Large Dams

Human and Environmental Benefits and Costs

Heidi Hull

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DR. HOLLY PETRILLO & DR. MICHAEL DEMCHIK

EXECUTIVE SUMMARY

Over the last five millennia cultures have improved upon ways to harness water for many uses such as flood control, irrigation, daily/industrial uses, and navigation. Many of the early dams were built to supply extensive areas of land with water to grow crops for increasing populations. In locations which receive low amounts of rain, containing the water when it is available provides for the communities year-round.

Water is essential for life (UNESCO-WWAP, 2003). When one aspect of an ecosystem is changed, the other parts must adapt or perish. A blockage in a river will inhibit fish migration, which is necessary for the survival of some species. This alteration in the fish life cycle will potentially lead to that species declination, even to the point of extinction. The downstream ecosystem will also be affected by flow rates, water temperature, and lack of particulate matter. The species living in this area depend on a defined range of habitat characteristics that if interrupted will have a significant effect on the flora and fauna in the area.

People are susceptible to ecosystem changes as well. Many gain their livelihood from occupations related to water, such as commercial fishing. When fish are affected, the people who depend on the species abundance will suffer if the aquatic populations decline to unsustainable levels. In certain cases, such as dam installations, people may also have to entirely abandon their way of life due to the inundation of their homes and land.

In the 1930s, the United States constructed the Hoover Dam that would set a standard for others to follow. Since that time, larger dams have continued to be built throughout the world. Egypt created one of the largest manmade bodies of water with the construction of the Aswan High Dam. Brazil and Paraguay, in South America, followed by completing the Itaipú Dam, the most expansive barrier used to generate substantial amounts of energy for both countries. In

Asia, China is finished the largest dam on the planet in 2009, the Three Gorges Project, which tamed the Yangtze River (Chang Jiang) and required the greatest number of people in the history of dam building to be relocated.

Large dams do have benefits associated with them. From an environmental and social perspective, these massive structure result in numerous negative impacts. The World Commission on Dams (WCD) set out in 1998 to explore the values associated with dams. Their results were difficult for some to accept: large dams fail to live up to their proposed goals (WCD, 2000).

LITERATURE REVIEW

Introduction

Dams have been constructed for millennia, influencing the lives of humans and the ecosystems they inhabit. Remnants of one such man-made structure dating back 5,000 years are still standing in northeast Africa (UNESCO-WWAP, 2003). Around 2950-2750 B.C., the first dam known to exist was built by the ancient Egyptians, measuring 11.3 meters [m] (37 feet [ft]) tall, with a crest length of 106 m (348 ft) and foundation length of 80.7 m (265 ft) (Yang, et al, 1999). The dam was composed of 100,000 tons of rubble, gravel, and stone, with an outer shell of limestone. The immense weight was enough to contain water in a reservoir estimated to have been 570,000 cubic meters [m^3] (20 million cubic feet [ft^3] or 460 acre-feet) in capacity (Yang, et al, 1999).

Types of Dams

According to World Dam Commission, the world has almost 900,000 dams built on the numerous rivers across six continents (2000). Of those structures, 45,000 are classified as large dams being 15 m (49.21 ft) or higher (foundation to crest) or having a height of 5-15 m (16.4-

49.12 ft) and a reservoir volume exceeding 3 million m^3 (106 million ft^3) (WCD, 2000). The four types of dams are gravity, embankment, arch, and buttress (Polaha & Ingraffea, 1999; BDS, 2009). The gravity dam uses the sheer weight of the earth, rock, and concrete to contain water (Polaha & Ingraffea, 1999). An embankment is made of earth or rock with the addition of an impermeable core (BDS, 2009). Arch dams require less material than the previous two types and depend on the strength of arch action to hold back the water and are typically located in "narrow spaces with strong abutments" (Polaha & Ingraffea, 1999). Buttress dams rely on added structures to support the wall against the pressure of the water and can vary in shape from "flat to circular" (Polaha & Ingraffea, 1999). Depending on the site, design, and materials available, any of the above types of dams may suit the needs and as most large project, will serve more than one purpose. The basic benefits of these barriers include: flood reduction and flow regulation, storage of water for food crop irrigation and daily use, generation of electricity, and increased port access. These benefits do intertwine with consequences impacting humans and the environment through species/habitat loss, inundated fertile land and archeological sites, and relocation of inhabitants.

Benefits

Flood Control and Flow Regulation

Before diversion schemes and other methods were used to move water, humans and other flora and fauna resided along brooks, streams, and rivers. These surface waters are part of a watershed, which is a defined area where precipitation falls to the earth and travels either across the surface or infiltrates into the ground; the water eventually converging into rivers flowing to a sea or ocean (CTIC, 2009) One component of a watershed is the floodplain, the area outside the bank of a river where water covers the ground during a flood.

