



ESMC

Ecosystem Services
Market Consortium

Pollutant Load Estimation Tool (PLET) Module

Version 2 (2025) – External Technical Documentation

Ecosystem Services Market Consortium

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1. Executive Summary

The Pollutant Load Estimation Tool (PLET) Module Version 2 (2025) is a Python-based implementation of the U.S. Environmental Protection Agency (USEPA) PLET framework, integrated into the Ecosystem Services Market Consortium (ESMC) EcoHarvest Monitoring, Reporting, and Verification (MRV) platform. The module quantifies field-scale and watershed-scale changes in water quantity and water quality resulting from agricultural best management practice (BMP) adoption and translates these changes into market-relevant water quality credits.

PLET v2 builds on the 2024 external PLET documentation by formalizing a containerized, API-driven architecture; expanding spatial attribution and normalization; and standardizing annual credit generation workflows aligned with USEPA guidance and Science Based Targets Network (SBTN) expectations.

2. Background and Purpose

ESMC PLET is derived from the USEPA Spreadsheet Tool for Estimating Pollutant Load (STEPL) and its web-based successor, PLET. These tools were originally developed to support Section 319 Clean Water Act reporting and watershed planning. ESMC adapted PLET into a modular, automated, and spatially explicit system to:

- Quantify runoff, nutrient, and sediment outcomes from BMP adoption
- Enable consistent, repeatable annual reporting
- Support watershed-aligned, market-ready water quality credits
- Integrate seamlessly with producer-facing digital MRV workflows

PLET Module Version 2 reflects ESMC’s transition from a pilot implementation to a production-grade system suitable for annual crediting cycles beginning in 2026.

3. System Architecture Overview

Figure callouts are provided throughout this section to align the narrative with the PLET Module v2 architecture diagrams.

The PLET Module operates as a containerized Python application within the EcoHarvest MRV ecosystem. User inputs, external datasets, and static lookup tables are combined programmatically to generate field- and watershed-scale outputs.

3.1 EcoHarvest MRV Context

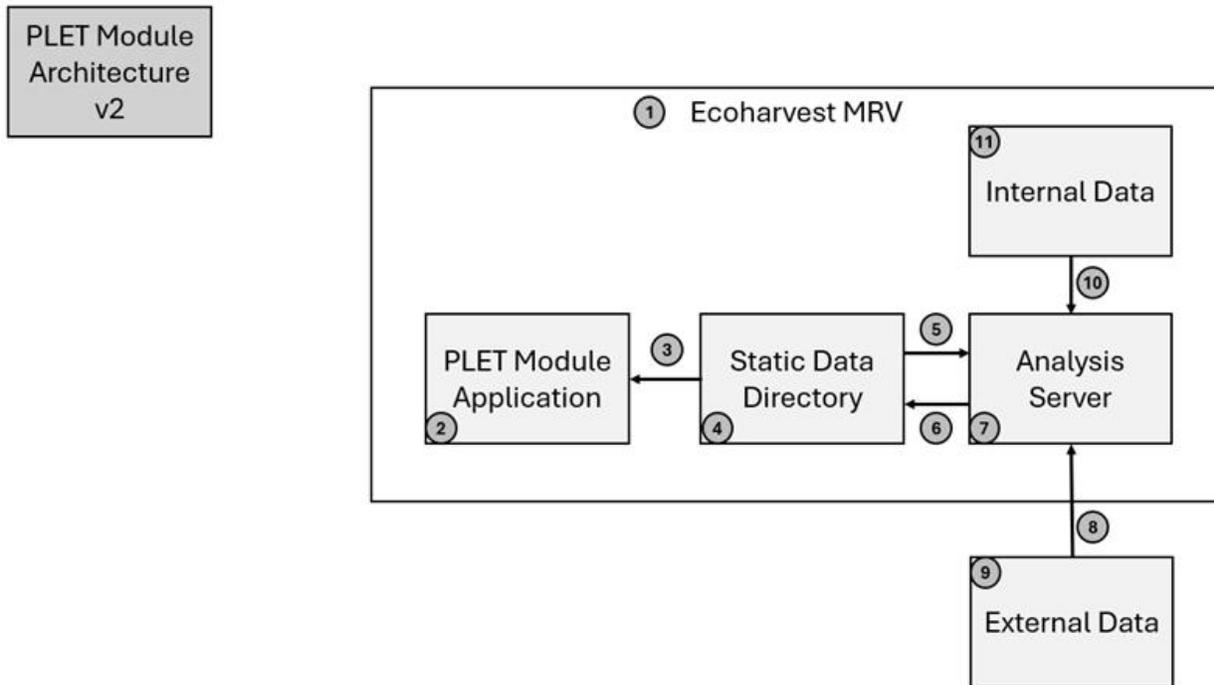


Figure 1 illustrates the overall PLET Module architecture within the EcoHarvest MRV ecosystem, highlighting the relationship between user inputs, static data, analysis services, and external datasets.

