SWAT+ Bug Notes

Note – All changes are indicated in updated source code with comments marked “KDW”. Line references are to lines in SWAT+P.R&R, not existing SWAT+ code. Bugs were detected using Revision 60.3; some bugs may have been corrected in later revisions. Updated source code, SWAT+P.R&R can be found at: <https://github.com/kevin-wallington/SWAT_P.RR>

**Description of more notable or pervasive bugs:**

* Water quality routine
  + There are numerous small errors in the new water quality routine (ch\_watqual3) based on Woldegiorgis et al.
  + Most notably, the implementation of algae growth and respiration and its linkage to nutrients is often misformulated (e.g. using net growth rate when growth rate should be used)
  + Subroutines affected: ch\_watqual3, ch\_watqual4
* Sediment tracking
  + In multiple routines, the sediment yield is adjusted (due to management practice, settling, etc.) but the individual size classes of sediment are not adjusted.
  + For example, when downland HRUs receive “run-on” from upland HRUs, some of the sediment in the run-on is allowed to settle. A transport capacity is calculated to limit the amount of sediment which is carried across the HRU and added to that HRUs yield.
  + In the existing SWAT+ code, settling sediment is subtracted from the total sediment pool, but the classes (sand, silt, etc.) are not affected. This leads to dissonance between the total sediment and the sum of its parts. Also, nutrients are unaffected
  + I correct the above issue by calculating the percent of total sediment which settles on the HRU and applying that percentage uniformly to the settling of all classes of sediment and sediment associated nutrients.
  + Subroutines affected: rls\_routesurf, smp\_bmpfixed, smp\_bmpfilter, perhaps others
* Surface runoff in urban HRUs
  + Surface runoff in urban HRUs is a weighted fraction of contribution from pervious areas and impervious areas.
  + However, after calculating this aggregate surface runoff, the aggregate is often used for the basis of many calculations regarding sediment and nutrient yields.
  + Instead, the original surface runoff calculated for pervious areas should be saved as another variables and used for calculations on those pervious areas.
  + Subroutines affected: several, see below
* Litter layer
  + SWAT+ has a new “litter” layer above the top soil layer. Plant residue enters this layer, where it remains until it mineralizes/decomposes into soluble P/humic P.
  + In the existing SWAT+ code, when residue mineralizes it enters a soluble P pool within *the litter layer*. However, when residues decomposes it enters a humic P pool within the *top soil layer*.
  + In the existing SWAT+ code, the litter layer soluble P pool is the sole source of soluble P in surface runoff – soluble P in the top soil layer does not contribute to soluble P in surface runoff. Also, soluble P leaching from the litter layer skips the first soil layer and enters the second soil layer (no soluble leaches from top soil layer).
  + Lastly, in the existing SWAT+ code, organic and inorganic P fertilizers are added to the top soil layer, not the litter layer.
  + To correct the issues with the formulation described above, I (1) eliminate the soluble P pool in the soil layer, (2) re-route mineralized litter P to the top soil layer, (3) reassign the top soil layer as the source for soluble P in surface runoff, and (4) allow leaching from the top soil into the second layer.
  + I think most of the above descriptions and changes applied for NO3 as well.
  + Subroutines affected: nut\_nminrl, nut\_nlch, nut\_solp
* Total vs. “Fresh” organic P
  + “Fresh organic P is associated the crop residue and microbial biomass” (SWAT 2009 theory document, p 208). P enters the “fresh” via organic fertilizer or crop residue and leaves via mineralization (80% - to soluble P pool) and decomposition (20% - to organic, humic pool).
  + In the existing SWAT+ code, throughout all routines (except perhaps cbn\_zhang2, nut\_orgnc2, NCsed\_leach, I did not work with those carbon routines), the “total” P pool is used where the “fresh” P pool should be used. This is problematic because the “fresh” P pool is initialized as only 2 percent of the total pool.
  + To correct the issue above, I changed most (all?) instances of the variable soil1(j)%tot(k) (jth HRU and kth soil layer) to soil1(j)microb(k). This could perhaps also be corrected by changing the initialization and leaving the variables as they are in the rest of the code (though the variable name would still be misleading).
  + Subroutines affected: mgt\_newtillmix, nut\_nminrl, nut\_psed, pl\_fert, pl\_graze, rls\_routesurf (or soil\_nutcarb\_init for changing initialization).
* Reservoir/wetland outflows
  + After simulating all reservoir (or wetland) processes (including sediment trapping and settling, nutrient settling, and water balance components), the outflows are subtracted from the reservoir.
  + In the existing SWAT+ code though, only the water outflow is subtracted (not the sediment or water quality variables).
  + To correct the above issue, I subtract outflows of sediment and all water quality variables when SWAT+ subtracts the water outflow.
  + Subroutines affected: res\_control and wetland\_control

