Introduction

In every society throughout history, water has always been the vital ingredient that makes life possible. Without adequate water supplies, survival is simply not possible. This importance is reflected in cultures around the globe. With growing populations and climate change, water is becoming more important than ever, and not just in parts of the world that experience water scarcity. We already live in a time of water refugees as large numbers of people are forced to migrate due to insufficient water supplies. There are also increasing reports of violent conflict around water rights. Tensions can and do rise across and inside borders surrounding access to water. Conflict around water will rise as strain on available supplies increases.

For permaculture design, water is the starting point around which a site's plan will unfurl. Water-harvesting earthworks are an aspect of site design that can be the difference between a site that performs poorly and one that thrives. On damaged sites without adequate water, the right earthworks can have unbelievable results. Few things are as exciting as watching a dying site come back to life as soon as the first rains hit the project site.

It is true that humans have done tremendous damage to the Earth. The destruction has been centuries in the making, and tremendous energy has been put into the destruction. Yet herein lies great hope for the future. It has taken colossal amounts of effort, energy, and time to degrade the planet to its present state. With a nearly infinitesimal portion of the energy and time needed to create the destruction, we can heal the damage that has been done. There is no law of nature that humans must be a destructive force on the planet. In fact, through our actions, we can greatly foster life while meeting our own needs. The simple beaver is able to create diverse habitats that become havens for all manner of plants and animals. While beavers are impressive, human beings have the power of creativity and a curiosity that provides us with greater and greater understanding of how nature works. We already have the knowledge to have a greater positive effect on the environment, and our knowledge is growing every year. This book is a look at how you can lay the groundwork to make this possible.

The book is divided into nine chapters and has six appendices to explain how to handle the necessary calculations needed for the earthworks described in the book. Chapter 1 looks at the state of water in the world today and the challenges we face for the future. Chapter 2 looks at one of the most remarkable pieces of water engineering in human history, the ancient Nabatean city of Petra. Petra provides both excellent models for water capture and storage, and a cautionary tale around the inherent dangers in earthworks. Chapter 3 takes a close look at the interactions between soil and water. It also provides some conceptual models for looking at landscapes. This knowledge is very helpful in designing earthworks, as it gives an understanding of water's behavior on the land. Chapter 4 looks at the permaculture design process and its strategies for dealing with the design of complex systems, such as water-harvesting systems. It provides a mental template by which you can look at and design a landscape. Chapter 5 covers specific site aspects that you will need to address in the course of designing and implementing a project on any site, including climate. It also covers the typical tools and machinery involved in design and implementation. Chapter 6 looks at specific techniques for water storage and where those approaches should and should not be used. Chapter 7 covers water interception techniques and cautions surrounding them. Chapter 8 looks at integrating the techniques from Chapters 6 and 7 with the strategies used in permaculture design. Chapter 9 looks at the risk involved when employing water-harvesting earthworks. This chapter will help you to identify when earthworks are a hazard on a site so that you can better know when not to use them. There are also six appendices at the end, providing the equations you will need for designing and costing water-harvesting earthworks.

The book is written so that each chapter lays the foundation for later chapters. As such, it is recommended that you read through the whole book in order, rather than diving straight into the techniques in Chapters 6 and 7. This will give you a better understanding of the subject and will help to prevent disastrous errors that can occur from doing the wrong thing in the wrong place.

1 The State of Water

The Colorado

On March 25, 2014, near the Sea of Cortez in the Sonoran Desert, a jovial crowd gathered in a dry, sandy riverbed flanked by cottonwood and willows on either side. They were there to witness a rare event. The occasion that attracted so much attention was a trickle of water moving along the dry riverbed at the speed of a lazy stroll. Two days earlier, the Morelos Dam had slowly opened the gates to the Colorado River.

This artificial mimicking of the natural spring flows that used to occur was a result of Minute 319 of the International Boundary and Water Commission. On November 20, 2012, both the United States and Mexico agreed to the goal of working toward the restoration of the Colorado River. This was the first time that a water allocation on an international river was made strictly for the environment.

Two months after the release from the dam, the flow of water, dubbed "the pulse," finally reached the Sea of Cortez on May 15. Three days later the Morelos Dam was once again closed, and the pulse ended. While the next four years were to see additional base flows released, these smaller allocations were, in total, less than the pulse flow of 2014. The ongoing base flows have helped to rejuvenate the lower Colorado, and in July of 2016 a sea lion was spotted in the upper estuary for the first time.

What made the pulse so special? Why was an international agreement necessary to restore a fraction of the water that had once fed a thriving, 3,000-square-mile delta? Since the completion of the Hoover Dam in 1936, ten dams have been built along the main stem of the Colorado River—this in addition to the three dams that preceded the Hoover Dam. Add to this the thirty-one major dams along the tributaries of the Colorado, as well as the irrigation channels built into the river system, and it becomes easy to see how the Colorado's flow never reached the sea.

Over the course of the 20th century, the river had come to be claimed for a human population that would grow to 30 million people. It became the source of power generation, irrigation, and municipal water supplies, but the success of these engineering projects came at the expense of the natural environment that ultimately supports those same people.

