

INTRODUCTION

The Susquehanna River Basin Commission (Commission) requires passby flows for certain withdrawals to establish limitations to avoid significant adverse impacts to the water resources of the Basin. When possible, streamflow conditions are monitored by local gages, but in many instances the Commission establishes passby flows for withdrawals from ungaged streams and monitors streamflow conditions using United States Geological Survey (USGS) reference gages. In doing so, reference gages are selected based on hydrologic similarities between the gaged and ungaged watersheds. However, the effectiveness of these reference gage selections for passby flow implementation has not been thoroughly investigated to date.

This study was conducted to evaluate the predictive accuracy associated with using reference gages to estimate passby flow conditions at ungaged withdrawal sites regulated by the Commission.

WITHDRAWAL SITES

Twenty surface water withdrawal sites with passby flow requirements on streams without USGS gages were selected for evaluation (Figure 1). Reference gages meeting specific selection criteria were used to calculate streamflow statistics and determine appropriate passby flow thresholds. Certain reference gages that report real-time streamflow data are then used for low flow monitoring and passby flow compliance purposes.

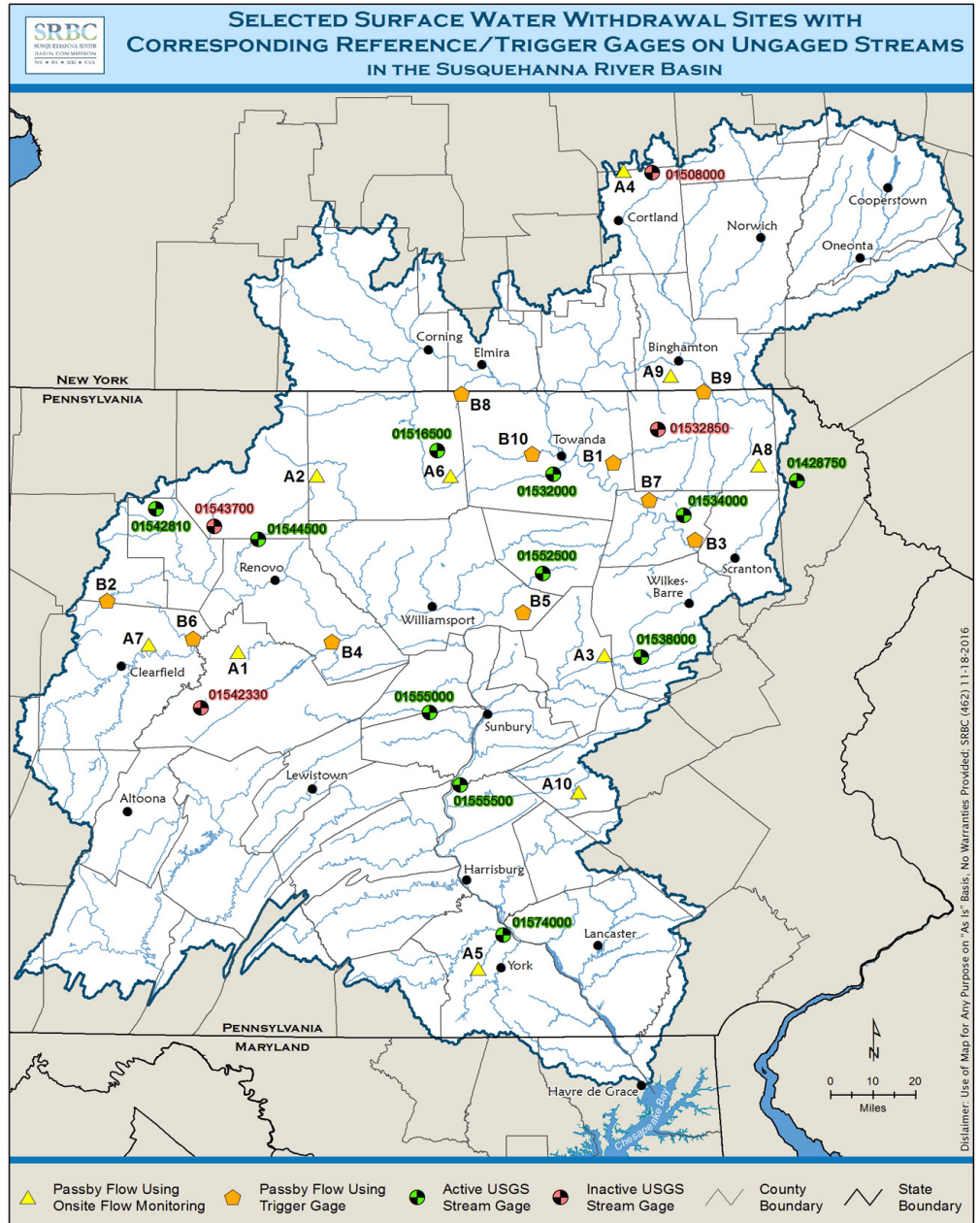


Figure 1. Selected Withdrawal Sites with Corresponding Reference/Trigger Gages

Four industry types were represented among the 20 withdrawal sites, including natural gas extraction, golf courses, skiing facilities, and water bottling. At ten of the withdrawal sites (A1 to A10), the operator maintains onsite flow monitoring devices to record streamflow and comply with applicable passby flow requirements. At the other ten sites (B1 to B10), operators monitor USGS real-time trigger gages located outside the source stream watershed to comply with applicable passby flow requirements.

