TEST OF A RECHARGE MODEL IN AN ARID VADOSE ZONE USING LONG TERM LYSIMETER DATA

By

Abundio Osuna Vizcarra
Department of Earth and Environmental Science
New Mexico Institute of Mining and Technology

June 1995

Submitted in partial fulfillment of the requirements for
the degree of Master of Science in Hydrology

Table of Contents

Acknowledgements

I would like to acknowledge the Waste Management Education Research Consortium (WERC) of New Mexico for funding my education at New Mexico Institute of Mining and Technology.

The Facultad de Ingeniería of the Universidad Autónoma de Chihuahua provided me with the opportunity to attend New Mexico Tech, and for that I express my thanks.

I appreciate much the support of the Tinker Foundation that nurtured the initial contacts between the Facultad de Ingenieria and Dr. Jan Hendrickx of the Hydrology Program of New Mexico Tech.

I would like to thank my advisor, Dr. Jan Hendrickx for his continued support throughout the course of my studies and my research.

I wish to thank Jos van Dam of the Department of Water Management, Agricultural University, Wageningen, The Netherlands for his important comments and Dr. Reinder Feddes for providing the latest version of the model SWAP for this study.

Finally, I dedicate this work to my wife Ana Maria and my sons Jose Pablo and Luis Andres for their support and understanding throughout my studies at Tech.

List of Figures

List of Tables

Abstract

The general objective of this study is to investigate whether recharge fluxes measured at depth 6 m in a bare lysimeter during the period 1983-1994 can be determined correctly with a model (SWAP) that does not include thermal vapor fluxes. The lysimeter is located near Las Cruces at the Jornada Research Facility on the New Mexico State University College Ranch, 40 km northeast of Las Cruces NM. The climate is semiarid with an average annual precipitation of 230 mm, occurring mainly during July through September. The annual potential evapotranspiration is 2390 mm. The lysimeter was constructed using a 2.44 m diameter highway culvert, 6 m deep, and was filled with Berino loamy fine sand in layers approximately 13 cm thick. SWAP is a transient one-dimensional isothermal finite-difference model that simulates the liquid phase of water and solute transport in the vadose zone for a wide range of initial and boundary conditions. The calibrated model accurately simulated the recharge measured in the lysimeter suggesting that temperature effects and vapor movement need not be taken into account for the evaluation of long term recharge fluxes through deep vadose zones.

Introduction

In arid and semi-arid regions, the evaluation of natural recharge often is required for management purposes. Recharge is particularly important in determining the safe yield from wells in a groundwater basin or for the design of waste disposal facilities. Because potential evapotranspiration exceeds precipitation most of the time, natural recharge is considered to be low in arid and semi-arid climates.

For more than three hundreds years lysimeters have been the only hydrological tool for direct measurements of groundwater recharge (Kohnke et al., 1940). In 1688, Philippe De la Hire in Paris installed leaden lysimeters which were filled with sandy loam to determine the relation between precipitation and the origin of springs. In this time and for almost two centuries later it was not commonly accepted by the scientific community that springs do originate from groundwater replenished by recharge.

Presently many practitioners frequently assume that diffuse recharge by precipitation through desert soils is negligible and, therefore, consider those deep dry unsaturated soils attractive for disposal of hazardous and radioactive waste (Mercer et al. 1983). Only through direct recharge measurements in lysimeters at Las Cruces site in the Chihuahuan desert and at the Hanford site in the Columbia Basin has it recently been confirmed that recharge in desert soils does indeed occur (Gee et al., 1994) so that deserts -after all- may not be such an ideal location for waste isolation. They conclude that water storage increases with time when soils are coarse-textured and plants are removed from the surface. Also, the lysimeters from Las Cruces and Hanford indicate that deep drainage (recharge) from bare, sandy soils can range from 10% to over 50% of the annual precipitation. However, no recharge occurred when the surface soils are silt loam. It was also found that under many conditions desert vegetation strongly reduces or even eliminates recharge (gee et al, 1994). Although these lysimeter investigations yielded valuable data for the understanding of the recharge mechanism in desert soils, they do not allow straightforward extrapolation from the lysimeter sites to their surrounding areas or from the monitored years to future or past times. Such extrapolations seem only feasible with the application of calibrated computer models that simulate water movement through dry unsaturated desert soils. Unfortunately, it is not so easy to calibrate a computer model for the accurate determination of recharge rates since the recharge is often only a very small percentage of the total amount of water stored in the profile.

Gee and Hillel (1988) state that quantification of recharge using lysimetry under a given set of soil, plant, and climate conditions for a specific site can provide a basis for calibration for recharge prediction. They also mentioned that small recharge rates are difficult to estimate based on water balance methods or using Darcian flux calculations based on tension gradients and estimated hydraulic conductivity. Stephens et al. (1986) studied the amount of recharge by direct infiltration of precipitation in a desert area near Socorro, New Mexico. The study area was instrumented with tensiometers and a neutron probe access tube to study soil water movement. Recharge was calculated from Darcy's equation and calculated as being equal to the unsaturated hydraulic conductivity corresponding to in situ water content. Both approaches indicate that the annual recharge rate may be about 20% of mean annual precipitation during the period of record used.

Another difficulty is to determine the exact actual evaporation rates from bare soils and actual transpiration rates from desert vegetation. Small errors in these rates mean large errors in the recharge rate. For example, an error of 5% or 10 mm in the annual actual evaporation rate from bare soil could result in an error of 50% in the annual recharge rate. Because we deal in this study with a non-vegetated lysimeter, we will only discuss evaporation from bare soils. The principles of water movement in dry soils caused by thermal and matric potential gradients have been extensively studied by the De Vries (1958), Philip and De Vries (1957), Milly (1982) and other investigators. As a result of these studies it is generally recognized that isothermal and thermal vapor fluxes tremendously affect the soil water status of the top centimeters of a bare soil surface and need to be taken into account during the evaluation of water balances of dry surfaces under arid conditions (e.g., Campbell, 198; Hanks and Ashcroft, 1986). However, there is also evidence that although the thermal vapor fluxes in general are at least one order of magnitude larger than the isothermal ones, frequently thermal fluxes can be neglected when the objective is to evaluate mean daily or annual vapor fluxes. The reason is the periodic nature of the diurnal and annual thermal vapor flux. On a daily basis it is moving downward during the day and upward during the night so that the net daily thermal vapor flux may become negligible (e.g. Milly 1984a). Milly (1984b) demonstrated with his classic simulation analysis of thermal effects on daily evaporation from two soils (a sand and a silt loam) in two contrasting climatic regions (a cool, moist and a hot, arid one) that thermal effects influencing vapor and liquid flow cancel each other out. He found that during a simulated month of evaporation from bare soil under four soil-climate pairs, the neglect of thermal effects caused an error in monthly calculated evaporation of only 1% of the total. On an annual basis the thermal fluxes at greater depth tends to move downward during summer and upward during winter. Scanlon (1994) measured in the Chihuahuan desert that downward summer temperature gradients opposed upward water potential gradients and thus are an indication of a downward driving force for thermal vapor flow during the summer. Numerical analysis of her measurements with Milly's model yielded downward values for the thermal fluxes during summer that slightly exceeded the upward values calculated during winter. The net mean annul downward vapor fluxes were calculated as 1.5 an 0.17 mm/year at depths of 0.5 and 5.0 m (Scanlon and Milly, 1994). Thus, the theoretical studies of Milly (1984a,b) and the analysis of the experimental data from a site in the Chihuahuan desert by Scanlon and Milly (1994) present strong evidence that daily and annual thermal effects can be ignored when the objective is to determine mean actual evaporation rates from bare desert soils.

On the other hand, the result presented by Scanlon and Milly (1994) indicates that the upward isothermal flux needs to be taken into account for the correct prediction of bare soil evaporation in the Chihuahuan desert. The annual evaporation of 162 mm at their site during the period October 1, 1989 to September 30, 1990 was largely caused by mean annual isothermal vapor fluxes of 128, 86, 35, and 16 mm at depths of 1.25, 7.5, 25, and 55 mm respectively. Similar observations have been made by other investigators. Feddes and Bastiaanssen (1992) showed that at low water contents the isothermal vapor diffusivity can contribute significantly to the evaporative flux. Fayer and Gee (1992) simulated recharge from a non-vegetated lysimeter filled with sand in a semi-arid environment during a period of one year using an updated version of the UNSAT-H computer program with and without a subroutine to predict the effects of isothermal vapor flow. The predicted recharge was 36 to 56% higher than the measured one without taking isothermal vapor flow into account, but improved to within 9% after inclusion of the vapor transport. In addition, they found that the model results were less sensitive to variations in the water retention and hydraulic conductivity functions when vapor was included. However, it appears that inclusion of isothermal vapor transport does not by itself increase the robustness of a model since Scanlon and Milly (1994) observed that one of the greatest sources of uncertainty in their simulations of water fluxes in desert soils is the hydraulic conductivity function. Connell et al. (1993) also used a model that included isothermal vapor transport and found that vapor flow contributed little to their model estimates of bare surface evaporation. However, they hypothesize that the minimal contribution of vapor flow may have been caused by the low accuracy of their hydraulic properties at low water contents. This indicates that changing the shape of the hydraulic conductivity curve for liquid flow may take care of the vapor flow. Such adaptation of the hydraulic conductivity could occur during the process of parameter optimization under dry soil conditions.

The studies reported in the literature strongly suggest that it is possible to simulate groundwater recharge from bare soils with a relatively simple one-dimensional isothermal model for unsaturated flow without taking into account thermal vapor fluxes. Therefore, the main study objective is to investigate whether the recharge measured in a bare lysimeter during the period 1983-1994 can be determined correctly with a model that does not include thermal vapor fluxes. In addition we want to discuss our experiences with a long-term lysimeter study and formulate recommendations for the continuation of the study and for new lysimeter studies elsewhere.

Methods

Study Area and Climate

The study area is located near Las Cruces at the Jornada Research Facility on the New Mexico State University College Ranch, 40 km northeast of Las Cruces NM. The climate is semiarid with an average annual precipitation of 230 mm, occurring mainly during July through September. The annual potential evapotranspiration is 2390 mm. The maximum and minimum average daily air temperatures are 36 and 13 °C. A weather station installed near the lysimeter provides data on wind speed, solar radiation, relative humidity, air temperature, and precipitation. data has been continuously collected at this station since 1983. The site is dominated by sediments derived from alluvial and fluvial processes (Gee et al., 1994). The surface soil is coarse textured and consist of fine-loamy, thermic Typic Haplargids (Wierenga et al., 1989).

The Las Cruces Lysimeter

The lysimeter was constructed using a 2.44 m diameter highway culvert, 6 m deep, and was filled with Berino loamy fine sand in layers approximately 13 cm thick (Fig. 1). The lysimeter was filled during the period from September 1982 to May 1983. The mass and water content were measured for each layer, yielding an average bulk density of 1.67 Mg/m^3. The soil surface was kept bare (vegetation free).

Two neutron probe access tubes were installed 0.8 m apart to a depth of 5.70 m to measure the water content. Tensiometers were installed in the wall of the lysimeter at approximately 60 cm intervals, from a depth 30 cm to 540 cm (Gee et al., 1994). The lysimeter was initially closed at the bottom, then was opened in July 1989 to measure recharge fluxes.

At the bottom of the lysimeter collection bottles were installed at six ports for measuring possible recharge. In July 1989 a vacuum was applied at the base of the lysimeter through suction candles equivalent to approximately -0.020 Mpa (200 cm) water. The volume of water collected in each bottle was measured using an electronic balance. In the spring of 1991 a failure of the pump temporarily decreased recharge, on May of the same year a new pump was installed. Near unit gradient conditions have been observed in the lysimeter for the last several years. Tensiometers values (except for the 30 cm depth) ranged from -0.0060 Mpa (60 cm suction) to -0.0200 Mpa (200 cm suction) over the entire depth of the lysimeter (Gee et al., 1994).

Determination of Hydraulic Soil Properties

The initial input of the van Genuchten parameters were taken from work done by Eric van Zanten (graduate student, personal communication, 1994). Several tests were performed by van Zanten to investigate layering in the soil profile. He concluded that the soil profile in the lysimeter is composed of three layers. The thickness for the first, second and third layer are 100, 310 and 290 cm respectively. He established also the retention characteristics by using plots of moisture and tension data at the same depth and at the same time, and used the computer program RETC to determine the initial soil parameters values used in this calibration. He also used two samples taken from the lysimeter to determine the saturated hydraulic conductivity by using the constant head method.

Model SWAP

SWAP is a transient one-dimensional isothermal finite-difference model that simulates the liquid phase of water flow and solute transport in the vadose zone for wide range of initial and boundary conditions (Belmans, et al., 1983; Feddes et al., 1988; Wesseling et al., 1993). It solves a slightly modified Richards′equation:

$$\frac{\partial h}{\partial t} = \frac{1}{C(h)}\frac{\partial}{\partial z}[K(h)(\frac{\partial h}{\partial z}+1)]-\frac{S(h)}{C(h)} \qquad \textbf{(1)}$$

where h is the soil water pressure head [L], t is the time [T], z is the vertical coordinate with origin at soil surface and positive upwards [L], C = dθ/dh is the differential soil-water capacity [L^{-1}], θ is the volumetric soil water content [L^3L^{-3}], K(h) is the hydraulic conductivity [LT^{-1}], and S(h) is the root extraction rate [T^{-1}]. For the discretization and solution scheme of the equation the approach of Celia et al. (1990) is used in order to reduce the water balance error due to non-linearity of the capacity term. The moisture transport is solved using an implicit finite difference scheme (e.g. Belmans et al.,1983).

The time step is taken as variable and is estimated as

$$\Delta hmax\ (t) = habs + |hrel| \qquad \textbf{(2)}$$

where hmax(t) is the maximum allowable change in pressure head in a time step, habs is the absolute tolerance in pressure head in a time step, and hrel is the relative tolerance. The limits for the maximum and minimum time step are user defined, the advised values are 0.2 day and 1.0E-08 day respectively.

Hysteresis of the water retention curve is take into account with the concept developed by Kool and Parker (1987). In this study on a bare lysimeter no vegetation is present so that S(h) equals zero.

A number of different initial, top, and bottom boundary conditions can be employed by the model. The initial condition can be either pressure head or volumetric water contents at each nodal point. The top boundary condition is calculated as the flux through the soil surface:

$$q = E - P \tag{3}$$

where q is the flux [LT^{-1}], E is the actual soil evaporation [L] and P is the precipitation depth. The model offers to calculate the potential evapotranspiration rate using the methods of Penman, Makkink, Monteith-Rijtema, or Priestly-Taylor. We used the latter for our simulation with the following daily input data measured at the weather station: precipitation [L], global radiation flux [WL^{-2}], mean daily temperature [°C], and mean daily air humidity. The potential evaporation according to Priestly-Taylor is calculated as

$$PE = 0.64 R_{net} \alpha \left[\frac{\nabla}{\nabla + \gamma}\right] \tag{4}$$

where R_{net} is the incoming radiation flux [WL^{-2}], α is an empirical constant (1.35), ∇ is the slope of the saturation curve at mean daily air temperature, and γ is the psychometric constant.

The actual soil evaporation rate in the model can be determined from the potential soil evaporation rate by the empirical methods of Black et al. (1969) and Boesten & Stroosnijder (1986) or by direct calculations from potential soil evaporation rate and top soil unsaturated hydraulic conductivity. The empirical methods have been developed for moderate climates and appear less attractive for arid conditions. They not only require experimentally determined soil parameters, but also tend to underpredict actual soil evaporation.

The actual soil evaporation is calculated as the upward flux controlled by the atmospheric demand and by the ability of the soil transport water toward the soil surface, i.e., the hydraulic conductivity of the top soil. During evaporation, the pressure head at the soil surface , $h_{surface}$, is assumed to be in equilibrium with the surrounding atmosphere, so that

$$h_{surface} = \frac{RT}{MG}\ln(r) \tag{5}$$

where R is the universal gas constant [$JM^{-1}K^{-1}$], T is the absolute temperature [^0K], M is the molecular mass of water [M], G is the acceleration gravity [LT^{-2}], and r is the mean relative air humidity [-]. The unsaturated hydraulic conductivity of the top layer of the soil is determined as the geometrical mean of K(h) at the soil surface and at node 1:

$$K_{geom} = \frac{[K(h_{surface})-K(h_{node1})]}{2} \qquad \textbf{(6)}$$

The actual soil evaporation is calculated directly with Darcy's law

$$E = K_{geom}[\frac{(h_{surface}-h_{node1})}{z}-1] \qquad \textbf{(7)}$$

where z is the distance between the soil surface and the depth of nodal point 1. A limiting condition on the actual calculated soil evaporation is that it is not allowed to exceed the potential soil evaporation calculated with the Priestly-Taylor method.

When precipitation exceeds evaporation, infiltration takes place. The infiltration rate is calculated as the flux into the first compartment assuming a pressure head of zero at the soil surface, regardless of the thickness of ponding.

Results and Discussion

Calibration

Calibration of a model refers to a demonstration that the model is capable of producing field-measured drainage which is the calibration value. Calibration is accomplished by finding a set of hydraulic parameters and boundary conditions that produce simulated fluxes that match field-measured values within a prescribed range of error. Frequently, models are calibrated by minimization of the difference between measured and simulated water content or tension (Boers, 1994). The model was calibrated over the period of September 1989 to December 1994 by trial and error until the calculated drainage matched the measured recharge in the lysimeter.

In this study we use the direct measured deep percolation (drainage) as the observed value to calibrate. The approach of Boers (1994) can not be used because the measured annual recharge often is less than 2 or 3% of the total amount of water stored in the lysimeter so that small errors in the water content caused by the measurement technique itself would cause large errors in the calculated recharge.

The initial conditions were described by the moisture content of each nodal point. Where a nodal point does not coincide with a measuring station, a linearly interpolated value between two adjacent stations was used. The total length of the lysimeter is 6.0 m and the deepest moisture content measurement is at 5.40 m. Moisture contents between 5.40 and 6.00 m are therefore completely unknown. As a best guess moisture contents in gravitational equilibrium with the 5.40 m measurement were taken as initial input. As a bottom boundary condition daily pressure heads were used (Fig. 2).

Potential evapotranspiration and potential evaporation were calculated according to Priestley and Taylor. This method calculates potential evaporation using net incoming radiation and slope value of the saturation vapor pressure curve at air temperature. Values of the variables used in the Priestley and Taylor method were all collected from the weather station located on the study area. For calculation of the actual evaporation, the option of reduction of potential soil evaporation was chosen. The actual soil evaporation was calculated for the model by using the Ritchie (1972) approach.

The final soil hydraulic properties obtained during the calibration process are summarized in Table 1. The saturated hydraulic conductivity of the first, second, and third layer were found to be 10.0, 115, and 5.0 cm/day. The results of the calibration are presented in Table 2. The total recharge measured in the lysimeter is 290 mm and the calculated for the models is 291 mm. Figure 3 shows the measured and calculated recharge during the period of simulation. Figures 4a, 4b, 4c, 4d, 4e, and 4f shows the measured and calculated water content for 1989, 1990, 1991, 1992, 1993, and 1994 respectively. In Table 3 are presented the measured and the calculated water storage in the soil profile.

Free Drainage. Free drainage seems to be the most appropriate boundary condition to describe the recharge from lysimeters. However, using this bottom boundary condition in the simulations rendered a poor fit with the measured data during dry years. Only during wet years simulated and measured data show a good correspondence. Figure 5 shows the results of the simulation using free drainage as a bottom boundary condition. The figure shows a poor fit for the years 1989, 1990, 1993, and 1994 which received little precipitation and a good fit for 1991 and 1992, years with relatively high rainfall.

Sensitivity Analysis

The purpose of a sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of the unsaturated zone parameters and boundary conditions. The final condition for a good calibration parameter is that it is sensitive for a change in the parameters that are optimized to realize the calibration. In this study these parameters are the soil physical parameters and the thickness of compartments.

Thickness of compartments. A sensitivity analysis was also performed to the thickness of compartments. Figure 6 shows the sensitivity analysis of the top compartment. The thickness of the top and bottom compartments used in calibration are 1.0 cm and 2.0 cm respectively. Note from equation (7) that the actual evaporation not only depends on the soil water pressure heads at the surface and at the first nodal point, but also on the thickness of the first soil compartment. The sensitivity analysis show higher actual soil evaporation using 2.0 cm than using 0.5 and 0.1 cm. The results of 0.5 and 0.1 cm were close to the results of simulation with 1.0 cm. From this result we also can conclude that a top compartment of 1 cm will yield accurate recharge and actual soil evaporation predictions without causing numerical instabilities during infiltration of heavy rainfall. Figure 7 present the result of the sensitivity analysis of the bottom compartment. From this result we can see clearly that this compartment is not so important in estimating recharge if the bottom boundary condition is pressure head. The model was also tested by using an homogeneous thickness of compartment of 1.0 cm without getting any improvement in our calculation. The compartments thickness used during the calibration are presented in the example of input file of SWAP presented in Appendix A.

van Genuchten Parameters. A variation of ±25% of the calibrated parameter was used during the sensitivity analysis of the van Genuchten parameters, except for the sensitivity of *n*. We use *n* (+25%) and *n*=1.02 which is the minimum value that can be found in soils. We did not a sensitivity analysis for θ_r because this parameter was set equal to zero during the simulation.

Figures 8, 9, and 10 shown the sensitivity analysis of K_{sat} for the first, second and third layer respectively. Except in the first layer, as K_{sat} increases the recharge calculated by the model also increases and as K_{sat} decrease also the recharge calculated by the model decreases. In the result of the sensitivity analysis of the first layer we can observe that exist a small difference with the calculated by the model. The changes observed are due mainly by the influence of the calculation of the actual soil evaporation and changes in the water content in the profile. Table 4 present the actual soil evaporation obtained during the calibration and during the sensitivity analysis of K_{sat}. The difference in the actual soil evaporation of the first layer with respect to the obtained in the calibration is because the hydraulic conductivity of the first layer play an important role in the computation of the actual soil evaporation.

The results of the sensitivity analysis of θ_{sat} are presented in Figures 11, 12, and 13 for the first, second, and third layer respectively. From these results we can observe that this parameter is very sensitive especially in the second and third layer.