**Line-by-line description of all bugs:**

Actions

Line 358 - Wrong variable used for calculating basin crop yield; replace “yield” with “pl\_yield”

Cal\_allo\_init

Lines 94-99 – Need to initialize channel for option not using chandeg; add if statement with “channel\_init = ch”

Cal\_conditions

Lines 94-102 – calibrating individual layers of soil is incompatible with “soil\_awc\_init” routine which is called in “cal\_parm\_select” for some soil variables; comment out layer identification and do loop

Line 173-175 – need to recalculate time of concentration when calibrating OVN; “time\_conc\_init” is called here rather than in “cal\_parm\_select” because need outside of HRU loop

Cal\_parm\_select

Line 46 – “ly” not an intent(in) variable anymore due to issue above

Lines 229-234 – need to recalculate tile\_ttime when calibrating tile\_lag

Lines 265-382 – do loops added to calibrate every soil layer (with same value – important to only use percent change for soil calibration with this formulation)

Lines 313, 323,331 – soil\_text\_init should only be called for top soil layer

Line 595,601,607 – issue with channel nutrient file “ielem”?

Cal\_parmchg\_read

Line 115 – change case from “cha” to “rte” for routing variables

Line 116 – change number of elements from sp\_ob\_chan to db\_mx%ch\_hyd

Line 117 – change case from “cha” to “sed” for sediment variables

Line 118 – change number of elements from sp\_ob\_chan to db\_mx%ch\_sed

Ch\_initial

Lines 106-126 – calculation of bed\_kd and bnk\_kd needs to be repeated here (or somewhere in the code) in case tc\_bed or tc\_bnk values are calibrated

Line 16-18 and 129-157 – channel storage and water quality need to be initialized using om\_init\_water

Ch\_read\_sed

Line 59 – moved down to line 124 so as not to exit do loop before checking bounds on parameters

Ch\_rtsed\_bagnold/kodatie/Molinas\_Wu/yangsand

Line 1082-1083 (for Bagnold, just before end of routine for all) – the bank erosion contributions of organic N and P are never added to the organic N and P stored in the water column (therefore routed downstream). Did not fix because incorporated bank erosion elsewhere.

Ch\_watqual3

Lines 199-210 and 262-308 – I had issues with inflow water quality concentrations, so I had to declare the variables and calculate the concentrations within watqual3 (instead of just in channel\_control)

Line 224-233 – “residence time” as used by the Woldegiorgis water quality simulation scheme (applied here) is really just a variable to indicate the relative volumes of inflow versus storage left from the previous time step; therefore, the residence time calculation here is changed from rttime/24 to rchstore/wtrin

Lines 235-238 – water temperature is used for calculating benthic sources, so water temperature calculation needs to be moved up to here

Line 430 – add if statement (rchdep > 0) to avoid dividing by zero

Line 437 – wrong variable used for daylength; change wgn\_pms(iwgn)%daylth (the dormancy threshold) to wst(iwst)%weat%daylenth (the actual daylength

Lines 462 – need to assign (temperature adjusted) algal growth rate parameter to factk before calculating the growth rate itself

Lines 463-464 – alg\_m1 is used as the zeroth-order equivalent rate for algal growth; as such, it should be calculated by calling the function wq\_kwm, not wq\_semianalyt

Lines 466-467 – like above, should call wq\_k2m, not wq\_semianalyt

Line 542, 560, 577, 603 (had been 469-471) – rather than using the net growth rate (alg\_m) the growth rate (alg\_m1) should be used for dissolved P (and N) uptake and the respiration/death rate (-alg\_m2) should be used of organic P source.

