

Misfortunes of zone scheme applied for storing hydrogeological data

A. Spalvins & R. Janbickis

Environment Modelling Centre, Riga Technical University, Latvia

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ABSTRACT: Misfortunes of the zone scheme unwisely applied by modelling programs for storing data of novel hydrogeological models (HM) are analysed. Methods for tuning zone converter modules are described, in order to help modellers to lessen side effects caused by this scheme.

1 INTRODUCTION

Various misfortunes happen due to the zone type memory saving scheme unwisely applied in such modern modelling HM programs, as Groundwater Vistas (GV) and Visual MODFLOW (VM) described in (Environment Simulations, 1997) and (Waterloo Hydrogeologic, 1998) manuals, accordingly.

Normally, about $10N$ records must be stored, to run HM, on a 3D approximation grid containing N nodes (Spalvins et al., 2000). There each grid node is described by nonidentical values of the following main parameters: the computed piezometric head φ ; the water permeability k of the soil; the thickness m of the stratum; the water pumping rate β and the other ones. Hence the typical value of N varies from 10^3 to 10^6 , the total size of the operational memory is considerable. However, this fact is irrelevant nowadays, and no memory saving schemes are currently important.

In the era of slow computers, any rational idea of memory saving was supported. The zone scheme is a survivor from this time. It is shown in this paper that, nowadays, the scheme has become a serious hindrance, and some effort must be spent to neutralize its side effects.

2 THE ZONE SCHEME AND ITS FAULTS

In former times, only simple HM were created (mostly for 2D areas only, data about k and m distributions were coarse). No computer-based tools were available for data interpolation and a modeller oneself represented the main force of creating HM. Under these conditions, the first modelling programmes originated, and the zone scheme was introduced. It was based on the following reasonable assumptions:

- rather small numbers $N_k, N_m \ll N$ of constants were needed to describe initial k and m distributions, because within large areas of the HM grid (zones), the k and m parameters were equal due to a crude staircase type approximation used;
- a modeller was able to specify manually the relationship between these zones, as geometrical images represented by polygons, and the corresponding constant values of k and m ; no special interpolation programmes were needed to solve such a simple task;
- a considerable memory saving was possible, because only a small list containing addresses of the HM grid nodes, corresponding with the zone constants of k and m , was stored.

Due to obvious advantages of the zone scheme, in the burdensome start of the computer era, the scheme was widely accepted and applied both by modellers and developers of the modelling programs. Moreover, the zones are uncritically used even by the novel GV and VM programs, in spite of the fact that none of the three above assumptions favoring the zone scheme is valid nowadays:

- the basic condition $N_k, N_m \ll N$ is not true for modern HM; moreover, high quality k and m distributions can be created beforehand by special interpolation tools where $N_k = N_m = N$;
- if N_k, N_m are large, a modeller cannot create manually veritable data maps; especially, when one deals with the computed k/m leakage distribution;
- there is no need to save a computer memory.

If a modern modelling program incorporates the zone scheme, the following problems are evident:

- the data prepared for HM by an external software (interpolation, calibration, etc.), or computed within the modelling program (for example, the leakance $m/k!$), may inadvertently get distorted, even ruined, due to bad tuning of the data converter module transforming information into the zone memory representation or backwards (see the section 3);
- according to the zone scheme, a modeller wholly participates in interpolating data for HM; and the risk of occurring numerous human caused, hardly detectable errors becomes high; this old fashioned role of the modeller contradicts the current trend to exclude a human from any routine performances which can be run reliably by rightly developed and aptly applied tools (Spalvins et al., 2000);
- the Windows system, used in the GV and VM programs for graphing zone polygons interactively on the computer screen, does not provide them as open data files applicable in the role of initial information for independent tools of interpolation; because of this mishap, any result based on the visual zone representation, in Windows, is like a work of art, which can never be repeated in all details, even by its author;
- as a coarse approximation, the zone scheme becomes awkward, if one tries to run it, as a numerical method; an enormous amount of data is needed to describe N_{k-1} or N_{m-1} tightly coordinated polygons, which must be used to interpolate jumplike changes of k and m parametres, accordingly, between neighboring zone areas of the HM grid;
- the zone forward and backward conversion processes are rather time consuming.

Because of the above listed faults, one should not use, at present, any zone-based technologies. They can be avoided, even in the GV and VM programmes, if the existing zone conversion modules are rightly tuned or the new ones developed.