- Frontend: React (JavaScript)
- Backend Database: PostGIS-enabled PostgreSQL
- Analysis Layer: Python (containerized services)
- Data Exchange: JSON and GeoJSON

The PLET Module is executed server-side as part of the EcoHarvest analysis pipeline and is designed to be run annually.

3.2 Data Flow Summary

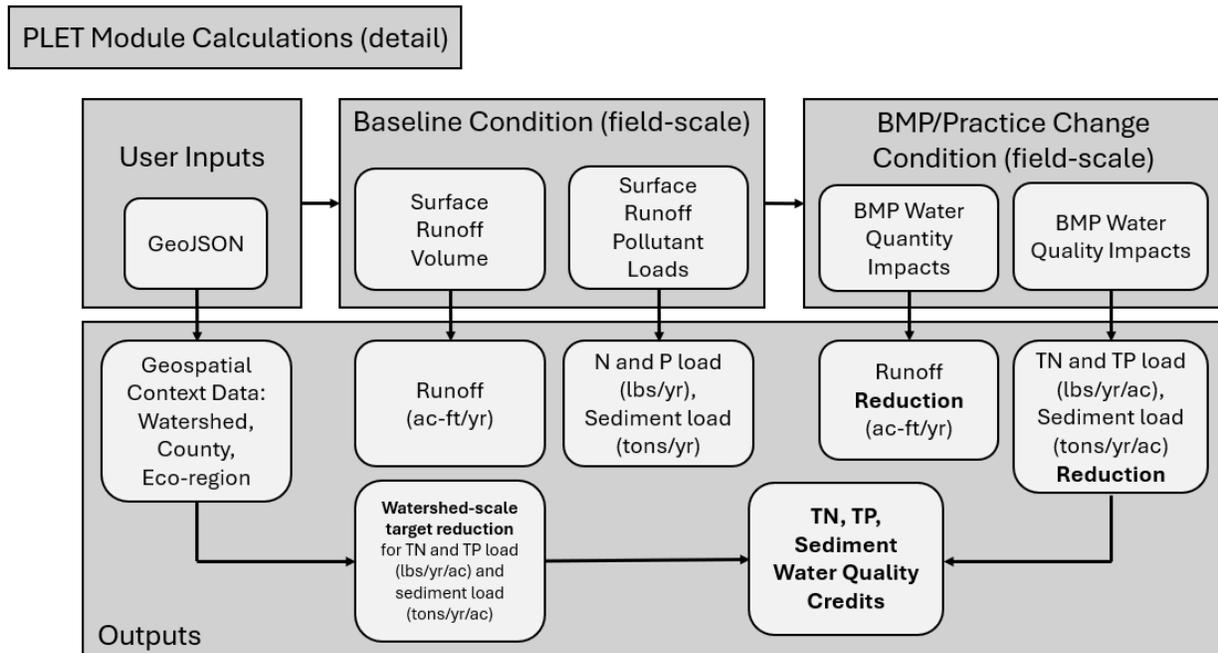


Figure 2 summarizes the detailed flow of inputs and outputs used by the PLET Module, including baseline calculations, BMP-induced changes, and final water quality credit generation.

1. User submits field geometry and BMP information via EcoHarvest
2. Inputs are stored as structured JSON/GeoJSON
3. Static and external datasets are joined programmatically
4. Baseline and practice-change scenarios are calculated
5. Watershed targets are applied
6. Field-scale credits are generated and normalized
7. Results are returned to EcoHarvest for reporting and aggregation

4. User Inputs

The fundamental input to the PLET Module is a GeoJSON file representing agricultural fields and associated management information. Required user-provided elements include:

- Field location and geometry
- Land use classification (cropland or pastureland)
- Selected BMP(s)
- Treated area of BMP implementation
- Programmatic identifiers (e.g., ESMC program year)

All geometries must be provided in EPSG:4326.

5. Programmatic Inputs

5.1 External Spatial and Tabular Datasets

PLET v2 relies on nationally consistent datasets, including:

- National Land Cover Dataset (NLCD)
- Cropland Data Layer (CDL)
- gNATSGO soils and hydrologic soil groups
- PRISM historic climate
- USDA NASS animal inventories
- EPA ecoregions
- NHDPlus and HydroBASINS watershed boundaries

These datasets provide the biophysical context required for runoff, nutrient, and sediment calculations.