Line 487 – replace “cbodo” with “cbodocon” (the concentration)

Line 505-506 – bc1\_m needs to be calculated before rch\_dox calculation, and thus need to be moved up in code; also, rather than using “factk” as input, use “bc1\_k”

Line 507-508 – like above, bc2\_m needs to be calculated before its use for calculating rch\_dox (otherwise “old” value from prior reach will be used)

Line 513-514 – rk4\_m (benthic oxygen) should not be included here as it is already accounted for in line 337; alg\_m\_o2 does need to be included in factm

Lines 534-536 – alg\_orgN\_m (algal death contribution to organic N) should be calculated here and added to factm for organicn calculation

Line 546 – algal uptake of NH4 should be subtracted from factm for ammonia N calculation

Line 561-562 – alg\_m\_no3 changed to alg\_no3\_m

Line 571 – nitrate N should not be zeroed out here

Line 579-580 – organic P from algal death/respiration should be added to factm for organic P calc

Line 605 – dissolve P uptake should be subtracted from factm for dissolved P calc

Ch\_watqual4

I did not use this routine, but it seems that many (all?) of the same bugs as above are present here as well

Channel\_allo

Line 21 – allocation needed for channel\_init

Channel\_control

Consider moving transmission losses, revap, and bank storage contributions to occur between routing and water quality/sediment simulation. Otherwise bank storage can have excessive dilution effect on low flow days.

Channel\_module

Line 157-158 and 344-345 – may want to change units for these outputs to m^3/s (more common for calibration use and intuitive interpretation) instead of ha-m

Ero\_cfactor

Line 47 – calculation of cover should be moved out of if loop because also used in else portion

Ero\_pkq

Lines 43-48 – consider using an alternative variable “surfq\_pervious” (see notes below in \_\_\_) for calculation of peak rate in urban HRUs

Ero\_ysed

Lines 54-58 – consider using “surfq\_pervious” and only the HRU area which is pervious for calculation of sed\_yld for urban HRUs. (1) Use surfq\_pervious because high surface runoff from impervious area shouldn’t impact sediment yield from impervious area (2) Calculate sedyld from reduced area here rather than in hru\_urban because the equation for sedyld is nonlinear – i.e. shouldn’t just multiply by (1-urbdb()%fimp) in hru\_urban

Hru\_control

Lines 88/93 – precipday needs to be assigned from wst()%weat%precip before using precipday to assign precip\_eff (otherwise precip\_eff is based on precip from prior HRU in loop)

Lines 217 – 222 – Need to also add each class of sediment (clay, silt, etc.) routed across HRU

Lines 227-232 – consider using surfq\_pervious to adjust inflpcp for urban HRUs

Lines 240 and 421-428 – consider moving wetland control to later in routine, important if want to route lateral flow through wetland (currently, code does not)

Lines 384 – 387 – here, add sediment associated nutrients that are routed across the HRU from run-on

Line 460 – move “call swr\_subwq” down, after all nutrient calculations and BMP impacts, so that all processes incorporated

Note – also may want to consider formulation for HRU output calculation for urban HRUs; for instance, the total water yield should perhaps multiply lateral and tile flow by the pervious area fraction (Lines 443-445).

Hru\_hyds

Lines 74, 77, 78 – conversions from HRU output to hydrograph units for chla, cbod, and dox should use “\* flo / 1000” not “\*cnv\_kg” (i.e. “\*area”); likewise for lines in lateral flow and tile flow hydrographs

Hru\_module

Line 372 – If adding surfq\_pervious as variable in routines, declare here

Hru\_urb\_bmp

Lines 33-40 – need to remove sediment of each class as well as total; I do so uniformly across all classes

Line 57 – should be “sedorgp = “, not “sedorgn = “

Hru\_urban

Lines 103-137 and 181-216 – if using alternative “surfq\_pervious” to calculate sediment load from pervious area fraction or urban HRU (see above), do not need to multiply pervious contribution by (1 – fimp) here

Hru\_urbanhr

Lines 117-137 – same as above if using surfq\_pervious

Hrudb\_init

Line 36-49 – need to assign land use pointers here (instead of in plant\_init) so that they occur before topohyd\_init is called (because topohyd\_init has code that uses tile drainage flag)

