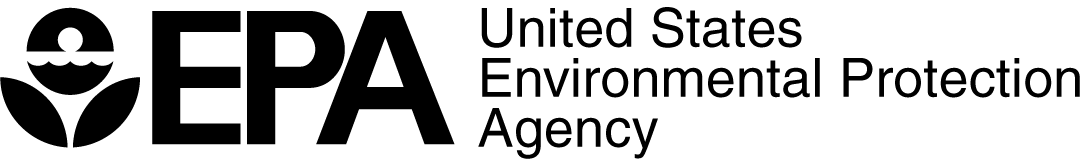
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LRPCD QUALITY ASSURANCE PROJECT PLAN

**Sp**

**Spreadsheet Tool for Quantifying Seepage Flux using Sediment Temperatures**

**NRMRL\LRPCD**

**Quality Assurance Project Plan (QAPP)**

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| --- | --- | --- | --- |
| **Title:** | **Spreadsheet Tool for Quantifying Seepage Flux using Sediment Temperatures** | | |
| **Division/Staff:** | | LRPCD\SSMB | |
| **QA Category:** | | III | |
| **ORD National Program:** | | SHC | |
| **RAP Project ID\Task ID:** | |  | |
| **QAPP Tracking Number:** | |  | |
| **Effective Date:** | |  | |
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# Project Description and Objectives

## State the purpose of the project and list specific project objective(s).

The purpose of the project is to develop an easy-to-use tool for calculating one-dimensional groundwater seepage direction and velocity using vertical temperature profile in sediments. The specific project objectives are to produce a Microsoft ™ Excel spreadsheet tool for performing the automated computation, with supplementary pop-up instructions embedded with the spreadsheet tool.

## Describe the software and its intended application.

One of the fundamental elements in groundwater-surface water interaction is determining the magnitude and direction of groundwater seepage flux. It has long been recognized that the flow of groundwater can affect the subsurface thermal distribution (Stallman, 1963; Suzuki, 1960)([. As a corollary, it is feasible to use heat flux as a natural tracer to inversely characterize groundwater and surface water interactions](#_ENREF_57) Anibas et al., 2011; Baskaran et al., 2009; Cartwright, 1970; Conant, 2004; Constantz, 2008; Gamble et al., 2003; Jensen and Engesgaard, 2011; Lowry et al., 2007; Schmidt et al., 2006; Silliman and Booth, 1993)[. Over the years,](#_ENREF_51) following on the theory of interaction between heat conduction processes and advection of water, researchers have developed methods utilizing sediment temperatures to inversely quantify groundwater seepage fluxes (Bredehoeft and Papadopulos, 1965; Hatch et al., 2006; Keery et al., 2007; Luce et al., 213; McCallum et al., 2012; Schmidt et al., 2007; Stallman, 1965; Suzuki, 1960)[. Specifically, the derivations of the general equation for the simultaneous, one-dimensional transport of heat and water through saturated sediments include: (1) Bredehoeft model (Bredehoeft and Papadopoulos, 1965), (2) Schmidt model (Schmidt et al., 2007), (3) Hatch model (Hatch et al., 2006), (4) Keery model (Keery et al., 2007), (5) McCallum model (](#_ENREF_57)[McCallum et al., 2012](#_ENREF_41)), and (6) Luce model (Luce et al., 213). Each models presented a unique analytical solution for solving seepage flux in the vertical direction based on the sediment temperature profile. The Bredehoeft and Schmidt models are based on the assumption of steady-state temperature conditions, whereas the Hatch, Keery, McCallum, and Luce models are based on the assumption of transient-state temperature conditions. None of these inverse methods requires model calibration. The uncertainty in the flux estimation originates from the combination of uncertainties in the value of input parameters and the potential disparity between the boundary conditions imposed by the models and the actual physical conditions of the site (Shanafield et al., 2011)[.](#_ENREF_50) The underlying prerequisite of using sediment temperatures to quantify seepage flux require the assumptions that the sediment is thermally and hydraulically homogeneous, the direction of flow is predominantly vertical within the physical boundaries of the monitored area, and that sediment temperature profiles are subjected to influences of diurnal and seasonal oscillations in the temperature of surface water.

To facilitate solving the above-mentioned analytical solutions, commercially available spreadsheet software will be used to create an easy-to-use calculator template for solving the magnitude and direction of groundwater seepage. Given the widespread use of the Microsoft ™ Excel software, a Microsoft ™ Excel spreadsheet tool will be created to perform the automated computation by utilizing Microsoft ™ Excel internal arithmetic operators, mathematical functions and add-ins. The tool will be capable of solving both steady-state and transient-state solutions. The spreadsheet tool will check and verify the format and time-interval of the raw temperature data. The user will be able to select the models to use, specify the accompanying input parameters (e.g. thermal conductivity, heat capacities, thermal dispersivity, porosity, sensor spacing...etc.), and define the sediment temperature pairs to use. For the steady-state models, the spreadsheet tool will use sediment temperatures directly to calculate seepage flux. Whereas for the transient-state models, the tool will initiate harmonic regression on the temperature time-series to determine amplitude ratio and phase shift of the diurnal temperature components, then applying the result to solve for the seepage flux.

