Civilization—the basis for water science

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Abstract The paper explores the alternative to the common view that civilization developed as a result of the ability to harness and manage large quantities of water for irrigation and public water supply. The “classical” view is dominated by events in Mesopotamia and the Nile and Indus valleys 4000–6000 years BP and is closely linked with urban development. The paper revisits the definition of “civilization” and considers the view that civilization is to be measured by the degree of independence from nature and that urbanization is not a necessary component. Although urbanization has been important in the progress of civilization, towns have developed away from large rivers and even without an organized water supply. The author argues that civilized ideas, aspirations and knowledge preceded the development of water science and engineering. Whilst the latter enables economic and social development, it is not essential for a civilized existence. It is also clear that most early manipulation of water was undertaken without a true scientific understanding, which has largely developed only in the last 400 years.

Key words civilization; urbanization; water engineering; water science

INTRODUCTION

The title of this symposium appears to be based on two fundamental propositions: first, that the invention of water science and engineering was critical to the development of civilization, and second, that the subsequent and continuing development of water science and engineering methods have been critical to the progress of civilization, and, indeed, are vital to its future.

The propositions are strong and persuasive. Not so long ago, I wrote the following rather simplistic thumbnail sketch:

“*The ability of the human race to manipulate water in the environment, to redistribute it in time and space, is one of the major characteristics that sets civilized man apart from the rest of the living world. Mankind took a giant step about 6000 years ago in Mesopotamia by diverting river water for use in irrigated agriculture. These first hydraulic engineers freed man from subsistence agriculture and enabled tradable agricultural surpluses to be created. In turn, this permitted the job specialization and extensive socio-economic re-organization that led to the development of the first cities, the Urban Revolution, and the development of writing to manage these new city states and their trade. Civilization was born. Even when urban civilization spread to better watered regions, it still required dams, aqueducts, pipes and drains to service man in his built environment.*

*Throughout history, water engineering has lain at the very foundation of civilization itself. States have fallen for lack of adequate provision. In the modern*
world, we can see the retreat of settlements from the desert margins as the mismanagement of soil and water resources combines with natural climatic stress. Indeed, the dual impact of agriculture and urban society has permanently altered global hydrology. Wherever they have spread, they have so modified the surface of the earth that the flows and exchanges of water bear their imprint, in some cases millennia after the impact occurred. Water has been an important element in the many-sided conflict between civilization and nature, and the roots of the conflict were present at the dawn of history” (Jones, 1997).

Nevertheless, the conference title ends with a question mark, and this paper is devoted to that query. There seem to be two logical alternate propositions: (1) that civilization is not dependent on water science, or, indeed, (2) that the causality could be reversed, that civilization has been the mainspring for the development of water science.

The first of these alternates may be interpreted in two ways: (1) that civilization and water science are independent, as a statistician would view independence, or (2) that civilization, at least, may exist without water science and engineering. The second interpretation is the stronger, and it seems axiomatic that water science and engineering cannot exist without civilization.

The weight of historical evidence does support the view that the manipulation of water resources has been instrumental and even essential for the progress of many obvious aspects of “civilization”, such as the growth of towns and the production of agricultural surpluses. However, we will be testing two premises in this paper: (1) that civilization can develop and exist without manipulating water resources, and (2) that water science and engineering are “products” of civilization rather than basic causes or enablers of civilization.

DEFINITIONS

We immediately encounter semantic problems with the most basic concepts. Ultimately, there is no universally accepted definition of “civilization”. In his book Civilizations, the eminent Oxford historian, Filipe Fernández-Armesto, has argued that all criteria for defining and measuring civilization are arbitrary and that they are generally based on the values of a particular time and place, e.g. 21st century western civilization (Fernández-Armesto, 2000). He further argues that there is no universal line of “progress” within civilizations. The development of urbanization, for example, though commonly taken as a hallmark of civilization, he sees as just one possible route, but not an essential one. For him, the critical mark of civilization is detachment from nature, the ability to adapt nature. “Civilization makes its own habitat” he says in the Preface (op.cit., p.vii), whether by modifying nature or by insulating itself from the environment. Fernández-Armesto deliberately structures his book to cover some of the most inhospitable environments first. The relatively hospitable alluvial floodplains at a time of drying climatic trends, e.g. Mesopotamia 6000 years ago, where many conventional historians have claimed civilization started, are relegated to chapter 4, after ice and deserts, semiarid grasslands and environments with excessive water.

