The Sea Water Intrusion (SWI) Package Manual
Part I. Theory, User Manual, and Examples.
Version 1.2

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Contents

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Release History

- Version 1.2. 5 April, 2005. Changed output file format of SWI package to standard MODFLOW budget file.
- Version 1.1. 14 September, 2004. Added ability to specify water type of sinks and sources.
- Version 0.2. 7 March, 2003. Bug-fix release.
- Version 0.1. 5 December, 2002.

1 Introduction

The Sea Water Intrusion (SWI) package is intended for the modeling of regional seawater intrusion with MODFLOW. The SWI package simulates the evolution of the three-dimensional density distribution through time; effects of the density distribution on the flow are taken into account explicitly. The main advantage of the SWI package is that each aquifer can be modeled with a single layer of cells. An existing MODFLOW model of a coastal aquifer can be modified to simulate seawater intrusion through the addition of one input file. The SWI package can simulate interface flow, stratified flow, and continuously-varying density flow.

The implemented formulation is based on the use of vertically integrated fluxes. Vertically integrated fluxes were introduced for variable density flow to describe instantaneous flow fields by Weiss (1982) and Maas and Emke (1988). Later, Strack (1995) used vertically integrated fluxes to develop a potential flow formulation for variable density flow. It was the latter formulation that formed the starting point for the development of the formulation outlined in this manual.

2 Conceptual model and approximations

2.1 Conceptual Model

The SWI package requires that the groundwater in each aquifer is discretized vertically into a number of zones bounded by curved surfaces. A schematic vertical cross–section of an aquifer is shown in Figure 1a; the thick lines represent the surfaces. The elevation of each surface is a unique function of the horizontal coordinates. The SWI package has two options. For the first option, called the *stratified flow* option, the water has a constant density in each zone and the density is discontinuous from zone to zone (Figure 1b). For the second option, called the *variable density flow* option, the surfaces bounding the zones are iso–surfaces of the density; the density varies linearly in the vertical direction in each zone and is continuous from zone to zone (Figure 1c).

2.2 Approximations

Four main approximations are made in the derivation of the formulations used in the SWI package:

1. The Dupuit approximation is adopted and will be interpreted to mean that the resistance to flow in the vertical direction is neglected (e.g. Strack, 1989, p.36). The Dupuit approximation is accurate for many practical problems of interface flow (e.g. Bear and Dagan, 1964), even if the slope of the interface is relatively steep (up to 45°; Chan Hong and Van Duijn, 1989). Strack and Bakker (1995) showed that adoption of the Dupuit approximation for variable density flow gives accurate results for the instantaneous flow field. It also compares well with fully 3D numerical solutions (MOCDENS3D and SEAWAT) for a rotating brackish zone (Bakker et. al, 2004).

2. The mass balance equation is replaced by the continuity of flow equation in the computation of the flow field (the Boussinesq–Oberbeck approximation; e.g. Holzbecher, 1998, p. 32); density effects are taken into account through Darcy's law.

3. Effects of dispersion and diffusion are not taken into account.

4. Inversion is not allowed. Inversion means that saltier (heavier) water is present above fresher (lighter) water, often resulting in the vertical growth of fingers. The SWI package is intended for the modeling of regional seawater intrusion, which is generally on a scale well beyond the size of the fingers.

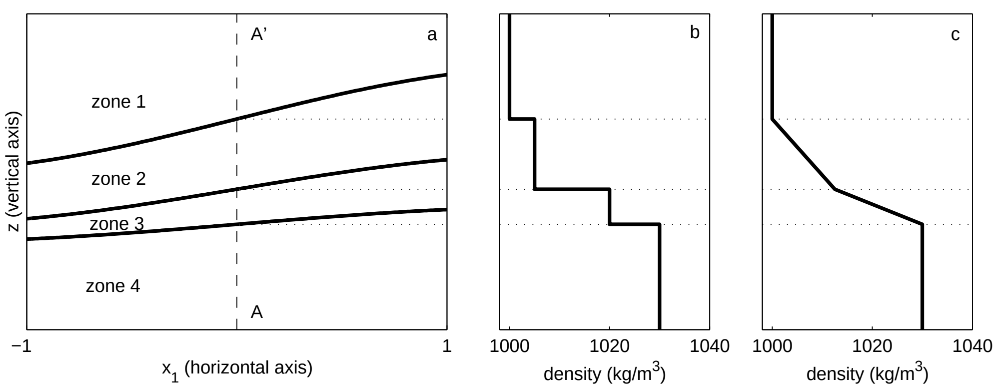

Figure 1: Conceptual models. (a) Vertical cross–section of an aquifer; (b) density distribution along A–A' for stratified flow; (c) density distribution along A–A' for variable density flow

3 Theory

This section outlines the mathematical formulation of the SWI package. Full details are given in Bakker (2003).

3.1 Mathematical derivation

For notational convenience, a Cartesian x_1, x_2, z coordinate system is adopted with the z axis pointing vertically upward (outside the 'Theory' section, an x, y, z coordinate system will be used). The groundwater is discretized vertically into N zones. Zones and surfaces are numbered from the top down; zone n is bounded on top by surface n (Figure 2). The elevation of surface n is represented by the function $\zeta_n(x_1, x_2)$; the elevation of the bottom of the aquifer is called ζ_{N+1} and the elevation of the top of the saturated aquifer is called ζ_1 (this can be the elevation of the (semi) confining layer or the phreatic surface). The three-dimensional density distribution is written in dimensionless form as

$$\nu = \frac{\rho - \rho_f}{\rho_f} \tag{1}$$

where ρ_f is the density of freshwater and $\rho(x, y, z)$ is the three-dimensional density distribution.

The dependent variables in the analysis are the freshwater head at the saturated top of an aquifer (called h_1) and the elevations of surfaces 2 through N. The comprehensive horizontal flow vector below surface p is called $\overset{p}{U}_i$ and is the vertically integrated flow between the bottom of the aquifer (z_b) and the elevation of surface p (ζ_p).

$$\overset{p}{U}_i = \int_{z_b}^{\zeta_p} q_i dz \qquad i = 1, 2 \tag{2}$$

where the index i is used to indicate the two horizontal components of a vector and q_i is the specific discharge vector. The specific dischare vector may be expressed in terms of the gradient of the freshwater head as (e.g. Holzbecher, 1998, p.35)

$$q_i = -k\partial_i h \qquad i = 1, 2 \tag{3}$$

where ∂_i stands for partial differentiation in the x_i direction ($\partial_i = \partial/\partial x_i$) and k is the freshwater hydraulic conductivity. The Dupuit approximation is adopted, and thus the pressure distribution in an aquifer is hydrostatic. This results in the following expression for the specific discharge vector (e.g. Strack, 1995)

$$q_i = -k\partial_i h_n + k\partial_i \int_{\zeta_n}^{z} \nu(x_1, x_2, z')dz' \qquad i = 1, 2 \tag{4}$$

where h_n is the head at elevation $z = \zeta_n$.

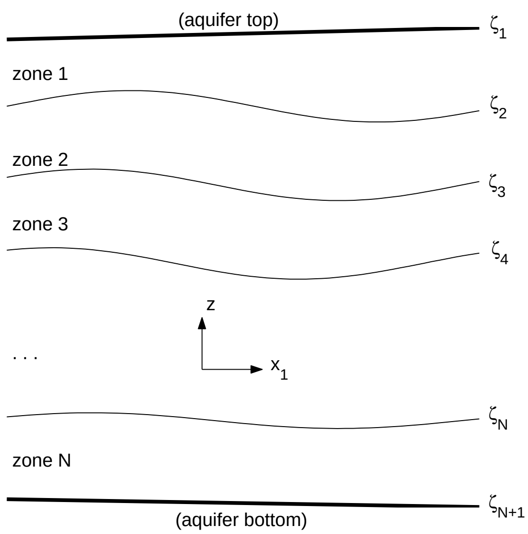

Figure 2: Schematic vertical cross-section of an aquifer

Continuity of total flow in the aquifer may be written as (since surface 1 is the top of the saturated aquifer)

$$\partial_i \overset{1}{U}_i = -S\frac{\partial h_1}{\partial t} + \gamma \qquad i = 1, 2 \tag{5}$$

where summation is assumed over repeated indices i here and in the remainder of this report (the Einstein summation convention). S [–] is the storativity and γ [L/T] is a source term. Similarly, continuity of flow below surface p ($p = 2, \ldots, N$) may be written as

$$\partial_i \overset{p}{U}_i = -n\frac{\partial \zeta_p}{\partial t} + \gamma_p \qquad i = 1, 2 \tag{6}$$

where n is the effective porosity and γ_p is a source term.

