THE SIMULATION OF WATER QUALITY IN THE WAIKATO AND TARAWERA RIVERS

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ABSTRACT

The causes and effects of water pollution are listed and the mechanisms of stream self-purification described. The parameters for which mathematical models have been developed are described and the success of the various previous models for predicting them is discussed. The equations governing the concentration of dissolved oxygen in a polluted waterway are developed and a review is made of the various finite difference schemes which are available for solving them.

Models are developed for predicting dissolved oxygen concentrations in two polluted New Zealand rivers, the Waikato and the Tarawera. It was found that the models used previously in other waterways were not adequate for either of these rivers. The model of the Waikato River uses the well-known Streeter-Phelps equation to model the exertion of BOD but includes the effects of the macrophyte and phytoplankton communities on the concentration of dissolved oxygen. The model of the Tarawera River uses the Monod equations to predict the concentrations of active biomass in the porous pumice sediments on the river bed, and successfully accounts for the high rate of oxygen uptake which has been observed. The way in which these models could profitably be developed is also discussed.

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NOTATION

HYDRAULIC AND COMPUTATIONAL PARAMETERS

$A(x,y)$	channel area
$[A]$ a,b,c,d	tridiagonal coefficient matrix and its component vectors
$b(x,y)$	channel width
$d(z)$	channel depth
d,h	dimensions of the sediment layers
E,F,G	longitudinal dispersion coefficients
E_p, E^*	numerical or pseudo-dispersion coefficient,corrected coefficient
g	gravitational acceleration
h,d	dimensions of the sediment layers
j,n	space and time indicies in finite difference notation
k,k'	non-dimensional dispersion coefficients
$K(x,y)$	channel conveyance
n	Manning friction coefficient
$Q(x,t)$	channel discharge
$q(x,t)$	lateral inflow per unit length of channel
$r(x,y)$	channel hydraulic radius
S_1	sum of eddy losses
$\mathrm{T}(C)$	transport operator
$T(x,t)$	water temperature
t	time
$u(x,y,z,t)$	instantaneous velocity
$U(x,t),V(x,t),W(x,t)$	cross-sectional average velocities
$u'(x,y,z,t)$	difference between instantaneous and mean velocity
$\bar{u}'(x,z,t)$	depth averaged velocity difference
x,y,z	Eulerian displacements, y vertical, x downstream
$y_0(x)$	average depth
$z(x)$	channel bed elevation, above datum.
$\alpha(x,t),\beta(x,t)$	velocity coefficients
$\Delta x,\Delta t$	mesh size and time step in finite difference notation
ε	lateral eddy diffusivity
λ,μ	time and space differencing parameters
ρ	advection parameter, $U\ \Delta t/\Delta x$
σ	dispersion parameter, $E\ \Delta t/\Delta x^2$
ξ	Lagrangian displacement variable

WATER QUALITY PARAMETERS

B,B^n	concentration of heterotrophic bacteria
C	pollutant concentration
$C_0,B_0\ldots$	initial concentrations
$C_i,B_i\ldots$	concentrations in tributary inflows
D,D_s	dissolved oxygen concentration,saturation concentration
k_1	BOD decay rate
k_2	reaeration rate
P,P^n	concentration of protozoa
S,S^n	concentration of substrate
$\alpha,\beta,\gamma,\delta$	substrate assimilation/bacteria growth parameters
$\varepsilon,\zeta,\eta,\theta$	bacteria consumption/protozoa growth parameters
ι,κ,λ	bacteria decline parameters
μ,ν,ξ	protozoa decline parameters
ϕ,ψ,ω,χ	step functions
$\Phi(C)$	biological rate operator

BIOLOGICAL TERMS

aerobic	occurring in the prescence of, making use of oxygen
algae	common name for a wide range of aquatic plants
anaerobic	occurring in the absence of, without making use of oxygen
bacteria	primitive micro-organisms, abundant in water and the soil
benthic	inhabiting the sediments on the bed of a waterway
biota	total population of animals and plants in a locality
coliform	a type of bacteria commonly found in the digestive systems of mammals, and also found in the soil
enzyme	catalyst released by an organism, commonly to increase the rate of breakdown of a substrate
endogenous metabolism	utilization of food stored within the cell
epiphyte	a plant which adheres to parts of another larger plant
eutrophic	enriched with nutrients, capable of supporting extensive plant and animal populations
exogenous metabolism	utilization of food obtained from outside the cell
heterotrophic	obtaining nourishment from organic substances, parasitic or saprophytic
indicator bacteria	bacteria typically of enteric origin whose presence in large numbers in in waterway indicates recent sewage contamination
lysis	cell rupture following starvation
macrophytes	rooted vascular aquatic plants, water weed
nutrient	inorganic compound required by plants for the synthesis of carbohydrate and protein
oligotrophic	deficient in one or more nutrients, incapable of supporting extensive plant and animal populations
periphyton	plants or animals adhering to parts of rooted aquatic plants
photorespiration	respiration which occurs in sunlight, at a higher rate than in the dark
photosynthesis	process whereby plants manufacture carbohydrate from inorganic compounds in the presence of sunlight, oxygen being released as a by-product
phytoplankton	plant plankton, small plants which drift with the surrounding water
protozoa	uni-cellular or non-cellular animals which often feed on bacteria
substrate	source of nourishment for heterotrophic organisms
turbidity	absorbance of light by suspended matter, usually over a wide range of wavelengths