There could even be a problem defining “water science”. Did Tibetan farmers really need to be displaying a knowledge of water science when they diverted small mountain
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streams by a few metres in order to irrigate their fields? Or is the collection of rainwater from roofs evidence of water science? I don’t think so. Grand Vizier Joseph’s prediction of seven lean years caused by a series of exceptionally high annual floods on the Nile, that drowned the livestock, washed away the villages and did not recede in time for the proper sowing of the fields, merits the title of “water science” far more. The date of Joseph’s prophecy was around 1660–1650 BC, according to David Rohl’s (2002) revised chronology, and its accuracy has been verified from an analysis of flood peak levels carved on the Semna Gorge (ibid., 164). In fact, Joseph’s interpretation of Pharaoh’s dream could rank as the most sophisticated hydrological prediction prior to the work of Roman civil engineers, like Vitruvius, at the beginning of the Christian era. Indeed, Joseph’s prediction was a “one off” and it was not until the 20th century that the British engineer H. E. Hurst devised his scientific theory of “persistence” in river flows that now bears his name, based on observation of the self-same river.

THE EVIDENCE

Let us look first at the traditional “cradles of civilization”, the alluvial plains of the Nile, Mesopotamia and the Indus, where the manipulation of water was certainly an important factor in the development of the outward trappings of civilization. Irrigation is thought to have begun in the Indus valley around 4500 BC and immediately increased the size and prosperity of the agricultural settlements, although walled towns did not appear there for another 1000 years and true cities, like Harappa and Mohenjo-Daro, were not found until 2500 BC. Mohenjo-Daro, with about 40,000 inhabitants, had a sophisticated system of drains and main sewers. In Egypt, walled towns appeared around 3400 BC and the city of Memphis appeared with the unification of Egypt in 3100 BC. As elsewhere in the Middle East, large areas of the alluvial flood plains provided naturally fertile lands that were regularly replenished by mud deposited in the annual floods. All that was required to create a large surplus of grain was irrigation during the growing season. In contrast, at Uruk, the first city-state of Sumeria founded on the Tigris–Euphrates delta around 3500 BC, the essential technical problem was land drainage rather than irrigation: once the swamps were drained the environment was fertile as well as bountiful. Nevertheless, in Fernandez-Armesto’s words:

“Civilization did not “originate” on alluvial soils (although they may have helped it along). Neither did agriculture. (But it) fed a particular kind of civilization: a form of agrarian mass production..... It used to be said that the “hydraulics” of these societies turned them into despotisms..... The complexities of water-management made them prey to organizing intelligences.

Our own agriculture is its lineal descendant..... It is therefore easy to see how students have simply accepted the fact that predecessors in the remote past strove to be like us: as we esteem our own methods the most, so we count every step towards them as progressive” (op. cit., p. 203).

The essential point here is that civilization did not originate with the hydraulic societies. By extension, it is now possible to say that neither did agriculture nor urban
living, and, indeed, that Gordon Childe’s “urban revolution” in Mesopotamia (Childe, 1942) was, like the so-called Neolithic “agricultural revolution”, a slow process of development that occurred gradually in a number of places, in a variety of ways, over a considerable period of time. To say, as Exeter historian Jeremy Black (1999) amongst many others, that the advent of farming brought “large groups of people together into settled communities”, is an over-simplification: there are innumerable examples of small scale, rural agricultural communities that never grew beyond that. And some needed to use water science to operate, others did not, depending on the local water balance.

Our understanding of the early development of agriculture and urban living has changed dramatically since the time of Gordon Childe. One key archaeological site that has been especially instrumental in changing views is Çatalhöyük in modern Turkey. Excavations there in the 1960s revealed a Neolithic settlement that had been occupied between 7000 and 5500 BC by a people who grew crops and domesticated sheep, but still relied heavily on hunting and gathering (Rudgley, 2000). Çatalhöyük was a half-way house in the development of both agriculture and urbanization. The town was a hilltop settlement with courtyards and shrines and a population of around 10 000, and to the best of current archaeological knowledge was probably the largest settlement developed up to that time. But there was no central drainage or water supply; there appears to be no evidence of dams, river diversion or irrigation. There is also no evidence of an hierarchically organized society, and this may add some support to the notion that the great cities of the alluvial floodplains owed more to a hierarchical society dominated by the rule and ambitions of priests and kings than to water science. Note that Çatalhöyük was not a temporary settlement. It survived for 1500 years and left a mound 15 m high. There is abundant evidence of religion and art, and the town was the focus of a major, long distance trading network. Interestingly, no evidence of warfare has been found.

