Evaluation of farm dam area-height-capacity relationships required for basin-scale hydrological catchment modelling

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Abstract

Farm dams form an integral part of basin-scale hydrological catchment modelling in developed regions such as the W. Cape, South Africa. In order to evaluate evaporation losses and demands supplied from farm dams, knowledge of the individual farm dam area-height-capacity relationships is required. The number of farm dams in the W. Cape water resource study total more than 4 000 with a combined storage estimated to be in excess of 120×1 (l^6 m3 In view of this large number of dams, a method was developed whereby the area-height-capacity relationships of these dams could be obtained economically, to an acceptable degree of accuracy, using a minimum of manual intervention and individual farm dam processing. This paper discusses the method used for evaluation of individual farm dam area-height-capacity relationships in the W. Cape.

Introduction

The assessment of the existing water resources and planning of further development was undertaken as part of the Western Cape System Analysis (WCSA). To perform this system analysis, monthly flow sequences are required at a range of locations along rivers in four basins comprising the study area. These are generated using a calibrated catchment model and a suite of other routines.

To calibrate the catchment model, various water demands within catchments have to be evaluated. These include consumption by forestry and irrigation, transpiration losses, evaporation and demands from standing water bodies such as farm dams and reservoirs. For this latter item, the evaluation of individual farm dam area-height-capacity relationships is required.

The number of farm dams in the four basins comprising the study area, namely the Berg, Palmiet, Riviersonderend and Eerste River basins, total more than 4 000 with a combined storage estimated to be in excess of 120×10^6 nr\ This is approximately equal to the combined storage of Lower and Upper Steenbras Dams and Wemmmershoek Dam. Various studies (Maaren and Moolman, 1985; Pitman and Pullen, 1989; Tarboton and Schulze, 1990) have shown that farm dams can have a significant effect on streamflow. These studies, mostly case-specific, have noted trends of larger effects in low mean annual runoff regions, significant effects in consecutive dry years, effects on streamflow variability and trends in ratios of dam surface area to catchment areas. In view of the large number of dams and their effect on streamflow, it has become necessary to devise a method whereby the area-height-capacity relationships of the dams could be obtained economically, to an acceptable degree of accuracy, using a minimum of manual intervention and individual farm dam processing. This paper discusses the method used for the evaluation of area-height-capacity relationships of farm dams in the W. Cape.

Data

Throughout the WCSA study, aerial photographs were used extensively for measurement of land use (e.g. irrigation and afforestation areas). It was thus also decided to utilise these photographs for digitising farm dam data, and consequently to process these data to render the area-height-capacity relationship of each dam.

With the aid of 1:10 000 scaled diapositives developed from 1:35 000 scaled aerial photographs, raw data (x,y,z co-ordinates) for a digital terrain model of each dam were constructed using a stereo photographic digitiser. Aerial photographs, taken at the end of summer when dams were near empty, were used.

Each digitised farm dam was described by the following level specifications: water level (WL), two intermediate levels (where possible), full-supply level (FSL), top of dam wall level and the level of the downstream toe of the embankment.

Problem description

Using the digitised data, the farm dam area-height-capacity relationship above the WL contour was easily calculated except when the dam was full at the time of aerial photography; when the dam was not full, at least two or more contours could be recorded (e.g. the WL contour and the FSL contour). With contour averaging (Fig. 1), the areas circumscribed by these contours and the height difference between the contours allowed the farm dam volume above the water surface to be calculated reasonably accurately.
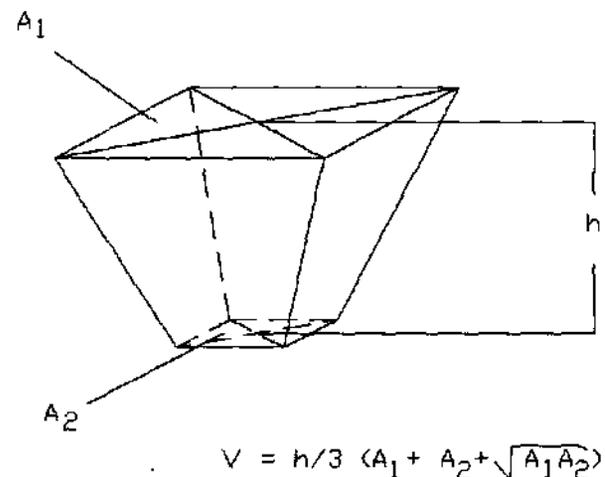

$$V = h/3 \ (A_1 + A_2 + \sqrt{A_1 A_2})$$

Figure 1
Equation used for volume calculation when contour averaging