Mgt\_harvbiomass

Lines 55-56 – clippings should be added to residue for each individual plant (ipl)

Mgt\_harvgrain

Lines 44-45 – since slow humus (soil1()%hs()) pool is not used in model for P, seed mass is instead added to the “fresh” organic (soil1()%microb()) pool

Mgt\_harvtuber

Lines 45-46 – same as above, add seed mass to fresh instead of slow humus pool

Mgt\_killop

Line 33-34 – same as harvbiomass, add clippings to residue for each plant (ipl)

Mgt\_newtillmix

Lines 156-157 and 209-210 – (here and in several other routines) the fresh, organic pools of N and P should use the variable soil1()%microb()% not soil1()%tot()% (which is “total” organic N or P).

Mgt\_sched

Line 206-207 – same as actions.f90, wrong variable used for calculating basin crop yield; replace “yield” with “pl\_yield”

NCsed\_leach

If using surfq\_pervious approach, will likely need to update this routine; I did not use this routine

Nut\_nlch

Line 60 – set percnly = ht1%no3 before do loop (no3 from run-on)

Lines 70-74 – use surfq\_pervious for sro in mobile water calculation

Line 85 – cosurf (not co) should use nperco factor

Line 87-91 – use surfq\_pervious for no3 in surface runoff

Lines 132-135 – this “lost” no3 just disappears, doesn’t reach stream but still leaves soil; I just commented this code out

Nut\_nminrl

Lines 92-97, 104-109 – (Litter Layer Issue – see explanation below), only use rsd1()%tot()%n/p for calculating c:n/p ratio, since litter dissolved nutrient pool has been removed

Lines 158-162 – re-direct mineralization P coming from litter layer to enter top soil layer

Lines 239-281 – all instances of soil1()%tot()% should be replaced with soil1()%microb()%, since these lines are meant to reference the fresh, organic pool

Lines 273-277 – decay of fresh organic material comes from microb pool unless using cbn\_zhang option

Nut\_orgnc2

If using surfq\_pervious approach, will likely need to update this routine; I did not use this routine

Nut\_psed

Lines 59-64 (and 113-121) – for sedpattach, soil1()%man()% pool only exists if using cswat 1, otherwise %microb should be used (“fresh”); also rsd1()%man% is not a pool used elsewhere in the model, instead I include all organic P in the litter layer here (summed across all plant types)

Lines 66, 99, 106-108 – as above change soil1()%man()% to soil1()%microb()%

Nut\_solp

Line 49/53 – add solp from runon to percolation for top soil layer

Lines 56-61 – update to use surfq\_pervious

Line 59/62/64 – replace rsd1(j)%mp%lab with soil1(j)%mp(1)%lab because soluble P should be lost from top soil layer not residue/litter layer (fertilizer applied to soil not litter)

Pest\_enrsb

Lines 42-47 – only use pervious area and flow to calculate cy and enrichment ratio

Pest\_lch

Lines 72-79, 91-95 – update to use surfq\_pervious for urban HRUs

Pl\_biomass\_gro

Line 48 – commented out b/c undoes effect of lines 33-46

Pl\_dormant

Lines 38-43 – commented out b/c “perennial” type include forest, where stem should not become residue

Pl\_fert

Lines 72-73/76-77 – change pool for fresh organic from soil1(j)%tot(1)%n or p to soil1(j)%microb(1)%n or p

Pl\_graze

Lines 111-112/117-118 – same as above

Pl\_mortality

Lines 23-24 – if want excess biomass to be added to residue, need to edit (currently it just makes the excess the new total residue); also, should excess even go to residue at all?

Pl\_waterup

Lines 130-132 – move up wuse limit to before calculating sum\_wuse

Plant\_init

Lines 62-64/75-82 – moved to hrudb\_init as described there

Lines 118/274-275 – since cvm = ln(c) and c<1, adding cvm in line 274 causes cvm and c to become too small; instead use maximum plant cvm as community cvm (i.e. community usle\_c is equal to maximum usle\_c among plants), and set baseline at cvm = -7 (usle\_c = 0.001)

Line 298 – add plant lai potential to community lai potential

Proc\_hru

Line 24 – why is topohyd\_init called again, already called in line 16

Res\_control

Line 27-29 – some disparities in how reservoirs and wetlands are handled in “control” routines, so need identifier when calling water quality or sediment routines