STREAMFLOW MONITORING

Field streamflow measurements at withdrawal sites and concurrent streamflow records at reference gages were obtained during the low flow months of July through November from 2011 to 2014. Ten streamflow measurements during baseflow conditions were targeted for each withdrawal site. Ideally, the baseflow measurements were to be obtained well after any measurable rainfall events in the watershed upgradient of the withdrawal site.

FIELD STREAMFLOW MEASUREMENTS

A FlowTracker® Handheld Acoustic Doppler Velocimeter (ADV) was used in the field to measure stream velocity and calculate streamflow rates. The bucket and drop leaf methods were employed for streamflow measurements in small headwater streams. Streamflow measurements were not taken at sites A1 and A7 due to land access issues. In total, streamflow measurements at 18 withdrawal sites, excluding A1 and A7, were carried forward for flow correlation analysis.

REFERENCE GAGE AND WITHDRAWAL SITE FLOW CORRELATIONS

The field streamflow measurements collected at the 18 ungaged withdrawal sites were plotted with concurrent streamflow values from Commission-selected passby flow reference gages. In general, the streamflow measurements at the withdrawal sites agreed well with the reference gage streamflow data. The

coefficients of determination (r^2) were found to be greater than 0.9 in over half (11) of the sites and greater than 0.8 in 17 sites (Figure 2). An exception was noted for site A10, located at Sweet Arrow Spring in the headwaters of an unnamed tributary to Swatara Creek with a drainage area of 0.1 mi². This exception was attributed to significant differences in drainage area size and hydrologic setting between the withdrawal site and reference gage.

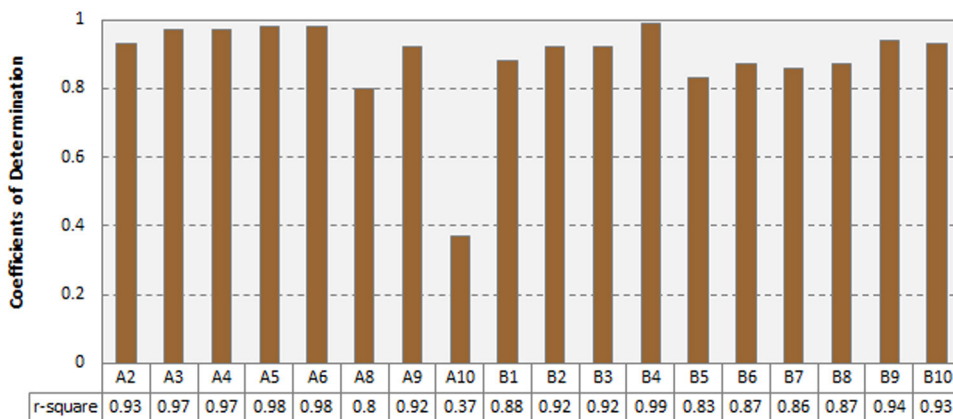


Figure 2. Coefficients of Determination between Flows at Withdrawal Sites and Concurrent Streamflows at Reference Gages