5.2 Lookup Tables

Lookup tables support efficient runtime calculations and include:

- Curve numbers by soil and land cover
- Infiltration rates
- Nutrient concentrations
- Erosion factors
- BMP removal efficiencies
- Animal nutrient and weight factors
- Watershed-scale target reductions

6. Calculation Framework

PLET Module calculations are divided into four conceptual stages:

6.1 Baseline Condition

For each field, baseline annual values are calculated for:

- Surface runoff volume (acre-feet/year)
- Total nitrogen (TN) load (lbs/year)
- Total phosphorus (TP) load (lbs/year)
- Sediment load (tons/year)

These represent expected outcomes under existing management conditions.

6.2 Practice Change Condition

BMP-specific efficiencies are applied to estimate post-implementation outcomes for:

- Runoff volume
- Nutrient loads
- Sediment loads

6.3 Field-Scale Reductions

Reductions are calculated as the difference between baseline and practice-change conditions and are normalized on a per-acre basis.

6.4 Watershed-Scale Targeting

Independently, watershed-scale baseline loads and programmatic reduction targets are calculated for each HUC12. Annual allowable reductions are derived based on:

- Base year
- Program duration
- Target percent reduction

7. Water Quality Credit Quantification

Annual water quality credits are calculated for each field as:

$$\text{Credit} = \text{Watershed Target Reduction} - \text{Field-Scale Reduction}$$

Credits are reported for:

- TN (lbs/ac/year)
- TP (lbs/ac/year)
- Sediment (tons/ac/year)

If the calculated value is negative, no credits are issued for that pollutant.

8. Outputs

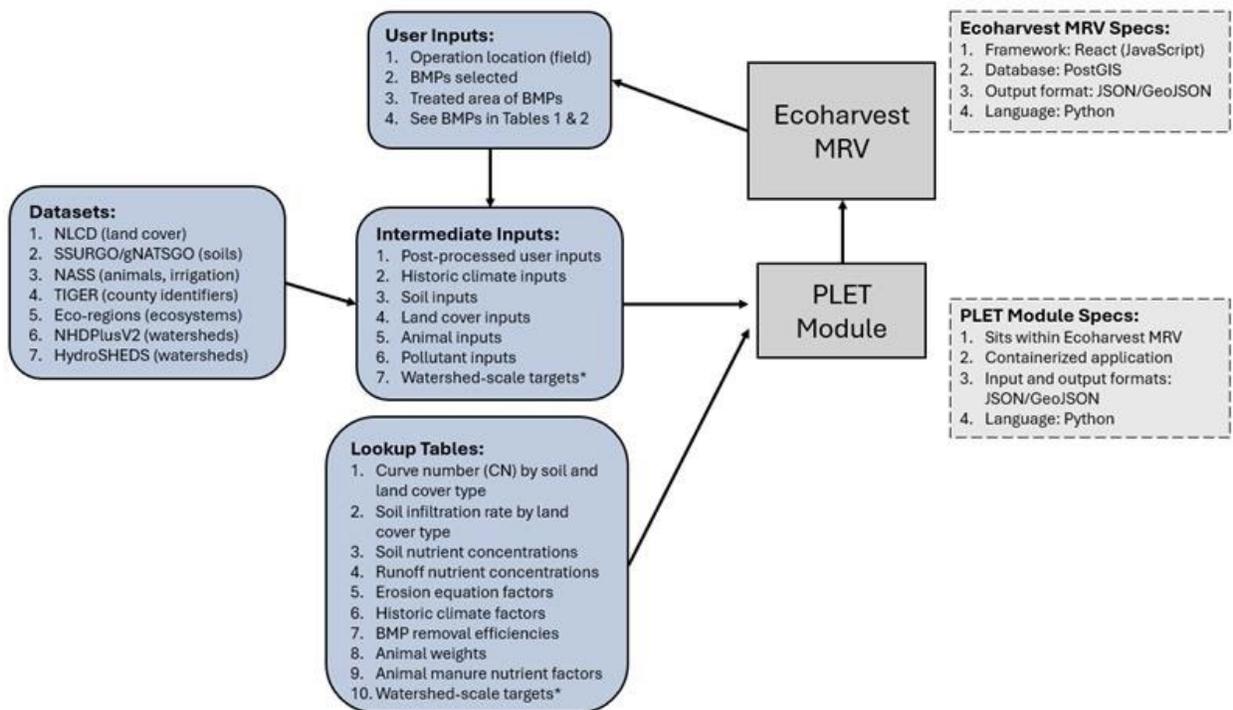


Figure 3 provides a consolidated view of PLET Module outputs, showing how field-scale results are aggregated to watershed scales and returned to the EcoHarvest MRV platform for reporting and crediting.