Combination of the continuity equations (5) and (6), and Darcy's law (4) result in

$$\boxed{\begin{aligned} \partial_i[\sigma_1 \partial_i h_1] &= S\frac{\partial h_1}{\partial t} - \gamma + R_1 \\ \delta_p \partial_i[\sigma_p \partial_i \zeta_p] &= n\frac{\partial \zeta_p}{\partial t} - \gamma_p + R_p \qquad p = 2, \ldots, N \end{aligned}} \tag{7}$$

where σ_n is defined as the comprehensive transmissivity below surface n, δ_n is a measure for the variation of the density between zones, and R_1 and R_2 are pseudo-source terms; the source term γ includes leakage between aquifers when flow is modeled in multiaquifer systems.

For *stratified flow*, δ_n, R_1 and R_p are defined as

$$\delta_1 = \nu_1, \qquad \delta_n = \nu_n - \nu_{n-1} \qquad n = 2, 3, \ldots, N \tag{8}$$

$$R_1 = -\sum_{n=1}^{N} \delta_n \partial_i[\sigma_n \partial_i \zeta_n] \tag{9}$$

$$R_p = -\partial_i[\sigma_p \partial_i h_1] - \sum_{n=1}^{p-1} \delta_n \partial_i[\sigma_p \partial_i \zeta_n] - \sum_{n=p+1}^{N} \delta_n \partial_i[\sigma_n \partial_i \zeta_n] \tag{10}$$

where ν_n is the dimensionless density of zone n.

For *variable density flow*, ν is defined as the dimensionless density along (iso)surface ζ_n and δ_n is computed using (8), but with the average dimensionless density, μ_n, of zone n

$$\mu_n = (\nu_n + \nu_{n+1})/2 \tag{11}$$

The terms R_1 and R_2 are defined as

$$R_1 = -\sum_{n=1}^{N} \delta_n \partial_i[\sigma_n \partial_i \zeta_n] + \sum_{n=p^*}^{N^*-1} \varepsilon_n \partial_i[\tau_n \partial_i(\zeta_n - \zeta_{n+1})] \tag{12}$$

$$R_p = -\partial_i[\sigma_p \partial_i h_1] - \sum_{n=1}^{p-1} \delta_n \partial_i[\sigma_p \partial_i \zeta_n] - \sum_{n=p+1}^{N} \delta_n \partial_i[\sigma_n \partial_i \zeta_n] + \sum_{n=p^*}^{N^*-1} \varepsilon_n \partial_i[\tau_n \partial_i(\zeta_n - \zeta_{n+1})] \tag{13}$$

where τ_p is the transmissivity of zone p:

$$\tau_p = k(\zeta_p - \zeta_{p+1}) \tag{14}$$

ε_p is a measure of the variation of the density over zone p:

$$\varepsilon_p = (\nu_{p+1} - \nu_p)/6 \tag{15}$$

and p^* is the number of the first surface below the top of the aquifer that is larger or equal to p, and N^* is the number of the last surface above the bottom of the aquifer. Notice that R_1 and R_p reduce to the equations for stratified flow, (9) and (10), when $\varepsilon_n = 0$ for all n.

3.2 Vertical leakage between aquifers

Density differences across a resistance layer separating two aquifers are taken into account by approximating the density to vary linearly in the vertical direction within a resistance layer. When lighter water leaks upward into an overlying aquifer with heavier water at the bottom, the lighter water is added as a source term to the zone with the same lighter water, instead of as a source term to the heavier water. Similarly, when heavier water leaks downward into an underlying aquifer with lighter water, the heavier water is added as a source term to the zone with the same heavier water. It is noted that areas where this special exchange of water is enforced are generally small in practice.

3.3 Solution procedure

Initial values must be specified for all dependent variables in each aquifer: the fresh water head h_1 at the saturated top of each aquifer, and the elevations ζ_n of surfaces 2 through N in each aquifer. Boundary conditions must be specified for the head, the head gradient, or a combination thereof, along all the boundaries of the model. The boundaries of surfaces 2 through N may potentially be moving. The boundary conditions for all surfaces are flux–specified during a timestep. When a surface intersects the bottom of an aquifer, the normal flux is set to zero. When a surface intersects the top of an aquifer, the normal flux is set to the normal component of the comprehensive flow in the aquifer. At the end of each time step, cells along the boundary of each surface are evaluated to determine whether the boundary should be moved horizontally, as will be discussed in the next section.

Given values for the head and elevations of the surfaces at time t, the head and elevations of the surfaces at time $t+\Delta t$ are computed as follows. The first of equations (7) is solved to compute the head at time $t+\Delta t$, using the elevations of the surfaces at time t to compute R_1; in case of multiaquifer flow the heads in all aquifers are solved simultaneously (as is common in MODFLOW). Next, the remaining equations of (7) are solved to compute the elevations of the surfaces at time $t+\Delta t$; this may be done for each aquifer separately. The terms R_p are computed using the head values at time $t+\Delta t$ and the elevations of the surfaces at time t. This procedure is equivalent to keeping the flow field fixed during a time step.

3.4 Tip and toe tracking

At the end of every timestep, it must be determined which parts of the boundaries of surfaces 2 through N are moving horizontally. Recall that the boundaries of each surface are flux specified during a timestep. As such, the surfaces can move up or down along the boundary during a timestep. The boundary of a surface is either near the bottom of an aquifer (referred to as a toe) or near the top of an aquifer (referred to as a tip). Here, the algorithm for dealing with a toe is discussed; the algorithm for a tip is analogous. The algorithm works separately along the rows and columns of a numerical grid.

Consider the surface shown in Figure 3. At the end of a timestep, the slope i of the surface in boundary cell j is determined as shown. If this slope is larger than a specified maximum threshold value, i_{max}, the surface is moved into the adjacent empty cell (Figure 3). This is accomplished by lowering the elevation of the surface in the boundary cell by a small amount $\Delta\zeta$ and at the same time specifying the elevation of the surface in the adjacent empty cell to be $\Delta\zeta$ above the base of the aquifer. As such, continuity of flow is ensured (an appropriate adjustment is made if the cell sizes are not equal). Conversely, if the thickness between the surface in cell j and the bottom of the aquifer is smaller than a minimum threshold value, $\Delta\zeta_{min}$, the surface is moved into the adjacent non-empty cell. This is accomplished by lowering the elevation in the toe cell to the

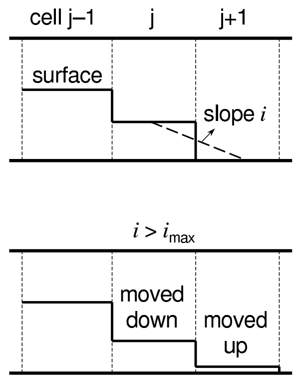

Figure 3: Toe tracking algorithm

bottom of the aquifer and increasing the elevation of the surface in the adjacent non-empty cell by the same amount. The above described algorithm requires the specification of three parameters: the maximum slope, i_{max}, the minimum thickness $\Delta\zeta_{min}$, and the small amount $\Delta\zeta$. Extensive experimentation has shown that transient simulations are rather insensitive to reasonable choices of these parameters. As a rule of thumb, it is sufficient to specify the maximum slope i_{max} by taking a representative value of the slope of a surface in an aquifer. Reasonable values for $\Delta\zeta$ and $\Delta\zeta_{min}$ may then be chosen as

$$\Delta\zeta = 0.1 i_{max}\Delta x \qquad \Delta\zeta_{min} = 0.1\Delta\zeta \tag{16}$$

where Δx is the cell size in the direction of seawater intrusion.

4 User Manual

To simulate seawater intrusion with MODFLOW and the SWI package, one additional input file, the SWI file, is required; the format of all other input files are described in the MODFLOW2000 manual (Harbaugh et al., 2000). The SWI file contains information on the initial density distribution in the aquifer, and the parameters for the transient evolution of the density distribution, as discussed in the previous section. The density distribution is specified by discretizing each aquifer vertically into a number of zones bounded by curved two-dimensional planes, as explained in Section 2.1. One has to decide whether flow is simulated as stratified flow or variable density flow. When flow is simulated as stratified flow, the surfaces represent interfaces between the different zones; the density is constant in each zone. When flow is simulated as variable density flow, the surfaces are iso-surfaces of the density (i.e. surfaces along which the density is constant); the density varies linearly in the vertical direction between these iso-surfaces.

Zones must be numbered from fresher/lighter water to saltier/heavier water. When the groundwater is discretized into N zones, the initial elevation of $N-1$ surfaces must be specified. The same number of surfaces must be specified in each aquifer, but surfaces may lie on top of each other (i.e. it is possible to simulate interface flow in the upper aquifer (by making sure all surfaces coincide) and variable density flow in the lower aquifers). An elevation must be specified in *every* cell. The elevation is equal to either the top of the saturated aquifer, the bottom of the aquifer, or an elevation somewhere in between. For example, consider the vertical cross–section shown in Figure 4a. The groundwater is discretized in three zones, and thus the elevations of two surfaces must be specified. The elevations of the two surfaces are shown in Figure 4b. Notice that the elevation of the surface between zones 1 and 2 is specified to be at the bottom of the aquifer when water above it is all zone 1 water, and at the top of the aquifer when the water below it consists of zones 2 or 3.

