# Controlled Drainage Synthesis: Flow Filling Methods

10/17/2017 Web Meeting

Attendees: Matt Helmers, Jane Frankenberger, Ben Reinhart, Gio Chighladze, Kelly Nelson, Dan Jaynes, Lori Abendroth, Lindsay Pease, Samaneh Saadat, Laurent Ahiablame

[Recording](https://mediaspace.itap.purdue.edu/media/20171017_CDWorkGroup_FlowFill/0_ynoufagm)

Gio first presented a flow chart showing the proposed steps for data filling and aggregation. The group confirmed that for both daily and sub-daily data, using replicate plot data should be prioritized over the water table approach used by Samaneh S. where she used hourly water table to get hourly drain flow. A daily approach to water table could potentially be used but would need to decide if to use average daily values or ending day water table.

The group then reviewed the completion status for each site. There are currently 5 sites (of 17) which are continuous without any gaps (UBWC\_OH, STORY\_IA, MUDS4, MUDS3\_OLD, MUDS2).

Jane proposed an approach for filling that Ben is working on for DPAC. It is based on the following.

**Assumption is that only two conditions cause drain flow on a given day:**

1. Precipitation (or snowmelt) occurred on that day above a certain threshold (Ben suggested 10mm based on [Lam et al. 2016](http://onlinelibrary.wiley.com/doi/10.1002/hyp.10871/abstract))OR
2. Drain flow, if above a certain threshold (Ben suggested minimum avg. daily flow during summer) from the day before continues

**Data needed:**

* Precipitation (possibly including an estimate of snowmelt if the method is used in the spring, particularly in areas where freeze/thaw cycles are significant drivers of hydrology. Ben did not include this.)
* Drain flow record to do…
  + (1) A regression of precipitation and drain flow in each season
    - Ben defined Winter [Jan-Mar], Spring [Apr-Jun], Summer [Jul-Sep], Fall [Oct-Dec]
    - Also, using a 3-day avg. precipitation (current day, day-1, day-2) provided a better R2 value on the regression, so that is the measure that was used initially. These relationships are still pretty weak though, ranging in R2 from 0.14-0.54.
  + (2) A 1st order recession of drain flow for each season.
    - Ben estimated the slope (k) for all drain flow recessions > 1 day and calculated as the linear slope of lnQ across the recession period (where Q = daily drain flow value).

**Method:**

For each day…

1. If there is precipitation (condition A), estimate the amount of drain flow using the seasonal regression (drain flow vs precipitation). This estimates the peak.
2. If there was drain flow the day before (condition B), apply recession equation () to that day's flow. This estimates the falling limb of drain flow.
3. If neither of these exist in a day, drain flow = 0.

The group discussed this regression-recession approach. The approach doesn’t include freeze-thaw/snowmelt which could generate some drain flow even if precipitation was zero and previous day’s drain flow was zero. But this would be constrained to late winter/early spring and probably not a large percent of total annual flow. Otherwise the assumption of zero flow when daily precipitation and no prior flow seems to be safe.

**Some graphs showing resulting time series with measured (blue, labeled “FD AVG”) and filled (orange, labeled “Ben\_FD”) are included at the end of this document. While thresholds were originally suggested for conditions A and B, these were not used as they are somewhat arbitrary and could vary through time and space opening up some bias. For the sake of having a simple approach for filling small gaps (<1 month), step 1 (regression) was applied whenever precipitation > 0 and recession was applied whenever prior day flow > 0.** Ben and Samaneh S. will work to compare this method with the water table method she used. Ideally, whatever filling method we use would be easily automated which may not be the case for the water table method. However, it was suggested that the regression-recession method only be used for gaps maybe less than or equal to one month. Gaps greater than this should look to either water table or some other method. Jane and Ben have discussed some potential improvements to the regression-recession method to improve the regression such as:

* Utilize soil moisture measurements to help identify drainage-inducing precipitation events and then use these events in the regression
* Establish a threshold of the previous day’s flow to reduce the number of days where precipitation is zero and drain flow continues. During the meeting Ben proposed using the average daily drain flow during the summer, the lowest flow season, as a threshold.
* Conduct the regression on the increase in drain flow [D(i) - D (i-1)] rather than just the daily value.

Gio asked the question of how much data needs to be present in order to aggregate to a certain time scale (e.g. >XX hrs to aggregate to daily avg. value). We can apply the regression-recession filling method to fill in any days where hourly data is missing. The group discussed how to aggregate monthly and annual flow. Gio proposed using a site-specific weighting scheme for doing this. This will be discussed by the group at a later meeting. In regards to synthesis, we may not need complete annual datasets as long as we have corresponding records for free drainage and controlled drainage during a given month.

NEXT STEPS: The group should focus on progressing through the proposed order for filling in order to establish more sites as complete continuous datasets.