The sensitivity analysis of α indicate that when this parameter increases the recharge calculated by the model also increases, observing more discrepancy with the recharge calculated in the first layer and less discrepancy in the second layer. The third layer present more difference the first two years of simulation. These results for the first, second, and third layer are presented in figures 14, 15, and 6 respectively.

The most sensitive parameter found during the sensitivity analysis was n, especially when we use the minimum value of this parameter ($n = 1.02$). The figures 17, 18, and 19 are the results for the first, second, and third layers respectively. From these results we can see that the results are totally out of the reality.

The parameter least sensitive in our model is l. From the results of the second layer (Fig. 21) and third layer (Fig. 22) we can observe that exist an small difference in recharge with the calculated by the model in the calibration. The Figure 20 show the results of the sensitivity analysis of the first layer. From this result we can see that exist more discrepancy on the recharge comparing with the second and third layer. The main reason for that is because the hydraulic conductivity curve depends on this parameter and as we discussed before the hydraulic conductivity of the first layer it is important in the computation of the actual soil evaporation.

Conclusion

The results of this study demonstrate that a simple one-dimensional model such as SWAP, that does not take into account temperature effects can correctly simulate the recharge measured in a lysimeter during the period 1983-1994. The measurement obtained from the lysimeter show that natural recharge in arid region can occur with an annual precipitation of 200 mm and 3000 mm annual potential evapotranspiration.

Due that after construction of the lysimeter is not recommendable to take samples to measure some hydraulic soil properties (e.g. hydraulic conductivity and water retention curves), we recommend to regularly measure soil water content and soil water tension and to increase measurement frequency after events of heavy rainfall in order to estimate these properties indirectly.

Given the importance of groundwater in arid zones the determination of recharge plays a fundamental role to establish sustainable substraction rates and risk analysis of contamination through recharge from polluted areas. Models could form a valuable tool in these analysis, if they are well calibrated. The direct measurements of recharge from lysimeters is indispensable for a satisfactory calibration. For this reason we strongly recommend to continue measurement of drainage in the lysimeter.

To obtain an accurate prediction of recharge, a variation of K_{sat} of the first and the third layer were needed during the calibration process. From this we can conclude that the boundary conditions are very important and that direct measurement of K_{sat} are needed. To describe better the boundary conditions more research is needed on others factors determining those boundary condition, such as the influence of vapor transport in the surface layer, the actual soil evaporation, and the correct description of the bottom boundary conditions. From the sensitivity analysis of the van Genuchten parameters we can conclude that the least sensitive parameter is l, and the most sensitive parameter is n.

References

Belmans, C., Wesseling, J.G. and Feddes, R.A., 1983. Simulation model of the water balance of a cropped soil: SWATRE. *J. Hydrol., 63:271-286.*

Boers, Th.M. 1994. Rainwater harvesting in arid and semi-arid zone. Ph.D. dissertation. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. Misc Report.

Campbell, G.S. 1985. Soil physics with basic. Transport models for soil-plant systems. Elsevier, New york, U.S.A. pp. 150.

Celia, M.A., E.T. Bouloutas, and R. L. Zarba. 1990. A general mass conservative solution for the unsaturated flow equation. *Water Resour. Res. 26:1483-1496.*

Connell, L.D., P.R. Bell, and R. Haverkamp. 1993. Modeling moisture movement in revegetating waste heaps. 2. Application to oil shale wastes. *Water Resour. Res. 29:1445-1455.*

De Vries, D.A. 1958. Simultaneous transfer of heat and moisture in porous media: Eos Trans. AGU 39:909-916.

Feddes, R.A., and W.G.M. Bastiaanssen. 1992. Forecasting soil-water-plant-atmosphere interactions in arid regions. In: H.J.W. Verplancke et al. (eds), Water Saving Techniques for Plant Growth. pp. 57-78.

Feddes, R. A., P.Kabat, P.J.T. Van Bakel, J.J.B. Bronswijk, and J. Halbertsma. 1988. Modelling soil water dynamics in the unsaturated zone - state of art. *J. Hydrol. 100:69-111.*

Gee, G. W., and D. Hillel. 1988. Groundwater recharge in arid regions: review and critique of estimation methods. *Hydrological processes 2:255-266.*

Gee, G.W., P.J. Wierenga, B.J. Andraski, M.H. Young, M.J. Fayer, and M.L. Rockhold. 1994. Variations in water balance and recharge at three western desert sites. *Soil Science Society of American Journal 58:63-72.*

Hanks, R.J. and G.L. Ashcroft. 1986. Applied soil physics. Advanced Series in Agricultural Sciences 8. Springer-Verlag, New York, U.S.A. pp. 159.

Hendrickx, Jan M.H., P. Hollanders, and P. J. Wierenga. 1993. Groundwater recharge through a bare sand soil in the Chihuahuan Desert. Submitted for publication by the Binational Water Policy Institute, El Paso Tx.

Hills, R.G., D.B. Hudson, I. Poroo, and P.J. Wierenga. 1989. Modeling one-dimensional infiltration into very dry soils, 2, estimation of the soil water parameters and model predictions. *Water Resour. Res., 25(6), 1271-1282..*

Kohnke, H., F.R. Dreibelbis, and J.M. Davidson. 1940. A survey and discussion of lysimeters and a bibliography on their construction and performance. USDA Misc. Publ. No. 374, Washington DC. May. pp. 68.

Kool, J.B., and J.C. Parker. 1987. Development and evaluation of closed form expressions for hysteretic soil hydraulic properties. *Water Resour. Res. 23:105-114.*

Mercer, J.W., Rao, P.S.C., and Marine, I.W. (Eds.). 1983. Role of unsaturated zone in radioactive and hazardous waste disposal. Ann Arbor Science, Ann Arbor, Michigan, USA>

Milly, P.C.D. 1982. Moisture and heat transport in hysteretic, inhomogeneous porous media: a matric head-based formulation and a numerical model. *Water Resour. Res. 18:489-498.*

Milly, P.C.D. 1984a. A linear analysis of thermal effects on evaporation from soil. *Water Resour. Res. 20:1075-1085.*

Milly, P.C.D. 1984b. A simulation analysis of thermal effects on evaporation from soil. *Water Resour. Res. 20:1087-1098.*

Nixon, P.R., and G. P. Lawless. 1960. Translocation of moisture with time in unsaturated soil profiles. *J. Geophys. Res., 65(2), 655-661.*

Philip, J.R. and D.A. De Vries. 1957. Moisture movement in porous materials under temperature gradients. Eos Trans. AGU 38:222-232.

Scanlon, B.R. 1994. Water and heat fluxes in desert soils. 1. Field studies. *Water Resour. Res. 30:709-719.*

Scanlon, B.R. and P.C.D. Milly. 1994. Water and heat fluxes in desert soils.2 . Numerical simulations. Water Resour. Res. 30:721-733.

Stephens, D.B., and R.G. Knowlton, Jr., 1986. Soil water movement and recharge through sand at a semiarid site in New Mexico. *Water Resour. Res., 22:881-889.*

Sophocleous, M.A. and Perry, C.A., 1985. Experimental studies in natural groundwater-recharge dynamics: the analysis of observed recharge events. *J. Hydrol., 81:297-332.*

Wesseling, J.G., J.A. Elbers, P. Kabat, and B.J. Van de Broek. 1993. SWAP93. Instructions for input. Winand Staring Centre, Wageningen, The Netherlands.

Wierenga, P.J., A.F. Toorman, D.B. Hudson, J. Vinson, M. Nash, and R.G. Hills. 1989. Soil physical properties at the Las Cruces Trench Site. NUREG/CR-5441. U.S. Nuclear Regulatory Commission. Washington D.C.

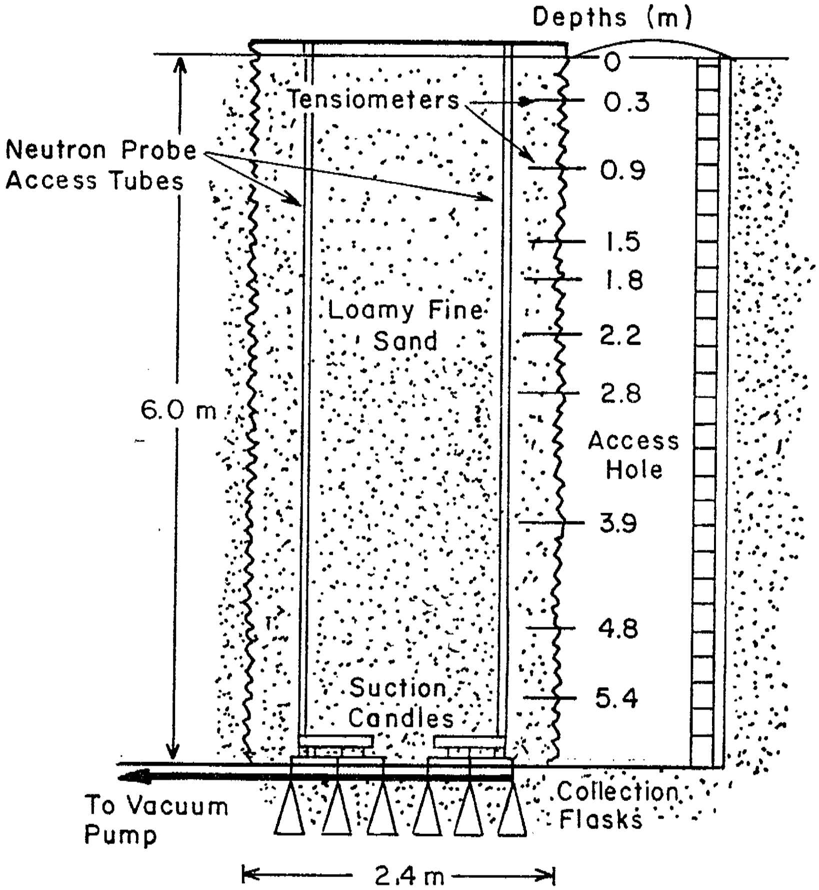

Figure 1.- Las Cruces Lysimeter

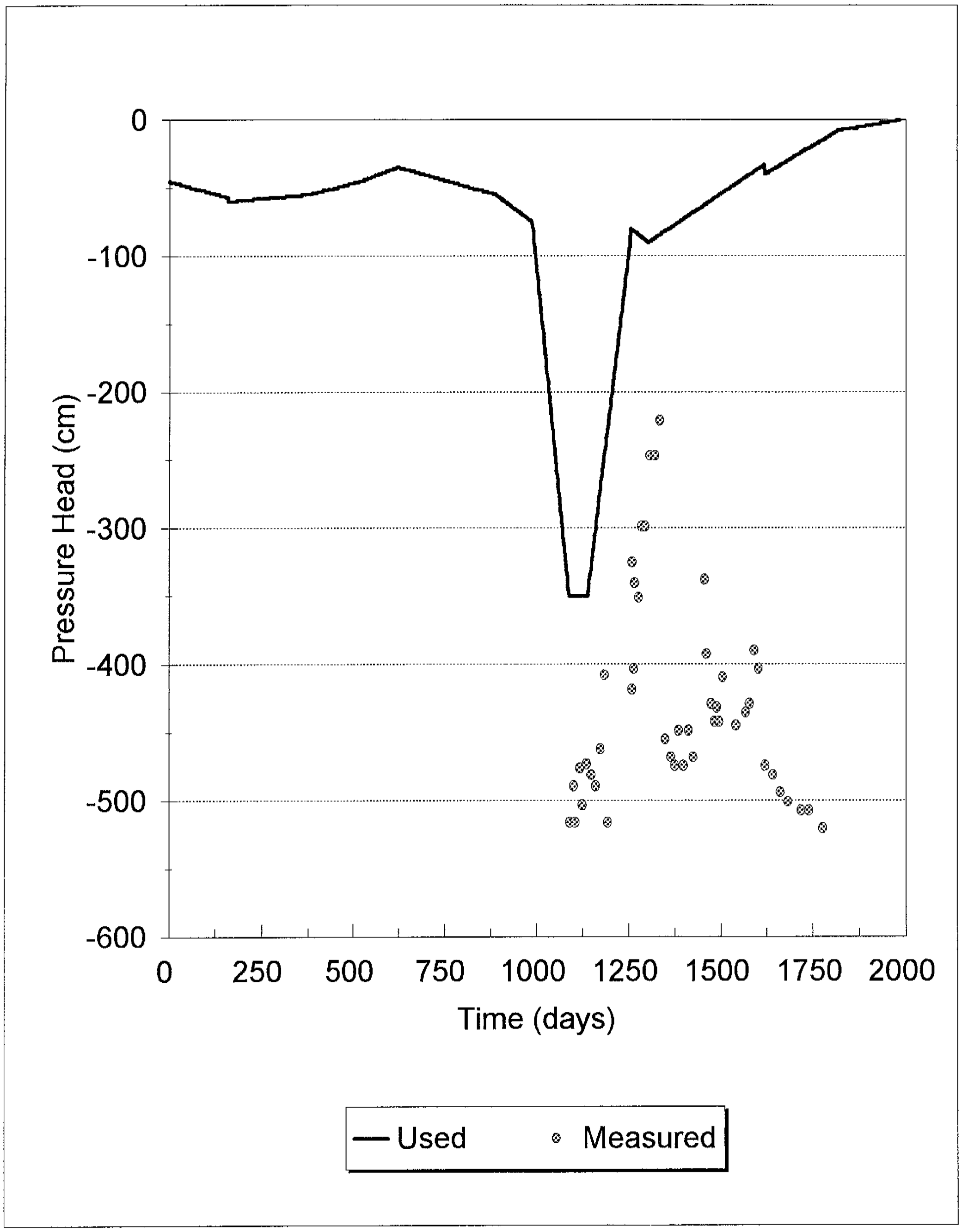

Figure 2.- Pressure Head Measured and Used During Calibration.

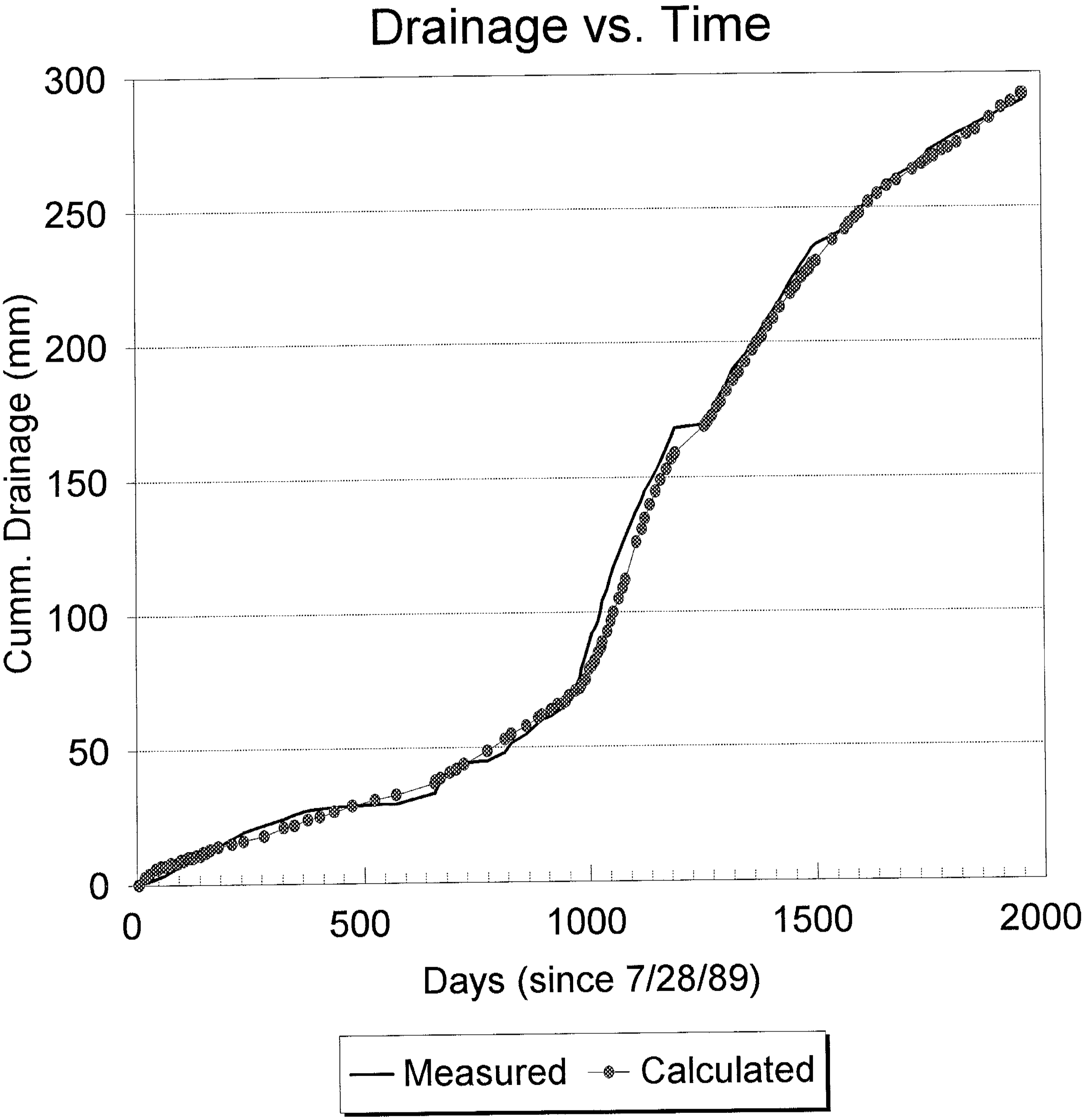

Figure 3.- Measured and Calculated Recharge.

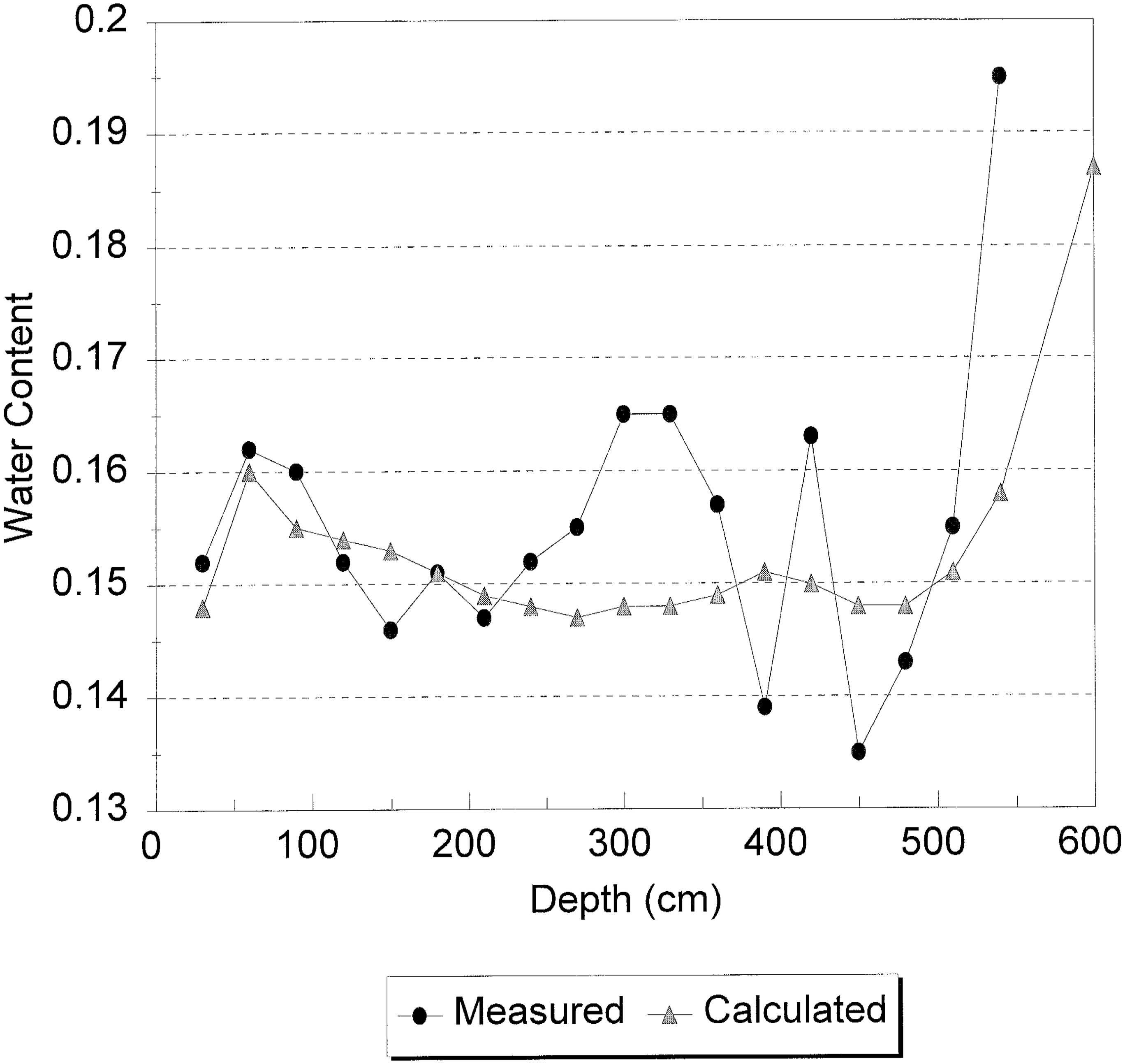

Figure 4a.- Water Content Measured and Calculated in 1989.