The Aral

Though the Colorado story has a glimmer of hope to it, a similar story on the other side of the world is an ongoing crisis on a far greater scale. In the 1950s, the Soviet Union redirected the Amu Darya and Syr Darya rivers in order to support desert agriculture in the area around the Aral Sea. The Aral Sea itself was dependent on those rivers to maintain its volume. Without the flow from the rivers, the Sea started to evaporate, leaving behind negative health effects and a ruined economy for tens of millions in the region. Infant mortality rose to a staggering 1 in 10; tuberculosis deaths rose 21 times higher; cancer saw a 10-fold increase; kidney disease rose 15 times higher; and gastritis deaths went up by 15 percent. To add insult to injury, up to 75 percent of the redirected water was wasted.

The water problems didn't end with an evaporating sea. The loss of volume of the sea had a corresponding loss of groundwater levels. This loss of groundwater, in turn, led to increased salinization of the soils of the region. This hindered local plant growth, contributing to erosion, which in turn led to a dependence on fertilizers for agriculture.

Dust storms are now a regular occurrence, with the salt content in the dust being as high as 90 percent, increasing respiratory illness. This salt can be carried a long distance, having harmful effects on agriculture far from the sea itself.

Through evaporation, the Aral split into the North and South Aral Seas in 1990. At that point, the Royal Geographical Society called the Aral Sea "the world's worst disaster." In an attempt to prevent the North Aral Sea from draining, a sand dam was built in the mid-1990s, though it had failed by the end of the decade. With funding from the World Bank, a new dam was completed in 2005, and since that time, the North Aral Sea has risen over 10 meters (32.8 feet), which has led to a revitalization of the fishing industry.

Talupula

Water crises also strike many communities on a local scale. Such is the case for Talupula, a remote village in Andra Pradesh, India. Once a dry tropical region, it has been growing increasingly arid over the decades, and the life-giving monsoons have become less reliable. Overgrazing and the harvesting of forests for fuel has denuded most of the landscape. During the dry season, the region has the look of a desert. This loss of vegetation has reduced the land's capacity to capture and store water. This, in turn has reduced the rate of groundwater recharge. The town relies on an aquifer over 1,000 feet deep; and the rate of abstraction is lowering the water level year by year. The biotic pressures on the landscape have diminished the recharge rate of the aquifer. While redirecting and damming river flows are not the culprits here, anthropogenic changes to the watershed are.

To compound problems, fluorite, fluorapatite, and other minerals in the rock leave the water heavily fluoridated, making fluorosis a health concern. From a health standpoint, the water is considered unsuitable for drinking, yet it is the only current option for the town's supply. High fluoride levels can also affect livestock reproduction and plant germination and growth. The high evaporation rate and low rates of recharge are suspected of compounding the fluoride issue.

Like every place in the world with a crisis looming over it, life chugs on, albeit with a sense of hopelessness in many of the residents. The environmental changes are progressing at a rate that even the young can perceive. And yet, as we will see in Chapter 7, Talupula offers an exciting ray of hope. As part of a cooperative project with the Green Tree Foundation of AP, India, we were able to turn a barren hillside into a mango orchard for under $1,000, using very simple earthworks.

Worldwide

Globally, humans use 4,000 km^3 of water each year. Of this, 70 percent is used for agriculture, 20 percent for industrial purposes, and 10 percent for domestic use. It should be noted that a portion of the agricultural usage is now tied into energy production with biofuels.

With population increasing and climate change growing more severe, the World Bank estimates that Central Africa and the Middle East will lose 6 percent of their GDP to water scarcity. For with a 2°C increase in global average temperature, the percentage of the global population affected by absolute water scarcity (meaning that individuals have less than 500 m^3 water per year) is predicted to increase by 5 to 20 percent, and the population experiencing water scarcity (less than 1,000 m^3 per year per individual) is predicted to increase by between 40 and 100 percent, depending on population rates and warming rates.

To meet the needs of decreasing water supplies, groundwater is being drawn on at increasing rates. Currently, 48 percent of agriculture globally relies on declining supplies of groundwater for irrigation. Over the coming decades, the declines in groundwater supplies will severely limit agriculture in many regions. In addition to human depletion of groundwater, climate change is also threatening supplies.

The rate of abstraction globally has increased threefold over the past 50 years and is increasing at 1 to 2 percent per year. It is estimated that abstraction will increase by a further 55 percent by 2050. Currently, 26 percent of the global water supply is provided by groundwater, and almost half of the water extracted is used to meet the need for potable water. This rate of withdrawal currently amounts to 8 percent of the mean global aggregate of groundwater recharge, but reliance on groundwater abstraction is greatest in regions of water scarcity. It is in these regions that recharge is often less than abstraction. Over-abstraction puts tremendous pressure on agriculture, threatening the food security of already impoverished nations. The result is often environmental refugees fleeing land that can no longer support them. For instance, roughly two thirds of India's irrigation needs are met by groundwater, and wells are being abstracted at a rate greater than they can recharge.

Degradation of groundwater is also an increasing problem. Over-abstraction in some coastal areas has allowed saltwater to backfill, contaminating the groundwater. Here, too, climate change is expected to exacerbate the problem as sea levels rise, putting more water systems at risk.