3 ZONE CONVERSION

The zone converter transforms data into the numbers of zones and backwards, as follows:

$$s_j = s_0 + \Delta_0 j, \Delta_0 = (s_n - s_0) / (I + i_n - i_l), j = I + i_j - i_l, n = I + i_n - i_l, j = 1, 2, \dots, n \quad (1)$$

where s_0, s_j, s_n are start, current, and end values, respectively, of the interval (s_0, s_n) to be converted; $i_l, i_j,$ and i_n are start, current and end numers of n zones applied; Δ_0 is the interpolation increment; j is the current number used to compute s_j .

The relative error δ_j [%] of (1) is given by the ratio:

$$\delta_j = 10^2 \Delta_0 / s_j, \delta_{max} = 10^2 \Delta_0 / s_0, \delta_{min} = \delta_{max} s_0 / s_n \quad (2)$$

If the ratio $s_n / s_0 \gg n$ then the interval (s_0, s_n) should be covered by ν subintervals where different $\Delta_0^{(t)}$ ($t = 1, 2, \dots, \nu$) must be applied, in order to keep the error δ_{max} under control. Let us consider the following typical example of the leakance k/m data: $s_0 = 10^{-9}$; $s_n = 10$; $s_n / s_0 = 10^{10} \gg n = 10^4$. If one tries to code these data, in a single interval, then $\delta_{max} = 10^{12}$ %! It means that small values of s_j will be inevitably lost, during the zone conversion. In (Gosk et al, 1999), the error $\delta_{max} = 0.9$ % was insured by introducing $\nu = 10$ decade (1:10) subintervals, as shown in Table 1. For each subinterval 10^3 zones were used.

Table 1. Zone coding by applying decade subintervals.

t	1	2	3	4	5	6	7	8	9	10
i_l	1	1001	2001	3001	4001	5001	6001	7001	8001	9001
i_n	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
s_0	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1.0
Δ_0	$9 \cdot 10^{-12}$	$9 \cdot 10^{-11}$	$9 \cdot 10^{-10}$	$9 \cdot 10^{-9}$	$9 \cdot 10^{-8}$	$9 \cdot 10^{-7}$	$9 \cdot 10^{-6}$	$9 \cdot 10^{-5}$	$9 \cdot 10^{-4}$	$9 \cdot 10^{-3}$

The decade scheme is customary for a modeller who must manually enter Table 1 in a computer, in order to tune the zone converter module of the GV and TM programs. Other numerical systems, for example, the octal (1:8) and hexadecimal (1:16) ones may be useful if the converter is tuned automatically.

It is possible to improve considerably the result provided by Table 1, especially, when new automatized converters are to be developed. Within a decade, the current error δ_j evenly decreases from $\delta_{max} = 0.9\%$ to $\delta_{min} = 0.09\%$, and $q = \delta_{max} / \delta_{min} = 10.0$ (see Fig.1).

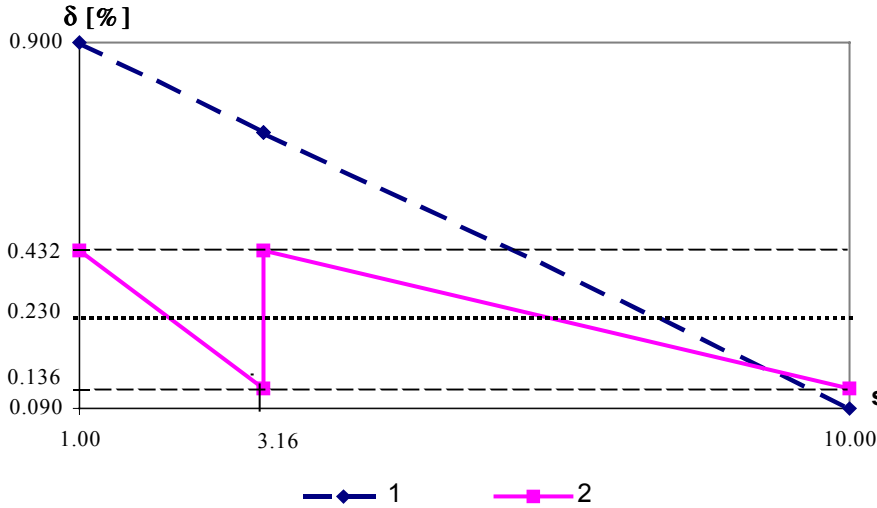


Figure 1. Graphs of the current relative error δ for the basic decade (1.00, 10.00); the graphs 1, 2 describe, correspondingly, the single decade and the one with two subintervals (1.00, 3.16), (3.16, 10.00). The notched graph of δ turns into the horizontal $\delta = 0.230$ when $v = n = 1000$ (see Table 2).

