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Computation of the Flow and Salinity Distribution in the Vicinity of Discharge and Intake Ports of a Desalination Plant

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Abstract. This paper describes the construction, development and application of a numerical model for calculating the flow and salinity distribution in coastal areas as a result of concentrated brine discharge from desalination plants. The flow is considered to be two-dimensional and steady; the fluid properties are assumed constant. The model applies constant eddy viscosity and diffusivity coefficients. The governing depth-integrated elliptic equations are solved by using a finite-volume iterative procedure.

The mathematical model accounts for the important physical factors affecting the concentrated brine dispersion process. These are the convective and diffusive transport, wind stresses, sea-bed friction and variable sea-bed elevation. The results of a parametric study on a hypothetical desalination plant discharge, under a range of meteorological, hydrological, topographical and plant operating conditions, show the importance of the various factors and the possible effects of discharge on intake conditions. As a predictive tool, the model should help to assess impact of discharge on the marine ecosystem and plant efficiency and to investigate means of alleviating such problems.

Introduction

The problem considered

Desalination plants consume huge amounts of energy for producing fresh water from sea water and dispose, to the environment, of large quantities of warmer and more concentrated brine. The natural marine ecosystem can adversely be affected by the resulting increase in salinity and temperature. In addition, the energy needed for separating fresh water from sea water increases with salinity. An increase in feedwater salinity from 4% to 5%, for example, would require about 25% more energy for separation [1; p. 49]. It is, therefore, essential that the intake port of the desalination plant should withdraw sea water at the nominal salinity. Discharge-intake port interaction must, accordingly, be minimized. To achieve this, detailed information about the salinity distribution is required and quite a few factors need to be considered. Such factors include the plant desalting capacity, the proper choice of plant site, and the proper location of discharge and intake ports under a variety of influential conditions. This problem, directly, addresses the program of energy utilization and conservation. From another point of view, the environmentalist would also like to assess the extent of the damage a desalination/power plant would inflict on the marine environment under the various conditions. Means of alleviating such problems are very much desired and sought.

This paper describes the construction and development of a mathematical model capable of computing the flow and salinity distribution in the vicinity of the discharge and intake ports of a desalination plant. This is carried out by a numerical simulation of the physical processes involved through solving the governing conservation equations and by incorporating appropriate boundary conditions.

The numerical model is applied for the simulation of flow and salinity variations of a hypothetical discharge problem. Figure 1 shows a schematic representation of the physical situation. The discharge and intake ports are assumed to be located on the shoreline and are 400m apart; the sea-current direction shown represents the worst case where it would, in the absence of other factors, deflect the discharged plume towards the intake port. A parametric study is conducted to investigate the effects of discharge on the intake conditions under various factors.

Practical relevance

The foregoing sub-section has highlighted some practical significance of the study. The work has an even wider scope of relevance where the dispersion of mass of a species into a body of fluid is involved. A numerous number of applications can be found in the chemical industries, irrigation canals, sedimentation and erosion in natural bodies of water, smoke exhausting into the air as well as the aforementioned desalination/power plant discharge in coastal areas.

Review of previous work

An early and extensive study of the effects of effluent disposal from a large desalination plant, operating on a hypothetical bay, was conducted by LeGros *et al.* [2; p.491]. The study contained a literature on the oceanography, meteorology and marine topography of a few selected coastal strips in the United States. The effects of interaction and of mixing of the various streams were considered. A criterion for the design of the outfall system was chosen. Recommendations were given on the type, frequency and intensity of pre-plant surveys and of post plant monitoring.