When MODFLOW/SWI is run, it solves for the equivalent freshwater head at the top of each aquifer, and for the elevations of all surfaces.

4.1 Additions to the NAME file

To run MODFLOW/SWI, one has to build an input file for the SWI package, and specify the name of this file and the name of an output file in the NAME file. The NAME file has a new file type called `SWI` for the input file of the SWI package and conforms to the standard syntax of the NAME file. For example, to read SWI data from `swiinput.swi` on unit number 23, add the following line to the NAME file:

```
SWI 23 swiinput.swi
```

The SWI input file requires the specification of a unit number for output of the elevations of the surfaces at the desired times. This file must be specified in the NAME file with the same unit

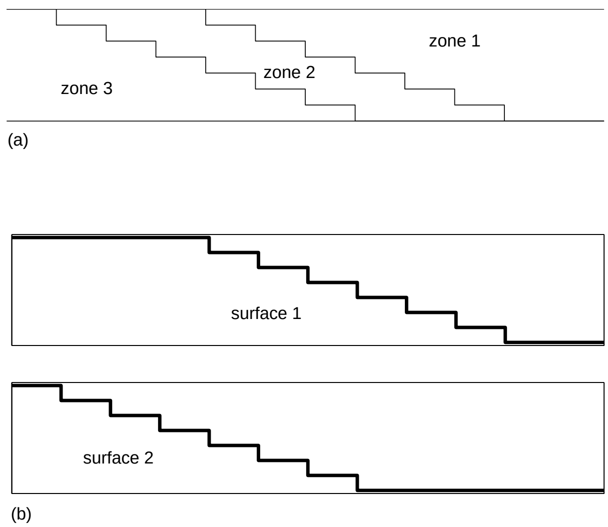

Figure 4: (a) An aquifer with three zones; (b) the elevations of the two planes that must be specified

number. For example, to write output to `swioutput.zta` on unit number 52, add the following line to the NAME file:

```
DATA(BINARY) 52 swioutput.zta
```

4.2 Input specifications of the SWI file

The SWI file contains data values for the different zones, algorithm parameters, the initial positions of the surfaces, and the type of sources and sinks.
FOR EACH SIMULATION

```
1.  Data:   NPLN        ISTRAT      ISWIZT      NPRN
    Format: I10         I10         I10         I10
2.  Data:   TOESLOPE    TIPSLOPE    ZETAMIN     DELZETA
    Format: F10.0       F10.0       F10.0       F10.0
3.  Data:   NU(ISTRAT=0: NPLN, ISTRAT=1: NPLN+1)
    MODULE: U1DREL
FOR EACH SURFACE
  FOR EACH LAYER
4.  Data:   ZETA(NCOL,NROW)
    Module: U2DREL
FOR EACH LAYER
5.  Data: SSZ(NCOL,NROW)
    Module: U2DREL
```

```
FOR EACH LAYER
6.  Data: ISOURCE(NCOL,NROW)
    Module: U2DREL
```

Explanation of variables read by the SWI Package

`NPLN`—Number of surfaces (planes). This equals the number of zones minus one.

`ISTRAT`—Flag indicating density distribution.

0 – density varies linear between planes.

1 – density is constant between planes.

`ISWIZT`—Flag and a unit number

If `ISWIZT`>0, unit number for ZETA

If `ISWIZT`≤ 0, ZETA will not be recorded.

`NPRN`—Number of steps between `ZETA` recordings; `ZETA` is recorded every `NPRN` steps.

`TOESLOPE`—Maximum slope of toecells.

`TIPSLOPE`—Maximum slope of tipcells.

`ZETAMIN`—Minimum elevation of a plane before it is removed from a cell (see (16) for a rule how to compute this parameter).

`DELZETA`—Elevation for a plane when it is moved into an adjacent empty cell (see (16) for a rule how to compute this parameter).

`NU`—Values of the dimensionless density

`ISTRAT` $= 1$ – Density of each zone (`NPLN+1` values).

`ISTRAT` $= 0$ – Density along each surface (`NPLN` values)

`ZETA`—Initial elevations of the surfaces.

`SSZ`—Effective porosity

`ISOURCE`—Source type of any external sources or sinks, specified with any outside package (i.e. Well package, Recharge package, Ghb package). There are three options:

If `ISOURCE`>0 – Sources and sinks are of the same type as water in zone `ISOURCE`. If such a zone is not present in the cell, sources and sinks are placed in zone at the top of the aquifer.

If `ISOURCE`= 0 – Sources and sinks are of the same type of water as at the top of the aquifer.

If `ISOURCE`< 0 – Sources are of the same type as water in zone `ISOURCE`. Sinks are of the same type of water as at the top of the aquifer. This option is useful for the modeling of the ocean bottom where infiltrating water is salt, yet exfiltrating water is of the same type as the water at the top of the aquifer.

4.3 Output file of elevations of surfaces

The output file with the elevations of the surfaces, with the extension `.zta` in this manual, is a standard MODFLOW binary budget file that can be read by a MODFLOW GUI capable of reading binary budget files. The labels of surfaces 1, 2, etc., are called `zetaplane1`, `zetaplane2`, etc. For example, if you are running Argus One, you can import the entire MODFLOW model without the SWI files in the Name file. After that, you need to rename the `.zta` file into `.bud` so that Argus One recognizes it. Import this file by going to PIEs – MODFLOW/Solute-Transport Post-Processing, and select the MODFLOW Budget File (MODFLOW-2000 v. 1.2 or later) option.

4.4 Running MODFLOW/SWI

The provided executable (`mf2k.exe`) is an implementation of the SWI package in MODFLOW2000. The program may be run on a win32 machine by opening a command prompt and typing `mf2k`. The program will then print to the screen the specific version number of MODFLOW2000 and of the SWI package, and ask to `Enter the name of the NAME file:`, as for any regular MODFLOW run. After the name of the NAME file has been entered the model will run. (This may take considerable time, depending on the size of the model; none of the examples presented in this manual take more than 30 seconds to run on a Pentium III 300 MHz machine; I know, your machine is much faster.) If the run was successful, the program terminates with the message
`Normal termination of MODFLOW-2000` If this message does not appear, and no error message appeared on the screen, check the `.lst` file for MODFLOW error messages.

5 Examples

Five examples will be presented in this section. All examples are hypothetical; examples of real world problems will be added when they become available. The presented examples make use of a number of MODFLOW packages; other packages have not yet been tested extensively, but no major problems are envisioned. In some of the examples, rather crude initial estimates of the elevations of the surfaces are used. It practice, it is advised to use as good a first estimate as possible. Since diffusion and dispersion are not taken into account, the amount of brackish water can only decline during a simulation, unless a brackish source is specified.

It is often sufficient to approximate the comprehensive flow in the aquifer system as incompressible, because heads change, in general, much quicker than the positions of the surfaces. In all examples, the comprehensive flow balance (7) is solved assuming steady-state conditions. Hence, the `Ss/tr` parameter in the Discretization file is set to `SS`. The simulation of the surfaces/interaces is transient of course.

A model of a coastal aquifer will, in general, need the specification of an area that represents the ocean floor. This area must be large enough such that all water that flows towards the ocean can actually discharge into the ocean (this is a common constraint on modeling groundwater outflow into a surface water body); it is advised to use GHB cells for this, as explained in examples 3 through 5.

In applying MODFLOW/SWI, care must be taken that the timestep is chosen small enough to obtain a stable solution. The timestep must be chosen at least so small that the tip or toe of a surface will not transgress an entire cell during a timestep (recall that the tip and toe tracking algorithm allows for the tip or toe to enter only one new cell per timestep). As for any MODFLOW run some variation of the timestep is recommended to assess the accuracy of a simulation. One more restriction of the current implementation of the SWI package is mentioned here. A surface cannot be drawn upward through a leaky layer. This means that when salt water starts leaking upward into a freshwater aquifer where no saltwater exists, no logic has been built in yet that will start a new surface between fresh water and salt water on the bottom of the freshwater aquifer. This would occur, for example, in Example 4 (Figure 8), if the discharge of the well in the upper aquifer is increased.