The temple town of Asiklihöyük on the River Melendiz in Central Anatolia, currently threatened by dam construction, dates from 8000 BC. There appears to be no evidence of waterworks, yet the inhabitants had a social hierarchy, worked copper, paved streets and cultivated cereals. Rudgley (2000) notes that the method of construction used for the main buildings at Asiklihöyük, stone facings with mud infill, was reused 6000 years later in the first Hittite cities. He makes the pertinent point that the historical civilizations of the ancient world built upon the knowledge of the Neolithic civilizations, which in turn continued to use knowledge gained in the Palaeolithic period. There are many continuities; the great cities of the alluvial flood plains did not suddenly appear without antecedents.

The great water scientists of the ancient world were, of course, the Romans. The Romans invented the mass provision of public water supply, of sewerage, showers, public baths, even some flushing toilets. The great Aqua Augusta, built under Marcus Agrippa for the Emperor Augustus in the first century BC, fed what they called the “matrix” of distributary pipes around the Bay of Naples, supplying Pompeii, Herculaneum and the Roman naval base at Misenum. This marvel of civil engineering directed water from the mountains around Sorrento for nearly 100 km to sustain towns where otherwise no town could exist on the basis of the local water resources (Harris, 2003). Rome itself was eventually fed by nine aqueducts, which allowed its population
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to grow from 150 000 at the time of Julius Caesar to over a million in the first century AD. Harris has described the aqueducts as “a quantum leap in civilization”. The Pont du Gard remains one of the greatest wonders of the Mediterranean.

The Romans were building a civilization whose requirements outstripped the local environmental resources. Their civil engineers made it possible, using the new invention of hydraulic cement and concrete. But they also based their work on some degree of water science. In his first century textbook De Diversis Fabricis Architectonicae Faventinus wrote:

“Now springs of water often gush up of their own accord, or they can often bubble up from wells. People who do not enjoy such plenty must use the clues that I give below to trace springs of water below ground, and they must collect in wells the water to be found lower down not far from springs..... So when you are looking for water you should consider the nature of the soils” (Plommer, 1973, p. 45).

The Romans admirably succeeded where the Greeks and others had had more limited success in sustaining large cities in the relatively dry Mediterranean climate. This they achieved partly through pure structural engineering and partly through a greater understanding of the science.

Away from the traditional cradles of civilization, civilizations developed in a great variety of environments with very differing histories. It is difficult to make generalizations and we are often hindered by the lack of attention given to water engineering by many archaeologists. However, it seems true to say that the need to understand water science is: (1) inversely proportional to the available water supply; and (2) proportional to the demands made upon it. Smaller communities generally demand less water and in a well-watered environment may be sustainable without much thought for water. The earliest villages are commonly found along rivers, lakes or coasts where there is little need for water works, e.g. the Neolithic to Iron Age lake villages of Europe. The greatest inventions seem to have been made where water is scarcer, e.g. the qanats of the Middle East and the aqueducts of Rome.

Great Zimbabwe and the ruined cities of Mashonaland date from the turn of the first millennium AD and represent an urban tradition that was largely lost in later centuries. They are now understood to have been built by the ancestors of the present Shona tribe. The towns were built on the hillsides of the Zimbabwe Plateau where rainfall was abundant and there was plentiful grassland for grazing (Stefoff, 1997), and there appears to have been little need for water science or engineering. Like many towns in drier regions, their riches came from international trade and they did not need to produce all the food they required themselves.

The Incas also built towns in the highlands in the 13th century. The classic example is Machu Picchu in the Peruvian Andes, a region with even more abundant rainfall. Local water harvesting must have been practised, but there are no aqueducts or irrigation channels, and the rivers were thousands of metres below. Fernández-Armesto discusses the highland civilizations of Mesoamerica and the Andes under the heading “Gardens of the clouds”, that provided cool and well-watered refuges: the Rain God was their great provider, not water scientists.