Brining *et al.* [3] discussed the environmental effects of desalination/power generation intake and discharge components. A methodology was presented for establishing an environmental management policy. Osman and Al-Gadaani [4] carried out a hydrographic survey of a shallow coastal lagoon bordered by a chain of fringing reefs, into which Jeddah power/desalination plant discharges its effluents. High water temperature and salinity were measured inside this area which had reduced the amount of dissolved oxygen. Scarlatos and Partheniades [5; pp. 111-123] discussed the state-of-the art of mathematical modelling of fine sediment transport in estuaries. Although most models utilized a linear relationship for both rates of deposition and erosion, their laboratory experiments indicated a more complicated behaviour and produced empirical correlations to express these processes. Rodi [6] carried out a survey of mathematical models for describing the turbulent transport of momentum, heat and mass with emphasis on the hydraulics applications in small water bodies. He found that the so-called two-equation models, and in particular the $k \sim \varepsilon$ model, offer the best compromise between width of applicability and computational economy. In large and shallow water bodies, the use of suitably chosen constant eddy viscosity/diffusivity coefficients can prove more appropriate in which the only influence of turbulence is through the bottom and wind stresses. Kuipers and Vreugdenhil [7] presented a detailed discussion and derivation of the depth-averaged equations. In a course of lectures, Spalding [8] described a variety of mathematical models for the numerical prediction of thermal pollution of natural waters. The types of models presented depend on the specific features of the physical situations.

Objectives of the study

The main objectives are to construct and develop a mathematical model for evaluating the flow and salinity distribution resulting from desalination plants discharge in shallow coastal areas. The model is to be applied to a discharge problem and to carry out a parametric study.

Mathematical Formulation

Basic assumptions

- Steady state
- Uniform properties
- Constant eddy viscosity and diffusivity coefficients
- Negligible vertical velocity component with two-dimensional velocity and salinity variations in the horizontal plane
- The governing equations are depth averaged assuming negligible variations of horizontal velocity and salinity over the depth.

The first assumption is an idealization, whereas the rest are in harmony with the free-surface-flow approximations in shallow and wide stretches of water; see, for example, Spalding [8].

The governing differential equations solved

Subject to the above basic assumptions, and for fixed Cartesian rectangular coordinate directions (x,y), the system of equations solved is:

Conservation of mass

$$\frac{\partial}{\partial x}(zu) + \frac{\partial}{\partial y}(zv) = 0\,, \tag{1}$$

where, u and v denote the velocity components in the x and y directions, respectively, and z is the local depth of flow.

Conservation of u-momentum

$$\frac{\partial}{\partial x}(zu^2) + \frac{\partial}{\partial y}(zuv) - \frac{1}{\rho}\frac{\partial}{\partial x}(z\mu\frac{\partial u}{\partial x}) - \frac{1}{\rho}\frac{\partial}{\partial y}(z\mu\frac{\partial u}{\partial y}) = S_u\,, \tag{2}$$

where, ρ is the sea-water density, μ is the turbulent viscosity and S_u is the source term for u and is given by:

$$S_u = -\frac{z}{\rho}\frac{\partial p}{\partial x} + zfv - C_f u(u^2 + v^2)^{1/2} + C_s\frac{\rho_{air}}{\rho} U_o (U_o^2 + V_o^2)^{1/2}\,, \tag{2'}$$

where, p is the static pressure, f is the Coriolis parameter, C_f is the bottom friction factor, C_s is the wind-force friction factor, ρ_{air} is the air density, U_0 and V_0 are the wind relative velocities, with respect to the water velocity, in the x and y directions, respectively.

Conservation of v-momentum

$$\frac{\partial}{\partial x}(zuv) + \frac{\partial}{\partial y}(zv^2) - \frac{1}{\rho}\frac{\partial}{\partial x}(z\mu\frac{\partial v}{\partial x}) - \frac{1}{\rho}\frac{\partial}{\partial y}(z\mu\frac{\partial v}{\partial y}) = S_v\,, \tag{3}$$

where, S_v is the source term for v and is given by:

$$S_v = -\frac{z}{\rho}\frac{\partial p}{\partial y} - zfu - C_f v(u^2 + v^2)^{1/2} + C_s\frac{\rho_{air}}{\rho} V_0(U_0^2 + V_0^2)^{1/2}. \tag{3'}$$

Conservation of salinity

$$\frac{\partial}{\partial x}(zuc) + \frac{\partial}{\partial y}(zvc) - \frac{1}{\rho}\frac{\partial}{\partial x}(z\frac{\mu}{\sigma}\frac{\partial c}{\partial x}) - \frac{1}{\rho}\frac{\partial}{\partial y}(z\frac{\mu}{\sigma}\frac{\partial c}{\partial y}) = S_c\,, \tag{4}$$

where, c is the concentration of salt in the solution, σ is the Schmidt number, and S_c is the source term for c which is, normally, zero.