The spreadsheet tool will provide an automated means for the calculation of groundwater seepage under ambient conditions. The tool can be used as a screening tool to determine groundwater sampling location; to evaluate spatial and temporal changes in the direction and magnitude of seepage fluxes; to assess changes in groundwater seepage caused by ground-water extraction and/or physical containment; to assess the contribution of groundwater seepage to contaminant exposure in the evaluation of risk management; and to evaluate the impacts of contaminated site remedies on the groundwater and surface water interaction. This information is an essential component in the characterization of natural systems as well as the determination of the effectiveness and optimization of remediation systems.

# Organization and Responsibilities

## Identify all project personnel, including QA, and related responsibilities for each participating organization, as well as their relationship to other project participants.

**Bob Lien U.S.EPA Technical Lead**

Responsible for overall project coordination, technical oversight, developing the spreadsheet template and supplementary pop-up instructions, programming, evaluation of the spreadsheet tool including review and alpha/beta testing, and assuring QA requirements are met.

**Jonathan Ricketts U.S. EPA Project Scientist**

Responsible for developing the spreadsheet template and supplementary pop-up instructions, programming, and QA aspects related to development of the spreadsheet tool.

**Robert Ford U.S.EPA Co-technical Lead**

Responsible for overall project coordination, technical oversight, evaluation of the spreadsheet tool including review and alpha/beta testing, and assuring QA requirements are met.

**Jim Voit U.S.EPA QA Manager**

Responsible for QA oversight and review/approval of this QAPP.

## Include a project schedule that includes key milestones.

* + June 2016 Draft version of the spreadsheet tool.
  + September 2016 Completion of review and beta testing.
  + December 2016 Final version of the spreadsheet tool.

# Functional Requirements

## Provide a list of the most important functions that the software system must address.

* Data input
* Internal checking for the data validity
* Computation
* Formatting of results

## Identify requirements for functionality, external interfaces (includes graphical user interfaces and interfaces which are needed for other programs to call subroutines from the software, as applicable), performance, and design constraints. Each requirement should be uniquely identified and defined such that its achievement is capable of being objectively verified and validated.

The spreadsheet must provide for input of data from a keyboard or copy/paste from existing electronic files.

The spreadsheet must be capable of performing the following internal checks for input data validity:

* The raw temperature time-series data must be in uniform time-interval;
* Input parameter values for the thermal properties and the porosity must be positive values;
* The porosity value is expressed as a fraction, not a percentage;
* The porosity value must be greater than zero (0) and less than one (1);
* The depth and sensor spacing values must be greater than zero (0);

The spreadsheet tool must be capable of performing harmonic regression, calculating amplitude ratio, phase shift, and flow velocity using standard arithmetic operators, mathematical functions and add-ins available in Microsoft ™ Excel.

The spreadsheet must provide the results in a format that can be easily transferred by the user to text, tables, and other software for visual display.

## Specify computer hardware and operating system requirements.

Hardware requirements: Hardware must be capable of running Microsoft ™ Windows and Microsoft ™ Excel

Software requirements: Microsoft ™ Windows operating system and Microsoft ™ Excel (current EPA version).

# System Design

## Provide an overview of the system design (e.g., block diagrams showing relationships between major program modules, hardware devices, and data input/output).

The system consists solely of the computer on which the spreadsheet resides. There are no separate program modules. All computations are performed using standard internal operators, functions and add-ins in Microsoft ™ Excel.

## Describe the components and subcomponents of the software design, including databases and internal interfaces. The description should link the software structure to the functional requirements.

The spreadsheet tool will use the internal operators, functions and add-ins within Microsoft ™ Excel to perform all computations. The spreadsheet tool will not link to any external or internal databases.

Input data will be provided by the user, either from the keyboard or copy/past into designated cells on the spreadsheet. The user will input the identity of temperature loggers and the values of sediment temperature with accompany information on when and where the temperature was measured. Embedded mathematical formula in designated cells will perform computation based on the input data.

The result of the program (e.g. the seepage flux values) will be displayed in designated cells with proper labeling. A positive seepage flux value represents upward flow, while a negative value indicates downward flow direction.

## Provide the rationale for selecting the proposed hardware and software tools.

Windows based computers and Microsoft ™ Excel are widely used computer platforms and spreadsheet software, respectively.

# Implementation

## Describe how a working software system is developed from the design specifications.

The mathematical solution to the inverse method of quantifying seepage flux using sediment temperatures is readily available in the referenced literatures. A summary of the background theory, including equations, formulas, and references is well documented in a published EPA report (EPA/600/R-15/454). The spreadsheet is programmed based on the published mathematical solution to calculate the groundwater seepage flux from inputs provided by the user.