5.1 Example 1, a rotating interface

The first example concerns interface flow between freshwater and seawater in a vertical plane. The plane of flow is 250 m long, 40 m high, and 2 m wide; the origin of an x, z coordinate system is chosen at the upper left-hand corner of the plane. Flow is confined at all times and the top and bottom of the aquifer are impermeable and horizontal (Figure 5a). There is a constant flow $Q_{x0} = 1$ m^2/d from left to right (gradient of 0.0125). The hydraulic conductivity is $k = 2$ m/d

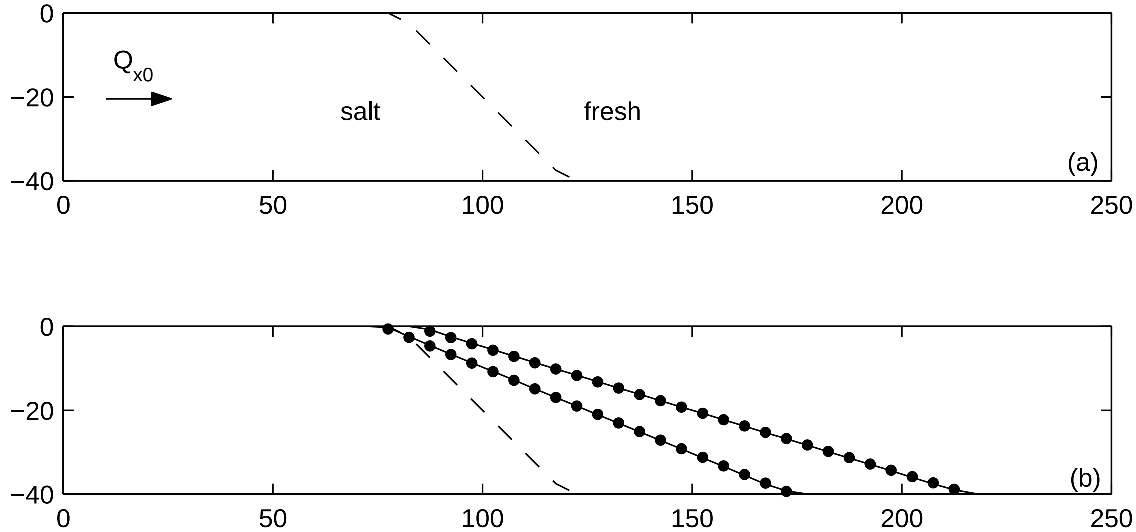

Figure 5: (a) Setup of example 1, (b) Position of interface at $t = 0$ (dashed), and $t = 200$ and $t = 400$; dots are exact solution

and the effective porosity is $n = 0.2$; the aquifer and water are treated as incompressible. The interface is, initially, at a 45° angle from $(x, z) = (80, 0)$ to $(x, z) = (120, -40)$ (Figure 5a). The density of the fresh and saltwater are $\rho = 1000$ kg/m^3 and $\rho = 1025$ kg/m^3, respectively. Hence, the dimensionless density difference of the fresh and saltwater are $\nu = 0$ and $\nu = 0.025$, respectively (computed with (1)).

The domain is discretized into 50 cells of 5 m wide, and the timestep is 2 d. A source of 2 m^3/d is specified in cell 1. MODFLOW requires the specification of 1 head-specified point (the rotation of the interface is independent of this choice); here, the head is fixed to 0.05 m at the top of the last cell.

There are two zones (a freshwater zone and a seawater zone) and thus one surface between them (`NPLN=1`). Flow is treated as stratified (`ISTRAT=1`) and the elevation of the interface is written to a file called `swiex1.zta` on unit number `ISWIZT=52` every `NPRN=100` times. The total number of time steps is 200, and thus the position of the interface is printed at 200 and 400 days. The slope of the interface varies from 1 (initial position) to about 0.2 (when it reaches the corner of the domain). The maximum slope of the toe and tip is chosen to be 0.2 (`TOESLOPE=TIPSLOPE=0.2`), and the $\Delta\zeta$ and $\Delta\zeta_{min}$ parameters are computed according to (16) (`ZETAMIN=0.01 DELZETA=0.1`). Since this is stratified flow with 2 zones, 2 ν values must be specified (`0` and `0.025`). The source/sink terms are specified to be fresh water (zone 1) everywhere (`ISOURCE=1`); the only source in this model is in cell 1.

Example 1 is summarized in Table 1; all input files are given in Appendix A. They are all standard MODFLOW input files (see Harbaugh et al., 2000), except for the file `swiex1.swi` which

Model size		Cell size		Number		Simulation	
L_x	L_y	Δx	Δy	N_x	N_y	Δt	t_{total}
250	2	5	2	50	1	2	400

Aquifer				Sources		Fixed head	
Layer	k	H	n	cell	source	cell	head
1	2	40	0.2	1	2	50	0.05

Seawater Intrusion						Density		
N_{zones}	Flow type	tipslope	toeslope	$\Delta\zeta$	ζ_{min}	zone	1	2
2	stratified	0.2	0.2	0.1	0.01	ρ	1000	1025

Table 1: Example 1 Summary Data. Units: meters, days, and kilograms

was explained above. The output file `swiex1.zta` contains, in the following order, the elevations of the top of the saturated aquifer, all surfaces (in this case only the interface), and the bottom of the aquifer at 200 d. and 400 d (in binary form); the format is the same as for the input of the interface elevations. The numeric values of the elevation of the interface at times 200 and 400 are shown in Appendix A for illustration.

Results are compared to the exact Dupuit solution of Wilson and Sa Da Costa (1982) and are shown in Figure 5b; the dots are the exact solution. The constant flow Q_{x0} results in an average velocity of $v_x = 0.125$ m/d. The exact (Dupuit) solution is a rotating straight interface of which the center moves to the right with a velocity of $v_x = 0.125$ m/d.

5.2 Example 2, a rotating brackish zone

The second example is a variation of the first example, but includes three zones and no constant flow. Consider two–dimensional, confined flow in a vertical cross–section. The origin of a Cartesian x, z coordinate system is chosen at the upper left-hand corner of the section; the aquifer is 40 m thick. The hydraulic conductivity is $k = 2$ m/d and the effective porosity is $n = 0.2$. A 300 m long section of the aquifer is considered and all boundaries are impermeable. The groundwater is divided into 3 zones: fresh, brackish, and salt water, with dimensionless densities of $\nu = 0$, $\nu = 0.0125$, and $\nu = 0.025$, respectively; at first, flow is treated as stratified. Initially, at time $t = 0$, both interfaces are straight and make a 45° angle with the horizontal and run from $(x, z) = (150, 0)$ to $(x, z) = (190, -40)$, and from $(x, z) = (110, 0)$ to $(x, y) = (150, -40)$. The head is fixed to 0.05 at the top of cell 1. The brackish zone will rotate to a horizontal position through time.

The domain is discretized into 60 cells of 5 m wide, and the timestep is 2 d. There are three zones and thus the initial elevations of two surfaces are specified. The shape of the brackish zone is computed at $t = 2000$ days by taking 1000 time steps. The maximum slope of the toe and tip is chosen to be 0.4, and the $\Delta\zeta$ and $\Delta\zeta_{min}$ parameters are computed according to (16). All

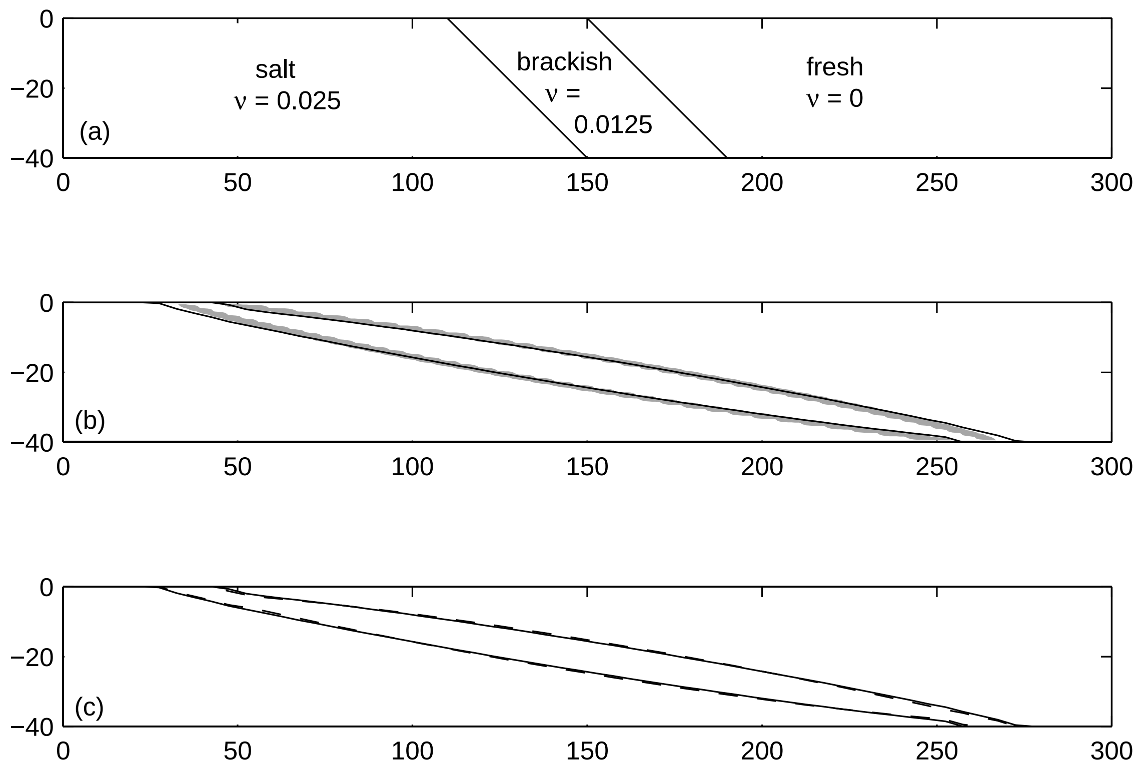

Figure 6: (a) Setup of Example 2, (b) Boundary of brackish zone after 2000 days; shaded area is SEAWAT, (c) Stratified (solid), versus variable density option (dashed)

Model size		Cell size		Number		Simulation	
L_x	L_y	Δx	Δy	N_x	N_y	Δt	t_{total}
300	2	5	2	60	1	2	2000

Aquifer				Fixed head	
Layer	k	H	n	cell	head
1	2	40	0.2	50	0.05

Seawater Intrusion						Density			
N_{zones}	Flow type	tipslope	toeslope	$\Delta\zeta$	ζ_{min}	zone	1	2	3
3	both	0.4	0.4	0.2	0.02	ρ	1000	1012.5	1025

Table 2: Example 2 Summary Data. Units: meters, days, and kilograms

sources/sinks are fresh water (zone 1). Example 2 is summarized in Table 2; all input files are shown in Appendix B.