The general form of transport equation

The above equations can be represented by a single equation of the form:

$$\frac{\partial}{\partial x}(zu\phi) + \frac{\partial}{\partial y}(zv\phi) - \frac{1}{\rho}\frac{\partial}{\partial x}(z\Gamma_\phi \frac{\partial \phi}{\partial x}) - \frac{1}{\rho}\frac{\partial}{\partial y}(z\Gamma_\phi \frac{\partial \phi}{\partial y}) = S_\phi , \quad (5)$$

where, ϕ is the general variable and stands for 1, u, v and c in equations (1) to (4), respectively; Γ_ϕ is the exchange (diffusion) coefficient and stands for 0, μ, μ and μ/σ in equations (1) to (4), respectively; and S_ϕ is the genral source term for ϕ.

Boundary conditions

Inlet: The velocity components, u's and v's, are set equal to the sea-current velocity components along and normal to the coast, respectively. The salinity at inlet is set equal to the sea-water salinity.

Outlet: The exit boundary is located far enough downstream to assume uniform conditions, or nearly so. The following conditions are imposed: uniform pressure distribution, and $v = \partial u/\partial x = \partial c/\partial x = 0$.

Coastline: The velocity and normal salinity gradient are set to zero.

Free stream: This boundary is located far offshore for the flow to assume the free-stream conditions. The velocity components and salinity are set equal to the sea-current and nominal salinity values.

Discharge port: The velocity and salinity at the discharge port are fixed according to the total rate and salinity of the flow being expelled.

Intake port: The velocity is fixed according to the intake flow rate; the salinity value is calculated by the program and is an output of the model.

Initial guess

The initial velocity field is set equal to the sea current; the initial salinity field is set uniform at the sea-current salinity.

The numerical solution procedure

Introduction

The set of equations (1) to (4) is partial, coupled and non-linear, and hence not amenable to analytical solutions. Numerical solutions are then sought. The mathematical model proposed uses a control-volume finite-difference method for discretizing the depth-integrated conservation equations. The numerical solution is based on the well-known SIMPLE algorithm of Patankar and Spalding [9] which is an iterative pressure-correction procedure. The computer program used and modified to suit the present desalination-plant-discharge problem is the 2/E/FIX code of Pun and Spalding [10]. Al-Sanea, Pun and Spalding [11] have briefly described and applied the line-by-line procedure, built into the 2/E/FIX code, in computing recirculating flows with heat transfer. Here, a general description of the solution procedure is outlined; more details can be found in the above cited references and in, for example, Patankar [12].

Major solution steps

(i) The flow domain is divided into discrete regions (control volumes or nodes) by constructing a finite-difference grid.

(ii) The partial-differential equations are transformed into finite-difference equations, for each variable at each node, by integrating the differential equations over the control volumes.

(iii) The resulting set of finite-difference equations for the hydrodynamic variables and salinity are solved by an appropriate algorithm.

(iv) The pressure field is determined by the SIMPLE algorithm, in which corrections based on local mass continuity requirements are made to the pressure field. Corresponding velocity corrections are also made to the velocity fields which are obtained from the solution of the momentum equations. By successive solution of the momentum, pressure-correction and salinity equations, the velocity, pressure and salinity fields are determined uniquely for given boundary conditions.

The finite-difference grid

The overall finite-difference grid used is shown in Fig. 1. Figure 2 shows a typical cell enclosing node P. Point P, the central node, has four neighboring nodes N, S, E and W at which the pressure and salinity values are stored. The velocities are located, as indicated by the arrows, halfway between these nodes, *i.e.* at the cell faces identified by n, s, e and w. This grid arrangement is known as a staggered-grid system. The grid spacings need not necessarily be uniform over the whole domain but can vary so that it is possible to locate more grid nodes in regions where steep variations of flow properties are expected.