Every year, “floods kill thousands and [affect] the lives of millions more (Clarke & King, 2004). The number of floods is on the rise. In 1992, 57 floods were recorded worldwide and by 2001, 156 floods were reported (Clarke & King, 2004). During President Roosevelt’s term, the Mississippi Delta suffered from reoccurring floods in 1912-13, 1916, and 1927, the latter event being the most devastating. Roosevelt called on the U.S. Army Corps of Engineers, a separate federal branch of the army created to perform civil engineering works throughout the nation (U.S. ACE, 2007). The Corps built dams upstream of the affected area on the Mississippi to alleviate any further damages from flooding (U.S. ACE, 2007).

Irrigation and Water Usage

With the construction of dams, the immediate availability of water increases. Transporting water for irrigation purposes has been performed for generations. A civilization dating back to 1000 B.C., called the city of Marib, was found to use an intricate diversion method for irrigating their fields (Lanz, 1995). In Africa and the Middle East, 1,272 and 793 large dams, respectively, are used primary for irrigation. Though dams may not be necessary for irrigating fields, the incorporation of such structures allows for increased amount of land to be cultivated. “Half the world’s large dams were built exclusively or primarily for irrigation and some 30-40% of the 271 million hectares irrigated worldwide rely on dams” (WCD, 2000). With the population increasing, the agriculture sector will face the increasing demand for food production. Today, the agriculture sector is currently the number one water consumer and will likely remain so for years to come (United Nations, 2002).

In addition to food production, water is also needed for human consumption. Reservoirs have enabled water supplies to also be diverted to serve populations. The Hetch Hetchy Dam, constructed in the1920s, was built to supply water to San Francisco 150 miles away (Bily, 2000).

Lake Mead, created by the Hoover Dam, provides 84% of Las Vegas' water needs.

Power Generation

In the mid 1770's, Bernard Forest de Bélidor, a French hydraulic and military engineer, wrote a four volume series about using falling water to derive electricity (EERE, 2008). The energy potential would certainly be able to provide many people and companies with sufficient, inexpensive power. The initial capital costs for construction may be significant, but many lenders are able to help fund the efforts. The World Bank had assisted many countries in projects in Africa, India, Asia, and elsewhere. Industries across the world are using this type of energy, which supplies five to nineteen percent of the total electricity produced in the U. S. (Leslie, 2005; Clarke & King, 2004).

Although advances in technology enable the production of hydropower without a dam present, seasonal changes in water flow make a containment barrier an ideal fix. Rivers fluctuate throughout the year with the waxing and waning of precipitation, freezing, and melting (Peterson, 1954). The variation makes production operations difficult to maintain without steady electricity. To circumvent this inconvenience, a dam is used to control the release of water to generate consistent energy, improving efficiency, which are typically regarded as best practices in managing most aspects of life.

Many advocates promote water generated power from a pollution perspective "because it does not foul the air or conspicuously degrade water…there [are] no invisible radioactive emissions, no possibility of meltdowns" (Echeverria, et al, 1989). With water power, businesses and people living next to the river are not required to live tangentially any longer. Power lines are utilized to bring electricity to the locations significantly long distances away from the source (USGS, 2008).

Navigation

When the design and topography allow for increased navigation inland and aid in the transport of manufactured goods, these dams provide an addition benefit. After construction of a dam, the area is filled, increasing the depth of the water, hence enabling larger ships to navigate to newly accessible ports (BDS, 2009). International trade relies on major rivers to transport product around the world. Markets for imports and exports were limited to seas, oceans, and the largest rivers, but with advancements in dam technology, accessibility has increased (FEMA, 2006).

Recreation

Water access is not limited to cargo transport. FEMA found the primary function of almost 40% of all reservoirs in the U.S. to be for recreation (2006). Not only do large dams supply water for food production and storage, provide electricity, and increase navigation, but create new locations for humans and wildlife to enjoy and inhabit. Essentially a large lake, a reservoir provides many people with opportunities to enjoy swimming, fishing, and boating (FEMA, 2006). Although dams have provided several benefits for humans, improving the lives of many; negative environmental and social impacts also occur (Richter & Thomas, 2008).

Costs

The number of people served, the water capacity, new habitats, energy potential, increased irrigable land, are all benefits and can be measurable. However, dams and the accompanying reservoirs also cause another series of issues, such as ecosystems being altered, people relocated, and species, land, and archeological sites lost. These factors are more difficult to quantify.

