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**Jewett Brook Phosphorus Loading**

**Methods**

Annual and monthly phosphorus mean loading rates from Jewett Brook for the period of May 2017 to April 2018 were estimated from stream discharge and phosphorus concentration measurements obtained during the period of January 2017 to September 2018. This date range was chosen to provide an adequate phosphorus sample size to support the development of loading regression models while limiting the data to recent months best representing agricultural management and other watershed features present during the tile drain monitoring period.

Discharge measurements for use in estimating phosphorus loading in Jewett Brook were obtained from the U.S. Geological Survey (USGS) stream flow gage station on Jewett Brook (USGS Reference No. 0429810, 3.74 mi2 drainage area). Average daily flow rates in cubic feet per second (cfs) for the period of 1/1/2017 to 9/30/2018 were downloaded for this site on 10/1/2018 from the USGS National Water System website (<https://waterdata.usgs.gov/vt/nwis/uv?site_no=04292810>). Average daily flow values after 10/11/2017 were identified as provisional by the USGS. No flow values were reported on a total of 35 winter days between 12/28/2017 and 2/21/2018 due to intermittent ice effects at the gage site. These missing values due to ice effects were replaced for this analysis with flow rates representing the mean value from the two nearest adjoining dates that had flow data provided. Zero discharge rates were reported on 74 days during the dry summer months of 2018. These zero values were replaced for this analysis with values of 0.001 cfs in order to permit logarithmic transformation of the data.

Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations measured in samples from Jewett Brook were obtained from the Vermont Department of Environmental Conservation, Lake Champlain Long-Term Monitoring website (<https://anrweb.vermont.gov/dec/_dec/LongTermMonitoringTributary.aspx>). Results from a total of 29 TP samples and 21 TDP samples obtained under a range of flow conditions from 2/24/2017 to 9/11/2018 were used for this analysis.

The USGS program LOADEST (Runkel et al. 2004) was used to calculate phosphorus loading rates in Jewett Brook from the stream flow and phosphorus concentration data. The utility program LoadRunner (Raymond et al. 2011) was used to automate runs of LOADEST.

LOADEST supports the development of regression models to calculate daily, monthly, and annual mean loads (with error estimates) from constituent concentration data and a time series of daily stream flow measurements. Several pre-defined regression model options are provided in LOADEST to predict loads from various combinations of stream flow and decimal time. For this analysis, LOADEST was allowed to automatically select the optimum regression model from the pre-defined list for both TP and TDP load estimation, based on a minimum value of the Akaike Information Criterion statistic.

Regression coefficients were fit by LOADEST using Maximum Likelihood Estimation, appropriate for uncensored data (no results below detection limits) and where regression residuals are normally distributed. Regression diagnostic procedures described in Runkel et al. (2004) were used to confirm that model residuals were independent, homoscedastic, and normally distributed.

**Results**

Application of the LOADEST program to the Jewett Brook data resulted in the selection of LOADEST regression model 2, described in equation 1, for both TP and TDP load estimation.

ln(L) = a0 + a1 ln(Q) + a2 ln(Q)2 (1)

where, ln(L) = natural log of the daily loading rate

ln(Q) = ln(daily stream flow rate) – center of ln(daily stream flow rate)

a0, a1, a2 are calibrated regression coefficients

Regression models calibrated from discharge and phosphorus concentration data obtained during the date range of 1/1/2017 to 9/30/2018 were used to estimate monthly and annual TP and TDP loading rates for the period of May 2017 to April 2018, which closely approximates the tile drain monitoring period. Loading estimates and their 95% confidence limits calculated by the LOADEST program are shown in Tables 1 and 2 for TP and TDP, respectively. These loading estimates apply at the location of the USGS stream gage station on Jewett Brook. No adjustments were made to account for the additional downstream watershed area.

**References**

Raymond P., N.H. Oh, R.M. Holmes, and G. Booth. 2011. LoadRunner v1.2b. Yale School of Forestry and Environmental Science. <https://environment.yale.edu/loadrunner/>

Runkel, R.L., C.G. Crawford, and T.A. Cohen. 2004. Load estimator (LOADEST): A FORTRAN program for estimating constituent loads in streams and rivers. U.S. Geological Survey Techniques and Methods Book 4, Chapter A5. Reston, VA. <https://water.usgs.gov/software/loadest/>

Table 1. Monthly mean total phosphorus (TP) loading rates and their 95% confidence limits in Jewett Brook during the tile drain monitoring period.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Month | Year | N Days | Mean Flow (cfs) | Mean Load (kg/day) | Lower 95% Limit (kg/day) | Upper 95% Limit (kg/day) |
| May | 2017 | 31 | 5.69 | 5.24 | 4.06 | 6.66 |
| June | 2017 | 30 | 5.62 | 5.40 | 3.89 | 7.31 |
| July | 2017 | 31 | 3.91 | 3.56 | 2.70 | 4.61 |
| Aug. | 2017 | 31 | 0.52 | 0.46 | 0.34 | 0.62 |
| Sep. | 2017 | 30 | 0.93 | 0.83 | 0.58 | 1.14 |
| Oct. | 2017 | 31 | 0.64 | 0.56 | 0.40 | 0.76 |
| Nov. | 2017 | 30 | 2.92 | 2.58 | 2.00 | 3.27 |
| Dec. | 2017 | 31 | 1.13 | 0.98 | 0.75 | 1.26 |
| Jan. | 2018 | 31 | 9.04 | 8.67 | 6.60 | 11.18 |
| Feb. | 2018 | 28 | 12.25 | 11.32 | 9.23 | 13.74 |
| Mar. | 2018 | 31 | 9.52 | 8.98 | 6.97 | 11.38 |
| Apr. | 2018 | 30 | 15.23 | 14.99 | 11.59 | 19.07 |
| Period Total | | 365 | 5.55 | 5.24 | 4.46 | 6.12 |

Table 2. Monthly mean total dissolved phosphorus (TDP) loading rates and their 95% confidence limits in Jewett Brook during the tile drain monitoring period.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Month | Year | N Days | Mean Flow (cfs) | Mean Load (kg/day) | Lower 95% Limit (kg/day) | Upper 95% Limit (kg/day) |
| May | 2017 | 31 | 5.69 | 3.90 | 2.79 | 5.30 |
| June | 2017 | 30 | 5.62 | 3.91 | 2.58 | 5.68 |
| July | 2017 | 31 | 3.91 | 2.70 | 1.88 | 3.74 |
| Aug. | 2017 | 31 | 0.52 | 0.39 | 0.26 | 0.56 |
| Sep. | 2017 | 30 | 0.93 | 0.66 | 0.42 | 0.98 |
| Oct. | 2017 | 31 | 0.64 | 0.46 | 0.30 | 0.68 |
| Nov. | 2017 | 30 | 2.92 | 2.02 | 1.44 | 2.75 |
| Dec. | 2017 | 31 | 1.13 | 0.81 | 0.56 | 1.13 |
| Jan. | 2018 | 31 | 9.04 | 6.23 | 4.38 | 8.60 |
| Feb. | 2018 | 28 | 12.25 | 8.31 | 6.29 | 10.78 |
| Mar. | 2018 | 31 | 9.52 | 6.53 | 4.71 | 8.83 |
| Apr. | 2018 | 30 | 15.23 | 10.57 | 7.54 | 14.42 |
| Period Total | | 365 | 5.55 | 3.83 | 3.05 | 4.75 |