The finite-difference equations

All difference equations can be cast in terms of a general variable ϕ, where ϕ stands for u, v, c, and p′ (pressure correction). Differences in the contents of each

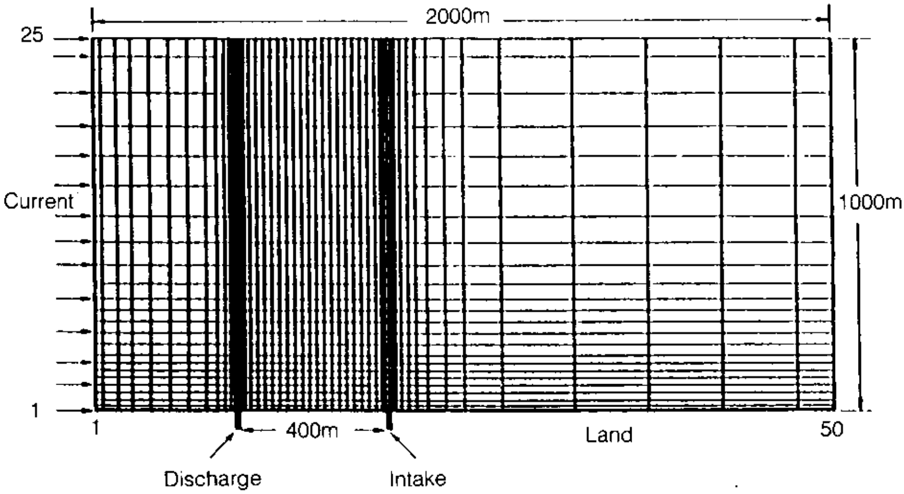


Fig. 1. **The physical situation and finite-difference grid layout**

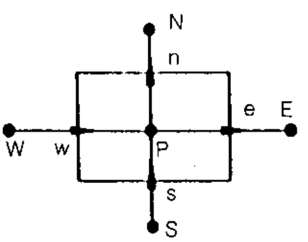


Fig. 2. **A typical finite-difference cell**

equation are contained in source terms. The general finite-difference equation linking the value of ϕ at P to those at N, S, E and W is obtained by integrating the differential equation (5) over the volume of the cell to yield:

$$A_P^\phi \phi_P = A_N^\phi \phi_N + A_S^\phi \phi_S + A_E^\phi \phi_E + A_W^\phi \phi_W + S_P^\phi , \qquad (6)$$

where,

$$A_P^\phi = A_N^\phi + A_S^\phi + A_E^\phi + A_W^\phi - S_P^{\phi\prime} . \qquad (6')$$

In the above equations, the source term S_ϕ is linearized as follows:

$$S_\phi V_P = S_P^\phi V_P + S_P^{\phi'} \phi_P V_P , \tag{7}$$

where, V_P is the volume of the finite-difference cell and A_N^ϕ , A_S^ϕ , A_E^ϕ and A_W^ϕ are the finite-difference coefficients of the variable ϕ.

Solution of the finite-difference equations

The above algebraic equations are coupled and non-linear and must be solved by an iterative process. The final solution is usually obtained after a number of iterations and by re-evaluating the values of the finite-difference coefficients every iteration. In the present program, the equations are solved simultaneously on a line-by-line basis by the Tri-Diagonal Matrix Algorithm (TDMA). The main solution steps can be summarized as follows:

(i) Guess values of variables in the field
(ii) Compute values of u on a line by solving the finite-difference form of the u-momentum equations
(iii) Compute values of v as in (ii) above
(iv) Compute values of c on the line
(v) Compute values of p′ by employing the mass continuity errors produced by u's and v's obtained from steps (ii) and (iii)
(vi) Correct pressures and velocities on the line
(vii) Move to next line and repeat steps (ii) to (vi) for the whole field
(viii) Repeat iterating the field until convergence is reached.

Treatment of variable-depth flow

Due to irregular sea-bed topography, variations in the depth of flow need to be accounted for. This problem is quite analogous to density variations in a compressible gas flow. The local flow depth (z) is, therefore, introduced inside the derivatives of the partial-differential equations. This variable depth is carried through the coefficients of the finite-difference equations by modifying the nominal cell areas and volumes.