Species Loss

The aquatic species inhabiting the waterways being dammed are immediately affected. The several species of salmon traversing the Skagit in the northwest of the United States, once abundant numbering about 2 million, have been reduced to under 9,000 (Rothfeder, 2000). Due to the dozens of dams built over the last 50 years to generate electricity, state fisheries biologists now transport the juvenile salmon 250 miles downstream to the ocean in order for the fish to complete their life cycle (Rothfeder, 2000). On the opposite side of the earth, China has species issues which cannot be remedied by tanker trucks.

The Chang Jiang basin is one of the richest ecosystems in China and concern for its sustainability foresees a number of species significantly declining, including the river dolphins, alligators, and paddlefish (Pitzl, 2007). The earth has five species of river dolphins, one of which resides in the Chang Jiang in China (Dudgeon, 2000). Dams fragmented the river and the increase of pollution from industries and the general population have affected the *Lipotes vexillifer* species; approximately 200 individuals remained in 2000 (Dudgeon, 2000).

Environmental Alterations and Degradation

As the world population continues to grow, the environment on which people depend will ultimately be negatively affected. The Aral Sea is acknowledged as the worst case of environmental degradation. The sea has lost 80% of its volume because of the diversion of the Amu and Syr rivers to irrigate the deserts of Uzbek and Kazakh for cotton production (Barlow & Clarke, 2002). “Almost all fish and waterfowl species have been decimated and the fisheries have collapsed entirely” (Barlow & Clarke, 2002). Flora and fauna are also affected by degradation to the landscape from the flooding upstream of dams and the lack thereof downstream.

Significant portions of land have been inundated by dam reservoirs, flooding approximately “one million square kilometers (about 380,000 square miles)” worldwide (Barlow & Clarke, 2002). The sediment once carried down rivers now accumulates behind the barriers reducing the fertility of floodplains downstream and causing “erosion of riverbanks, coastal deltas, and even distant coastlines” (Pearce, 2006). West Africa’s coastal lagoons are all being washed away because limited particulate material is available to replenish the shoreline (Pearce, 2006). “The solids in the Nile River have decreased to such an extent that the Delta coastline is already showing signs of receding” (Parker, 1995a). The lack of flood waters is also causing similar situations in the Californian Imperial Valley, the Netherlands, and the Australian Snowy Mountain project, where the soil salinity is increasing, affecting soil quality and crop production (Davidson & Brooke, 2006). Further inland, flooding rivers do cover the ground, periodically sluicing areas inhabited by humans and cause millions of dollars in damage.

Dam Failures

The environment is an intricate system, all its parts interconnected to work together. Though lack of water has had severe outcomes, too much water is also taking its toll in other parts of the world. The reason for the failure could be linked to design, material, site, attack, or a combination.

The Carbora Bassa Dam in Mozambique, built by the Portuguese, has been a target of sabotage over many years of civil wars within the country, which has weakened the structure (Rothfeder, 2001). In 2000, Mozambique experienced the most devastating flood on record when the spillway of the Carbora Bassa broke open causing a torrent of water to flood the villages downstream (Rothfeder, 2001). People, having found safety in trees, were stranded for five days in order to escape the muddy water lapping at their feet (Rothfeder, 2001). Mozambicans had to deal with their homes being flooded during the rainy season, but for people living next to large rivers where large dams have been built or are in the process of being constructed, their homes are or soon will be permanently underwater.

Social Effects

"… [D]ams have physically displaced 40-80 million people worldwide, and most of these people have never regained their former livelihoods (WCD, 2000). Inhabitants along rivers will not only be affected by water quality issues, but their way of life will be altered indefinitely. People living downstream of a dam are also forced into social change. Senegal and Mauritania are two locations where the altered flow of the river upstream "had severe implications for [their] cultural traditions and livelihoods" (Skinner, 2000).

They are powerless watching their towns, "ancestral shrines, cultural patterns", their way of life, as it is swallowed up by a flooding river (Goldsmith & Hildyard, 1984). The loss of homes includes the land on which they were built. The land along rivers is typically prime soil for growing crops. A dam creates a permanent flooded condition causing the river fills its banks, saturates the floodplains, and engulf the land below (Leslie, 2005).

"In general, those people relocating worked relatively flat and fertile area and now must move to steeper and infertile hillsides and upland areas" (Heming, et al, 2001). In the new locations, they will still need food and fuel, which then requires them to "cultivate the steep slopes in order to grow the necessities" (Heming, et al, 2001). As the new residents strive to survive, they will indirectly cause increases in water runoff and soil erosion because of forest and grassland destruction for crops (Heming, et al, 2001).