Revised Proposed order of data filling (Changes/Updates/Suggestions are in red):

1. PI QA/QC identify freezing events/known periods with zero flow
2. For data gaps <= 4 hours; linearly interpolate between first/last data point
3. Use replicate (if present) to fill missing data for gaps > 4 hours
   1. Used for both hourly and daily values
4. Use water table data (if present) to model missing data
   1. Use this for gaps greater than a month
5. Method used by Ben
   1. If there is precipitation (condition A), estimate the amount of drain flow using the seasonal regression (drain flow vs precipitation).
   2. If there was drain flow the day before (condition B), apply recession equation to that day's flow.
   3. If neither of these exist in a day, drain flow = 0.
6. If > 25% of days in one year are still missing, do not use that year.

DPAC site order:

1. PI QA/QC identify freezing events/known periods with zero flow
2. Use water table data (if present) to model missing data
3. Use replicate (if present) to fill missing data (daily time step)
   1. Use daily regression equation
4. For remaining data gaps; linearly interpolate between first/last data point

GIO’s NOTES and IDEAS:

Recession Slope

* Recession slope is right-skewed. Using **Geometric mean** to calculate the seasonal average recession slope will be more appropriate than arithmetic mean. The latest predictions (Dec 6, 2018) are based on Trimmed Mean with 10% data removed from the both end.

3-Day Rolling Average Precipitation

* Earlier trials showed that 2-day rolling mean precipitation produced a slightly better prediction of peak flows when used for limited sites (SERF\_IA, SERF\_SD, STJOHNS, and HENRY) based on R2 values (Fig.1).
* Current version of 3-day rolling mean has a cumulative effect because each individual precipitation has the same weight when calculating the average. This creates overestimation of tile flow in certain cases which manifest as squared peaks (Fig.2) One of the solutions is to introduce weights (for example 0.1, 0.3, 0.6) when calculating rolling average.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date | Precip | Current 3-day Rolling Ave | New 3-day Rolling Ave (10%, 30%, 60%) | New 2-day Rolling Ave (40%, 60%) |
| 2012-05-01 | 0 | 0 | 0 | 0 |
| 2012-05-02 | 0 | 0 | 0 | 0 |
| 2012-05-03 | 3 | 1.0 | 1.8 | 1.8 |
| 2012-05-04 | 5 | 2.7 | 3.9 | 4.2 |
| 2012-05-05 | 1 | 3.0 | 2.4 | 2.6 |
| 2012-05-06 | 0 | 0 | 0 | 0 |