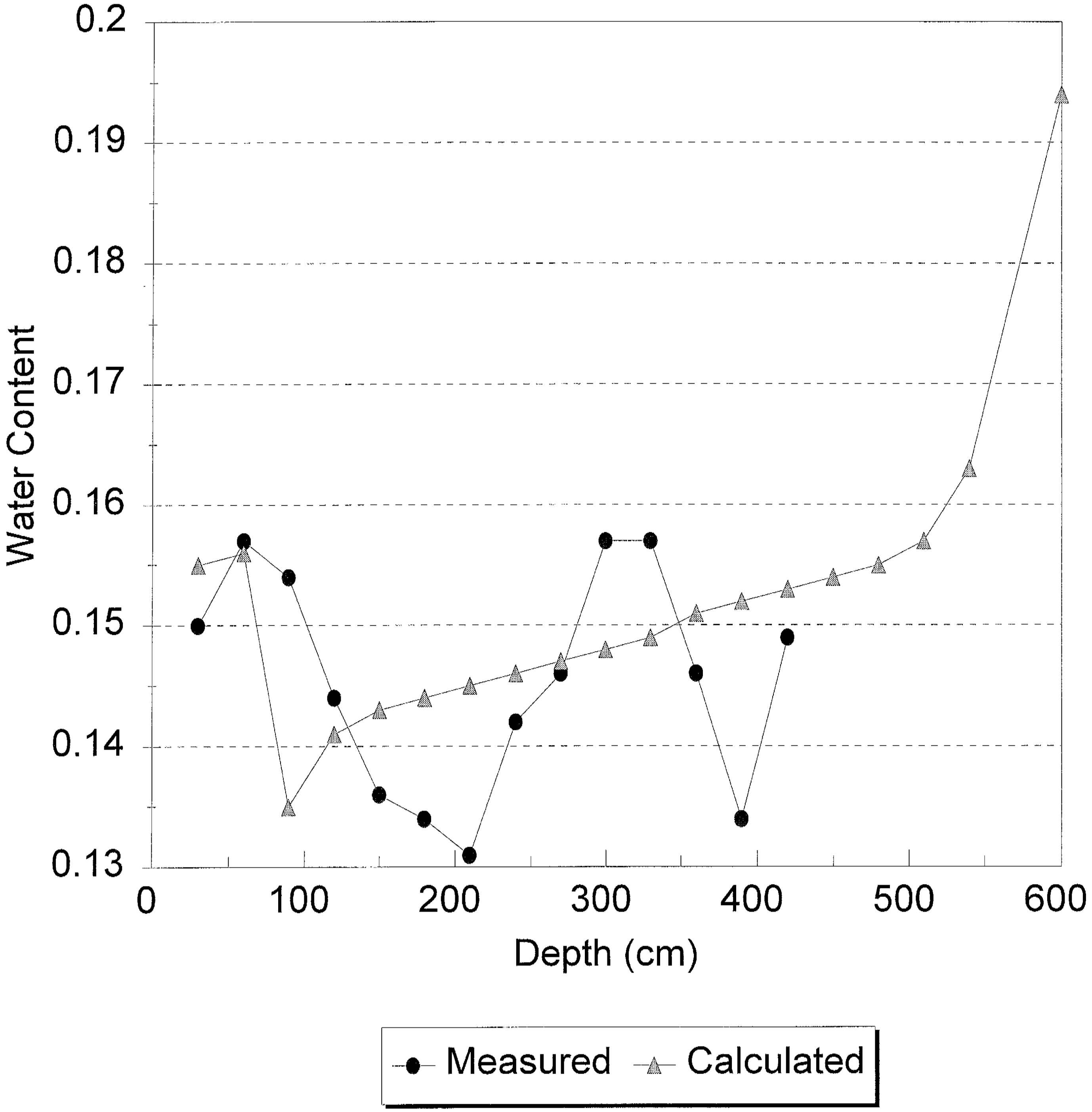

Figure 4b.- Water Content Measured and Calculated in 1990.

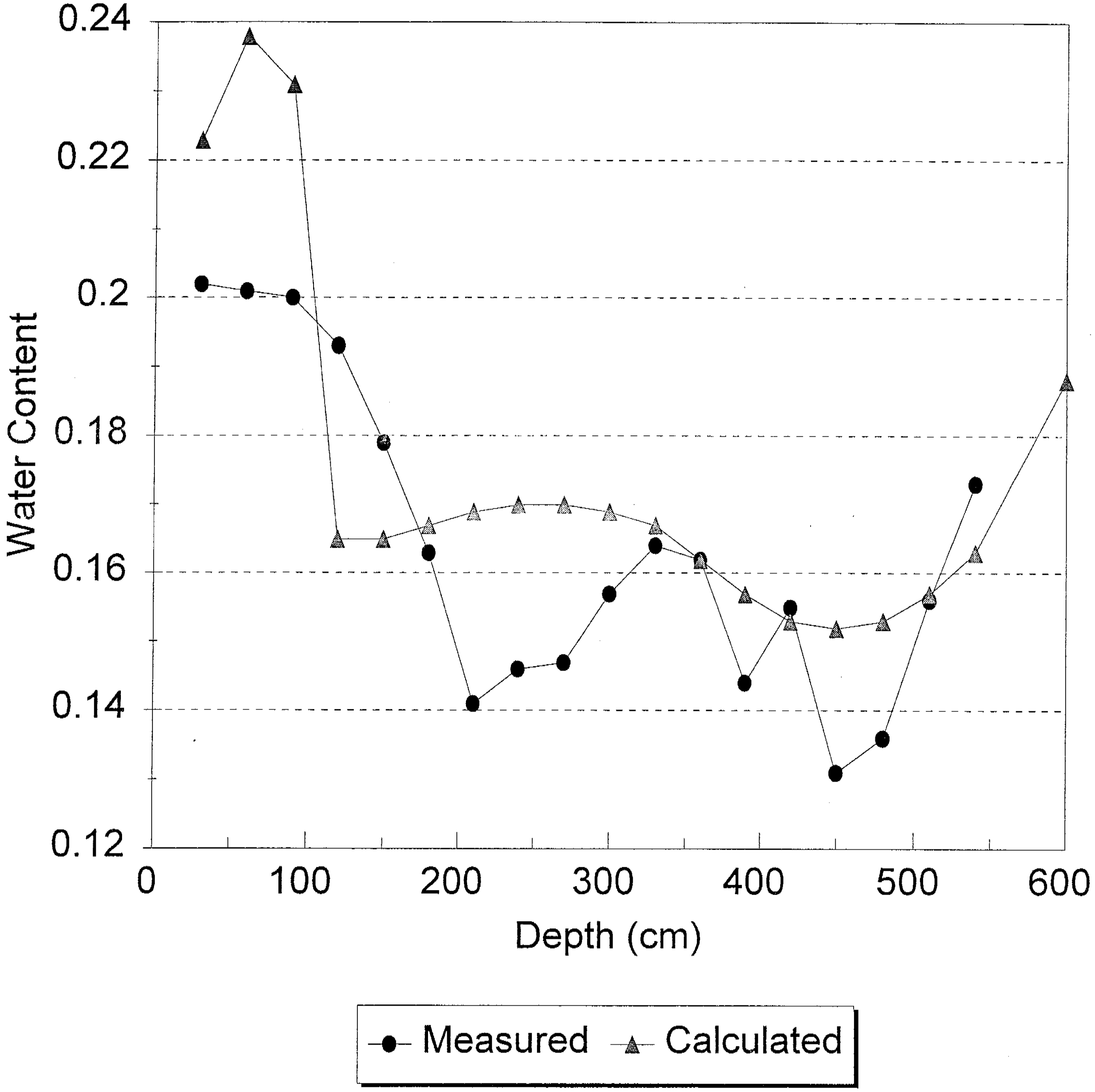

Figure 4c.- Water Content Measured and Calculated in 1991.

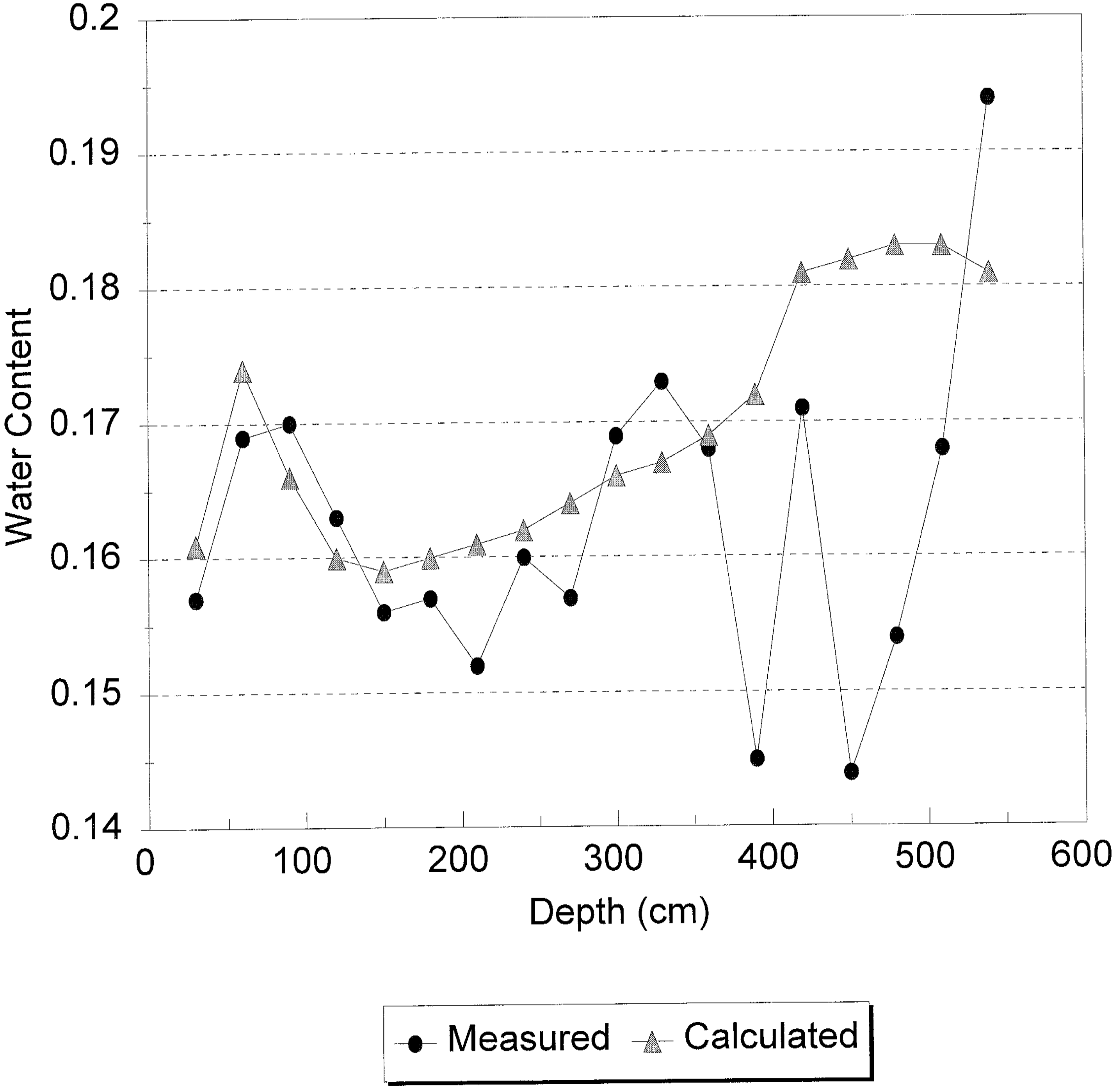

Figure 4d.- Water Content Measured and Calculated in 1992.

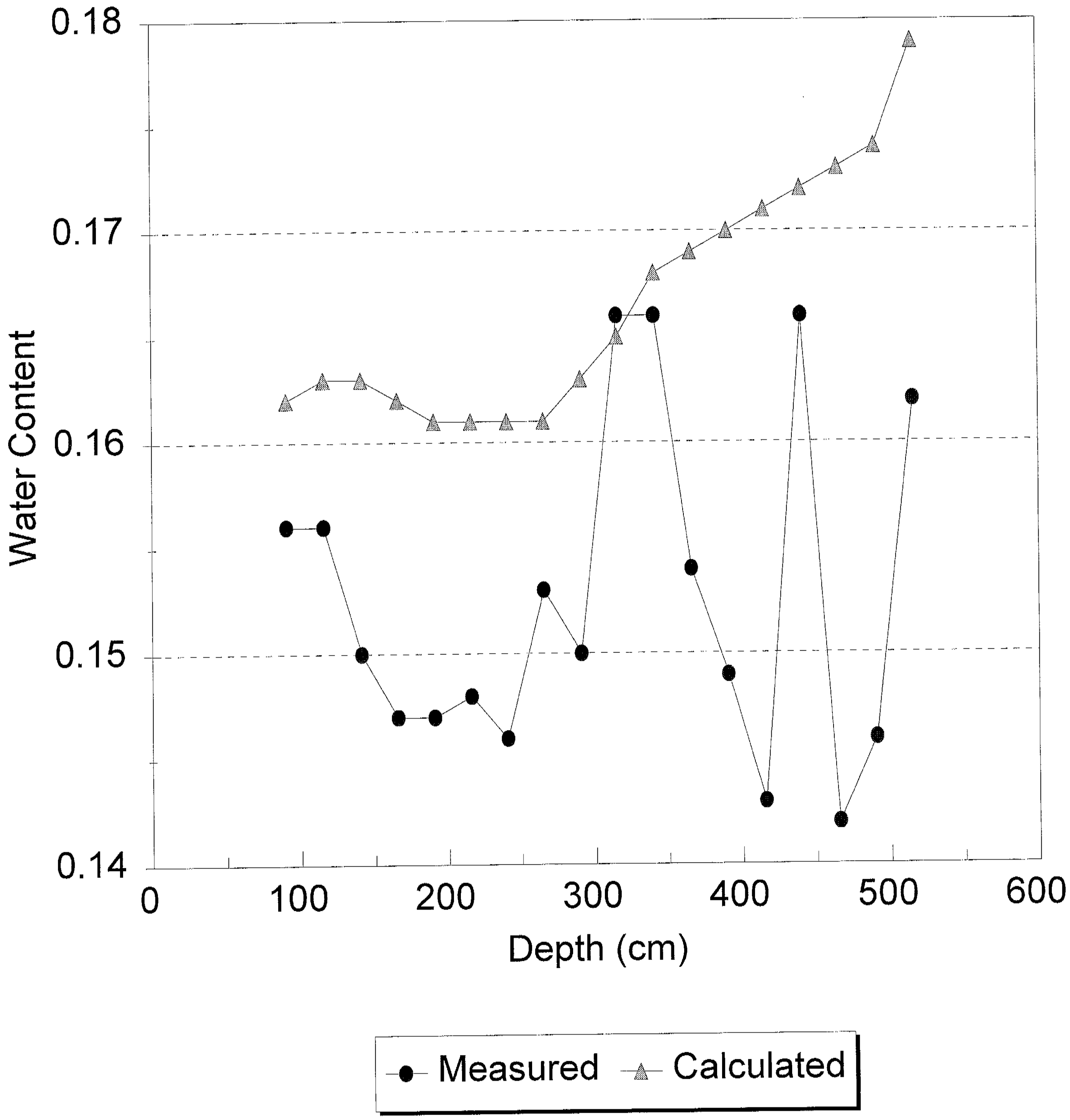

Figure 4e.- Water Content Measured and Calculated in 1993.

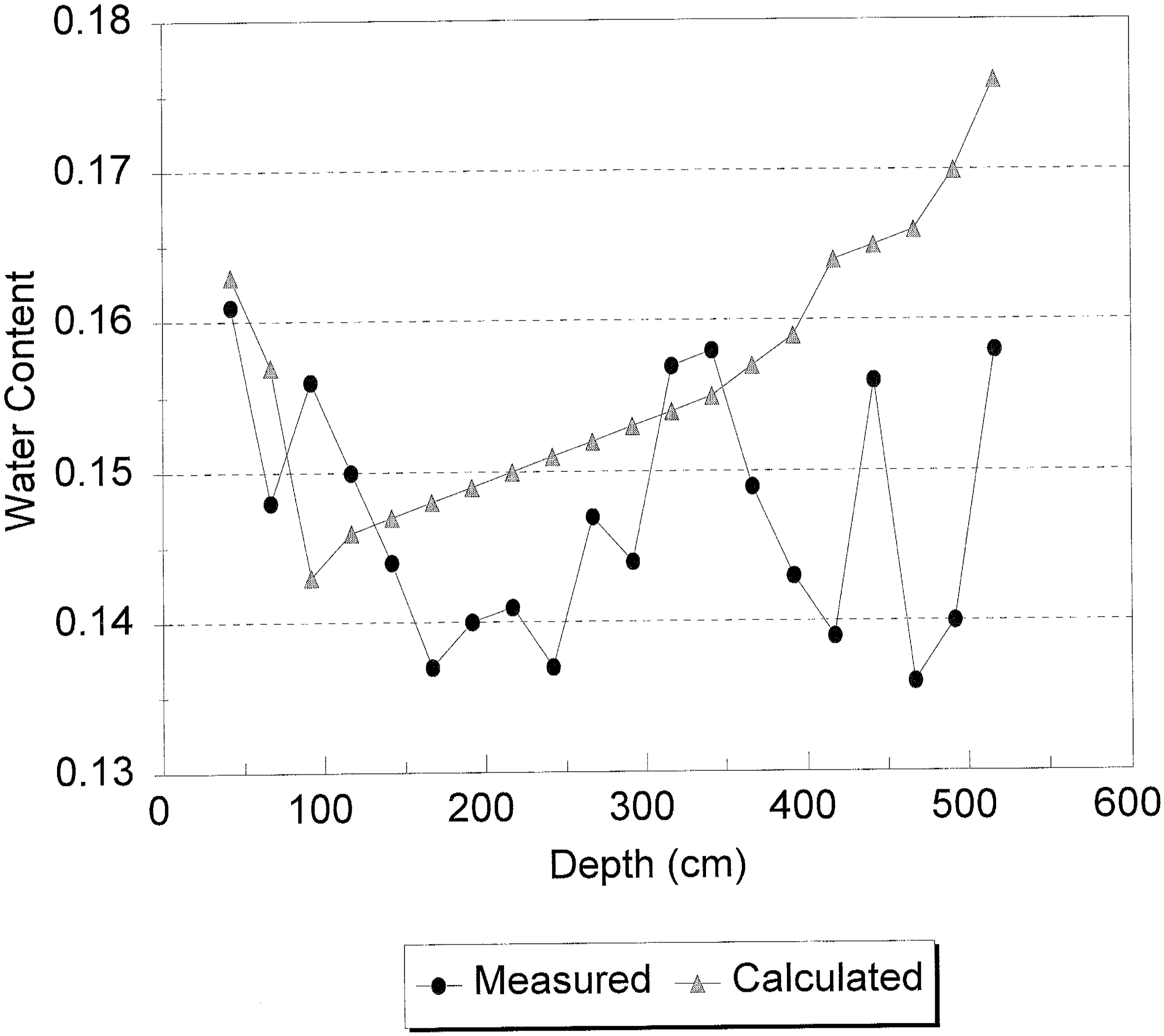

Figure 4f.- Water Content Measured and Calculated in 1994.

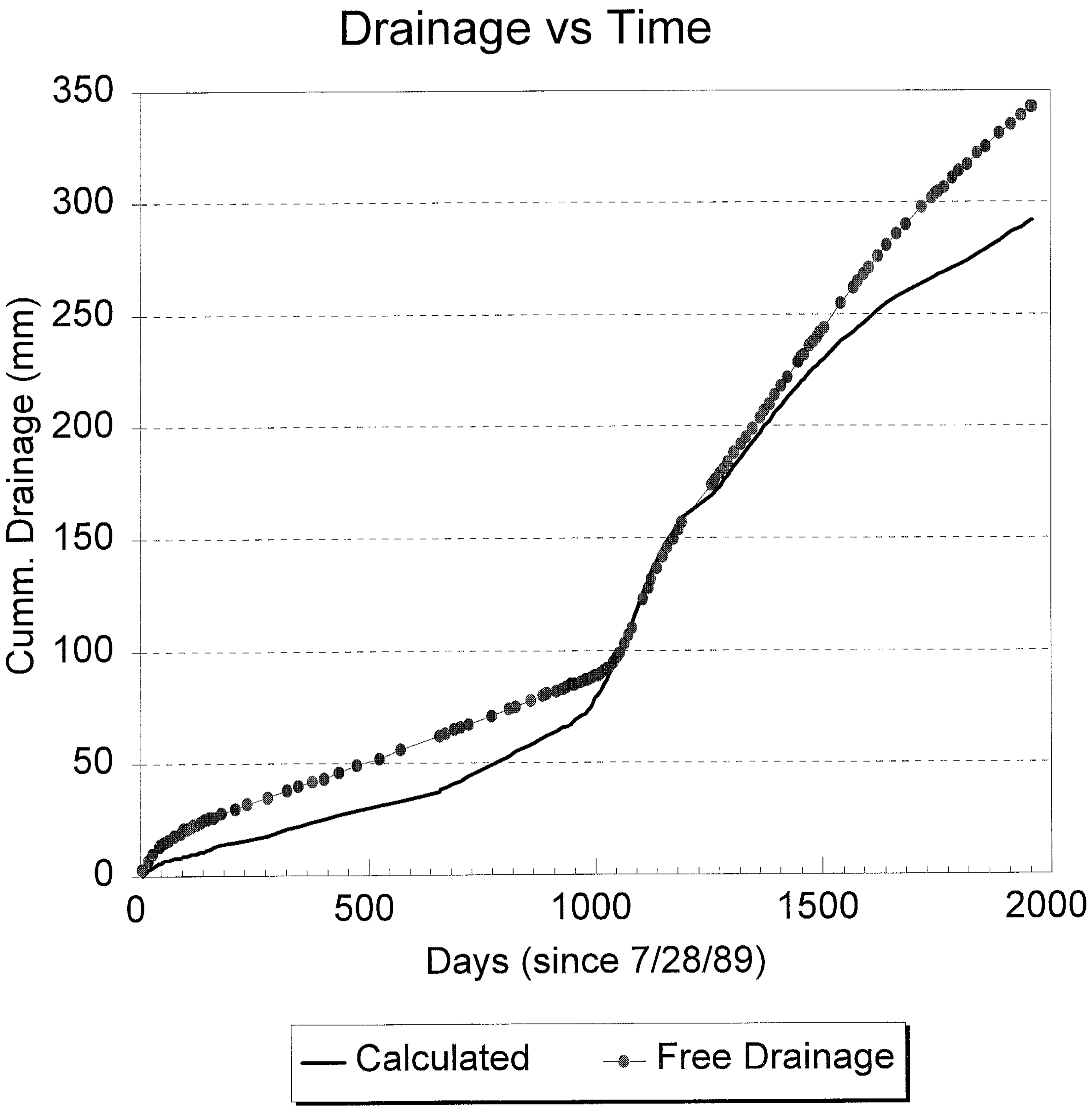

Figure 5.- Free Drainage.