Many people are asked to move to villages or cities. In Porto Velho, Brazil, natives of the area are finding difficulty visualizing a new life, one that does not include fishing in the river rapids or living from a vegetable farm; their new homes are locate in a village without access to either (Partlow, 2008). The dam near Porto Velho was not the first and will most likely not be the last to bring about such controversy. The following case studies analyze dams built on four continents and selected benefits and costs of each.

CASE STUDIES

Introduction

The impact of each dam depends on the climate of the region, number of people served, and primary purpose for which the structure was build. The following case studies provide an overview of the countries in which these sizable barriers were constructed. Each case discusses the reasoning for the dam along with the benefits and concerned brought about by the projects. Four case studies will explore continents around the globe that contain the large dams known as Hoover (Boulder) Dam, Aswan High Dam, Itaipú Dam, and the Three Gorges Dam.

North America

The Area

The Colorado River, located in the Great Basin of the southwest United States, flows through an area fairly dry throughout, varying mainly in temperature from north to south. “The topography of western Colorado causes large variation in climate within short distances, but a few generalizations…apply to the whole area” (WRCC, 2006a). The mountain summits, peaks and valleys average less than 32°F throughout the year (WRCC, 2006a). Hundreds of miles downstream in the Lake Mead National Park, along the Arizona, Nevada, California border, temperatures can exceed 120°F in the summer and average 30°F in the winter (Gibbs, 2002; NPS, 2009).

The Colorado River Basin covers an area of 637,000 square kilometers (246,000 square miles) and expands across seven states consisting of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, and the northeast area of bordering Mexico (Atkins, 2007; USBR, 2008). “The Colorado River Basin is a snowmelt-driven system that depends on winter snowfall for its summer season supply” (Edwards & Redmond, 2005). The Upper Basin, of Colorado, Utah and Wyoming, make up about “15% of the watershed area and produces about 85% of the entire basin’s average annual runoff” (Edwards & Redmond, 2005). With variations in the amount of snow accumulated in the winter months, the output of the river will vary accordingly, receiving from 8-15 inches of precipitation annually, Nevada getting the least amount (WRCC, 2006b). In the early 1900s, Arizona suffered a few costly flooding incidents, which caused $2 million in damages per year (Davidson & Brooke, 2006; Clarkin, 2000). In 1918, Arthur Powell Davis, the U.S. Reclamation Director, proposed taming the Colorado River with the largest structure of its time (Davidson & Brooke, 2006; Clarkin, 2000).

Hoover Dam

The design entailed a concrete arch-gravity type dam (PBS, 2001; USBR, 2008). The contract was awarded to Six Companies and the construction schedule was advanced in order to provide jobs due to the massive unemployment caused by the Great Depression (Corfield, 2007). Over 21,000 people from 47 states plus foreign workers were involved in building the dam and began work in 1932 (USBR, 2004a; USBR, 2004b; Clarkin, 2000).

The complete dam, including all structures, was finished in 1936 almost 2 years ahead of schedule (NID, 2004). The barrier spans 379 meters (1,244 feet) across the Black Canyon, measures 201 m (660 ft) at the base and 13.7 m (45 ft) at the crest, and stands at 221 m (726 ft) tall and contains over 3 million m^3 (118 million ft^3) of concrete (NID, 2004; DWMI, 2009; Gibbs, 2002; USBR, 2008). Hoover Dam cost more than US$165 million to complete, holds back an artificial body of water known as Lake Mead, which is a 35 million m^3 (1.24 trillion ft^3

or 9.2 trillion gallon) reservoir, and the power plant within the dam generates 4 billion kilowatt-hours (491 tonnes of coal equivalent) of hydroelectric power annually (PBS, 2001; Gibbs, 2002; DWMI, 2009).

Benefits

When proposed, the purposes for building the Hoover Dam were flood control, sediment regulation, irrigation, municipal and industrial water supply, and generation of electrical power (Davidson & Brooke, 2006). Those farms in the basin needed water and by "storing the spring floods," water would be available to irrigate 8.7 trillion m^2 (2.16 million acres) rather than 2.67 trillion m^2 (660,000 acres) (USBR, 2004a).

The population of the Colorado River Basin has continued to grow and now is home to between 17 and 28 million people who depend on the river as their primary source of water (USBR, 2008; Atkins, 2007; MSNBC, 2007). Lake Mead, the reservoir behind Hoover dam, has created "new wildlife habitats along the shores where, in 1985, 250 species of birds were identified in the region" (Clarkin, 2000). The area has also become a prime recreation location where nine million people visit Lake Mead each year for swimming, boating, skiing, fishing, etc (USBR, 2008).