Well-watered though most sites were, the biggest cities do show evidence of water engineering at work. Most notable is Tiahuanaco, founded by the Maya in the early centuries AD near Lake Titicaca. Here irrigation channels drew water from the lake for
up to 16 km not only watering the raised bed agriculture, but also protecting it from violent changes in temperature (op. cit., p. 280). But as with the Middle East, so the Aztec and Inca towns of Mesoamerica were not the first urban settlements in the region. They were preceded by proto-cities at least as far back as 1750 BC, which show less sophisticated use of water. Indeed, they had less need for they were much smaller and there would probably have been less incentive to produce a surplus for trade and the trappings of empire than under the rule of the Aztecs or Inca.

A similar situation probably existed further north in the Mississippi basin, where city mounds like Cahokia near St Louis housed about 10 000 people in the early part of the last millennium. Here water was super-abundant, at least during the floods. The application of water science seems to have been limited to constructing platforms of earth to build on and ridges to cultivate crops safely above the floods.

In the above examples, I have largely concentrated on the classic measures of material civilization, yet art and religion, astronomy and mathematics are all trappings of civilization that pre-date any water engineering. The magnificent cave paintings of Lascaux, 17 500 years old, are by no means the earliest art. The Gontzi ivory from the Ukraine, probably the oldest lunar calendar, is a similar age. The megalithic grandeur of Stonehenge (4000–1800 BC) contains a highly sophisticated solar calendar. None of the peoples who created these were water scientists.

Finally, it is plain that until the early modern period most engineering successes were achieved with limited understanding of the science. The so-called “subterranean theory”, holding that rivers are fed by water raised underground from the oceans, generally held sway. Aristotle and Vitruvius were the greatest early advocates of a meteorological source, but their works were either suppressed or mislaid for well over a millennium. Although Da Vinci and Palissy made some theoretical progress in the 16th century, the 17th century field experiments by Perrault and Mariotte mark the real beginnings of modern water science. But quantitative theory had to wait until the hydrogeological work of Darcy, Dupuit and Forchheimer in the 19th century, and the details of land surface processes were not worked out until the 20th century.

CONCLUSIONS

These examples illustrate the diversity of development and dispel any notion that civilizations can only develop when water resources are manipulated, let alone understood. The progress of civilization began slowly and has gradually accelerated. Evolution may be a more fitting term than revolution for much of this time, but there are also discontinuities and there are reversals, and different regions have followed very different pathways. The inventions of irrigation, drainage, public water supply and sewerage were all significant technological advances that have assisted mankind in its proliferation and in the colonization of the globe, as no doubt will new technologies like desalination, long-distance strategic water transfers or even rainmaking, in the 21st century. More people means more brains to advance civilization and assist the mental evolution of mankind. Modern communication systems, like the Internet, assist the exchange of ideas as did the cities in the past. They also release us even more from the need to congregate together in order to exchange ideas: they are the latest step on the
ladder of human communication following the development of language, writing, printing and telecommunications.

Water science and engineering have played an important part in enabling some of this to come about. Irrigation enabled larger crop yields to support larger populations, to fuel trade, to free more members of society from the grind of subsistence and to have time to think. Bigger cities and more trade enabled greater exchange of ideas. In the modern era, public water supply and sanitation have helped in the eradication of disease—though the battle is far from won and is losing ground in many parts of the developing world. Globally, 3.4 million die each year from water-related diseases (WHO, 2001). If malaria had been effectively tackled 30 years ago when effective control measures first became available, Africa’s GDP could now be about $100 billion greater (IWMI, 2003). Safe water is perhaps the greatest challenge for water science this century; far more significant than global warming (cp. Jones, 1999). Polluted water is becoming a potential threat to civilization in some regions.

Nevertheless, in defining what we mean by “civilization” I would go further than Fernández-Armesto. Civilization is not simply to be measured in terms of control of nature. It is a state of mind to be measured in mental achievement: in art, religion, philosophy, science and, yes, water science. Water science should rightly be seen as a product of civilization, not a cause. Nor is it the ultimate foundation or enabler. It is merely a very significant player.

REFERENCES