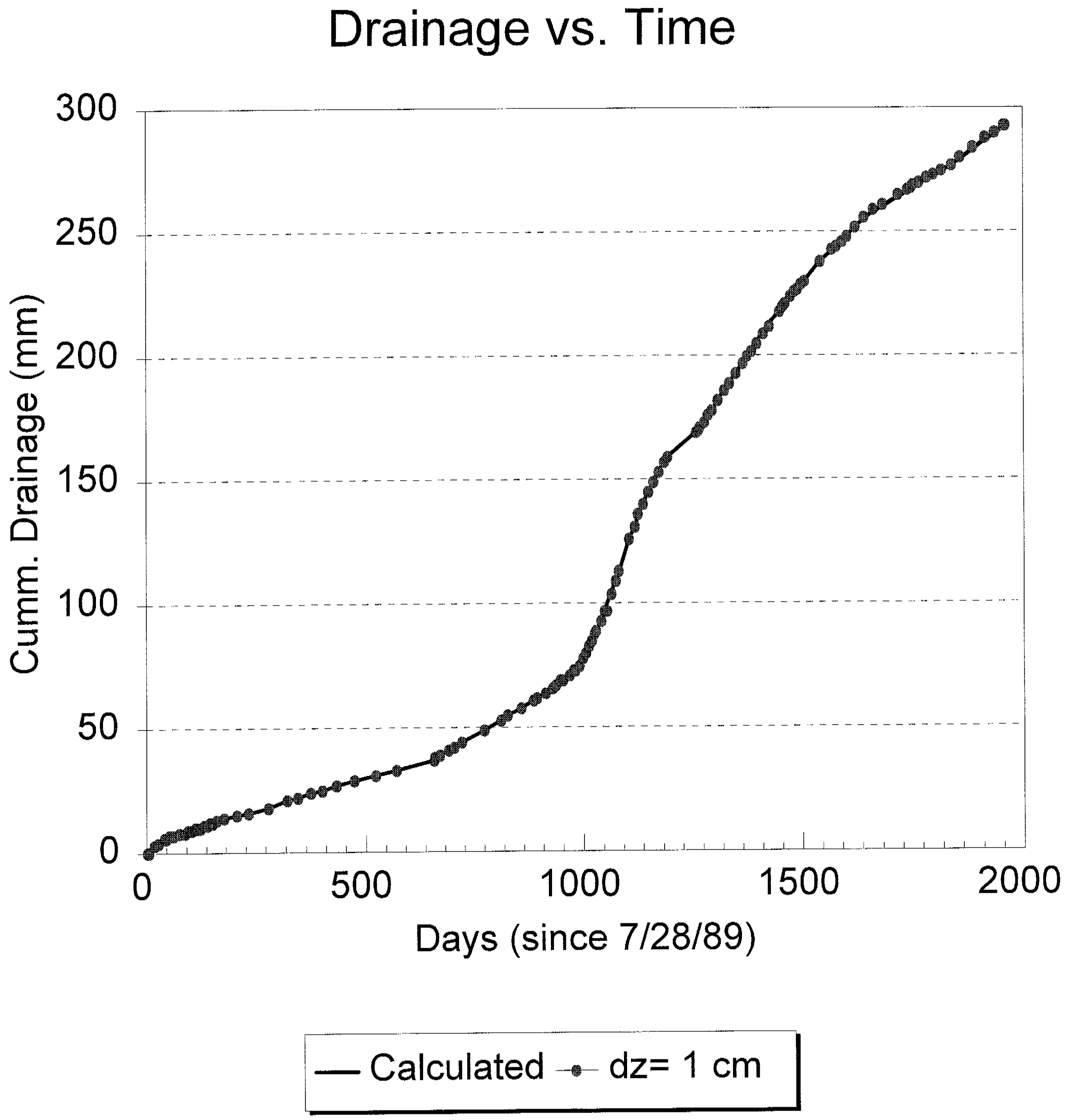

Figure 7. Sensitivity Analysis of Bottom Compartment.

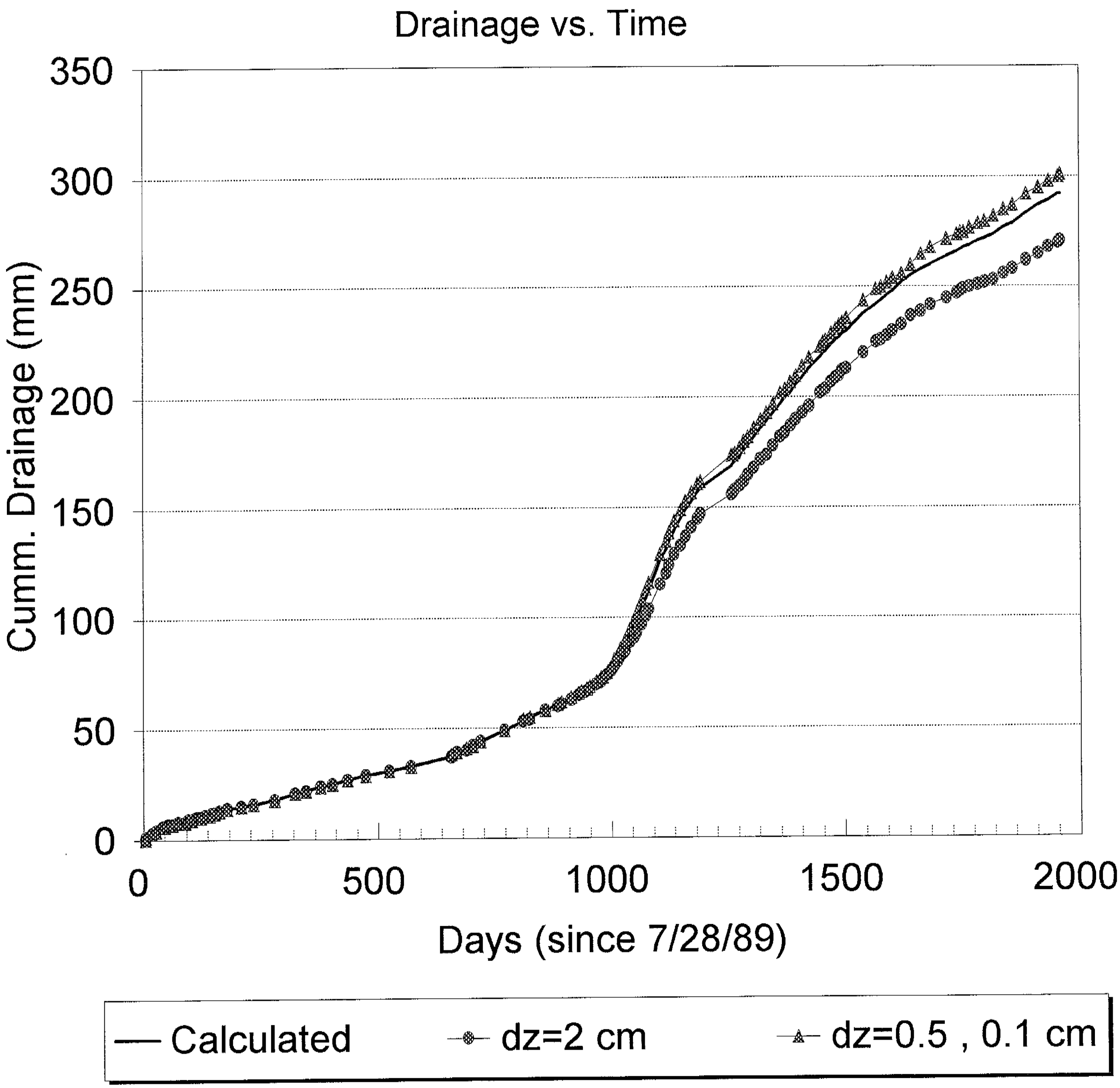

Figure 6.- Sensitivity Analysis of Top Compartment.

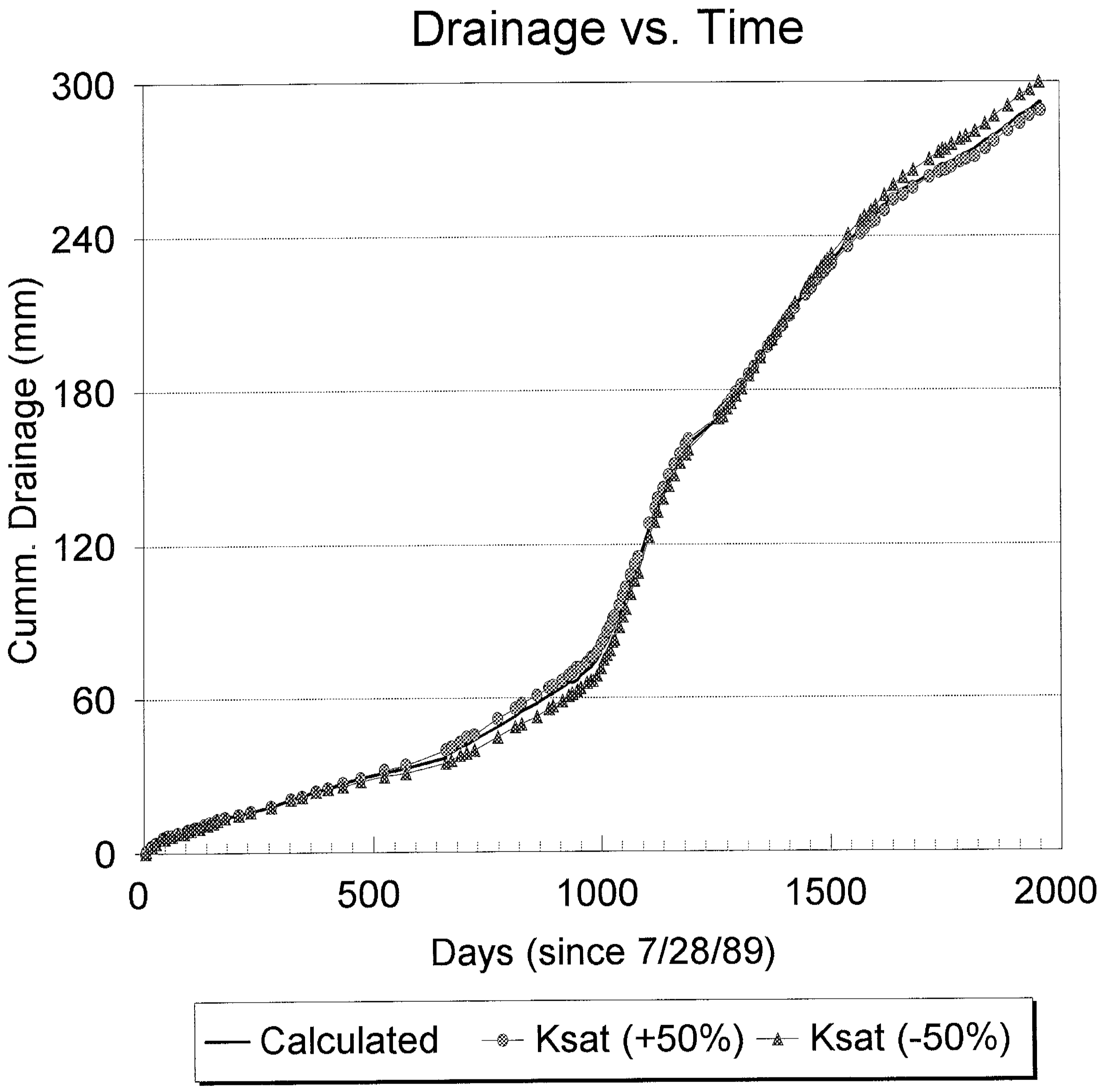

Figure 8.- Sensitivity Analysis of K_{sat} of First Layer.

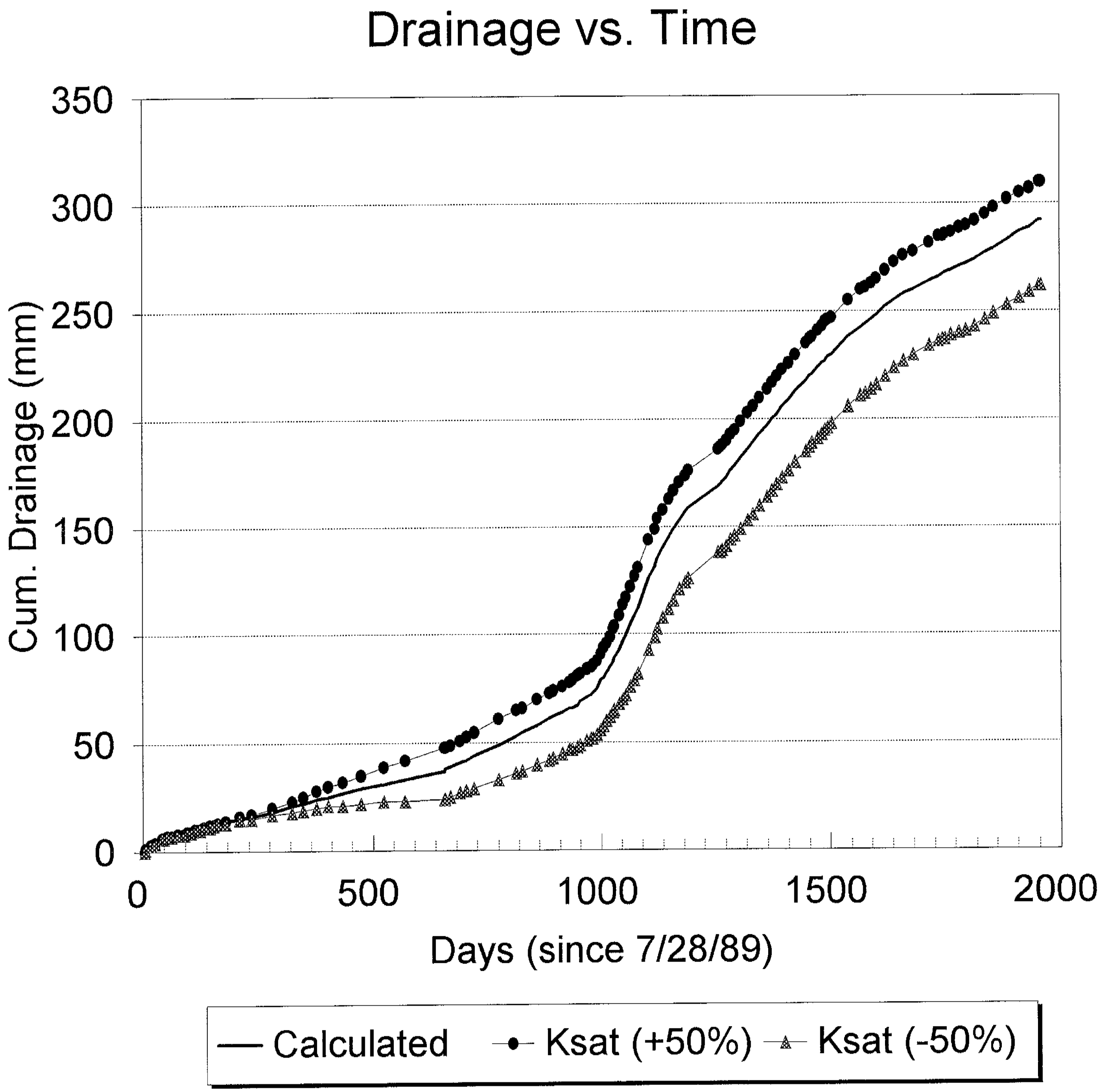

Figure 9.- Sensitivity Analysis of K_{sat} of Second Layer.

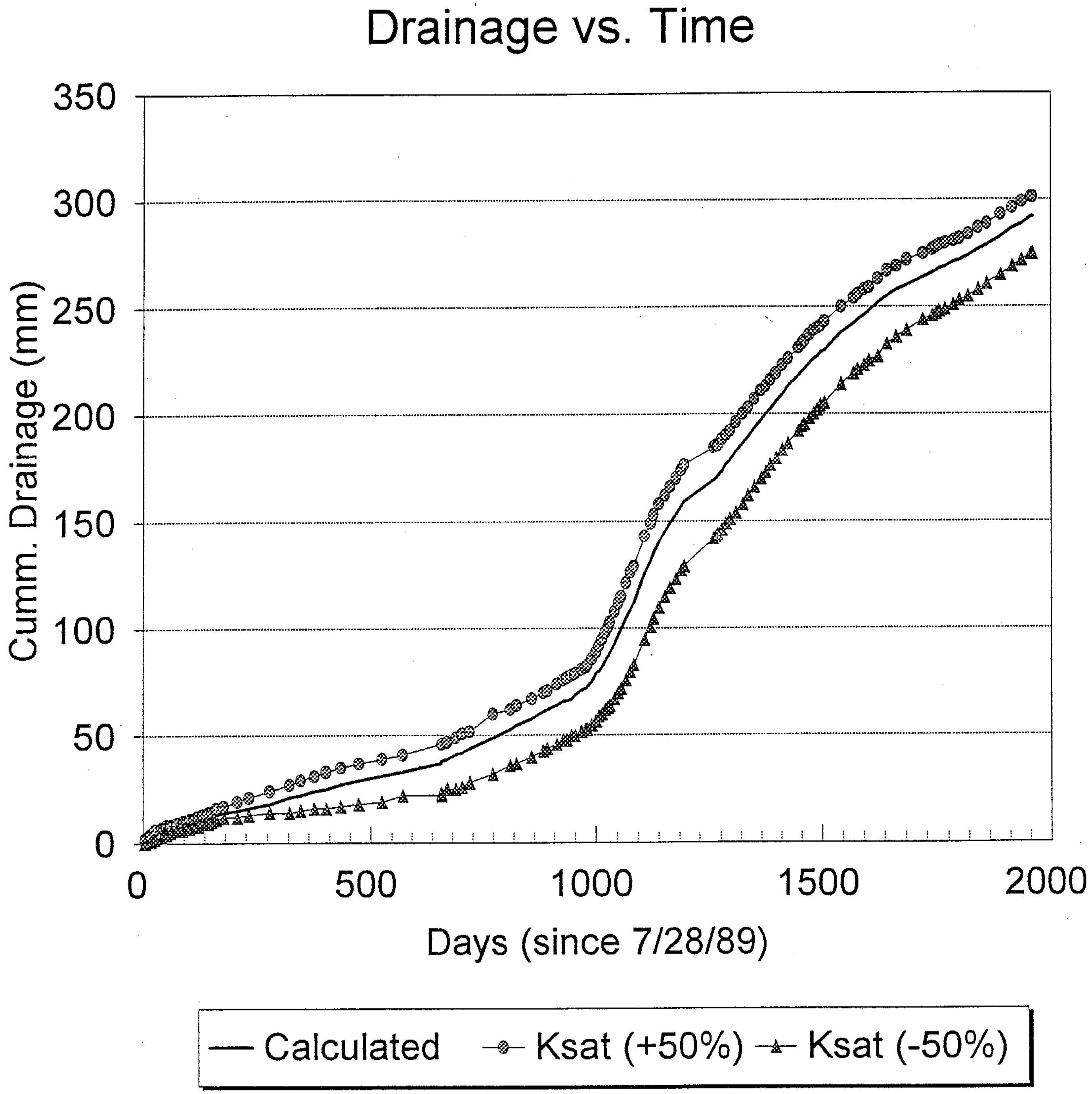

Figure 10.- Sensitivity Analysis of K_{sat} of Third Layer.

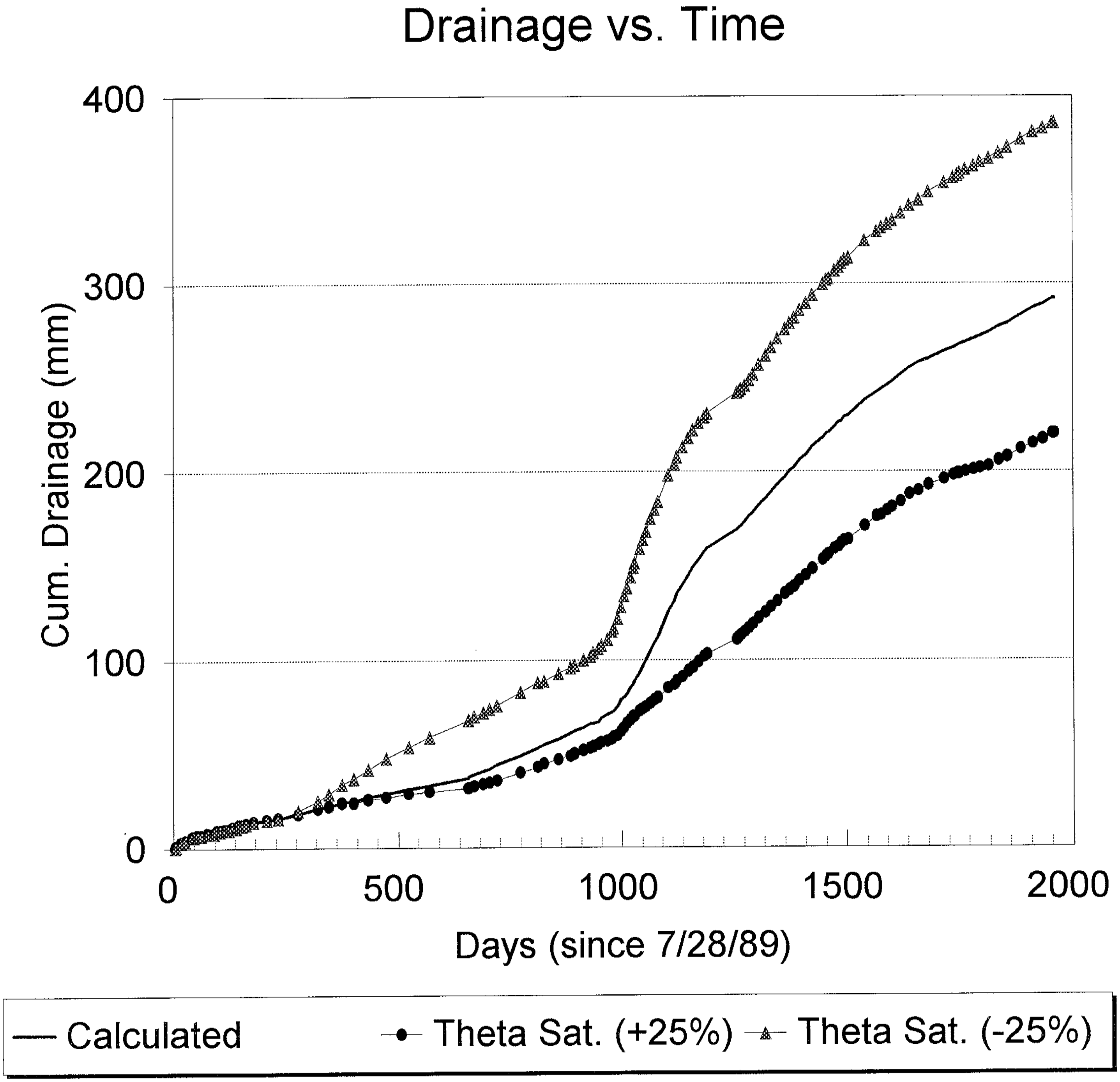

Figure 11.- Sensitivity Analysis of θ_{sat} of the First Layer.