8. Outputs

PLET v2 produces a standardized set of outputs, including:

- Field-scale GeoJSON results
- Watershed-scale (HUC12) baseline and target GeoJSONs
- Credit result GeoJSON and CSV files
- Aggregated summaries at HUC4, HUC8, HUC12, and Pfafstetter Level 5
- Log files for traceability and QA/QC

All outputs are returned to EcoHarvest as a structured package for reporting and downstream aggregation.

9. What Changed from PLET v1 to PLET v2 (2025)

PLET Module v2 (2025) reflects a deliberate methodological and architectural evolution informed by ESMC–Tetra Tech technical deliberations in 2024–2025, including a formal evaluation of alternative approaches for setting watershed-scale nutrient and sediment

targets. The changes described below are grounded in the *Summary of Alternative TMDL Options Memo* (Saia, 2025) and associated internal analyses, and were made to improve feasibility, transparency, consistency, and auditability while maintaining alignment with USEPA science.

9.1 Shift in How Watershed-Scale Targets Are Defined

v1 (2024 approach): Relied conceptually on the availability of regulatory Total Maximum Daily Loads (TMDLs) to define watershed targets. In practice, TMDLs were difficult to operationalize at scale due to: lack of standardized, machine-readable TMDL limit values; highly heterogeneous document formats; inconsistent pollutant definitions, phases, and implementation timelines across watersheds; and no existing Python libraries to extract and harmonize ATTAINS-linked documentation.

v2 (2025 approach): Establishes watershed-scale targets using the PLET modeling framework itself, run at the HUC12 scale with *no BMPs applied*, to estimate baseline agricultural TN, TP, and sediment loads. This applies an explicit, programmatic percent reduction target to these modeled baselines, rather than attempting to extract numeric limits directly from TMDL documents. This approach was selected as the most feasible and defensible option after evaluating ATTAINS/TMDLs, MANAGE, SPARROW, and USEPA nutrient criteria.

This change ensures that baseline loads and field-scale reductions are generated using the same modeling framework, that targets can be applied consistently across the continental U.S., and that the system is operationally scalable for annual crediting cycles.

9.2 Formal Evaluation of Alternative Target-Setting Approaches

Between mid-2024 and late-2025, ESMC and Tetra Tech evaluated several candidate approaches for defining watershed-scale nutrient and sediment targets, including:

- **USEPA ATTAINS/TMDLs** – Ultimately deemed impractical due to lack of accessible numeric limits and non-standard documentation
- **USDA MANAGE database** – Provides measured field data but has limited spatial coverage and uneven study density across ecoregions
- **USGS SPARROW models** – Offer national coverage but rely on older model vintages and require complex regional integration
- **USEPA Ecoregional Nutrient Criteria** – Empirically derived but dated and require substantial post-processing to convert concentrations to loads

While these datasets remain valuable for *contextual validation*, PLET v2 adopts a PLET-based baseline + reduction target approach as the primary crediting mechanism, with other methods reserved for reasonableness checks and future verification exercises.

9.3 Introduction of Explicit, Long-Term Reduction Trajectories

New additions in v2 include the adoption of a 20-year cumulative reduction framework referenced to a 2023 baseline year; target reductions aligned with major regional and national nutrient strategies, including the Gulf Hypoxia Action Plan and Chesapeake Bay TMDL with a 45% reduction in TN over 20 years, a 45% reduction in TP over 20 years, and a 20% reduction in sediment over 20 years.

These cumulative targets are applied linearly by year, resulting in 2.25% annual TN and TP reduction expectations as well as 1.0% annual sediment reduction expectations.

Field-scale credits are only issued when modeled BMP-driven reductions exceed the applicable annual target for the evaluation year.

9.4 Clear Separation of Modeling, Targeting, and Crediting Logic

PLET v2 introduces a clearer conceptual and computational separation between:

1. **Field-scale BMP impacts** – Modeled changes in runoff, TN, TP, and sediment resulting from BMP implementation
2. **Watershed-scale targets** – Independently calculated annual reduction expectations derived from baseline loads and long-term goals
3. **Credit issuance** – Determined as the difference between (1) and (2) on a per-acre basis

This separation improves transparency for reviewers and avoids implicit assumptions that modeled BMP impacts alone define credit eligibility.