Concerns

However, the creation of a new habitat and recreational area has caused places downstream to deteriorate. The lack of sediment deposits in the Gulf of California delta has altered the area habitat to the point that wildlife, such as deer, birds, and bobcats, have begun to disappear (Clarkin, 2000). The sands and silts normal destined for the delta remain trapped behind Hoover Dam. "Prior to 1963, 91,000 acre-feet were deposited each year in Lake Mead," but with the installation of Glen Canyon Dam, the life span in regard to sedimentation has become indefinite (USBR, 2008). Although the downstream issues still exist, the sediment deposition behind the dam is alleviated, upkeep of the dam is still necessary.

In 1998, the United State Bureau of Reclamation "replaced the needle valves with jet flow gates after two failures at other dams resulted in the death of five operating personnel (International Water Power, 1998). The Hoover dam was the last project in the $2.5 million five-year needle valve replacement program (International Water Power, 1998). Now more water can flow through the outlets, but water usage play a significant role in the condition of the Colorado downstream. "In drought years, the riverbed is literally dry miles short of the delta [and at times] there is barely a trickle of water as the river enters" Mexico (Pitzl, 2007). In this case, the United States/Mexico treaty of 1944, "which guarantees Mexico 1,500,000 acre-feet annually" is violated causing strain between the countries (USBR, 2008). The issue has been alleviate due to "abundant rainfall in recent years along much of the Mexico-US border region" amending the water-sharing arrangements for the time being (CIA, 2009).

Africa

The Area

Egypt, the most northeast country in Africa.. The land area of the country is 995,450 km^2 (384,345 mi^2) and the water occupies an additional 6,000 km^2 (2,317 mi^2) (CIA, 2009). The whole of the country is desert with hot, dry summers and moderate winters, directly influenced by the air massing coming from the Sahara (CIA, 2009). "The southern region, crossed by the Tropic of Cancer, receives very hot and sand-laden winds in the spring, followed by high winds off of the Mediterranean" (CIA, 2009). The climate is regarded as subtropical in the north, where it rains less than 8 inches annually, and the area south of Cairo experiences basically no precipitation (Parker, 1995a). The rest of the country is arid and tropical, for example, at Aswan the average monthly temperature for January is 62°F (16°C) and July 92°F (33°C) (Parker, 1995a).

"The Nile is the only perennial waterway that flows on Egyptian soil, separating the Sahara Desert into the Western Desert, a direct continuation of the Libyan Desert, and to the east, the Eastern or Arabian Desert" (Parker, 1995a). The majority of Egypt's population, over 80 million, resides within 12 miles of the Nile River (PBS, 2001; CIA, 2009). The annual floods of the Nile River, resulting from late summer rains, carried more than 100 million tons of soil to the lower Nile Valley and cleansed the soil to prevent salt accumulation (Thompson, 2000).

Aswan High Dam

However, years passed when the yearly floods did not occur and caused widespread drought and famine (PBS, 2001). In 1952, Egyptian president Gamal Abdal-Nasser pledged to control his country's annual flood with an expansive dam across the Nile River (PBS, 2001). The dam would control flooding, provide water for irrigation year round, and supply hydroelectric power (PBS, 2001). At a cost of US$450 million, construction on the Aswan High Dam began in 1960 and completed in 1971(Davidson & Brooke, 2006; Thompson, 2000). Bid on and designed by Soviet engineers, the rock-filled, impermeable clay core embankment dam reached a final volume of material of 1.6 million m^3 (58 million ft^3) (Thompson, 2000).

The structure measures 3,829 m (12,562 ft) in length, 111 m (364 ft) in height, and widths of 40 m (131 ft) at the crest and 980 m (3,215 ft) at the base (Thompson, 2000). With the twelve Francis turbines, each with an output of 175 megawatts, the electrical energy generation is an annual average of 10 billion kilowatt-hours (1,228 tonnes of coal equivalent) (Ford, 2007). The reservoir "Lake Nasser, contains some 200 billion ft^3 (5.7 billion m^3) of water" (Kich, 2007).

Benefits

After completion, "the dam controls flooding, ensures reliable and regular water supply to irrigated farms along the river, and provides hydroelectric power and water for human consumption and industrial use" (Kich, 2007). Due to the lack of rain fall "agricultural activity is impossible without the help of irrigation" (Parker, 1995a). With the water controlled by the dam, year-round release has enabled farmers to increase their output from one to three harvests per year, depending on the crop" (Kich, 2007).