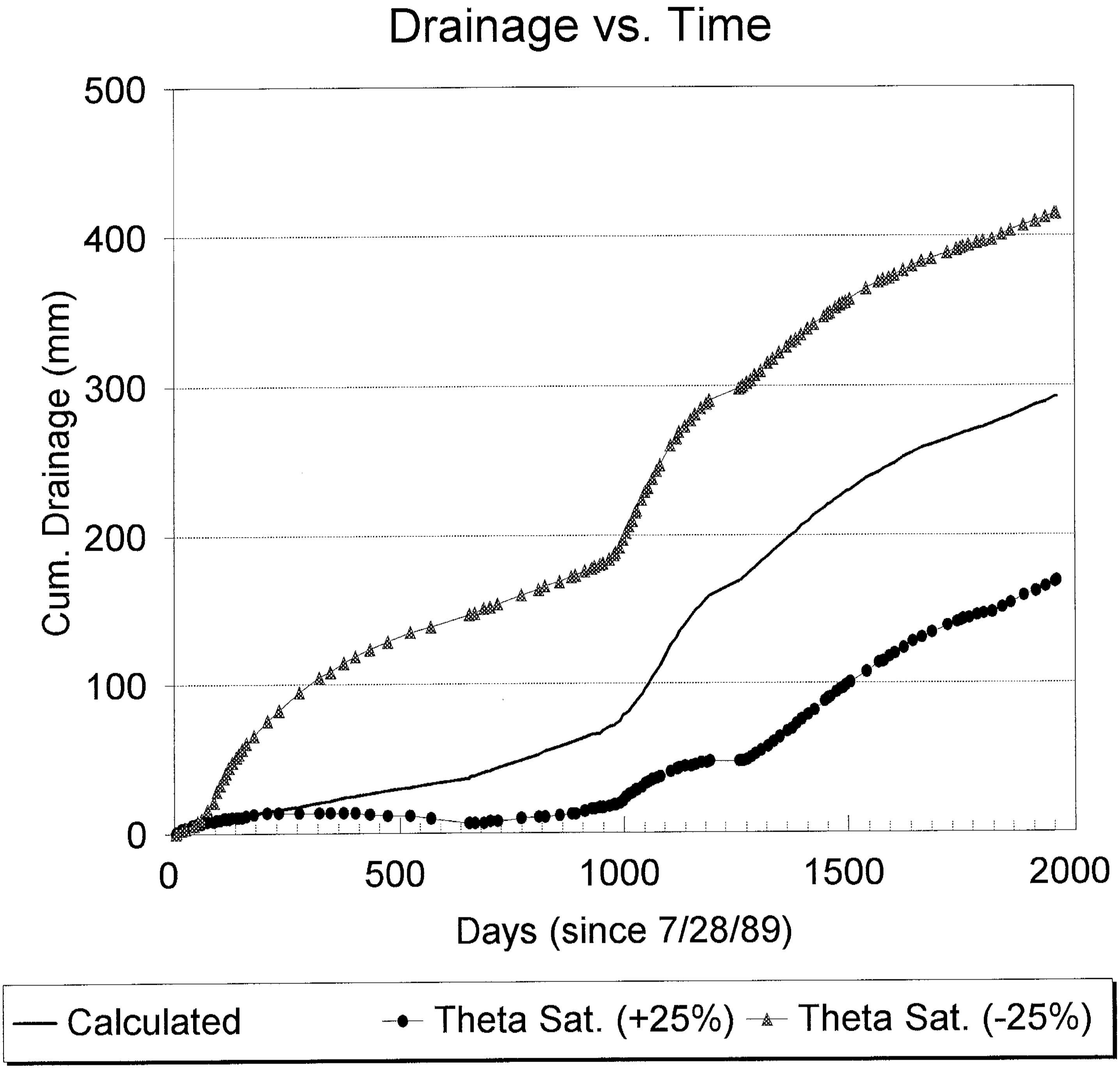

Figure 12.- Sensitivity Analysis of θ_{sat} of the Second Layer.

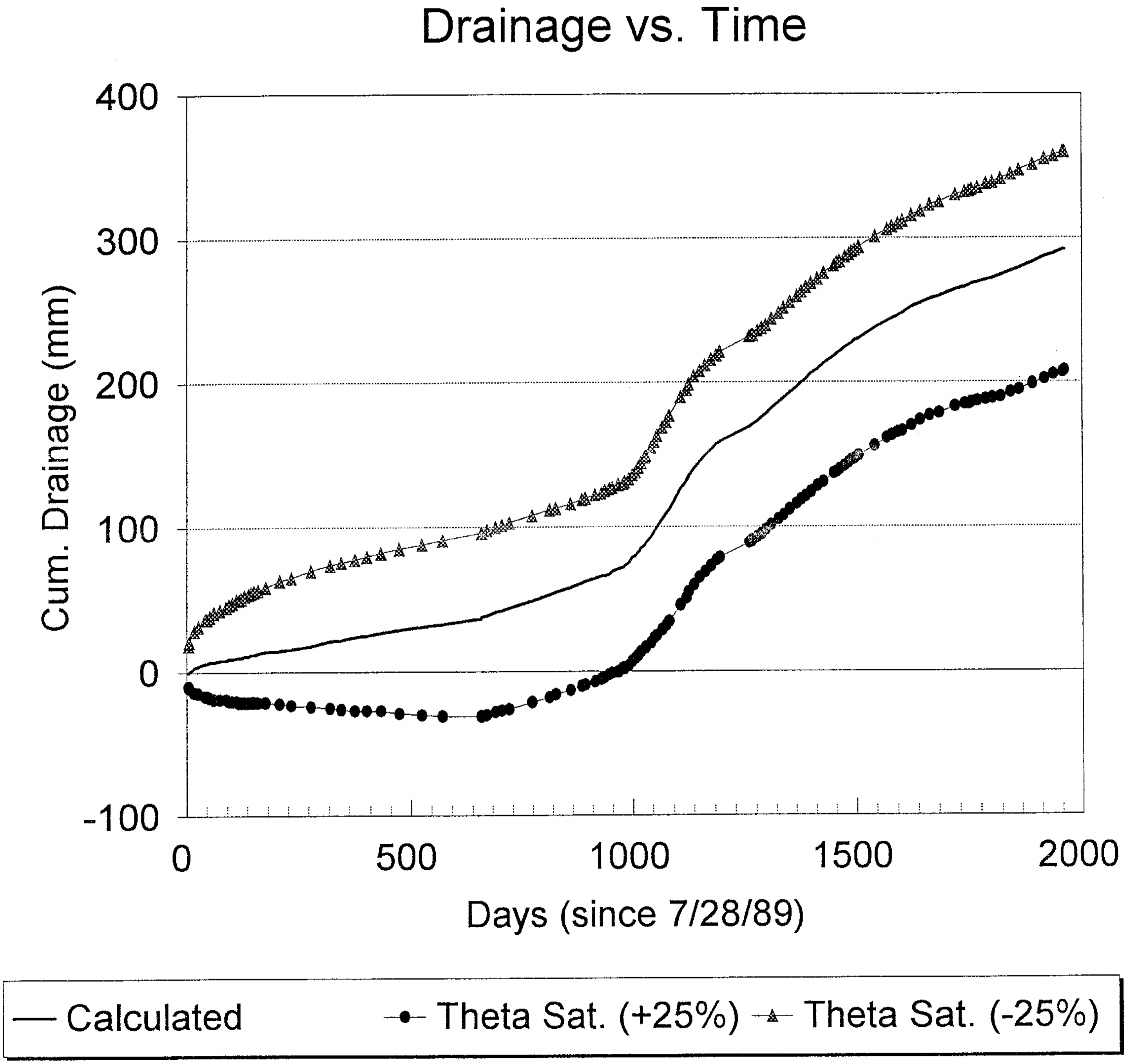

Figure 13.- Sensitivity Analysis of θ_{sat} of the Third Layer.

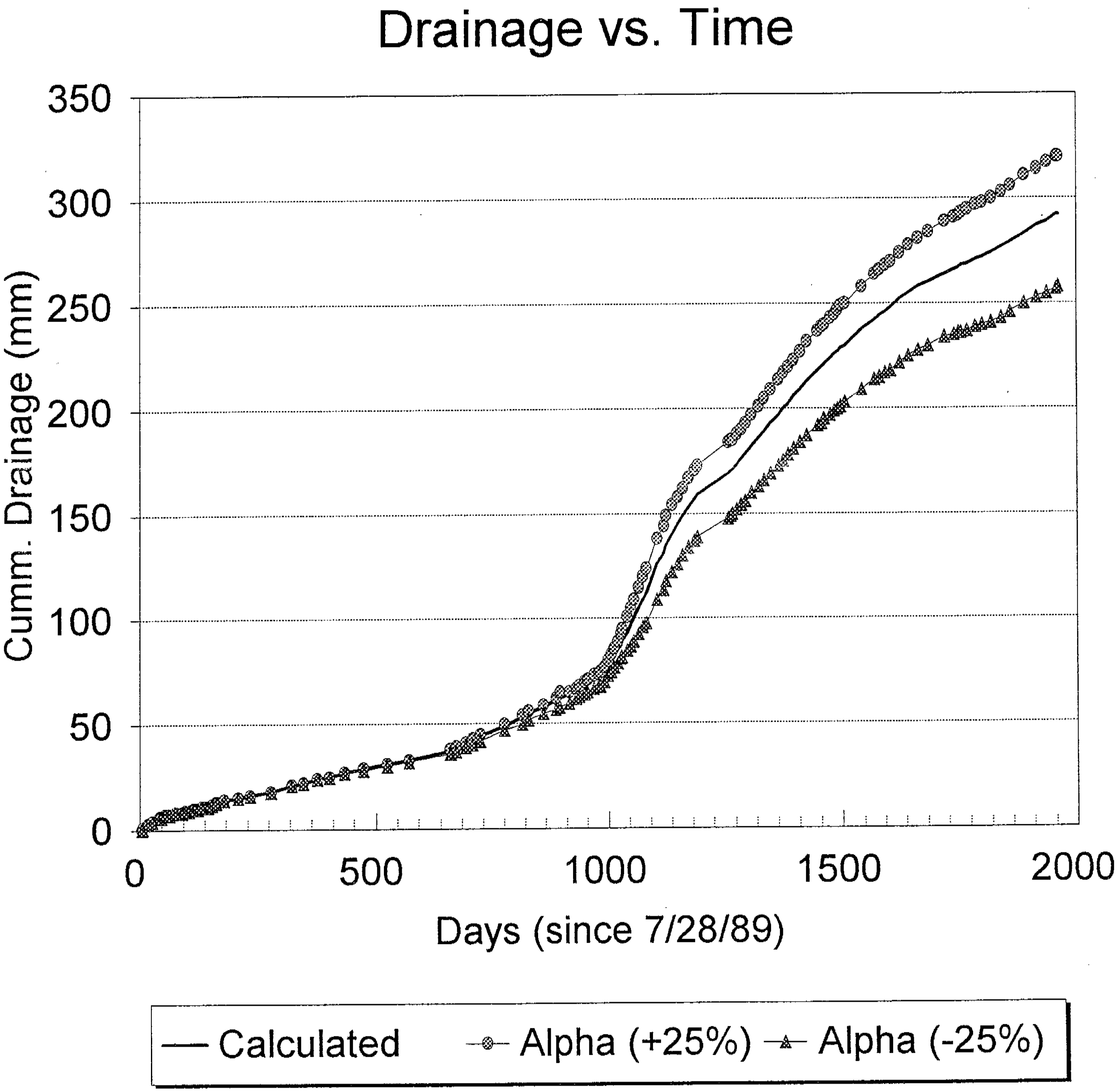

Figure 14.- Sensitivity Analysis of α of the First Layer.

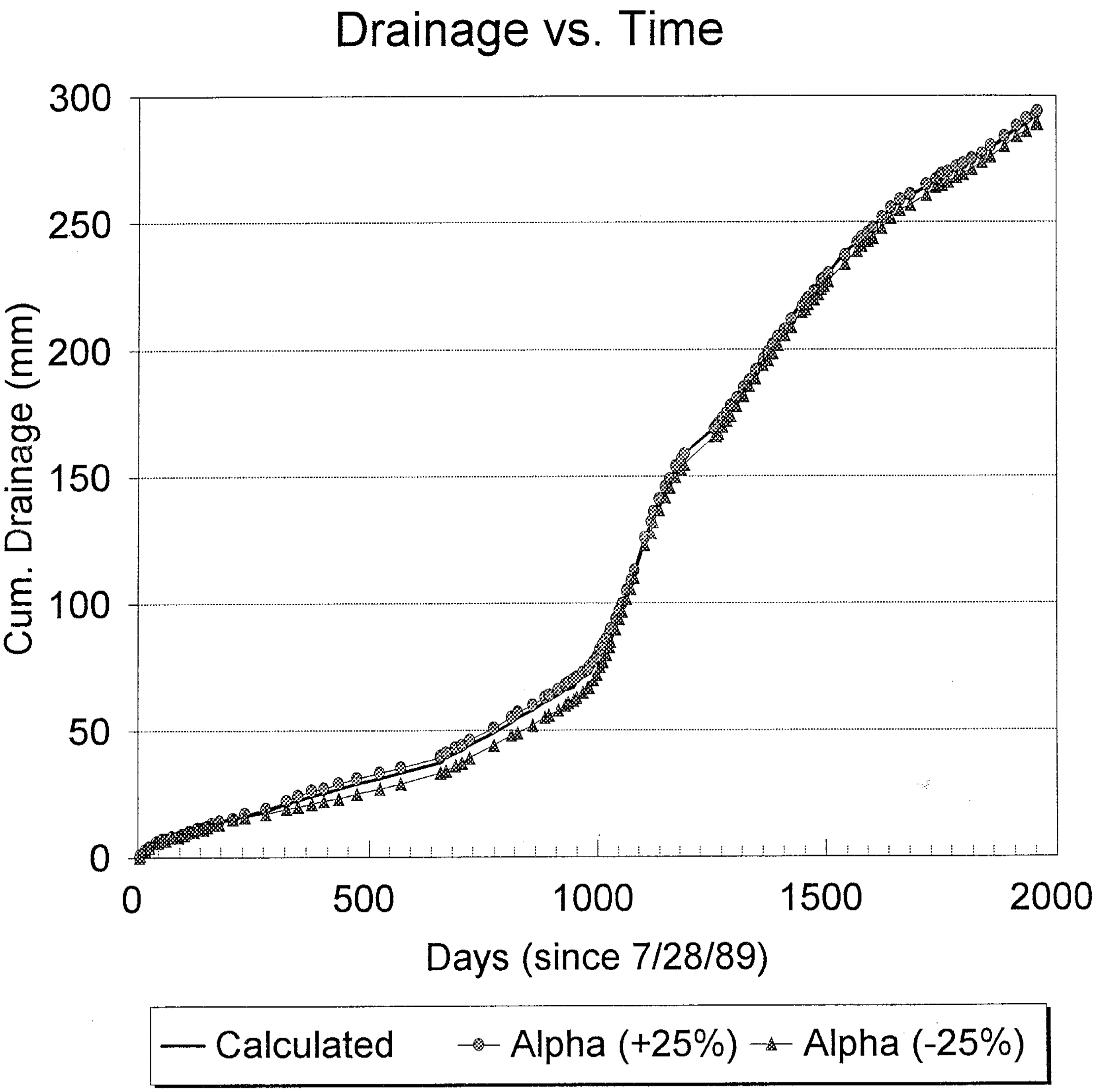

Figure 15.- Sensitivity Analysis of α of the SecondLayer.

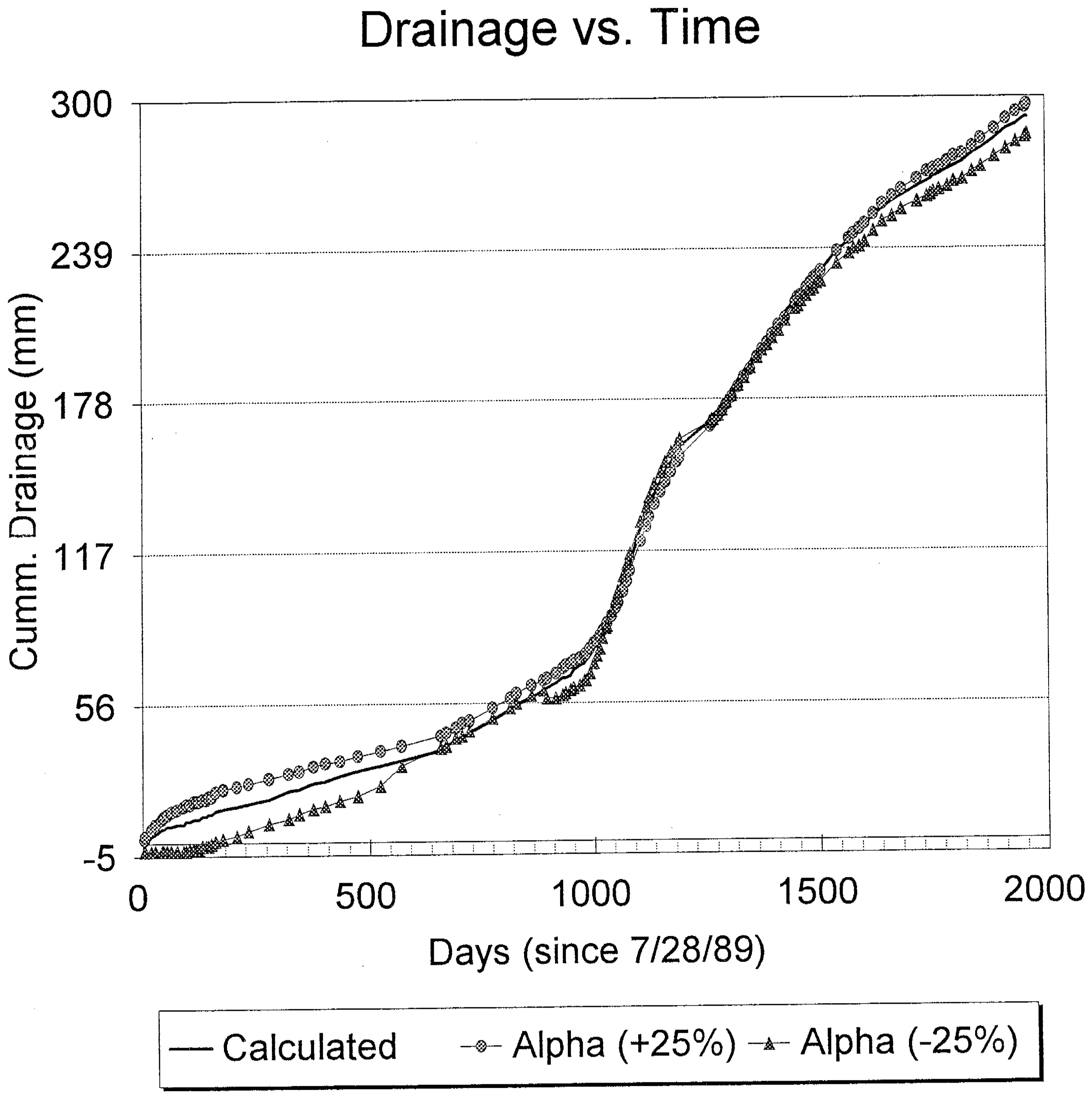

Figure 16.- Sensitivity Analysis of α of the Third Layer.