Convergence and stability of the procedure

The convergence is monitored through the use of residuals (errors). A residual of a variable ϕ at a node P, denoted by R_P, is defined, with reference to equation (6), by:

$$R_P = \phi_P A_P^\phi - \sum_i A_i^\phi \phi_i - S_P^\phi , \qquad (8)$$

where, ϕ_P is the value at the previous iteration, and the summation is over the four cell faces.

All residuals are suitably normalized and a solution that produces sufficiently small field residuals, for all variables, is regarded as a converged one. This is provided that the field values of variables solved do not change by more than, say, 0.01% during successive iterations.

As to the stability of the procedure, it is found that the use of under-relaxation factors (β, where $\beta<1$) is sometimes beneficial and necessary. This is done as follows:

$$\phi_{new} = \beta \phi^* + (1-\beta) \phi_{old} , \qquad (9)$$

where, ϕ^* is the value of ϕ that is just being solved.

Results and Discussion

Introduction

The mathematical model constructed and developed in the previous section is applied for the simulation of a discharge problem. The physical situation is depicted in Fig. 1 along with the size and distribution of the finite-difference grid used. A parametric study is conducted by varying one parameter at a time, while keeping the rest of parameters at the default values. Sample of results is presented and discussed.

Problem definition and default values of parameters

A hypothetical desalination plant withdraws 12000 kg/s of sea water for de-salting at 50% recovery rate (capacity of about 140 million gpd) and discharges 6000 kg/s of brine at twice the concentration of salt in the sea. It is required to determine the salinity range between the plant discharge and intake ports and the salinity at the intake to the plant (c_{int}) for:

- Sea-current component parallel to coastline (u_{sea}) = 0.05 m/s.
- Sea-current component normal to coastline (v_{sea}) = 0.0 m/s.
- Wind-speed component parallel to coastline (u_{wind}) = 0.0 m/s.
- Wind-speed component normal to coastline (v_{wind}) = 0.0 m/s.

- Sea-water salinity (c_{sea}) = 4% (*i.e.* 40000 ppm).
- Area of discharge (A_{dis}) = 20 m^2.
- Salinity at discharge (c_{dis}) = 8% (*i.e.* 80000 ppm).
- Velocity of discharge (V_{dis}) = 0.3 m/s.
- Discharge and intake orientations: normal to coastline.
- Uneven sea-bed topography: depth at coastline = 2 m and increases at a slope of 1.8% away from coast.

It is also required to determine the salinity distribution and c_{int} when the above default values are changed.

Parameters studied

A parametric study is carried out and the variables are altered as follows (default values are underlined):

(i) Plant's de-salting capacity, through changing V_{dis}:
V_{dis}(m/s) = 0.1, 0.2, $\underline{0.3}$, 0.4, 0.5.

(ii) Discharge orientation:
discharge angle = $\underline{90}$°, 45°, 135° with respect to coastline.

(iii) u_{sea}(m/s) = 0.01, 0.02, $\underline{0.05}$, 0.10, 0.20.
(iv) v_{sea}(m/s) = $\underline{0.00}$, –0.01, 0.01.
(v) u_{wind}(m/s) = $\underline{0.0}$, –3.0 , 3.0 ; v_{wind}(m/s) = $\underline{0.0}$, –3.0, 3.0.
(vi) Intake orientation: intake angle = $\underline{90}$°, 45°, 135° w.r.t. coastline.
(vii) Sea-bed slope = 0.8%, $\underline{1.8}$%, 3.8% with depth at coastline = 2 m.

The components of velocity, u and v, are in the x- and y-directions, respectively: x is along the coast and is positive from discharge to intake; y is normal to the coast and is positive from land to sea.