Tracking groundwater is difficult, and we have only a rough picture of what reserves are in place and just how much they are declining. In 2002, NASA started tracking groundwater levels with its GRACE mission (Gravity Recovery and Climate Experiment). From the data it has collected, we know that one third of the Earth's large groundwater basins are being depleted at an alarming rate.

Spread of deserts

Two billion people live in drylands globally, most of them below the poverty line. Accounting for 41.3 percent of all land and 44 percent of cultivated land, and containing 50 percent of the world's livestock, these areas are increasingly coming under threat of desertification. Deforestation, farming practices, mining, and climate change are increasing the spread of deserts across dryland areas.

As drylands further degrade, they are expected to lower the global production of food by 12 percent over the next 25 years, raising food prices by some 30 percent, leaving nearly a billion people hungry. We lose 23 hectares a minute (over 12 million hectares a year) to desertification.

The deforestation and degradation of Talupula has been a process many decades in the making. It took massive engineering projects to choke off the Aral Sea and to use up the Colorado River before the river could reach the ocean. The Earth's water problems have been centuries in the making. To do the damage we have done has taken tremendous energy and billions of labor hours and machine hours. To put it succinctly, it has taken a lot of work to muck up the Earth to the extent we have.

One obvious and important lesson to be gleaned from the Aral Sea, Colorado River, and even Talupula is that what happens upstream affects what happens downstream. We also see that large-scale engineering projects can lead to large-scale problems. Both the drying of the Aral Sea and the reduction of the Colorado River have come about through inappropriate approaches to irrigation. These two stark examples are played out on a less dramatic scale throughout much of the world today.

These three examples also show us a ray of hope. The explosion of life in the Colorado Delta, the return of fisheries to the North Aral Sea, and the results of Talupula show us just how quickly systems can be rejuvenated when we add water.

Water is vital for all life on the planet. No water, no life. We need water to survive. We need water to produce the food we eat. We also use water in cooking and cleaning processes, sanitation, and to manufacture the items we need in our daily lives.

War and conflict

With growing water scarcity comes an increase in conflict over water. This conflict takes place not only between nations but also within nations as well. In January 2014, for instance, a small dam in Kyrgyzstan was targeted with mortar rounds by Tajik security forces as part of a conflict over water- and pasture-access rights. Water supply systems are also used as targets in terrorist attacks. Such was the case in an attack on Afghan schoolgirls in April 2012, when their school's water supply was poisoned out of opposition to the education of girls. Class conflict within a nation, too, has arisen around water rights. Growing water scarcity in the small village of Rasooh, in the state of Jammu and Kashmir, India, for instance, has seen assaults on lower caste Dalit women attempting to access village well water. Police were then needed to guard the well. The well was later damaged by a group of members of the upper caste to show their disapproval of the lower caste accessing the well.

These are but three small examples of a growing number of conflicts involving water. Africa, Asia, Australia, Europe, and North and South America all have recent records of violence or attempted violence involving water. While there are major international conflicts involving water, such as the ongoing Syrian Civil War, there is a growing number of lesser national and international conflicts around water. Increased water scarcity, together with an increasing population and the spread of deserts, makes the risk of increased future conflict more and more likely. Securing sustainable water supplies for populations at risk will increasingly become a prerequisite for peace.

Where there is hope

While the sheer numbers of people and the advent of machinery have accelerated the process, the degradation of drylands has been millennia in the making. The catastrophes of the Colorado River and the Aral Sea both required massive engineering projects. Aquifer depletion has required electric and fossil-fuel–powered pumps to withdraw water at rates greater than recharging. Damaging the environment is not that easy to do. It takes tremendous concentrated effort to really muck things up. Yes, humankind has made a real mess of much of the globe, but not without expending trillions of labor hours and quadrillions of kilocalories to do so. Simply put, breaking the planet is hard work.

The really good news is that by working in cooperation with nature, we can undo most of the damage we have done with a fraction of the time and energy it took to cause the damage in the first place. I never cease to be amazed when, time and time again, degraded systems start to turn around immediately after the first rainfall on the repair site. Earth repair is one of those rare cases in which fixing the mess is easier than making it in the first place. This book is about the first steps toward making that repair.

Just add water!

A successful ecological system requires water. There is no way around this. Without water, there is no life. In the Earth's drylands, the importance of water is no mystery. In the wetter regions, however, it is often overlooked. In Ontario, Canada, where I grew up and currently live, water is often seen as a nuisance in the spring—something that can interfere with planting. Yet drought is an all-too-common occurrence in the late summer. Many Ontario farmers just surrender to the mercy of the weather and hope for adequate rainfall during the growing season. Whether you are living in drylands, a humid temperate climate, or a rainforest, water-harvesting earthworks have the potential to improve agriculture and local ecosystems.

Humans are a part of the biosphere. Through both our history and our prehistory, we have made some real ecological blunders. Yet we have the potential not only to meet our own needs but also to foster biodiversity and ecosystem health while meeting those needs. We can be good stewards of the land instead of the biological equivalent of rowdy hooligans.

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