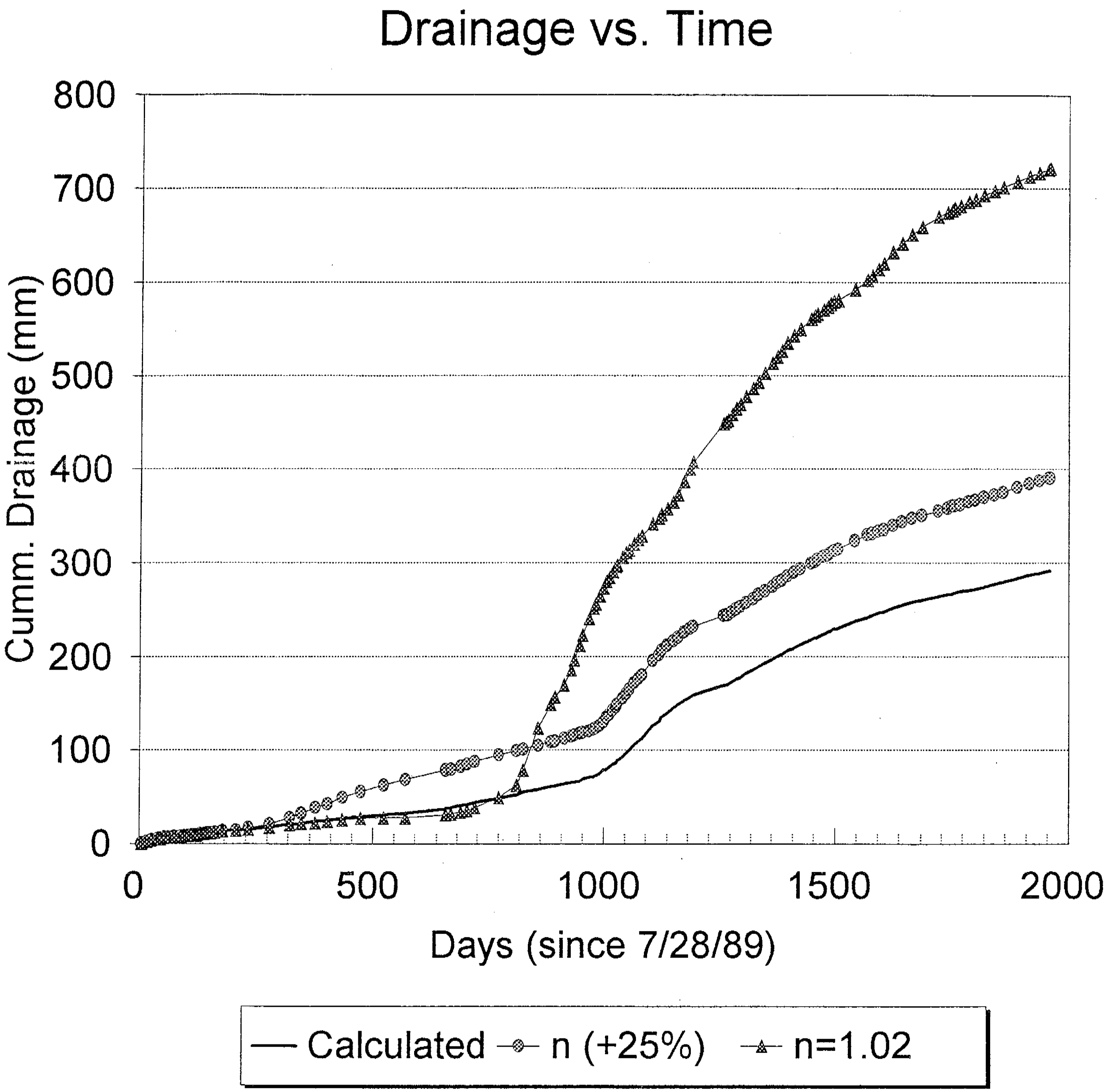

Figure 17.- Sensitivity Analysis of *n* of the First Layer.

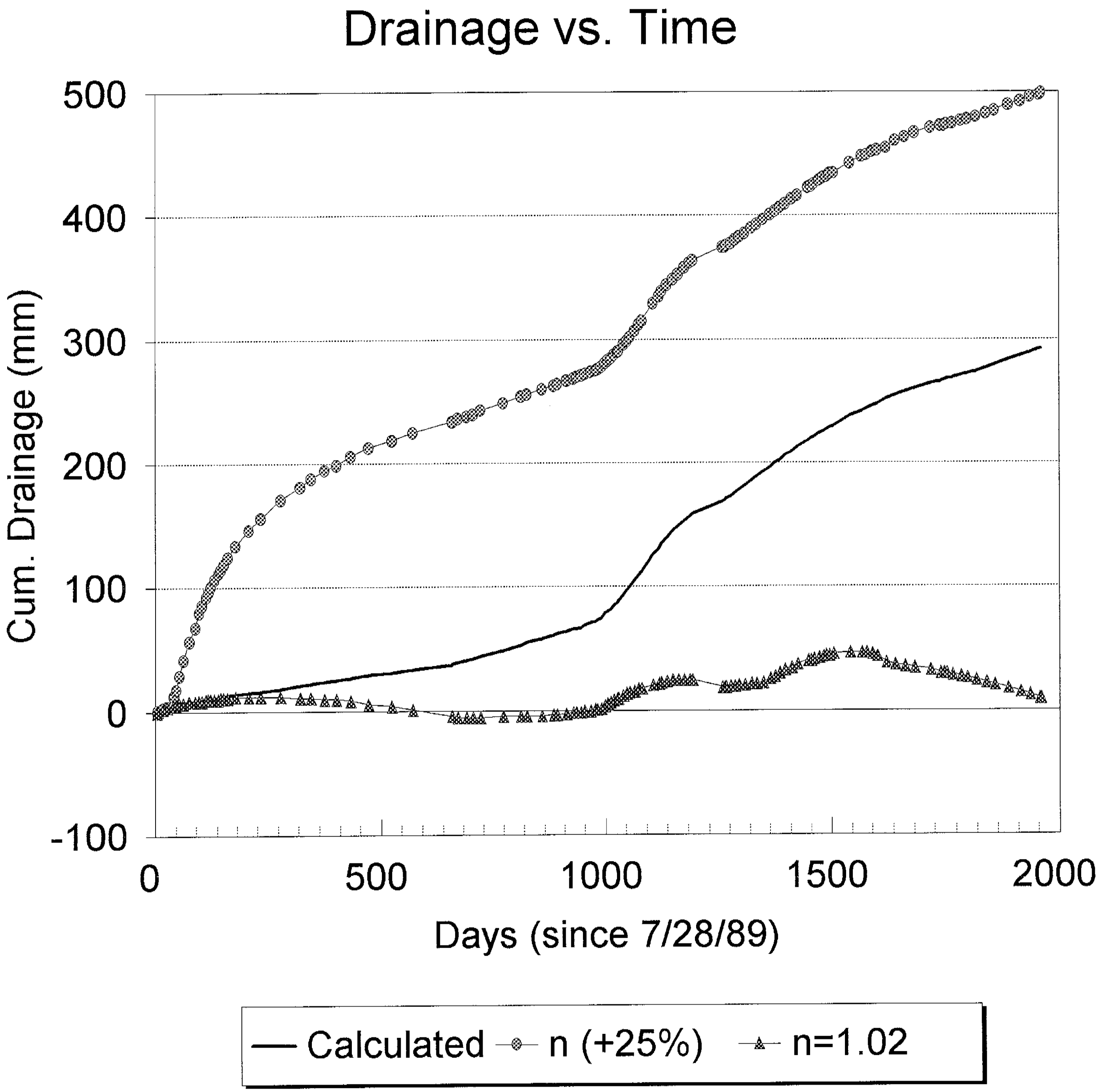

Figure 18.- Sensitivity Analysis of *n* of the Second Layer.

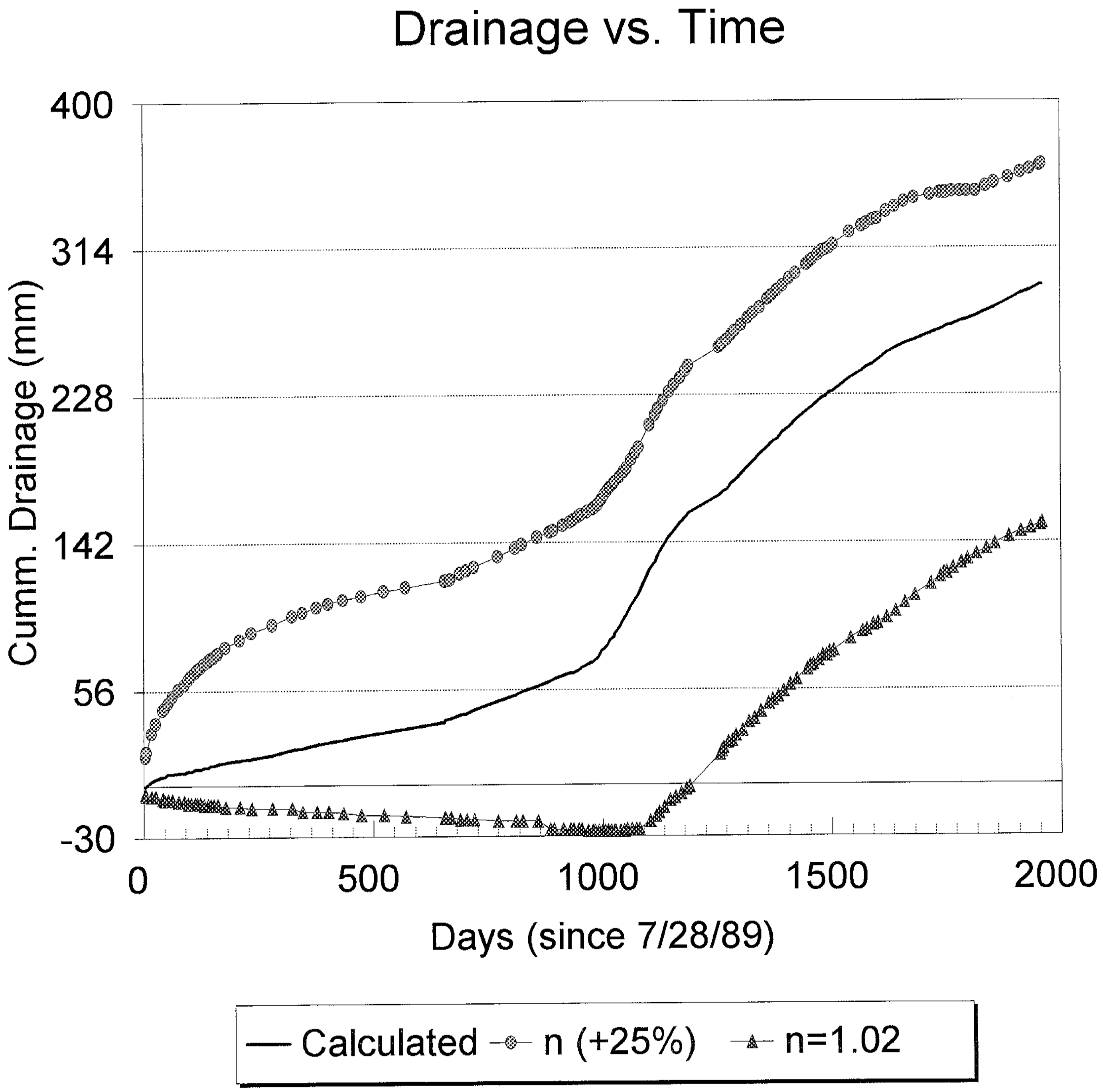

Figure 19.- Sensitivity Analysis of *n* of the Third Layer.

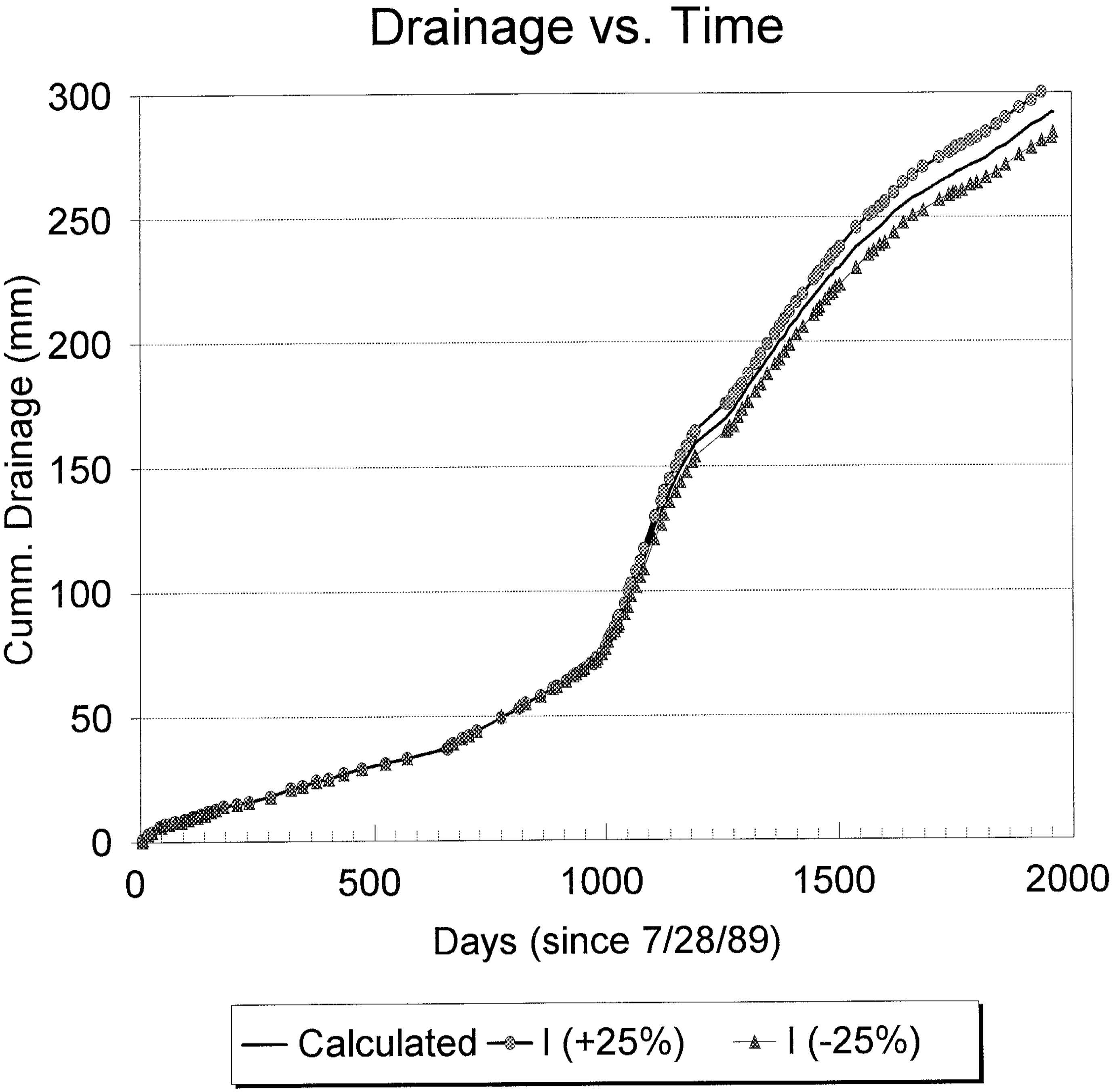

Figure 20.- Sensitivity Analysis of *l* of the First Layer.

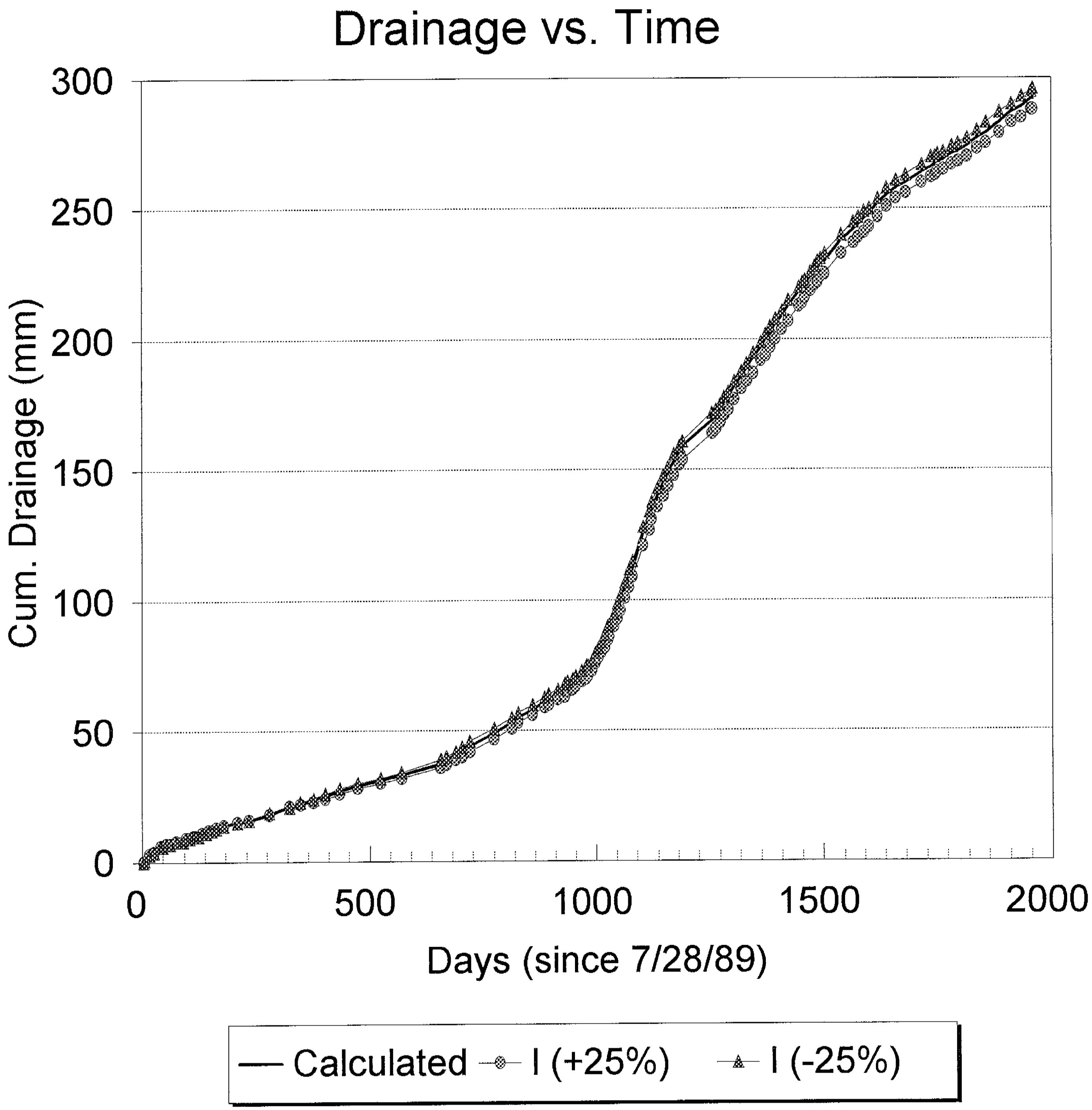

Figure 21.- Sensitivity Analysis of *l* of the Second Layer.

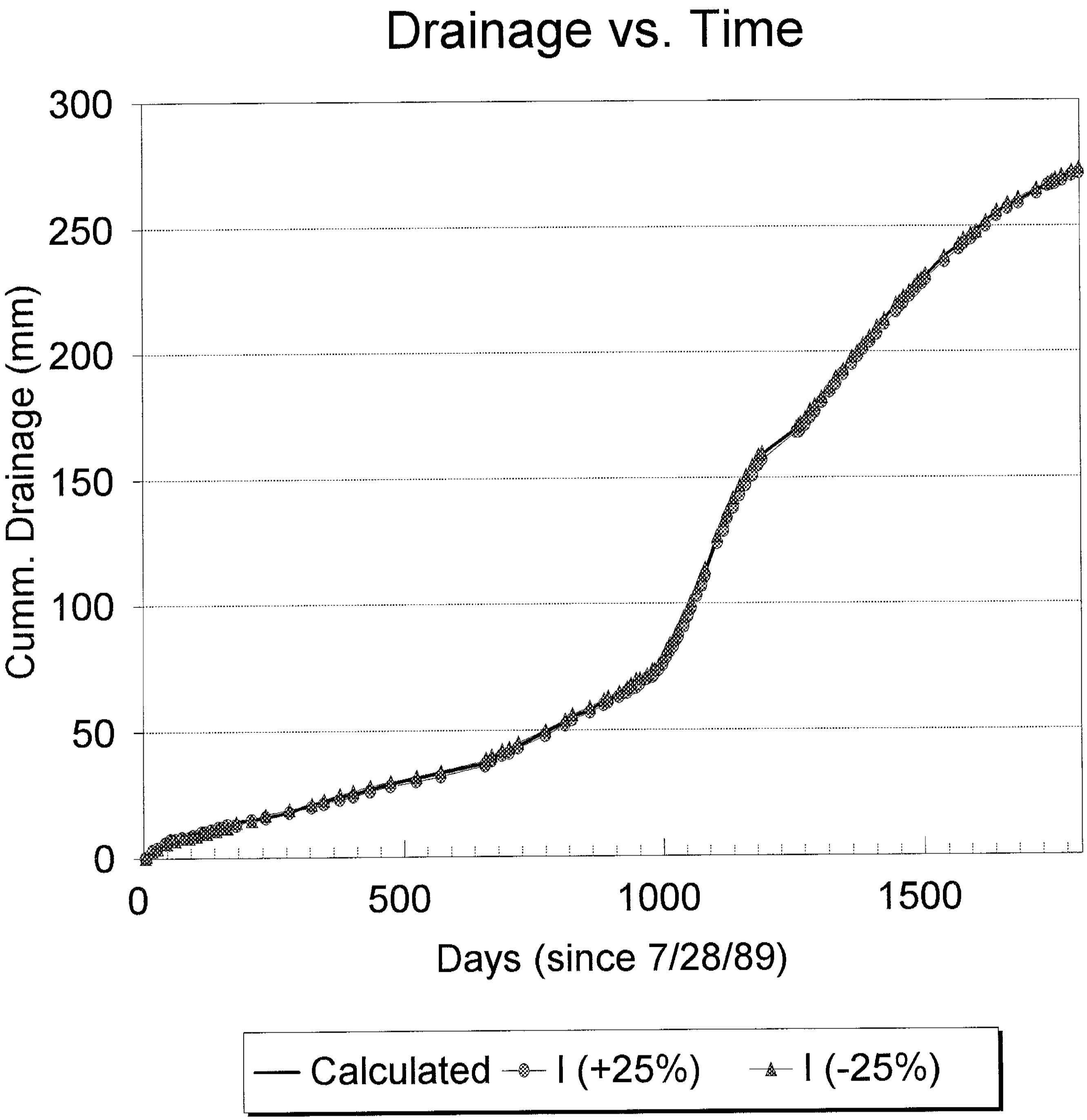

Figure 22.- Sensitivity Analysis of *l* of the Third Layer.

Layer	1	2	3
Thickness (cm)	100.000	310.000	190.000
θ_r ($cm^3.cm^{-3}$)	0.000	0.000	0.000
θ_s ($cm^3.cm^{-3}$)	0.282	0.272	0.250
K_S ($cm.day^{-1}$)	10.000	115.000	5.000
α (cm^{-1})	0.056	0.080	0.029
l (-)	0.790	0.500	0.500
n (-)	1.350	1.250	1.370
α_w (cm^{-1})	0.024	0.000	0.000

Table 1.- Soil Characteristics Obtained in Simulation.