Form of presentation

Sample results of the above parametric studies are presented in the form of salinity contour plots and tables of values. Fig. 3 depicts the salinity contours close to the discharge and intake locations for the case when all variables are set at the default values. Fig. 4 shows the change in salinity distribution due to imposing a north-eas-

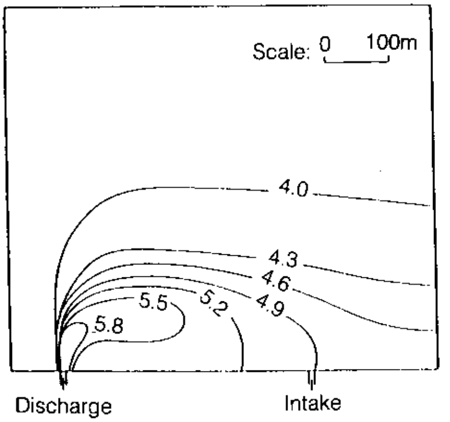


Fig. 3. **Salinity contours (%); Variables are at default values**

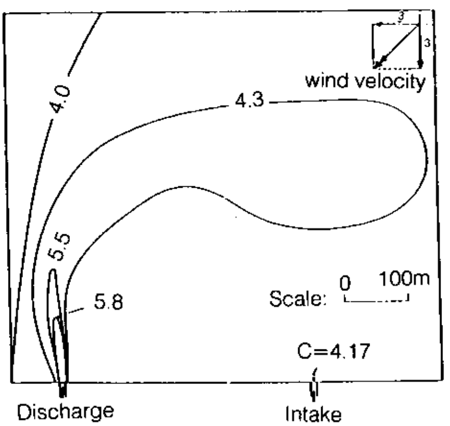


Fig. 4. **Salinity contours (%); Effects of north-easterly wind w.r.t. coast, other variables are at default values (Wind velocity component = 3 m/s)**

terly wind with respect to coastline, with a wind speed component of 3 m/s. The rest of the results are presented in the form of tables of values of the parameters varied and the correspondingly calculated salinity values at the plant intake. Tables 1 to 7 contain just these information for the parameters given in Section 3.3, in the same listed order.

Discussion of the Results

Salinity contours

The computed salinity contours shown in percentages in Fig. 3, under the default values of parameters, reveal that significant dispersion and mixing with the sea water take place initially. This is reflected by the fast drop in values from 8% to 5.8% only within a short distance after discharge. The free-stream salinity is 4% and is shown enveloping the discharged plume which is being deflected towards the coast by the prevailing sea-current conditions. It is clearly seen that the intake is influenced by the discharge conditions, and the computed value of salinity at the plant intake (c_{int}) is about 4.9%. The results shown in Fig. 4 are the outcome of imposing a north-easterly wind as indicated. The wind stress deflects the plume slightly upstream (against the sea current) and increases its spread into the sea. The intake port escapes now the worst effects of the plume but is still withdrawing water at 4.17% salinity, a value which is slightly higher than the nominal sea-water salinity. Effects of different wind conditions on c_{int} will be seen later.

Effects of discharge flow rate on salinity at intake

Table 1 indicates that c_{int} decreases with increasing the discharge velocity for the prevailing conditions. This is due to the fact that increasing V_{dis} increases the mass and momentum of the discharge. The deflection of the plume towards the intake due to sea-current crossflow is accordingly reduced.

Table 1. Effects of discharge velocity on salinity at intake (other variables are set at default values).

V_{dis}	(m/s)	=	0.1	0.2	0.3	0.4	0.5
c_{int}	(%)	=	5.11	5.05	4.96	4.91	4.88

Effects of discharge angle on salinity at intake

When all other parameters assume their default values, the change in angle of discharge results in noticeable effects on c_{int}, as can be seen in Table 2. These results may be expected in the sense that c_{int} decreases as the discharge angle, with respect to intake, increases. The mathematical model predicts about 20% total change in c_{int} due to 45° alteration in discharge angle.

Table 2. Effects of discharge angle on salinity at intake (other variables are set at default values).

Angle of discharge =				Sea
	(normal)	(45° towards intake)	(45° away from intake)	Land
c_{int} (%) =	4.96	5.63	4.74	

Effects of u_{sea} on salinity at intake

For the range of current speed investigated, Table 3 shows that c_{int} increases with u_{sea} due to increase in plume deflection towards the intake. However, this picture is more complex since u_{sea} affects both direction of plume movement and the rate of salt dispersion.

Table 3. Effects of sea-current velocity parallel to coastline on salinity at intake (other variables are set at default values).

u_{sea}	(m/s)	=	0.01	0.02	0.05	0.10	0.20
c_{int}	(%)	=	4.67	4.84	4.96	5.08	5.09

Effects of v_{sea} on salinity at intake

Table 4 shows the effects on c_{int} of having a small component of sea-current speed normal to coastline. A current component away from coastline gives a 3% lower c_{int} under the prevailing conditions.