Results at t=2000 days are compared to results obtained with SEAWAT (Guo and Langevin, 2002). For SEAWAT, the aquifer is discretized into 12,000 cells of 1 by 1 meter and the transport equation is solved with the TVD option in MT3DMS, specifying zero diffusion or dispersion. Results are shown in Figure 6b; the gray zone is the zone in SEAWAT corresponding to 5% to 45% salt, and 55% to 95% salt, the solid lines are the elevations of the interfaces as computed by MODFLOW/SWI. The SWI results predict a slightly faster rotating brackish zone and SEAWAT a slightly slower rotating zone. The faster rotation by MODFLOW/SWI may be caused by adoption of the Dupuit approximation, while the slower rotation by SEAWAT may be caused by numerical dispersion.

For illustration purposes, the same problem is solved with the variable density option. This requires two changes in the SWI input file. First, the `ISTRAT` parameter must be set to `0` to indicate variable density flow (rather than stratified flow). Second, the `NU` variable now needs 4 input values: the value of ν along the top of zone 1, the two surfaces, and the bottom of zone 3, so that the fourth line in the `swiex2.swi` file becomes:

```
0.000000 0.000000 0.025000 0.025000
```

Notice that this gives an average value of $\nu = 0.0125$ in the brackish zone. The position of the surfaces after 2000 days is not that much different from the stratified simulation. The results are shown in Figure 6c.

A more detailed comparison to MOCDENS3D (Oude Essink, 1998) and SEAWAT is described in Bakker et.al (2004).

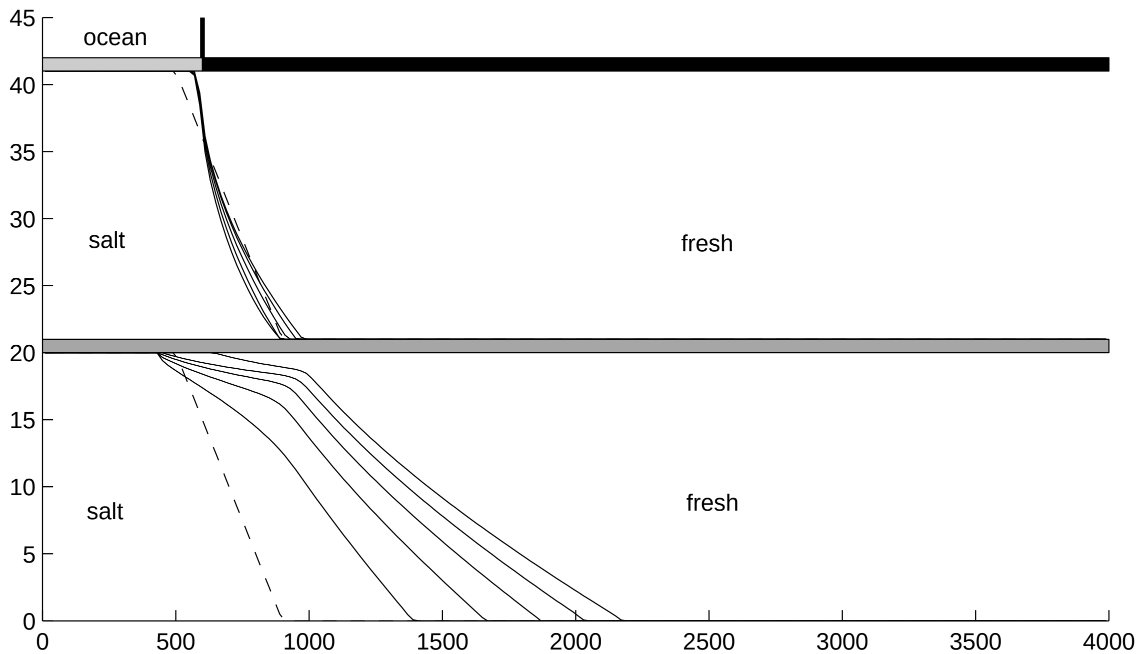

Figure 7: Example 3, initial interface positions (dashed), and position every 100 years (solid)

5.3 Example 3, intrusion of an interface in a two-aquifer system, vertical cross-section

This example considers interface flow in a two-aquifer system. The plane of flow is 4000 m. long and 2 m. wide; both aquifers are 20 m. thick and are separated by a leaky layer of 1 m thickness. The origin of the x, z coordinate system is chosen at the lower left-hand corner of the plane. The hydraulic conductivities of the top aquifer is 2 m/d and of the bottom aquifer is 4 m/d; the effective porosity of both aquifers is 0.2. Flow is semi-confined at all times. The first 600 m of the top of aquifer 1 represents the ocean floor; the freshwater head at the ocean bottom is 50 m. The leaky layer between aquifers 1 and 2 has a vertical resistance to flow of $c = 100$ days (Vcont=0.01). The vertical resistance to outflow in the ocean is $c = 50$ days (Vcont=0.02). There is a comprehensive flow of 0.015 m^2/d towards the ocean (equally distributed over both aquifers at the boundary).

Initially the interface between the fresh and seawater is straight and is at the top of each aquifer at $x = 500$ and at the bottom of each aquifer at $x = 900$; i.e. the initial slope is 0.05. The dimensionless density is $\nu = 0.025$.

Each aquifer is discretized into 200 cells of 20 m long and the timestep is 1 year. The last cell in the top aquifer has a source of 0.01 m^3/d, and the last cell in the bottom aquifer a source of 0.02 m^3/d. The ocean bottom is modeled with the General Head Boundary (GHB) package. The head in the GHB cells is specified to the equivalent fresh water head at the bottom of the ocean (50 m). The `Cond` value is computed as the `Vcont` value (0.02) of the ocean bottom multiplied by

Model size		Cell size		Number		Simulation	
L_x	L_y	Δx	Δy	N_x	N_y	Δt	t_{total}
4000	2	20	2	200	1	365	182500

Aquifer			
Layer	k	H	n
1	2	20	0.2
2	4	20	0.2

Leaky layer		
Layer	H	`Vcont`
1	1	0.01

Sources		
layer	cell	source
1	200	0.01
2	200	0.02

GHB			
layer	cell	head	`Cond`
1	1-30	50	0.8

Seawater Intrusion					
N_{zones}	Flow type	tipslope	toeslope	$\Delta\zeta$	$\zeta_{\min}$
2	stratified	0.4	0.04	0.06	0.006

Density		
zone	1	2
ρ	1000	1025

Table 3: Example 3 Summary Data. Units: meters, days, and kilograms

the area of the cell (40). The water in the GHB cells representing the ocean is salt. Hence, when the GHB cell acts as a source the infiltrating water is zone 2. When the GHB acts as a sink, water that flows out of the cells is of the same type as the water at the top of the aquifer. Hence, the `ISOURCE` parameter is set to -2. The tip and toe tracking parameters are a `TOESLOPE` of 0.02, a `TIPSLOPE` of 0.04, a `DELZETA` of 0.06 and a `ZETAMIN` of 0.006. Example 3 is summarized in Table 3; all input files are shown in Appendix C. The positions of the interface after 100, 200, 300, 400, and 500 years are shown in Figure 7.

5.4 Example 4, upconing of an interface below a pumping well in a two-aquifer system

Consider three–dimensional flow in the same two-aquifer system as in the previous example. The area of interest extends 1300 m in the x-direction, and 1000 m in the y-direction. The upper aquifer is bounded on top by the ocean floor in the west (Figure 8a); a 300 m wide section of ocean floor is modeled. The flow entering the domain in the east is 0.12 m^2/d., so that the total flow entering the system is 120 m^3/d. A well of discharge $Q = 70$ m^3/d is situated in the top aquifer at $(x, y) = (975, 525)$.

Initially, the interface between the fresh and seawater is straight and is at the top of each aquifer at $x = 250$ and at the bottom of each aquifer at $x = 450$; i.e. the initial slope is 0.1. The dimensionless density of the seawater is $\nu = 0.025$.

