Quantifying Representative Sampling Using a Hydrologic Analysis Tool

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Outline

Introduction

Data Review Process
  Step 1 - Flow Data Quality
  Step 2 - Sample Collection Timing
  Step 3 - Percent Capture

Conclusion

Questions
Perspective…and Disclaimer

- OWP has over 15 year of stormwater research experience.
- Research based monitoring with some regulatory compliance monitoring.
- Primarily flow-weighted composite Event Mean Concentration (EMC) water quality sampling.
What is representative sampling?

Statistics
Subset from a population such that the group of samples has the same distribution of characteristics as the entire population.

Stormwater Monitoring
Flow and water quality data that has the same range and frequency of occurrences as the entire runoff event from a particular location.

Locations have the same characteristics as the larger system of interest.
Representative Sample

Defined in the study plan, Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan (SAP) or similar document.

Lots of resources available to plan for and incorporate representative sampling.

Not many resources available to determine if a sample is still representative after it has been collected.
Data Review Process

Step 1 - Flow Data Quality
- Study plan requirements
- Collection errors
- Known Relationships

Step 2 - Sample Collection Timing
- Individual samples taken at appropriate times during event.

Step 3 - Percent Capture
- Quantify how much of the runoff event was sampled.
Step 1 – Flow Data Quality

Flow-Weighted Sampling

Most accurate intra-event sampling scheme.

Typically used to obtain Event Mean Concentration (EMC).

Error in flow measurements = inappropriate sample timing.

Not a true EMC composite sample.

Load Calculations

Load = EMC x Runoff Volume

Error in runoff volume directly translates to error in load calculations.
## Study Plan Requirements

### Rainfall Data
- Duration
- Depth
- Volume
- Intensity
  - Average
  - Instantaneous Max
  - 1-hr Max

### Runoff Data
- Duration
- Time to Peak
- Peak Flow Rate
- Total Volume
Collection Errors

View Raw Data for Inconsistencies

Physical Constraints

- Flow begins after rainfall begins.
- Flow ends after rainfall ends.
- Samples collected during runoff.
Known Relationships

Volumetric Runoff Coefficient ($R_v$)

Measured: $R_v = \frac{V_{runoff}}{V_{rainfall}}$

Predicted: $\bar{R}_v = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$

Relative Percent Difference (RPD)

If $RPD = \frac{|Predicted - Measured|}{Predicted} \leq ThresholdValue \quad (e.g., \, 0.2) \quad then \quad Accept$

Time of Concentration ($T_c$)

Measured: Time from hyetograph center-of-mass to hydrograph center-of-mass or other method.

Predicted: NRCS Method from TR-55 or other method.
Step 2 - Sample Collection
Timing

Check to see if samples were collected at an appropriate time so that they are representative of the runoff.

Qualitative - Graphs
Quantitative - Uniformity Index
Rate Graph

Time-Weighted Sampling

[Graph showing runoff flow rate over time with markers for successful samples and rainfall intensity.]
Rate Graph

Flow-Weighted Sampling

![Graph showing runoff flow rate and rainfall intensity over time.](image-url)
Cumulative Depth Graph

Flow-Weighted Sampling

Graph showing depth over time with different lines representing rainfall, runoff, and successful sample points.
Cumulative Depth Graph

Time-Weighted Sampling
Autosampler Backlog

Autosampler sample routine

- Purge
- Rinse
- Sample
- Purge

Routine can take 2+ minutes to complete

Urban drainages can have very flashy runoff responses.

If the trigger for the next sample is received before the previous sample routine is completed, then it is added to the sample queue.
Autosampler Backlog

Rate Graph

Cumulative Depth Graph
Qualitative

Uniformity Index

Want to determine if the intervals are equal.

Time or volume interval between samples
Uniformity Index

Coefficient of Variation (COV)

\[ UI = COV = \frac{Standard \, Deviation \, (\sigma)}{Mean \, (\mu)} \]

COV is a normalized standard deviation

Allows for comparison of the variability between different data sets.

Small COV -> Little Variation
Big COV -> Large Variation

Uniformity Threshold (UT)

\[ If \, UI \leq UT \, then \, Uniform \, Interval \]

(0.5 Threshold determined by trial-and-error.)
Step 3 - Percent Capture

• For composite samples.
• Many different methods
  – Percentage of entire runoff time occurring between first and last samples.
  – Percentage of entire runoff volume occurring between first and last samples.
  – Etc.
OWP Method

Assumes flow-weighted sampling

\[ PC = \frac{V_{rep}}{V_{runoff}} \times 100 \]

- \( V_{rep} \) = represented volume
- \( V_{runoff} \) = total runoff volume
Represented Volume ($V_{rep}$)

Volume represented in the sample.
Best visualized with a cumulative runoff (mass curve) hydrograph.
Represented Volume ($V_{rep}$)
Represented Volume ($V_{\text{rep}}$)

\[ V_{\text{rep}} = \sum_{i=1}^{m} \Delta V_i \]
Represented Volume ($V_{rep}$)

\[ V_{rep} = \sum_{i=1}^{m} \Delta V_i = \Delta V_1 + \Delta V_2 + \Delta V_4 + \Delta V_6 \]
Total Runoff Volume \((V_{\text{runoff}})\)

Total event runoff volume.

Numeric integration method.

\[
V_{\text{runoff}} = \int_{t=0}^{t=n} q(t) = \sum_{t=0}^{n-1} \frac{q(t) + q(t + 1)}{2} \left( (t + 1) - (t) \right)
\]
Percent Capture

\[ PC = \frac{V_{\text{rep}}}{V_{\text{runoff}}} \times 100 \]

- \( V_{\text{rep}} \) = represented volume
- \( V_{\text{runoff}} \) = total runoff volume

Minimum Allowable PC
If \( PC \geq \) Minimum Allowable then Representative
Conclusion

Any monitoring project should have a post-data collection QC process.

3-point data review process

- Flow Data Quality
- Project Requirements
- Data Errors
- Known Relationships

Sample Collection Timing

- Rate Graph
- Cumulative Depth Graph
- Uniformity Index
- Percent Capture

Intent is to ensure quality monitoring data is generated, either for research or regulatory compliance purposes.
Questions?

Thank You

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