## Describe how the requirements for functionality, external interfaces, performance, and design constraints will be verified and validated.

Functionality will be validated by comparison with the results calculated by hand and by comparison with the results of problems published in the literature (e.g., Hatch, 2006; Bredehoeft and Papadopulos, 1965). The spreadsheet tool will contain no external interfaces.

## Describe how release and delivery of the product is managed, including versions for alpha and beta testing.

The spreadsheet will be supplied in Microsoft ™ Excel workbook format to alpha and beta testers. Following testing and finalization, the spreadsheet tool will undergo peer review and clearance prior to publication in electronic Microsoft ™ Excel workbook form.

## Describe the procedures for controlling, documenting, and archiving all significant changes to software and hardware.

All significant changes to the software will be described in a bound notebook. Each new version of the spreadsheet workbook will be archived onto EPA’s OneDrive with the date/version number and referenced to the description in the notebook.

## Identify the archiving software used for controlling, documenting, saving, and recovering changes made to the source code.

No special archival software is required. Standard protocol of file saving/backup to OneDrive and the local network M: drive will be used.

# Validation, Verification, and Testing

## Describe the testing strategy that will be used along with the procedures for each planned test. Testing may include individual module tests, integration tests, system testing, acceptance testing, and alpha and beta testing.

The individual components of the calculations within the spreadsheet tool will be desk checked using a hand held calculator. The spreadsheet will be tested by comparison of the groundwater seepage velocity calculated by the spreadsheet with that calculated using a hand held calculator. Alpha and beta testing will be performed by distributing the final draft version of the spreadsheet to assigned individuals within the EPA, USGS and industry.

## Describe the procedure for checking the correctness of outputs.

The correctness of the spreadsheet output will be determined by comparison with the results calculated by hand and by comparison with the results of problems published in the literature (e.g., Hatch, 2006; Bredehoeft and Papadopulos, 1965). The spreadsheet will be considered correct if values are within +/- 10% for the seepage flux velocity.

## Describe how it will be determined if the developed software product conforms to requirements, and whether the software product fulfills the intended use and user expectations. This includes analysis, evaluation, review, inspection, assessment, and testing of the software product and the processes that produced the product.

The dominant requirement for the spreadsheet is the accurate calculation of groundwater seepage velocity. The spreadsheet will be determined to conform to the requirements by comparison of the spreadsheet results with those from published problems. The spreadsheet will undergo alpha and beta testing to assess whether the tool meets user expectations.

# Documentation, Maintenance, and User Support

## Specify the requirements for project documentation (e.g., requirements and design document, configuration maintenance plan, operations manual, source code, user’s guide).

The project “documentation” will be:

* Spreadsheet workbook for seepage velocity calculation;
* Introduction page and pop-up instructions which will be embedded in the workbook. No additional user’s guide or operations manual will be required. The description of the background theory, including equations, formulas, and references will be referred to the published EPA report (EPA/600/R-15/454).

## Describe the procedures for maintenance and user support when software or data generated by the project will be distributed outside NRMRL.

The spreadsheet tool will be distributed via the EPA-NRMRL website. It is not anticipated that maintenance will be needed. Questions regarding the spreadsheet and documentation will be routed to a designated USEPA contact person.

## Define the methods and facilities used to maintain, store, secure, and document controlled versions and related artifacts of the identified software during all phases of the software life cycle.

During development, the spreadsheet will be backed up onto the local network M: drive. The most recent version of the spreadsheet will be archived onto EPA’s OneDrive. The versions and significant changes to the spreadsheet will be documented in a bound notebook.

# Reporting

## List and describe the deliverables expected from each project participant.

Bob Lien/Jonathan Ricketts:

* + Draft version of the spreadsheet tool.
  + Final version of the spreadsheet tool.

Robert Ford/Bob Lien:

* + Review comments of the alpha/beta testing regarding to the draft version of the spreadsheet tool;
  + Final version of the spreadsheet tool.

## Specify the expected final product(s) that will be prepared for the project (e.g., software, user documentation, user interface).

* + Microsoft ™ Excel spreadsheet tool for calculation of groundwater seepage velocity;
  + Supplementary pop-up instructions of the spreadsheet tool will be embedded in the workbook.

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# Revision History

|  |  |  |
| --- | --- | --- |
| Revision # | Description | Effective Date |
| Enter QA tracking Number | For initial version enter “Initial Version”. | Date Approved by NRMRL QAM |
| Enter QA tracking Number | Brief description of version changes |  |

Include large tables, figures, appendices, and other supplemental material at the end of the QAPP. Example tables are included, and should be modified as needed to accommodate project specific requirements.

Flow charts showing work flow and process should be included when possible.

Process

Decision

Process

Add Tables and other Addenda here