Each aquifer is discretized in 20*26 square cells of 50 by 50 m; the well is at the center of cell (10,20). The timestep is one year. The tip and toe tracking parameters are a `TOESLOPE` and `TIPSLOPE` of 0.05, a `DELZETA` of 0.25 and a `ZETAMIN` of 0.025. Example 4 is summarized in Table 4; all input files are given in Appendix D.

The position of the interface after 50 years is shown in Figure 8b, and after 400 years in Figure

Model size		Cell size		Number		Simulation	
L_x	L_y	Δx	Δy	N_x	N_y	Δt	t_{total}
1300	1000	50	50	26	20	365	146000

Aquifer			
Layer	k	H	n
1	2	20	0.2
2	4	20	0.2

Leaky layer		
Layer	H	`Vcont`
1	1	0.01

Sources		
layer	cell	source
1	(1-20,26)	2
2	(1-20,26)	4
1	(10,20)	-70

GHB			
layer	cell	head	`Cond`
1	(1-20,1-6)	50	50

Seawater Intrusion					
N_{zones}	Flow type	tipslope	toeslope	$\Delta\zeta$	ζ_{min}
2	stratified	0.05	0.05	0.25	0.025

Density		
zone	1	2
ρ	1000	1025

Table 4: Example 4 Summary Data. Units: meters, days, and kilograms

8c. There is a significant upconing below the well in the bottom aquifer.

5.5 Example 5, shape of a brackish zone below a square island

Consider a square island of 525 by 525 meters. The origin of the coordinate system is chosen at the center of the island. Below the island is a 50 m thick aquifer with a hydraulic conductivity of 10 m/d. There is an infiltration on the island of 2 mm/d (specified with the recharge package). In addition, there is an area of 100 by 100 meter where there is a combined net discharge of 80 m^3/d (the dark gray area in Figure 9a). The island is surrounded by an ocean with an equivalent freshwater level of 0.05 m; the vertical resistance to outflow in the ocean is $c = 2$ days (Vcont = 0.5).

The domain is discretized into 21 by 21 cells of 50 by 50 m. A timestep of 50 days is used. The tip and toe tracking parameters are not too important (there is only a tip where the brackish zone intersects the top of the aquifer); tip and toeslope are 0.05; delzeta and zetamin are computed with (16). The ocean is represented by a strip of 150 meter (6 cells) wide around the island (the light gray area in Figure 9a). Groundwater below the island consists of freshwater ($\nu = 0$), brackish water ($\nu = 0.0125$), and seawater ($\nu = 0.025$). Initially the brackish zone below the island is 10 m thick and extends from 25 to 35 meters below the surface; below the strip representing the ocean the surfaces bounding the brackish zone are at the top of the aquifer. Example 5 is summarized in Table 5; all input files are shown in Appendix E.

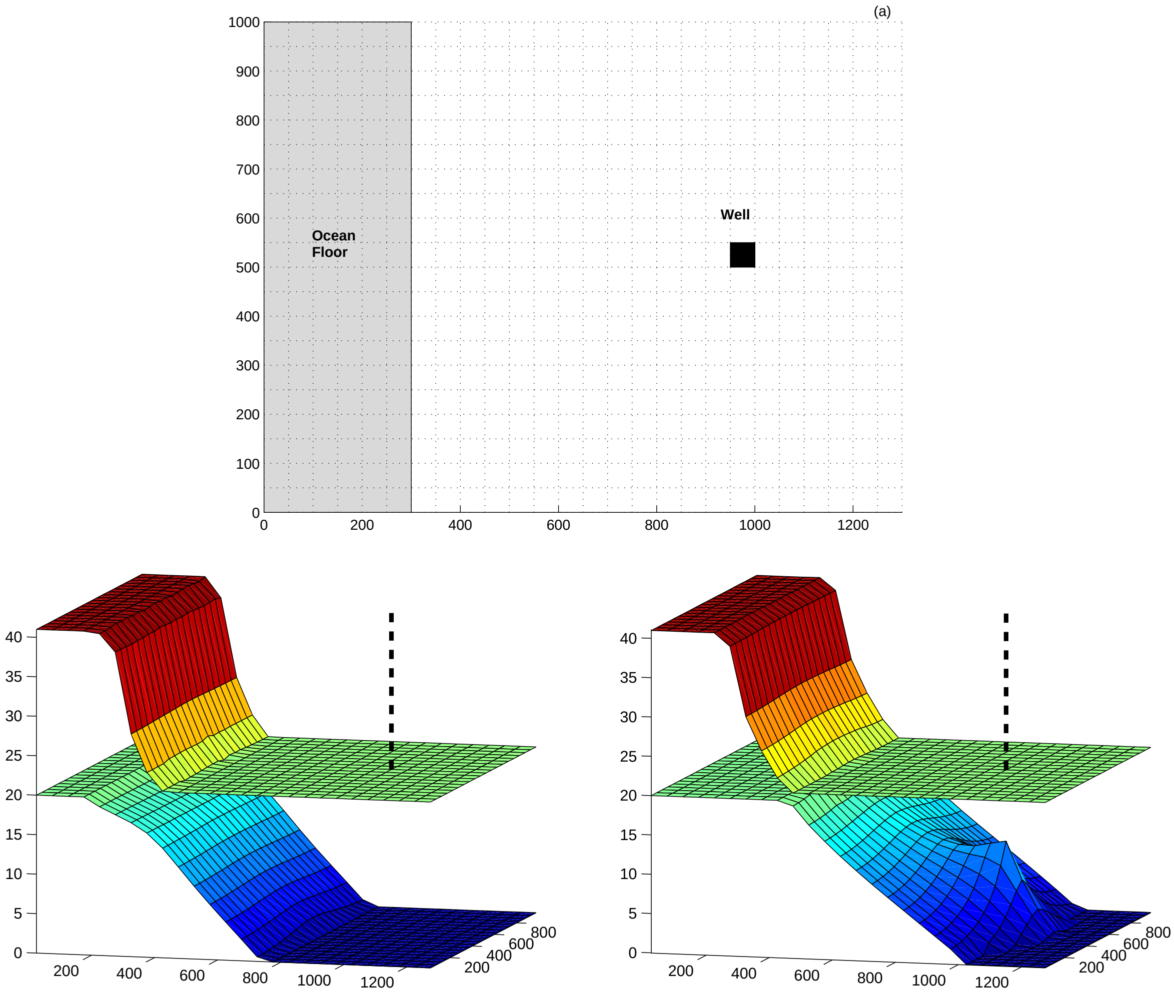

Figure 8: Example 4. (a) Setup, (b) Position of interfaces after 50 years, (c) position of interfaces after 400 years

Model size		Cell size		Number		Simulation	
L_x	L_y	Δx	Δy	N_x	N_y	Δt	t_{total}
1050	1050	50	50	21	21	200	10000

Aquifer				Recharge		
Layer	k	H	n	layer	cell	recharge
1	10	50	0.2	1	(4-18,4-18)	0.002

Source			GHB			
layer	cell	source	layer	cell	head	`Cond`
1	(8-9,8-9)	-20	1	3 cells along boundary	0.05	1250

Seawater Intrusion						Density			
N_{zones}	Flow type	tipslope	toeslope	$\Delta\zeta$	$\zeta_{\min}$	zone	1	2	3
3	stratified	0.05	0.05	0.25	0.025	ρ	1000	1012.5	1025

Table 5: Example 5 Summary Data. Units: meters, days, and kilograms

The position of the top and bottom of the brackish zone (i.e. surfaces 1 and 2) at t=10,000 days are shown in Figures 9b and 9c. The contour interval in Figure 9b is 5 m. The dotted line in Figure 9c represents the Ghyben-Herzberg position of an interface (i.e. the interface position corresponding to the head distribution after 10,000 days), if the problem was modeled as interface flow.