9.5 Architectural and Operational Maturation

Relative to v1, PLET v2 formalizes several implementation aspects:

- Fully containerized, API-driven execution within the EcoHarvest MRV analysis server
- Explicit ingest validation, logging, and QA/QC checks
- Standardized GeoJSON and CSV outputs designed for annual reuse and cross-program comparison
- Improved traceability between baseline assumptions, target definitions, and credit outcomes

9.6 Elements Intentionally Preserved from v1

To maintain methodological continuity and comparability:

- Core hydrologic and pollutant load equations remain unchanged from USEPA PLET and STEPL
- Empirical, lookup-based BMP efficiencies are preserved
- Annual time-step reporting is retained

- Results remain simulation-based rather than measurement-based

9.7 Reviewer-Relevant Implications

For technical reviewers, regulators, and buyers:

- PLET v2 does not change the underlying science; it clarifies how targets and credits are operationalized
- The approach trades theoretical regulatory precision for practical scalability and transparency
- Outputs are more reproducible, auditable, and comparable across regions and years

10. Key Assumptions and Limitations

- One BMP per field per run is supported in v2
- Annual time step (no intra-annual dynamics)
- Empirical, lookup-based efficiencies consistent with USEPA PLET
- Not a process-based hydrologic model

Future versions may expand multi-BMP interactions and dynamic representations.

11. Versioning and Governance

- Version: PLET Module v2.0 (2025)
- Codebase: Git-managed with main and dev branches
- Annual dataset updates aligned with ESMC reporting cycles

12. References and Attribution

The PLET Module Version 2 (2025) is methodologically grounded in established USEPA tools and guidance. All equations, lookup tables, and BMP efficiencies implemented in the PLET Module are directly translated from or aligned with USEPA PLET and STEPL documentation, with extensions developed by the ESMC to support automated, spatially explicit, and market-ready crediting workflows.

Primary Methodological References

United States Environmental Protection Agency (USEPA). 2018. *Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) User's Guide*, Version 4.4. Prepared by Tetra Tech for the USEPA, Fairfax, VA. 90 pp.

United States Environmental Protection Agency (USEPA). 2022. *Pollutant Load Estimation Tool (PLET) User's Guide*, Version 1.0. Prepared by Tetra Tech for the USEPA, Fairfax, VA. 61 pp.

United States Environmental Protection Agency (USEPA). 2023. *Pollutant Load Estimation Tool (PLET)*. Available at: <https://www.epa.gov/nps/plet>

United States Environmental Protection Agency (USEPA). 2023. *Best Management Practice Efficiency References for the Pollutant Load Estimation Tool*. Prepared by Tetra Tech for the USEPA.

United States Environmental Protection Agency (USEPA). 2023. *Best Management Practice Definitions Document for the Pollutant Load Estimation Tool*.

ESMC PLET Module Documentation and Implementation Sources

Ecosystem Services Market Consortium (ESMC). 2024. *PLET Module Analysis Documentation (ANALYSIS.md)*. Internal technical documentation describing PLET module architecture, calculations, inputs, and outputs.

Ecosystem Services Market Consortium (ESMC). 2024. *PLET Module Developer Documentation (DEVELOPER.md)*. Internal documentation detailing repository structure, deployment, and EcoHarvest MRV integration.

Ecosystem Services Market Consortium (ESMC). 2024. *PLET Module Data Update Procedures (DATA_UPDATES.md)*. Internal documentation describing external dataset sources, update frequency, and maintenance workflows.

Ecosystem Services Market Consortium (ESMC). 2024. *PLET Module Repository README*. Overview of module purpose, structure, and supporting documentation.

Supporting Datasets and Standards

USDA National Agricultural Statistics Service (NASS). County-level livestock inventories.

USDA Natural Resources Conservation Service (NRCS). Gridded National Soil Survey Geographic Database (gNATSGO).

Multi-Resolution Land Characteristics (MRLC) Consortium. National Land Cover Dataset (NLCD).

USGS and USEPA. National Hydrography Dataset Plus (NHDPlus) Version 2.

HydroSHEDS. HydroBASINS Watershed Boundaries, Pfafstetter Level 5.

PRISM Climate Group. Historical climate datasets.

13. Contact Information

For technical questions, implementation details, or collaboration inquiries, please contact the Ecosystem Services Market Consortium (ESMC) at info@ecosystems-services-market.org or submit issues via the official PLET Module repository.