Concerns

However, without the natural nutrient input provided by past flooding, the harvests of up to three crops a year require "massive support of fertilizer" (Parker, 1995a). Prior annual floods not only cleansed the soils of salts and deposited nutrients, but also reduced the number of rats and disease-bearing snails. With the decline of flooding, incidences of disease have been on the increase" (Thompson, 2000). In Lake Nasser, the stagnant to slow-moving water of the reservoir is prime habitat for snails that carry schitosomiasis causing parasites, which "infect intestinal and urinary tracts, causing general listlessness and more serious consequences, including failure of internal organs and cancer" (Salisbury, 2000; Davidson & Brooke, 2006).

The headwaters of the Nile originate in Ethiopia and Uganda and cross through Sudan before reaching Egypt. Until recently, the countries upstream abided by colonial era agreements from 1902 and 1929, forbidding Ethiopia, Uganda, Kenya, and Tanzania from altering the flow of Nile (Ford, 2007). Ethiopia is reportedly demanding a re-examination of 1959 water-sharing agreement between Sudan and Egypt, which gives Egypt 55.5 billion m^3 (1.9 trillion ft^3) and Sudan 18.5 billion m^3 (653 billion ft^3) annually (Ford, 2007). Ethiopia "wants an additional share…to install large-scale irrigation projects" (George, 1998).

With Ethiopia's plans to irrigate about 3 million hectares of farmland, Egyptian could face shortages of water, electricity, and increased siltation (George, 1998). Uganda also began construction in 2007 in Bujagali, on the Ugandan section of the Nile north of Lake Victoria (Ford, 2007). Egypt can only cooperate due to the infeasibility of going to war. Internally, Egyptians have been affected by the construction of the dam which required ten thousand people to relocate, altered natural habitats, submerged ancient temples and monuments that were not able to be moved to higher locations (Davidson & Brooke, 2006; Thompson, 2000).

South America

The Area

The Paraná River is the seventh largest in the world and second longest in South America, running along the border between Brazil and Paraguay (Parker, 1995b; Lopez, et al, 2000). To the east of the river is Brazil, the fifth largest country in the world, covering an area of 8.5 million square kilometers (3.3 million square miles) and having a population over 170 million people (Perz, 2007; Parker, 1995b). Brazil's southern uplands and Rio Grande do Dul are subtropical in climate characterized by hot summers and cold winters (Parker, 1995b). On the west bank of the Paraná is the country of Paraguay, significantly smaller in comparison, composed of 406,750 square kilometers (156.757 square miles) with a population just under 7 million (CIA, 2009). In Paraguay, annual temperatures average between 77°F and 79°F [25°C-26°C] and substantial temperature swings can occur throughout the day due to cold winds from the south (Parker, 1995b). In the surrounding region of the Paraná, rainfall varies by location and ranges from less than 39 inches to over 78 inches (Parker, 1995b).

Itaipú Dam

During the 1960s, the area experienced consecutive years of drought, lacking water needed for drinking, irrigation, and industry (Parker, 1995b). As a result of the drought, the leaders of Brazil and Paraguay forged a partnership in 1966 by signing an agreement to create a mutually beneficial dam. They formed the Itaipú Binacional and worked with the International Engineering Company to build the Itaipú Dam (PBS, 2001).

The project complex stretches 7.7 kilometers (4.8 miles) across the river, with the Itaipú Dam making up 1 kilometer (3,300 feet) of the total length and standing 196 meters (643 feet) in height (Davidson & Brooke, 2006). The barrier is a hollow concrete gravity dam, which allowed 35% less material to be used without reducing the strength, though this section of the project still used 12.8 million cubic meters (453 billion cubic feet) of concrete (Davidson & Brooke, 2006; Krauter, 1998).

Benefits

More than 30,000 workers were employed during the building of Itaipú dam over the seven years from 1995 to 2002 (Krauter, 1998; Davidson & Brooke, 2006). The reservoir the dam created, Itaipú Reservoir, is calculated to have a 29 billion m^3 (1.02 trillion ft^3) capacity (PBS, 2001). The energy production capacity is 12,600 megawatts with an annual production of 93,428 gigawatt-hours, the energy equivalent of 11 billion tonnes of coal (PBS, 2001; Roluti, 2008). The project took around 18 years to materialize and over US$18 billion to build (PBS, 2001).

With the water capacity of Itaipú, the governments were able to provide water to homes, farms, and industry. In addition, plenty of water is present to flow through the 18 generators and produce enough power to supply 78% of Paraguay's and 25% of Brazil's electricity needs (Davidson & Brooke, 2006; Roluti, 2008). The Paraná was not navigable before the dam due to rapids and falls, so the installation did not create an extra barrier to inhibit ship passage (Parker, 1995b).