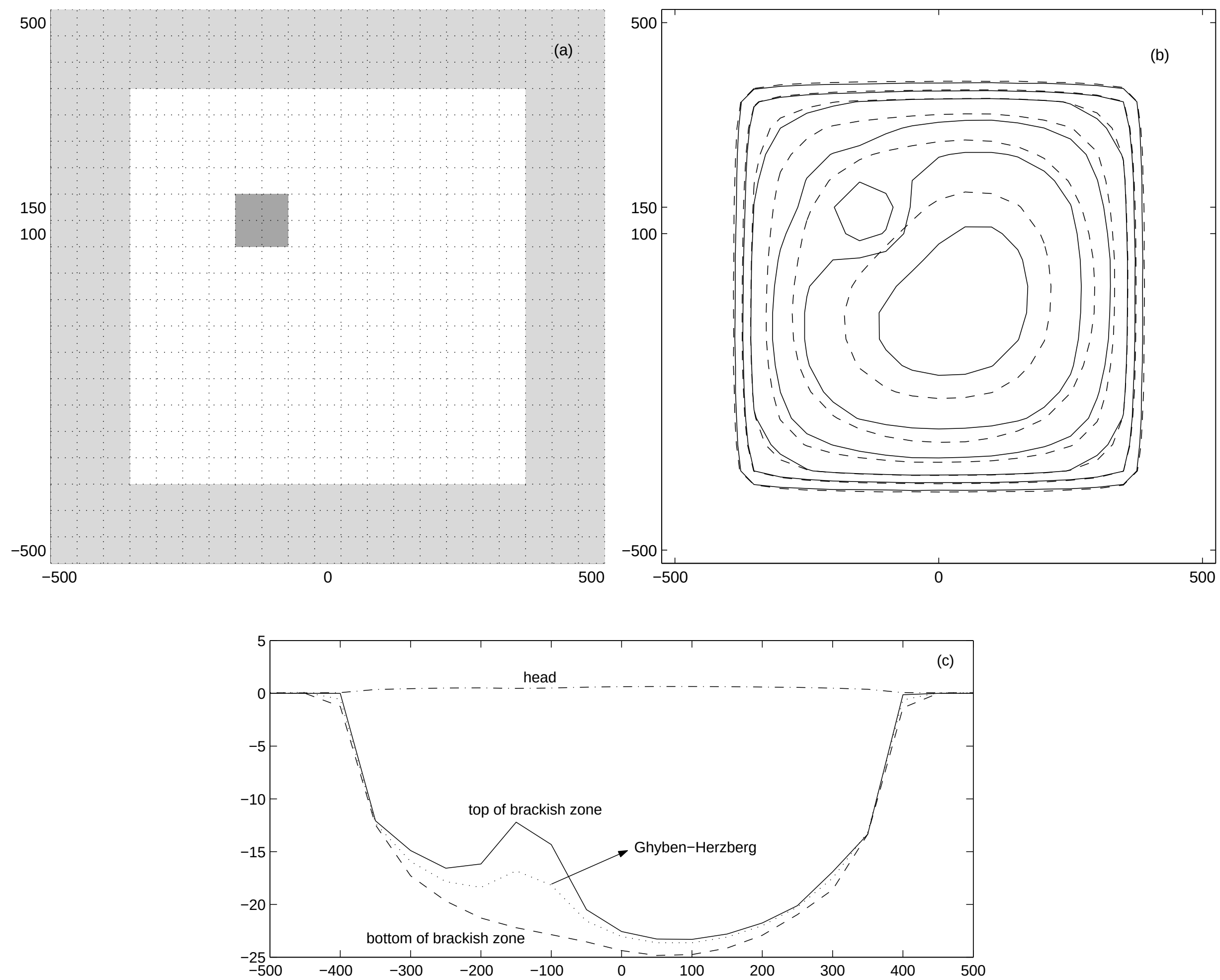

Figure 9: Example 5. (a) Setup, (b) Contours of elevation of top (solid) and bottom (dashed) of brackish zone at 10,000 days; contour interval -28:4:0, (c) Cross section along row 8 at 10,000 days

6 References

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A Input files example 1

Name file: swiex1.nam

```
GLOBAL 1 swiex1.glo
LIST 2 swiex1.lst
DIS 10 swiex1.dis
BAS6 3 swiex1.ba6
OC 22 swiex1.oc
BCF6 11 swiex1.bc6
WEL 12 swiex1.wel
PCG 19 swiex1.pcg
SWI 23 swiex1.swi
DATA(BINARY) 30 swiex1.hds
DATA(BINARY) 51 swiex1.bgt
DATA(BINARY) 52 swiex1.zta
```

Discretization file: swiex1.dis

```
         1         1        50         1         0         0
 0
CONSTANT 5
CONSTANT 2
CONSTANT 0
CONSTANT -40
400.000000 200 1.000000 SS
```

Basic package file: swiex1.ba6

```
FREE
INTERNAL          1 (FREE)   -1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 -1
999.990000
CONSTANT 0.05
```

Output control file (using numeric codes): swiex1.oc
First line

```
0 0 30 0
```

The following two lines are repeated 200 times (once for each time step)

```
0 1 1 1
0 0 1 0
```

Block-centered flow package file: swiex1.bc6

```
0 1.000000e+030 0 0.000000 0 0
 00
CONSTANT 1
CONSTANT 80
```

Well package file: swiex1.wel

```
         1        51
         1
         1         1         1         2
```

Preconditioned conjugate-gradient file: swiex1.pcg

```
50 25 1
0.000010 0.000010 1.000000 0 0.000000 3.000000 1.000000
```

Sea water intrusion package file: swiex1.swi

```
         1         1        52       100
  0.200000  0.200000  0.010000  0.100000
INTERNAL          1 (FREE)   -1
0.000000 0.025000
INTERNAL          1 (FREE)   -1
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 -2.500000 -7.500000 -12.500000 -17.500000 -22.500000 -27.500000 -32.500000 -37.500000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
CONSTANT 0.2
CONSTANT 1
```

Output file: swiex1.zta (only zeta values corresponding to the interface at $t = 200$ and $t = 400$ are shown; transformed from the budget file)

```
t = 200
         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0   -0.2540   -2.4421   -4.5482   -6.6307   -8.7017
  -10.7659  -12.8258  -14.8828  -16.9381  -18.9924  -21.0466  -23.1014  -25.1576  -27.2163  -29.2789
  -31.3479  -33.4278  -35.5293  -37.6509  -39.2616  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000
  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000
t = 400
         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0   -0.7586   -2.4786   -4.0344
   -5.5728   -7.1025   -8.6273  -10.1490  -11.6685  -13.1867  -14.7038  -16.2202  -17.7361  -19.2519
  -20.7677  -22.2836  -23.7999  -25.3169  -26.8348  -28.3540  -29.8751  -31.3988  -32.9265  -34.4611
  -36.0090  -37.5755  -39.0067  -39.9000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000  -40.0000
```

B Input files example 2

Name file: swiex2.nam

```
GLOBAL 1 swiex2.glo
LIST 2 swiex2.lst
BAS6 3 swiex2.ba6
BCF6 11 swiex2.bc6
PCG 19 swiex2.pcg
SWI 23 swiex2.swi
OC 22 swiex2.oc
DIS 10 swiex2.dis
DATA(BINARY) 30 swiex2.hds
DATA(BINARY) 51 swiex2.bgt
DATA(BINARY) 52 swiex2.zta
```

Discretization file: swiex2.dis

```
         1         1        60         1         0         0
 0
CONSTANT 5
CONSTANT 2
CONSTANT 0
CONSTANT -40
2000.000000 1000 1.000000 SS
```

Basic package file: swiex2.ba6

```
FREE
INTERNAL          1 (FREE)   -1
-1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
999.990000
CONSTANT 0.05
```

Output control file (using numeric codes): swiex2.oc
First line

```
0 0 30 0
```

The following two lines are repeated 1000 times (once for each time step)

```
0 1 1 1
0 0 1 0
```

Block-centered flow package file: swiex2.bc6

```
0 1.000000e+030 0 0.000000 0 0
 00
CONSTANT 1
CONSTANT 80
```

Preconditioned conjugate-gradient file: swiex2.pcg

```
50 25 1
0.000010 0.000010 1.000000 0 0.000000 3.000000 1.000000
```

Sea water intrusion package file: swiex2.swi (for simulation with stratified flow)

```
         2         1        52      1000
  0.400000  0.400000  0.020000  0.200000
INTERNAL          1 (FREE)   -1
0.000000 0.012500 0.025000
INTERNAL          1 (FREE)   -1
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 -2.500000 -7.500000
-12.500000 -17.500000 -22.500000 -27.500000 -32.500000 -37.500000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
INTERNAL          1 (FREE) -1
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 -2.500000 -7.500000
-12.500000 -17.500000 -22.500000 -27.500000 -32.500000 -37.500000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000 -40.000000
-40.000000
CONSTANT 0.2
CONSTANT 1
```

C Input files example 3

Name file: swiex3.nam

```
GLOBAL 1 swiex3.glo
LIST 2 swiex3.lst
BAS6 3 swiex3.ba6
BCF6 11 swiex3.bc6
WEL 12 swiex3.wel
PCG 19 swiex3.pcg
SWI 23 swiex3.swi
OC 22 swiex3.oc
DIS 10 swiex3.dis
GHB 24 swiex3.ghb
DATA(BINARY) 30 swiex3.hds
DATA(BINARY) 51 swiex3.bgt
DATA(BINARY) 52 swiex3.zta
```

Discretization file: swiex3.dis

```
         2         1       200         1         0         0
 1 0
CONSTANT 20
CONSTANT 2
CONSTANT 41
CONSTANT 21
CONSTANT 20
CONSTANT 0
182500.000000 500 1.000000 SS
```

Basic package file: swiex3.ba6

```
FREE
CONSTANT 1
CONSTANT 1
999.990000
CONSTANT 1
CONSTANT 1
```

Output control file (using numeric codes): swiex3.oc
First line

```
0 0 30 0
```

The following two lines are repeated 500 times (ones for each time step)

```
0 1 1 1
0 0 1 0
```