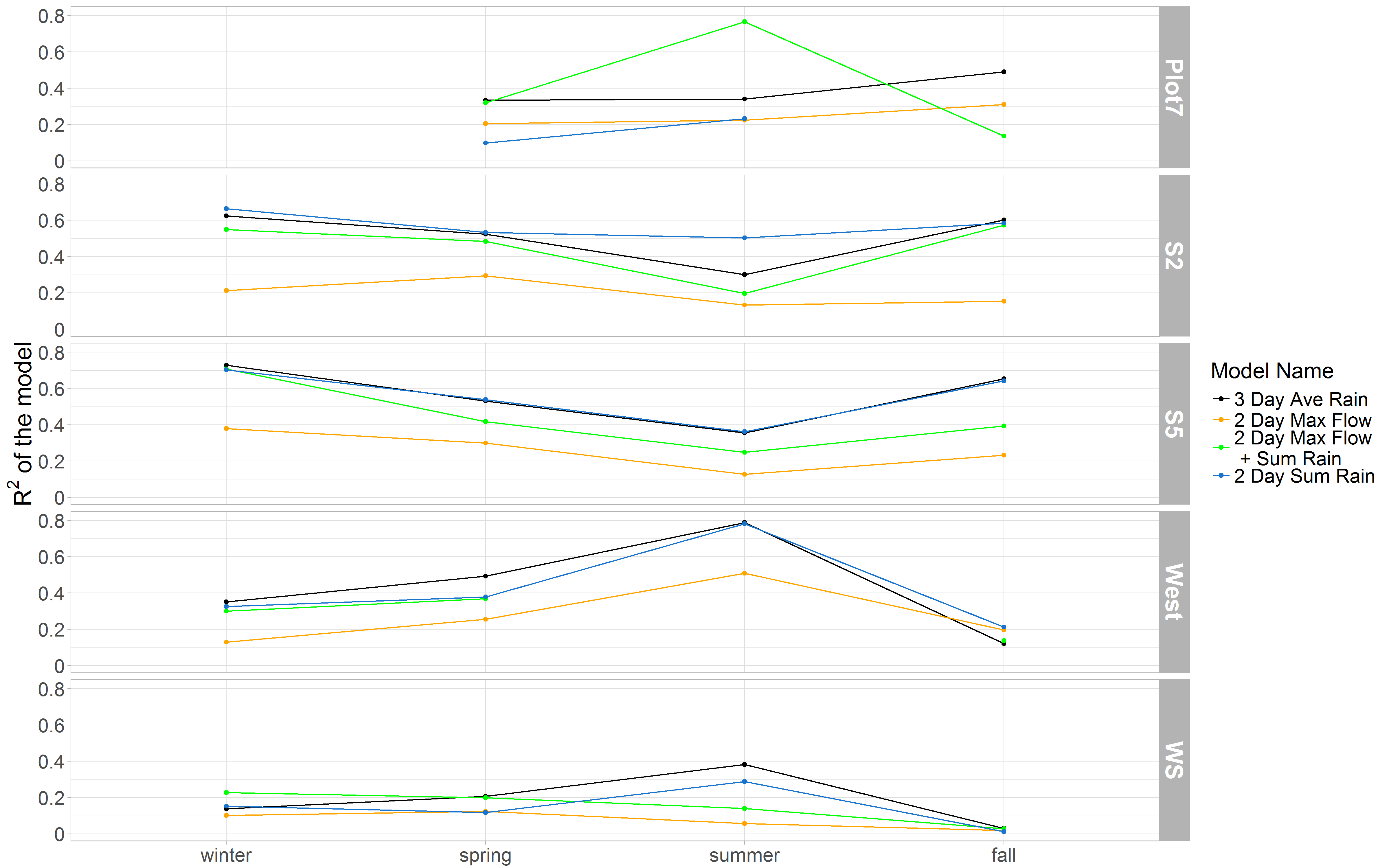


Figure 1. R2 of peak flow predictions models.

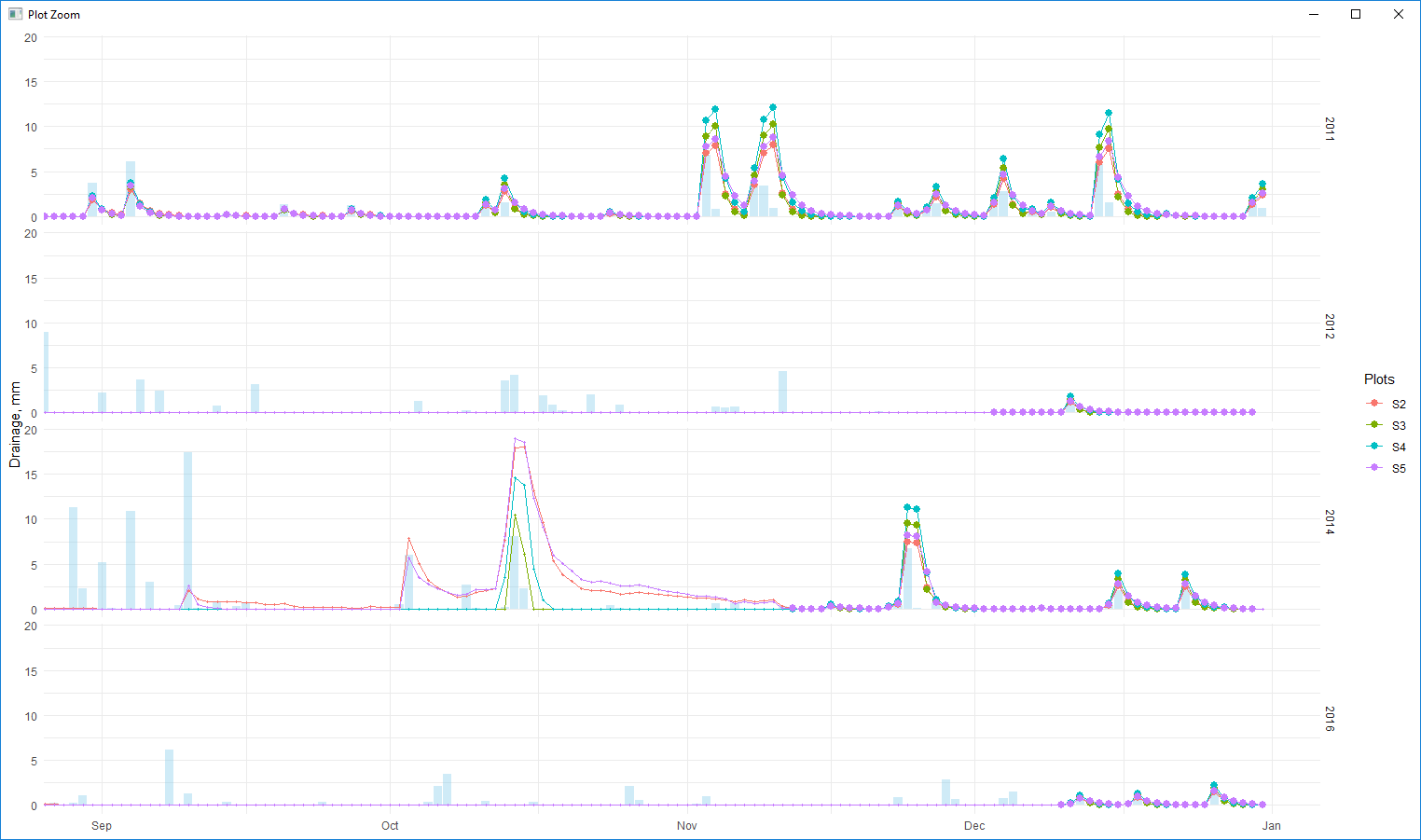


Figure 2. Gap-filled data at SERF\_IA. Predicted flows are shown with bigger points.