Effects of wind velocity on salinity at intake

At calm wind conditions, the calculated c_{int} is equal to 4.96%. The tabulated values at the end of the arrows shown schematically on Table 5 represent c_{int} as calculated by imposing the wind speed and direction indicated by the particular arrow. Eight arrows are shown for eight different wind conditions with a wind speed component of 3 m/s. It is seen that the south-easterly wind with respect to the coast produces

Table 4. **Effects of sea-current velocity normal to coastline on salinity at intake (other variables are set at default values).**

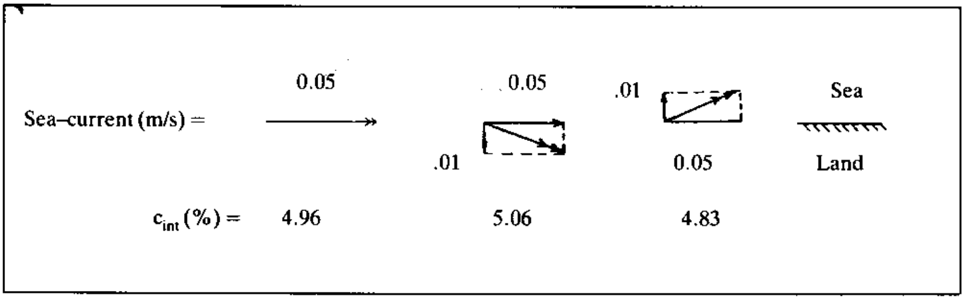
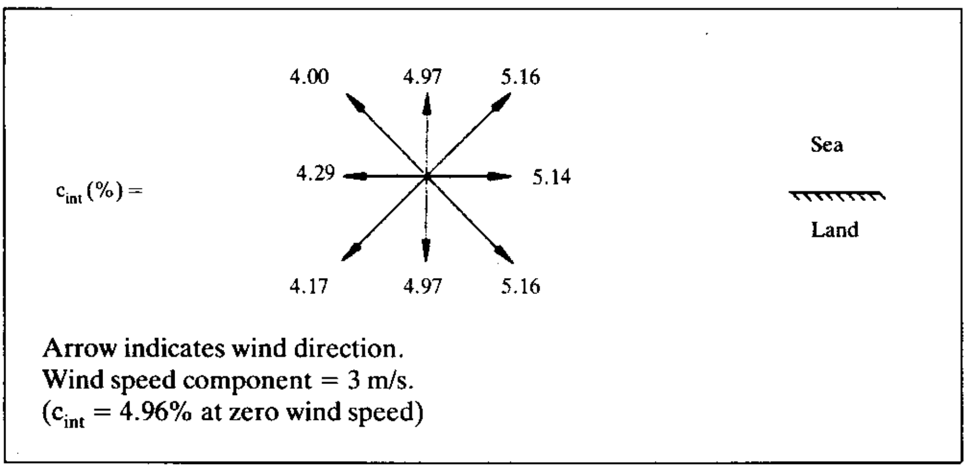


Table 5. **Effects of wind velocity on salinity at intake (other variables are set at default values).**

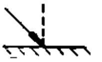
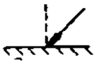
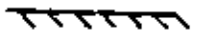


the most favourable effects on the intake; the worst effects result from a westerly wind in general. It can be concluded that moderate to high wind velocities are important in transporting the high salinity at discharge.

Effects of intake angle on salinity at intake

The results given in Table 6 show that the intake angle has no influence on c_{int}. This finding suggests that the intake conditions have no noticeable effects on the generated flow pattern and salinity distribution resulting from the discharge, under the conditions studied. This trend is also assisted by the fact that the salinity gradients near the intake port are very small.