Line 42-44 – reservoir inflow should be assigned before trapping (moved up from line 198)

Line 69-74 – move nutrient routine up to occur with sediment rather than after evap, seep, and precip

Lines 101-121 – all water quality variables need to be subtracted following outflow, not just water volume

Res\_sediment

Line 36 – overflow velocity should be calculated using outflow (ht2%flo), not reservoir volume (wbody%flo)

Lines 45-74 – this formulation does not maintain balance between total sediment and the sum of its components; see new routines “res\_trap” (lines 80-113,159-166) and “res\_sediment2” (lines 98-178) for adjustment

Rls\_routesoil

Lines 36-46 – lines added to add N and P from lateral flow run-on to soil layers

Rls\_routesurf

Lines 36-37 – commented out; ht1 used for dissolved nutrients in run-on, added to percolate

Lines 64-76 – sediment transport capacity applied to size classes as well as total sediment

Lines 77-87 – sediment associated N and P added to top soil layer if settles or passed through via ht2

Sim\_initday

Line 88 – need to initialize surfq\_pervious here if using

Smp\_bmpfixed

Lines 47-51 – need to subtract sediment from each size class as well as total

Smp\_filter

Line 140/144 – sedtrap moved up, needs to be calculated before updating sedyld

Soil\_awc\_init

Lines 79-81 – need to reset sumul, sumfc, and sumwp to zero between runs of the routine for different soils

Lines 103-106 – water table depth should be adjustment of soil profile depth

Soil\_nutcarb\_init

Note – I moved lines 24-84 to soil\_test\_init (and edited there according to new P formulation) and changed much of the initialization; with existing code, review whether \* 100000 is appropriate in lines 49,69,70

Lines 104/110/112 – hs (stable humus) pool isn’t used in the model for P, all humus P should be assigned to hp

Soil\_nutcarb\_write

Line 50 – soil1(ihru)%tot should be %microb

Soil\_phys\_init

Lines 150-152 - need to reset sumul, sumfc, and sumwp to zero between runs of the routine for different soils

Lines 103-106 – water table depth should be adjustment of soil profile depth

Lines 136-148 – depth fraction should be implemented for most nutrients

Sq\_canopyint

Lines 28/40 – precip\_eff should come from hru\_module, not be declared anew (and thereby resetting value)

Sq\_crackflow

Lines 36-44 – adjust for surfq\_pervious

Sq\_daycn

Line 45 – save surfq\_pervious before updating surfq for impervious effects

Line 50/52 – use precip\_eff\_imp for calculating impervious runoff

Sq\_greenampt

Should be edited to properly account for impervious area effects in manner similar to daycn (above)

Stor\_surfstor

Line 97 – commented out because repreated in line 149

Surface

Line 46 – assign precip\_eff\_imp before allowing canopy to intercept precipitation

Lines 71-76 – adjust for using surfq\_pervious

Line 86 – Note, peakr is superceded by calculation in hru\_control (lines 243-247)

Lines 93-95 – ero\_ovrsed should only be called for subdaily simulation

Swr\_drains

Lines 194-198 – adjust for surfq\_pervious

Swr\_latsed

Line 143/148/180 – change %tot(1)% to %microb(1)%

Swr\_percmain

Line 190 – change to loop only through layers at above layer of drain, not full soil profile

Swr\_satexcess

Line 75-81 – adjust for surfq\_pervious

Line 127/134-135/142-145 – seepage must be added to/subtracted from percolation in order for proper nutrient leaching

Swr\_subwq

Line 82-83 – include subsurface N in calc of total N yield

Lines 84-86 – where does 0.1 come from, in mg/L was 0.04 in SWAT 2012

Lines 89/95 – should be percent carbon content, not kg/ha

Lines 90-94 – include enrichment ratio for calculating carbon

Wetland\_control

Lines 50-52 – added wetland identifier for use as input to sediment and water quality routines

Lines 72-90 – all sediment and water quality variable inflows should be modified by fracwet

Lines 145-150 – move nutrient routine up to follow sediment, precede

Lines 165-184 – need to subtract outflowing sediment and nutrients, not just water volume