The ratio q can be reduced $10^{1/v}$ -fold if the decade (1.00, 10.00) is covered by v subintervals. Each subinterval includes n/v zones where n is the total number of zones applied for the interval. The tuning parameters for the converter are given by the following formulas:

$$\begin{aligned} q &= \delta_{max} / \delta_{min} = 10^{1/v}, \quad \delta_{max} = 10^2 (q - 1) v / n, \quad s_0^{(t)} = q^{t-1}, \\ \Delta_0^{(t)} &= s_0^{(t)} \delta_{max} 10^{-2}, \quad t = 1, 2, \dots, v \end{aligned} \quad (3)$$

where, $s_0^{(t)}$, $\Delta_0^{(t)}$ are the start and increment values, accordingly, of the t -th subinterval. The graphs of δ contains v notches enveloped by the horizontals δ_{max} and δ_{min} . The graphs for $v = 1, 2$ are shown in Fig.1. Numerical parameters, given by (2) when $n = 10^3$ are included, in Tables 2 and 3.

Table 2. Parametres for the first subinterval ($t = 1$) of the decade (1.00, 10.00) coded by $n = 10^3$ zones in v subintervals.

v	1	2	3	4	10	20	100	1000
$q = s_0^{(2)}$	10.000	3.162	2.154	1.778	1.259	1.122	1.023	1.002
$\delta_{max} \%$	0.900	0.432	0.346	0.311	0.259	0.244	0.233	0.230
$\Delta_0^{(1)} * 10^3$	9.000	1.365	0.745	0.553	0.326	0.274	0.238	0.230

Table 3. Tuning parametres for the decade (1.00, 10.00) covered by $n = 10^3$ zones if $v = 10$.

t	1	2	3	4	5	6	7	8	9	10	11
$s_0^{(t)}$	1.000	1.259	1.585	1.995	2.512	3.162	3.981	5.012	6.309	7.943	10.000
$\Delta_0^{(t)} * 10^3$	0.259	0.326	0.410	0.517	0.650	0.819	1.031	1.298	1.634	2.057	—

It follows from Tables 2 and 3 that the method based on (3) considerably reduces the parameter q and the error δ_{max} , as well. The variant ($v = 10; n = 10^3$) of Table 3 seems to be optimal, because its main characteristics ($q = 1.259 > 1.002$, $\delta_{max} = 0.259 > 0.230$) are only slightly lower than the ones of the ultimate case ($n = v = 10^3$). It follows from the above theoretical considerations that it is possible to introduce effective methods of tuning the zone converter module and to eliminate possible errors caused by the zone scheme.

4 CONCLUSIONS

The zone scheme was introduced for building HM in the beginning of the computer era. Nowadays, none of motives supporting the scheme is valid. For this reason, the zone scheme has become a burdensome hindrance on the way of modern computer technologies applied for the HM. It is possible to reduce its bad influence, if the module, responsible for converting data into the zone representation and backwards, is rightly tuned. Effective conversion algorithms are found which can be also applied for developing automatized zone converter programs.

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Aivars Spalvins, Dr.sc.ing.

Romans Janbickis, M.sc.ing.

Riga Technical University, Environment Modelling Centre

Address: 1/4 Meza Str., Riga, LV-1048, Latvia

Phone: +371 7089518; E-mail: emc@egle.cs.rtu.lv

Spalviņš A., Janbickis R. Zonu shēmas trūkumi hidroģeoloģisko datu glabāšanai.

Analizēti trūkumi, kuri piemīt zonu shēmai. Tā neapdomīgi tiek izmantota datu glabāšanai modernās programmās, kuras lieto hidroģeoloģiskajiem modeļiem (HM). Apskatītas metodes zonu konvertera moduļa noskaņošanai, kuras ļauj modelētājam vājināt šīs shēmas radītās nevēlamās blakus parādības.

Спалвинь А., Янбический Р. Недостатки зонной схемы применяемой для хранения гидрогеологических данных.

Проанализированы недостатки зонной схемы, которая неосторожно применяется для хранения данных в некоторых моделирующих программах предназначенных для гидрогеологических моделей (ГМ). Рассмотрены методы настройки модуля конвертера зон. Они помогают моделировщику уменьшить нежелательные побочные явления, которые порождаются этой схемой.