Year	Actual Soil Evap. (mm)	Potential Soil Evap. (mm)	Precipitation (mm)	Measured Rech. (mm)	Calculated Rech. (mm)	Total θ in Profile Initial (cm) †	Total θ in Profile Final (cm)
1989	144.0	906.0	177.0	11.82	12.0	89.8	91.8
1990	228.0	3124.0	250.0	17.24	18.0	91.8	91.5
1991	273.0	3068.0	433.0	29.95	30.0	91.5	104.3
1992	305.0	3224.0	385.0	109.22	108.0	104.2	101.5
1993	189.0	3279.0	265.0	81.04	80.0	101.4	100.8
1994	196.0	3262.0	212.0	40.32	43.0	100.7	97.8
Total	1335.0	-	1722.0	289.59	291.0	-	-

† Water contents used in simulation

Table 2.- Results of Calibration.

Year	Measured (cm)		Calculated (cm)	
	Initial	**Final**	**Initial**	**Final**
1989	92.81	95.64	89.80	90.90
1990	94.74	87.63	90.80	91.10
1991	88.74	97.83	90.90	104.3
1992	91.26	99.41	103.30	100.3
1993	100.63	102.26	99.90	100.5
1994	95.17	95.24	99.80	96.9

Table 3.- Measured and Calculated Total Water Storage in the Profile.

Year	Actual Soil Evaporation (mm)						
	During Calibration	First Layer		Second Layer		Third Layer	
		Ksat (+50%)	Ksat (-50%)	Ksat (+50%)	Ksat (-50%)	Ksat (+50%)	Ksat (-50%)
1989	144.0	146.0	144.0	144.0	144.0	144.0	144.0
1990	228.0	230.0	227.0	228.0	229.0	228.0	228.0
1991	273.0	275.0	269.0	273.0	273.0	273.0	273.0
1992	305.0	311.0	294.0	305.0	305.0	305.0	305.0
1993	189.0	190.0	186.0	188.0	189.0	189.0	189.0
1994	196.0	198.0	191.0	196.0	196.0	196.0	196.0

Table 4.- Actual Soil Evaporation Obtained During the Sensitivity Analysis of Ksat.

Appendix A

Example of Input File of SWAP

```
GENERAL
----------------------------------------------------------------------

>genhdr:
 'Waterbalance study, data 1987, New Mexico'

>output:
 2 1  '89.bal'

>exfile:
 0

>anafil:
 0
 '89.dra'

>timeva:
 1989  1989  206 365  1e-6 0.2  2  0.001

>redeva:
 1
 0.7

>irriva:
 0

>solute:
 0

>methdr:
 'meteorological conditions'

>topbnd:
 2  1

>metfil:

 1989  'meteo.dat'

>crphdr:
 'Natural vegetation, Jornada, New Mexico'

>sinkva:
 0   0   0
```

```
>rootac:
 0.     365.    366.

>excons:
 1.35

>crpfil:
 1989  'swap93.inp'

>crppro:
 0

>profil:
  3   98  27  62  98
 1.0  1.0  2.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
 4.0  4.0  4.0  4.0  4.0  3.0  3.0  4.0  4.0  4.0
 4.0  4.0  4.0  6.0  4.0  6.0  4.0  4.0  4.0  4.0
 4.0  4.0  5.0  8.0 10.0 10.0 10.0 10.0 10.0 10.0
10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  8.0
 6.0  5.0  4.0  4.0  3.0  3.0  4.0  4.0  4.0  4.0
 4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
 4.0  4.0  4.0  4.0  3.0  3.0  2.0  2.0

>soilfl:
 'swap93.inp'
 'swap93.inp'
 'swap93.inp'

>pondmx:
 10.0

>incond:
 0
0.100 0.105 0.110 0.117 0.120 0.125 0.130 0.133 0.137 0.142
0.144 0.146 0.148 0.150 0.152 0.154 0.156 0.157 0.156 0.156
0.156 0.156 0.156 0.156 0.156 0.154 0.152 0.150 0.149 0.148
0.147 0.146 0.144 0.142 0.141 0.140 0.141 0.141 0.142 0.140
0.138 0.137 0.141 0.146 0.150 0.149 0.149 0.148 0.152 0.156
0.160 0.160 0.161 0.161 0.158 0.155 0.152 0.147 0.142 0.138
0.142 0.147 0.152 0.144 0.136 0.128 0.128 0.128 0.128 0.132
0.136 0.140 0.144 0.147 0.153 0.160 0.167 0.173 0.180 0.187
0.193 0.180 0.180 0.180 0.180 0.180 0.180 0.180 0.180 0.180
0.180 0.180 0.180 0.180 0.180 0.180 0.180 0.180
```

```
>bbdfil:
 'swap93.inp'

>drains:
 0

>mobile:
 0

>balance:
 0
balance.gen balance.moi balance.rts balance.sol balance.wb



CROP PARAMETERS
------------------------------------------------------


>sink89:
 -000.  -000.  -000.  -000.  -000.  -000.  -000.

>root89:
 1
 1  00.  365  00. /

>lasc89:
 0.0  0.0  0.0

>prin89:
 0

>soco89:
 1
 1  0.0  365  0.0 /

SOIL CHARACTERISTICS
-------------------------------------------------

>solhd1:
 'optimized surfacelayer (0-100cm)'

>metho1:
 1
```

```
>soild1:
  0.0 0.282 10.0  0.056   0.79 1.35  0.024

>hyster:
  -1
  0.2


>solhd2:
 'optimized layer2 (100-410cm)'

>metho2:
 1

>soild2:
 0.0  0.272  115.0  0.08  0.50  1.25  0.0


>solhd3:
 'optimized layer3 (410-600cm)'

>metho3:
 1

>soild3:
 0.0  0.25  5.0  0.029  0.50  1.37  0.0


BOTT0M BOUNDARY
-------------------------------------------------------

>bothdr:
 'daily pressure head'

>swbotb:
 4

>dayprh:
 1
 1   -30    365   -57 /
```

Appendix B

Example of Output File of SWAP

```
GENERAL VARIABLES
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
TIME PARAMETERS:
start year of calculations     : 1989 (-)
end year of calculations       : 1989 (-)
first day of calculations      :  206 days
last day of calculations       :  365 days
total number of days           :  160 days
interval between outputs       :    1 days
maximum time step              :  .20 days

SOIL PARAMETERS:
depth of the soil profile      : 600.0 cm
number of profile-layers       :     3 (-)
total number of compartments   :    98 (-)
bottom compartment of each layer : 27   62   98

COMPARTMENT SIZES AND DEPTHS OF NODES :
no  size   node  no  size   node  no  size   node  no  size   node
---------------------------------------------------------------------
 1   1.0    -.5  26   6.0  -95.0  51  10.0 -300.0  76   3.0 -516.5
 2   1.0   -1.5  27   4.0 -100.0  52  10.0 -310.0  77   4.0 -520.0
 3   2.0   -3.0  28   4.0 -104.0  53  10.0 -320.0  78   4.0 -524.0
 4   4.0   -6.0  29   4.0 -108.0  54  10.0 -330.0  79   4.0 -528.0
 5   4.0  -10.0  30   4.0 -112.0  55  10.0 -340.0  80   4.0 -532.0
 6   4.0  -14.0  31   4.0 -116.0  56  10.0 -350.0  81   4.0 -536.0
 7   4.0  -18.0  32   4.0 -120.0  57  10.0 -360.0  82   4.0 -540.0
 8   4.0  -22.0  33   5.0 -124.5  58  10.0 -370.0  83   4.0 -544.0
 9   4.0  -26.0  34   8.0 -131.0  59  10.0 -380.0  84   4.0 -548.0
10   4.0  -30.0  35  10.0 -140.0  60  10.0 -390.0  85   4.0 -552.0
11   4.0  -34.0  36  10.0 -150.0  61  10.0 -400.0  86   4.0 -556.0
12   4.0  -38.0  37  10.0 -160.0  62  10.0 -410.0  87   4.0 -560.0
13   4.0  -42.0  38  10.0 -170.0  63  10.0 -420.0  88   4.0 -564.0
14   4.0  -46.0  39  10.0 -180.0  64  10.0 -430.0  89   4.0 -568.0
15   4.0  -50.0  40  10.0 -190.0  65  10.0 -440.0  90   4.0 -572.0
16   3.0  -53.5  41  10.0 -200.0  66  10.0 -450.0  91   4.0 -576.0
17   3.0  -56.5  42  10.0 -210.0  67  10.0 -460.0  92   4.0 -580.0
18   4.0  -60.0  43  10.0 -220.0  68  10.0 -470.0  93   4.0 -584.0
19   4.0  -64.0  44  10.0 -230.0  69  10.0 -480.0  94   4.0 -588.0
20   4.0  -68.0  45  10.0 -240.0  70   8.0 -489.0  95   3.0 -591.5
21   4.0  -72.0  46  10.0 -250.0  71   6.0 -496.0  96   3.0 -594.5
22   4.0  -76.0  47  10.0 -260.0  72   5.0 -501.5  97   2.0 -597.0
23   4.0  -80.0  48  10.0 -270.0  73   4.0 -506.0  98   2.0 -599.0
24   6.0  -85.0  49  10.0 -280.0  74   4.0 -510.0
25   4.0  -90.0  50  10.0 -290.0  75   3.0 -513.5
```

BOUNDARY CONDITIONS : TOP OF THE SOIL PROFILE

CHOICE OF CONDITIONS:
header : meteorological conditions
choice top boundary conditions : 2 (-)
boundary conditions varying : 1 (-)

FILE(S) METEOROLOGICAL DATA:
year file
1989 meteo.dat

PONDING:
maximum thickness of ponding : 10.0 cm.

REDUCTION OF EVAPORATION:
reduction model option : 1 (-)
parameter (alpha, beta or dummy) : .70 cm d-1/2 or cm1/2

CROP PARAMETERS

GENERAL:
header : Natural vegetation, Jornada, New Mexico
choice of crop production : 0

SINKTERM AND ROOT EXTRACTION:
shape of sink term : 0 (-)
relation between Hlim3 and Hlim4 : 0 (-)
water uptake function : 0 (-)

NON-ACTIVE LAYER:
maximum thickness of n.a. layer : .0 cm
time at which n.a.layer starts : 365. day
time of maximum thickness : 366. day

EXTRA CONSTANTS:
Priestley and Taylor constant : 1.350

FILE(S) CROP DATA:
year file
1989 swap93.inp

SOIL PHYSICAL DATA

GENERAL:

layer file

SOIL PHYSICAL DATA OF LAYER 1: optimized surfacelayer (0-100cm)

theta_r	theta_s	Ks	alfa_d	l	n	m	alfa_w
.000	.282	15.000	.0560	.790	1.350	.259	.0240

SOIL PHYSICAL DATA OF LAYER 2: optimized layer2 (100-410cm)

theta_r	theta_s	Ks	alfa_d	l	n	m	alfa_w
.000	.272	115.000	.0800	.500	1.250	.200	.0000

SOIL PHYSICAL DATA OF LAYER 3: optimized layer3 (410-600cm)

theta_r	theta_s	Ks	alfa_d	l	n	m	alfa_w
.000	.250	5.000	.0290	.500	1.370	.270	.0000

BOUNDARY CONDITIONS: BOTTOM OF THE SOIL PROFILE

GENERAL:

input file : swap93.inp

header : daily pressure head

type of lower boundary condition : 4 (-)

PRESSURE HEAD OF LOWEST COMPARTMENT: (cm)

day	pressh	day	pressh	day	pressh	day	pressh	day	pressh	day	pressh
206	-45.	233	-47.	260	-49.	287	-51.	314	-53.	341	-55.
207	-45.	234	-47.	261	-49.	288	-51.	315	-53.	342	-55.
208	-45.	235	-47.	262	-49.	289	-51.	316	-53.	343	-55.
209	-45.	236	-47.	263	-49.	290	-51.	317	-53.	344	-55.
210	-46.	237	-48.	264	-50.	291	-52.	318	-54.	345	-56.
211	-46.	238	-48.	265	-50.	292	-52.	319	-54.	346	-56.
212	-46.	239	-48.	266	-50.	293	-52.	320	-54.	347	-56.
213	-46.	240	-48.	267	-50.	294	-52.	321	-54.	348	-56.
214	-46.	241	-48.	268	-50.	295	-52.	322	-54.	349	-56.
215	-46.	242	-48.	269	-50.	296	-52.	323	-54.	350	-56.
216	-46.	243	-48.	270	-50.	297	-52.	324	-54.	351	-56.
217	-46.	244	-48.	271	-50.	298	-52.	325	-54.	352	-56.
218	-46.	245	-48.	272	-50.	299	-52.	326	-54.	353	-56.
219	-46.	246	-48.	273	-50.	300	-52.	327	-54.	354	-56.
220	-46.	247	-48.	274	-50.	301	-52.	328	-54.	355	-56.
221	-46.	248	-48.	275	-50.	302	-52.	329	-54.	356	-56.
222	-46.	249	-48.	276	-50.	303	-52.	330	-54.	357	-56.
223	-46.	250	-48.	277	-50.	304	-52.	331	-54.	358	-56.

```
224  -47.  251  -49.  278  -51.  305  -53.  332  -55.  359  -57.
225  -47.  252  -49.  279  -51.  306  -53.  333  -55.  360  -57.
226  -47.  253  -49.  280  -51.  307  -53.  334  -55.  361  -57.
227  -47.  254  -49.  281  -51.  308  -53.  335  -55.  362  -57.
228  -47.  255  -49.  282  -51.  309  -53.  336  -55.  363  -57.
229  -47.  256  -49.  283  -51.  310  -53.  337  -55.  364  -57.
230  -47.  257  -49.  284  -51.  311  -53.  338  -55.  365  -57.
231  -47.  258  -49.  285  -51.  312  -53.  339  -55.
232  -47.  259  -49.  286  -51.  313  -53.  340  -55.
```

