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# HAROLD EDWIN HURST

## Father of the Nile, NRIAG Director (**1918 – 1924 )**

1 January 1880-7 December 1978

The name of Dr H. E. Hurst will for most be linked with the study of the River Nile, but at the same time he will be remembered for his pioneering study of persistence in hydrological phenomena, a topic which was drawn to his attention by his studies of the long-term Nile records with which he worked over many years.

Harold Edwin Hurst was born in 1880 near Leicester and left school at 15 to train as a teacher. He later won a scholarship which enabled him to go to Oxford University in 1900, where he obtained a first class honours degree in physics. He remained at Oxford for three years as a lecturer and demonstrator, while doing research on the discharge of electricity in gases.

In 1906, Sir Henry Lyons, then Director-General of the Survey of Egypt, visited Oxford and mentioned the opportunities for scientific work in Egypt. As a result, Hurst applied for a post and started work in the Survey Department in October 1906. This was the start of a unique career in the service of the Egyptian Government, which lasted from 1906 to 1968, through a number of changes of regime from Lord Cromer to President Nasser.

Hurst's career started in terrestrial magnetism and astronomy—he was in charge of the magnetic survey of Egypt—but was from the beginning also concerned with meteorology and water. In 1913, he became head of the Meteorological Service, which also recorded data about the Nile. In 1915, the physical work of the Survey and the hydrological work were combined in the Physical Department of the

Ministry of Public Works, of which Hurst became the head. At this time a number of projects for the control and conservation of Nile waters had been proposed, but there was a need for physical measurements of rainfall and river flow over a vast network of tributaries before these proposals could be designed in engineering terms. The Physical Department under Hurst's leadership was responsible for collecting data throughout the Nile basin in Egypt, Sudan and East Africa, and for a large amount of related research. The results of this work were published in the numerous volumes of Nile Basin which, with their supplements covering a succession of five-year periods, provide a massive documentary account of the rainfall, discharge measurements, river levels and river flows at a hundred sites throughout the basin. The set of volumes, which provides the most thorough statistics for any river in existence, includes descriptions of the different basins and their hydrology, and was accompanied by a number of research papers published by the Physical Department on related topics like flow measurement techniques and sediment load.

Before he retired from the post of Director-General of the Physical Department in 1946, Vol. VII of Nile Basin was published, entitled 'The Future Conservation of the Nile' by Hurst, Black and Simaika. This proposed the supplementation of reservoirs designed to store the annual flood by large and long-term over-year storage, which they called 'century storage'. This control was to be effected by reservoirs in Lake Victoria and Lake Albert, with the construction of the Jonglei Canal Diversion Scheme to reduce transmission losses in the swamps of the Sudd region, together with reservoirs on the main Nile and on Lake Tana. The concept of century storage and the relationship between yield and reservoir capacity was based on a study of annual flows and the relationship between range, or the maximum accumulated departure from the mean or draft, the standard deviation of the flows, and the number of years of record.

It was shown that the relationship between range and number of years was different if the order of the observations was preserved, from the value using an arbitrary order, or in other words that dry and wet years are clustered. If the ratio of range to standard deviation R„/S„ is expressed as nh, then 1.0>A>0.5 for natural phenomena, whereas h tends to 0.5 for independent series. For a large number of phenomena, such as river flows, rainfall, temperature, tree rings and mud varves, Hurst found that the average value of h was 0.72 with a standard deviation of 0.09. The discrepancy between 0.72 and the theoretical value of 0.5 predicted by classical theory is known as the Hurst phenomenon. The theory of storage was further developed in The Nile published in 1952 and Long-Term Storage in 1965. The latter was sub-titled 'An experimental study' and this aptly describes the approach. The theoretical relationship between range and sample size for an independent process was tested by an experiment in which sixpences were shaken in a box and thrown on to a table; it was not until later that the relationship was derived mathematically by Feller. After his initial findings, Hurst continued to pursue an explanation of the phenomenon he had discovered. The first model which reproduced the Hurst phenomenon was devised by him with a card experiment which reproduced a normal distribution with a random shift in the mean introduced at random intervals determined by the cutting of a joker in a probability pack. This card experiment reproduced a value of h of about 0.72, which was similar to that found in the case of natural phenomena. This ingenious model was not superseded for a number of years by models which had a rigorous mathematical basis.

These researches were carried out for an immediate practical purpose, and were soon translated into practical engineering works. Although the specific proposals for conservation projects which were based on the concept of century storage were replaced by the proposal for the Aswan High Dam, the principles of long-term storage were retained in this large reservoir on the main Nile, and indeed the other conservation projects like the Jonglei Canal have recently come back into prominence. At the same time the Hurst phenomenon has given rise to a number of research studies. For instance, Wallis and Mandelbrot note in 1968 that 'we are indebted to Harold Edwin Hurst for the remarkable empirical discovery that the log R/S curves of hydrologie records typically have slopes that exceed 0.5'; they quote Lloyd's statement of 1967 that 'we are, then, in one of those situations, so salutary for theoreticians, in which empirical discoveries stubbornly refuse to accord with theory. All of the researches described above lead to the conclusion that in the long run R(n) should increase like n°5, whereas Hurst's extraordinarily well documented empirical law shows an increase like nh, where h is about 0.7. We are forced to the conclusion that either the theorists' interpretation of their own work is inadequate or their theories are falsely based; possibly both conclusions apply'. There is no space to describe the various theories or models which have been suggested by a number of eminent statisticians and engineers to explain the Hurst phenomenon; it is sufficient to say that few men can in their lifetime have seen achievements so diverse as the Nile projects, whose construction was based on the hydrological observations and theories for which he was responsible, and also a continuing scientific controversy to explain the observations.

Dr Hurst was created a Companion of St Michael and St George, and awarded a DSc by Oxford University and a Telford Gold Medal by the Institution of Civil Engineers; he continued as Scientific Consultant to the Egyptian Ministry of Public Works to the age of 88. He continued to take an interest in matters of hydrology and Nile development and to attend scientific meetings and seminars. Perhaps the most appropriate honour he received was that of Grand Officier de l'Ordre du Nil.