Concerns

The US$18 billion dollar project, though providing benefits for a large amount of people, also necessitated a half million people being resettled, as well as affecting the local ecosystems to a great extent (Davidson & Brooke, 2006). “By 1974, it was reported that almost 85% of the forest on the Paraguayan side of the Paraná River had disappeared” (Davidson & Brooke, 2006). In the reservoir upstream of the dam, other changes have occurred. The *Serrasalmus marginatus*, a species of piranha, invaded the Upper Parana River after construction of the Itaipú dam (Agostinho, 2003). A study has show the invasion has caused a reduction of the native species *Serrasalmus spilopleura* (speckled piranha), a small fish which is major part of the commercial fisheries and aquarium market in Brazil (Luna, et al, 2009).

Asia

The Area

China is the fourth largest country in the world with a land area of 9.3 million km^2 (3.0 million mi^2), of which about 15% is arable (CIA, 2009; Pitzl, 2007). Of China’s one billion plus population, 96% of the people inhabit half the national territory (Parker, 1995c). Much of the population relies on two major rivers that run through the country. The river that supplies Beijing, with headwaters in the Mongolian mountains, is the Huang He (Yellow River) in the north central part of China (Parker, 1995c). The Chang Jiang (Yangtze River), the third-longest river in the world, is the other which runs through south central China and has a more regular flow pattern compared to the Huang He (Parker, 1995c). With a more dependable water source, the Chinese connected the Chang Jiang and Huang He through the construction of the Grand Canal” (Pitzl, 2007).

The Chang Jiang "deposits about 170 million m^3 (6 billion ft^3) of silt onto its floodplains [annually], where about half of the foodstuffs consumed by China's billion-plus people are grown, including a large percentage of the nation's rice, wheat, barley, corn, and beans" (Pitzl, 2007). The climate is diverse with central and south China characterized as tropical and subtropical having humid summers and warm/cool winters (Parker, 1995c). Shanghai, the metropolis located near the Chang Jiang alluvial plain, experiences average temperatures in January of 4°C (39°F) and July of 28°C (82°F) and intense annual precipitation, mostly in the summer, of more than 120-165 cm (62-66 inches) (Parker, 1995c).

The Three Gorges Dam

During the monsoon season, the Chang Jiang is subject to recurring, damaging floods (Pitzl, 2007). The uncontrollable floods claimed thousands lives: in 1931-145,000 people, 1935-142,000 people, 1949-5,699 people, 1954-33,169 people; and 1998-1,526 people (CTGP, 2002). In the 1950s, due to the series of floods, Mao Tse-tung, the Chinese Communist leader from 1893-1976, ordered feasibility studies to be conducted on potentially damming the river (Pitzl, 2007). The country's engineers found Three Gorges to have the best combination of topographical and geological conditions for building a dam (CTGP, 2002).

Construction began in 1993, just upstream of the city Yichang at the site Sandouping, and completion is scheduled for 2009 (Carmichael, 2000; CTGP, 2002). The reservoir will serve multiple purposes such as flood control, hydroelectric power, irrigation waters, and increase navigation inland (PBS, 2001). The Three Gorges Dam, a record setting feat, is estimated to have a final cost of US$29.8 billion (CTGP, 2002). About 20,000 people have been working almost non-stop to complete the 2.3 km (1.24 mi) long, 185 m (600 ft) high structure by 2009 (CTGP, 2002; PBS, 2001). The gravity dam contains 14.86 million m^3 (518 million ft^3) of concrete and creates a reservoir extending up to 600 km (370 mi) upstream, with a capacity of 39.3 billion m^3 (1.39 trillion ft^3) of water (PBS, 2001; Carmichael, 2000).

Benefits

The major city of Chongqing, located in an area of rich manufacturing and agriculture activities, is now a major port city due to the reservoir flood waters increasing access for ocean-going vessels (Pitzl, 2007). The Three Gorges Dam Project included a 5 series lock allowing larger ships to navigate inland, upgrading navigation from ten million tons to fifty million tonnage fleets (CTGP, 2002). With such a development, the effort approved by the Peoples' Congress to transform the "largely rural agrarian society to a developed economy" will move towards fruition (Carmichael, 2000).

Another aspect of industrialization is having sufficient electricity for manufacturing and other elements of living. In terms of energy generation, the dam's powerhouse will have a production capacity of 18,200MW (CTGP, 2002). Upon completion, Three Gorges Project will be the largest hydropower producing dam on the planet, continuously transmitting power to Central China, East China, Guangdong, and Chongqing with a maximum reach of 1,000 km (621 mi) (Heming, et al, 2001; CTGP, 2002). This power will be able to replace some of the demand previously fulfilled by burning of China's high-sulfur coal, which is a source of air pollution (Carmichael, 2000).

