.71		19.71		0	0.007730922	0
13	254950.2	1999	2827.17	2827.17			1.108910681	0	0
13	254950.2	2000	9542.97	9542.97			3.743072176	0	0
13	254950.2	2001	216.99	216.99			0.085110739	0	0
13	254950.2	2002	144.81	93.78	50.49	0.54	0.036783654	0.019803868	0.000211806
13	254950.2	2003	8.46			8.46	0	0	0.003318295
13	254950.2	2004	4100.13	3253.32	2.16	844.65	1.276060972	0.000847224	0.331299995
13	254950.2	2005	3958.56	3955.32	3.24		1.551408863	0.001270836	0
13	254950.2	2006	5561.19	5557.86	3.33		2.179978678	0.001306137	0
13	254950.2	2007	7369.47	7369.47			2.890552743	0	0
13	254950.2	2008	717.66	712.62	5.04		0.279513411	0.001976857	0
13	254950.2	2009	1191.33	1085.49		105.84	0.425765502	0	0.04151399
13	254950.2	2010	140.31	78.66	4.32	57.33	0.030853084	0.001694449	0.022486744
13	254950.2	2011	64.89	2.7	54	8.19	0.00105903	0.021180607	0.003212392
14	94003.65	1992	604.62	595.44		9.18	0.633422213	0	0.009765578
14	94003.65	1993	20.16		20.16		0	0.021445976	0
14	94003.65	1994	47.07	23.22		23.85	0.024701169	0	0.025371355
14	94003.65	1995	1361.52	1293.57		67.95	1.376084865	0	0.072284427
14	94003.65	1997	4.23		4.23		0	0.004499825	0

Unit	Area (ha)	Disturbance Year	Area Disturbed	Fires (ha)	Harvest (ha)	Insects (ha)	Fires %	Harvest %	Insects %
14	94003.65	1999	44.55	44.55			0.047391777	0	0
14	94003.65	2000	238.77	238.77			0.254000776	0	0
14	94003.65	2001	20.52	20.52			0.02182894	0	0
14	94003.65	2002	918.36	861.93	56.43		0.916911205	0.060029584	0
14	94003.65	2004	1090.26	1081.98	8.28		1.15099786	0.008808169	0
14	94003.65	2005	388.08	388.08			0.412835034	0	0
14	94003.65	2006	100.44	100.44			0.106846915	0	0
14	94003.65	2007	2626.65	2626.65			2.794200012	0	0
14	94003.65	2008	134.46	134.46			0.143036999	0	0
14	94003.65	2009	747.09	747.09			0.794745736	0	0
14	94003.65	2010	38.79	30.78	8.01		0.032743409	0.008520946	0
14	94003.65	2011	56.43	56.43			0.060029584	0	0