DEFINITIONS

Reference Gages

Selected USGS stream gages that best represent hydrologic conditions at ungaged sites based on similar watershed characteristics. Reference gages are required to have a minimum of 10 recent years of record and are used to calculate streamflow statistics and determine passby flow thresholds.

Trigger Gages

Selected real-time USGS stream gages that best represent hydrologic conditions at ungaged sites based on similar watershed characteristics. Trigger gages are used for low flow monitoring, operations, and compliance.

Baseflow

The portion of streamflow typically attributed to groundwater discharge, which can sustain streamflow over long-term periods of dry conditions.

Passby Flow

A prescribed streamflow threshold at which a regulated withdrawal must cease in order to limit instream impacts during low flow conditions.

To verify appropriate selection of reference gages, alternate reference gages were identified using the USGS Pennsylvania Baseline Streamflow Estimator (BaSE) by means of map correlation. Commission-selected reference gages for 11 withdrawal sites evaluated were in agreement with BaSE-recommended reference gages. Further investigations of the other six sites with available field streamflow measurements revealed high flow correlations with BaSE-recommended reference gages, except for sites A4 and A10. Certain BaSE-recommended reference gages resulted in good flow correlations (i.e. USGS 01547950 Beech Creek at Monument, PA for Mosquito Creek site) that were comparable to those associated with Commission-selected reference gages and could be considered as alternative reference gages for passby flow determination and compliance.

FLOW STATISTICS

The Commission typically calculates flow statistics at withdrawal sites using an appropriate reference gage and the drainage area ratio method. To build confidence in passby flows generated for ungaged streams using this method, annual mean and low flow statistics were also calculated using the USGS StreamStats application for comparison. Monthly low flow statistics, expressed as percent exceedance flows, were generated from BaSE tool outputs. These statistics were compared with drainage area ratio method results, which relied on reference gage selections, to evaluate the agreement between determined passby flow thresholds. The differences in computed average daily flow (ADF) were less than 5 cubic feet per second (cfs) for 70 percent of the evaluated withdrawal sites, and differences in 7-day, 10-year low flows (7Q10) were less than 3 cfs for 95 percent of the withdrawal sites assessed. The average difference between the two sets of monthly passby flow thresholds varied from 0.1 to 28.8 cfs.

CONCLUSIONS AND RECOMMENDATIONS

The selection of appropriate reference gages for performing hydrologic analyses at ungaged withdrawal sites is critical in determining passby flow thresholds and monitoring adherence to Commission low flow protection requirements. Flow correlation analysis and the evaluation of flow statistics show that Commission practices for monitoring ungaged streams have been successful.

- Commission-selected reference gages for determining and monitoring passby flow requirements at 17 of 18 ungaged withdrawal sites were found to perform reasonably well based on flow correlation analyses using withdrawal site streamflow measurements and concurrent stream gage data, which highlights the effectiveness of suitable reference gages in passby flow implementation.

- A poor flow correlation between the Commission-selected reference gage and field streamflow measurements for 1 of 18 ungaged withdrawal sites was attributed to significant differences in drainage area size and hydrogeologic setting, which emphasizes the importance of continuing to adhere to accepted reference gage selection criteria.
- The majority of Commission-selected reference gages (11 of 20) for ungaged withdrawal sites were found to be in agreement with the highest correlated stream gages identified using the map correlation method in the BaSE application, which supports the Commission's reference gage selection methodology.
- Use of the drainage area ratio method for generating local streamflow statistics for ungaged withdrawal sites was found to be appropriate.