Table 6. **Effects of intake angle on salinity at intake (other variables are set at default values).**

Angle of intake =				Sea  Land
	(normal)	(45° towards discharge)	(45° away from discharge)	
c_{int} (%) =	4.96	4.96	4.96	

Effects of sea-bed slope on salinity at intake

The default sea-bed slope is equal to 1.8% and the depth at coastline is 2m. It is required to know the effects on c_{int} had the plant been constructed at a coastal site with a different slope; all other conditions being the same. The results presented in Table 7 show that as the sea-bed slope increases c_{int} decreases. This suggests that dispersion into deeper coastal areas is more effective, as expected.

Table 7. **Effects of sea-bed slope on salinity at intake (other variables are set at default values).**

Sea-bed slope (%)	=	0.8	1.8	3.8
c_{int} (%)	=	5.15	4.96	4.82

Effects of recovery rate and discharge salinity on results

In the present calculations, a recovery rate of 50% is used with direct discharge to the sea. This gives a concentration factor (cf), defined as c_{dis}/c_{sea}, of 2.0. In general, different recovery rates are employed and the reject brine is pre-mixed with cooling water, after passing through the turbine condensers, before it is finally discharged to the sea. The salinity at discharge and concentration factor will be different from those used in the present study. However, since the salinity is treated as a passive variable, the trend of the results will not change and the dimensionless results will be independent of c_{dis} and c_{sea}. Accordingly, the recovery rate and salinity at discharge are not regarded as determinant factors and are only considered for their relative importance.

Conclusions

Achievements of the present work

A mathematical model for evaluating the flow and salinity distribution in bodies of water is constructed and developed. The model uses a control-volume finite-difference method. The model accounts for the important physical factors affecting the concentrated brine dispersion process and is capable of simulating complex flow situations and variable sea-bed elevation. The mathematical model is applied to compute the flow and salinity range in the vicinity of the discharge and intake ports of a hypothetical desalination plant. A parametric study is conducted for various factors. Under the conditions investigated, the results show possible effects of discharge on intake conditions. This will adversely affect the plant performance and power consumption. The model should help to assess impact of discharge on the environment and plant performance; help in selecting possible better alternative plant sites and discharge/intake port locations; help in studying the effects of installing artificial barriers, etc. and all under a variety of conditions.

Suggestions for future work

Field measurements are required to test the model accuracy. Solving for the additional thermal characteristics of the discharge. Incorporating a more sophisticated model of turbulence as, for example, the depth-integrated $k \sim \varepsilon$ model. Developing a transient (time-dependent) salinity-hydraulic model. Developing a vertical-section model for simulation in deep waters. The inclusion of density variation with salinity and temperature. Applying the model to real situations where actual meteorological, hydrological and topographical data are available. This is to investigate whether problems can exist under certain conditions and to possibly suggest means to alleviate such problems.

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حساب الجريان وتوزيع الملوحة بالقرب من نقاط مأخذ ماء البحر والرجيع لمحطة تحلية

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ملخص البحث. يهدف البحث إلى تركيب وتطوير وتطبيق أنموذج رياضي لحساب الجريان وتوزيع الملوحة في المناطق الساحلية الناتجة عن طرد الملوحة المُركَّزة في محطّات التحلية. يستعمل الأنموذج طريقة الحجم المحدّد لحل المعادلات المتحكمة في المسألة. يعتبر السريان ثنائي الأبعاد وغير متغير مع الوقت، مع اعتبار خواص السائل ثابتة.

يأخذ الأنموذج الرياضي في نظر الاعتبار العوامل الفيزيائية المهمة والتي تؤثر على عملية انتشار وتشتيت الملوحة المُركَّزة. هذه العوامل هي: الانتقال بالحمل والنشر، إجهاد الرياح، الاحتكاك مع القعر والمسقط الرأسي المتغير لقعر البحر. أوضحت نتائج الدراسة التي طبقت على محطة تحلية افتراضية وتحت تأثير أحوال أرصادية وهيدرولوجية وطوبوغرافية وأوضاع تشغيل للمحطة معيّنة أهمية العوامل المختلفة والتأثيرات الممكنة التي تحصل على مأخذ ماء البحر للمحطة. يساعد الأنموذج الرياضي على تقدير مدى تأثير الملوحة المُركَّزة المطرودة من محطات التحلية على البيئة البحرية وأداء المحطة ودراسة وسائل لتخفيف المشكلات الناتجة.