Those in the north, who experience water shortages from the uneven distribution will also benefit from the containment of the Chang Jiang (CIA, 2009). From the reservoir, water can be channeled via the Grand Canal to bring additional water to the insufficiently supplied north, especially Beijing.

Concerns

Though the dam provides benefits to people in other locations of China, the area is significantly affected. Immediate effects will be the “reduction in numbers of species in the river basin, most notably river dolphins, alligators, and paddlefish” (Pitzl, 2007). Hundreds of early habitation sites, temples, and sculptures dating back many centuries are inundated along with 150,000 acres (28,000 hectares) of land reported to be farmland and orange orchards (Carmichael, 2000; Heming, et al, 2001).

The 1-2 million inhabitants relocated, a record number for any dam worldwide, from the numerous five hundred cities, towns, and villages now underwater, must go elsewhere, most likely to a location with more people and lower quality land (Heming, et al, et al, et al, 2001; Pitzl, 2007; CTGP, 2002). A study found 81% of migrants removed to distant locations “were not accustomed to growing cotton and vegetables” and 78% “were not used to growing grain” (Heming, et al, 2001). These findings were not surprising considering that in Zigui County the dominate crop was fruit, especially oranges (Heming, et al, 2001). The migrants are asked to learn a new job, attempt to fit in within a new community which may or may not be receptive, lose their social network “paying a high socio-cultural price” due to a lack of personal income and property, and the overall adjustment to a strange new environment (Heming, et al, 2001).

CRITIQUE

Dams have altered environments for millennia. However, the Hoover Dam was a turning point for the future of large dams. Of the benefits and concerns people could say “the two most important environmental impacts…were the precedent it created and the population growth that it fostered in the American southwest” (Clarkin, 2000). As the years passed by, the size of the dams has increased since the accomplishment in North America. The dams in Africa, South American, and Asia each are feats in their own right. The Hoover dam composed of over 3 million m^3 of concrete and a reservoir capacity of 35 million m^3 were the numbers to beat. The Aswan High Dam made of 1.6 million m^3 of material and a reservoir of 5.6 billion m^3 is the leader in capacity. The Itaipú Dam held the former title of the world's largest structure at 12.8 million cubic meters of concrete (29 billion cubic meters reservoir) and power generation at 12,800 MW. With the completion of the Three Gorges Dam in 2009, the project will top several categories including structure size with 14.86 million m^3 of concrete (a reservoir capacity of 39.3 billion m^3) and power generation in the amount of 18,200 MW.

In each case, the reasoning for building these large dams amounted to flooding issues with the important secondary benefit or irrigation. However, Brazil and Paraguay were keen on the hydroelectric power to supplement their electricity needs. Several groups of people in each of the populations benefit from dams being constructed, however, those negatively affected were also significant in number. Millions of people were basically forced to find new places to live in order for others to have their demands met. The species affected will also have to adapt to a new environment or perish like numerous fauna have before them. The WCD concluded that while "dams have made an important and significant contribution to human development," in "too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment" (2000).

CONCLUSION

Most rivers have already been managed in some form; not many qualify as pristine. The World Commission on Dams has reported on the effects of large dams, and small, after their two year study. In view of the planned technical, financial, and economic performance versus the actual outcomes, the WCD found large dams to fall short of meeting any of the expected goals

(2000). The ecosystems, biodiversity and downstream livelihoods are well documented and were found to be degraded, along with limited success in predicting and avoiding loss in these areas (WCD, 2000). For example, the Commission found "the use of fish passes to mitigate the blockage of migratory fish has had little success, as the technology has often not been tailored to specific sites and species" (WCD, 2000). Most facilities do not even have fish passages (Marmulla, 2001).

Most relocatees are not adequately provided for either. Knowing one way of life and being asked to move where the population is denser, or the land is lower quality, or acquiring skills are necessary for a new career, can be a shock many may not be able to overcome. For the engineers, they have been asked to build a dam that will enable people to have more food, possibly year round, as well as electricity, drinking water, and recreation. Those who are asked to sacrifice their homes may get overlooked for a presumed great good.

Declines in fish populations to burying homes and cultures, other methods should be explored in greater depth. The designers of the Three Gorges Project (TGP) were advised to go the route of several smaller dams, but chose to move forward with the plan in hand. On the TGP website, several pages boast of being the largest in a number of categories. Many years prior, not long after the Hoover Dam was completed, Francis Crowe, "the [Bureau of Reclamation] surveyor on the project, later put it, "I was wild to build this dam—the biggest dam built by anyone, anywhere" (Pearce, 2006).

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