Block-centered flow package file: swiex3.bc6

```
0 1.000000e+030 0 0.000000 0 0
 00 00
CONSTANT 1
CONSTANT 40
CONSTANT 0.01
CONSTANT 80
```

Well package file: swiex3.wel

```
         2        51
         2
         1         1       200      0.01
         2         1       200      0.02
```

Ghb package file: swiex3.ghb

```
30  20
30
1 1 1  50 0.8
1 1 2  50 0.8
1 1 3  50 0.8
1 1 4  50 0.8
1 1 5  50 0.8
1 1 6  50 0.8
1 1 7  50 0.8
1 1 8  50 0.8
1 1 9  50 0.8
1 1 10 50 0.8
1 1 11  50 0.8
1 1 12  50 0.8
1 1 13  50 0.8
1 1 14  50 0.8
1 1 15  50 0.8
```

```
1 1 16  50 0.8
1 1 17  50 0.8
1 1 18  50 0.8
1 1 19  50 0.8
1 1 20  50 0.8
1 1 21  50 0.8
1 1 22  50 0.8
1 1 23  50 0.8
1 1 24  50 0.8
1 1 25  50 0.8
1 1 26  50 0.8
1 1 27  50 0.8
1 1 28  50 0.8
1 1 29  50 0.8
1 1 30  50 0.8
```

Preconditioned conjugate-gradient file: swiex3.pcg

```
50 25 1
0.000010 0.000010 1.000000 0 0.000000 3.000000 1.000000
```

Sea water intrusion package file: swiex3.swi

```
         1          1         52        100
  0.020000  0.040000  0.006000  0.060000
INTERNAL          1 (FREE)   -1
0.000000 0.025000
INTERNAL          1 (FREE)   -1
41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000
41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000 41.000000
41.000000 40.500000 39.500000 38.500000 37.500000 36.500000 35.500000 34.500000 33.500000 32.500000 31.500000 30.500000
29.500000 28.500000 27.500000 26.500000 25.500000 24.500000 23.500000 22.500000 21.500000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000 21.000000
INTERNAL          1 (FREE)   -1
20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000
20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000 20.000000
20.000000 19.500000 18.500000 17.500000 16.500000 15.500000 14.500000 13.500000 12.500000 11.500000 10.500000 9.500000
8.500000 7.500000 6.500000 5.500000 4.500000 3.500000 2.500000 1.500000 0.500000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
CONSTANT 0.2
CONSTANT 0.2
CONSTANT -2
CONSTANT 0
```

D Input files example 4

Name file: swiex4.nam

```
GLOBAL 1 swiex4.glo
LIST 2 swiex4.lst
BAS6 3 swiex4.ba6
BCF6 11 swiex4.bc6
WEL 12 swiex4.wel
PCG 19 swiex4.pcg
SWI 23 swiex4.swi
OC 22 swiex4.oc
DIS 10 swiex4.dis
GHB 24 swiex4.ghb
DATA(BINARY) 30 swiex4.hds
DATA(BINARY) 51 swiex4.bgt
DATA(BINARY) 52 swiex4.zta
```

Discretization file: swiex4.dis

```
         2        20        26         1         0         0
 1 0
CONSTANT 50
CONSTANT 50
CONSTANT 41
CONSTANT 21
CONSTANT 20
CONSTANT 0
146000.000000 400 1.000000 SS
```

Basic package file: swiex4.ba6

```
FREE
CONSTANT 1
CONSTANT 1
999.990000
CONSTANT 1
CONSTANT 1
```

Output control file (using numeric codes): swiex4.oc
First line

```
0 0 30 0
```

The following two lines are repeated 400 times (ones for each time step)

```
0 1 1 1
0 0 1 0
```

Block-centered flow package file: swiex4.bc6

```
0 1.000000e+030 0 0.000000 0 0
 00 00
CONSTANT 1
CONSTANT 40
CONSTANT 0.01
CONSTANT 80
```

Well package file: swiex4.wel

```
        41        51
        41
         1         1        26         2
         1         2        26         2
         1         3        26         2
         1         4        26         2
         1         5        26         2
         1         6        26         2
         1         7        26         2
         1         8        26         2
         1         9        26         2
         1        10        26         2
         1        11        26         2
         1        12        26         2
         1        13        26         2
         1        14        26         2
         1        15        26         2
         1        16        26         2
         1        17        26         2
         1        18        26         2
         1        19        26         2
         1        20        26         2
         2         1        26         4
         2         2        26         4
         2         3        26         4
         2         4        26         4
         2         5        26         4
         2         6        26         4
         2         7        26         4
         2         8        26         4
         2         9        26         4
         2        10        26         4
         2        11        26         4
         2        12        26         4
         2        13        26         4
         2        14        26         4
         2        15        26         4
         2        16        26         4
         2        17        26         4
         2        18        26         4
         2        19        26         4
         2        20        26         4
         1        10        20       -70
```

Ghb package file: swiex4.ghb

```
       120        20
       120
         1         1         1        50        50
         1         2         1        50        50
         1         3         1        50        50
         1         4         1        50        50
         1         5         1        50        50
         1         6         1        50        50
         1         7         1        50        50
         1         8         1        50        50
         1         9         1        50        50
         1        10         1        50        50
         1        11         1        50        50
         1        12         1        50        50
         1        13         1        50        50
         1        14         1        50        50
         1        15         1        50        50
         1        16         1        50        50
         1        17         1        50        50
         1        18         1        50        50
         1        19         1        50        50
         1        20         1        50        50
```

Last 20 lines are repeated for columns 2 through 6.
Preconditioned conjugate-gradient file: swiex4.pcg

```
50 25 1
0.000010 0.000010 1.000000 0 0.000000 3.000000 1.000000
```

Sea water intrusion package file: swiex4.swi

```
         1         1        52        50
  0.050000  0.050000  0.025000  0.250000
INTERNAL          1 (FREE)   -1
0.000000 0.025000
INTERNAL          1 (FREE)   -1
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
41.0 41.0 41.0 41.0 41.0 38.5 33.5 28.5 23.5 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0
INTERNAL          1 (FREE)   -1
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
20.0 20.0 20.0 20.0 20.0 17.5 12.5 7.5 2.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
CONSTANT 0.2
CONSTANT 0.2
INTERNAL          1 (FREE)   -1
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
-2 -2 -2 -2 -2 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
CONSTANT 0
```

E Input files example 5

Name file: swiex5.nam

```
GLOBAL 1 swiex5.glo
LIST 2 swiex5.lst
BAS6 3 swiex5.ba6
BCF6 11 swiex5.bc6
WEL 12 swiex5.wel
RCH 13 swiex5.rch
PCG 19 swiex5.pcg
SWI 23 swiex5.swi
OC 22 swiex5.oc
DIS 10 swiex5.dis
GHB 24 swiex5.ghb
DATA(BINARY) 30 swiex5.hds
DATA(BINARY) 51 swiex5.bgt
DATA(BINARY) 52 swiex5.zta
```

Discretization file: swiex5.dis

```
         1        21        21         1         0         0
 0
CONSTANT 50
CONSTANT 50
CONSTANT 0
CONSTANT -50
10000.000000 200 1.000000 SS
```

Basic package file: swiex5.ba6

```
FREE
CONSTANT 1
999.990000
CONSTANT 0.05
```

Output control file (using numeric codes): swiex5.oc
First line

```
0 0 30 0
```

The following two lines are repeated 200 times (ones for each time step)

```
0 1 1 1
0 0 1 0
```

Block-centered flow package file: swiex5.bc6

```
0 1.000000e+030 0 0.000000 0 0
 00
CONSTANT 1
CONSTANT 500
```

Well package file: swiex5.wel

```
         4        51
         4
         1         8         8        -20
         1         9         8        -20
         1         8         9        -20
         1         9         9        -20
```

Ghb package file: swiex5.wel

```
      216        20
      216
        1         1         1      0.05      1250
```

Repeated for a strip of 3 cells along entire boundary
Recharge package file: swiex5.rch

```
1 0
1
INTERNAL          1 (FREE)   -1
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
0.0 0.0 0.0 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.002 0.0 0.0 0.0
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0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

Preconditioned conjugate-gradient file: swiex5.pcg

```
50 25 1
0.000010 0.000010 1.000000 0 0.000000 3.000000 1.000000
```

Sea water intrusion package file: swiex5.swi

```
        2         1        52        20
  0.050000  0.050000  0.025000  0.250000
INTERNAL          1 (FREE)   -1
0.000000 0.012500 0.025000
INTERNAL          1 (FREE)   -1
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 -25.0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
INTERNAL          1 (FREE)   -1
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 0 0 0
0 0 0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 0 0 0
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0 0 0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 0 0 0
0 0 0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 0 0 0
0 0 0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 0 0 0
0 0 0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 -35.0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
CONSTANT 0.2
INTERNAL          1 (FREE)   -1
-3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3
-3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3
-3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -3 -3 -3
-3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3
-3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3
-3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3
```