INITIAL CONDITIONS

```
THE WATER CONTENT PROFILE IS GIVEN
node :    1     2     3     4     5     6     7     8     9    10
theta :  .100  .105  .110  .117  .120  .125  .130  .133  .137  .142
prh  : -341. -295. -258. -215. -199. -177. -157. -147. -134. -120.
node :   11    12    13    14    15    16    17    18    19    20
theta :  .144  .146  .148  .150  .152  .154  .156  .157  .156  .156
prh  : -115. -110. -106. -101.  -97.  -93.  -90.  -88.  -90.  -90.
node :   21    22    23    24    25    26    27    28    29    30
theta :  .156  .156  .156  .156  .156  .154  .152  .150  .149  .148
prh  :  -90.  -90.  -90.  -90.  -90.  -93.  -97. -130. -133. -137.
node :   31    32    33    34    35    36    37    38    39    40
  41    42    43    44    45    46    47    48    49    50
  51    52    53    54    55    56    57    58    59    60
  61    62    63    64    65    66    67    68    69    70
  71    72    73    74    75    76    77    78    79    80
  81    82    83    84    85    86    87    88    89    90
  91    92    93    94    95    96    97    98
theta :  .147  .146  .144  .142  .141  .140  .141  .141  .142  .140
  .138  .137  .141  .146  .150  .149  .149  .148  .152  .156
  .160  .160  .161  .161  .158  .155  .152  .147  .142  .138
  .142  .147  .152  .144  .136  .128  .128  .128  .128  .132
  .136  .140  .144  .147  .153  .160  .167  .173  .180  .187
  .193  .180  .180  .180  .180  .180  .180  .180  .180  .180
  .180  .180  .180  .180  .180  .180  .180  .196
prh  : -141. -145. -154. -163. -168. -173. -168. -168. -163. -173.
 -184. -189. -168. -145. -130. -133. -133. -137. -123. -110.
  -98.  -98.  -96.  -96. -104. -113. -123. -141. -163. -184.
 -163. -141. -117. -138. -165. -198. -198. -198. -198. -180.
 -165. -151. -138. -130. -114.  -99.  -85.  -75.  -65.  -56.
  -49.  -65.  -65.  -65.  -65.  -65.  -65.  -65.  -65.  -65.
  -65.  -65.  -65.  -65.  -65.  -65.  -65.  -45.

Initial watercontent of the profile :     89.8 (cm)
```

```
1 W A T E R B A L A N C E  O F  T H E  S O I L : 1989

 1 julian daynumber
 2 precipitation + irrigation
 3 runoff
 4 interception
 5 evaporation of ponding layer
 6 actual transpiration
 7 actual soil evaporation
 8 flux through bottom of the soil profile (- = out)
 9 lateral drainage flux of all drainage levels (- = in)
10 watercontent of the soil profile + ponding layer, end of the day
11 potential transpiration
12 potential soil evaporation

all data are in cm. water.

  1    2      3     4      5      6      7      8      9    10    11     12
day precip runoff interc evpond transp evapor flxbot flxdra endwc transp evapor
nr. period period period period period period period period       period period
     cumu   cumu   cumu   cumu   cumu   cumu   cumu   cumu         cumu   cumu

206  .000  .000  .000  .000  .000  .117  .079  .000 89.8  .000  .864
      .0    .0    .0    .0    .0    .1    .1    .0         .0    .9

207  .000  .000  .000  .000  .000  .034  .010  .000 89.8  .000  .548
      .0    .0    .0    .0    .0    .2    .1    .0         .0   1.4

208  .000  .000  .000  .000  .000  .022 -.004  .000 89.7  .000  .873
      .0    .0    .0    .0    .0    .2    .1    .0         .0   2.3

209  .410  .000  .000  .000  .000  .188 -.011  .000 90.0  .000  .931
      .4    .0    .0    .0    .0    .4    .1    .0         .0   3.2

210  .430  .000  .000  .000  .000  .165 -.016  .000 90.2  .000  .781
      .8    .0    .0    .0    .0    .5    .1    .0         .0   4.0

211  .000  .000  .000  .000  .000  .149 -.020  .000 90.0  .000  .759
      .8    .0    .0    .0    .0    .7    .0    .0         .0   4.8

212 2.560  .000  .000  .000  .000  .700 -.022  .000 91.9  .000  .815
     3.4    .0    .0    .0    .0   1.4    .0    .0         .0   5.6

213  .000  .000  .000  .000  .000  .290 -.023  .000 91.6  .000  .783
     3.4    .0    .0    .0    .0   1.7    .0    .0         .0   6.4
```

```
214  .000  .000  .000  .000  .000  .222 -.023  .000 91.3  .000 1.082
     3.4    .0    .0    .0    .0  1.9    .0    .0         .0  7.4

215  .000  .000  .000  .000  .000  .188 -.024  .000 91.1  .000 1.051
     3.4    .0    .0    .0    .0  2.1   -.1    .0         .0  8.5

216  .000  .000  .000  .000  .000  .165 -.023  .000 90.9  .000 1.029
     3.4    .0    .0    .0    .0  2.2   -.1    .0         .0  9.5

217 2.260  .000  .000  .000  .000  .700 -.023  .000 92.5  .000  .866
     5.7    .0    .0    .0    .0  2.9   -.1    .0         .0 10.4

218  .000  .000  .000  .000  .000  .290 -.022  .000 92.1  .000 1.115
     5.7    .0    .0    .0    .0  3.2   -.1    .0         .0 11.5

219  .000  .000  .000  .000  .000  .222 -.022  .000 91.9  .000  .933
     5.7    .0    .0    .0    .0  3.5   -.1    .0         .0 12.4

220  .000  .000  .000  .000  .000  .188 -.021  .000 91.7  .000 1.096
     5.7    .0    .0    .0    .0  3.6   -.2    .0         .0 13.5

221  .000  .000  .000  .000  .000  .165 -.020  .000 91.5  .000 1.068
     5.7    .0    .0    .0    .0  3.8   -.2    .0         .0 14.6

222  .000  .000  .000  .000  .000  .149 -.020  .000 91.3  .000 1.034
     5.7    .0    .0    .0    .0  4.0   -.2    .0         .0 15.6

223  .000  .000  .000  .000  .000  .131 -.019  .000 91.2  .000  .977
     5.7    .0    .0    .0    .0  4.1   -.2    .0         .0 16.6

224  .250  .000  .000  .000  .000  .128 -.019  .000 91.3  .000  .714
     5.9    .0    .0    .0    .0  4.2   -.2    .0         .0 17.3

225  .000  .000  .000  .000  .000  .007 -.018  .000 91.3  .000  .007
     5.9    .0    .0    .0    .0  4.2   -.3    .0         .0 17.3

226 3.200  .000  .000  .000  .000  .700 -.017  .000 93.7  .000  .917
     9.1    .0    .0    .0    .0  4.9   -.3    .0         .0 18.2

227  .000  .000  .000  .000  .000  .290 -.017  .000 93.4  .000 1.026
     9.1    .0    .0    .0    .0  5.2   -.3    .0         .0 19.3

228  .000  .000  .000  .000  .000  .222 -.016  .000 93.2  .000 1.012
     9.1    .0    .0    .0    .0  5.4   -.3    .0         .0 20.3
```

```
229  .000  .000  .000  .000  .000  .188 -.016  .000 93.0  .000  .969
     9.1    .0    .0    .0    .0   5.6   -.3    .0         .0  21.2

230  .080  .000  .000  .000  .000  .165 -.015  .000 92.9  .000  .719
     9.2    .0    .0    .0    .0   5.8   -.3    .0         .0  22.0

231 1.040  .000  .000  .000  .000  .700 -.015  .000 93.2  .000  .797
    10.2    .0    .0    .0    .0   6.5   -.4    .0         .0  22.8

232  .030  .000  .000  .000  .000  .290 -.014  .000 92.9  .000  .500
    10.3    .0    .0    .0    .0   6.8   -.4    .0         .0  23.3

233  .360  .000  .000  .000  .000  .222 -.014  .000 93.1  .000  .770
    10.6    .0    .0    .0    .0   7.0   -.4    .0         .0  24.0

234  .000  .000  .000  .000  .000  .188 -.013  .000 92.9  .000  .979
    10.6    .0    .0    .0    .0   7.2   -.4    .0         .0  25.0

235  .000  .000  .000  .000  .000  .165 -.013  .000 92.7  .000  .906
    10.6    .0    .0    .0    .0   7.4   -.4    .0         .0  25.9

236  .000  .000  .000  .000  .000  .149 -.012  .000 92.5  .000  .987
    10.6    .0    .0    .0    .0   7.5   -.4    .0         .0  26.9

237  .000  .000  .000  .000  .000  .137 -.012  .000 92.4  .000  .998
    10.6    .0    .0    .0    .0   7.6   -.4    .0         .0  27.9

238  .640  .000  .000  .000  .000  .128 -.012  .000 92.9  .000  .321
    11.3    .0    .0    .0    .0   7.8   -.4    .0         .0  28.2

239  .200  .000  .000  .000  .000  .077 -.011  .000 93.0  .000  .077
    11.5    .0    .0    .0    .0   7.8   -.5    .0         .0  28.3

240  .030  .000  .000  .000  .000  .114 -.011  .000 92.9  .000  .478
    11.5    .0    .0    .0    .0   8.0   -.5    .0         .0  28.8

241  .030  .000  .000  .000  .000  .108 -.011  .000 92.8  .000  .491
    11.5    .0    .0    .0    .0   8.1   -.5    .0         .0  29.3

242  .030  .000  .000  .000  .000  .103 -.011  .000 92.7  .000  .568
    11.6    .0    .0    .0    .0   8.2   -.5    .0         .0  29.8

243 1.070  .000  .000  .000  .000  .700 -.010  .000 93.1  .000  .851
    12.6    .0    .0    .0    .0   8.9   -.5    .0         .0  30.7
```

```
244  .000  .000  .000  .000  .000  .290  -.010  .000  92.8  .000  .505
     12.6   .0    .0    .0    .0   9.2   -.5    .0          .0  31.2

245  .000  .000  .000  .000  .000  .222  -.010  .000  92.5  .000  .582
     12.6   .0    .0    .0    .0   9.4   -.5    .0          .0  31.8

246  .000  .000  .000  .000  .000  .166  -.010  .000  92.4  .000  .952
     12.6   .0    .0    .0    .0   9.5   -.5    .0          .0  32.7

247  .000  .000  .000  .000  .000  .086  -.009  .000  92.3  .000  .942
     12.6   .0    .0    .0    .0   9.6   -.5    .0          .0  33.7

248  .330  .000  .000  .000  .000  .149  -.009  .000  92.4  .000  .837
     13.0   .0    .0    .0    .0   9.8   -.6    .0          .0  34.5

249  .380  .000  .000  .000  .000  .137  -.009  .000  92.7  .000  .468
     13.3   .0    .0    .0    .0   9.9   -.6    .0          .0  35.0

250  .360  .000  .000  .000  .000  .128  -.009  .000  92.9  .000  .939
     13.7   .0    .0    .0    .0  10.0   -.6    .0          .0  35.9

251  .000  .000  .000  .000  .000  .120  -.009  .000  92.8  .000  .906
     13.7   .0    .0    .0    .0  10.2   -.6    .0          .0  36.8

252  .000  .000  .000  .000  .000  .114  -.008  .000  92.6  .000  .949
     13.7   .0    .0    .0    .0  10.3   -.6    .0          .0  37.8

253  .000  .000  .000  .000  .000  .108  -.008  .000  92.5  .000  .785
     13.7   .0    .0    .0    .0  10.4   -.6    .0          .0  38.6

254  .000  .000  .000  .000  .000  .103  -.008  .000  92.4  .000  .903
     13.7   .0    .0    .0    .0  10.5   -.6    .0          .0  39.5

255  .000  .000  .000  .000  .000  .099  -.008  .000  92.3  .000  .576
     13.7   .0    .0    .0    .0  10.6   -.6    .0          .0  40.0

256  .250  .000  .000  .000  .000  .095  -.008  .000  92.5  .000  .769
     13.9   .0    .0    .0    .0  10.7   -.6    .0          .0  40.8

257  .760  .000  .000  .000  .000  .092  -.008  .000  93.1  .000  .832
     14.7   .0    .0    .0    .0  10.8   -.6    .0          .0  41.6

258  .000  .000  .000  .000  .000  .089  -.007  .000  93.0  .000  .854
     14.7   .0    .0    .0    .0  10.9   -.6    .0          .0  42.5
```

```
259  .000  .000  .000  .000  .000  .086  -.007  .000  92.9  .000  .859
     14.7   .0    .0    .0    .0   11.0   -.6    .0          .0   43.3

260  .000  .000  .000  .000  .000  .084  -.007  .000  92.8  .000  .784
     14.7   .0    .0    .0    .0   11.0   -.6    .0          .0   44.1

261  .000  .000  .000  .000  .000  .081  -.007  .000  92.7  .000  .690
     14.7   .0    .0    .0    .0   11.1   -.7    .0          .0   44.8

262  .000  .000  .000  .000  .000  .079  -.007  .000  92.7  .000  .590
     14.7   .0    .0    .0    .0   11.2   -.7    .0          .0   45.4

263  .000  .000  .000  .000  .000  .077  -.007  .000  92.6  .000  .719
     14.7   .0    .0    .0    .0   11.3   -.7    .0          .0   46.1

264  .000  .000  .000  .000  .000  .075  -.007  .000  92.5  .000  .830
     14.7   .0    .0    .0    .0   11.4   -.7    .0          .0   47.0

265  .050  .000  .000  .000  .000  .074  -.007  .000  92.5  .000  .252
     14.8   .0    .0    .0    .0   11.4   -.7    .0          .0   47.2

266  .000  .000  .000  .000  .000  .072  -.007  .000  92.4  .000  .768
     14.8   .0    .0    .0    .0   11.5   -.7    .0          .0   48.0

267  .000  .000  .000  .000  .000  .071  -.007  .000  92.3  .000  .776
     14.8   .0    .0    .0    .0   11.6   -.7    .0          .0   48.8

268  .000  .000  .000  .000  .000  .069  -.006  .000  92.2  .000  .791
     14.8   .0    .0    .0    .0   11.6   -.7    .0          .0   49.6

269  .000  .000  .000  .000  .000  .068  -.006  .000  92.2  .000  .769
     14.8   .0    .0    .0    .0   11.7   -.7    .0          .0   50.3

270  .000  .000  .000  .000  .000  .067  -.006  .000  92.1  .000  .792
     14.8   .0    .0    .0    .0   11.8   -.7    .0          .0   51.1

271  .000  .000  .000  .000  .000  .055  -.006  .000  92.0  .000  .743
     14.8   .0    .0    .0    .0   11.8   -.7    .0          .0   51.9

272  .000  .000  .000  .000  .000  .040  -.006  .000  92.0  .000  .747
     14.8   .0    .0    .0    .0   11.9   -.7    .0          .0   52.6

273  .000  .000  .000  .000  .000  .036  -.006  .000  91.9  .000  .746
     14.8   .0    .0    .0    .0   11.9   -.7    .0          .0   53.3
```

```
274  .000  .000  .000  .000  .000  .033 -.006  .000 91.9  .000  .741
     14.8   .0   .0   .0   .0 11.9  -.7   .0        .0 54.1

275  .000  .000  .000  .000  .000  .030 -.006  .000 91.9  .000  .712
     14.8   .0   .0   .0   .0 12.0  -.7   .0        .0 54.8

276  .200  .000  .000  .000  .000  .060 -.006  .000 92.0  .000  .738
     15.0   .0   .0   .0   .0 12.0  -.7   .0        .0 55.5

277  .180  .000  .000  .000  .000  .060 -.006  .000 92.1  .000  .400
     15.1   .0   .0   .0   .0 12.1  -.8   .0        .0 55.9

278  .000  .000  .000  .000  .000  .059 -.006  .000 92.0  .000  .537
     15.1   .0   .0   .0   .0 12.1  -.8   .0        .0 56.5

279  .000  .000  .000  .000  .000  .058 -.006  .000 92.0  .000  .645
     15.1   .0   .0   .0   .0 12.2  -.8   .0        .0 57.1

280  .000  .000  .000  .000  .000  .057 -.006  .000 91.9  .000  .645
     15.1   .0   .0   .0   .0 12.3  -.8   .0        .0 57.8

281  .760  .000  .000  .000  .000  .056 -.006  .000 92.6  .000  .172
     15.9   .0   .0   .0   .0 12.3  -.8   .0        .0 57.9

282  .000  .000  .000  .000  .000  .056 -.006  .000 92.5  .000  .630
     15.9   .0   .0   .0   .0 12.4  -.8   .0        .0 58.6

283  .000  .000  .000  .000  .000  .055 -.006  .000 92.5  .000  .639
     15.9   .0   .0   .0   .0 12.4  -.8   .0        .0 59.2

284  .000  .000  .000  .000  .000  .054 -.005  .000 92.4  .000  .627
     15.9   .0   .0   .0   .0 12.5  -.8   .0        .0 59.8

285  .000  .000  .000  .000  .000  .054 -.005  .000 92.4  .000  .585
     15.9   .0   .0   .0   .0 12.5  -.8   .0        .0 60.4

286  .000  .000  .000  .000  .000  .053 -.005  .000 92.3  .000  .617
     15.9   .0   .0   .0   .0 12.6  -.8   .0        .0 61.0

287  .000  .000  .000  .000  .000  .052 -.005  .000 92.2  .000  .604
     15.9   .0   .0   .0   .0 12.6  -.8   .0        .0 61.6

288  .000  .000  .000  .000  .000  .052 -.005  .000 92.2  .000  .610
     15.9   .0   .0   .0   .0 12.7  -.8   .0        .0 62.2
```

```
289  .000  .000  .000  .000  .000  .051  -.005  .000  92.1  .000  .611
     15.9   .0    .0    .0    .0   12.7   -.8    .0          .0   62.9

290  .000  .000  .000  .000  .000  .051  -.005  .000  92.1  .000  .532
     15.9   .0    .0    .0    .0   12.8   -.8    .0          .0   63.4

291  .000  .000  .000  .000  .000  .050  -.005  .000  92.0  .000  .554
     15.9   .0    .0    .0    .0   12.8   -.8    .0          .0   63.9

292  .000  .000  .000  .000  .000  .050  -.005  .000  92.0  .000  .543
     15.9   .0    .0    .0    .0   12.9   -.8    .0          .0   64.5

293  .030  .000  .000  .000  .000  .049  -.005  .000  91.9  .000  .221
     15.9   .0    .0    .0    .0   12.9   -.8    .0          .0   64.7

294  .000  .000  .000  .000  .000  .049  -.005  .000  91.9  .000  .484
     15.9   .0    .0    .0    .0   13.0   -.8    .0          .0   65.2

295  .000  .000  .000  .000  .000  .048  -.005  .000  91.8  .000  .518
     15.9   .0    .0    .0    .0   13.0   -.9    .0          .0   65.7

296  .000  .000  .000  .000  .000  .048  -.005  .000  91.8  .000  .526
     15.9   .0    .0    .0    .0   13.1   -.9    .0          .0   66.2

297  .000  .000  .000  .000  .000  .047  -.005  .000  91.7  .000  .519
     15.9   .0    .0    .0    .0   13.1   -.9    .0          .0   66.8

298  .000  .000  .000  .000  .000  .038  -.005  .000  91.7  .000  .447
     15.9   .0    .0    .0    .0   13.2   -.9    .0          .0   67.2

299  .000  .000  .000  .000  .000  .031  -.005  .000  91.6  .000  .512
     15.9   .0    .0    .0    .0   13.2   -.9    .0          .0   67.7

300  .000  .000  .000  .000  .000  .025  -.005  .000  91.6  .000  .501
     15.9   .0    .0    .0    .0   13.2   -.9    .0          .0   68.2

301  .000  .000  .000  .000  .000  .024  -.005  .000  91.6  .000  .508
     15.9   .0    .0    .0    .0   13.3   -.9    .0          .0   68.7

302  .000  .000  .000  .000  .000  .023  -.005  .000  91.5  .000  .459
     15.9   .0    .0    .0    .0   13.3   -.9    .0          .0   69.2

303  .000  .000  .000  .000  .000  .022  -.005  .000  91.5  .000  .466
     15.9   .0    .0    .0    .0   13.3   -.9    .0          .0   69.6
```

```
304  .000  .000  .000  .000  .000  .022  -.005  .000  91.5  .000  .252
     15.9   .0    .0    .0    .0  13.3   -.9    .0          .0  69.9

305  .000  .000  .000  .000  .000  .022  -.005  .000  91.5  .000  .399
     15.9   .0    .0    .0    .0  13.3   -.9    .0          .0  70.3

306  .000  .000  .000  .000  .000  .017  -.005  .000  91.4  .000  .429
     15.9   .0    .0    .0    .0  13.4   -.9    .0          .0  70.7

307  .000  .000  .000  .000  .000  .019  -.005  .000  91.4  .000  .403
     15.9   .0    .0    .0    .0  13.4   -.9    .0          .0  71.1

308  .000  .000  .000  .000  .000  .017  -.005  .000  91.4  .000  .419
     15.9   .0    .0    .0    .0  13.4   -.9    .0          .0  71.6

309  .000  .000  .000  .000  .000  .019  -.005  .000  91.4  .000  .438
     15.9   .0    .0    .0    .0  13.4   -.9    .0          .0  72.0

310  .000  .000  .000  .000  .000  .014  -.005  .000  91.4  .000  .364
     15.9   .0    .0    .0    .0  13.4   -.9    .0          .0  72.4

311  .000  .000  .000  .000  .000  .016  -.005  .000  91.3  .000  .438
     15.9   .0    .0    .0    .0  13.4   -.9    .0          .0  72.8

312  .000  .000  .000  .000  .000  .016  -.005  .000  91.3  .000  .416
     15.9   .0    .0    .0    .0  13.5   -.9    .0          .0  73.2

313  .000  .000  .000  .000  .000  .017  -.005  .000  91.3  .000  .414
     15.9   .0    .0    .0    .0  13.5   -.9    .0          .0  73.6

314  .000  .000  .000  .000  .000  .014  -.005  .000  91.3  .000  .396
     15.9   .0    .0    .0    .0  13.5   -.9    .0          .0  74.0

315  .000  .000  .000  .000  .000  .015  -.005  .000  91.3  .000  .398
     15.9   .0    .0    .0    .0  13.5  -1.0    .0          .0  74.4

316  .000  .000  .000  .000  .000  .014  -.005  .000  91.2  .000  .330
     15.9   .0    .0    .0    .0  13.5  -1.0    .0          .0  74.7

317  .000  .000  .000  .000  .000  .014  -.005  .000  91.2  .000  .386
     15.9   .0    .0    .0    .0  13.5  -1.0    .0          .0  75.1

318  .000  .000  .000  .000  .000  .014  -.005  .000  91.2  .000  .376
     15.9   .0    .0    .0    .0  13.5  -1.0    .0          .0  75.5
```

```
319  .000  .000  .000  .000  .000  .016  -.005  .000  91.2  .000  .403
    15.9   .0   .0   .0   .0  13.6  -1.0   .0        .0  75.9

320  .000  .000  .000  .000  .000  .013  -.005  .000  91.2  .000  .370
    15.9   .0   .0   .0   .0  13.6  -1.0   .0        .0  76.3

321  .000  .000  .000  .000  .000  .013  -.005  .000  91.1  .000  .319
    15.9   .0   .0   .0   .0  13.6  -1.0   .0        .0  76.6

322  .000  .000  .000  .000  .000  .013  -.005  .000  91.1  .000  .435
    15.9   .0   .0   .0   .0  13.6  -1.0   .0        .0  77.0

323  .000  .000  .000  .000  .000  .012  -.005  .000  91.1  .000  .136
    15.9   .0   .0   .0   .0  13.6  -1.0   .0        .0  77.2

324  .000  .000  .000  .000  .000  .009  -.005  .000  91.1  .000  .472
    15.9   .0   .0   .0   .0  13.6  -1.0   .0        .0  77.6

325  .150  .000  .000  .000  .000  .039  -.005  .000  91.2  .000  .482
    16.1   .0   .0   .0   .0  13.7  -1.0   .0        .0  78.1

326  .200  .000  .000  .000  .000  .038  -.005  .000  91.3  .000  .469
    16.3   .0   .0   .0   .0  13.7  -1.0   .0        .0  78.6

327  .000  .000  .000  .000  .000  .038  -.005  .000  91.3  .000  .393
    16.3   .0   .0   .0   .0  13.7  -1.0   .0        .0  79.0

328  .000  .000  .000  .000  .000  .038  -.005  .000  91.3  .000  .347
    16.3   .0   .0   .0   .0  13.8  -1.0   .0        .0  79.3

329  .000  .000  .000  .000  .000  .038  -.005  .000  91.2  .000  .467
    16.3   .0   .0   .0   .0  13.8  -1.0   .0        .0  79.8

330  .000  .000  .000  .000  .000  .037  -.005  .000  91.2  .000  .430
    16.3   .0   .0   .0   .0  13.9  -1.0   .0        .0  80.2

331  .000  .000  .000  .000  .000  .037  -.005  .000  91.1  .000  .401
    16.3   .0   .0   .0   .0  13.9  -1.0   .0        .0  80.6

332  .000  .000  .000  .000  .000  .037  -.005  .000  91.1  .000  .189
    16.3   .0   .0   .0   .0  13.9  -1.0   .0        .0  80.8

333  .000  .000  .000  .000  .000  .037  -.005  .000  91.1  .000  .296
    16.3   .0   .0   .0   .0  14.0  -1.0   .0        .0  81.1
```

```
334  .000  .000  .000  .000  .000  .030  -.005  .000  91.0  .000  .325
    16.3   .0    .0    .0    .0   14.0  -1.0    .0         .0   81.4

335  .000  .000  .000  .000  .000  .017  -.005  .000  91.0  .000  .321
    16.3   .0    .0    .0    .0   14.0  -1.1    .0         .0   81.8

336  .000  .000  .000  .000  .000  .015  -.005  .000  91.0  .000  .334
    16.3   .0    .0    .0    .0   14.0  -1.1    .0         .0   82.1

337  .000  .000  .000  .000  .000  .016  -.005  .000  91.0  .000  .375
    16.3   .0    .0    .0    .0   14.0  -1.1    .0         .0   82.5

338  .000  .000  .000  .000  .000  .014  -.005  .000  90.9  .000  .385
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   82.9

339  .000  .000  .000  .000  .000  .015  -.005  .000  90.9  .000  .385
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   83.2

340  .000  .000  .000  .000  .000  .013  -.005  .000  90.9  .000  .349
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   83.6

341  .000  .000  .000  .000  .000  .014  -.005  .000  90.9  .000  .384
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   84.0

342  .000  .000  .000  .000  .000  .011  -.005  .000  90.9  .000  .364
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   84.3

343  .000  .000  .000  .000  .000  .012  -.005  .000  90.8  .000  .366
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   84.7

344  .000  .000  .000  .000  .000  .012  -.005  .000  90.8  .000  .352
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   85.1

345  .000  .000  .000  .000  .000  .011  -.005  .000  90.8  .000  .261
    16.3   .0    .0    .0    .0   14.1  -1.1    .0         .0   85.3

346  .000  .000  .000  .000  .000  .010  -.005  .000  90.8  .000  .330
    16.3   .0    .0    .0    .0   14.2  -1.1    .0         .0   85.6

347  .000  .000  .000  .000  .000  .012  -.005  .000  90.8  .000  .337
    16.3   .0    .0    .0    .0   14.2  -1.1    .0         .0   86.0

348  .000  .000  .000  .000  .000  .012  -.005  .000  90.8  .000  .370
    16.3   .0    .0    .0    .0   14.2  -1.1    .0         .0   86.4
```

```
349  .000  .000  .000  .000  .000  .012 -.005  .000 90.7  .000  .258
     16.3   .0    .0    .0    .0  14.2  -1.1   .0         .0  86.6

350  .000  .000  .000  .000  .000  .000 -.005  .000 90.7  .000  .000
     16.3   .0    .0    .0    .0  14.2  -1.1   .0         .0  86.6

351  .000  .000  .000  .000  .000  .016 -.005  .000 90.7  .000  .286
     16.3   .0    .0    .0    .0  14.2  -1.1   .0         .0  86.9

352  .000  .000  .000  .000  .000  .007 -.005  .000 90.7  .000  .330
     16.3   .0    .0    .0    .0  14.2  -1.1   .0         .0  87.2

353  .000  .000  .000  .000  .000  .010 -.005  .000 90.7  .000  .360
     16.3   .0    .0    .0    .0  14.2  -1.1   .0         .0  87.6

354  .000  .000  .000  .000  .000  .009 -.005  .000 90.7  .000  .358
     16.3   .0    .0    .0    .0  14.2  -1.2   .0         .0  87.9

355  .000  .000  .000  .000  .000  .010 -.005  .000 90.7  .000  .340
     16.3   .0    .0    .0    .0  14.2  -1.2   .0         .0  88.3

356  .000  .000  .000  .000  .000  .009 -.005  .000 90.6  .000  .295
     16.3   .0    .0    .0    .0  14.3  -1.2   .0         .0  88.6

357  .000  .000  .000  .000  .000  .009 -.005  .000 90.6  .000  .313
     16.3   .0    .0    .0    .0  14.3  -1.2   .0         .0  88.9

358  .000  .000  .000  .000  .000  .009 -.006  .000 90.6  .000  .353
     16.3   .0    .0    .0    .0  14.3  -1.2   .0         .0  89.2

359  .000  .000  .000  .000  .000  .010 -.006  .000 90.6  .000  .316
     16.3   .0    .0    .0    .0  14.3  -1.2   .0         .0  89.6

360  .000  .000  .000  .000  .000  .009 -.006  .000 90.6  .000  .177
     16.3   .0    .0    .0    .0  14.3  -1.2   .0         .0  89.7

361  .000  .000  .000  .000  .000  .009 -.006  .000 90.6  .000  .165
     16.3   .0    .0    .0    .0  14.3  -1.2   .0         .0  89.9

362  .100  .000  .000  .000  .000  .032 -.006  .000 90.6  .000  .202
     16.4   .0    .0    .0    .0  14.3  -1.2   .0         .0  90.1

363 1.070  .000  .000  .000  .000  .000 -.006  .000 91.7  .000  .000
     17.4   .0    .0    .0    .0  14.3  -1.2   .0         .0  90.1
```

```
364  .180  .000  .000  .000  .000  .065  -.006  .000 91.8  .000  .065
     17.6    .0    .0    .0    .0  14.4  -1.2    .0          .0  90.2

365  .030  .000  .000  .000  .000  .222  -.005  .000 91.6  .000  .382
     17.7    .0    .0    .0    .0  14.6  -1.2    .0          .0  90.6


day precip runoff interc evpond transp evapor flxbot flxdra endwc transp evapor
 1    2      3      4      5      6      7      8      9    10     11     12


error in water balance due to discretisation :    .023 %
```