QUAL2KW

Last Revision Date: 08/31/2009

General Information

Model Abbreviated Name: **QUAL2KW**

Model Extended Name: **QUAL2KW**

Model Overview/Abstract:
QUAL2Kw is a river and stream water quality model that is intended to represent a modernized version of the QUAL2E model (Brown and Barnwell, 1987). QUAL2Kw is related to the QUAL2K model that was developed by Dr. Steven Chapra (Chapra and Pelletier, 2003). QUAL2Kw includes some processes and options that are not in QUAL2K. QUAL2Kw is similar to QUAL2E in the following respects:

- One dimensional. The channel is well-mixed vertically and laterally.
- Steady state hydraulics. Non-uniform, steady flow is simulated.
- Diel heat budget. The heat budget and temperature are dynamically simulated as a function of meteorology on a diel time scale.
- Diel water-quality kinetics. All water quality variables are dynamically simulated on a diel time scale.
- Heat and mass inputs. Point and non-point loads and abstractions are simulated.

The QUAL2Kw (Q2Kw) framework includes the following new elements:

- **Software environment and interface.** Q2Kw is implemented within the Microsoft Excel/VBA environment. It is programmed in the Windows macro language: Visual Basic for Applications (VBA). Excel is used as the graphical user interface.
- **Model segmentation.** QUAL2E segments the system into river reaches comprised of equally spaced elements. In contrast, Q2Kw can use unequally-spaced reaches. In addition, multiple loadings and abstractions can be input to any reach.
- **Carbon speciation.** Q2Kw uses two forms of carbon, rather than BOD, to represent organic carbon. These forms are a slowly oxidizing form (slow dissolved organic carbon) and a rapidly oxidizing form (fast dissolved organic carbon). In addition, non-living particulate organic matter (detritus) is simulated. This detrital material includes particulate organic carbon, nitrogen, and phosphorus.
- **Anoxia.** Q2Kw accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled.
- **Bottom algae.** Q2Kw explicitly simulates attached bottom algae using either zero-order or first-order growth kinetics.
- **Luxury uptake.** Variable stoichiometry of nitrogen and phosphorus in bottom algae is simulated.
- **Light extinction.** Light extinction is calculated as a function of algae, detritus and inorganic solids.
- **pH.** Both alkalinity and total inorganic carbon are simulated. These are used to determine pH.
- **Pathogen indicator.** A generic pathogen indicator is simulated (e.g. fecal coliform or Enterococci). Pathogen indicator removal is determined as a function of temperature, light, and settling.
- **Sediment-water interactions.** Sediment-water fluxes of dissolved oxygen and nutrients are simulated internally rather than being prescribed. Oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, diagenesis reactions within the sediments, and the concentrations of soluble forms in the overlying waters.
- **Sediment heat flux.** Sediment-water heat flux and sediment temperature is simulated using a Fick's law formulation to account for conduction between the water and sediment and hyporheic flow and heat exchange.
- **Hyporheic respiration.** Exchange of water between the surface water column and the hyporheic

zone, and simulation of sediment pore water quality, including optional simulation of growth and respiration of heterotrophic bacteria biofilm in the hyporheic zone.

- **Automatic calibration.** A genetic algorithm is included to determine the optimum values for the kinetic rate parameters to optimize the goodness of fit of the model compared with observed data.
- **Monte Carlo simulation.** Ready to run Monte Carlo simulations with either the YASAIw add-in, also available from the Department of Ecology, or Crystal Ball, including an example using YASAIw.

Keywords:	Water quality model, QUAL2Kw, QUAL2K, river, model, temperature, dissolved oxygen, nutrients, nitrogen, phosphorus, periphyton, hyporheic, Monte Carlo, genetic algorithm

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Model Homepage:	http://www.ecy.wa.gov/programs/eap/models.html
Substantive Changes from Prior Version:	The latest version adds Monte Carlo simulation capability.
Plans for further model development:	Monte Carlo simulation capability using Crystal Ball. For information on how to use Crystal Ball with the current version, please contact Greg Pelletier at gpel461@ecy.wa.gov

User Information

Technical Requirements

Computer Hardware
Standard desktop PC or laptop

Compatible Operating Systems
Microsoft Windows 98 or higher

Other Software Required to Run the Model
Microsoft Excel 2003 or later

Download Information

The QUAL2Kw modeling framework and documentation are available to download.

Using the Model

Basic Model Inputs
Headwater flow and water quality, reach geometry, optional reach-specific rates and initial conditions, air temperature, dewpoint, wind speed, cloud cover, shade, light extinction parameters, options for solar, longwave, and evaporation calculations, point source abstractions or inflow and water quality, diffuse source abstraction or inflow and water quality, global parameter values for kinetic rates and constants, optional goodness-of-fit function and genetic algorithm settings, observed data for comparison with model output

Basic Model Outputs
Summary of point and diffuse sources, hydraulics, temperature, average water quality, diel minimum water quality, diel maximum water quality, optional continuous diel water quality, sediment fluxes

User Support

User's Guide Available?
A QUAL2Kw user guide with documentation of all model equations and inputs is provided with the distribution of the model.

User Qualifications
Expert in water quality modeling, graduate degree in civil or environmental engineering or equivalent, or several years of experience conducting water quality modeling studies.

Model Science

Problem Identification
QUAL2Kw was developed as a general purpose framework for simulating water quality in rivers and streams. It is applicable to rivers that are vertically well mixed and for periods with steady flow. QUAL2Kw is widely used for Total Maximum Daily Load studies of rivers for evaluation of temperature and eutrophication, including nutrients, dissolved oxygen, and pH.

Summary of Model Structure and Methods
QUAL2Kw is a finite difference numerical model. Numerical integration is performed using either Euler or 4th-order Runge-Kutta methods. QUAL2Kw simulates dynamic water quality changes to represent diel variations with a user-specified time step (typically about 5-10 minutes) assuming steady flow by repeating a 24-hour period of diel forcing for a user-specified number of days.

Model Evaluation
Verification of code.
QUAL2Kw is written in both Fortran and Excel VBA and both codes yield identical results given the same inputs. The redundant codes serve as verification for each other.

Corroboration of model results with observations.
QUAL2Kw predictions have been corroborated with observations in applications to numerous river systems in Washington including TMDL studies for temperature, nutrients, dissolved oxygen, and pH in the Wenatchee River, Walla Walla River, Deschutes River, Stillaguamish River, and temperature studies of the East Fork Lewis River, Willapa River, and others. The state of Oregon has also applied QUAL2Kw for several TMDL projects (e.g. Umpqua River). QUAL2Kw has also been corroborated with observations in applications to rivers in Nepal and Colombia.

Case Studies
Kannel, P.R., Lee, S., Lee, Y.-S., Kanel, S.R. and Pelletier, G.J. 2007. Application of automated QUAL2Kw for water quality and management in the Bagmati River, Nepal. Ecological modeling 202 (2007) 503-517.

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